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Dr. (HC). Ir. Airlangga Hartarto, M.B.A., M.M.T.
Coordinating Minister for Economic Affairs,
Republic of Indonesia

INDONESIA

POST-PANDEMIC OUTLOOK:

Environment and Technology Role for Indonesia Development

Editors:
Rahmat Trialih
Fefi Eka Wardiani
Rendy Anggriawan
Cendra Devayana Putra
Ahmad Said

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Daerah Khusus Ibukota Jakarta 10340
Whatsapp: 0811-8612-369
e-mail: penerbit@brin.go.id
website: penerbit.brin.go.id
Penerbit BRIN
@penerbit_brin
penerbit_brin

In cooperation with:
Overseas Indonesian Students' Association Alliance (OISAA)
Mayapada Tower 1, Fl. 19,
Jln. Jend. Sudirman, Kav. 28,
South Jakarta 12920
e-mail: kesekretariatan@ppi.id
website: ppi.id

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Publisher's Note

As a scientific publisher, BRIN Publishing holds a high responsibility to enlighten society's intelligence and awareness through the provision of qualified publications available to the public at large. The fulfillment of this statutory obligation is one of the publisher's roles in promoting the educational and intellectual life of the nation as mandated by the Preamble of the 1945 Constitution. Furthermore, this book has encountered quality control mechanisms through the editorial process, including peer review.

This book is one of the four book series titled *Indonesia Post Pandemic Outlook* written by Indonesian scholars abroad to offer multidisciplinary strategies for Indonesia to recover stronger post-pandemic. In the discussions of this book series, the contributors propose their policy recommendations by referring to the Sustainable Development Goals, Indonesia's Long Term National Development Plan (RPJP), and the United Nations Research Roadmap for COVID-19 Recovery.

On this account, we hope that this book can offer valuable inputs and great recommendations for policymakers and stakeholders. Besides, it is expected that this book can provide knowledge and insight for the readers to be optimistic in aiming for a better post-pandemic future through collective actions and collaboration.

As a final note, we would like to deliver our heartfelt gratitude to everyone taking part in the process of this book.

BRIN Publishing

Opening Remarks Coordinating Minister for Economic Affairs Republic of Indonesia

The COVID-19 pandemic has impacted various aspects of human life, from health to the economy. Nevertheless, Indonesia can always rise and face challenges as a formidable nation. In the midst of a pandemic, Indonesia can continue to encourage community economic recovery through various COVID-19 Pandemic Handling and National Economic Recovery Programs (PC-PEN).

After the pandemic, the world is no longer the same. Amid the "5C" economic disruption (COVID-19, Conflict of Russia-Ukraine, Climate Change, Commodity Prices, and Cost of Living getting higher), which is currently the 'perfect storm that overshadows the world's recovery, Indonesia is required to be a country that continues to promoting its recovery more inclusively and sustainably. Various ways and activities that we do every day have changed due to digitalization and increasing public awareness of the importance of preserving the environment along with the increased economic activity. Digitalization and awareness of the importance of environmental aspects are essential.

Indonesia realized this and then made technology and environmental issues through the energy transition become two of the three pillars carried out in the G20 Presidency of Indonesia in 2022, along with the pillars of health recovery. Technology development through the Digital Economy is a necessity and important considering Indonesia's huge potential. In the ASEAN Region, Indonesia's Digital Economy is the highest, with a market share of 40% or worth USD70 billion. This value is estimated to grow to reach USD146 billion in 2025. This potential needs to be optimized for the benefit of the wider community, and it is hoped that the nation's sons and daughters can become significant players in this field.

In addition to the digital economy, we have recently been made aware of the importance of economic development while prioritizing environmental sustainability. Development without the environmental insight that has been carried out so far has impacted climate change, becoming a threat to human life and activities. Awareness of the negative impacts of climate change has underpinned the idea of a green economy and pushed for a global agreement through the Paris Agreement. Indonesia took part in this and conveyed its commitment to reducing emissions as stated in the Nationally Determined Contributions (NDC). However, to realize these various targets, Indonesia needs to continue to meet a large number of resource needs, increase technological capacity, and encourage the expertise of its human resources. We must continue supporting these various efforts and require cooperation from all stakeholders, including the private sector, government, academia, and the community. Technological and environmental aspects are important to face the challenges that continue to emerge and encourage a more solid, inclusive, and sustainable Indonesian economic recovery.

Indonesia Post-Pandemic Recovery Outlook: Environment and Technology Role for Indonesia Development presents various articles that will enrich us with technology and environment knowledge. This book also shows the important role of technology and the environment in building a more sustainable Indonesia. Hopefully, this book can provide knowledge and encourage us, especially the readers who will later become the locomotive of change, to present technological innovations and make our nation's development more sustainable and environmentally friendly.

Dr. (HC). Ir. Airlangga Hartarto, M.B.A., M.M.T.
Coordinating Minister for Economic Affairs

Opening Remarks
Coordinator of OISAA

The history noted that on October 25, 1908, Indische Vereeniging was established as an Hindia students' association in Leiden, Netherlands. In 1922, the name was changed to Indonesische Vereeniging or Indonesian Students Association, with Mohammad Hatta as one of its leaders (1926–1930). In Australia in 2007, the Indonesian Students Association, which has spread worldwide, agreed to declare itself as an alliance. Since then, this organization is called Overseas Indonesian Students' Association Alliance (OISAA) or Perhimpunan Pelajar Indonesia Dunia (PPI Dunia), becoming the most extensive Indonesian students' organization comprising 60 member countries spread across three regions: Asian-Oceania, America-Europe, and Middle East-Africa. In its journey, OISAA has contributed to various activities such as education, research/study, training/workshop, and community service as the commitment to achieving Golden Indonesia 2045.

In the OISAA Cabinet of "*Cendekia APIK*", we focus on the strategy and approach called "Penta Helix" strategy and approach as a methodology for integrating multi-stakeholder and governance in response to all the current challenges and issues in Indonesia. With this model, OISAA has collaborated and synergized with the government, universities, industries, media, and community. It takes a strategic synergy between the whole elements of Penta Helix so that the goals of Golden Indonesia 2045 can be accomplished. These components are linked to the five directorates and three bureaus; one is the Directorate of Research and Policy Studies (Ditlitka), which focuses on facilitating Indonesian scholars to contribute their scientific knowledge to Indonesia's development.

The Indonesia Post-Pandemic Outlook Series is one of the most crucial works by Ditlitka of OISAA. The books highlight the persistent changes and impacts due to the outbreak of COVID-19. Not only that matter, but the essence of these books will also articulate the mitigation plans for the future pandemic or crises in Indonesia. Written and researched carefully by the authors, the books tell various topics within four categories: "Rethinking Health and Economics Post-COVID-19", "Social Perspectives", "Environment and Technology Role for Indonesia Development", and "Strategy towards Net-Zero Emissions by 2060 from the Renewables and Carbon-Neutral Energy Perspective".

Above all, what are the hope and possible solution to this global super-pandemic for all humanity, especially Indonesia? Those are the areas we are trying to address in these books, to see the outlook beyond COVID-19 in Indonesia based on the UN Research Roadmap for the post-pandemic recovery. These books will be presented and promoted to the government and related stakeholders such as scholars, policymakers, and, most importantly, society. This condition will ensure that the quintessence of these books will positively impact the nation towards the Indonesia's greater. I think this book series can be helpful as a beautiful masterpiece that provides valuable insights and mitigation plans for crises in Indonesia, in the same manner as we have learned from this super pandemic that caused the global disruptions.

In this opportunity, I greatly appreciate all the parties involved in finishing this book series, namely the authors, editors, reviewers, board of directors, commission chairs and members, and the National Research and Innovation Agency publishing house (BRIN Publishing). After all, the collaboration from all the parties who worked tirelessly has enabled the achievement of this critical goal.

Although many possibilities and challenges will happen in the future, I believe these books will encourage legacy to the scientific knowledge in Indonesia. Moreover, this legacy is proof of Indonesian students' awareness of their country, even though they live and study worldwide.

Faruq Ibnul Haqi, S.T., M.RgnlUrbPlan., Ph.D. (Cand.)
President of Overseas Indonesian Students' Association Alliance (OISAA)

Opening Remarks Directorate of Research and Policy OISAA

The Directorate of Research and Policy Studies (Ditlitka) of the Overseas Indonesian Students' Association Alliance (OISAA), commonly known as PPI Dunia, focuses on facilitating Indonesian scholars to contribute their scientific knowledge to the development of Indonesia by promoting knowledge translation and evidence-based policymaking.

COVID-19 has ravaged the world's economy in the past two years, upended existing social support structures, and strongly impacted global geopolitics. Written by over 85 scholars from 22 countries, which are part of the Directorate's nine commissions, this book series titled *Indonesia Post-Pandemic Outlook* aims to present the perspectives of Indonesian scholars on the current pandemic and propose multidisciplinary strategies for Indonesia to recover stronger post-pandemic.

In brief, four books constitute the series as follows:

- Rethinking Health and the Post-COVID-19 Economy by the Health, Economics, and Tourism & Creative Economy Commissions, covering a wide range of topics, including digital health, virtual tourism, international corporate taxation, and green bonds.
- Social Perspectives by the Education, Culture, and International Relations Commissions, covering a wide range of topics, including international relations, social and culture, and education.
- Role of Environment and Technology for Indonesia's Development by the Environment and Technology Commissions covering a wide range of topics, including disaster and greening management, food defense and security, waste and pollution management, as well as human resource and public service.
- Strategy towards Net-Zero Emissions by 2060 from the Renewables and Carbon-Neutral Energy Perspectives by the Energy Commission, covering a wide range of topics, including renewable energy and carbon-neutral related strategies in achieving Net-Zero Emissions in 2060.

Through this book series, the Directorate strongly believes there are many lessons from the current crisis that provide valuable references as the guides for us to anticipate future pandemics and other crises. The books emphasize the need for comprehensive joint efforts between government agencies and the various components of our nation and the need for forward-looking policies to benefit future generations.

Written with policymakers and the public in mind, the books will be presented to the Indonesian government and relevant stakeholders such as academia, NGOs, and the media and made open access to the public. The authors have also aligned their policy recommendations with the Sustainable Development Goals, Indonesia's Long Term

National Development Plan (RPJP), and the United Nations Research Roadmap for COVID-19 Recovery.

The completion of this series is a testament to what is possible when individuals work across siloes and push boundaries to support nation-building. While change and challenges are inevitable for any nation, we hope this series will leave a lasting positive impact on society and promote a legacy of knowledge translation from OISAA *Cendekia APIK*.

On behalf of the Directorate, we extend our deepest appreciation and gratitude to all the parties involved—authors, reviewers, commission chairs and members, OISAA *Cendekia APIK*'s President and Board, national-level Indonesian Student Association chapters, and the National Research and Innovation Agency publishing house (BRIN Publishing) that made all of this possible.

Board of Directors, Directorate of Research and Policy Studies
OISAA *Cendekia APIK*

Muhammad Aswin Rangkuti

Radityo Pangestu

Anthony Paulo Sunjaya

Afifah Muharikah

David Firnando Silalahi

Chapter 1

Environment and Technology as the Foundation of Indonesia's Sustainable Development

Rahmat Trialih, Fefi Eka Wardiani, Rendy Anggriawan, Cendra Devayana Putra, & Ahmad Said

The COVID-19 pandemic has hit the whole world, including Indonesia, since 2019. In 2022, the COVID-19 pandemic began to recover and activities in the world, including Indonesia, gradually returned to normal. However, the word "normal" here does not become "normal" as it used to be, but a new term appears, namely a new normal. This new normal situation can pose a threat to Indonesia as the largest archipelagic country with the fourth largest population in the world. However, the government cautiously views it as an opportunity to take Indonesia further. Therefore, an idea emerged to make this pandemic the initial fundamental to achieving digital and economic transformation in Indonesia (Kusnadi & Hikmawan, 2020). The Indonesian government website states that the government's current focus is to implement a national recovery policy strategy.

R. Trialih, F. E. Wardiani, & A. Said
University College Cork, Ireland, e-mail: rtrialih@gmail.com

Trialih, R., Wardiani, F. E., Anggriawan, R., Putra, C. D., & Said, A. (2022). Environment and technology as the foundation of Indonesia's sustainable development. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and technology role for Indonesia development* (1–6). DOI: 10.55981/brin.538.c503
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The national economic recovery policy strategy is a formula made by the central government so that Indonesia can still carry out the work targets that have been set nationally and ensure that these policies can be implemented consistently. In practice, this strategy seeks to maximize communication between the top and bottom to achieve adequate, reasonable, and smooth national integration. In general, the central government will act as a regulator that takes a holistic economic recovery policy. Meanwhile, the local government will play a role in implementing the policy so that the people of Indonesia can feel the new development (Evans & Yen, 2006). In addition, its implementation requires continuous communication and collaboration between the government, the civil society, practitioners, the business world, and academia.

This book tries to present the right ideas for Indonesia's recovery after the COVID-19 pandemic from an environmental and technological perspective. As an archipelagic country with 17,491 islands, it is not surprising that this geographical advantage needs to be utilized by Indonesia to realize the strategy that has been set. The environment itself has become a pressing issue worldwide, including in Indonesia. In this case, we see that if Indonesia can appear to bring about environmental issues, this will have a good impact. In addition, today's technological developments have become a factor that cannot be separated from human life. Almost all sectors and communities cannot be separated from technology. This proves that technology has been proven to bring changes in business processes in a country. In this regard, we also see that technology can transform the system in Indonesia so that it becomes a comfortable, safe, and reliable system for all people in Indonesia.

As we know, today's technological advances have had environmental impacts and humanitarian issues (Aithal & Aithal, 2016; Shurtleff, 2002). These two impacts cause a significant influence on rapid ecological changes and affect the relationship between humans with humans and between humans with nature. In addition, with existing technological advances, the development of a country is based on technology-based development. If we look at this development, it is certainly good because it builds civilization, but it also has issues that have the potential to emerge new problems. In the development process, natural resources play a critical role in life, and the utilization of natural resources should run in balance with development (Inose & Pierce, 1984). However, in reality, this is not the case; we usually find that exploitation of natural resources is excessive which makes the development's ecosystem or environment is damaged. On the other hand, development in this era has a good side and improves existing facilities, increasing the community's economy around the development. Development is also a sign that an area is progressing. Technology-based development also can make society becomes more modern.

Based on this brief explanation, we can conclude that the role of the environment and technology in changing Indonesia for the better is essential. Through this, we, the environmental and technology commission under the auspices of Perhimpunan Pelajar Indonesia Dunia (PPID) or Overseas Indonesian Students Association Alliance (OISAA), try to share the thoughts of Indonesian students to help the development of Indonesia in the future with a focus on Indonesia's post-pandemic condition economic recovery. This topic is the foundation and the primary concern of all chapters in this book. This book is divided into four major sections: disaster and greening management development, waste and pollution management development, food defense and security development, and human resource and public service development.

Section one is titled disaster and greening management development. This section focuses on the solution in disaster prevention and greening management and consists of four chapters. Chapter 2 explain the general concepts and recent progressions of defossilization technologies in the chemical industry to meet the "net-zero emissions" goal. Additionally, Chapter 3 focuses on nature-based solutions (NbS), such as the bioremediation approach, which holds great promise for improving agricultural sustainability. Chapter 4 specifically focus on the remediation of heavy metals and Chapter 5 clearly explain and provide knowledge about geomorphological watersheds.

The second section is waste and pollution management development. This section discusses the solution to managing the waste and pollution that happened. Chapter 6 discuss the membrane technology for wastewater. Then, Chapter 7 discusses air pollution due to the rapid development of industry in Indonesia, especially industry 4.0. Chapter 8 discuss the impact of textile dyes on health and their remediation on the environment. While Chapter 9 gives information about several mitigation strategies that have been implemented by other countries and global communities that are also considered in order to keep the spread of microplastics at the lowest level. Additionally, Chapter 10 discusses the critical point that city society adapting to human life to reduce carbon emissions. Such as using green transportation, green building, green industry, etc.

The next section is titled food defense and security development. This section focus on how we can achieve food defense and avoid the scarcity of food that happened annually. Chapter 11 discuss the potential of coastal sand marginal land resources to improve food security post-Covid-19 pandemic in Indonesia. This is in accordance with one of the top priorities in the UN Research Roadmap for COVID-19 recovery, which is to develop a strategy for preventing degradation and preserving land resources to be better integrated to support food security. Chapter 12 explains the internet of things (IoT) implementations of smart packaging by a novel approach for managing food waste. Then, Chapter 13 contented the smart supply chain. It tells how technology can transform the agricultural industry in the post-pandemic era. Later, this chapter consisted of the logistic problem in Indonesia and give a strategy to change it through a smart food supply chain.

The last section is human resources and public service development. This section discusses the role of technology in creating good human resources and giving society the appropriate living service. Chapter 14 discuss the role of technology in enabling knowledge management in the educational sector. Later, it offers guidance on building a proper knowledge management system and what we need to give attention to and consider when building information systems. Additionally, Chapter 15 focuses on transportation issues in Indonesia and how technology can help solve these issues through smart, efficient, and inclusive systems. This chapter also explains the transportation problem in Indonesia. Later, it gives recommendations based on previous research solutions, current technology, and other countries' success stories. Furthermore, chapter 16 discusses blockchain technology that creates effective e-government. This chapter talks about the emergence of blockchain technology and its use in societies. This chapter provides the utilization of blockchain for government and the recommendation to succeed government transformation using blockchain. Chapter 17 discusses a brief review of related hospital information systems. Additionally, it explains the module list in hospital information systems and how it can be a game-changer in Indonesia's medical world. Chapter 18 is related to the previous chapter but more focused on electronic health records. This chapter provides information regarding the benefits, functions, foundations, and challenges in implementing electronic health records in Indonesia.

We hope that the ideas we have written down can help stakeholders make Indonesia for the better, especially in the post-pandemic era of COVID-19. In addition, we hope that our ideas can give a contribution to Indonesia's development in the future.

References

Aithal, P. S., & Aithal, S. (2016). Opportunities & Challenges for Green Technologies in 21st Century. In International Journal of Current Research and Modern Education (IJCRME) ISSN: Vol. I. http://ssrn.com/abstract=2837272

Evans, D., & Yen, D. C. (2006). E-Government: Evolving relationship of citizens and government, domestic, and international development. Government Information Quarterly, 23(2), 207–235. https://doi.org/https://doi.org/10.1016/j.giq.2005.11.004

Inose, H., & Pierce, J. R. (1984). Information technology and civilization. World Futures, 19(3–4), 293–303. https://doi.org/10.1080/02604027.1984.9971988

Kusnadi, I. H., & Hikmawan, M. D. (2020). Digital cohesion in era of pandemic COVID-19 in Indonesia. International Journal of Engineering Research and Technology, 13(7), 1775–1779. https://doi.org/10.37624/ijert/13.7.2020.1775-1779

Shurtleff, D. K. (2002). The Effects of Technology on Our Humanity. The US Army War College Quarterly: Parameters, 32(2). https://doi.org/10.55540/0031-1723.2098

SECTION 1

DISASTER AND GREENING MANAGEMENT DEVELOPMENT

Chapter 2

Defossilizing Chemical Industry as an Integrated Solution for Indonesia's Climate and Pandemic Crisis

Radityo Pangestu

A. The Impact of The Chemical Industry on Climate Change

In light of international commitment to limit global warming at a level of 1.5° to 2°C, it is no exaggeration that all countries must put "net-zero emissions goal" as their utmost priority. This target, however, requires holistic efforts from multiple stakeholders and will reshape the way contributing sectors develop for decades to come. According to Indonesia's Nationally Determined Contribution (NDC), the country's total greenhouse gas (GHG) emissions would skyrocket from 1,334 Mton-CO_2e (in 2010) to 2,869 Mton-CO_2e (in 2030) if no countermeasures were implemented. Also, although the levels of emissions from industrial processes and product use (IPPU) were

R. Pangestu
Kobe University, Japan, e-mail: pangestu.radityo@gmail.com

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lower than in other sectors, such as energy, waste, agriculture, and forestry, the 2030's business-as-usual projection level of this sector was almost 2-fold higher than the number of emissions in 2010 (Government of Indonesia, 2021).

Unfortunately, to date, most discussions about climate change focus heavily on the energy and forestry sectors only. Meanwhile, improvements in the IPPU sector could also help enhance the emission reduction from both sectors. The emissions from the chemical industry, to be specific, are somewhat underestimated. Thus far, many attempts still focus on reducing and recycling industrial wastes, which is also an important objective. However, it is even more crucial to address the most fundamental problem—the dependency of the chemical industry on fossil resources as its raw materials. At the same time, as the world has progressively phased out fossil fuels as the primary energy source, many natural gases and oil exploration projects worldwide will end soon. This trend means that the chemical industry needs immediate undertakings to find alternative resources to secure its material input supply.

In the case of the energy sector, decarbonization is practicable by substituting fossil fuels with zero- or low-carbon power sources, such as wind, solar, hydro, and nuclear power. However, "decarbonizing the chemical industry" is impossible because almost all products we use today contain GHG. Moreover, most of those products contain materials originating from fossil-based resources. As a result, the extensive industrial revolution has resulted in the surplus of carbon concentration in the atmosphere transferred from the lithosphere. This CO_2 emission "leaks" from the manufacturing process of chemicals (production phase) during the period when commercial derived products deliver their functions (use phase) and after the disposal of those products (end-of-life phase). Hence, decoupling chemical production from fossil resources is arguably the most effective climate change mitigation measure for this sector.

Amid the struggle of fighting climate disasters, the entire world faces the second global crisis—the COVID-19 pandemic. Many climate campaigners expressed their concerns about how policymakers in many nations take this pandemic situation as an excuse to renege on their climate commitments (Harvey, 2020). Interestingly, accelerating climate action by greening the chemical industry could unlock the possibility of creating new jobs—one keyword that is pivotal for any post-pandemic recovery plan. Therefore, mitigation of climate disaster and the COVID-19 pandemic can be executed by outlining approaches that simultaneously address both crises.

This chapter explains the general concepts and recent progressions of defossilization technologies in the chemical industry to meet the "net-zero emissions" goal. As CO_2 predominantly contributes to global GHG emissions compared to other gases, the discussion in this chapter is limited to this emitter only. Moreover, even though the chemical industry also employs carbon as a source of energy, this chapter mainly focuses on the topics related to carbon utilization as raw materials (feedstocks). Lastly, the interconnection of the defossilization concept in the chemical industry with post-pandemic recovery is also discussed.

B. Decoupling Chemical Industry from Fossil Resources

Aside from being employed as fuels, fossil resources are now still the primary components to manufacture various important chemicals utilized by plastic, electronic, textile, food, cosmetic, pharmaceutical, and other manufacturing industries. These so-called petrochemicals are extracted or processed from non-renewable carbon sources, such as natural gas, petroleum, and coal. The vast majority of daily products used by humans contain components manufactured from these fossil-based raw materials. Besides, the International Energy Agency (IEA) report shows that the oil consumption as a feedstock for plastic production in the United States, Europe, China, and India would outnumber the quantity of oils utilized for transportation (International Energy Agency, 2018).

As shown in Figure 2.1, numerous commodity chemicals are derived from fossil-based feedstocks. Natural gas liquids (NGLs) drilled from the Earth's surface, including ethane, propane, and butane, are intermediates to generate olefins, such as ethylene propylene, which are raw materials to produce various platform chemicals, e.g., ethanol and 1,3-butadiene (for synthetic rubbers), and polymer, e.g., polyethylene (PE; for plastic packaging), polyvinyl chloride (PVC; for pipes and electric cables) and polyacrylic acid (PAA; for superabsorbent and disposable diapers). Meanwhile, benzene, toluene, and xylene (BTX) are formed from catalytic reforming of naphtha, one of the fractions from petroleum refining. These chemicals are starting materials to produce commercial polymers, such as polystyrene (PS; for Styrofoam products), nylon-6 (for synthetic fibers), bisphenol-A (BPA; for food ware products), polyurethane (PU; for kitchen foams, automobile interiors, and decorations), polyethylene terephthalate (PET; for plastic bottles) and phthalic anhydride (for plasticizers and dyestuffs). Coal gasification generates syngas consisting of hydrogen

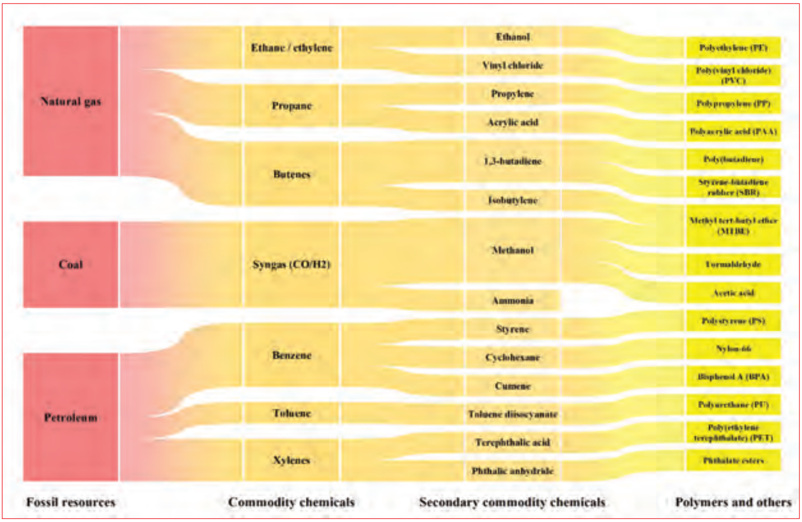


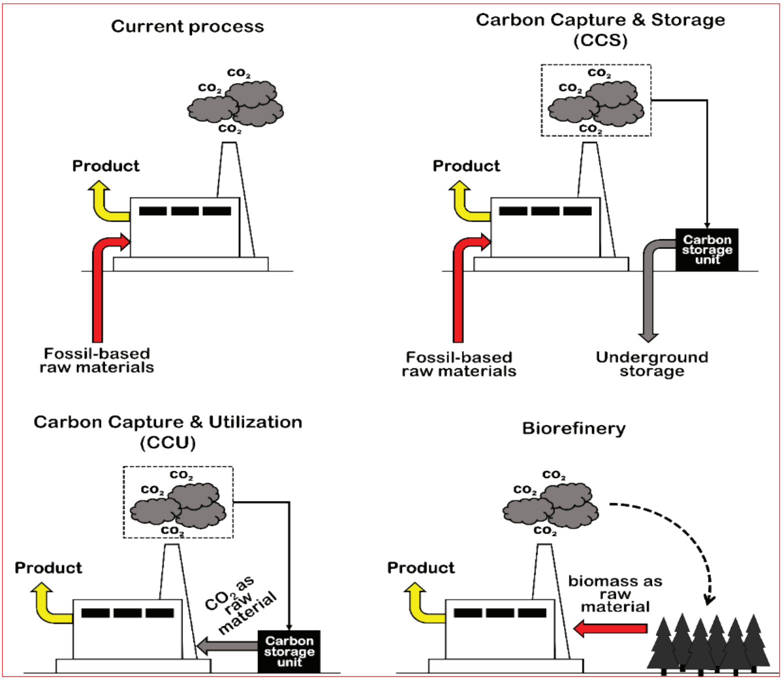
Figure 2.1 Production Flow of Several Fossil-Based Commodities in the Chemical Industry

and carbon monoxide, precursors for producing methanol and ammonia. Both chemicals, plus ethylene and propylene, are commodities with the most significant global production volumes and the highest GHG emissions compared to other chemicals (International Energy Agency, 2013).

C. Achieving Net-Zero Emissions in the Chemical Industry

To date, there are three approaches to achieving net-zero emissions (or, in this case, net-CO_2 emission) in the chemical industry. Briefly, as illustrated in Fig. 2.2., the CO_2 emission produced from converting fossil resources into target chemicals in the current industrial process leads to the positive accumulation of GHGs in the atmosphere. For that reason, many scientists explore methods to avoid the release of CO_2 by capturing the gas and storing it underground, i.e., geological storage, in the form of supercritical fluid, known as carbon capture and storage (CCS). However, this strategy still uses fossil resources as feedstocks. Therefore, rather than transferring the gas below the surface, the second approach, termed carbon capture and utilization (CCU), attempts to employ the generated CO_2 as a raw material to synthesize various chemicals. Unfortunately, there are still numerous technological limitations to efficiently obtaining the CO_2 with high purity from the air and performing the chemical conversion using CO_2 as the substrate due to its low reactivity. Meanwhile, the third approach uses organisms, such as plants and microorganisms, as a natural CO_2 capturer and converter before its utilization.

In CCS, CO_2 is captured using various methods, such as chemical adsorption, physical absorption, membrane separation, and biofixation. However, amine solution absorption is the most common technique (Rahimpour et al., 2020). The emitted gas can be directly captured from the ambient air (emitted during production, use, and end-of-life phase) and from point sources (emitted during production and end-of-life phase). Point-source-CO_2 captured from post-combustion of coal using the amine method has been well-established with a technological readiness level (TRL) of 9 (The Highest Score from 0 to 9). In contrast, direct capture of CO_2 from the air via the adsorption-desorption process has a TRL of 7 (Bui et al., 2018). The captured gas is then transported using pipelines or ships and stored underground. CO_2 is sequestrated by injecting it (in a supercritical fluid form) several kilometers below the Earth's surface in the location of depleted oil and gas fields, deep un-minable coal seams, or deep saline aquifer formations. It can also be stored in stable carbonate forms by a subsequent reaction with metal oxides (called mineral carbonation) (Nocito & Dibenedetto, 2020).



Source: Recreated with several adaptations from Gabrielli et al. (2020)

Figure 2.2 Schemes of the Current Industrial Process to Produce Chemicals from Fossil Resources and Three Approaches for Defossilizing the Chemical Industry: Carbon Capture and Storage (CCS), Carbon Capture and Uutilization (CCU), and Biorefinery

Despite public debates regarding its long-term safety, CCS's impact on reducing atmospheric CO_2 concentration is somewhat undeniable. Data in 2018 shows that there were 37 major commercial-scale CCS facilities worldwide; most of them were in the United States and China (Bui et al., 2018). Meanwhile, in Indonesia, Pertamina and several multinational companies have initiated CC(U)S projects in Java, Sumatra, and Papua by 2021 (Karyza, 2021; Maulia, 2021; Pertamina, 2021a).

CCS may avoid the CO_2 release but not necessarily solve the unsustainability issue with fossil-based resources in the chemical industry. Therefore, in CCU, the carbon released during the manufacturing process is recycled to synthesize CO_2-based chemical products, thus supporting the circular carbon economy concept. It is worth noting that the captured CO_2 can also be utilized as fuels, mineral carbonization, construction materials, and others. However, its utility for chemical production is the only subject discussed here. A production-scheme scenario by Kätelhön et al. (2019) examined the conversion reaction of captured CO_2 into methanol (eq. 1) and methane (eq. 2) by reaction with hydrogen obtained from water electrolysis, as expressed by the following reactions:

$$CO_2 + 3\,H_2 \rightleftharpoons CH_3OH + H_2O \quad \text{(eq. 1)} \quad \text{(Rihko-Struckmann et al., 2010)}$$
$$CO_2 + 4\,H_2 \rightleftharpoons CH_4 + 2\,H_2O \quad \text{(eq. 2)} \quad \text{(Rönsch et al., 2016)}$$

Obtained methane is convertible to generate ammonia, whereas methanol can be an intermediate to produce olefins and BTX. Therefore, the second reaction is analog to the production flow depicted in Fig. 2.1. In France, theoretically, this route could reduce up to 50% of GHG emissions from the chemical industry over the entire product life cycle (from production until the end-of-life phase). Besides, further improvements could still be achieved by employing lower carbon-footprint electricity sources, such as solar or wind power, for the process. In terms of TRL, these methane-and-methanol-based

CCU strategies are assessed at a score of 7 or higher (Kätelhön et al., 2019); thus, adequately mature for industrial-scale development.

To date, these technologies are still optimized to establish cost-effective processes which use greener catalysts and consume less power and water. Despite its slow development, CCU technology has gained much attention from governments, industries, and investors. According to data from 1980, more than 1,500 patents related to CO_2 utilization for fuels and chemicals have been published, and most of them came from the United States (Norhasyima & Mahlia, 2018). Carbon Recycling International (CRI) was the first company that has started to produce CO_2-based methanol at an industrial scale in 2012 in George Olah Plant, Iceland, and, by 2019, its capacity has reached about 5 million liters of product per year and converted around 5,600-ton CO_2 per year (Richter, 2019). In Indonesia, a feasibility study to build a CO_2-based ammonia production plant in Sulawesi began in early 2021 in collaboration with Japan (Mitsubishi Corporation, 2021).

Both CCS and CCU have numerous obstacles in establishing methods to capture and convert CO_2 effectively and economically. Meanwhile, the biorefinery approach employs a natural system available in organisms, i.e., photosynthesis, to perform those works. This system transforms CO_2 into organic carbons as intermediate chemicals, such as ethanol, lactic acid, acetic acid, and glycerol, to generate target chemicals with higher economic values via well-established chemical reactions. As defined by IEA Bioenergy, biorefinery is a sustainable process to convert biomass into a variation of bio-based products and bioenergy (de Jong et al., 2012). In this process, renewable biomasses, such as grasses, starch, sugar crops, oil crops, lignocellulose, algae, and other organic residues, can substitute fossil-based feedstocks (Takkellapati et al., 2018).

Of all the renewable feedstocks, lignocellulose biomass (LB) is the most studied material. The general processing steps aim to transform LB into so-called ‘bio’-based chemicals using various methods, such as thermochemical, chemical, biochemical, or/and mechanical techniques. LB contains three significant convertible fractions based on its chemical structure: cellulose, hemicellulose, and lignin. Cellulose and hemicellulose are polysaccharides; thus, they have sugar(s) as their main monomers. Cellulose is thicker due to its linear glucan structure, whereas hemicellulose is less stiff and also composed of xylans, mannans, galactans, and arabinans (Brunner, 2014). In contrast, lignin consists of aromatic carbons possessing guaiacyl, syringyl, and *p*-hydroxyphenyl groups (Mathews et al., 2015). Commonly, these polymers are separated and broken down into their monomers using pre-treatment and enzymatic hydrolysis steps. Afterward, simpler monomers are transformed into the platform chemicals via the fermentation step.

As depicted in Figure 2.3, numerous petroleum-based chemicals shown in Fig. 2.1. can also be synthesized from LB as feedstock substitutes. For instance, essential commodity chemicals, such as acetic acid, can be produced from cellulose and hemicellulose in lieu of synthe-

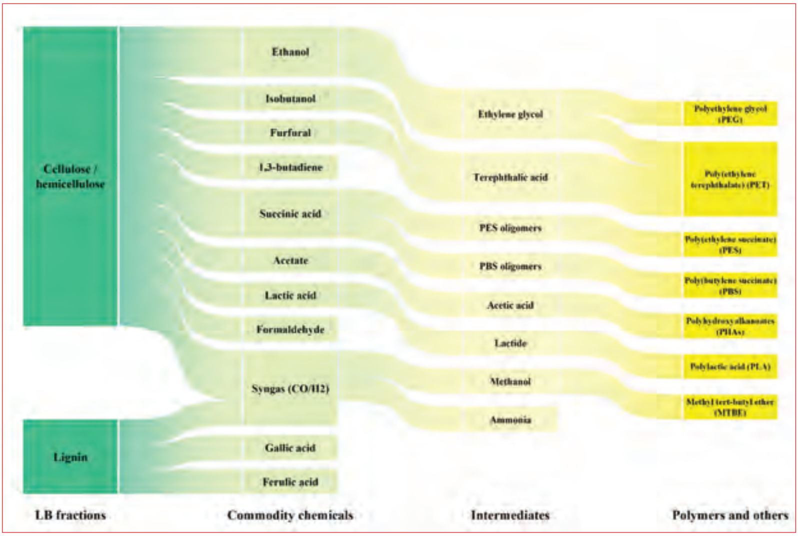


Figure 2.3 Production Flow of Several Bio-Based Chemicals Using Lignocellulose-Based Carbon Feedstocks

sized from syngas-origin methanol. Also, instead of extracting NGLs to manufacture 1,3-butadiene, this chemical can be produced from bioethanol via catalytic conversion or fermentation (Jones, 2014; Mori et al., 2021). Bio-PET, a bio-based version of PET, can be synthesized by mixing bio-ethylene glycol (bio-EG) with bio-terephthalic acid (bio-TPA) obtained from transforming bio-furfural or bio-isobutanol (Nakajima et al., 2017). In addition to bio-based traditional plastics, LB can also be utilized to make "bio-based biodegradable" (originated from renewable sources and can naturally be degraded) plastics, e.g., polylactic acid (PLA) and polyhydroxyalkanoates (PHAs), from bio-based monomers, e.g., bio-lactic acid and bio-acetic acid, respectively. Besides being greener, those commercial biodegradable polymers also possess thermal, mechanical, rheological, and physical properties that are competitive with fossil-based plastics. Thus, they are futuristic plastics that can substitute low-density polyethylene (LDPE), polystyrene, and other mainstream plastics (Naser et al., 2021).

TRL of biorefinery varies depending on the type of feedstock utilized and target chemicals produced. Conventional (starch and sugar crop-based feedstocks), oleochemical (oil crop-based feedstocks), LB, and marine biorefineries (microalgae and macroalgae-based feedstocks) have TRL levels at around 9, 7–9, 6–8, and 5–6, respectively (Lindorfer et al., 2019). Also, several biorefinery projects, especially ones related to biodiesel commodities have been initiated in Indonesia (Pertamina, 2021b). However, despite being less energy-intensive than CCU, biorefinery has one limitation related to its high land use requirement. A large amount of land for crop cultivations must be prepared near production plants to reduce the emissions from transporting process. A calculation shows that bio-based methanol production required almost 50-fold more area than CO_2-based methanol (CCU via direct capture and point source feedstock) (Gabrielli et al., 2020). Extensive deforestation in Malaysia and Indonesia might correlate with biodiesel refineries (Manikandan et al., 2016). Therefore, stricter regulations are needed to avoid a massive biodiversity loss.

In general, all three routes have prospective contributions to reducing CO_2 emissions from the chemical industry. It is also apparent that, unlike CCU and biorefinery, CCS does not entirely fit the "defossilization" concept. Nevertheless, compared to other schemes, this approach requires less fundamental adaptation in terms of infrastructure changes to the existing oil and gas production plants. Hence, this sector can be an immediate and transitional measure to fit low-carbon goals. As a tropical country, developing biorefinery technologies in Indonesia is very attractive. Also, green job creation is one of the foreground benefits of this approach (Kahar et al., 2022). However, the environmental aspect related to land-use change emissions should be carefully considered. Of all, CCU could be the most sustainable alternative. However, the high energy required to perform the chemical reactions is currently one of the most concerning bottlenecks for this approach. Also, the carbon intensity of energy applied to the process must be low carbon; otherwise, the total CO_2 emitted can surpass the emission level from the current industrial processes (Gabrielli et al., 2020).

D. Impact Of Defossilization on Green Jobs

In 2020 alone, the pandemic caused the loss of at least 255 million full-time jobs globally. Several climate-friendly industries, on the contrary, could potentially offer more vacancies for new workers compared to other sectors. For instance, in the case of Indonesia, one estimation claimed that 15.3 million green jobs would be created by 2045, mainly in the energy sector, if the government could adequately implement low-carbon strategies (Srivastava, 2021). Although, by far, the contribution of the chemical industry in expanding the employment rate has not been shrewdly calculated, this sector will undoubtedly help surge the availability of green-collared jobs.

According to Statistics Indonesia (BPS) (2020), manufacturing industries contributed to about 9.6% of jobs in Indonesia—albeit not all are related to the chemical industry. Unfortunately, the current systems adopted in the chemical industry are considered more capital intensive. Since many chemical plants use more robots than humans, expanding production plant capacity does not significantly create jobs. Data from the U.S. Census Department in 2007 revealed that petrochemical manufacturing was the subsector with the lowest labor/capital (L/C) ratio (indicates the number of jobs created per $1 million investment in productive capital) compared to other subsectors in chemical industries (Heintz & Pollin, 2011).

In contrast, fossil-resources-free industries, such as biorefinery plants, could generate more jobs than the current system. For instance, calculations using the L/C ratio in the plastic industry show that traditional petroleum-based plastic production generated only 1.2 direct and 3.1 indirect jobs (4.3 jobs, in total). In contrast, bio-based plastic production would generate 1.2 direct and 5.7 indirect jobs (6.9 jobs, in total) (Heintz & Pollin, 2011). A higher L/C ratio of indirect jobs from the bio-based plastic industry might be due to the labor-intensive cultivation stage, thereby requiring more human power. Furthermore, a report by one independent research provider unveiled that a direct-air-CO_2-capture plant with a one-million-ton capacity could create about 3,428 direct jobs. However, most of these jobs would be temporary and related to plant investment only. Meanwhile, employment related to the plant operations were estimated to be around 359 jobs (Larsen et al., 2020). These numbers will assuredly amplify if the CO_2 capture plant is also coupled with carbon utilization technology as an integrated CCUS system.

Contrasting the belief that phasing out fossil resources will jeopardize the employment rate, defossilization is, in fact, beneficial from the perspective of economics. The number of green jobs created from this sector can negate the unemployment loss from pandemics and the closure of fossil resource extraction plants. Therefore, phasing out fossil feedstock in the chemical industry must be encouraged.

E. Conclusion and Recommendation

Mitigating the climate threat requires comprehensive undertakings from all contributing sectors. Regrettably, the chemical industry is one area that tends to be overlooked by many. "Fossil fuel phase-out" is one of the most eminent jargons in any climate campaign. However, the fossil feedstock phase-out for the industry also needs to be provoked. By far, there are three schemes to realize this goal, namely via CCS, CCU (or, as an integrated-CCUS), and biorefinery. Altogether, those three defossilization routes provide, to varying extents, novel sustainability employments. These job opportunities can certainly negate the impacts of unemployment caused by the pandemic that began this decade. As the global transition to the green industry is inevitable, the Indonesian government must act post-haste to recognize this trend by preparing its infrastructures and human resources. Besides, this pandemic can be a kickstart to make a momentous shift toward developing a greener economic system.

Above all, actualizing this concept can be burdensome. Howbeit, here are several recommendations to implement the chemical industry defossilization as one of the country's climate endeavors:

1. As the world is moving faster to implement a low-carbon chemical industry, Indonesia must also promptly immerse this concept. To address this, the development of the three previously discussed approaches must be reinforced altogether into the national strategic master plan. However, in the document of Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Indonesia's LTS-LCCR 2050), the employment of CCUS technology still mainly focuses on the energy sector, whereas adopting it for supplying the feedstocks to the petrochemical industry is also indispensable.
2. Various schemes to produce bioplastics from numerous biomass have been invented (Kawaguchi et al., 2022). Stimulating the local manufacturers to develop and adopt these routes into their

production systems can be done by proposing several regulations. Indonesian government, to date, has initiated several bilateral and multilateral partnerships to advance these three technologies. Incorporating these topics into national research fund priorities is also pivotal. In addition, strategies to promote biorefinery through partnership schemes between startup and state-owned enterprises can also be explored.

3. During the transition to defossilize the chemical industry, action plans for resource efficiency must also be executed. Improving waste utilization technologies could help attain resource efficiency (Pangestu, 2021). Regardless, this resource efficiency concept can also reduce the carbon footprint of chemical plants in non-carbon-based commodities, i.e., inorganic chemicals.
4. In addition to the feedstock supplies, GHG emissions from the chemical industry also majorly come from its energy input. Therefore, transitioning to greener energy for the industrial process is also urgent and must be done concurrently.
5. As yet, the studies that examine the economic impacts of these three defossilization schemes in Indonesia, particularly ones related to green job creation, are still inadequate. This information is crucial to proposing strategic policies related to integrating low-carbon industry goals with COVID-19 recovery plans.

References

Brunner, G. (2014). Processing of Biomass with Hydrothermal and Supercritical Water. In Supercritical Fluid Science and Technology (Vol. 5, pp. 395–509). Elsevier. https://doi.org/10.1016/B978-0-444-59413-6.00008-XBui, M., Adjiman, C. S., Bardow, A., Anthony, E. J., Boston, A., Brown, S., Fennell, P. S., Fuss, S., Galindo, A., Hackett, L. A., Hallett, J. P., Herzog, H. J., Jackson, G., Kemper, J., Krevor, S., Maitland, G. C., Matuszewski, M., Metcalfe, I. S., Petit, C., … Mac Dowell, N. (2018). Carbon capture and storage (CCS): The way forward. *Energy and Environmental Science*, *11*(5), 1062–1176. https://doi.org/10.1039/c7ee02342a

De Jong, E., Higson, A., Walsh, P., & Wellisch, M. (2012). Bio-based Chemicals: Value Added Products from Biorefineries (Task 42 Biorefinery). IEA Bioenergy. https://www.ieabioenergy.com/wp-content/uploads/2013/10/Task-42-Biobased-Chemicals-value-added-products-from-biorefineries.pdf

Gabrielli, P., Gazzani, M., & Mazzotti, M. (2020). The Role of Carbon Capture and Utilization, Carbon Capture and Storage, and Biomass to Enable a Net-Zero-CO 2 Emissions Chemical Industry. Industrial & Engineering Chemistry Research, 59(15), 7033–7045. https://doi.org/10.1021/acs.iecr.9b06579

Government of Indonesia. (2021). *Nationally Determined Contribution Republic of Indonesia 2021*. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Indonesia%20First/Updated%20NDC%20Indonesia%202021%20-%20corrected%20version.pdf

Harvey, F. (2020, 7 April). *Japan waters down climate commitments, using coronavirus as an excuse*. Bulletin of the Atomic Scientists. https://thebulletin.org/2020/04/japan-waters-down-climate-commitments-using-coronavirus-as-an-excuse/

Heintz, J., & Pollin, R. (2011). The economic benefits of a green chemical industry in the United States protecting health and the environment. *Political Economy Research Institue*, *1*(May), 1–44.

International Energy Agency. (2013). *Technology Roadmap Energy and GHG Reductions in the Chemical Industry via Catalytic Processes*. https://www.iea.org/reports/technology-roadmap-energy-and-ghg-reductions-in-the-chemical-industry-via-catalytic-processes

International Energy Agency. (2018). The future of petrochemicals – Analysis. In *International Energy Agency*. https://www.iea.org/reports/the-future-of-petrochemicals

Jones, M. D. (2014). Catalytic transformation of ethanol into 1,3-butadiene. Chemistry Central Journal, 8(1), 53. https://doi.org/10.1186/s13065-014-0053-4

Kahar, P., Rachmadona, N., Pangestu, R., Palar, R., Triyono Nugroho Adi, D., Betha Juanssilfero, A., Yopi, Manurung, I., Hama, S., & Ogino, C. (2022). An integrated biorefinery strategy for the utilization of palm-oil wastes. *Bioresource Technology*, *344*, 126266. https://doi.org/10.1016/J.BIORTECH.2021.126266

Karyza, D. (2021, 13 October). *Repsol to start operating "first" CCS facility in Indonesia by 2027*. The Jakarta Post. https://www.thejakartapost.com/news/2021/10/13/repsol-to-start-operating-first-ccs-facility-in-indonesia-by-2027.html

Kätelhön, A., Meys, R., Deutz, S., Suh, S., & Bardow, A. (2019). Climate change mitigation potential of carbon capture and utilization in the chemical industry. *Proceedings of the National Academy of Sciences of the United States of America*, *166*(23), 11187–11194. https://doi.org/10.1073/pnas.1821029116

Kawaguchi, H., Takada, K., Elkasaby, T., Pangestu, R., Toyoshima, M., Kahar, P., Ogino, C., Kaneko, T., & Kondo, A. (2022). Recent advances in lignocellulosic biomass white biotechnology for bioplastics. *Bioresource Technology*, *344*, 126165. https://doi.org/10.1016/J.BIORTECH.2021.126165

Larsen, J., Herndon, W., & Hiltbrand, G. (2020, 23 June). *Capturing New Jobs and New Business: Growth Opportunities from Direct Air Capture Scale-Up*. https://rhg.com/research/capturing-new-jobs-and-new-business/

Lindorfer, J., Lettner, M., Hesser, F., Fazeni, K., Rosenfeld, D., Annevelink, B., & Mandl, M. (2019). Technical, economic and environmental assessment of biorefinery concepts. In *IEA Bioenergy task 42*. https://www.ieabioenergy.com/wp-content/uploads/2019/07/TEE_assessment_report_final_20190704-1.pdf

Manikandan, N. A., Kumar, R. V., Pugazhenthi, G., & Pakshirajan, K. (2016). Biorefinery and possible deforestation. In S. K. Brar, S. J. Sarma & K. Pakshirajan (Eds.) *Platform Chemical Biorefinery* (pp. 307–322). Elsevier. https://doi.org/10.1016/B978-0-12-802980-0.00016-X

Mathews, S. L., Pawlak, J., & Grunden, A. M. (2015). Bacterial biodegradation and bioconversion of industrial lignocellulosic streams. *Applied Microbiology and Biotechnology*, *99*(7), 2939–2954. https://doi.org/10.1007/s00253-015-6471-y

Maulia, E. (2021, 29 November). *BP unveils up to $3bn CCUS project in Indonesia, country's first*. Nikkei Asia. https://asia.nikkei.com/Spotlight/Environment/BP-unveils-up-to-3bn-CCUS-project-in-Indonesia-country-s-first

Mitsubishi Corporation. (2021, 19 March). *Signing of Memorandum of Understanding regarding CCS Joint Study for Clean Fuel Ammonia Production in Indonesia*. https://www.mitsubishicorp.com/jp/en/pr/archive/2021/html/0000046720.html

Mori, Y., Noda, S., Shirai, T., & Kondo, A. (2021). Direct 1,3-butadiene biosynthesis in Escherichia coli via a tailored ferulic acid decarboxylase mutant. *Nature Communications*, *12*(1). https://doi.org/10.1038/S41467-021-22504-6

Nakajima, H., Dijkstra, P., & Loos, K. (2017). The recent developments in biobased polymers toward general and engineering applications: Polymers that are upgraded from biodegradable polymers, analogous to petroleum-derived polymers, and newly developed. *Polymers*, *9*(10), 1–26. https://doi.org/10.3390/polym9100523

Naser, A. Z., Deiab, I., & Darras, B. M. (2021). Poly(lactic acid) (PLA) and polyhydroxyalkanoates (PHAs), green alternatives to petroleum-based plastics: a review. *RSC Advances*, *11*(28), 17151–17196. https://doi.org/10.1039/d1ra02390j

Nocito, F., & Dibenedetto, A. (2020). Atmospheric CO_2 mitigation technologies: carbon capture utilization and storage. *Current Opinion in Green and Sustainable Chemistry*, *21*, 34–43. https://doi.org/10.1016/J.COGSC.2019.10.002

Norhasyima, R. S., & Mahlia, T. M. I. (2018). Advances in CO_2 utilization technology: A patent landscape review. *Journal of CO_2 Utilization*, *26*, 323–335. https://doi.org/10.1016/j.jcou.2018.05.022

Pangestu, R. (2021). Resource efficiency progresif sebagai kunci ekonomi hijau Indonesia berkelanjutan – Pembelajaran dari beberapa negara Asia. In R. Pangestu, R. Rifat, D. A. Prihardini, & F. Pirade (Eds.), *Indonesia Emas Berkelanjutan 2045: Kumpulan Pemikiran Pelajar Indonesia Sedunia Seri 7 Lingkungan* (pp. 165–181). LIPI Press. https://doi.org/10.14203/press.359

Pertamina. (2021a, 18 June). *Committed to Reduce CO_2 Emissions, Pertamina Collaborates with Japanese Companies & ITB for CCUS Study in Gundih Field*. https://www.pertamina.com/en/news-room/news-release/committed-to-reduce-co2-emissions-pertamina-collaborates-with-japanese-companies-and-itb-for-ccus-study-in-gundih-field

Pertamina. (2021b, 18 November). *KESDM supports Pertamina's "Biorefinery" as the key to Indonesia's clean energy transition*. https://pertamina.com/en/news-room/news-release/kesdm-supports-pertamina.s-biorefinery-as-the-key-to-indonesia.s-clean-energy-transition

Rahimpour, M. R., Farsi, M., & Makarem, M. A. (2020). *Advances in Carbon Capture*. Elsevier. https://doi.org/10.1016/C2018-0-05339-6

Richter, C. (2019, August 28). *World's first commercial CO_2 to methanol plant*. Georgia Institute of Technology. https://smartech.gatech.edu/handle/1853/61845

Rihko-Struckmann, L. K., Peschel, A., Hanke-Rauschenbach, R., & Sundmacher, K. (2010). Assessment of methanol synthesis utilizing exhaust CO_2 for chemical storage of electrical energy. *Industrial and Engineering Chemistry Research*, *49*(21), 11073–11078. https://doi.org/10.1021/IE100508W

Rönsch, S., Schneider, J., Matthischke, S., Schlüter, M., Götz, M., Lefebvre, J., Prabhakaran, P., & Bajohr, S. (2016). Review on methanation – From fundamentals to current projects. *Fuel*, *166*, 276–296. https://doi.org/10.1016/J.FUEL.2015.10.111

Srivastava, R. (2021, 21 October). *How to tackle COVID-19 jobs crisis and climate change? Invest in clean energy*. The Japan Times. https://www.japantimes.co.jp/news/2021/10/21/world/job-crisis-clean-energy/

Statistics Indonesia. (2020). *Proporsi Tenaga Kerja pada Sektor Industri Manufaktur (Persen), 2018-2020*. Accessed on February 1, 2022 from https://www.bps.go.id/indicator/9/1217/1/proporsi-tenaga-kerja-pada-sektor-industri-manufaktur.html

Takkellapati, S., Li, T., & Gonzalez, M. A. (2018). An overview of biorefinery-derived platform chemicals from a cellulose and hemicellulose biorefinery. *Clean Technologies and Environmental Policy*, *20*(7), 1615–1630. https://doi.org/10.1007/s10098-018-1568-5

Chapter 3

Nature-Based Solution and Regenerative Circular System Design towards Agricultural Land Management Bioremediation: A Review

Ade Brian Mustafa

A. Sustainability of Agricultural Soils

Agriculture is expected to assist countries in achieving multiple development goals nowadays. These objectives include food security, increased employment, environmental stewardship, and lower poverty and undernourishment rates (Otsuka, 2021). Agricultural land resources should be used to ensure the sustainability of the living environment, preserve biological balance, and increase soil resource quality. Sustainable agricultural development refers to the ability to use agricultural land indefinitely and the application of effective and efficient agricultural land utilization (Nasikh et al., 2021). The world's rapidly growing population has placed additional strain on the soil resource to meet increased demand for food, fiber, and soil-derived

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A. B. Mustafa
Shanghai Jiao Tong University, China, e-mail: adebrianmustafa@gmail.com

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materials. Novel approaches are needed as a result of such pressures. Increased and intensified agricultural production has pressured the soil to its limits in many parts of the world, resulting in soil degradation and, eventually, the loss of agricultural land (Pozza & Field, 2020).

Agriculture is reliant on healthy soils, and both are required for food security (Hurni et al., 2015). There is substantial evidence that farming intensification has a negative impact on soil diversity, which may have implications for present and future food security. For example, intensive soil use as agricultural expansion in Brazil's Maranhão, Tocantins, Piauí, and Bahia (MATOPIBA) region induced changes in soil physical properties to critical levels, reducing soil physical quality, and limiting soil functions such as plant growth, water availability, air diffusion, and soil resistance to degradation (Santos et al., 2021). It also indicated that long-term agricultural land usage altered soil bacterial and archaeal communities, as well as their potential N cycle functions in both bulk soil and rhizosphere (Merloti et al., 2022). Both the preservation of considerable levels of functional biodiversity in the soil and the management of functional diversity above the surface are intimately intertwined. Both are extremely susceptible to changes in the soil ecosystem (El Mujtar et al., 2019). In addition, more evidence and instruments are needed to establish legislative and regulatory coherence to fulfill the SDGs, which are inextricably linked, whether they are for achieving food security or sustainability on Earth (Vidar, 2021).

The multitude of artificial chemicals is growing by the day, and many of them are recalcitrant, with the majority of them being xenobiotic. Pesticide demand has increased from 0.2 million tons in 1950 to 5 million tons in 2000, according to a Food and Agriculture Organization (FAO) report, resulting in the loss of arable land, the death of non-targeted bacteria, birds, and native wildlife, and posing a risk to humans. It is estimated that 10 million tons of harmful chemicals are emitted into the environment each year. These contaminants are carcinogenic and long-lasting, wreaking havoc on ecosystems, jeopardizing environmental health, and causing harm to all living creatures (Arora, 2018).

Most agricultural approaches use organic or inorganic inputs to boost crop yield. Inputs include fertilizers, biosolids, antibiotics, insecticides, and other chemicals. Capturing and treating agricultural waste streams is problematic due to the wide geographic territory and reachability of agricultural contaminants. The removal of these substances is commonly accomplished through bioremediation. It is based on the biological process that degrades, converts, or mineralizes concentrated contaminants into non-toxic compounds through biological mechanisms (Evans, 2018). Bioremediation is among the most recent applications for eliminating organic toxins using natural resources, including fungi, bacteria, microorganisms, and vegetation (Yadav et al., 2021). Bioremediation is a long-term and cost-effective workable alternative to these ecological problems, in which microorganisms in the ecological system transform, degrade, and remove pollutants (Turan et al., 2022).

B. Bioremediation in the Agricultural Sector

A large number of chemical compounds are used in the industry and agriculture sectors for human benefit. Some of these chemicals end up as soil contaminants, resulting in a wide range of complex mixtures being released into the environment (Adriano et al., 2015). Identifying and eliminating the principal causes of heavy metal contamination in soil-plant systems is the first step in fighting heavy metal contamination. Environmental rules must be more strictly supervised and enforced, especially in the case of significant emitters like mineral extraction and processing, smelting, and other metal-consuming enterprises. It is indeed crucial for constructing regional and national databases of metals and metalloids abundance in irrigation water and atmospheric fluxes. This could allow for a more realistic assessment of present contamination levels and future trend projections. If irrigation water has a high concentration of metals or metalloids, simple and effective procedures for eliminating contaminants before the water reaches the field should be devised; if this is not practicable, alternative clean water sources should be explored. In addition, rather than total concentration, metal phytoavailability is the focus of risk management in soil contamination with metals-related problems, and there are numerous strategies to avoid metal through phytoavailability. Liming of acidic soils is recommended, primarily in locations where there is a high danger of pollutant accumulation (e.g., Cd, Pb). Liming materials come in various forms, each with its acid-neutralizing capacity, rate constants, and expense. Furthermore, phytoremediation has been promoted as a low-cost, environmentally acceptable method of cleaning up polluted soils (Zhao et al., 2015).

Because of their proclivity for dispersion, long-distance movement, and bioaccumulation in the food supply chain, organochlorine pesticides (OCPs) threaten global ecology and hinder human health. During OCP phytoremediation, processes such as phytoaccumulation, rhizoremediation, and phytotransformation are known to occur. Vegetation has been found to significantly boost OCP elimination from the soil when compared to unplanted soil due to uptakes within plant tissues and high microbial degradation of OCP within the root zone. Discovering and implementing strategies to promote plant growth and rhizospheric microbial interaction and bioaugmenting potential pesticide degraders to improve degradation and incorporating biosurfactant producers to continually improve pesticide bioavailability in the rhizospheric soil could all aid field progress (Singh & Singh, 2017).

Bioremediation has included the use of algae and plants. Microbes like *Pseudomonas japonica, Pseudomonas fluorescens, Pseudomonas aeruginosa, Brevibacterium iodinum Saccharomyces cerevisiae,* and *Alcaligenes faecalis* have been found to participate actively in bioremediation. Moreover, *Anaeromyxobacter, Saccharibacteria, Desulfomicrobium, Terrimonas, Sphingobium, Comamonas, Zoogloea, Acinetobacter,* and *Thiobacillus* have all demonstrated anaerobic degradation of polycyclic aromatic and heterocyclic refractory organic compounds like indole, pyridine, and quinoline. Phytoremediation, which includes phytodegradation, phytoextraction, phytostabilization, phytotransformation, or rhizodegradation, and rhizofiltration, uses green plants. Phytoremediation has also been reported with *Citrus limetta, Solanum tuberosum, Luffa acutangular, Cucumis sativus,* and *Citrus limon*. Bioremediation occurs when a microorganism interacts with the pollutant that is being remedied. The interaction is determined by the pollutants' metabolic and chemical properties. The availability of metal ions and other toxic compounds, site characteristics, temperature, pH, moisture content, nutrient availability, redox potential, and oxygen concentration are all important environmental factors affecting bioremediation (Ghosh et al., 2021).

In addition to their role as bioremediation causatives, microbial activity has another dimension because it also fosters soil fertility through their diverse compounds. Many of these metabolites can be classified into different groups, such as xenobiotic degradation intermediates, biotransformed intermediates, and even rhizobacteria-produced plant growth factors. In addition to its ability to break down hydrocarbons, *Pseudomonas* has previously shown indole acetic acid synthesis, nitrogen fixation, and phosphate solubilization. These are important components for encouraging plant growth and increasing soil fertility. Furthermore, field studies revealed that an engineered *Escherichia coli* containing atrazine chlorohydrolase effectively removed atrazine from polluted soil (Rebello et al., 2021). Scientists from all over the world have been searching for innovative engineering possibilities to incorporate microbe-stimulating materials. Continually advancing bioaugmentation technologies are expected to provide researchers with a better understanding of cell genetic manipulation and overcome microbiological constraints. Many pollutants escape microbe degrading activity, owing to the microbes' inability to interact with or attach to the contaminants' surfaces. New methods should be developed to enhance the efficacy of microbes and, thus the efficiency of bioremediation (Vishwakarma et al., 2020).

Pesticide biodegradation takes various paths depending on the pesticide, environment, and microbe. Fungi and bacteria serve as important in pesticide biodegradation. Fungi biotransform pesticides by incorporating trivial structural changes, rendering into non-toxic forms, and releasing the substance into the soil for further biodegradation by bacteria. Several fungi such as *Avatha discolor, Stereum hirsutum, Pleurotus ostreatus, Hypholoma fasciculare, Flammulina velupites, Dichomitus squalens, Coriolus versicolor, Auricularia auricula,* and *Agrocybe semiorbicularis* have demonstrated their ability to degrade pesticides like organophosphorus compounds, chlorinated, dicarboximide, phenylurea, triazine, and phenylamide. Furthermore, microbes commonly reported in pesticide bioremediation include *Mycobacterium* sp., *Phanerochaete Chrysosporium*, *Pandoraea* sp., *Klebsiella* sp., *Bacillus* sp., and *Pseudomonas* sp., (Odukkathil & Vasudevan, 2013).

Pollutant presence and concentration are not expected to affect microorganism growth, indicating their potential to affect the bioremediation process. Furthermore, fertilizer addition is preferred for an optimum C:N:P = 100:10:1 balance to promote microbial biostimulation for appropriate bioremediation, and bioremediation of soil contaminated with hydrocarbons and pesticides was possible by utilizing bio-stimulation of native microbial communities (Islas-García et al., 2015).

C. Integrating Nature-Based Solutions and Agro-Bioremediation

Nature-based solutions (NbS) are treatment technologies and redevelopment strategies that are nature-based, cost-effective, ecologically friendly, socially inclusive, economically viable, and well-received by the wider public. The NbS concept is innovative, and further research is needed to understand its benefits and drawbacks better and improve its applicability. NbS delivers various ecosystem services, supports the sustainable production of products and resources, and protects ecosystem integrity (Kumar & Kunhamu, 2022). Green and sustainable remediation (GSR) has also emerged in recent years, asking for how to maximize the “net environmental benefit” while also taking social and economic gains into account (Song et al., 2019).

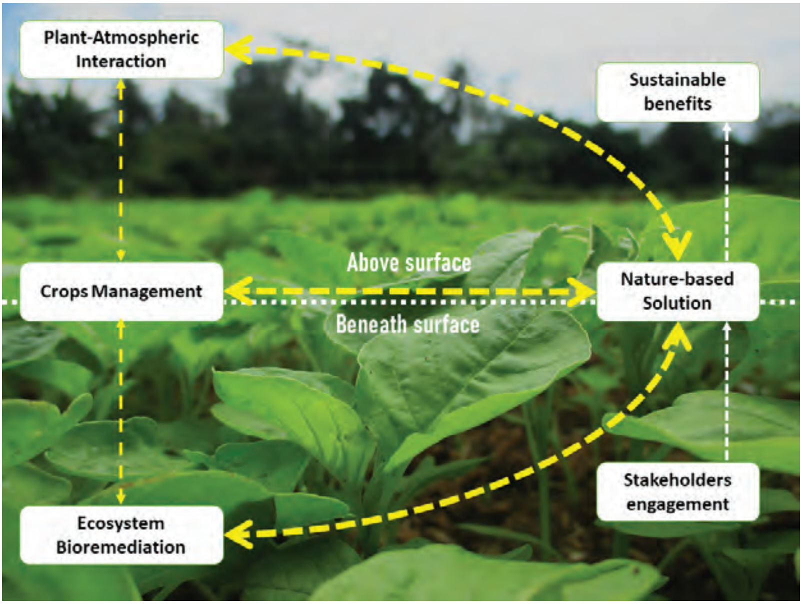

Figure 3.1 The Framework of NbS and Agro-Bioremediation

Additionally, because of their multifunctionality, agroecology and other regenerative food systems are the most promising alternative for food security, contributing to resilience through broader spectrum of diversity and self-sufficiency (Anderson & Rivera-Ferre, 2021).

Figure 3.1 shows the integration framework between two surface interactions under NbS and agro-bioremediation. In the agricultural areas, the interaction of both surfaces is interlinked. From above ground, solar radiation, wind, air temperature, humidity, rainfalls, and even farming management are factors that influence plant growth. While in below the surface, the soil characteristics, microbes-plant interaction, water content, and mineral nutrients are examples of factors affecting plant growth. Thus, it is highlighted to streamline ecosystem restoration thoroughly by bioremediation and NbS agricultural landscape management. NbS should play an essential role in these surfaces, through extensive support and engagements from relevant stakeholders, and could eventually achieve sustainable benefits. It aligns with Schreefel et al. (2020) stated that regenerative agriculture concentrates on the environmental aspects of sustainability, which encompasses elements such as enhancing and improving soil health, optimizing resource management, mitigating climate change, improving nutrient availability, and improving water quality and availability, outlined by both principles (e.g., improve soil quality) and actions (e.g., use perennials). Transitioning to regenerative agriculture entails more than a set of 'climate-smart' mitigation and adaptation strategies backed by technical innovation, policy, education, and outreach (Gosnell et al., 2019).

Grasses are the most prevalent functional group of herbaceous species utilized for phytoremediation, owing to their vast diversity and a broad range of stress tolerance. They often develop sod or dense cover, which can be used for various applications. There is a substantial global seed business to facilitate the commercial dissemination of grasses for various reasons. Flowering ornamentals, sedges, and rushes are other monocots suitable for smaller projects. The chemistry of herbicides, their physiological and morphological properties, plant detoxification mechanisms, and plant-rhizosphere interactions all affect remediation mechanisms (i.e., their hydrophobicity, solubility, and phytotoxicity). In the configuration of the tree–shrub–multispecies grass ecosystems for contaminant remediation, determining biotic and abiotic stress gradients in plant microenvironments is crucial. Understanding the spatially and temporally aspects of each stress, as well as the measures that alleviate specific stresses, is an important element of this. Microbial symbionts could also affect the success of phytoremediation activities and the species or genotypes chosen. By enhancing nutrient uptake, absorbing heavy metals, and shielding the host from metal toxicity, arbuscular mycorrhizal (AM) fungus can aid some host plants in adapting and surviving. Soils and landscape restoration is also a transdisciplinary synthesis of soil management and restoration in various landscapes. Real-world examples of successful bioremediation technologies include (1) short-rotation woody crops used to improve ecosystem services at landfills, (2) riparian buffer systems used to reduce agrichemical flow from agroecosystems, (3) urban afforestation used to develop forests in municipalities, and (4) grasslands used for soil phosphorus phytoremediation, and (5) surface mine reclamation employs woody species (Casler et al., 2021).

Plant-microorganism interactions enable various functions, including phytostabilization, storage in specific portions of the plant (phytoextraction and phytoaccumulation), and degradation of pollutants from soil, water, sludge, and sediment. Compost and biochar, for instance, have been researched for their ability to increase soil fertility and structure while also supporting plants in the removal of toxins from polluted soil. Carbonaceous materials are usually neglected wastes, although their application in products aligns well with the circular economy's goals. Phyto-assisted bioremediation is an environmentally friendly technology that produces a byproduct (biomass) that can be profitably valorized to produce energy or new materials, lowering the technology's costs compared to traditional soil remediation strategies (Ancona et al., 2022). In today's environment, the bulk of organic and inorganic (heavy metals) contaminants could be controlled sustainably by promoting the circular bioeconomy and establishing a sustainable engineered process by employing engineered biochar. The use of bioengineered biochar methods for pollutant removal has various advantages. Some benefits include carbon sequestration potential, microbial growth-promoting activities, environmental friendliness, water retention, long-lasting, improved soil fertility, the ability to immobilize pollutants, and low cost. Microbes can be inoculated and immobilized on biochar to develop a successful soil bioremediation mechanism. The enzymes responsible for contaminant detoxification in the approaches are released by the immobilized microbes. These enzymes are responsible for breaking down environmental target substrates into simpler substances (Liu et al., 2021).

Traditional approaches like salt leaching and soil amendments and NbS like phytoremediation have all been tried and tested with varying degrees of success. Cyanobacteria have emerged as a possible biotechnological tool for ecosystem restoration because of their unique properties, such as increasing carbon and nitrogen and promoting soil stabilization. When a vegetal mesh covered the inoculated soils, the cyanobacteria were able to deal with abiotic stress and soil erosion. The application of habitat improvement measures to reduce physiological stress and the detrimental impact of overland flow and precipitation yielded better outcomes (Román et al., 2021). Furthermore, the nano-sand-stabilizer may successfully stimulate cyanobacterial colonization and proliferation, hence favoring the establishment of biocrust. This study demonstrates viable biotechnology for fast repairing sand and promoting biocrust growth in desert areas (Li et al., 2021). Cyanobacteria can endure a wide range of salinities, and certain species can adapt to fluctuations in salinity. Their effectiveness in agricultural salty soil remediation has been shown, primarily through laboratory testing, but limited research has focused on their applicability in natural ecosystem restoration (Rocha et al., 2020).

NbS frameworks in agricultural operations are defined as the use of natural processes or components to improve ecosystem functions in agriculturally affected habitats and landscapes and livelihoods, and other socio-cultural functions. One of the NbS framework's selling points is that it shows how to change patterns in which crop production leads to environmental problems (e.g., agrochemical spills into waters), which causes additional challenges for farm productivity (e.g., polluted soils, water threatening pollinators, and food safety), and how particular challenges are intertwined across landscapes. NbS in agriculture will require the identification of entry sites and the support of a varied range of actors in the production landscape to be effective throughout agricultural societies, local government extension workers, and downstream value chain actors at the regional and global levels. Public and private actors should build partnerships based on a shared aim of recovering important production landscapes through NbS to ensure wide support and the most significant possibility for long-term management reform. Restorative NbS techniques involve long-term commitments, which can be assisted by policy (Simelton et al., 2021).

Unlike traditional remediation approaches, which are expensive, time-consuming, and can result in secondary contamination, tree-based phytoremediation is a non-invasive, cost-effective option with a wide range of uses. It is a low-cost strategy relating to urban green infrastructure (parklands, corridors, and urban agriculture), which has numerous advantages, including improved general environmental, well-being, socio-cultural, and financial circumstances for the city's population. Initially, urban green infrastructure comprises various tree species that can minimize soil contamination, particularly the contamination due to toxic heavy metals (HMs). The ability of vegetation to maintain, absorb, and break down pollutants (including HMs) from contaminated urban soils, allowing for their reuse and transformation into environmentally friendly locations. This is connected to urban ecosystem regeneration relying on tree species' responsibilities (Ilic et al., 2020).

Notwithstanding, urban agriculture or cropping is gaining popularity around the world. As a result, phytomanagement application along with phytoremediation could be the best option for city dwellers' desire for nature in the urban landscape. Because many urban soils have higher concentrations of trace metals likely Cd, Cu, Mn, and Zn than soils in rural or forests, it is essential to determine whether remediation methods such as phytoremediation are in advance. Nature-based solutions, particularly phytotechnologies, offer potential methods of dealing with contaminated urban soils. However, the major drawback of this technique is related to the time aspect, which it takes to reduce metal concentrations in the soil. To address this issue, low trace metal-accumulating vegetables (safe cropping system) can be cultivated alongside metal hyperaccumulating plants (in situ phytoextraction). Without any regulatory restrictions, this association cropping would allow the area to be used for vegetable farming. Due to time restrictions, laws and regulations are expected to evolve and validate the use of phytotechnologies to clean up soils (only once substantially contaminated) before the lands are reused for vegetable cropping(Bouzouidja et al., 2019).

D. Land Management Bioremediation and Circular Economy Systems

When agricultural species serve as vegetation in NbS, they perform numerous functions. Grass strips, for example, control soil erosion and increase crop yields, and vetiver grass can act as phytoremediation by trapping phosphorous. Physical factors such as slope angles and root structures also affect the efficiency of crop plantations. Furthermore, weed mulch and simple weed strips are used to create micro-terraces, ultimately resulting in less soil erosion and higher productivity. Planting trees also aids in the capture of airborne particles and pollutant gases. Overgrazing can reduce the soil's ability to trap contaminants, resulting in these and other suspended sediments. Legumes further provide supplementary ecological services such as enhanced biological diversity, preserved erosion, and improved soil structure (Miralles-Wilhelm, 2021). Essentially, natural tree (shrubs and trees) regeneration in agricultural landscapes necessitates the strategic planning of land-sparing and land-sharing approaches throughout broad spatial scales to accomplish production and preservation needs (Sato et al., 2016).

By restoring ecosystems and rebuilding natural capital, the circular economy cannot only slow but ultimately stop biodiversity loss and reverse it. On the other hand, the circular economy is currently receiving insufficient attention as a systemic approach. Despite playing an important role in biodiversity, the circular economy's regenerative and restorative attributes have customarily been left out of the well-known 3Rs—"reduce, reuse, recycle"—regarding the waste hierarchy. The 3Rs emphasize reducing the adverse impact of human activities by 'turning off the tap' on waste, soil contamination, and resource demand, whereas the second set of 3Rs focuses on the potential benefits of reversing the world's degrading ecosystems. Frequently associated, the favorable 3Rs are not more important in and of themselves, and reducing waste and pollution should continue to be a top priority. Many heavily contaminated sites will need to be remedied before restorative and regenerative practices can be used to aid natural decontamination processes used in biological-based technologies such as phytotechnologies and microbial processes (Schröder et al., 2021). Circularity has the ability to provide practical solutions for strengthening such vulnerable systems. Large-scale investment in regenerative, peri-urban agriculture, for example, could provide foods closer to customers while reducing environmental impact and fragility. According to a study undertaken by the Ellen MacArthur Foundation, a circular scenario might contribute to a 50% decline in pesticide and artificial fertilizer consumption across Europe by 2030, compared to 2012 (United Nations Environment Programme, 2021).

Ecosystem restoration improves natural cycles by restoring the functionality of degraded soils. Healthy soil is required for the closure of biological processes that produce organic resources and also use organic material to maintain soil fertility and productivity. All nutrients would be appropriately restored to the biosphere in a circular system. In the urban environment, this means that nutrients are collected in the organic component of municipal solid waste and wastewater streams, treated, and returned to the soil in the form of organic fertilizer (Ellen MacArthur Foundation, 2017). The contribution of soils to provisioning, regulation, and maintenance services emphasizes the importance of soil properties in a circular economy. Soil and natural resource play critical roles in the circular economy, such as providing space for societal activities. They serve as a repository for mineral resource stocks and provide opportunities to generate biobased resources to substitute mineral resource utilization. Their function in the biogeochemical cycles is significant for completing the water, nutrient, and soil purification cycles once these resources have been deposited in the soil as waste. As a result, soil recovery and reuse are required to ensure the future supply of natural resources and services to an increasing global population. The circular economy establishes a framework for managing natural capital as an asset, including biodiversity, water, fossil fuels, mineral resources, and soil. Thereby, it encourages efficient use and management (Breure et al., 2018). Furthermore, the vermicomposting approach provides a window of opportunity for bacteria and earthworms to work together to degrade waste and stimulate nutrients (Lirikum et al., 2022). Vermicompost has been shown to assure agricultural sustainability, enhance waste management, contaminant remediation, biogas production, and livestock feed production, making it a viable circular economy strategy (Kamar Zaman & Yaacob, 2022).

The narrative of biological agents as remediation in the circular system could also be the bioeconomy framework. The bioeconomy efficiently uses biological (bio-based) resources through efficient production and conversion mechanisms, culminating in economic and environmental benefits while simultaneously facilitating the transition to a more sustainable society. Thus, phytotechnologies and bioremediation depend on the ability of specific plants, fungi, or bacteria to degrade, stabilize, or eradicate contaminants in diverse environmental compartments. Nevertheless, no reference markets or economically viable alternatives have been offered, and the entire value chain has yet to be thoroughly researched. Admittedly, the biomass produced due to phyto- and bioremediation interventions has been labeled as waste. While acknowledging the importance of pollution prevention, human society must make significant efforts to prevent pollution and repair growing areas of the territory through comprehensive and coordinated policy approaches. A political agenda that prioritizes the prevention, repair, and restoration of contaminated environments is driving the importance of rhizosphere, soil, and coastline management in pertaining to human activities at the macro scale (Francocci et al., 2020). Additionally, the circular economy would be really sustainable only if it contributes to societal reform. Significant adjustments are required in global, regional, and national contexts from a policy standpoint. For effective progress, policies at all levels of government must be aligned and coordinated (Connor, 2021).

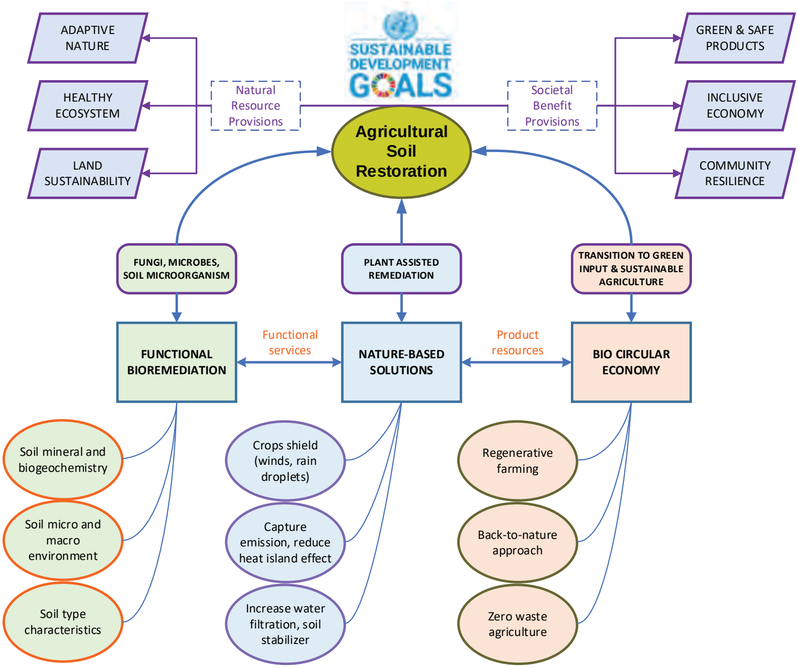

Figure 3.2 Agro-Symphony in Bioremediation, Nature-Based Solution, and Circular Economy

The interrelationship of each aspect in bioremediation, NbS, and circular economy for sustainable agricultural land management is depicted in Figure 3.2. Improving soils in their micro-environment is critical because it can affect the conditions above ground. The addition of NbS features such as phytoremediation plants also serves other functions to protect the environment where bioremediation occurs. Furthermore, as proper and healthy soil quality for the agricultural landscape is achieved, the circular economy framework can be implemented. As a result of the holistic management of soil restoration, sustainable agriculture is achieved.

Sustainable land restoration incorporates sustainability principles into land management and rehabilitation. Furthermore, implementing circularity principles into restoration solutions such as resource and product reuse, recycling, and recovery can significantly help long-term sustainable soil restoration. Chemical immobilization, rhizospheric engineering, and meta-transcriptomics are technological interventions used to grow crops on contaminated or polluted land. Crop diversification strategies can aid in the restoration of degraded lands by improving soil fertility, supporting sustainable agriculture, and boosting rural participation. This requires finding natural variations that are nutritionally comparable to typical agricultural plants which are resilient enough to survive on degraded soils. Efficient waste management processes for recycling and reuse of industrial wastes can help restore circularity by reducing the amount of land required for waste disposal and reducing dangerous chemicals entering soil systems. Coal and urban waste compost can be combined to form "technosol, " then applied to mined areas to stimulate plant cover and land restoration. Incorporating these ideas into restoration efforts can also benefit the environment (Priyadarshini & Abhilash, 2020). By combining waste-derived technosols into land recycling for green areas, cities and megacities can become more sustainable, and agricultural output and human health could significantly improve. This also provides human food security and ecosystem services and serves as a substrate for urban agroforestry systems if constructed from technosols materials. In urban regions, the addition of created technosols and de-sealed soils can assist in the restoration of ecosystem functioning and food supply services. It is a viable option for assisting our nature bounce back (Rodríguez-Espinosa et al., 2021).

Agricultural transformation, including the adoption of sustainable intensification technology, is thus likely to occur only if public investments in farmer assistance are ensured, even in locations with significant yield discrepancies (Silva et al., 2021). Because restoration is such a complex undertaking, it involves improvements in a variety of fields as well as the long-term application of traditional and indigenous knowledge (including biocultural knowledge). Furthermore, restoring degraded landscapes is essential for sustaining the land's biocultural relevance. As a result, integrating land restoration research at multiple sizes and levels is critical for producing realistic and actionable restoration packages based on nature-based solutions and ecosystem-based methods to achieve a successful restoration milestone (Abhilash, 2021).

E. Conclusion

Improving agricultural land ecosystems currently necessitates positive collaboration from diverse stakeholders and society. The sustainability of the land is in our collective hands. Therefore, we must protect this limited resource for the sake of future generations' continuity. Land restoration based on bioremediation, which combines the principles of nature-based solutions and the circular economy, will generate a long-term benefit. On the one hand, integrative restoration could improve soil from the micro and macro environment structures. Additionally, the implementation of regenerative agriculture can support an interconnected cycle loop, and appropriate land quality can be achieved for sustainable agricultural purposes. The benefits of the nexus will be amplified in the future as land restoration efforts are maximized.

References

Abhilash, P. C. (2021). Restoring the Unrestored: Strategies for Restoring Global Land during the UN Decade on Ecosystem Restoration (UNDER). *Land*, *10*(201), 1–17. https://doi.org/10.3390/land10020201

Adriano, D. C., Bollag, J. M., Frankenberger, W. T., & Sims, R. C. (2015). Bioremediation of contaminated soils. In *Bioremediation of Contaminated Soils* (Third Edit). Elsevier Inc. https://doi.org/10.2134/agronmonogr37

Ancona, V., Rascio, I., Aimola, G., Caracciolo, A. B., Grenni, P., Uricchio, V. F., & Borello, D. (2022). Plant-assisted bioremediation: Soil recovery and energy from biomass. In *Assisted Phytoremediation* (pp. 25–48). Elsevier Inc. https://doi.org/10.1016/b978-0-12-822893-7.00012-4

Anderson, M. D., & Rivera-Ferre, M. (2021). Food system narratives to end hunger: extractive versus regenerative. *Current Opinion in Environmental Sustainability*, *49*, 18–25. https://doi.org/10.1016/j.cosust.2020.12.002

Arora, N. K. (2018). Bioremediation: a green approach for restoration of polluted ecosystems. *Environmental Sustainability*, *1*(4), 305–307. https://doi.org/10.1007/s42398-018-00036-y

Bouzouidja, R., Bouquet, D., Pierart, A., Shahid, M., Guern, C. Le, Jean-Soro, L., Dumat, C., & Lebeau, T. (2019). Metal Contamination in Urban Soils Use of Nature-Based Solutions for Developing Safe Urban Cropping. In J. C. Sanchez-Hernandez (Ed.), *Bioremediation of Agricultural Soils* (1st Editio, p. 22). CRC Press. https://doi.org/10.1201/9781315205137

Breure, A. M., Lijzen, J. P. A., & Maring, L. (2018). Science of the Total Environment Soil and land management in a circular economy. *Science of the Total Environment*, *624*, 1125–1130. https://doi.org/10.1016/j.scitotenv.2017.12.137

Casler, M. D., Hallett, R. A., & Lin, C. (2021). Bioremediation and soils. In J. A. Stanturf & J. Mac A. Callaham (Eds.), *Soils and Landscape Restoration* (Vol. 9, pp. 237–273). https://doi.org/10.1016/B978-0-12-813193-0.00009-6

Connor, K. E. O. (2021). Microbiology challenges and opportunities in the circular economy. *Microbiology*, 1–3. https://doi.org/10.1099/mic.0.001026

El Mujtar, V., Muñoz, N., Prack Mc Cormick, B., Pulleman, M., & Tittonell, P. (2019). Role and management of soil biodiversity for food security and nutrition; where do we stand? *Global Food Security*, *20*(April 2018), 132–144. https://doi.org/10.1016/j.gfs.2019.01.007

Ellen MacArthur Foundation. (2017). *Urban Biocycles*. https://ellenmacarthurfoundation.org/cities-urban-biocycles

Evans, L. (2018). Bioremediation Techniques for Agricultural Pollutants. In *Reference Module in Earth Systems and Environmental Sciences*. Elsevier Inc. https://doi.org/10.1016/b978-0-12-409548-9.11259-x

Francocci, F., Trincardi, F., Barbanti, A., Zacchini, M., & Sprovieri, M. (2020). Linking Bioeconomy to Redevelopment in Contaminated Sites : Potentials and Enabling Factors. *Frontiers in Environmental Science*, *8*(September), 1–13. https://doi.org/10.3389/fenvs.2020.00144

Ghosh, S., Sharma, I., Nath, S., & Webster, T. J. (2021). Microbial Ecology of Wastewater Treatment Plants. *Microbial Ecology of Wastewater Treatment Plants*, 11–40. https://doi.org/10.1016/c2019-0-04695-x

Gosnell, H., Gill, N., & Voyer, M. (2019). Transformational adaptation on the farm: Processes of change and persistence in transitions to 'climate-smart' regenerative agriculture. *Global Environmental Change*, *59*(November), 101965. https://doi.org/10.1016/j.gloenvcha.2019.101965

Hurni, H., Giger, M., Liniger, H., Mekdaschi Studer, R., Messerli, P., Portner, B., Schwilch, G., Wolfgramm, B., & Breu, T. (2015). Soils, agriculture and food security: The interplay between ecosystem functioning and human well-being. *Current Opinion in Environmental Sustainability*, *15*, 25–34. https://doi.org/10.1016/j.cosust.2015.07.009

Ilic, Z. H., Solomun, M. K., & Sumatic, N. (2020). *Phytoremediation: Nature based solution for contaminated urban soils*. https://doi.org/10.5194/egusphere-egu2020-828

Islas-García, A., Vega-Loyo, L., Aguilar-López, R., Xoconostle-Cázares, B., & Rodríguez-Vázquez, R. (2015). Evaluation of hydrocarbons and organochlorine pesticides and their tolerant microorganisms from an agricultural soil to define its bioremediation feasibility. *Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes*, *50*(2), 99–108. https://doi.org/10.1080/03601234.2015.975605

Kamar Zaman, A. M., & Yaacob, J. S. (2022). Exploring the potential of vermicompost as a sustainable strategy in circular economy: improving plants' bioactive properties and boosting agricultural yield and quality. *Environmental Science and Pollution Research*, *29*(9), 12948–12964. https://doi.org/10.1007/s11356-021-18006-z

Kumar, B. M., & Kunhamu, T. K. (2022). Nature-Based Solutions in Agriculture: A Review of the Coconut (Cocos nucifera L.)-Based Farming Systems in Kerala, "the Land of Coconut Trees." In *Nature-Based Solutions*. Elsevier Inc. https://doi.org/10.1016/j.nbsj.2022.100012

Li, Z., Chen, C., Gao, Y., Wang, B., Wang, D., Du, Y., Liu, L., Wu, Z., & Cai, D. (2021). Synergistic effect of cyanobacteria and nano-sand-stabilizer on biocrust formation and sand fixation. *Journal of Environmental Chemical Engineering*, *9*(1), 104887. https://doi.org/10.1016/j.jece.2020.104887

Lirikum, Kakati, L. N., Thyug, L., & Mozhui, L. (2022). Vermicomposting: an eco-friendly approach for waste management and nutrient enhancement. *Tropical Ecology*, *0123456789*. https://doi.org/10.1007/s42965-021-00212-y

Liu, H., Kumar, V., Yadav, V., Guo, S., Sarsaiya, S., Binod, P., Sindhu, R., Xu, P., Zhang, Z., Pandey, A., & Kumar Awasthi, M. (2021). Bioengineered biochar as smart candidate for resource recovery toward circular bio-economy: a review. *Bioengineered*, *12*(2), 10269–10301. https://doi.org/10.1080/21655979.2021.1993536

Merloti, L. F., Pedrinho, A., Mendes, L. W., Gontijo, J. B., da Fonseca, M. de C., Chaves, M. G., Chaves, S. S. de F., Camargo, P. B. de, & Tsai, S. M. (2022). Long-term land use in Amazon influence the dynamic of microbial communities in soil and rhizosphere. *Rhizosphere*, *21*(November 2021), 100482. https://doi.org/10.1016/j.rhisph.2022.100482

Miralles-Wilhelm, F. (2021). Nature-based solutions in agriculture: Sustainable management and conservation of land, water and biodiversity. In Https://www.fao.org/publications/card/en/c/CB3140EN/ (Ed.), *Nature-based solutions in agriculture: Sustainable management and conservation of land, water and biodiversity*. Food and Agriculture Organization of the United Nations and The Nature Conservancy. https://doi.org/10.4060/cb3140en

Nasikh, Kamaludin, M., Narmaditya, B. S., Wibowo, A., & Febrianto, I. (2021). Agricultural land resource allocation to develop food crop commodities: lesson from Indonesia. *Heliyon*, *7*(7), e07520. https://doi.org/10.1016/j.heliyon.2021.e07520

Odukkathil, G., & Vasudevan, N. (2013). Toxicity and bioremediation of pesticides in agricultural soil. *Reviews in Environmental Science and Biotechnology*, *12*(4), 421–444. https://doi.org/10.1007/s11157-013-9320-4

Otsuka, K. (2021). Strategy for Transforming Indonesian Agriculture. *Bulletin of Indonesian Economic Studies*, *57*(3), 321–341. https://doi.org/10.1080/00074918.2021.2002387

Pozza, L. E., & Field, D. J. (2020). The science of Soil Security and Food Security. *Soil Security*, *1*(8), 100002. https://doi.org/10.1016/j.soisec.2020.100002

Priyadarshini, P., & Abhilash, P. C. (2020). Fostering sustainable land restoration through circular economy-governed. *Restoration Ecology*, *28*(4), 719–723. https://doi.org/10.1111/rec.13181

Rebello, S., Nathan, V. K., Sindhu, R., Binod, P., Awasthi, M. K., & Pandey, A. (2021). Bioengineered microbes for soil health restoration: present status and future. *Bioengineered*, *12*(2), 12839–12853. https://doi.org/10.1080/21655979.2021.2004645

Rocha, F., Lucas-borja, M. E., Pereira, P., & Muñoz-rojas, M. (2020). Cyanobacteria as a Nature-Based Biotechnological Tool for Restoring Salt-A ff ected Soils. *Agronomy*, *10*(9), 1–15. https://doi.org/10.3390/agronomy10091321

Rodríguez-Espinosa, T., Navarro-Pedreño, J., Lucas, I. G., & Belén Almendro-Candel, M. (2021). Land recycling, food security and Technosols. *Journal of Geographical Research*, *4*(3), 44–50. https://doi.org/10.30564/jgr.v4i3.3415

Román, J. R., Chamizo, S., Roncero-Ramos, B., Adessi, A., De Philippis, R., & Cantón, Y. (2021). Overcoming field barriers to restore dryland soils by cyanobacteria inoculation. *Soil and Tillage Research*, *207*(November 2020). https://doi.org/10.1016/j.still.2020.104799

Santos, R. S., Wiesmeier, M., Cherubin, M. R., Oliveira, D. M. S., Locatelli, J. L., Holzschuh, M., & Cerri, C. E. P. (2021). Consequences of land-use change in Brazil's new agricultural frontier: A soil physical health assessment. *Geoderma*, *400*(April), 115149. https://doi.org/10.1016/j.geoderma.2021.115149

Sato, C. F., Wood, J. T., Stein, J. A., Crane, M., Okada, S., Michael, D. R., Kay, G. M., Florance, D., Seddon, J., Gibbons, P., & Lindenmayer, D. B. (2016). Natural tree regeneration in agricultural landscapes: The implications of intensification. *Agriculture, Ecosystems and Environment*, *230*, 98–104. https://doi.org/10.1016/j.agee.2016.05.036

Schreefel, L., Schulte, R. P. O., de Boer, I. J. M., Schrijver, A. P., & van Zanten, H. H. E. (2020). Regenerative agriculture – the soil is the base. *Global Food Security*, *26*(June), 100404. https://doi.org/10.1016/j.gfs.2020.100404

Schröder, P., Forslund, T., & Sell, M. (2021). *The role of the circular economy in addressing the global biodiversity crisis*. Chatham House. https://circulareconomy.earth/publications/the-role-of-the-circular-economy-in-addressing-the-global-biodiversity-crisis?utm_source=twitter&utm_medium=pacecircular&utm_campaign=socialmedia&utm_term=4d191ecb-fd4b-46ad-a686-e66951e11d28

Silva, J. V., Reidsma, P., Baudron, F., Laborte, A. G., Giller, K. E., & van Ittersum, M. K. (2021). How sustainable is sustainable intensification? Assessing yield gaps at field and farm level across the globe. *Global Food Security*, *30*(November 2020). https://doi.org/10.1016/j.gfs.2021.100552

Simelton, E., Carew-reid, J., Coulier, M., Damen, B., & Howell, J. (2021). NBS Framework for Agricultural Landscapes. *Frontiers in Environmental Science*, *9*(August), 1–16. https://doi.org/10.3389/fenvs.2021.678367

Singh, T., & Singh, D. K. (2017). Phytoremediation of organochlorine pesticides: Concept, method, and recent developments. *International Journal of Phytoremediation*, *19*(9), 834–843. https://doi.org/10.1080/15226514.2017.1290579

Song, Y., Kirkwood, N., Maksimovi, Č., Zheng, X., Connor, D. O., Jin, Y., & Hou, D. (2019). Science of the Total Environment Nature based solutions for contaminated land remediation and brown fi eld redevelopment in cities : A review. *Science of the Total Environment*, *663*, 568–579. https://doi.org/10.1016/j.scitotenv.2019.01.347

Turan, M., Argin, S., Bolouri, P., Arjumend, T., Ersoy, N., Yıldırım, E., Güneş, A., Ekinci, M., & Birinci, D. (2022). Bioremediation of contaminated soil with plant growth rhizobium bacteria. *Assisted Phytoremediation*, 265–284. https://doi.org/10.1016/b978-0-12-822893-7.00013-6

United Nations Environment Programme. (2021). *Circularity to Restore the Earth*. United Nations Environment Programme. https://www.unep.org/news-and-stories/speech/circularity-restore-earth

Vidar, M. (2021). Soil and Agriculture Governance and Food Security. *Soil Security*, 100027. https://doi.org/10.1016/j.soisec.2021.100027

Vishwakarma, G. S., Bhattacharjee, G., Gohil, N., & Singh, V. (2020). Current status, challenges and future of bioremediation. In *Bioremediation of Pollutants* (pp. 403–416). Elsevier Inc. https://doi.org/10.1016/B978-0-12-819025-8.00020-X

Yadav, M., Singh, G., & Jadeja, R. N. (2021). Bioremediation of organic pollutants: a sustainable green approach. In *Sustainable Environmental Clean-up*. Elsevier Inc. https://doi.org/10.1016/b978-0-12-823828-8.00006-2

Zhao, F., Zhu, Y., Tang, Z., & Mcgrath, S. P. (2015). Soil Contamination in China: Current Status and Mitigation Strategies. *Environmental Science & Technology*, *49*, 750–759. https://doi.org/10.1021/es5047099

Chapter 4

Remediation of Heavy Metals Polluted Soils in Indonesia

Rendy Anggriawan

A. Persistent Organic Pollutants (POPs) in General Understanding

Soil is a natural element that is the same important as water and air. Soil is a natural object, part of the Earth's surface that can be overgrown by plants and has characteristics as a result of the work of climatic factors and living things on the parent material, which is influenced by topographical conditions within a certain period of time. Soil, as a natural resource for agricultural purposes, has two main functions, as a source of nutrients for plants and as a medium where plant roots are anchored, water and nutrient is stored.

Excessive use of natural resources such as the conversion of agricultural land to built-up land for settlement or industry to sup-

R. Anggriawan
Indian Institute of Technology Roorkee, India, e-mail: rendyagr@gmail.com

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port human needs at the current level puts excessive pressure on the environment. Increased development, including industry, is not only able to absorb labor but also causes negative impacts if it is not managed properly. One example is industrial activities that dispose of waste into rivers/water bodies used as sources of irrigation water.

Waste that is disposed of into water bodies and becomes a source of irrigation water for agricultural land that is still productive has an impact that is not only detrimental to the sustainability of farming on that land but can result in damage to the ecosystem. One of the impacts that occur on agricultural land is soil contamination.

Since 1978 in the Bandung region, Indonesia, to be precise, the Rancaekek sub-district and its surroundings have developed into a textile industrial area, and up to now, there are more than thirty textile factories located between Rancaekek–Cicalengka (Adji, 2006). A large number of factories has an impact on the wastewater that is flowed through the surrounding rivers, especially if the wastewater treatment plant from the factory is not functioning optimally.

Cikijing river water and rice fields in Rancaekek District, Bandung, Indonesia, which are close to the industrial area, contain heavy metals Ni, Zn, Cu, Cd, Co, Cr, and Pb (Suganda et al., 2002). In addition, the rice fields in Rancakeong Block, Linggar Village, Rancaekek District contain heavy metals Zn, Ni, Cd, Co, Cr, Cu, and Pb (Adji, 2006). Both total and available (ionic) values in the soil. The presence of all available values of these heavy metals has been successfully absorbed in plant roots and translocated into plant tissue.

Various contaminants that enter the soil will result in decreased soil function as one of the causes of soil damage or soil degradation. Soil degradation will be followed by a decrease in land productivity. This can cause serious problems because it can harm farmers and hinder efforts to increase the production and safety of agricultural products, which in turn can threaten national food security.

Heavy metal was all metal elements that have a specific gravity with a value of more than 5 g/cm^3 (Pierzynski et al., 2015). In the earth's crust, metals are divided into macro metals and micro metals

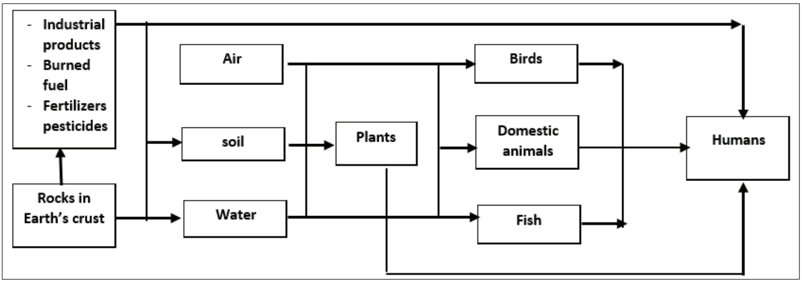
(Darmono, 1995). Macro metals consist of iron (Fe), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), potassium (K), and aluminum (Al). Micro metals include barium (Ba), lead (Pb), zinc (Zn), nickel (Ni), tin (Sn), copper (Cu), uranium (U), cadmium (Cd), silver (Ag), mercury (Hg), and gold (Au). Some of these metals are categorized as metals that are more potentially toxic to humans, are Pb, Ni, As, Hg, Zn, Cu, and Cd.

When plant parts that absorb heavy metals such as leaves and fruit/seeds are consumed by animals or humans, it will gradually cause poisoning for those who consume them. Therefore, it is necessary to improve the nature of the contaminated soil so that the plants can reproduce adequately. Efforts that can be done in restoring soil pollution are remediation. Remediation can be defined as the process of recovering from a contaminated condition so that it is clean again using plants (phytoremediation) or microbes (bioremediation).

The purpose of this paper is to further describe the problem of heavy metals and the influence of anthropogenic activities on soil pollution, describe remediation techniques for heavy metal polluted soil based on the results of recent research in Indonesia, and provide recommendations for phytoremediation modeling.

B. Heavy Metals Problems and its Remediation Technique

Mining activities have affected health due to contamination of local water sources and have a detrimental effect on the environment, mining of coastal sand which causes erosion, or long-term effects in reducing biodiversity or increasing the level of fish mortality (WHO, 2008). The disposal of tailings is carried out in the environment, which is usually disposed of in artificial reservoirs, rivers or lakes, and the sea. In mineralogy, tailings can consist of various minerals such as silica, iron silicate, magnesium, sodium, potassium, and sulfide. Among these minerals, sulfides have chemically active properties and, when in contact with air, will undergo oxidation to form acidic salts, and the acid stream contains a number of toxic metals such as



Source: Farcasanu et al. (2018)

Figure 4.1 Various Sources of Heavy Metal Pollution and Their Cycle

cadmium, mercury, arsenic, lead, and mercury which can pollute or damage the environment (UNO. 1995).

The research results reported that heavy metal contamination occurred in gold mining areas, industrial waste disposal, and agriculture (fig. 4.1.). Community gold mining waste such as Pongkor, West Java contains up to 240 ppm Hg and 0.1 ppm Cd and is simply wasted in the surrounding environment both in the rice fields and the Cikaniki River (Hidayati N et al., 2004). Textile industrial waste containing heavy metals reaches 296.5 thousand tons per year which pollutes the rice fields and Cikijing River, Bandung (Rija S, 2000). Meanwhile, heavy metals Pb and Cd from motor vehicles contaminated rice fields in North Coast Java (Pantura) area, covering 40% of the 105,557 ha of rice fields in the Karawang-Bekasi area (Kasno et al., 2000). In the Cirebon–Palimanan area, Pb contamination in rice fields reaches 30.08 ppm, causing the Pb content in rice approach the danger threshold for consumption (Miseri & Santoso, 2000).

The existence of industrial activities in coastal areas causes the disposal of a number of organic chemicals, heavy metal compounds, and compounds from other industrial wastes. Industrial wastes containing toxic compounds released into the environment will have a negative and toxic effect on organisms in food webs (Dembitsky & Rezanka, 2003). Chemical properties and biological functions toxicity varies depending on the concentration and type of metal. Cr, Pb, Cu, Zn, Ni, Hg, Cd, and Co are very toxic both in the basic form and in the form of dissolved salts. The presence of these compounds in aquatic, soil, and atmospheric environments causes very serious problems for organisms. The most dangerous cause for human health is its bioaccumulation into the food chain. The most common cause of heavy metal contamination is the consumption of food and drinking water.

Identification of carcinogenic compounds such as arsenic takes a long time. Pollution of arsenic compounds in the soil has resulted from human activities, including pesticides, burning, wood preservation, and mining. Around ten thousand sites worldwide are contaminated with arsenic with the highest concentration being 26.5 mg/kg (Hingston et al., 2001)

C. Heavy Metals Remediation Technique

Several techniques used to remediate heavy metal polluted soil are containment, solidification, vitrification, soil washing, soil flushing, pyrometallurgy, electrokinetic, and phytoremediation (Chen et al., 2016). *Containment* measures are often carried out as measures to prevent or significantly reduce the migration of contaminants in soil or groundwater. *Solidification/stabilization* using cement is an alternative waste treatment with the aim of reducing the environmental pollution.

Vitrification is a remediation technique in which a substance is transformed into glassy materials. *Soil washing* is a remediation technique based on the theory that prone contaminants bind to fine-grained soils (silt and loam), which tend to bind to coarse-grained soils. These techniques include ex-situ remediation, which involves removing harmful pollutants from the soil by washing the soil with liquid, scrubbing the soil, and then separating the clean soil from contaminated soil and washing water (Dellisanti et al., 2009).

Soil flushing is an in-situ remediation technology that can occur in an unsaturated zone, a saturated zone, or both. The flushing solution increases the mobility or solubility of the adsorbed contaminants to the soil matrix. *Pyrometallurgy* is a process of metallurgical extraction using heat energy. The temperature reached up to 2000°C. *Electrokinetic* remediation is a technology for restoring soil contaminated with heavy metals and organic compounds through an in-situ process using low voltage and constant direct current (DC).

Phytoremediation is a technique to use plants and their parts to decontaminate waste and environmental pollution problems either ex-situ using artificial ponds or reactors or in-situ or directly in the field on soil or areas contaminated with waste (Subroto, 1996). Phytoremediation is also characterized as a form of contamination retention that is intervened by non-food plants, including trees, aquatic plants, and grasses.

D. Remediation of Polluted Soils in Indonesia

The remediation techniques commonly used in Indonesia are phytoremediation and bioremediation. Both of these techniques are considered more efficient and do not require large costs. Phytoremediator plants used are derived from local plants, some are tree species. Examples of phytoremediator plants used are *Ipomoea aquatic, Pennisetum Purpuroides, Boehmeria nivea, Cordyline fruticosa, Sansevieria Trifasciata, Celosia Plumosa*, and *Chrysopogon zizanioides*. Whereas bacteria used in remediating heavy metal contaminated soil are using indigenous bacteria and mycorrhizal bacteria. Recent research related to remediation of heavy metal contaminated soil in Indonesia is presented in Table 4.1.

Table 4.1 Recent Research on Heavy Metal Remediation Polluted Soil in Indonesia

Recent Research	Author, Year
Effect of Compost and Biochar on Phytoremediation of Soil Contaminated with Cadmium from Lapindo Mud Volcano Using Water Spinach	(Lestari & Aji, 2020)
Study on The Addition of EDTA to the Phytoremediation of Lead	(Nadhila et al., 2021)
Potential of Phytoremediation of Lead Contaminated Soil (Pb) with EDTA Addition Using King Grass (Pennisetum Purpuroides)	(Anugroho et al., 2020)

Recent Research	Author, Year
The Potential of Rami (Boehmeria nivea) for Phytoremediation of Copper Contaminated Soil	(Lestari & Pratama, 2020)
Phythoremediation Lead Metals Contaminated Soils (Pb) Using Sansevieria Trifasciata and Celosia Plumosa	(Ratnawati & Fatmasari, 2018)
Bioremediation of Lead Using Indigenous Bacteria Isolated from Leachete Contaminated Soil	(Rahadi et al., 2020)
Remediation of Cobalt (Co) polluted Soil Using Bioremediator and Ameliorant	(Purbalisa & Dewi, 2019)
Bioremediation of Pb by Agar Liquid Waste Indigent Bacterial	(Ikerismawati, 2019)
Bioremediation of Pb in Textile Waste with Staphylococcus Aureus and Bacillus Subtilis	(Maulana et al., 2017)
Heavy Metals Remediation Polluted Soil by Using Biochar	(Hidayat, 2015)
Bioremediation of Soils Contaminated Heavy Metals Cd, Cu, and Pb by Using Endomikoriza	(Chairiyah et al., 2013)

One of the sources of heavy metal pollutants in Indonesia comes from gold mining waste.. The main activity in gold mining is the process of separating gold ore from rock using metals which in turn will produce waste. The waste obtained can be in the form of solids (tailings) and liquid waste. Kuranchie et al., (2013) explained that obtaining or it will produce several forms of waste, namely tailings, slugs, dust, and liquid waste. This waste can spread widely to the surrounding area if there is no proper handling.

Gold mining waste in the form of solids or tailings has characteristics such as sand with a fine texture, low organic matter content, acidity, and high heavy metal content (Fashola et al., 2016). Heavy metals contained in these wastes include Hg, As, Pb, Cd, Cr, and Cu (Ngure et al. 2017; Xiao et al. 2017). Lead is a heavy metal with a high enough concentration in gold mine tailings waste (Siregar & Zakiyah, 2016).

Textile waste is waste generated in the testing process, starch removal, bleaching, cooking, dyeing, printing, and refinement processes. The cotton refinement process produces more and stronger waste than the waste from the synthesis material refinement process. Waste originating from the textile dyeing process is a major factor in environmental pollution problems. Water pollution from the textile industry can come from wastewater from the production process, waste from lubricants and oil, chemical waste from the production process, waste from scraps of cloth, and others. Some water pollutants include dyes, high salt concentrations, and heavy metals. The resulting waste includes heavy metal arsenic, lead, cadmium, zinc, chromium, copper, halogenated hydrocarbons (from the dressing and finishing process), pigments, dyes, tensioactives (surfactants), and organic solvents (MEI, 2005).

Acid Mine Water (AAT) is wastewater from mining with high acidity (low pH, <4). AAT arises from the reaction results of the oxidation of rocks exposed to water, resulting in sulfuric acid and iron hydroxide deposits (Achterberg et al. 2003). The yellowish color that settles at the bottom of the mining channel or on the walls of the silt deposition pond is a visual representation of iron hydroxide deposits (Aubé, 2004).

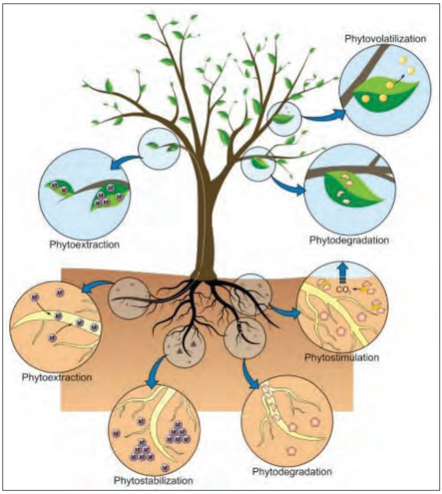
E. Case Study of Phytoremediation and its Uptake Model

1. Phytoremediation of Heavy Metals using Vetiveria zizanioides

Phytoremediation is a technique for recovering polluted land by using plants to clean, absorb, degrade, transform and immobilize pollutants, both heavy metals, and organic and inorganic compounds. Vetiver or nard is a type of grass plant originating from India. This plant can be grown throughout the year and is known to many people for a long time as a source of perfume. In Indonesia, the vetiver plant is used as an herbal product in the form of essential oils which are useful in relieving inflammation, aromatherapy, floor cleaner, preventing bacterial infections, increasing immunity, treating insomnia, and accelerating wound healing (Mulyono et al., 2012). This plant is categorized as a non-food crop and not for consumption by living things, with the result that this plant is very suitable to be used to remediate pollutants.

Plants generally have several mechanisms for removing pollutants in the soil (Figure 4.2). Phytoremediation runs naturally with a six-stage process carried out by plants for contaminants or surrounding pollutants. Phytoextraction is the absorption of pollutants by plants from the air or soil through the roots which are then stored in the plant canopy. This type of plant is known as a hyperaccumulator which have the ability to store specific metals in high concentrations in the aerial portion (0.01% to 1% dry weight, depending on the metal). Phytofiltration is a process that uses plants to absorb, collect, and precipitate contaminants, especially heavy metals or radioactive elements, from water media through root systems or other submerged organs.

Phytostabilization, organic or inorganic contaminants, are introduced into the lignin in the cell wall from the root of the cell to

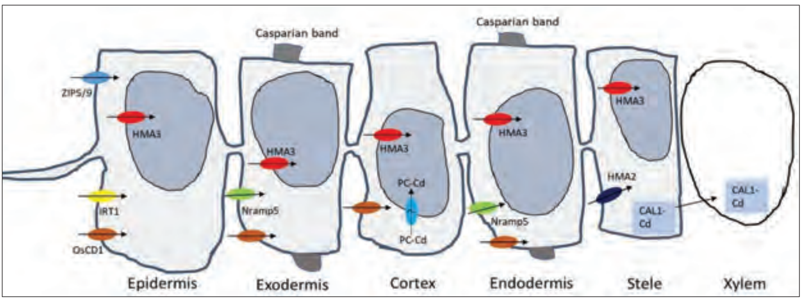


Source: J.C. et al. (2014)

Figure 4.2 Schematic Representation of Phytoremediation become humus. The metal is precipitated in an insoluble form by root exudate and is then trapped in the ground matrix. In rhizodegradation growing roots can encourage the development of damaging rhizosphere microorganisms and utilize exudates and plant metabolism as a source of carbon and energy. In addition, plants can release their own biodegradation enzymes. The use of rhizodegradation is limited to organic contaminants. In phytodegradation, organic contaminants are degraded (metabolized) or mineralized in plant cells by specific enzymes including nitroreductase, dehalogenase (degradation of chlorinated solvents and pesticides), and laccases (degradation of aniline) (Ryllot et al., 2008).

Phytovolatilization is the process of absorbing pollutants by plants and these pollutants are converted to evaporative properties which are then transpired by plants. Here, the absorbed pollutants will be released by the plants into the air. In the periodic table, some ions in group IIB, VA, and VIA elements, especially mercury, selenium, and arsenic are absorbed by plant roots and converted into non-toxic forms which are then volatilized into the atmosphere (Ali et al., 2013).

Vetiver (*Vetiveria zizanioides*) is a metal hyperaccumulator plant that has high absorption or accumulation properties in its plant tissues (MacGrath et al., 1993). Although in Indonesia it is included as a spice plant, the vetiver plant does not require special growing requirements



Source: Luo & Zhang (2021)

Figure 4.3 Heavy Metals Uptake and Transport Schematic in Roots like other plants. With a massive root system, this plant can grow well in extreme soil and environmental conditions (Truong, 2001). This plant has a very high tolerance to drought conditions or water stress, flooding conditions, hot environmental temperatures, tolerance to very acidic soil pH conditions, resistance to aluminum and manganese toxicity, and very tolerant to various metals such as arsenic, cadmium, copper, chrome, and nickel (Benavides et al., 2021). Recent research also supports that vetiver can survive in acid mine drainage soils (Kiiskila et al., 2019).

Heavy metals in the soil such as cadmium are in an insoluble form and are not available to plants. However, the solubility of heavy metals in soil can be increased by plants through the release of exudate substances in plant roots which will change the pH conditions in the rhizosphere (Dalvi et al., 2013). Two pathways lead to the physiological absorption of heavy metals through apoplastic and symplastic routes. The apoplastic pathway is a passive absorption process by diffusion. While the symplastic pathway is an active transport absorption process and an energy-consuming plasma membrane transport process that requires a gradient potential and electrochemical concentration (Peer et al., 2013).

Heavy metal complexes with various chelating agents will be formed when the heavy metals enter the root system. As a result, the toxicity will be lost because it does not move from the cytoplasm or vacuole, the cell wall (Ali et al., 2013). Plant cell walls or vacuoles are the sites of the detoxification of heavy metals. Heavy metal toxicity will disappear after storage in the root vacuole, this will also reduce its transportation which is quite far to the top of the plant (Thakur et al., 2016).

Until now, in most living organisms, the biological activity of certain heavy metals such as cadmium has not been known. Some heavy metals in hyperaccumulator plants such as nickel and zinc have the function of plant resistance to herbivorous organisms (Jiang et al., 2005). Cadmium in the plasma membrane will be absorbed as a carrier of essential elements through the roots, which have low substrate selectivity (Clemens et al., 2001).

2. Phytoremediation Uptake Model

The absorption of heavy metals in the phytoremediation process can be described through a simple system uptake plant model. This model is used to predict the contribution of various pathways through which heavy metals travel on different plant parts such as leaves, stems, and roots. This model includes three paths, namely the soil-root-leaf path, the soil-air-leaf path, and the path (Ouyang & Wan, 2008). The Simple Absorption Model is represented by four types of models, namely the soil model, root model, stem model, and leaf model (Ibrahim & el Afandi, 2020).

Soil Model, the bioaccumulation factors (BCF) approach which is commonly used in soil models is actually easy to use, but the limitation of this approach is that the lack of accuracy will greatly reduce its usefulness as a tool for risk evaluation and decision-making. Therefore, another parameter used besides BCF is the distribution coefficient between water and soil in dry conditions (Mouchet, 2008).

In this modeling experiment, experiments in the lab were carried out by determining in advance the concentration of heavy metals, namely heavy metals in water used to irrigate plants and soil using polyethylene bottles that had been washed and pre-soaked in the acid solution for 24 hours. The samples were then conditioned in an acid state until they reached pH 2. The concentration of heavy metals was then measured using AAS which was calibrated using a standard solution. Then the calculation follows the following equation:

$$CMn - Kd * Cw, \text{ where:}$$

CM: mass plant concentration; Kd: Distribution Coefficient of Hm; Cw: Hm concentration in water.

$$Cw/Csoils - KWS, \text{ where:}$$

Cw: Hm concentration in water; Csoil: Hm concentration in soil; Kws: Partition coefficient of Hm (between two phases soil and water)

Root Model, determination of the root model. It is represented by the following equation: Mass balance: flux in – flux out is given by:

Cw: Hm concentration in water, Csoil: Hm concentration in soil, Kd: distribution coefficient. Concentration divided by plant mass:

$$Cw - Csoils / KWS, \text{ where:}$$

Cxy: concentration of the Hm inside the xylem; Cr: concentration of Hm in the root; Krw: Partition coefficient of Heavy metals in two phases root zone and water

The steady-state is important to consider because the chemical conditions of the solution in the rhizosphere to which the plants are actually exposed are very different from the chemistry of bulk soil solutions and must be properly quantified (Paquin et al., 2002). On the other hand, the degree of accumulation at the site of action (biotic ligand) is assumed to be related to the toxicological response. Set to steady conditions and settle for heavy metal concentrations in plant roots.

$$((Cw * Q) - \left(\frac{Cr * Q}{Krw * M}\right) - (K * Cr))$$

$$Cr - \left(\frac{Q}{\frac{Q}{Krw}} + KM\right) * \left(\frac{Csoil}{Ksw}\right)$$, where:

Q: Flow of water in the soil (ml/kg); K: Rate of change in time; M: Plant mass; KM: Rate of change in mass of the plant; Ksw: Partition coefficient of heavy metals in two phases of soil and water

Stem model, stem model calculated according to xylem phloem (Briggs & Sculpher, 1998; Dettenmaier et al., 2009) in the following equation:

TSCF – 0.784*EXP ((- logKow – 1.78/2.44)2), where:

TSCF: Translocation stem concentration factor

Leaf Model, Leaf model is calculated in the following equation:

*LogBCF – 0.578*logKow + 1.588,* Where:

BCF: Bioaccumulation factors; Kow: Partition coefficient of heavy metals between two phases (organic compound) and water

$$\text{Outflux: } \left(\frac{Q}{Mr} * Kws\right) * Cs - \left(\frac{Q}{Mr} * Krw\right) * Cr - (Kr * Cr),$$

where:
Q: Flow of the water from the soil to the root (ml/kg); Mr: Mass of the root; Kws: Partition coefficient of Heavy metals between two phase waters; Cs: Concentration of Heavy metals in soil; Kr: Rate of change in the weight of the root.

$$\text{Influx to leaves: } \frac{Cl}{K} - (Q(Ml + Krw) * Cr), \text{ where:}$$

K: Rate of change in days; Q: water flow through the stem to the leaves (ml/kg); Cl: Heavy metals concentration in leaves; Cw: Heavy metals concentration in water; Ml: leaves mass; Kaw: Partition coefficient of Heavy metals (between two-phase air and water); Ca: Concentration of Heavy metals in air sample;

F. Conclusion

Heavy metal pollution of soil in Indonesia is mostly caused by the activities of the mining and the textile industry. Heavy metal pollution that occurs has entered the area of agricultural land for food crops so that heavy metals are found to have accumulated in plant tissues that can be dangerous to humans' health. *Vetiveria zizanioides* plants are the best candidates for heavy metal hyperaccumulator plants in the phytoremediation process based on their high absorption of heavy metals and non-food crops, so they can be further utilized as non-consumable products. A simple Plant Uptake Model (UPM) system has been used successfully in estimating heavy metal uptake in soil and its accumulation in plant tissues (stems, roots, and leaves). This model can be used in the management of phytoremediation related to the type and ability of plant species according to polluted soil and environmental conditions.

References

Adji S S. (2006). *Rehabilitasi Tanah Sawah Tercemar Natrium dan Logam Berat melalui pencucian, Penggunaan Vegetasi, Bahan Organik dan Bakteri*. https://repository.ipb.ac.id/handle/123456789/40756

Ali, H., Khan, E., & Sajad, M. A. (2013). Phytoremediation of heavy metals—Concepts and applications. *Chemosphere*, *91*(7), 869–881. https://doi.org/10.1016/J.CHEMOSPHERE.2013.01.075

Anugroho, F., Kurniati, E., & Alvin Pohan Effendi, B. (2020). Potensi Fitoremediasi Tanah Tercemar Timbal (Pb) Dengan Penambahan EDTA Menggunakan Rumput Raja (Pennisetum purpuroides). *Jurnal Sumberdaya Alam Dan Lingkungan*, *7*(1), 1–8. https://doi.org/10.21776/UB.JSAL.2020.007.01.1

Aubé, B. (2004). The Science of Treating Acid Mine Drainage and Smelter Effluents. https://www.semanticscholar.org/paper/The-Science-of-Treating-Acid-Mine-Drainage-and-Aub%C3%A9/bea33be43f063bf768d36e7fb6bf36af5cfb550a

Benavides, B. J., Drohan, P. J., Spargo, J. T., Maximova, S. N., Guiltinan, M. J., & Miller, D. A. (2021). Cadmium phytoextraction by Helianthus annuus (sunflower), Brassica napus cv Wichita (rapeseed), and Chyrsopogon zizanioides (vetiver). *Chemosphere*, *265*, 129086. https://doi.org/10.1016/J.CHEMOSPHERE.2020.129086

Briggs, A., & Sculpher, M. (1998). An introduction to Markov modelling for economic evaluation. *PharmacoEconomics*, *13*(4), 397–409. https://doi.org/10.2165/00019053-199813040-00003

Chairiyah, R. R., Guchi, H., & Rauf, A. (2013). Bioremediasi Tanah Tercemar Logam Berat Cd, Cu, Dan Pb Dengan Menggunakan Endomikoriza. *Jurnal Agroekoteknologi Universitas Sumatera Utara*, *2*(1), 97390. https://doi.org/10.32734/JAET.V2I1.5836

Chen, J. P., Wang, L. K., Wang, M. H. S., Hung, Y. T., & Shammas, N. K. (2016). Remediation of heavy metals in the environment. *Remediation of Heavy Metals in the Environment*, 1–528. https://doi.org/10.1201/9781315374536

Dalvi, A., Dalvi, A. A., & Bhalerao*, S. A. (2013). Response of Plants towards Heavy Metal Toxicity: An overview of Avoidance, Tolerance and Uptake Mechanism. *Annals of Plant Sciences*, *2*(09), 362–368. https://www.annalsofplantsciences.com/index.php/aps/article/view/87

Darmono. (1995). *Logam Dalam Sistem Biologi Makhluk Hidup*. UI-Press.

Dellisanti, F., Rossi, P. L., & Valdrè, G. (2009). In-field remediation of tons of heavy metal-rich waste by Joule heating vitrification. *International Journal of Mineral Processing*, *93*(3–4), 239–245. https://doi.org/10.1016/J.MINPRO.2009.09.002

Dembitsky, V. M., & Rezanka, T. (2003). Natural occurrence of arseno compounds in plants, lichens, fungi, algal species, and microorganisms. *Plant Science*, *6*(165), 1177–1192. https://doi.org/10.1016/J.PLANTSCI.2003.08.007

Dettenmaier, E. M., Doucette, W. J., & Bugbee, B. (2009). Chemical hydrophobicity and uptake by plant roots. *Environmental Science and Technology*, *43*(2), 324–329. https://doi.org/10.1021/ES801751X/SUPPL_FILE/ES801751X_SI_001.PDF

Farcasanu, I. C., Popa, C. V., & Ruta, L. L. (2018). Calcium and Cell Response to Heavy Metals: Can Yeast Provide an Answer? *Calcium and Signal Transduction*. https://doi.org/10.5772/intechopen.78941

Fashola, M. O., Ngole-Jeme, V. M., & Babalola, O. O. (2016). Heavy Metal Pollution from Gold Mines: Environmental Effects and Bacterial Strategies for Resistance. *International Journal of Environmental Research and Public Health*, *13*(11). https://doi.org/10.3390/IJERPH13111047

Hidayat, B. (2015). Remediasi Tanah Tercemar Logam Berat Dengan Menggunakan Biochar. *Jurnal Pertanian Tropik* , *2*(1), 51–61. https://doi.org/10.32734/JPT.V2I1.2878

Hidayati N, Juhaeti T, & Syarif F. (2004). *Karakterisasi Limbah dan vegetasi pada Penambangan Emas Rakyat dan Penambangan Emas PT ANTAM Pongkor*.

Hingston, J. A., Collins, C. D., Murphy, R. J., & Lester, J. N. (2001). Leaching of chromated copper arsenate wood preservatives: a review. *Environmental Pollution (Barking, Essex : 1987)*, *111*(1), 53–66. https://doi.org/10.1016/S0269-7491(00)00030-0

Ibrahim, N., & el Afandi, G. (2020). Phytoremediation uptake model of heavy metals (Pb, Cd and Zn) in soil using Nerium oleander. *Heliyon*, *6*(7), e04445. https://doi.org/10.1016/J.HELIYON.2020.E04445

Ikerismawati, S. (2019). Bioremediasi Pb Oleh Bakteri Indigen Limbah Cair Agar. *Jurnal Biosilampari : Jurnal Biologi*, *1*(2), 51–58. https://doi.org/10.31540/BIOSILAMPARI.V1I2.288

J.C., P., Pratas, J., Varun, M., DSouza, R., & S., M. (2014). Phytoremediation of Soils Contaminated with Metals and Metalloids at Mining Areas: Potential of Native Flora. *Environmental Risk Assessment of Soil Contamination*. https://doi.org/10.5772/57469

Jiang, R. F., Ma, D. Y., Zhao, F. J., & McGrath, S. P. (2005). Cadmium hyperaccumulation protects Thlaspi caerulescens from leaf feeding damage by thrips (Frankliniella occidentalis). *The New Phytologist*, *167*(3), 805–814. https://doi.org/10.1111/J.1469-8137.2005.01452.X

Kasno A, Adiningsih, Sulaeman, & Subowo. (2000). Status Pencemaran Pb dan Cd pada lahan sawah intensifikasi Jalur pantura Jawa Barat. *Proseding Kongres Nasional Himpuan Ilmu Tanah Indonesia VII*.

Kiiskila, J. D., Sarkar, D., Panja, S., Sahi, S. v., & Datta, R. (2019). Remediation of acid mine drainage-impacted water by vetiver grass (Chrysopogon zizanioides): A multiscale long-term study. *Ecological Engineering*, *129*, 97–108. https://doi.org/10.1016/J.ECOLENG.2019.01.018

Kuranchie, F. A., Shukla, S. K., & Habibi, D. (2013). Mine wastes in Western Australia and their suitability for embankment construction. *Research Outputs 2013*, 1443–1452. https://doi.org/10.1061/9780784412787.145

Lestari, N. D., & Aji, A. N. (2020). Pengaruh Kompos Dan Biochar Terhadap Fitoremediasi Tanah Tercemar Kadmium Dari Lumpur Lapindo Menggunakan Kangkung Darat. *Jurnal Tanah Dan Sumberdaya Lahan*, *7*(1), 167–176. https://doi.org/10.21776/UB.JTSL.2020.007.1.21

Lestari, N. D., & Pratama, N. R. (2020). Potensi Tanaman Rami (Boehmeria Nivea) Untuk Fitoremediasi Tanah Tercemar Tembaga. *Jurnal Tanah Dan Sumberdaya Lahan*, *7*(2), 291–297. https://doi.org/10.21776/UB.JTSL.2020.007.2.13

Luo, J. S., & Zhang, Z. (2021). Mechanisms of cadmium phytoremediation and detoxification in plants. *The Crop Journal*, *9*(3), 521–529. https://doi.org/10.1016/J.CJ.2021.02.001

Maulana, A., Supartono, & Mursiti, S. (2017). Bioremediasi Logam Pb pada Limbah Tekstil dengan Staphylococcus aureus dan Bacillus subtilis. *Indonesian Journal of Chemical Science*, *6*(3), 256–261. https://doi.org/10.15294/IJCS.V6I3.16639

Miseri, R. A., & Santoso, A. Z. P. B. (2000). Dampak Asap Kendaraan Bermotor terhadap Kadar timbal (Pb) dalam tanah dan tanaman di sekitar jalan raya Palimanan Cirebon. *Prosiding Kongres Nasional VII Himpunan Ilmu Tanah Indonesia* .

Nadhila, U., Nadhila, U., & Titah, H. S. (2021). Kajian Penambahan EDTA Pada Fitoremediasi Logam Berat Timbal. *Jurnal Teknik ITS*, *9*(2), F117–F122. https://doi.org/10.12962/j23373539.v9i2.53280

Ouyang, Z., & Wan, B. (2008). Modeling of Moisture Diffusion in FRP Strengthened Concrete Specimens. *Journal of Composites for Construction*, *12*(4), 425–434. https://doi.org/10.1061/(ASCE)1090-0268(2008)12:4(425)

Paquin, P. R., Gorsuch, J. W., Apte, S., Batley, G. E., Bowles, K. C., Campbell, P. G. C., Delos, C. G., di Toro, D. M., Dwyer, R. L., Galvez, F., Gensemer, R. W., Goss, G. G., Hogstrand, C., Janssen, C. R., McGeer, J. C., Naddy, R. B., Playle, R. C., Santore, R. C., Schneider, U., … Wu, K. B. (2002). The biotic ligand model: a historical overview. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, *133*(1–2), 3–35. https://doi.org/10.1016/S1532-0456(02)00112-6

Pierzynski, G. M., McDowell, R. W., & Sims, J. T. (2015). Chemistry, Cycling, and Potential Movement of Inorganic Phosphorus in Soils. *Phosphorus: Agriculture and the Environment*, 51–86. https://doi.org/10.2134/AGRONMONOGR46.C3

Purbalisa, W., & Dewi, T. (2019). Remediasi Tanah Tercemar Kobalt (Co) Menggunakan Bioremediator Dan Amelioran. *Jurnal Tanah Dan Sumberdaya Lahan*, *6*(2), 1237–1242. https://doi.org/10.21776/UB.JTSL.2019.006.2.4

Rahadi, B., Susanawati, L. D., & Agustianingrum, R. (2020). Bioremediasi Logam Timbal (Pb) Menggunakan Bakteri Indigenous Pada Tanah Tercemar Air Lindi (Leachate). *Jurnal Sumberdaya Alam Dan Lingkungan*, *6* (3), 11–18. https://doi.org/10.21776/UB.JSAL.2019.006.03.2

Ratnawati, R., & Fatmasari, R. D. (2018). Fitoremediasi Tanah Tercemar Logam Timbal (Pb) Menggunakan Tanaman Lidah Mertua (Sansevieria trifasciata) Dan Jengger Ayam (Celosia plumosa). *Al-Ard: Jurnal Teknik Lingkungan*, *3*(2), 62–69. https://doi.org/10.29080/ALARD.V3I2.333

Rija S. (2000). Evaluasi Pengaruh Tanah terpapar air buangan tekstil terhadap pertumbuhan tanaman padi swah. *Kongress Nasional VII Himpunan Ilmu Tanah Indonesia*.

Siregar, U. J., & Zakiyah, R. (2016). Growth Of Four Tree Species On Media Containing Gold Mine Tailing Of Pt Antam Ubpe Pongkor. *Jurnal Silvikultur Tropika*, *7*(3), S72–S76. https://doi.org/10.29244/J-SILTROP.7.3.S72-S76

Subroto, M. A. (1996, June). Fitoremediasi . *Pelatihan and Lokakarya Peranan Bioremediasi Dalam Pengelolaan Lingkungan*.

Suganda H, Setyorini D, Kusnadi H, Saripin I, & Kurnia U. (2002). Evaluasi pencemaran limbah industri tekstil untuk kelestarian lahan sawah. *Prosiding Seminar Nasional Multifungsi Dan Konversi Lahan Pertanian. Pusat Penelitian Dan Pengembangan Tanah Dan Agroklimat. Badan Penelitian Dan Pengembangan Pertanian.*

Thakur, S., Singh, L., Wahid, Z. A., Siddiqui, M. F., Atnaw, S. M., & Din, M. F. M. (2016). Plant-Driven Removal of Heavy Metals From Soil: Uptake, Translocation, Tolerance Mechanism, Challenges, And Future Perspectives. *Environmental Monitoring and Assessment*, *188*(4). https://doi.org/10.1007/S10661-016-5211-9

Chapter 5

Soil Erosion Estimation Using RUSLE Method

Asep Muhammad Hidayatulloh & Rendy Pratama Agusta

A. Soil Erosion

Nowadays, the urbanization activity and population increase has caused natural resources such as soil and land to depleting time by time. Many development projects have changed the morphology and land function, which in turn caused many environmental problems. One of them is known as soil erosion. Soil erosion or soil loss is a phenomenon in which many the soil properties experienced serious degradation due to external forces. The erosion phenomenon is deeply affected by several factors, such as rainfall (errosivity/R factor), soil type (erodibility/K factor), topography (slope and steepness/LS factor), control practices (P factor), and vegetation cover (C factor). For a long period, many scientists have been studying the soil ero-

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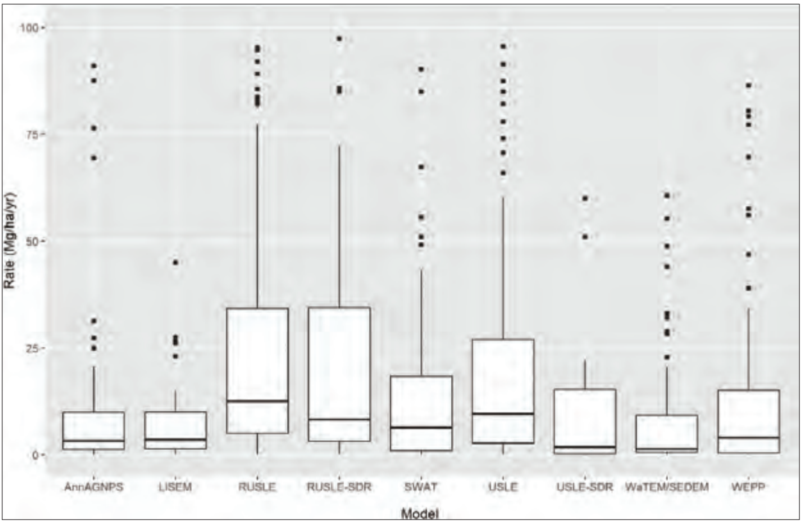
A. M. Hidayatulloh & R. P. Agusta
King Abdulaziz University, Saudi Arabia, e-mail: asep.muhammad.h@gmail.com

Hidayatulloh, A. M., & Agusta, R. P. (2022). Soil erosion estimation using RUSLE method. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and technology role for Indonesia development* (69–80). DOI: 10.55981/brin.538.c507 ISBN: 978-623-7425-85-4 E-ISBN: 978-623-7425-89-2

sion process, the causes, and its impacts in the socio-environmental field (Bennett & Chapline, 1928). They also have determined that this phenomenon is mainly caused by water, hill slope, and minor catchment (Turnbull et al., 2010). A few years later, the method to calculate erosion become more advanced since the existence of Geographic Information System (GIS) software as a device to create a model simulation for larger catchment and more complex surface run-off. The Digital Elevation Model (DEM) generation, watershed delineation, and morphometric parameters extraction can be obtained using ArcHydro and morphometric toolbox in GIS.

There are several methods to predict soil erosion, for example Erosion Potential Model (EPM) (Gavrilovic, 1962), Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978), and the revision of USLE method known as Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1991). RUSLE is regarded as one of the most



Source: Borrelli et al. (2021)

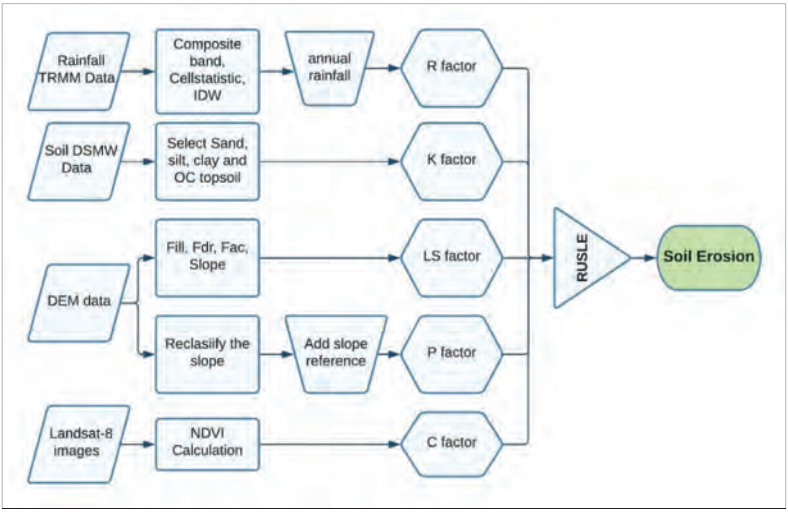
Figure 5.1 Comparison of the RUSLE and Eight Soil Erosion Prediction Most Commonly Used Models Based on the GASEMT Database popular methods in the world based on Global Applications of Soil Erosion Modelling Tracker (GASEMT) database (Figure 5.1). Another methods are Water Erosion Prediction Project (Flanagan and Nearing, 1995), Pan-European Soil Erosion Risk Assessment (Kirkby et al., 2004), and Soil Water Assessment Tool or SWAT (Moriasi et al., 2012). The RUSLE is a model that can appropriately produce accurate results and easier to apply in some specific areas, such as mountainous tropical watershed (Millward & Mersey, 1999), in Mediterranian area Tunisia (Gaubi et al., 2017; Kefi et al., 2012), in Algeria (Benkadja et al., 2015), and in Morocco (Chadli, 2016). The calculation using RUSLE model mainly focused on rainfall or errosivity factor as the main variable and most important factor of erosion problem. Since the the RUSLE method using satellite images without in-situ field, the results will be depends on the quality and resolution of satellite images. Therefore to assess the accuracy, the result should be compared and validated with reliable field data and published literatures.

B. Methodology

The methodology for calculating soil erosion comprises the following:

1. DEM Generating from ALOS PALSAR with 12.5 m spatial resolution, obtained from Alaska Satellite Facility (ASF).
2. Collecting five soil erosion factors; R factor from rainfall data, K factor from Digital Soil Map of the World (DSMW) data, C factor from Landsat-8 satellite image, and P factor from DEM and references data.
3. Calculate soil erosion RUSLE model using raster calculator in ArcGIS software.
4. Morphometric parameters of the watershed extract using Archydro and morphometric toolbox.

Figure 5.2 shows the flow chart of soil erosion estimation using the RUSLE method in ArcGIS software. Some additional toolboxes used in this study are include Conversion to raster or polygon, Map reclassification, Composite bands, Cell statistics, and Inverse Distance Weighting (IDW).



Source: Author

Figure 5.2 Flowchart of the Soil Erosion Estimation Using the RUSLE Method

1. Soil Erosion Estimation

The RUSLE method can be expressed using the following equation:

$$A = R \times K \times LS \times P \times C \quad \text{.......................(1)}$$

Where:
- A = Average soil loss (ton/ha/yr)
- R = Rainfall erosivity factor (MJ mm/ha/hr/yr)
- K = Soil erodibility factor (ton ha hr MJ/ha/mm)
- LS = Topography factor (Slope length and steepness)
- P = Conservation/anti erosive factor
- C = Land cover management factor

1) Errosivity Factor (R)

Errosivity or R factor related to the rainfall energy. The longer the duration of rainfall, the higher the potency of erosion. The high-resolution annual rainfall data can be obtained from Climatic Research Unit data (Harris et al., 2020) then processed using composite band and cell statistics tools. The interpolation rainfall distribution is calculated using Inverse Distance Weighting (IDW) tools. The R factor can be obtained from rainfall data using Hurni's empirical equation (Hurni, 1985):

$$R = -8.12 + 0.562 \times P \quad \text{.......................(2)}$$

Where: P = annual rainfall ($mm/year^{-1}$)

2) Errodibility Factor (K)

The soil erodibility or K factor is related to the lithology and soil quality that responds to the erosion. The K value ranges between 0 and 1, the smallest value indicates the soil is most susceptible to erosion. There are four elements that affected the K factor in this formula: soil structure and texture, the organic content, soil coarse fragments, and its permeability (Williams, 1995). K factor is calculated using the following equation:

$$K_{RUSLE} = f_{csand} \times f_{cl-silt} \times f_{organic} \times f_{hisand} \quad (3)$$

Where : f_{csand} = coarse-sand contents factor

$f_{cl-silt}$ = clay to silt ratios factor

$f_{organic}$ = organic carbon content factor

f_{hisand} = sand contents factor

3) Length and Steepness Factor (LS)

The length and steepness (LS) factor are related to the topographic factor. The watershed with high LS will have high soil erosion. This study calculates LS using the equation from Moore and Burch (Moore & Burch, 1986):

$$LS = \left(\frac{Slope\ Length}{22.13}\right)^{0.4} \times \left(\frac{0.01745 \sin(\theta)}{0.0896}\right)^{1.3} \times 1.6 \quad \text{........(4)}$$

Where: Slope length = flow accumulation multiply cell size (using GIS technique)

θ = slope degree

4) Cover Management Factor (C)

The C factor is related to land cover management. Vegetation has the great potency to protect the soil from erosion, control the energy of rainfall, and reduce the speed of rainfall and run-off, which can be known based on Normalized Difference Vegetation Index (NDVI) value. Bare land has zero NDVI, while vegetation has a value more than 0. The C factor can be estimated using Colman equation (Colman et al., 2018) while depends on NDVI value.

$$C\ factor = 0.1\left(\frac{-NDVI+1}{2}\right) \quad \text{........ (5)}$$

$$NDVI = \frac{NIR-IR}{NIR+IR} \quad \text{........(6)}$$

Near Infra-Red (NIR) for band 5 and Infra-Red (IR) for band 4 in Landsat image-8. NDVI is a dimensionless indicator and the value ranges from the minimum (-1.0) to the maximum (1.0). The NDVI with a negative value is for water, 0-0.1 value is for soil, and those with the value more than 0.1 is for vegetation.

5) Control Practices Factor (P)

The P factor is the ratio of soil loss with specific support practice. The control practices can reduce the potential of erosion by reducing the amount and velocity of run-off, modifying the flow pattern and direction of surface run-off (Renard et al., 1991). The value ranges of P factor are between 0 and 1. The various farming practices like crop rotation, contour farming, and shelterbelts can reduce soil erosion. In estimating the P factor, there are at least two assumptions. First, P factor can predicted by assuming the three-parameter of soil control are known: contouring, strip-cropping, and terracing, all of them refer to slope grades and their corresponding P factor values (Shin, 1999) as shown in Table 5.1. The second is P factor assumed as 1 for all watersheds in arid land area (Gaubi et al., 2017).

Table 5.1 P Factor Values based on the Slope Classes

Slope (%)	Conservation Support Practices (P factor)		
	Contouring	Strip Cropping	Terracing
0–0.7	0.55	0.27	0.10
7–11.3	0.60	0.30	0.12
11.3–17.6	0.80	0.40	0.16
17.6–26.8	0.90	0.45	0.18
>26.8	1	0.50	0.20

Source: Shin (1999)

2. Watershed Morphometric Parameter

Morphometric parameters have an important role in the hydrologic behavior of the watersheds (Elfeki et al., 2017). The morphometric parameters of the watershed include area, perimeter, elevation, watershed length, slope, stream order, infiltration number, bifurcation ratio, drainage texture, and drainage density. The morphometric parameters were calculated using several equations, like Horton-Strahler equations (Horton, 1945; Strahler, 1964).

1) The Drainage density (D) of the watershed is obtained by stream length divided by the area of the watershed, mainly in km/km2 units. The area with mountainous relief and impermeable subsurface have a high value of drainage density, and the area with low relief and permeable subsurface material has a low value of drainage density.
2) The drainage texture (Dt) is a parameter that depends on rainfall, soil type, vegetation, relief, and infiltration number. Dt has been classified into five groups: very fine (>8), fine (6–8), moderate (4–6), coarse (2–4), and very coarse (<2) (Smith, 1950).
3) Infiltration number is the output part of drainage density and stream frequency.
4) The bifurcation ratio (Rb) is the ratio between the number of streams of an order to the next order in a drainage network. High Rb values indicates the watershed controlled drainage pattern structurally, while the low values indicate less structural disturbance in drainage pattern.
5) Elongation ratio is defined as the ratio between the length of the watershed with its diameter (Schumm, 1956). The area with low relief and few structural influences has Re value close to 1.0, and the area with high relief and much steeper has values ranging from 0.8 to 0.6 (Strahler, 1964).

Table 5.2 The Morphometric Parameters of the Watershed with its Equation and References

Morphometric Parameters	Equation	References
Elevation (m)	H	GIS software
Watershed Area (km2)	A	GIS software
Watershed Perimeter (km)	P	GIS software
Longest Flow Path (km)	Lf	GIS software
Basin Length (km)	Bl	GIS software
Drainage Density (km/km2)	Dd = Lu/A	Horton (1945)
Drainage Texture	Dt = Dd * Fd	Smith (1950)

Morphometric Parameters	Equation	References
Bifurcation Ratio	Rb = Nu/(Nu+1)	Schumm (1956)
Infiltration Number	NF	Horton (1945)
Relief Ratio	Rr = R/L	Schumm (1956)
Elongation Ratio	Re =	Schumm (1956)
Circularity Ratio	Rc	
Compactness Coefficient	Cc =	Strahler (1964)

C. Conclusions

The RUSLE model has been proven as potential method for estimating soil erosion that supported by GIS software and satellite images data. Five natural factors were used as input for calculate soil loss. The area with high or severe risk needs further attention for mitigation purposes. This area has correlation with high and steep slope. This study can provide useful information of the soil erosion risk map and morphometric parameters and also can help land decision-makers to manage sustainable water resource and evaluate risk assessment of the watershed.

References

Benkadja, R., Boussag, F., & Benkadja, A. (2015). Identification et évaluation du risque d'érosion sur le bassin versant du K'sob (Est Algérien). *Bulletin of Engineering Geology and the Environment, 74*(1), 91–102. https://doi.org/10.1007/S10064-014-0611-y

Bennett, H. H., & Chapline, W. R. (1928). *Soil erosion a national menace.* US Department of Agriculture.

Borrelli, P., Alewell, C., Alvarez, P., Anache, J. A. A., Baartman, J., Ballabio, C., Bezak, N., Biddoccu, M., Cerda, A., Chalise, D., Chen, S., Chen, W., De Girolamo, A. M., Gessesse, G. D., Deumlich, D., Diodato, N., Efthimiou, N., Erpul, G., Fiener, P., . . . Panagos, P. (2021). Soil erosion modelling: A global review and statistical analysis. *Science of the total environment, 780*, 146494. https://doi.org/10.1016/j.scitotenv.2021.146494

Chadli, K. (2016). Estimation of soil loss using RUSLE model for Sebou watershed (Morocco). *Modeling Earth Systems and Environment, 2*, 1–10. https://doi.org/10.1007/s40808-016-0105-y

Colman, C. B., Garcia, K. M. P., Pereira, R. B., Shinma, E. A., Lima, F. E., Gomes, A. O., & Oliveira, P. T. S. (2018). Different approaches to estimate the sediment yield in a tropical watershed. *Revista Brasileira de Recursos Hidricos*, *23*(47), 1–9. https://doi.org/10.1590/2318-0331.231820170178

Elfeki, A., Masoud, M., & Niyazi, B. (2017). Integrated rainfall–runoff and flood inundation modeling for flash flood risk assessment under data scarcity in arid regions: Wadi Fatimah basin case study, Saudi Arabia. *Natural Hazards, 85*(1), 87–109. https://doi.org/10.1007/s11069-016-2559-7

Flanagan, D., & Nearing, M. (1995). USDA-Water Erosion Prediction Project: Hillslope profile and watershed model documentation. *Nserl Rep, 10*, 1–123.

Gaubi, I., Chaabani, A., Ben Mammou, A., & Hamza, M. (2017). A GIS-based soil erosion prediction using the revised universal soil loss equation (RUSLE) (Lebna watershed, Cap Bon, Tunisia). *Natural Hazards, 86*(1), 219–239. https://doi.org/10.1007/s11069-016-2684-3

Gavrilovic, S. (1962). A method for estimating the average annual quantity of sediments according to the potency of erosion. *Bulletin of the Faculty of Forestry, 26*(1), 151–168.

Harris, I., Osborn, T. J., Jones, P., & Lister, D. (2020). Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset. Scientific data, 7(1), 1-18.

Horton, R. E. (1945). Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. *Geological Society of America Bulletin, 56*(3), 275–370. https://doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2

Hurni, H. (1985). An ecosystem approach to soil conservation. Soil erosion and conservation, In El-Swaify, S. A., Moldenhauer, W. C., & Lo, A. (Eds.), *Soil conservation society of America* (pp. 759–771). Ankeny, Iowa.

Kefi, M., Yoshino, K., & Setiawan, Y. (2012). Assessment and mapping of soil erosion risk by water in Tunisia using time series MODIS data. *Paddy and Water Environment, 10*(1), 59–73. https://doi.org/10.1007/s10333-011-0265-3

Kirkby, M., Jones, R. J., Irvine, B., Gobin, A., Cerdan, O., van Rompaey, A. J J., Le Bissonnais, Y., Daroussin, J., King, D., Montanarella, L., Grimm, M., Vieillefont, V., Puigdefabregas, J., Boer, M., Kosmas, C., Yassoglou, N., Tsara, M., Mantel, S., . . . Huting, J. (2004). *Pan-European soil erosion risk assessment: the PESERA Map, Version 1 October 2003*. Explanation of Special Publication Ispra 2004 No. 73 (SPI 04.73).

Millward, A. A., & Mersey, J. E. (1999). Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed. *Catena, 38*(2), 109–129. https://doi.org/10.1016/S0341-8162(99)00067-3

Moore, I. D., & Burch, G. J. (1986). Physical basis of the length-slope factor in the universal soil loss equation. *Soil Science Society of America Journal, 50*(5), 1294–1298. https://doi.org/10.2136/sssaj1986.03615995005000050042x

Moriasi, D., Rossi, C., Arnold, J., & Tomer, M. (2012). Evaluating hydrology of the Soil and Water Assessment Tool (SWAT) with new tile drain equations. *Journal of soil and Water Conservation, 67*(6), 513–524. https://doi.org/10.2489/jswc.67.6.513

Renard, K. G., Foster, G. R., Weesies, G. A., & Porter, J. P. (1991). RUSLE: Revised universal soil loss equation. *Journal of Soil and Water Conservation, 46*(1), 30–33.

Schumm, S. A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological Society of America bulletin, 67*(5), 597–646. https://doi.org/10.1130/0016-7606(1956)67[597:EODSAS]2.0.CO;2

Shin, G. (1999). *The analysis of soil erosion analysis in watershed using GIS* [Doctoral Disertation, Department of Civil Engineering, Gang-won National University, South Korea]

Smith, K. G. (1950). Standards for grading texture of erosional topography. *American journal of Science, 248*(9), 655–668. https://doi.org/10.2475/ajs.248.9.655

Strahler, A. N. (1964). Part II. Quantitative geomorphology of drainage basins and channel networks. In *Handbook of Applied Hydrology* (pp. 4–39). McGraw-Hill.

Turnbull, L., Wainwright, J., & Brazier, R. E. (2010). Changes in hydrology and erosion over a transition from grassland to shrubland. *Hydrological Processes: An International Journal, 24*(4), 393–414. https://doi.org/10.102/hyp.7491

Williams, J. R. (1995). The EPIC model. In Singh, V. P. (Ed.), *Computer models of watershed hydrology* (pp. 909–1000). Water Resources Publications.
Wischmeier, W. H., & Smith, D. D. (1978). *Predicting rainfall erosion losses: A guide to conservation planning*. Department of Agriculture, Science, and Education Administration.
Climatic Research Unit Harris et al. 2020. (https://crudata.uea.ac.uk/cru/data/hrg/)

SECTION 2

WASTE AND POLLUTION MANAGEMENT DEVELOPMENT

Chapter 6

The Use and Potential of Membrane Technology for Wastewater Treatment in Post-COVID-19 Pandemic

Nabilla Dewi Septiani & Dyah Wahyu Untari

A. Introduction

The Coronavirus Disease 2019 (COVID-19) pandemic has posed severe threats to humans and the environment. The findings of severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2) traces in wastewater and the practice of disinfecting outdoor spaces in several cities in the world including Indonesia, which can result in the entry of disinfectants and their byproducts into storm drainage systems and their subsequent discharge into rivers and coastal waters, raise the issue of environmental, ecological, and public health effects.

Paleologos et al. (2020) conducted a review of this case and reported that the presence of SARS-Cov-2 has been detected in untreated wastewater in several countries, such as in the Netherlands,

N. D. Septiani & D. W. Untari
Indian Institute of Technology Madras, India, e-mail: nabillaseptiani57@gmail.com

Septiani, N. D., & Untari, D. W. (2022). The use and potential of membrane technology for wastewater treatment in post-COVID-19 pandemic. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and technology role for Indonesia development* (83–96). DOI: 10.55981/brin.538.c505
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Australia, Greece, and the United States. SARS-Cov-2 macromolecules were found in the saliva, blood, and anal swabs of patients, raising the question of viral gastrointestinal infection and oral transmission routes for the virus. Van Doremalen et al. (2020) reported that SARS-Cov-2 may live from 4 until 72 hours on environmental surfaces, depending on the nature of the surface material. While a report from the US Centers for Disease Control and Prevention (CDC) suggested that the virus can survive up to 17 days in the environment (Moriarty, 2020).

Wastewater that is generated from handling SARS-Cov-2 contains a lot of bacteria, viruses, and disinfectants that contain chemical compounds and drugs that endanger public health. Waste from the medical laboratory needs to be handled more seriously because the chemicals used in the medical laboratory test process cannot be decomposed only by aeration or activated sludge. These materials contain heavy metals and infectious materials. Hence, it must be sterilized or normalized into non-hazardous waste. However, health facilities in hospitals and health centers usually use aerobic and anaerobic systems by using bacteria as a medium in decomposing pollutants for the wastewater. Thus, the increased use of disinfectants in this pandemic will disrupt the performance of wastewater treatment plants because many disinfectants could remove the bacteria in the system. For this reason, an effective solution is needed in the treatment of wastewater in the hospital and health facilities.

In order to minimize disease transmission from hospital wastewater that may have a high load of pathogens and drugs waste during a pandemic, Sozzi et al. (2015) suggested that these be first treated in-situ, before being discharged to the municipal sewerage network. Membrane technology is one of the solutions which are very effective in treating wastewater that contains disinfectants and biological waste (bacteria and viruses) so that it becomes non-hazardous waste.

B. Membrane

Membrane is a thin layer between two adjacent phases acting as a semipermeable (selective barrier) and regulating the exchange of substances between the two compartments. Membrane is widely used for medical treatment such as hemodialysis, water treatment plant (reverse osmosis), and wastewater treatment plant.

There is a classification of membranes based on the material source, cross-section structure, bulk structure, geometry, and separation regime. The classifications are as given:

1. Material source : organic or polymer, inorganic
2. Cross-section structure : symmetric, asymmetric
3. Bulk structure : integrally, composite
4. Geometry : flat sheet, tubular
5. Separation regime : porous, nonporous, ion exchange

Membrane material from organic or polymer is preferred to use over inorganic material. There are advantages of polymer material as membrane, such as many different types of polymeric material are commercially available, a large variety of different selective barriers, i.e., porous, nonporous, charged, and affinity can be prepared by versatile methods. Furthermore, the production of large membrane areas with consistent quality is possible on a technical scale at a reasonable cost based on reliable manufacturing processes, and various membrane shapes (flat sheet, hollow fiber, capillary shape, tubular, capsule) and formats including membrane modules with high packing density can be produced. A very well-defined regular pore structure is difficult to achieve, and the mechanical strength, the thermal stability, and the chemical resistance (e.g., at extreme pH values or in organic solvent) are rather low for many organic polymers.

There are examples of membranes from organic-or polymer-based on its materials. The classifications are as given:

- *Polysulfone* (PS) *and Polyethersulfone* (PES)

PS and PES membranes are widely used in microfiltration and ultrafiltration preparation, also for support in nanofiltration and reverse osmosis. The advantages of this material are, that it is stable in high temperatures, has wide pH tolerance (for pH 2–13), fairly good chlorine resistance, easy to fabricate membranes in a wide variety of configurations, and these materials have a flux or high permeability. Meanwhile, the disadvantages of these materials are, that it has a low-pressure limit which is typically 100 psig or 7 atm with flat sheet membrane and 25 psig or 1.7 atm with hollow fibers, these materials are also hydrophobic.

- *Cellulose acetate* (CA)

Cellulose acetate is prepared from cellulose by acetylation, i.e., reaction with acetic anhydride, acetic acid, and sulfuric acid. The advantages of this material are, it is hydrophilic, relatively easy to manufacture, the raw material is a renewable resource, and it can be prepared into a membrane with a pore size range that varies from microfiltration to reverse osmosis. The disadvantages of this material are, it has a fairly narrow temperature and pH range (3–7), poor resistance to chlorine, and it is highly biodegradable which can make the membrane not last longer to be used.

- *Polyamide* (PA)

Polyamide is characterized by having an amide bond in structure (-CONH-). Polyamide can be divided into three groups, i.e., aliphatic polyamide, semi-aromatic polyamides, and aromatic polyamides. The advantages of this material are, it has a wider pH and temperature rather than CA material, and it is also hydrophilic. The disadvantage is this material has poor resistance to chlorine.

C. Membrane Processes

As one of the most recent advances, membrane technology has developed as an effective technique for treating various types of wastewater streams. Impurities are reduced to the required level by using this method. A membrane process is good because it does not use much energy, can be used for a long time, and is easily scaled up. It could be organic or inorganic, depending on the material in the process. There are five membrane processes based on the pore size. The classifications are as given:

1. *Microfiltration* (MF)

Microfiltration is a pressure-driven process where separated compounds are in nanoparticles with a diameter of 0.1–0.2 μm. It is used as the first pre-treatment in NF and RO membrane processes. MF does not remove organic matter. However, when pre-treatment is applied, the increased removal of organic material can occur. MF can be used as a pre-treatment to RO or NF to reduce fouling potential. The main disadvantages of MF are that it cannot eliminate contaminants that are < 1 mm in size. In addition, MF is not an absolute barrier to viruses. However, when used in combination with disinfection, MF appears to control these microorganisms in water.

2. *Ultrafiltration* (UF)

Ultrafiltration membrane process can separate compounds in which the particle size is between 0.005 and 10 μm, which is between MF and RO. UF membranes are highly prominent water filters with low energy consumption in the removal of pathogenic microorganisms, macromolecules, and suspended matter among others. However, UF has some limitations including its inability to remove any dissolved inorganic substances from water and regular cleaning to maintain high-pressure water flow.

3. *Nanofiltration* (NF)

Nanofiltration is capable of removing ions that contribute significantly to the osmotic pressure hence allowing operation pressures that are lower than those RO. For heavily polluted water, NF needed a pre-treatment process to be effective.

4. *Forward Osmosis* (FO)

Forward osmosis is a natural occurrence where the solvent moves from a region of lower concentration to the higher concentration region across a permeable membrane. This process is found to be highly efficient with low-rate production of brine and is well studied as it promises to solve water problems. However, regeneration of the draw solution is highly expensive for the desalination process, hence the use of NF or RO for regeneration of the draw solution.

5. *Reverse Osmosis* (RO)

Reverse osmosis is a pressure-driven technique used to remove dissolved solids and smaller particles. RO is only permeable to water molecules. The applied pressure on the RO should be enough hence water can be able to overcome osmotic pressure. The pore structure of RO membrane is tighter than UF, they convert hard water to soft water, and they are practically capable of removing all particles, bacteria and organics, and it also requires less maintenance. Some disadvantages of RO are it includes the use of high pressure which is expensive compared to other membrane processes and are also prone to fouling. RO has very small pores and is able to separate particles smaller than 0.1 nm.

Membrane Module and Selection (Ezugbe & Rathilal, 2020)

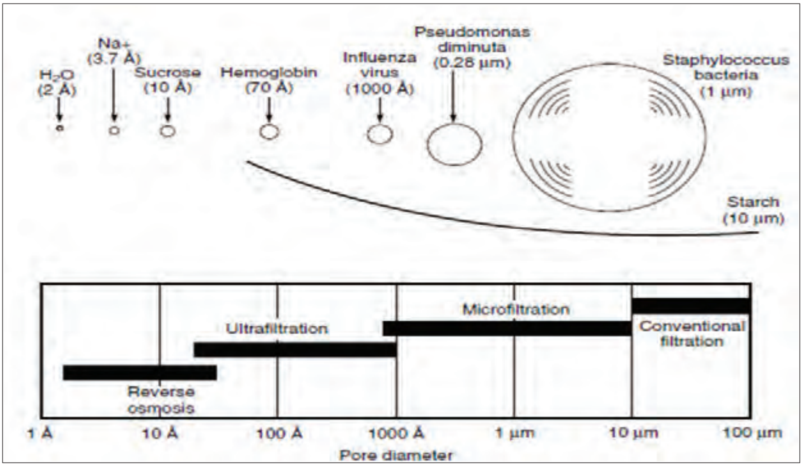
There are four selections of membrane based on the membrane module. The classifications are as given:

1. Plate-and-Frame Module. It is the oldest developed modular, used for high suspended particles wastewater treatment.
2. Tubular Module. It is an exterior casing (shell). Tubes are inserted into which the fluid to be processed is pumped under pressure. To treat feed having high solid contents, the water permeate out from the membrane goes via the tubing into the housing.
3. Spiral Wound Modular. This module is most often used in RO and NF procedures. The treated water fills the spiral wound module perpendicular to the membrane.
4. Hollow Fiber Module. In a pressure vessel, closed or open end. Depending on its intended usage, it might be shell-side (outside) or bore-side (inside).

D. Membrane Technology for Virus Removal in Wastewater

The use of membrane technology for wastewater treatment especially in the post-pandemic of SARS-Cov-2 ought to consider the size of virus particles. Varga Z et al. (2020) stated that SARS-Cov-2 size ranges from 60 to 140 nm in diameter. In another recent research, virus-like particles in infected SARS-Cov-2 patients were 70–110 nm in diameter. This state is similar to another study, where Bar-On et al. (2020) found that SARS-Cov-2 is an enveloped virus with a diameter of 100 nm. In recent years, virus reduction has become a priority in treating virus-contaminated wastewater/drinking water. According to (Chen et al., 2021), there are a lot of countries and institutions that research how to remove viruses from water, but they are mainly in the United States, France, Canada, the Netherlands, China, Spain, Japan, South Korea, etc.

Based on the size of virus particles, we can decide which membrane is used. In the case of SARS-Cov-2, the membrane process that

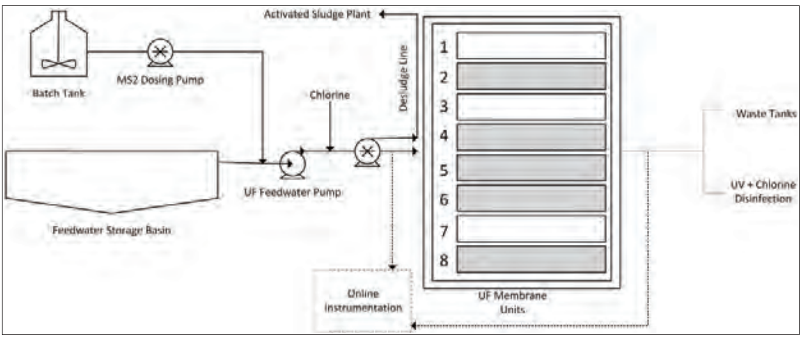


Source: Reeve (2016)

Figure 6.1 Particles Size and Membrane Filtration Range can be used is UF or RO. With the advantages and disadvantages of both processes, we can determine which process is more effective in installation, maintenance, and the ability to filter the virus and other wastewater pollution.

Reeve P. et al. (2016) stated that UF membrane technology is mostly used widely in wastewater treatment recycling schemes as a physical barrier to eliminate human pathogens including bacteria, protozoa, and viruses. But in Australia, where they experiment with the membrane, treatment implementation for UF requires validation to demonstrate that the process can provide the effectiveness of pathogenic microorganisms. Furthermore, Reeve P. et al (2016) designed a schematic of the UF membrane to demonstrate that the membrane can work effectively for viruses.

In the graph above, a batch tank with MS2 dosing is a highly concentrated stock culture that was selected as the virus surrogate. In this case, the wastewater that was contaminated with the virus. The feed water is used to minimize the suspension of suspended solids, filled and isolated to allow the chlorine or disinfectant to decay from the chlorinated secondary effluent process. Online instrumentation is used to monitor the feed and quality parameters of filtrate water



Source: Reeve (2016)

Figure 6.2 Schematic of the UF Membrane Testing Configuration which are pH, temperature, free and total chlorine, conductivity, and turbidity. The key to this online instrumentation for UF performance are trans-membrane pressure, resistance, and flow rate.

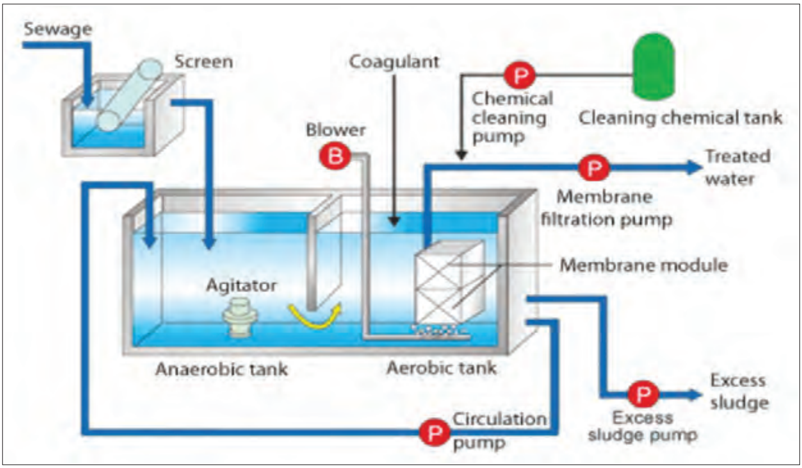
Categories and Elimination of Viruses in Water Treatment

Viruses are non-cellular, 10–100 nm-sized particles that contain nucleic acids (DNA and RNA). Live in the host for life and are infective, making them difficult to remove. UV disinfection is ineffective against Adenovirus, which has double-stranded DNA and is often found in WWTPs (Hata et al., 2013). Also, enteroviruses, rotaviruses, hepatitis A viruses, and noroviruses may live for months in natural water (Brooks et al., 2020). Most viruses in WWTP influent were negatively charged since the isoelectric point (IEP) is lower than the influent pH. There are two types of viruses: those living outside of host cells, cohabitating with microbes, and living within host cells. As a rule, viruses are smaller than the pores of MF membranes but more significant than those of NF and RO membranes. MF removes viruses by a factor of 0.3–2.2 (Chen et al., 2021). The surface of the vast majority of viruses is mostly made of proteins that give them their unique properties. Techniques including filtration, flocculation, coagulation, sedimentation, and disinfection help decrease viruses in wastewater and provide virologically safe recycled water. In requirement to formulate effective wastewater reclamation systems, users need to know how well each wastewater treatment unit removes viruses on average, and this is called a "viral LR credit". (Teunis et al., 2009)

It has been advocated by current standards (Amarasiri et al., 2017) regarding wastewater reclamation operations that the numerous systems in which successive wastewater treatment procedures are established in order to ensure that a total virus removal efficiency assessed by virological risk assessment surpasses the predetermined performance goal, should be used to limit viral infection risks for any kind of reclaimed wastewater use. Various academic difficulties need to be addressed further, such as 1) how to consider left-censored datasets in the computation of virus removal efficiency and 2) what indicators and procedures are acceptable for verifying virus removal/disinfection effectiveness in daily wastewater reclamation systems.

E. Membrane Bioreactor (MBR)

In some studies, researchers started to combine membranes with reactors that consist of aerobic or anaerobic bacteria to recycle the wastewater from hospitals or health facilities. This combination is called a membrane bioreactor (MBR). The process of membrane bioreactor is first introduced in the late 1960s after the commercialized ultrafiltration and microfiltration is improved. The new development of the membrane bioreactor was started in 1989 by Yamamoto and colleagues with the idea to sink the membrane inside the bioreactor. The main process inside the membrane bioreactor is a combination process of a membrane in a bioreactor to filter biomass (Hernaningsih, 2014).



Source: Wardhani (2015)

Figure 6.3 MBR System for Wastewater

In the last five decades, strengthened by the rapid improvement in engineering and materials science, the use of membrane technology in water treatment has become increasingly popular with one example being the MBR. Membrane bioreactor has two forms, which are aerobic membrane bioreactor (AeMBR) and anaerobic membrane bioreactor (AnMBR). (Zhu Y, 2021)

There are many types of membrane bioreactor systems. It is developed for two processes, suspended growth and attached growth. The most general type that is mostly used in submerged membrane bioreactor (SMBR) and external membrane bioreactor (EMBR). Submerged MBR is the type that is mostly used, where the membrane module is installed inside the reactor-activated sludge, which can be seen in Figure 6.3.

Removal efficacy of the MBR is mostly based on the following four processes (Chen et al., 2021):

1. Viruses are attracted to sludge particles through adsorption. Virus aggregates may bind to sludge particles that contain numerous bacteria and organic substances bigger than membrane pore size, reducing virus passage probability.
2. Interception of membrane
3. The cake and gel layers adsorb to the membrane surface. A virus's behavior in an aqueous medium is determined by viral protein (including hydrophobic and charged areas) and not by the membrane modules of MBRs with varying pore sizes. These membrane modules exhibit no evident change in the retention with the same virus water quality factors, including pH and temperature.
4. In MBRs, adsorption and aggregation processes via biofilm and cake layer rather than size exclusion are employed to remove viruses (typically from 0.1 to 0.4 μm).

Permeate is pumped out of the membrane module and suspended solids are retained by the membrane and removed back into the tank. Sludge formation occurs in the reactor. Submerged MBR is very popular because it does not need large land space, the energy need is low, and also has good filterability. However, submerged MBR requires larger and better membrane for filterable wastewater, which backwash cleaning is more often and lower membrane usage than external MBR. Submerged MBR has operating conditions according to Table 6.1.

Table 6.1 Operating Condition of Submerged MBR

Parameter	Value
Instant flux (L/m²h)	25–35
Long term flux (L/m²h)	15–30
Trans-membrane pressure (kPa)	20
Biomass concentration (gMLSS/L)	5–25
Sludge age (day)	> 20
Sludge production (kgSS/kgCOD)	< 0.25
Detention time (hour)	1–9
Food to microorganisms ratio	< 0.2
Volumetric load (m³/day)	0–20
Air flow rate (Nm³/hour per module)	8–12
Operational temperature (°C)	10–35
Operational pH	7–7.5
Backwash frequency (minute)	5–16
Backwash time (second)	15–30
Energy consumption for filtration (%)	0.2–0.4
Energy consumption for aeration (%)	80–90
Energy consumption for permeate pump (%)	10–20

Source: Wardhani (2015)

The use of membrane bioreactor not only to manage wastewater pollution but also can be used as wastewater reclamation to produce drinking water. However, more parameters analysis should be done to release the wastewater filtrate as clean water that is safe for drinking water.

F. Conclusion

In this chapter, the membrane technology and processes are explained, including types and selection of membranes. Types of membrane that can be used in this case are ultrafiltration (UF) or reverse osmosis (RO), based on the size of membrane pore and virus particles. Several aspects which should be consider of choosing these types of membranes are the availability of the membrane, effectiveness of the process, maintenance and also the cost estimation. In this chapter, also explained about membrane bioreactor that can also treat wastewater, which is a combination of aerobic and anaerobic tank with membrane filtration inside the tank. Using membrane technology can give benefits for wastewater treatment than common WWTPs process.

Reference

Amarasiri, M., Kitajima, M., Nguyen, T. H., Okabe, S., & Sano, D. (2017). Bacteriophage removal efficiency as a validation and operational monitoring tool for virus reduction in wastewater reclamation: Review. https://doi.org/10.1016/j.watres.2017.05.035

Bar-On Yinon M., Flamholz, A., Phillips, R., & Milo, R. (2020). SARS-Cov-2 (COVID-19) by the numbers. *eLife 9*. https://doi.org/10.7554/eLife.57309.

Brooks, Y. M., Spirito, C. M., Bae, J. S., Hong, A., Mosier, E. M., Sausele, D. J., Fernandez-Baca, C. P., Epstein, J. L., Shapley, D. J., Goodman, L. B., Anderson, R. R., Glaser, A. L., & Richardson, R. E. (2020). Fecal indicator bacteria, fecal source tracking markers, and pathogens detected in two Hudson River tributaries. *Water Research*, *171*, 115342. https://doi.org/10.1016/j.watres.2019.115342

Chen, C., Guo, L., Yang, Y., Oguma, K., & Hou, L. an. (2021). Comparative effectiveness of membrane technologies and disinfection methods for virus elimination in water: A review. *Science of the Total Environment*, *801*, 149678. https://doi.org/10.1016/j.scitotenv.2021.149678

Ezugbe, E. O., & Rathilal, S. (2020). Membrane technologies in wastewater treatment: A review. *Membranes*, *10*(5). https://doi.org/10.3390/membranes10050089

Hata, A., Kitajima, M., & Katayama, H. (2013). Occurrence and reduction of human viruses, F-specific RNA coliphage genogroups and microbial indicators at a full-scale wastewater treatment plant in Japan. *Journal of Applied Microbiology*, *114*(2), 545–554. https://doi.org/10.1111/jam.12051

Hernaningsih, T. (2014). Aplikasi membrane bioreactor (MBR) untuk proses daur ulang air limbah. *JAI* Vol. 7, No. 2, 109–118. https://media.neliti.com/media/publications/245834-aplikasi-membrane-bioreactor-mbr-untuk-p-5ed2df2d.pdf.

Moriarty, L. F. (2020). Public health responses to COVID-19 outbreaks on cruise ships worldwide, February-March 2020. *MMWR Morbidity and Mortality Weekly Report*. 69(12): 347–352._https://doi.org/10.15585/mmwr.mm6912e3.

Nqombolo, A., Mpupa A., Moutloali, R. & Nomngongo, P. N. (2018). Wastewater treatment using membrane technology. *Wastewater and Water Quality*. https://doi.org/10.5772/intechopen.76624.

Paleologos, E. K., O'Kelly, B. C., Tang, C. S. et al. (2020). Post COVID-19 water and wastewater management to protect public health and geoenvironment. *Journal of Environmental Geotechnics*. 8(3): 193–207. https://doi.org/10.1680/jenge.20.00067.

Reeve, P. (2016). Virus removal of new and aged UF membranes at full scale in a wastewater reclamation plant. *Environmental Science: Water Research and Technology*. 2: 1014–1021. https://doi.org/10.1039/c6ew00197a.

Sozzi, E., Fabre, K., Fesselet, J., Ebdon, J. E. & Taylor, H. (2015). Minimizing the risk of disease transmission in emergency settings: novel in situ physic-chemical disinfection of pathogen-laden hospital wastewaters. *PLOS Neglected Tropical Diseases*. 9(6): article e0003776._https://doi.org/10.1371/journal.pntd.0003776.

Teunis, P. F. M., Rutjes, S. A., Westrell, T., & de Roda Husman, A. M. (2009). Characterization of drinking water treatment for virus risk assessment. *Water Research*, *43*(2), 395–404. https://doi.org/10.1016/j.watres.2008.10.049

van Doremalen N., Bushmaker, T., & Morris, D. H. et al. (2020). Aerosol and surface stability of SARS-Cov-2 as compared with SARS-CoV-1. *New England Journal of Medicine*. 382: 1564–1567._https://doi.org/10.1056/NFJMc2004973.

Varga, Z, V. (2020). Electron microscopy of SARS-CoV-2: a challenging task– Authors' reply. *The Lancet* 395 (10238, E100). https://doi.org/10.1016/S0140-6736(20)31185-5.

Wardhani N. A. (2015). Review: membran bioreactor dan aplikasinya dalam reklamasi air. https://www.researchgate.net/publication/288630050_membran_bioreaktor_dan_aplikasinya_dalam_reklamasi_air.

Chapter 7

Persistent Organic Pollutants (POPs) in Indonesia

Aulia Nur Mustaqiman, Latonia Nur Adyanis, & Fefi Eka Wardiani

A. Persistent Organic Pollutants (POPs) in General Understanding

1. Definition and Types

Hazardous organic compounds are persistent, bioaccumulated, susceptible to long-range transboundary airborne movement and deposition, and are likely to have significant harmful public health or ecological effects both close and far from their source persistent organic pollutants (POPs) (Ballschmiter et al., 2002). They infect far-flung locations where they have never been used or produced, posing a global threat. They build up throughout the food web, reaching peak levels in the top species, and pose risks to health and wild animals (EC, 2017).

A. N. Mustaqiman, L. N. Adyanis & F. E. Wardiani
Chung Yuan Christian University, Taiwan, e-mail: aulia.nur.m2112@gmail.com

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Many POPs were formerly applied to crops, medical management, industry, and industrial operations, among other things. However, due to their resistance and poor management of decommissioned products, such as old electrical equipment containing polychlorinated biphenyls (PCBs), even forbidden POPs can linger in the environment for years. Furthermore, surely POPs are still being directly discharged into the atmosphere: polycyclic aromatic hydrocarbons (PAHs) are released by combustion, mainly from automobile exhaust emissions (EC, 2017).

However, some newly discovered, emerging POPs, such as perfluoroalkylated substances (PFASs), a class of industrial chemicals, and polybrominated diphenyl ethers (PBDEs) (also known as brominated flame retardants), have recently been controlled, are scheduled to be regulated, or are being considered for rules. Although there is less data on these newer pollutants than on heritage POPs, it is known that some (such as PFASs) operate differently in humans and animals than older POPs, attaching predominantly to protein and, to a lesser extent, fat (EC, 2017).

The primary sources of air pollution that contribute to the accumulation of POPs are (1) the use of specific pesticides, (2) the fabrication and use of specific chemicals, and (3) the unintentional formation of certain substances in burning waste, combustion, metal production, and vehicles, according to the POP protocol of the Convention on Long-Range Transboundary Air Pollution (LRTAP) (Ballschmiter et al., 2002).

In December 2000, diplomats from 122 countries signed a treaty in Johannesburg, South Africa, to restrict the manufacturing, importing, exporting, dumping, and using hazardous chemicals that can last for decades in the environment. In May 2001, the Agreement was finally signed during a summit in Stockholm, Sweden. Like previous multilateral environmental treaties, the Stockholm Convention on Persistent Organic Pollutants relies on the scientific expertise of its 179 parties. The Agreement aims to protect human health and the environment from POPs by decreasing and eliminating their environmental contamination and subsequent human exposure. In addition, it knows the significance of monitoring data in the efficient application of standards. It encourages parties to engage in global monitoring arrangements to obtain comparable monitoring data on the presence of POPs, identify changes in their concentrations over time, and provide data on their regional and global environmental transport (Magulova & Priceputu, 2016).

Magulova and Priceputu (2016) discuss the Stockholm Convention's Global Monitoring Plan's (GMP) implementation. The Plan provides a single global platform for generating and exchanging data on POP levels in three "core media": atmospheric air, human samples (blood or milk), and water. Although the manufacturing and use of many POPs were outlawed by the United Nations Stockholm Convention in 2004, they continue to be a health danger worldwide due to multiple sources of continued exposure. POPs are still manufactured and used in countries that have not ratified the Stockholm Convention, such as India and other South Asian countries. In India, PCBs will not be phased out until 2025. Despite being outlawed in some countries, the organochlorine pesticide dichlorodiphenyltrichloroethane (DDT) is widely used to control disease vectors worldwide. DDT was only recently made illegal in Mexico, and it is still widely used in Africa and Asia. India is the world's leading producer and consumer of DDT (La Merrill et al., 2019).

All chlorinated substances, such as aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, and toxaphene, have accidentally generated by-products or chemical products, such as hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs), and polychlorinated dibenzo-p-dibenzo-p-dibenzo-p-d (PCDFs). HCB has also been used to make fungicides. Aldrin, dieldrin, endrin, heptachlor, mirex, and hexachlorobenzene are the only single compounds; the remainder are complex combinations of isomers and congeners (PCBs, PCDDs, PCDFs, toxaphene). PCBs are made up of a total of 209 congeners, with about 120–140 of them occurring in the environment. Two semivolatile halogenated chemicals were discovered that are most likely of natural sources and showed all of the characteristics of a human, persistent pollutant: persistence, bioaccumulation, and local to world dispersion (Ballschmiter et al., 2002; Trojanowicz, 2020).

Existing monitoring procedures (air and human bio-monitoring) must be long-term sustainable to analyze fluctuations in concentrations over time. National air monitoring operations that provided data for the first monitoring reports continued in the second phase, and additional projects to aid the development of the second reports were found. For the new air monitoring activities, collaboration with key partners has guaranteed expense data collection and the deployment of standard POPs monitoring protocols. As measures to enforce the Convention have been accepted, the continuing United Nations Environmental Programme/World Health Organization (UNEP/WHO) human milk survey has continued to provide valid long-term results revealing how human exposure to POPs has evolved (Magulova & Priceputu, 2016).

2. Impact for Environment and Human Health

The Stockholm Convention defines POPs as carbon-based compounds that stay in the environment for a long time and are widely dispersed. They gather in the fatty tissues of living creatures, posing a threat to humans and wildlife (Trojanowicz, 2020). Most POPs known to date have been prohibited or regulated worldwide due to concerns about their harm to ecosystems and human health (EC, 2017).

POPs may cause several developmental, metabolic, neurodegenerative, and neoplastic problems in humans. There are reasonable concerns about such consequences; these concerns can be integrated with the fact that humans commonly contain combinations of POPs at low and high concentrations (Pumarega et al., 2016). According to many pieces of research, POP exposure has been associated with several health impacts, including hormone-dependent cancers, reproductive health issues, metabolic problems (including type-2 diabetes), obesity, and increased susceptibility to viral diseases (Bonefeld-Jorgensen et al., 2011; Ghosh et al., 2014; Skakkebaek et al., 2016; Weihe et al., 2016; Yu et al., 2000). In addition, POPs and their neurological consequences, such as IQ deficits or autism, are becoming more concerned (Mitchell et al., 2012; Stewart et al., 2008). However, because of the long period between exposure and the beginning of health problems, as well as the influence of a range of other environmental factors, establishing definitive links between POP exposure and any health effects remains a significant challenge (Antignac et al., 2016).

Water pollution is commonly connected with a large amount of wastewater being dumped into the environment from various sources. Furthermore, due to the wide range of pollution sources, such as dwellings, hospitals, industries, veterinary services, and agriculture, and their various application procedures, effluents' composition and characterization are wholly different and very complex. According to the Stockholm Convention, persistent Organic Pollutants (POPs are one type of substance found in wastewaters and are challenging to eradicate (Titchou et al., 2021). These pollutants are stable organic compounds resistant to photolytic, chemical, and physical destruction (El-Shahawi et al., 2010).

The Agreement acknowledges the existence of scientific and technological data on emissions, atmospheric processes, the effects of persistent organic pollutants on human health and the environment, and the importance of continuing scientific and technical collaboration to understand these concerns better. Analyzing the convoluted geographical and temporal picture of a compound's environmental destiny at the global trace level, a classic difficulty requiring expertise in global environmental chemistry, necessitates problem-oriented, highly sensitive, and accurate analytical measurements (Ballschmiter et al., 2002).

Understanding the long-range distribution and origins of these hazardous chemicals requires detecting and monitoring POPs in the environment. Long-term studies can also be used to examine the success of international control efforts by identifying patterns in levels (EC, 2017).

B. Source and Distribution of POPs

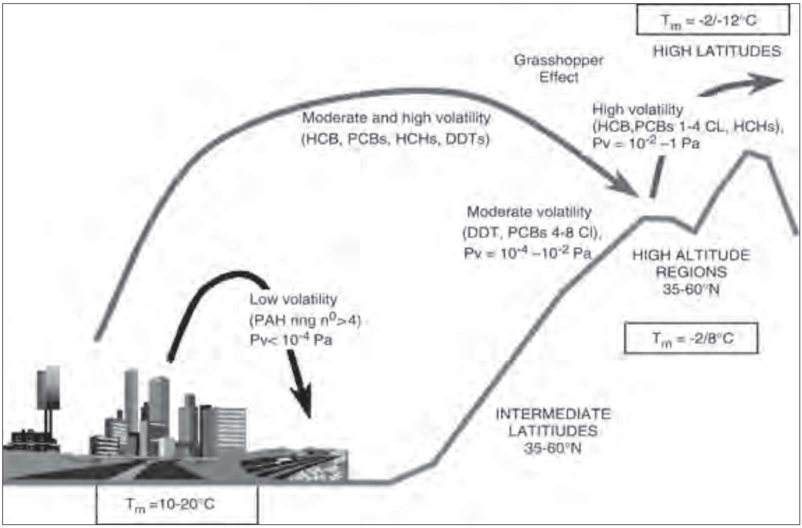
POPs produced and used in industries, urban, and agricultural areas are the primary sources released to the environment. Based on their production POPs were divided into intentionally and unintentionally produced chemicals (UPOPs) (Stockholm Convention, 2021). Intentional POPs are currently used in manufacturing, industrial processes, agriculture. For example, mentioned in Kodavanti and Loganathan (2014) study, PCBs are used in various industrial applications (such as electrical transformers and large capacitors). Another example was dDDT, an insecticide used in agriculture. DDT is still used in some countries to control malaria as a mosquito insecticide (US EPA, 2021a). Though DDT has been banned worldwide, its traces are still found in any level of the environmental compartment (Hofmann et al., 2012; Ueno et al., 2003).

On the other hand, UPOPs are chemicals produced by industrial processes and combustion. For example, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/Fs) are by-products of incomplete combustion in municipal and medical waste incineration and backyard burning of trash (Stockholm Convention, 2021). Due to their persistent characteristics when released into the environment, these chemicals have two pathways. First, they persisted in the background environment through favorability. Second, they are transported from the source into another world through the atmosphere and surface water. Atmospheric long-range transport of POPs supported by the dust cloud from the Pacific Ocean to North America (US EPA, 2021b). Research on founding POPs concentration in a pristine location such as the Arctic proved the long-range transport of POPs (Hofmann et al., 2012; Jia et al., 2014).

1. Stationary

   Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) are two POPs categorized as unintentional produced during incomplete combustion at certain conditions. PCDD/Fs can prove POPs from stationary sources through many monitoring studies. The combustion process that possibly produced these chemicals were waste incineration (Bie et al., 2007; Liu et al., 2012; McKay, 2002; Peng et al., 2020), medical waste incinerator (Du et al., 2013), smelting (Cagnetta et al., 2016; Mei et al., 2015), and burning coal for power production (Tian et al., 2021; Yu et al., 2021).

2. *Atmosphere*
   POPs distribution in the atmosphere pathway was through global atmospheric circulation. Polycyclic aromatic hydrocarbons (PAHs), as one of the POPs produced during incomplete combustion, were predicted to be transported to the Pacific Ocean by the northeast monsoon from rich East Asian region with the most significant impact on the coal-burning area (Sato et al., 2009). In another study by Gong et al. (2019) about the Himalayan POPs transport mechanism, POPs emitted in Himalaya lowland were



Source: Lioy (2006)

Figure 7.1 Grasshopper Effect of Persistent Organic Pollutants Atmospheric Movement Illustration Surface Water transported to high altitudes. Through modeling, 90% of POPs are trapped along the way through high altitudes due to gaseous deposition to soil/foliage and rainfall scavenging across the Himalayas. Lioy (2006) demonstrates the process of PAHs long-range transport from lower altitudes to higher altitudes named as grasshopper effect. Different POPs undergo the grasshopper effect and scatter through different volatility characteristics in different altitudes.

POPs that disperse in the environment through different sources of pollution can stay in all ecosystem components due to their persistent and cumulative properties. Surface water is the primary pathway to enhancing human exposure through drinking and water usage (Nguyen et al., 2017). Han and Currell (2017) studied POPs transport processes in the water bodies. Figure 7.2. describes the POPs cycle in surface water. POPs experience an

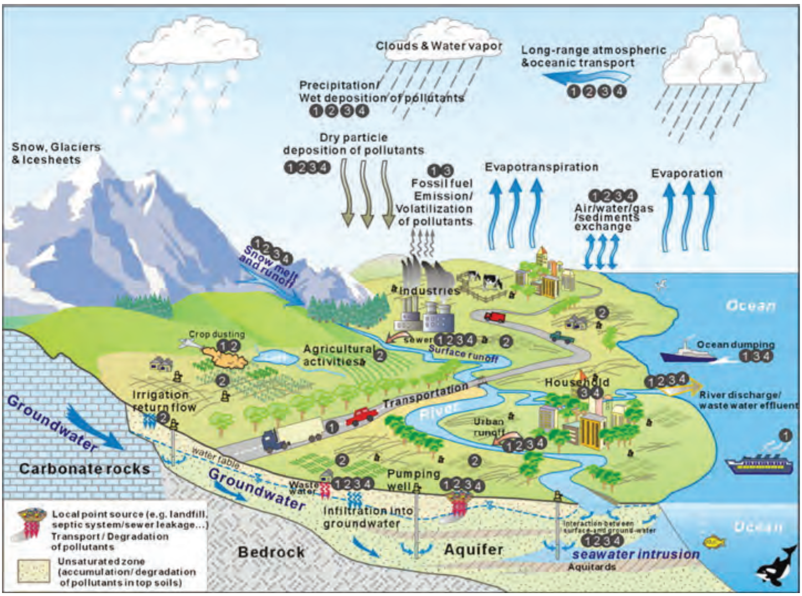


Figure 7.2 Persistent Organic Pollutants

air-soil-water exchange expected from their persistent characteristics and might be done by a long-range transport system that is connected with the atmospheric system. The cycle of POPs was a complex system of exchange and transformation processes that occur between air, soil, sediment, water, and biota. Evaporation of these chemicals dominates as the primary process in low latitudes regions while deposition plays in higher altitudes. While in mid-latitude areas, seasonal cycling of deposition and evaporation happens. Another way POPs are transported in the water cycle is through exchange and interaction between surface water and groundwater aquifers (karst and fractured aquifers).

C. Source: Han & Currell (2017) Control Technologies for POPs

Effective control of POPs contamination can be carried out, especially on sources of incomplete combustion (diesel engines, incinerators, coal industry, motor vehicles, etc.), which are the primary sources of POPs contamination in the atmosphere, water, and environment. The control of POPs contamination includes (Guo et al., 2020): (1) optimization of the combustion conditions of the incinerator process, one of which is the strategy for controlling temperature, time, turbulence, and oxygen demand parameters; (2) physisorption method through injection of active carbon into the exhaust gas and through fabric filter (FF); (3) Using chemical inhibition by injection of inhibitors into the exhaust gas (example: addition of nitrogen components, alkali (Qian, 2018), sulfur (Ogawa et al., 1996), ammonia injection, etc.); and (4) catalyzed destruction. Catalytic destruction can be carried out using Catalytic Filter (CR) and Selective Catalytic Reduction (SCR) technologies which have been proven to effectively reduce PCDDs/Fs contamination levels and have already been used in incinerator systems and powerful engines.

It is determining incredibly small amounts of essential contaminants that used to be a difficult and time-consuming task, particularly in industrial waste incineration, cement manufacture, metallurgical operations, and the refining and petrochemical sector. On the other hand, it is measuring emissions of minimal quantities of critical pollutants used to be a complex and time-consuming process–especially in applications like the aforementioned sectors. Therefore, it needs a technology that is available to periodically monitor the environment named Control Architecture for Dioxin Monitoring System.

The Dioxin Monitoring System is made up of three primary components, all of which may be customized to meet the demands of specific applications: filters, sample units, and controller units. Its modular design and controller architecture place emphasis on ease of use. When the automated sampling procedure is finished, the operator replaces a filter cartridge and sends the cartridge with the accumulated pollutant sample to the laboratory, where analysis may be completed considerably more effectively than on-site. In addition, all features are accessible through remote access. This, along with the Dioxin Monitoring System's integrated architecture, makes it incredibly less expensive to run than mobile measuring stations that need time-consuming installation and de-installation, and it also simplifies laboratory studies.

On the other hand, an automatic dioxin sampling system is ideal for long-term isokinetic sampling of hazardous organic chemicals in municipal and industrial waste incineration plants. Aside from dioxins, the system may collect furans and other POPs) such as PCBs and PAHs. The automated dioxin sampling system may be configured with the ParTrace option, which allows for heavy metal and fine particle collection to get the most out of the system.

Based on the explanation above, the steps taken by the Indonesian government in implementing POPs regulations are reasonable and can be appreciated. The initial step is in the way of government awareness and concern for PCB contamination. PCBs contamination is hazardous and can potentially pollute the environment, one of which can contaminate one of the components in the food chain. As time goes by, the Indonesian government already has several capabilities and technology and research collaboration networks in monitoring dioxins in the country. Hence, the state hopes that it will be able to prevent and overcome the dangers of POPs in Indonesia.

Consequently, all stakeholders should be able to follow and adapt to the development of dioxin regulation in the country. This is a common consequence that needs to be faced by all stakeholders, especially in the industrial business sector, in this case, manufacturing entrepreneurs. The entrepreneurs need to work hard in planning and implementing business so that their business activities can be free from dioxin contamination. In this case, they must prepare careful planning, including budgets, management plans, monitoring plans, and other supporting systems that support the prevention of dioxin hazards. These are not easy and require awareness and cooperation from various parties.

Academics and consultants are also crucial in this POPs circle (instead of the Indonesian government). In this case, they need to update their knowledge and experience to monitor and analyze POPs in Indonesia. Because POPs are still a new thing and different from other regulatory gases, the development and sustainability of POPs must be improved through networking and training for people, especially those who work as practitioners.

D. POPs Regulations in Indonesia

The Indonesian government's concern and vigilance towards the dangers of POPs contamination have been shown through the government's attention and participation in the Stockholm Convention on 23 May 2001, and the effort of the Convention showed into force in 2004. Delegations of Indonesian government representatives also joined and thus Indonesian government became one of the 152 countries that signed the International Agreement about POPs contamination. As one of the supporting countries for the Stockholm Convention, the Indonesian government is following up on its support efforts through the establishment of Law No. 19 the Year 2009 concerning the Ratification of the Stockholm Convention on Persistent Organic (Stockholm Convention Persistent Organic Pollutants). The regulation shows the state's efforts to support and contribute to the Stockholm Convention. The Indonesian government is obliged to implement the international agreement provisions such as the prohibition of production, restriction of use, destruction of materials or waste containing POPs, and restoring the environment contaminated by POPs. One of the POPs congeners which are already regulated in the Stockholm Convention and became the initial attention of the Ministry of the Environment is PCBs, among various other types of POPs PCDDs/Fs, PCDEs, PBDDFs, PBBs, and PBDEs.

The Indonesian government, prior to the implementation of the Stockholm Convention and Law No. 19 the Year 2009, has had PP No. 74 the Year 2001 concerning the B3 Management (Toxic and Hazardous Substances) along with Government Regulation (PP) No. 18 the Year 1999 concerning Management of Hazardous and Toxic Materials which was later changed to PP No. 85 the Year 1999. Hazardous and Toxic Materials (PB3) are materials that, due to their nature and/or concentration and/or concentration and/or amounts either directly or indirectly, can damage the environment, human health, and the survival of humans and other living creatures. Moreover, B3 management is activities including production, transportation, distribution, storage, and or disposing of hazardous and toxic materials.

Table 7.1 National Regulations Regarding POPs

No.	Regulations	Descriptions
1	Kep. Ka. BAPEDAL Nomor KEP-68/BAPEDAL/05/1994	Procedures for Obtaining a Permit for Storage, Collection, Operation of Processing, Processing, and Final Landfilling of Hazardous and Toxic Waste
2	Kep. Ka. BAPEDAL Nomor KEP-01/BAPEDAL/09/1995	Procedures and Technical Requirements for Storage and Collection of Hazardous and Toxic Waste
3	Kep. Ka. BAPEDAL Nomor KEP-02/BAPEDAL/09/1995	Hazardous and Toxic Waste Documents
4	Kep. Ka. BAPEDAL Nomor KEP-03/BAPEDAL/09/1995	Technical Requirements for the Treatment of Hazardous and Toxic Waste

No.	Regulations	Descriptions
5	Kep. Ka. BAPEDAL Nomor KEP-04/BAPEDAL/09/1995	Procedure for Requirements for Stockpiling of Processed Results, Requirements for Locations of Former Processing, and Locations for Former Landfills of Hazardous and Toxic Waste
6	Kep. Ka. BAPEDAL Nomor KEP-05/BAPEDAL/09/1995	Hazardous and Toxic Waste Symbols and Labels
7	Kep. Ka. BAPEDAL No. KEP-02/BAPEDAL/02/1998	Procedure for Supervision of Hazardous and Toxic Waste Management in the Regions
8	Kep. Ka. BAPEDAL No. KEP-03/BAPEDAL/03/1998	Partnership Program on Hazardous and Toxic Waste Management in Regions
9	Kep. Ka. BAPEDAL No. KEP-04/BAPEDAL/04/1998	Determination of Level I of Priority Provinces for Partnership Programs in the Management of Hazardous and Toxic Waste in the Regions
10	UU No. 19 Tahun 2009	Ratification of the Stockholm Convention on Persistent Organic Pollutants
11	UU No. 32 Tahun 2009	Protection and Management of the Environment
12	PP No. 18 Tahun 1999	Management of Hazardous Wastes and Toxic
13	PP No. 85 Tahun 1999	Amendment to PP No. 18 of 1999 concerning the Management of Hazardous and Toxic Waste
14	PP No. 74 Tahun 2001	Management of Hazardous and Toxic Materials (appendix)
15	PP No. 26 Tahun 2002	Radioactive Substance Transport Safety
16	PP No. 27 Tahun 2002	Radioactive Waste Management
17	Permen LH. No. 30 Tahun 2009	Management of Licensing and Supervision of Hazardous and Toxic Waste Management and Supervision of Recovery Due to Pollution of Hazardous and Toxic Waste by Regional Governments
18	National Implementation Plan on Elimination and Reduction of Persistent Organic Pollutants in Indonesia (July 2008)	
19	Peraturan Menteri Pertanian No. 24/Permentan/SR.140/2011	Requirements and Procedures for Pesticide Registration Terms

Source: (Dit.PB3., 2015) https://sib3pop.menlhk.go.id

The United Nations Industrial Development Organization (UNIDO) directly provided support to Indonesia regarding the participation of the Stockholm Convention by organizing a workshop in June 2003 on the Dissemination in Inventory Results of POPs Chemicals in Indonesia which produced outputs, one of which was the recommendation **not** to using organochlorine-based pesticides which are the source of POPs. Other prohibited POP chemicals are aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, toxaphene, and hexachlorobenzene. The inventory results involved several relevant government institutions, including the Ministry of Environment, Ministry of Agriculture, Ministry of Transportation, Ministry of Manpower, Ministry of Health, Ministry of Home Affairs, and Ministry of Trade. In conclusion, the Indonesian government at that time does not explicitly have laws governing the quality standards of POPs as stated in the Stockholm Convention. The Indonesian government, in addition, also requires an integrated institutional approach from upstream to downstream regarding formulating national policies especially POPs in the environmental sector.

UNIDO, on the most recent occasion, also contributed by providing a grant in the presence of a gas chromatography (GC) and electron capture detector (ECD) test machine in 2019 to the Indonesian government, accepted and represented by the Deputy for Natural Resources Development Technology, Agency for the Assessment and Application of Technology (BPPT) together with Ministry of Environment and Forestry (KLHK) which will be placed in the Environmental Laboratory (PTL). The initial GC-ED application will be utilized to measure PCBs in transformer oil samples in the polluted area survey program, international collaboration between the KLHK and UNIDO. Recently, there has not been a single laboratory in Indonesia that can analyze the content of dioxins or POPs in mobile and stationary sources. Therefore, this is the right step and a beginning for the progress of POPs research in Indonesia.

Several findings related to dioxins, one of which was shown by collaborative research from the International Pollutant Elimination

Network (IPEN) in 2019 in collaboration with the NEXUS3 Foundation, Arnika, and Ecoton found that the concentration of dioxin in chicken eggs from a village in Sidoarjo, East Java, was one of the highest in Asia. Those findings were the first, and there had never been a research result like this before in Indonesia. Dioxin contamination inside poultry, eggs, and meat products was also found in other countries. After being traced, the cause was animal feed contaminated with PCB-based industrial waste that was illegally disposed of. PCB contamination in livestock products generally starts from animal feed contaminated by PCBs. Especially livestock whose feed is not controlled or loose chickens left to find their feed. IPEN researchers focused their studies on villages near an industry in Mojokerto, which imports about 40% of paper waste for its production. The paper containers ordered by this factory contain low-quality plastic waste, which is then sold to rural communities that depend on garbage for their livelihoods. The Statistics Indonesia (BPS) shows that Indonesia's plastic waste import figure increased by 141% in 2018 to 283,000 tons, mainly imported waste from Australia, Canada, Ireland, Italy, New Zealand, the UK, and the United States. The import increased after China closed its country from importing waste in early 2017. This might be a factor that led to the finding of PCBs in eggs.

Researcher from Ecoton (Ecological Observation and Wetlands Conservation) explains that the results of research exhibited 16 congeners of toxins from plastic waste found in chicken eggs belonging to villagers. Sampling activities were conducted in some villages, including three egg samples from Bangun Village, three egg samples from Tropodo Village, and six egg samples purchased at a supermarket. Eggs from Bangun Village and Tropodo Village contained dioxin levels of 200 picograms per fat gram, while the standard set by the Drug and Food Control Agency (BPOM) only 2.5 picograms per gram of egg. The results showed that the content of POPs contaminants, including dioxin in eggs content from Tropodo, far exceeded the content in control eggs purchased from supermarkets. Most supermarket are below the detection limit of laboratory equipment. Meanwhile, those in Tropodo and Bangun's egg samples exceeded the average standard limit, especially for the dioxin in Tropodo was 70 times higher than the dioxin safety standard in food controlled by the BPOM .

KLHK has also designed and developed a B3 information system regarding persistent organic pollutants called Toxic and Hazardous Substances and Persistent Organic Pollutants Information System (SIB3&POPs), which aims to provide education to the public about the integrated results of studies and research on POPs from various institutions into the official website of the Indonesian government regarding the handling of POPs in Indonesia. The goal of this program is to establish an information site/portal on POPs that can provide information on the problem of handling POPs in Indonesia for the Indonesian people and the international community.

The expected output from the collaboration is to complement the current SIB3&POPs content, especially the data and results of activities that cooperation partners have carried out in handling POPs so far. The following are some outputs that are expected to be displayed in SIB3 & POPs with data sources from cooperation partners.

1. A complete, clear, and easy-to-understand description of the 21 POPs materials that have been banned by the Stockholm convention (12 dirty dozen and 9 new POPs). It is necessary to include data on the study results of its effect on the health of the environment and living things. (BPPT, KLHK, Ministry of Agriculture, and UNIDO).
2. Analysis of research data on POPs pollution in Indonesia that has so far been carried out and published by relevant agencies, especially for government cooperation partners (BPPT, KLHK, and Ministry of Agriculture) including a GIS map of pollution distribution.
3. The public needs to know the industry data of products containing POPs materials so that the general public can wisely switch to the products that are environmentally friendly (Ministry of Industry, UNIDO).

4. Simple technological ways to detect POPs contamination in our environment that can be easily carried out by the public (KLHK, Ministry of Agriculture, BPPT).
5. Simple technology packages for the waste management or treatment caused by the use of POPs materials so that they can be applied by the community and industry (BPPT).
6. Information on research laboratories capable of conducting research, analysis, and scientific investigations on cases of B3 and POPs pollution by industry in Indonesia (KLHK, BPPT).
7. Information on substitutes for POPs for the development of similar industries that use materials that are safer for the environment and human health (BPPT, KLHK, Ministry of Agriculture).
8. Educational information for the public that is easy to understand in written documents, caricature images, slide shows, video clips, and others in Indonesian (BPPT, KLHK, Ministry of Agriculture, Ministry of Industry, UNIDO).
9. Information on existing regulations, both nationally and internationally, in Indonesian to make it easier for the community and industry to use POPs materials (KLHK)
10. Information about experts from various circles who understand POPs issues deeply are able to be used as a keynote resource for future activities in handling POPs in Indonesia (BPPT, KLHK, Ministry of Agriculture, UNIDO)

E. Conclusion

Persistent Organic Pollutants (POPs) produced and used in industries, urban, and agricultural areas are the primary sources released to the environment. Based on their production, POPs were divided into intentionally and unintentionally produced chemicals (UPOPs). POPs may cause several developmental, metabolic, neurodegenerative, and neoplastic problems in humans. Analysis of research data on POPs pollution in Indonesia that has so far been carried out and published by relevant agencies, especially for government cooperation partners.

References

Antignac, J. P., Main, K. M., Virtanen, H. E., Boquien, C. Y., Marchand, P., Venisseau, A., Guiffard, I., Bichon, E., Wohlfahrt-Veje, C., Legrand, A., Boscher, C., Skakkebæk, N. E., Toppari, J., & Le Bizec, B. (2016). Country-specific chemical signatures of persistent organic pollutants (POPs) in breast milk of French, Danish and Finnish women. Environmental Pollution, 218, 728–738. https://doi.org/10.1016/j.envpol.2016.07.069

Ballschmiter, K., Hackenberg, R., Jarman, W. M., & Looser, R. (2002). Man-made chemicals found in remote areas of the world: The experimental definition for POPs. Environmental Science and Pollution Research, 9(4), 274–288. https://doi.org/10.1007/BF02987503

Bie, R., Li, S., & Wang, H. (2007). Characterization of PCDD/Fs and heavy metals from MSW incineration plant in Harbin. Waste Manag., 27(12), 1860–1869. https://doi.org/10.1016/j.wasman.2006.10.014

Bonefeld-Jorgensen, E. C., Long, M., Bossi, R., Ayotte, P., Asmund, G., Krüger, T., Ghisari, M., Mulvad, G., Kern, P., Nzulumiki, P., & Dewailly, E. (2011). Perfluorinated compounds are related to breast cancer risk in greenlandic inuit: A case control study. Environmental Health, 10(1), 88. https://doi.org/10.1186/1476-069X-10-88

Cagnetta, G., Hassan, M. M., Huang, J., Yu, G., & Weber, R. (2016, 2016/03/15). Dioxins reformation and destruction in secondary copper smelting fly ash under ball milling. *Scientific Reports, 6*(1), 22925. https://doi.org/10.1038/srep22925

Du, Y., Jin, Y., Lu, S., Peng, Z., Li, X., & Yan, J. (2013, Feb). Study of PCDD/Fs distribution in fly ash, ash deposits, and bottom ash from a medical waste incinerator in China. *J Air Waste Manag Assoc, 63*(2), 230–236. https://doi.org/10.1080/10962247.2012.746753

European Commission. Directorate General for the Environment. & University of the West of England (UWE). Science Communication Unit. (2017). Persistent organic pollutants: Towards a POPs free future. Publications Office. https://data.europa.eu/doi/10.2779/170269

El-Shahawi, M. S., Hamza, A., Bashammakh, A. S., & Al-Saggaf, W. T. (2010). An overview on the accumulation, distribution, transformations, toxicity and analytical methods for the monitoring of persistent organic pollutants. Talanta, 80(5), 1587–1597. https://doi.org/10.1016/j.talanta.2009.09.055

Ghosh, S., Murinova, L., Trnovec, T., Loffredo, C., Washington, K., Mitra, P., & Dutta, S. (2014). Biomarkers Linking PCB Exposure and Obesity. Current Pharmaceutical Biotechnology, 15(11), 1058–1068. https://doi.org/10.2174/1389201015666141122203509

Guo, X. X., Ma, Y. F., Lin, X. Q., Li, X. D., Xiang, Y. F., & Wu, A. J. (2020, Sep). Reduction of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans by Chemical Inhibition and Physisorption from a Municipal Solid Waste Incineration System. *Energy & Fuels, 34*(9), 11237–11247. https://doi.org/10.1021/acs.energyfuels.0c01918

Han, D., & Currell, M. J. (2017, 2017/02/15/). Persistent organic pollutants in China's surface water systems. *Science of The Total Environment, 580,* 602–625. https://doi.org/https://doi.org/10.1016/j.scitotenv.2016.12.007

Hofmann, L., Stemmler, I., & Lammel, G. (2012, Mar). The impact of organochlorines cycling in the cryosphere on global distributions and fate--2. Land ice and temporary snow cover. *Environ Pollut, 162,* 482–488. https://doi.org/10.1016/j.envpol.2011.10.004

Jia, S., Wang, Q., Li, L., Fang, X., Shi, Y., Xu, W., & Hu, J. (2014, Nov 1). Comparative study on PCDD/F pollution in soil from the Antarctic, Arctic and Tibetan Plateau. *Sci Total Environ, 497-498*, 353–359. https://doi.org/10.1016/j.scitotenv.2014.07.109

Kodavanti, P. R. S., & Loganathan, B. G. (2014). Polychlorinated biphenyls, polybrominated biphenyls, and brominated flame retardants. In (pp. 433–450). Elsevier. https://doi.org/10.1016/b978-0-12-404630-6.00025-7

La Merrill, M. A., Johnson, C. L., Smith, M. T., Kandula, N. R., Macherone, A., Pennell, K. D., & Kanaya, A. M. (2019). Exposure to Persistent Organic Pollutants (POPs) and Their Relationship to Hepatic Fat and Insulin Insensitivity among Asian Indian Immigrants in the United States. Environmental Science & Technology, 53(23), 13906–13918. https://doi.org/10.1021/acs.est.9b03373

Lioy, P. J. (2006, 2006/05/01). Employing dynamical and chemical processes for contaminant mixtures outdoors to the indoor environment: The implications for total human exposure analysis and prevention. *Journal of Exposure Science & Environmental Epidemiology, 16*(3), 207-224. https://doi.org/10.1038/sj.jes.7500456

Liu, H. M., Lu, S. Y., Buekens, A. G., Chen, T., Li, X. D., Yan, J. H., Ma, X. J., & Cen, K. F. (2012, Jan). *Baseline soil levels of PCDD/Fs established prior to the construction of municipal solid waste incinerators* *in China. Chemosphere, 86*(3), 300-307. https://doi.org/10.1016/j.chemosphere.2011.10.033

Magulova, K., & Priceputu, A. (2016). Global monitoring plan for persistent organic pollutants (POPs) under the Stockholm Convention: Triggering, streamlining and catalyzing global POPs monitoring. *Environmental Pollution, 217*, 82–84. https://doi.org/10.1016/j.envpol.2016.01.022

McKay, G. (2002). Dioxin characterisation, formation and minimisation during municipal solid waste (MSW) incineration: Review. *Chemical Engineering Journal, 86*(3), 343–368. https://doi.org/10.1016/S1385-8947(01)00228-5

Mei, W., Guorui, L., Xiaoxu, J., Wenbin, L., Li, L., Sumei, L., Minghui, Z., & Jiayu, Z. (2015, 2015/05/01/). Brominated dioxin and furan stack gas emissions during different stages of the secondary copper smelting process. *Atmospheric Pollution Research, 6*(3), 464-468. https://doi.org/https://doi.org/10.5094/APR.2015.051

Mitchell, M. M., Woods, R., Chi, L.-H., Schmidt, R. J., Pessah, I. N., Kostyniak, P. J., & LaSalle, J. M. (2012). Levels of select PCB and PBDE congeners in human postmortem brain reveal possible environmental involvement in 15q11-q13 duplication autism spectrum disorder. *Environmental and Molecular Mutagenesis, 53*(8), 589–598. https://doi.org/10.1002/em.21722

Nguyen, D. D., Tsai, C. L., Hsu, Y. C., Chen, Y. W., Weng, Y. M., & Chang, M. B. (2017, Apr). PCDD/Fs and dl-PCBs concentrations in water samples of Taiwan. *Chemosphere, 173*, 603-611. https://doi.org/10.1016/j.chemosphere.2017.01.087

Ogawa, H., Orita, N., Horaguchi, M., Suzuki, T., Okada, M., & Yasuda, S. (1996, Jan). Dioxin reduction by sulfur component addition. *Chemosphere, 32*(1), 151-157. https://doi.org/10.1016/0045-6535(95)00241-3

PB3. (2015). *Sistem Informasi Bahan Berbahaya Beracun dan Pencemar Organik Persisten*. KLHK-RI. Retrieved 21 December fromhttp://sib3pop.menlhk.go.id/

Peng, Y., Lu, S., Li, X., Yan, J., & Cen, K. (2020). Formation, Measurement, and Control of Dioxins from the Incineration of Municipal Solid Wastes: Recent Advances and Perspectives. *Energy & Fuels, 34*(11), 13247–13267. https://doi.org/10.1021/acs.energyfuels.0c02446

Pumarega, J., Gasull, M., Lee, D.-H., López, T., & Porta, M. (2016). Number of Persistent Organic Pollutants Detected at High Concentrations in

Blood Samples of the United States Population. PLOS ONE, 11(8), e0160432. https://doi.org/10.1371/journal.pone.0160432
Sato, K., Li, H., Tanaka, Y., Ogawa, S., Iwasaki, Y., Takami, A., & Hatakeyama, S. (2009). Long-range transport of particulate polycyclic aromatic hydrocarbons at Cape Hedo remote island site in the East China Sea between 2005 and 2008. *Journal of Atmospheric Chemistry, 61*(3), 243–257. https://doi.org/10.1007/s10874-009-9135-4
Skakkebaek, N. E., Rajpert-De Meyts, E., Buck Louis, G. M., Toppari, J., Andersson, A.-M., Eisenberg, M. L., Jensen, T. K., Jørgensen, N., Swan, S. H., Sapra, K. J., Ziebe, S., Priskorn, L., & Juul, A. (2016). Male Reproductive Disorders and Fertility Trends: Influences of Environment and Genetic Susceptibility. *Physiological Reviews, 96*(1), 55–97. https://doi.org/10.1152/physrev.00017.2015
Stewart, P. W., Lonky, E., Reihman, J., Pagano, J., Gump, B. B., & Darvill, T. (2008). The Relationship between Prenatal PCB Exposure and Intelligence (IQ) in 9-Year-Old Children. *Environmental Health Perspectives, 116*(10), 1416–1422. https://doi.org/10.1289/ehp.11058
Stockholm Convention. (2021). *Listing of POPs in the Stockholm Convention*. http://www.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx
Tian, X., Cui, K., Sheu, H.-L., Hsieh, Y.-K., & Yu, F. (2021). Effects of Rain and Snow on the Air Quality Index, PM2.5 Levels, and Dry Deposition Flux of PCDD/Fs. *Aerosol and Air Quality Research, 21*(8), 210158. https://doi.org/10.4209/aaqr.210158
Titchou, F. E., Zazou, H., Afanga, H., El Gaayda, J., Akbour, R. A., & Hamdani, M. (2021). Removal of Persistent Organic Pollutants (POPs) from water and wastewater by adsorption and electrocoagulation process. *Groundwater for Sustainable Development, 13*, 100575. https://doi.org/10.1016/j.gsd.2021.100575
Trojanowicz, M. (2020). Removal of persistent organic pollutants (POPs) from waters and wastewaters by the use of ionizing radiation. Science of The Total Environment, 718, 134425. https://doi.org/10.1016/j.scitotenv.2019.134425
Ueno, D., Takahashi, S., Tanaka, H., Subramanian, A. N., Fillmann, G., Nakata, H., Lam, P. K. S., Zheng, J., Muchtar, M., Prudente, M., Chung, K. H., & Tanabe, S. (2003, 2003/10/01). Global Pollution Monitoring of PCBs and Organochlorine Pesticides Using Skipjack Tuna as a Bioindicator. A*rchives of Environmental Contamination and Toxicology, 45*(3), 378–389. https://doi.org/10.1007/s00244-002-0131-9

US EPA. (2021a). *DDT - A Brief History and Status.* https://www.epa.gov/ingredients-used-pesticide-products/ddt-brief-history-and-status

Weihe, P., Debes, F., Halling, J., Petersen, M. S., Muckle, G., Odland, J. Ø., Dudarev, A. A., Ayotte, P., Dewailly, É., & Grandjean, P. (2016). Health effects associated with measured levels of contaminants in the Arctic. *International Journal of circumpolar health, 75*(1), 33805.

Yu, F., Cui, K., Sheu, H.-L., Hsieh, Y.-K., & Tian, X. (2021). Atmospheric Concentration, Particle-bound Content, and Dry Deposition of PCDD/Fs. *Aerosol and Air Quality Research, 21*(5). https://doi.org/10.4209/aaqr.210059

Yu, M.-L., Guo, Y. L., Hsu, C.-C., & Rogan, W. J. (2000). Menstruation and reproduction in women with polychlorinated biphenyl (PCB) poisoning: Long-term follow-up interviews of the women from the Taiwan Yucheng cohort. *International Journal of Epidemiology, 29*(4), 672–677. https://doi.org/10.1093/ije/29.4.672

Chapter 8

Impacts of Textile Dyes on Health and the Environment and It's Remediation

Zahraturrahmi

A. Impact of the Textile Industry

Over the last few long time, the worldwide textile industry has become one of the foremost vital industries. There is no denying that the textile industry contributes to the financial development of the worldwide economy (Reyhan, 2014). The textile industry produces around 1 trillion dollars, contributes 7% of worldwide exports, and utilizes around 35 million laborers worldwide (Desore & Narula, 2018).

Despite its evident significance, this industrial sector is one of the most significant worldwide polluters and expends tall sums of power and chemicals (Bhatia, 2017). The extraordinary accentuation is set on the colossal utilization of drinking water in different operations

Zahraturrahmi
Isparta Uygulamalı Bilimler Üniversitesi, Turkey, e-mail: zahraturrahmi25@gmail.com

Zahraturrahmi. (2022). Impacts of textile dyes on health and the environment and it's remediation. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and technology role for Indonesia development* (119–134). DOI: 10.55981/brin.538.c508 ISBN: 978-623-7425-85-4 E-ISBN: 978-623-7425-89-2

of its generation chain, such as washing, fading, and dyeing, among others (Hossain, et al. 2018).

The textile industry can have a broad list of natural impacts (Muthu, 2017). The discussed contamination created includes, for illustration, the discharge of particulate matter and tidy, oxides of nitrogen and sulfur, and unstable natural compounds. The scraps of textile textures, yarns, and disposed packaging constitute the strong squander. On the other hand, the textile slime uncovers overflow volumes and undesirable composition issues, frequently displaying tall loads of natural matter, micronutrients, overwhelming metal cations, and pathogenic microorganisms (Bhatia, 2017).

The most harm caused by the textile industry to the environment, in any case, are those coming about from the release of untreated effluents into the water bodies (Bhatia, 2017), which generally constitute 80% of the overall emanations delivered by this industry (Wang, 2016). Within the composition of most of the remaining waters of the material industry, there are generally elevated levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) (Setiadi, et al. 2006). The more prominent accentuation should be credited to the expansive sum of non-biodegradable organic compounds, particularly textile dyes (Orts, et al. 2018).

A dye could be a colored compound, ordinarily utilized in arrangement, which is competent of being settled to a texture. The dye must be 'fast' or chemically steady. Thus the color will not wash with cleanser and water or blur on exposure to daylight. Dyeing is regularly exhausted in an unusual arrangement containing dyes and specific chemical fabric. After dyeing, dye particles have an uncut chemical bond with fiber atoms. Temperature and time control are two critical components in dyeing (Mawla, 2021). One of its properties is the capacity to give color to a given substrate (Shamey & Zhao, 2014) because of the nearness of chromophoric bunches in its atomic structures. In any case, the property of settling the color to the fabric is related to the auxotrophic bunches, which are polar and can tie to polar bunches of textile strands (Wardman, 2017).

The color related to textile dyes not only causes harm to the water bodies but also avoids the entrance of light through water, which lessens the rate of photosynthesis and dissolved oxygen levels. It influences the whole oceanic biota (Setiadi et al., 2006; Imran et al., 2015; Hassan & Carr, 2018). The textile dyes act as harmful, mutagenic, and carcinogenic specialists (Aquino et al., 2014; Khatri, et al. 2018). They endure as natural poisons and cross whole nourishment chains giving biomagnification (Sandhya, 2010). Such creatures at higher trophic levels appear to have higher levels of defilement than their prey (Newman, 2015).

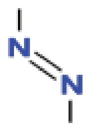
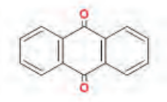
This chapter discusses the impact of textile dyes on health and the environment and its remediation. There are more than 10,000 colors utilized in textile fabricating alone, about 70% being azo dyes complex in structure and manufactured in nature (Hassaan, 2016; Ananthashankar, 2012). A significant source of color discharge into the environment is related to the fragmented fatigue of dyes onto textile fiber from a watery coloring prepare, and the got to diminish the sum of leftover color in material gushing has gotten to be a significant concern in later a long time (Hassaan & Nemr, 2017).

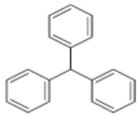
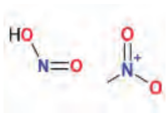
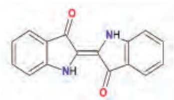
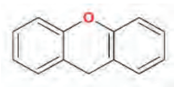
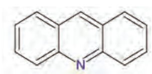
B. Dyes and Classification

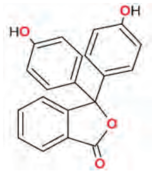
Dyes are common or fake substances that give color to diverse filaments utilized within the material, pharmaceutical, nourishment, corrective, plastic, photographic and paper, and other businesses (Chequer, et al. 2013). Colorants can be pigments or dyes. Pigments are insoluble for all intents and purposes, and the particles that make them up extend from 1–2 μm. Colors are effectively broken up in the water and have a molecule measure extending from 0.025–1.0 μm (Braun, 1983 & Esteves et al., 2016). The mechanical preferences for the utilization of fake dyes are based on (i) being chemically steady over time, (ii) being dormant to physical, chemical, and biological degradation, and (iii) being able to deliver color to the fiber to be dyed through reproducible forms, keeping up the color concentrated (Zucca, 2018) and (iv) are more fetched (Paz, 2017).

Dyes assimilate light within the unmistakable range (400–700 nm) and have expanded conjugation and one or more chromophores (Kuenemann, 2017). Chromophores contain heteroatoms such as N, O, and S and incorporate bonds such as -N=N- (azo), =C=O (carbonyl), NO or N-OH (nitrous), -NO2 or NO-OH (nitro), and C=S (sulfur) (Pereira & Alvez, 2011). Chromophore bunches are unsaturated and comprise biotas or bunches of particles. The course of action of progressive single and twofold bonds reverberates, permitting the retention of light beams (Berradi et al., 2019). Synthetic dyes display considerable fundamental differences and thus have exceptionally diverse chemical and physical properties (Pereira & Alvez, 2011). Table 8 presents the most chromophores that impact the classification of dyes. In expansion to chromophores, most colors contain autochrome bunches, which are not capable of color but are for escalated (tone) and affinity for the the fibre. A few of them are -NH3 (amine), -COOH (carboxyl), HSO3 (sulphonate), and -OH (hydroxyl) (Pereira & Alvez, 2011; International Agency for Research on Cancer, 2010).

Table 8.1 Classification and Characteristics of Dyes

Dye Chemical Classes	Chromophore Structure	Examples of Dyes	Characteristics
Azo		-Methyl Orange A -Congo Red -Orange G -Amaranth	Azo dyes are frequently used (60%). These dyes have a functional group (-N=N-) linking two alkyl or aryl radicals, symmetrical and or asymmetrical, identical or non-azoic.
Anthraquinone		- Remazol Brilliant Blue R - Reactive Bright Blue X-BR - Reactive Blue 4 - Alizarin Red S	Anthraquinone dyes are the second most widely used dyes due to their low price, accessibility, and performance in the dyeing process. They have anthraquinone chromophore groups comprising two carbonyl groups on either side of a benzene ring.

Dye Chemical Classes	Chromophore Structure	Examples of Dyes	Characteristics
Triphenylmethane		-Malachite Green - Crystal Violet - Bromophenol Blue - Light Green SF	These molecules have a central sp3 hybridized carbon atom, bonded to three aryl groups, and belong to the textile industry's most commonly used synthetic dyes.
Nitro and Nitroso		- Naphthol Yellow S - Disperse Yellow 26 - Disperse Yellow 14	In nitro dyes, a nitro group conjugates to an electron donor group via an aromatic system. Nitro dyes always contain a hydroxyl group as a donor.
Indigoid		- Indigo Carmine - Ciba Blue 2B	Synthetic indigo is the most widely used dye in the textile industry worldwide. It is highly resistant to light and high temperatures.
Xanthene		- Rhodamine 6G - Rhodamine 123 - Fluorescein	Xanthenes are dyes used in the food, cosmetics, paper, and ink manufacturing industries because of their superior dyeing and coloring properties. Still, they are poorly biodegradable, and some of them are very toxic.
Acridine		- Acridine orange - Basic Yellow 9	Acridine dyes are heat-resistant, although they have low lightfastness. They are currently not very important commercially.

Dye Chemical Classes	Chromophore Structure	Examples of Dyes	Characteristics
Phthalein		- o-cresolphthalein - Thymolphthalein - Dixylenolphthalein - Phenolphthalein	Phthalein dyes are employed to titrate weak acids. Phthalein dyes are insoluble in water but soluble in alcohol. There are frequently in the construction, coatings, electronics, and electrical industries.

Source: Ardila-Leal et al., (2021)[1]

C. Impacts of Textile Dyes on Health and the Environment

Besides contain many mechanical poisons, the textile dyes are profoundly harmful and possibly carcinogenic (Sharma, et al. 2018), so they are related to natural corruption and different maladies in creatures and people (Khan & Malik, 2018).

The biggest generator of colored wastewater is evaluated to be the textile industry (Senthivelan, et al. 2016; Hadibarata, 2012). Around 20% of the dye used for dyeing textile strands is not settled and disposed of within the wastewater, resulting in an elevated level of contamination (Kant, 2012). In any case, the natural harm does not depend interestingly on the sum of color released; moreover, it depends on the colors blended with the other substances, all with harmful properties that make up the emanating from the industries (Tkaczyk, 2020; Clarke, 1980).

The colored wastewater, sometimes contains dyes, evident to the bare eye (<1 ppm) (Golka, et al. 2004; Mojsov, et al. 2016), released into surface or groundwater bodies, diminish the concentration of broken up oxygen within the water (Ali, 2010). It increments the values of physicochemical and biological parameters such as the

[1] The chemical structures were elaborated in the software ACD/ChemSketch, version 2020.1.2, Advanced Chemistry Development, Inc., Toronto, ON, Canada, www.acdlabs.com, 2020.

chemical oxygen demand (COD) (Zhou et al.,2017), biochemical oxygen demand (BOD), total dissolved solids (TDS), total nitrogen (TN), total phosphorus (TFP), and non-biodegradable organic compounds. On the other hand, wastewater has a fluctuating pH and overwhelming metals such as chromium (Cr), arsenic (Ar), and zinc (Zn) (Berradi et al., 2019).

In common, synthetic dyes are not biodegradable due to their chemical properties and structure, creating an antagonistic impact on the environment (Husain, 2006). Most synthetic dyes are obstinate, carcinogenic, and harmful to biological systems (Aghaie-Khouzani et al., 2012). On the other hand, the negative effect of dyes can be biomagnified, creating high damage rates at elevated trophic levels (Lellis et al., 2019). In any case, the harmfulness of each dye must be surveyed separately, as the harm they cause depends on the structure and introduction concentration (Ferraz, 2011), which implies that dyes can endure for a long time (~50 a long time or more) within the environment (Pereira & Alves, 2011). The dyes' determination is closely related to their chemical reactivity, so unsaturated compounds are less determined than immersed ones. The perseverance of fragrant compounds increments as the number of chemical and halogen substitutions increments; the same happens for the perseverance of colors (Berradi et al., 2019). It illustrates the pertinence of assessing the debasement of dyestuffs separately and in combination. The foremost agent dyes in utilizing a place in the azo, anthraquinone, or triarylmethane classes (Berradi et al., 2019; Liu et al., 2021).

The azo course dyes have broadly considered their utilization and negative impacts. Between 60% to 70% of the azo dyes are poisonous, carcinogenic, and safe for routine Physico-chemical treatments (Berradi et al., 2019). The harmfulness of azo dyes takes after their chemical lessening and the consequent arrangement of fragrant amines, such as benzidine, dimethoxy-benzidine, and dimethyl-benzidine. The aromatic amines' poisonous quality is due to their metabolic oxidation since the oxidation produces electrophilic reductive mediators (diazonium salts) that empower covalently tied to DNA. These compounds are mutagenic and cause illnesses such as cancer. A variety of this instrument is the chemical decrease of a few of the azo bonds (found in certain dyes) to compare poisonous fragrant mono-azo amine (Sarayu & Sandhya, 2012; Varjani et al., 2020; Sarkar et al., 2017).

When azo ionic dyes are disposed of in surface or wastewater, they can tie to suspended natural matter by electrostatic intuitive follow to dregs or wastewater slime, expanding the perseverance (Soriano et al., 2014). Also, colored water or sullied slime contact oceanic creatures exchanges the poisonous compounds through the nourishment chain to people, causing wellbeing disarranges such as hypertension, issues, queasiness, dying, ulceration of the skin or the layers and mucous films. Depending on the introduction dosages of colors, significant harms may happen to the kidney, regenerative framework, liver, brain, and central anxious framework (CNS) (Sarayu & Sandhya, 2012; Sarkar et al., 2017). Parrot et al. (2016) assessed the impacts of azo dyes on the big-headed angle (Pimephales promelas) within the embryonic (larval) organize by comparing the dye impacts at diverse concentrations. Creators found that the utilization of 25.4 mg L−1 and 16.7 mg L−1 of the azo dyes Scatter Yellow 7 and Sudan Red G, separately, diminished the survival of the hatchlings, biting the dust between four and ten days after hatch.

D. Remediation of Textile Dyes Impact

1. Harmonization of Environmental Standards

Harmonization of environmental standards requests as a way to assist substantial natural targets around the world since natural issues frequently transgress national borders and are of concern to the individuals of different countries. Distinctive importers' benchmarks can hoist exporters' fabricating costs, as specific guidelines require distinctive strategies to avoid utilizing natural benchmarks as a frame of protectionism (Houses of Parliament, 2014).

Harmonizing defilement impediments from dyeing production lines seems to assist in moderating the natural issues related to Azo dyes and other dyes. Since the situations in each nation are not standardized, harmonization can lead to wastefulness. As concerns color release from coloring factories: Every environment incorporates a diverse absorptive capacity for water poisons; The taken toll required to expel color contamination varies between nations; Readiness to contribute to a more beneficial environment at individual cost varies from nation to nation, for case, in connection to the degree of nearby destitution (Houses of Parliament, 2014).

2. Water Remediation

In numerous nations, it is required for textile dyeing production lines to introduce effluent treatment plants (ETPs) to treat wastewater. Sometime recently it clears out the manufacturing plant premises. Weight for viable profluent treatment is additionally mounting, and numerous worldwide buyers are presently appearing more concerned over whether or not textiles are created with due ecological consideration. This move within the textile trade's worldview implies that in the future, it is likely that the operation of an ETP will be indispensable to support commerce within the competitive world of advertising (Houses of Parliament, 2014).

Because of their chemical steadiness and manufactured nature, responsive Azo dyes are not entirely corrupted and show moderate debasement by ordinary wastewater treatment strategies (Puvaneswari, 2006). They are troublesome to expel since they are outlined to be steady in oxygen-consuming conditions, but biotreatment in anaerobic conditions can result in an era of unsafe fragrant amines (Puvaneswari, 2006). Remediation does not right now capitalize on this reality.

Wastewater is often treated with actuated slime, and the fluid profluent is discharged to adjacent surface waters. Ekici et al. (2001) tried Azo dye solidness in both actuated slime and water, concluding that they were moderately steady within the sea-going environs and cannot be successfully debased in standard wastewater plants. Physicochemical methods can reduce toxic quality levels, but balance is not total, and a more concentrated slime is made, successfully exchanging the contamination issue between stages. The time is taken, and handling time is too inadmissible (Houses of Parliament, 2014).

New, cheap, and proficient remediation strategies must be planned. Cases of rising innovations incorporate, but are not limited to:

1. Advanced oxidation processes (AOPs) (Hassaan & Nemr, 2017);
2. Zero-valent iron degradation processes. (Pereira & Freire, 2006);
3. Better Physico-chemical treatment methods (including precipitation, coagulation, adsorption, flocculation, flotation, electrochemical destruction, mineralization, and decolorization process) (Gogate and Pandit, 2004);
4. Fungal Degradation. (Bumpus, 2004);
5. Bacterial remediation. (Sudha et al.,2014);
6. Waterless dyeing technology;
7. Synthetic biology. (UCL iGEM, 2014);

E. Conclusion

In conjunction with many mechanical toxins, the textile dyes are profoundly poisonous and possibly carcinogenic, related to environmental degradation and different illnesses in creatures and people. The biggest generator of colored wastewater is assessed to be the textile industry. Approximately 20% of the color utilized for dyeing textile strands is not settled and is arranged within the wastewater, resulting in an elevated level of contamination. Harmonization of environmental standards requests to assist in fathoming important natural goals worldwide. New, cheap, and proficient remediation strategies ought to be deliberated. Cases of rising innovations incorporate, but are not limited to, advanced oxidation processes (AOPs); zero-valent iron degradation processes; better Physico-chemical treatment methods; fungal degradation; bacterial remediation; waterless dyeing technology, and synthetic biology.

References

Aghaie-Khouzani, M., Forootanfar, H., Moshfegh, M., Khoshayand, M.R., Faramarzi, M.A. (2012). Decolorization of some synthetic dyes using optimized culture broth of laccase producing ascomycete Paraconiothyrium variabile. *Biochem. Eng. J*. 2012, *60*, 9–15.

Ali, H. (2010). Biodegradation of Synthetic Dyes—A Review. *Water Air Soil Pollut*. 2010, 213, 251–273.

Ananthashankar, R. (2012). *Treatment of textile effluent containing reactive red 120 dye using advanced oxidation*, M. Sc, A [Thesis], Dalhousie University, Halifax, Nova Scotia, 145.

Aquino, J. M., Rocha-Filho, R. C., Ruotolo, L. A., Bocchi, N., & Biaggio, S. R. (2014). Electrochemical degradation of a real textile wastewater using -PbO2 and DSA® anodes. *Chemical Engineering Journal*, *251*, 138–145 .

Ardila-Leal, L.D., Poutou-Piñales, R.A., Pedroza-Rodríguez, A.M., Quevedo-Hidalgo, B.E. (2021). A Brief History of Colour, the Environmental Impact of Synthetic Dyes and Removal by Using Laccases. *Molecules*, *26*, 3813. MDPI. https://doi.org/10.3390/ molecules26133813.

Berradi, M., Hsissou, R., Khudhair, M., Assouag, M., Cherkaoui, O., Bachiri, A., Harfi, A. (2019). Textile finishing dyes and their impact on aquatic environs. *Heliyon*, *5*, e02711.

Bhatia, S. C. (2017). *Pollution control in textile industry*. WPI Publishing.

Braun, H. (1983) .Particle Size and Solubility of Disperse Dyes. *Coloring Technology, 13*, 62–72.

Bumpus, J. A. (2003). Biodegradation of Azo Dyes by Fungi. https://doi.org/10.1201/9780203913369.ch38 .https://www.researchgate.net/publication/265796409_38_Biodegradation_of_Azo_Dyes_by_Fungi.

Chequer, F.M.D., Oliveira, G.A.R., Ferraz, E.R.A., Cardoso, J.C., Zanoni, M.V.B., Oliveira, D.P. (2013). Textile Dyes: Dyeing Process and Environmental Impact. In *Eco-Friendly Textile Dyeing and Finishing* (151–176). Intech.

Clarke, E.A.; Anliker, R. (1980). Organic Dyes and Pigments. In *Anthropogenic Compounds. The Handbook of Environmental Chemistry* (35). Springer.

Desore, A., & Narula, S. A. (2018). An overview on corporate response towards sustainability issues in textile industry. *Environment Development and Sustainability*, *20*(4), 1439–1459.

Esteves Torres, F.A., Zaccarim, B.R., de Lencastre Novaes, L.C., Jozala, A.F., Alves dos Santos, C., Simas Teixeira, M.F., Carvalho Santos-Ebinuma, V. (2016). Natural colorants from filamentous fungi. Appl. Microbiol. Biotechnol. 100, 2511–2521.

Ferraz, E.R.A.; Grando, M.D.; Oliveira, D.P. (2011). The azo dye disperse orange 1 induces DNA damage and cytotoxic effects but does not cause ecotoxic effects in Daphnia similis and Vibrio fischeri. Journal of Hazardous Materials, 192, 628–633.

Gogate, P.R & Pandit, A.B. (2004) A Review of Imperative Technologies for Wastewater Treatment I: Oxidation Technologies at Ambient Conditions. *Advances in Environmental Research*, 8, 501 – 551. http://dx.doi.org/10.1016/S1093-0191(03)00032-7.

Golka, K.; Kopps, S.; Myslak, Z.W. (2004). Carcinogenicity of azo colorants: Influence of solubility and bioavailability. *Toxicology Letters*, *151*, 203–210.

Hadibarata, T., Mohd Yusoff, A.R., Kristanti, R.A. (2012). Decolorization and Metabolism of Anthraquionone-Type Dye by Laccase of White-Rot Fungi Polyporus sp. S133. *Water Air Soil Pollution*, *223*, 933–941.

Hassaan, M. A. (2016). Advanced oxidation processes of some organic pollutants in fresh and seawater, PhD, A [Thesis]. Faculty of Science, Port Said University, 180.

Hassaan, M. A. and El Nemr, A. (2017). Advanced Oxidation Processes for Textile Wastewater Treatment. *International Journal of Photochemistry and Photobiology*, *2*(3), 85–93 .

Hassaan, M. A., & Nemr, A. E. (2017). Health and Environmental Impacts of Dyes: Mini Review. *American Journal of Environmental Science and Engineering, 1*(3), 64 – 67. https://doi.org/10.11648/j.ajese.20170103.11. http://www.sciencepublishinggroup.com/j/ajese.

Hassan, M. M., & Carr, C. M. (2018). A critical review on recent advancements of the removal of reactive dyes from dyehouse effluent by ion-exchange adsorbents. *Chemosphere*, *209*(1), 201–219.

Health and Safety Executive, HSE (2016). Dyes and chemicals in textile finishing: An introduction. Dyeing and Finishing Information Sheet No 1- HSE information sheet. (accessed 2016.10.10).

Hossain, M. S., Das, S. C., Islam, J. M., Al Mamun, M. A., & Khan, M. A. (2018). Reuse of textile mill ETP sludge in environmental friendly bricks effect of gamma radiation. *Radiation Physics and Chemistry*, *151*, 77---83.

Houses of Parliament. (2014). *The Environmental, Health and Economic Impacts of Textile Azo Dyes.* The Parliamentary Office of Science and Technology, 7 Millbank, London SW1P 3JA. www.parliament.uk/post.

Husain, Q. (2006). Potential Applications of the Oxidoreductive Enzymes in the Decolorization and Detoxification of Textile and Other Synthetic Dyes from Polluted Water: A Review. Crit. Rev. *Biotechnol*, *26*, 201–221.

Imran, M., Crowley, D. E., Khalid, A., Hussain, S., Mumtaz, M. W., & Arshad, M. (2015). Microbial biotechnology for decolorization of textile wastewaters. *Reviews in Environmental Science and Biotechnology*, *14*(1), 73–92.

International Agency for Research on Cancer. (2010). Some Aromatic Amines, Organic Dyes, and Related Exposures. In *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. International Agency for Research on Cancer (IARC).

Kant, R. (2012). Textile dyeing industry an environmental hazard. *Natural Science*, *4*, 22–26.

Khan, S., & Malik, A. (2018). Toxicity evaluation of textile effluents and role of native soil bacterium in biodegradation of a textile dye. Environmental Science and Pollution Research - International, *25*(5), 4446–4458.

Kuenemann, M.A., Szymczyk, M., Chen, Y., Sultana, N., Hinks, D., Freeman, H.S., Williams, A.J., Fourches, D., Vinueza, N.R. (2017). Weaver's historic accessible collection of synthetic dyes: A cheminformatics analysis. Chemical Science, *8*, 4334.

Lellis, B., Fávaro-Polonio, C.Z., Pamphile, J.A., Polonio, J.C. (2019). Effects of textile dyes on health and the environment and bioremediation potential of living organisms. *Biotechnology Research and Innovation, 3*, 275–290.

Liu, Y.Q., Maulidiany, N., Zeng, P., Heo, S. (2021). Decolourization of azo, anthraquinone and triphenylmethane dyes using aerobic granules: Acclimatization and long-term stability. *Chemosphere, 263*, 128312.

Mawla, G. (2021). *Different Types of Dyes with Chemical Structure*. Daffodil International University. Textile learner. https://textilelearner.net/different-types-of-dyes-with-chemical-structure/. Accessed on March 20, 2022,

Maysoon, M., Hassan, A., Hassan, A.K., Hamad, A.H & Shther, D.E. (2019). Treatment of Contaminated Water with Industrial Dyes by

Using Nano Zero Valent Iron (NZVI) and Supported on Pillared Clay, *Advances in Analytical Chemistry*, *9*(1), 1-7. https://doi.org/10.5923/j.aac.20190901.01.

Mojsov, K.D., Andronikov, D., Janevski, A., Kuzelov, A., Gaber, S. (2016). The application of enzymes for the removal of dyes from textile effluents. *Advanced Technologies, 5*, 81–86.

Muthu, S. S. (2017). Introduction. In S. S. Muthu (Ed.), *sustainability in the textile industry* (1–8). Heidelberg: Springer.

Newman, M. C. (2015). Fundamentals of ecotoxicology: The science of pollution. CRC Press.

Orts, F., del Río, A. I., Molina, J., Bonastre, J., & Cases, F. (2018). Electrochemical treatment of real textile wastewater: Trichromy Procion HEXL®. *Journal of Electroanalytical Chemistry*, *808*, 387–394.

Parrott, J.L., Bartlett, A.J., Balakrishnan, V.K. (2016). Chronic toxicity of azo and anthracenedione dyes to embryo-larval fathead minnow. *Environment Pollution*. *210*, 40–47.

Paz, A., Carballo, J., Perez, M.J.É., Domínguez, J.É.M. (2017). Biological treatment of model dyes and textile wastewaters. *Chemosphere, 181*, 168–177.

Pereira, L. & Alves, M. (2011). Dyes Environmental Impact and Remediation. In Malik, A., Grohmann, E., (Eds). *Environmental Protection Strategies for Sustainable Development Strategies for Sustainability*; Springer.

Pereira, W. S. & Freire, R. S. (2006). Azo dye degradation by recycled waste zero-valent iron powder. *Journal Brazilian Chemical Society*, *17*(5). https://doi.org/10.1590/S0103-50532006000500003

Puvaneswari, N., et al. (2006). Toxicity assessment and microbial degradation of azo dyes. *Indian journal of experimental biology*, *44*(8), 618.

Reyhan, E. (2014). *Global Textile Industry*. Retrieved… from https://www.morethanshipping.com/global-textile-industry/. Accessed on March 20, 2022.

Sandhya, S. (2010). Biodegradation of azo dyes under anaerobic condition: Role of azoreductase. In H. A. Erkurt (Ed.), biodegradation of azo dyes. The handbook of environmental chemistry (vol. 9) (pp. 39---57). Berlin, Heidelberg: Springer.

Sarayu, K. & Sandhya, S. (2012). Current Technologies for Biological Treatment of Textile Wastewater—A Review. *Applied Biochemical Biotechnology*. *167*, 645–661.

Sarkar, S., Banerjee, A., Halder, U., Biswas, R., Bandopadhyay, R. (2017). Degradation of synthetic azo dyes of textile industry: A sustainable

approach using microbial enzymes. *Water Conservation Science Engineering*, *2*, 121–131.
Senthivelan, T., Kanagaraj, J., Panda, R.C. (2016). Recent Trends in Fungal Laccase for Various Industrial Applications: An Eco-friendly Approach—A Review. Biotechnol. Bioprocess Enginering, *21*, 19–38.
Setiadi, T., Andriani, Y., & Erlania, M. (2006). Treatment of textile wastewater by a combination of anaerobic and aerobic processes: A denim processing plant case. In S Ohgaki, K Fukushi, H Katayama, S Takizawa, & C Polprasert (Eds.), *Southeast Asian Water environment 1: Selected papers from the first International symposium on Southeast Asian Water environment (biodiversity and Water environment)*, (159–166). IWA Publishing.
Soriano, J.J., Mathieu-Denoncourt, J., Norman, G., de Solla, S.R., Langlois, V.S. (2014). Toxicity of the azo dyes Acid Red 97 and Bismarck Brown Y to Western clawed frog (Silurana tropicalis). Environmental Science and Pollution Research, *21*, 3582–3591.
Sudha, M, Saranya. A., Selvakumar. G & Sivakumar, N. (2014). Microbial degradation of Azo Dyes: A review. *International Journal of Current Microbiology and Applied Sciences*, *3*(2), 670–690.
Suteu, D., Zaharia, C. & Malutan, T. (2011). Biosorbents Based On Lignin Used In Biosorption Processes From Wastewater Treatment. In Ryan J. Paterson (Ed.), *Lignin: Properties and Applications in Biotechnology and Bioenergy* (27). Nova Science Publishers.
Tkaczyk, A.; Mitrowska, K.; Posyniak, A. (2020). Synthetic organic dyes as contaminants of the aquatic environment and their implications for ecosystems: A review. *Science of the Total Environment*, *717*, 137222.
UCL i-GEM. (2014). Project Goodbye Azo Dyes. Website. https://www.itqb.unl.pt/labs/microbial-and-enzyme-technology/other-activities/ucl-igem-2014. Accessed on March 20, 2022.
Varjani, S., Rakholiya, P., Ng, H.Y., You, S., Teixeira, J.A. (2020). Microbial degradation of dyes: An overview. *Bioresource Technology*. *314*, 123728.
Wang, D. M. (2016). Environmental protection in clothing industry. In L. Zhu (Ed.), *sustainable development: Proceedings of the 2015 International Conference on sustainable development (ICSD2015)*,729–735). Singapore: World Scientific Publishing Co Pte Ltd.
Welham, A. (2000). *The theory of dyeing (and the secret of life). Journal of the Society of Dyers and Colourists*, *116*, 140–143.

Zhou, L., Xu, K., Cheng, X., Xu, Y., Jia, Q. (2017). Study on optimizing production scheduling for water-saving in textile dyeing industry. *Journal of Cleaner Production*. *141*, 721–727.

Zucca, P., Cocco, G., Sollai, F., Sanjust, E. (2015). Fungal laccases as tools for biodegradation of industrial dyes. *Biocatalysis, 1*, 82–108.

Chapter 9

The Existence of Microplastics as an Emerging Concern in Daily Routines and the Implications of Global Mitigation Efforts

Jihan Nabilah Hanun, Fahir Hassan, & Fahrudin Sidik

A. The Definition of Microplastics

It has been known that plastic materials are remarkably persistent and potentially interfere environment due to their durable and chemical-resistant characteristics. Plastic items cannot be completely degraded in the natural environment, but they will produce microplastics over time as a trace of the degradation process. Microplastics can be defined as a plastic material that goes through fragmentation, which subsequently forms particles less than 5 mm in size (GESAMP, 2019; Liu et al., 2020). However, there is no explicit agreement in the definition of microplastic size. Some researchers also speculate that nano-sized plastic can be categorized into microplastics (Gigault et al., 2018). Therefore, microplastic size can be included in the size of 5

J. N. Hanun, F. Hassan, & F. Sidik
Chung Yuan Christian University, Taiwan, e-mail: jihanabillah@gmail.com

Hanun, J. N., Hassan, F., & Sidik, F. (2022). The existence of microplastics as an emerging concern in daily routines and the implications of global mitigation efforts. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and technology role for Indonesia development* (135–152). DOI: 10.55981/brin.538.c509 ISBN: 978-623-7425-85-4 E-ISBN: 978-623-7425-89-2

mm to 1 nm. The microplastics' sources are categorized in two main ways: primary and secondary microplastics (Hanun et al., 2021) as shown in Figure 9.1.

The meaning of primary sources is intended for microplastics contained in the discharge of wastewater deliberately produced for specific purposes in the manufacturing process. These microplastic types were usually found in the shape of pellets or microbeads. The mass production of microplastics aims to meet the needs of producing various personal care products (PCPs) or other essential items. Some applied wastewater treatment technologies can relieve microplastics from wastewater, such as membrane bio-reactor (MBR), gravity sand filtration (GSF), dissolved air flotation (DAF), and aerated biological filter (BAF), disc-filter (DF), and advanced oxidation. But, there are still few amounts of smaller microplastic particles that survive (± 0.1%-0.5%), which in size larger than 100 μm particularly (Wu et al., 2021).

Meanwhile, secondary microplastic is derived from the fragmentation of larger plastics. It happened due to several environmental factors like UV exposure (photodegradation), temperature, mechanical abrasion, or even chemical oxidation. These intense natural pressures that impact plastics' physical and chemical nature are also known as weathering/aging processes (Hanun et al., 2021). The weathering process will affect several microplastic properties: color, surface morphology, size, crystallinity, and density (Guo & Wang, 2019). Microbial activities, although in a minor role, also become one of the causes of microplastic degradation since microplastics are created to be resistant to biodegradation (Thompson et al., 2005).

Several shapes or morphologies of microplastics are commonly distributed in the environment, such as microbeads (including spherical or irregular shapes), pellets, films, fragments, and foams. Some of the researchers also investigate microplastics' color and shapes. Identifying microplastic shapes and colors aims to help inform the distribution's origin (Helm, 2017).

Figure 9.1 Primary Sources of Microplastics in the Environment

The term fibers is usually found as the results of clothing shreds produced during washing and drying or even the friction of cloth-made material such as carpet, upholstery, blanket, or doll fur. Foams often come from expanded polystyrene foam products such as insulation or food packaging. Henceforth, fragment and film microplastics generally yielded from the fragmentation of more oversized plastic items such as water mineral bottles, carry bags, construction materials, containers, electronics, toys, etc. The difference between fragments and films is based on color. Film microplastics are figured as fine pieces, while fragments come up as colored pieces. In addition, polymer types are also considered to inform microplastics' physical and chemical properties (Rochman et al., 2019).

Microplastics spread in seawater, fresh water, terrestrial, and atmospheric ecosystems. We cannot stop it from spreading unless we have been prevented and aware of the dangers since early. Therefore, education and socialization about microplastics is indispensable so prevention movements can be carried out optimally and avoid the dangers before severe effects occur.

B. Microplastic Exposures in Daily Life

Throughout this time, we have been unknowingly contaminated by microplastics through our daily habits. Microplastics form in tiny particles, making them easily carried by the wind and settle in the dust around the house. Moreover, the tiny size of microplastics results in inhalation and can deposit in the respiratory tract. Cox et al. (2019) revealed that annual inhalation of microplastic particles for female and male children in the United States (US) were 35338 and 40225 items, while female and male adults were 48270 and 61928 items. Possible sources of airborne microplastics inside the house may come from synthetic textiles (composed of nylon, polyester, polyurethane, polyolefin, acrylic, and vinyl-type polymers), erosion of synthetic rubber tires, city dust transferred by the wind, clothes, house furniture like carpet and blanket, materials in buildings, tumble dryer exhaust, etc.

Moreover, Zhang et al. (2021) revealed several parameters in textile washing that will influence in the release of fiber from the clothing. It includes viz. washing cycle and time, detergent and softener, temperature, water hardness, washing machine type, drying, textile aging, textile structure and surface configuration, and so on. Indeed, synthetic clothing seems to be the most significant contributor to airborne microplastics, yet fiber materials and quantity depend on the fashion and season. O'Brien et al. (2020) investigated that 58 fibers/m3 were released from fleece polyester blankets during mechanical drying into the surrounding air with the experimental conditions set into the 'Normal Dry' program at 56-59°C for 20 minutes. Poor ventilation and indoor airflow result in higher concentrations of indoor microplastics, whereas people spend 70% to 90% of their time at the house (Prata, 2018).

During the pandemic, the use of masks is a must to prevent the transmission of the Covid-19 virus. Surgical face masks, made of polymer materials, have recently become a potential microplastic source in the environment. L. Li et al. (2021) simulated the inhalation of microplastics by wearing some types of masks such as N95, surgical, cotton, fashion, non-woven, and activated carbon masks for 720 hours by using a vacuum pump with a flow rate of 15 L/min as the breathing simulation. It was found that spherical and fiber-like microplastic inhalation risk increased with increasing inhalation time, except for N95 masks. The number of microplastics accumulated during the simulation reached at least 300 particles performed by the N95 mask. Meanwhile, the highest microplastics were produced by activated carbon masks, with the particles reaching 2149 items.

On the other hand, microplastics can be accidentally consumed via tap water, drinking water, bottled water, salt, honey, sugar, alcohol, vegetables, and seafood. According to a report established by Cox et al. (2019), female and male children were at least consuming 38722 and 41106 items annually, while female and male adults were ingesting 46013 and 51814 items annually via foods and beverages. Dowarah et al. (2020) also revealed that microplastic intake from the local community in India at least gained around 3917.79 ± 144.71 particles/year through bivalve consumption. In a single meal, the average family consumed between 300 and 700 grams of mussels/clams, excluding the weight of shells. Exposure to microplastics from plants is also possible, considering that contaminated soil or irrigation water can carry microplastics to the plant's organs through the roots (Enyoh et al., 2020). It will be more severe if the plants are for consumption, such as vegetables and fruits.

Another invention of microplastic exposure to the human body is revealed by Fadare et al. (2020). It stimulates the presence of microplastics in commercial plastic food containers known for food packaging, fast food delivery, and water consumption. One of the polymer types is inscribed as a polypropylene material. The results showed that the extraction of microplastics generated 3 to 38 mg of microplastics per item. This number can be exacerbated by the addition of washing or shaking during the delivery process. Hernandez et al. (2019) also revealed that a single plastic teabag released 11.6 billion microplastics and 3.1 billion nano plastics into a cup of steeping at a brewing temperature of 95°C. Other than that, D. Li et al. (2021) revealed more severe problems, which found that propylene-based baby bottle carries the potential for release of microplastics during cleaning, sterilizing, and mixing liquids in the bottle. It was shown that the number of microplastic particles increased from 6 million to 55 million particles per liter during the boiling process at 70–95°C. Meanwhile, the sterilization process increased the release of microplastics by up to 35%.

Other microplastic sources inherent in our daily life can be found as cigarette butts, food wrappers, plastics straw, shopping bags, plastic bottles and the cap (Free et al., 2014), tennis ball, glitters, and paint (Gaylarde et al., 2021; Yurtsever, 2019). Sun et al. (2020) found that the distribution of microplastics from personal care products (PCPs) like cleansing products, hand sanitizer, toothpaste, soap, shaving cream, bubble bath, sunscreen, and shampoo that drifted from WWTPs discharge was approximately 1500 tons/year.

C. The Impacts of Microplastic Exposures on Human Health

Microplastics in the environment occur in a low concentration. However, susceptible individuals can be severely affected and worsen their health conditions. An illustration of the conclusion of the effects of microplastics on human health can be seen in Figure 9.2. Microplastics, formerly regarded as harmless particles and without toxicity, are now recognized as potentially harmful to human health, depending on the level of exposure and sensitivity. Several pieces of research have acknowledged microplastics' toxication, such as oxidative stress, cytotoxicity, altering metabolism, immunity disruption, translocation to a distant organ, etc. (Rahman et al., 2021). In addition, microplastic particles are difficult to remove from our body, leading to chronic inflammation and increasing the risks of cancer as the result of deposition and accumulation. Moreover, combining microplastics with other particles may increase immunological and neurological disorders (Crawford & Quinn, 2017).

Microplastic particles have been identified as having a large surface area prone to performing as a carrier for microorganisms (biofilm) or other pollutants. Additives and monomers may leak from the microplastic particles into the organism corpus when those are ingested. Organic compounds incorporated in persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and UV filters, have been found in microplastics collected from the ecosystem (Prata et al., 2020; Santana-Viera et al., 2021). Also, microorganisms may generate and colonize on the microplastic surface, leading to biofilms forming. According to the research conducted by Murphy et al. (2020), microorganisms such as *Clostridium perfringens, Arcobacter spp., Enterobacter spp., Helicobacter spp.,* and *Escherichia coli* were discovered in polyethylene microplastics cultivated in river water in situ for 14 days. Therefore, microplastics will be considered hazardous materials and bring higher toxicity to the human body while ingested, judging from their chemical contents inside the particles.

Animal studies, such as mice or cell culture, were used to investigate the effects of microplastics on human health. These studies have considered various aspects of standard clinical research with animals (Prata et al., 2020). Experiments on mice found that ingestion of a dose as low as 0.01 mg of 5-micron polystyrene microparticles each day resulted in a reduction in spermatogenic cells, as well as a reduction in the number of sperm produced after 42 days (Xie et al., 2020). Adverse Outcome Pathways, which systematically interpret the available toxicological data, concluded that the presence of microbeads formed reactive oxygen species (ROS), which trigger the occurrence of oxidative stress. This illness becomes a major toxicological threat to human health despite the great uncertainty about its use (Jeong & Choi, 2019).

Inhalation of atmospheric microplastic quantities and properties is another method of exposure. Smaller and denser particles are more likely to lodge farther into the lungs. At high levels, dust may trigger the overloading of microplastics, resulting in an intensive release of chemotactic chemicals that widens blood vessels and prevents macrophages from migrating. In addition, proinflammatory microplastics in the lungs exhibit vigorous oxidative activity (Vianello et al., 2019). Besides that, dermal contact with microplastics must be reflected regardless of its fewer effects. According to Prata et al. (2020), nano plastics can cross the dermal barrier and cause toxicity.

Until this publication, there is no proof that microplastics negatively impact human health. Primarily, the observations are based on organism models (in vivo/in vitro), even though they have the same limitations as those used to evaluate microplastics' impact on animal health. Despite the absence of evidence that microplastics pose a risk to human health at current ambient concentrations, researchers have found that microplastics are also detectable in the human placenta. Ragusa et al. (2021) investigated microplastics in six women's placentas and found about 12 pigmented microplastics with a size range of 2 to

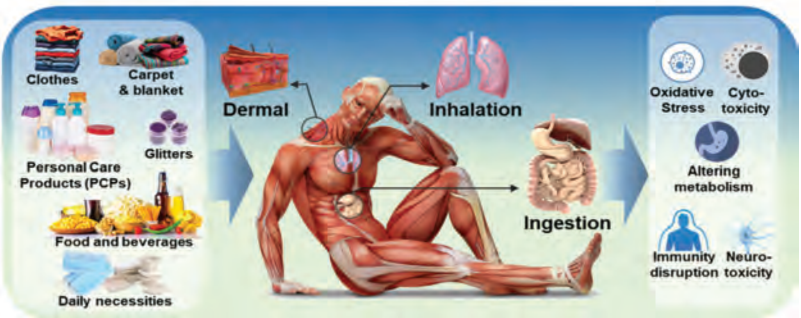


Figure 9.2 Potential Effects of Microplastic Exposures on the Human Body

10 μm. This microplastic is thought to be derived from paints, nail polishes, cosmetics, and other types of personal care items.

D. Actions of Minimizing Microplastics in the Environment

Mitigation strategies are necessary to reduce microplastic contamination in the environment since the number of microplastics increases with the increase in plastic usage. It will make more efficient to do the prevention contamination that starts ourselves. The support of environmental enthusiasts or the environmentalist community will also be beneficial in terms of socializing and campaigning the dangers of microplastics and the importance of reducing the use of plastic items in daily life.

1. Self-prevention from the Contamination of Microplastics

The movement to reduce the spread of microplastics cannot be separated from the reduction of plastic as a precursor material. Several steps can be taken to reduce the spread of microplastics in the environment, especially in the neighborhood where all the loved ones gather. Launched an article published by Global Citizen, there are a few ways to decrease microplastic trace. Some of them are installing a filter to catch microplastics, washing hands and air drying; preventing to purchase of synthetic clothing and changing to natural clothing instead, such as cotton, silk, wool, hemp, or linen; reducing the consumption of plastic products as well as purchase for plastic-free products (PCPs), and utilizing public transportation. Researches agree that microfiber dominates the abundance of microplastic in the environment (Huang et al., 2021; Wright et al., 2020; Zhang et al., 2020). Therefore, changing washing and drying techniques from machine system to hand washing and air drying will greatly impact the microplastics. Change that starts from ourselves is better than having to wait for others. One of the changes in our habits can change the state of the environment for the better.

2. The Role of Community Movement in Spreading Awareness of Microplastics

Community movements with those diverse backgrounds have grown worldwide, addressing eliminating microplastics. For example, Wasser 3.0 (a German non-profit research group) has rapidly used the microplastic agglomeration method to reduce water microplastics. TeamSeas, Ocean Conservancy, and The Ocean Cleanup communities are concerned about microplastic distribution in oceans, rivers, and beaches. In Taiwan, the Micro PC community is dedicated to reducing microplastics and minimizing biological and environmental damage through innovative non-consumable filtration technologies. A Netherlands community called "Beat the microbead" has encouraged customers to be more selective about purchasing items in cosmetics issues. In this case, the customers can check the product risk level and the specific microplastics contained through a mobile application. Besides that, a community developed by a London student group named The Tyre Collective concerns mitigation movement in tire wear emissions by capturing tire wear at the source to ensure clean air and safeguarding the environment and health.

Furthermore, specific communities, such as Waste Bazaar (revolutionize in Africa) and Tontonton (plastic community from Vietnam), are using app-based platforms for more accessible accommodation on reducing microplastic sources. In Indonesia, the Siklus community disseminates creative information by conducting door-to-door campaigns. Specifically, they provide an alternative by replacing refill stations with low-value plastic, enabling residents to obtain daily necessities in any quantity without using plastic packaging.

Regarding the awareness of the microplastics survey conducted by Zhang et al. (2020), only 26% of the 437 valid respondents had heard of microplastics. For this reason, some communities aim to reduce the number of microplastics, spread knowledge, and increase awareness of microplastics since most people raise awareness from life experience and ordinary senses rather than knowledge and research.

E. Global Mitigation Efforts in Overcoming the Issue of Microplastics

On the topic of removing plastic pollution from the environment and reducing plastic usage in general, citizens continue to participate in the trend of responses to global environmental concerns that began in the 1960s and still lasted in these days (Völker et al., 2020). Although it does not directly regulate "Microplastic" at the international level, there have been several agreements made by global organizations such as the United Nations (UN), The Group of 7 (G7), and the World Economic Forum (WEF), and the World Bank. At the international level, this agreement and discussion forum discuss plastic policies from an economic perspective, plastic waste management, and clean production efforts. Indeed, these agreements do not specifically target microplastic as an object of policy, but at least they have targeted plastic and solid waste management as microplastic sources (Klein et al., 2018).

Several countries have set and implemented regulations to deal with microplastic issues. For example, the United States (US) has banned the usage of microbeads in several cosmetic products as a scrub material which is prohibited at the federal level under the "Microbead-Free Waters Act." The same agreement was also made by Cosmetics Act which prohibits using microbeads as a scrubber. Besides that, additional state-level regulations have been developed or are still being implemented in several countries like China. China is likewise at the forefront of research projects in the microplastics field, so many publications related to microplastics have been established. This country's goal is to ban the manufacture of "Microplastic" after December 31, 2020, and the sale of "Microplastic" after December 31, 2022.

Moreover, the same implementations were done by Korea and the US, which committed to employing microbeads as a scrub in cosmetic products. In European Union (EU), microplastic challenges are being discussed in terms of polymer types associated with waste contamination. Restriction of Restrictive Chemicals proposed by the

EU may take effect as early as 2022 (Mitrano & Wohlleben, 2020). Steensgaard et al. (2017) suggested that plastic litter, as the initiation of microplastic distribution in the environment, should undergo monitoring and reporting requirements similar to hazardous waste, including an evaluation of polymer persistency and its degradation rate.

At smaller-scale like industrial and manufacturing levels, a standard has been set in the form of an environmentally friendly label in the format of ISO 14006, namely eco-design, as part of an environmental management system. Eco-design refers to action-made during the development phase of a product to minimize the product's environmental impact throughout its entire life cycle (Pigosso et al., 2013).

Reducing the amounts of microplastics released into the environment is generally linked to the four Rs hierarchy in the plastics industry, such as reduction at the source, reuse of goods, following collection, and recycling of those products. Legislation managing plastics manufacture, waste management, and the use of sustainable resources should be consolidated and enforced (Calero et al., 2021). By learning from implemented action and the dangers of microplastics

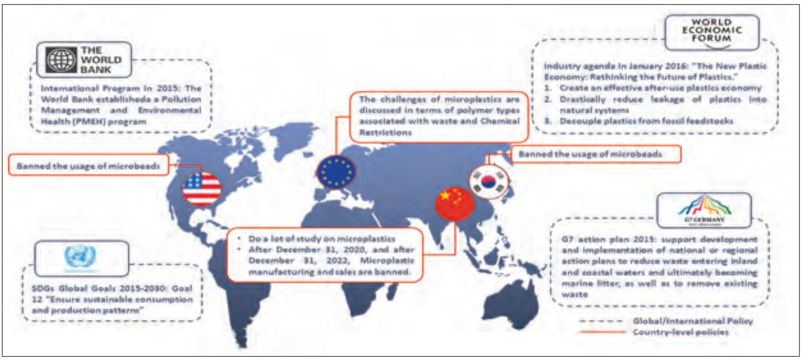


Figure 9.3 Examples of Mitigation Efforts in Several Countries and Global Communities

mentioned above, it will be very worthy for the government to start implementing policies on producers and support the development of alternative materials in the future while still in the early stages.

F. Conclusion

The longer the microplastics spread, the more severe the distribution along with the increase in plastic production and use by the community. Microplastics originated from wastewater treatment plant discharge produced by industrial systems and the fragmentation of more oversized plastic items or plastic litter in the environment due to weathering. Microplastics have become a complicated and challenging issue since it adheres to us through inhalation and ingestion. Besides that, microplastics is harmful for human health because of their microplastic properties, even though they pose risks and are still in development nowadays. The harmony of the self-prevention movement and the community's role is fundamental in reducing the number of microplastics in the environment.

Furthermore, the government should pay attention to the distribution of microplastics and start evaluating and monitoring their existence while it is still in the early stage to prevent more significant impacts in the future. There is no harm in educating, outreaching, and preventing microplastics to minimize the possible impacts of their existence. The assessment of microplastics in natural environments is indispensable to provide tangible results of microplastic occurrence. Therefore, it is hoped that this study can help the public be more aware and believe that microplastics and their impacts are a real threat to us in the future.

References

Calero, M., Godoy, V., Quesada, L., & Martín-Lara, M. (2021). Green strategies for microplastics reduction. *Current Opinion in Green and Sustainable Chemistry*, *28*, 100442. https://doi.org/10.1016/j.cogsc.2020.100442

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). Human Consumption of Microplastics. *Environ Sci Technol*, *53*(12), 7068-7074. https://doi.org/10.1021/acs.est.9b01517

Crawford, C. B., & Quinn, B. (2017). Physiochemical properties and degradation. In *Microplastic Pollutants* (57–100). https://doi.org/10.1016/b978-0-12-809406-8.00004-9

Dowarah, K., Patchaiyappan, A., Thirunavukkarasu, C., Jayakumar, S., & Devipriya, S. P. (2020). Quantification of microplastics using Nile Red in two bivalve species Perna viridis and Meretrix meretrix from three estuaries in Pondicherry, India and microplastic uptake by local communities through bivalve diet. *Mar Pollut Bull*, *153*, 110982. https://doi.org/10.1016/j.marpolbul.2020.110982

Enyoh, C. E., Shafea, L., Verla, A. W., Verla, E. N., Qingyue, W., Chowdhury, T., & Paredes, M. (2020). Microplastics Exposure Routes and Toxicity Studies to Ecosystems: An Overview. *Environ Anal Health Toxicol*, *35*(1), e2020004. https://doi.org/10.5620/eaht.e2020004

Fadare, O. O., Wan, B., Guo, L.-H., & Zhao, L. (2020). Microplastics from consumer plastic food containers: Are we consuming it? *Chemosphere*, *253*, 126787. https://doi.org/https://doi.org/10.1016/j.chemosphere.2020.126787

Free, C. M., Jensen, O. P., Mason, S. A., Eriksen, M., Williamson, N. J., & Boldgiv, B. (2014). High-levels of microplastic pollution in a large, remote, mountain lake. *Mar Pollut Bull*, *85*(1), 156–163. https://doi.org/10.1016/j.marpolbul.2014.06.001

Gaylarde, C. C., Neto, J. A. B., & da Fonseca, E. M. (2021). Paint fragments as polluting microplastics: A brief review. *Marine Pollution Bulletin*, *162*, 111847. https://doi.org/https://doi.org/10.1016/j.marpolbul.2020.111847

GESAMP. (2019). Guidelines for the monitoring and assessment of plastic litter in the ocean (Kershaw P.J., Turra A. and Galgani F. editors), (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). *Rep. Stud. GESAMP* (99), 130.

Gigault, J., Halle, A. T., Baudrimont, M., Pascal, P. Y., Gauffre, F., Phi, T. L., . . . Reynaud, S. (2018). Current opinion: What is a nanoplastic? *Environment Pollution*, *235*, 1030–1034. https://doi.org/10.1016/j.envpol.2018.01.024

Guo, X., & Wang, J. (2019). The chemical behaviors of microplastics in marine environment: A review. *Marine Pollution Bulletin*, *142*, 1–14. https://doi.org/10.1016/j.marpolbul.2019.03.019

Hanun, J. N., Hassan, F., & Jiang, J.-J. (2021). Occurrence, Fate, and Sorption Behavior of Contaminants of Emerging Concern to Microplastics: Influence of the Weathering/Aging Process. *Journal of Environmental Chemical Engineering*, 106290. https://doi.org/10.1016/j.jece.2021.106290

Helm, P. (2017). Improving microplastics source apportionment: A role for microplastic morphology and taxonomy? *Analytical Methods*, *9*, 1328–1331. https://doi.org/10.1039/C7AY90016C

Hernandez, L. M., Xu, E. G., Larsson, H. C. E., Tahara, R., Maisuria, V. B., & Tufenkji, N. (2019). Plastic Teabags Release Billions of Microparticles and Nanoparticles into Tea. *Environ Sci Technol*, *53*(21), 12300–12310. https://doi.org/10.1021/acs.est.9b02540

Huang, Y., He, T., Yan, M., Yang, L., Gong, H., Wang, W., . . . Wang, J. (2021). Atmospheric transport and deposition of microplastics in a subtropical urban environment. *Journal of Hazardous Materials*, *416*, 126168. https://doi.org/10.1016/j.jhazmat.2021.126168

Jeong, J., & Choi, J. (2019). Adverse outcome pathways potentially related to hazard identification of microplastics based on toxicity mechanisms. *Chemosphere*, *231*, 249-255. https://doi.org/https://doi.org/10.1016/j.chemosphere.2019.05.003

Klein, S., Dimzon, I. K., Eubeler, J., & Knepper, T. P. (2018). Analysis, Occurrence, and Degradation of Microplastics in the Aqueous Environment. In M. Wagner & S. Lambert (Eds.), *Freshwater Microplastics : Emerging Environmental Contaminants?* (51–67). Springer International Publishing. https://doi.org/10.1007/978-3-319-61615-5_3

Li, D., Yang, L., Kavanagh, R., Xiao, L., Shi, Y., Kehoe, D. K., . . . Wang, J. J. (2021). Sampling, Identification and Characterization of Microplastics Release from Polypropylene Baby Feeding Bottle during Daily Use. *Journal of visualized experiments : JoVE*(173). Retrieved 2021/07//, from http://europepmc.org/abstract/MED/34369927. https://doi.org/10.3791/62545

Li, L., Zhao, X., Li, Z., & Song, K. (2021). COVID-19: Performance study of microplastic inhalation risk posed by wearing masks. *J Hazard Mater*, *411*, 124955. https://doi.org/10.1016/j.jhazmat.2020.124955

Liu, P., Zhan, X., Wu, X., Li, J., Wang, H., & Gao, S. (2020). Effect of weathering on environmental behavior of microplastics: Properties, sorption and potential risks. *Chemosphere*, *242*, 125193. https://doi.org/10.1016/j.chemosphere.2019.125193

Mitrano, D. M., & Wohlleben, W. (2020). Microplastic regulation should be more precise to incentivize both innovation and environmental safety. *Nature Communications*, *11*(1), 5324. https://doi.org/10.1038/s41467-020-19069-1

Murphy, L., Germaine, K., Dowling, D. N., Kakouli-Duarte, T., & Cleary, J. (2020, 2020//). Association of Potential Human Pathogens with Microplastics in Freshwater Systems. Proceedings of the 2nd International Conference on Microplastic Pollution in the Mediterranean Sea, Cham.

O'Brien, S., Okoffo, E. D., O'Brien, J. W., Ribeiro, F., Wang, X., Wright, S. L., . . . Thomas, K. V. (2020). Airborne emissions of microplastic fibres from domestic laundry dryers. *Sci Total Environ*, *747*, 141175. https://doi.org/10.1016/j.scitotenv.2020.141175

Pigosso, D. C. A., Rozenfeld, H., & McAloone, T. C. (2013). Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies. *Journal of Cleaner Production*, *59*, 160–173. https://doi.org/https://doi.org/10.1016/j.jclepro.2013.06.040

Prata, J. C. (2018). Airborne microplastics: Consequences to human health? *Environ Pollut*, *234*, 115-126. https://doi.org/10.1016/j.envpol.2017.11.043

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. *Sci Total Environ*, *702*, 134455. https://doi.org/10.1016/j.scitotenv.2019.134455

Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., . . . Giorgini, E. (2021). Plasticenta: First evidence of microplastics in human placenta. *Environ Int*, *146*, 106274. https://doi.org/10.1016/j.envint.2020.106274

Rahman, A., Sarkar, A., Yadav, O. P., Achari, G., & Slobodnik, J. (2021). Potential human health risks due to environmental exposure to nano- and microplastics and knowledge gaps: A scoping review. *Sci Total Environ*, *757*, 143872. https://doi.org/10.1016/j.scitotenv.2020.143872

Rochman, C. M., Brookson, C., Bikker, J., Djuric, N., Earn, A., Bucci, K., . . . Hung, C. (2019). Rethinking microplastics as a diverse contaminant suite [https://doi.org/10.1002/etc.4371]. *Environmental Toxicology and Chemistry*, *38*(4), 703-711. https://doi.org/https://doi.org/10.1002/etc.4371

Santana-Viera, S., Montesdeoca-Esponda, S., Sosa-Ferrera, Z., & Santana-Rodriguez, J. J. (2021). UV filters and UV stabilizers adsorbed in microplastic debris from beach sand. *Mar Pollut Bull*, *168*, 112434. https://doi.org/10.1016/j.marpolbul.2021.112434

Steensgaard, I. M., Syberg, K., Rist, S., Hartmann, N. B., Boldrin, A., & Hansen, S. F. (2017). From macro- to microplastics - Analysis of EU regulation along the life cycle of plastic bags. *Environ Pollut*, *224*, 289–299. https://doi.org/10.1016/j.envpol.2017.02.007

Sun, Q., Ren, S.-Y., & Ni, H.-G. (2020). Incidence of microplastics in personal care products: An appreciable part of plastic pollution. *Science of The Total Environment*, *742*, 140218. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.140218

Thompson, R., Moore, C., Andrady, A., Gregory, M., Takada, H., & Weisberg, S. (2005). New Directions in Plastic Debris. *Science*, *310*(5751), 1117. https://doi.org/doi:10.1126/science.310.5751.1117b

Vianello, A., Jensen, R. L., Liu, L., & Vollertsen, J. (2019). Simulating human exposure to indoor airborne microplastics using a Breathing Thermal Manikin. *Scientific Reports*, *9*(1), 8670. https://doi.org/10.1038/s41598-019-45054-w

Völker, C., Kramm, J., & Wagner, M. (2020). On the Creation of Risk: Framing of Microplastics Risks in Science and Media [https://doi.org/10.1002/gch2.201900010]. *Global Challenges*, *4*(6), 1900010. https://doi.org/https://doi.org/10.1002/gch2.201900010

Wright, S. L., Ulke, J., Font, A., Chan, K. L. A., & Kelly, F. J. (2020). Atmospheric microplastic deposition in an urban environment and an evaluation of transport. *Environ Int*, *136*, 105411. https://doi.org/10.1016/j.envint.2019.105411

Wu, M., Tang, W., Wu, S., Liu, H., & Yang, C. (2021). Fate and effects of microplastics in wastewater treatment processes. *Sci Total Environ*, *757*, 143902. https://doi.org/10.1016/j.scitotenv.2020.143902

Xie, X., Deng, T., Duan, J., Xie, J., Yuan, J., & Chen, M. (2020). Exposure to polystyrene microplastics causes reproductive toxicity through oxidative stress and activation of the p38 MAPK signaling pathway. *Ecotoxicology and Environmental Safety*, *190*, 110133. https://doi.org/10.1016/j.ecoenv.2019.110133

Yurtsever, M. (2019). Tiny, shiny, and colorful microplastics: Are regular glitters a significant source of microplastics? *Marine Pollution Bulletin*, *146*, 678–682. https://doi.org/https://doi.org/10.1016/j.marpolbul.2019.07.009

Zhang, Y.-Q., Lykaki, M., Alrajoula, M. T., Markiewicz, M., Kraas, C., Kolbe, S., . . . Stolte, S. (2021). Microplastics from textile origin – emission and reduction measures. *Green Chemistry*, *23*(15), 5247-5271. https://doi.org/10.1039/d1gc01589c

Zhang, Y., Kang, S., Allen, S., Allen, D., Gao, T., & Sillanpää, M. (2020). Atmospheric microplastics: A review on current status and perspectives. *Earth-Science Reviews*, *203*, 103118. https://doi.org/https://doi.org/10.1016/j.earscirev.2020.103118

Chapter 10

The Integrated Biochar Industry for Indonesian Rural Area Households: Study Case on Forest Biomass and Carbon Sequestration

Surya Bagus Mahardika

A. Forest Biomass and Indonesia's Rural Area at a Glance

Biomass and carbon sequestration has excellent attention from forest managers and experts all over the world, and biomass and carbon estimation was the critical point to overcome future forest management (Dong et al., 2014; Jagodziński et al., 2018; Khan et al., 2018; Parresol, 2001; Zeng et al., 2017). Climate change effects on forestry are also essentials factors that need to acquire on a statistical basis (Lei et al., 2016; Schneider et al., 2018; Trautenmüller et al., 2021; Vaughn et al., 2021; Xiang et al., 2021; K. Xu et al., 2021; Zhang et al., 2020).

Biomass allometric models are essential methods to examine forests biomass and carbon modeling. Indonesia (Kusmana et al.,

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S. B. Mahardika
Northeast Forestry University, China, e-mail: suryabagusmahardika@gmail.com

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2018) has conducted biomass allometric models for *Sonneratia* spp. However, the allometric model for all tree species is still limited. Since climate change issues occur in all countries, forestry biomass estimation is essential to dealing with the zero carbon emission goals. Forest biomass has a huge potential to reduce carbon emissions and as a bio-energy source (Suntana et al., 2009). Many industries have established bio-energy-based products to address greenhouse gas (GHG) emissions such as bio-methanol, biochar, biofuels, bio-based chemical, and other bio products.

Biochar is the new solution worldwide, such as managing agriculture or forestry residue and climate change (Anand et al., 2022). Biochar is highly correlated with biomass and carbon sequestration. There are several ways to obtain sustainable raw materials. As a developing country, Indonesia must take a robust plan in the future because natural resources are fundamental for our necessities and industry sectors. Hence, in recent decades, many worse situations caught a terrible effect on the environment, such as the Lumpur Lapindo mining, forest fire in Sumatra, and deforestation in Kalimantan and Papua. Those problems were primarily reported because the roadmaps were not implemented using a scientific base. It showed us that the scientific base had not been well implemented in those several work/projects. Therefore, Penta helix's five actors (academics, business, community, government, and media) should take extra action to mainstream the scientific base rather than other issues.

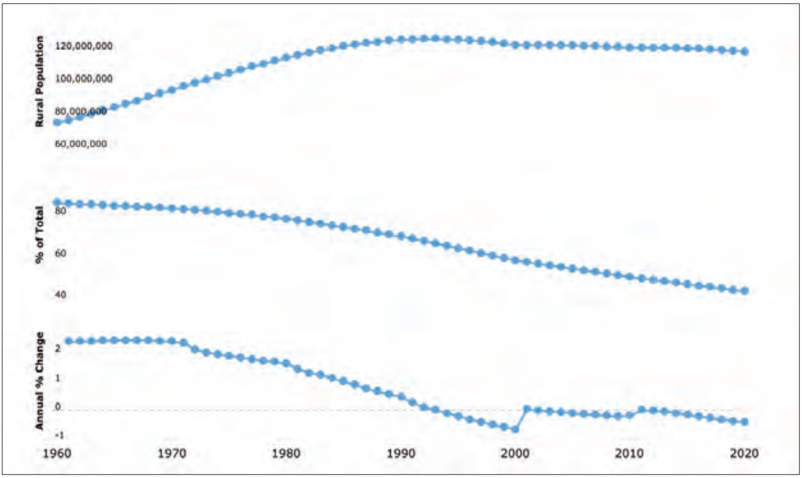
The Penta helix five actors led the people to pay attention to the current issues. Otherwise, the next generation will suffer from climate change's adverse effects. The most common problems are getting a job, earning a stable income, and having enough food and other necessities. Climate issues are still not popular because they are unrelated to their lives. However, for several locations in the region or their surroundings, something worse affected by climate change will make it easier to understand climate change, such as rising sea level, flooding, long dry season, changing rainy or sunny season, etc.

Before those disasters, it would be better for human beings to care for the earth's future.

The tropical rainforest has a tremendous amount of biomass compared to other forest types. Because tropical rain forest above and belowground saves many biomasses; stem, branch, foliage, root, and the forest litter. On the other hand, crop waste can also be used in the biochar industry. Bio-charcoal is the known name of biochar. The biomass was processed by pyrolysis, torrefaction, gasification, and carbonization through thermochemical conversion in the partial air supply. Syngas and biochar are known carbonization products (Anand et al., 2022).

In this chapter, we have examined the potential of forest biomass as a biochar industry main source. However, theoretically all carbonic materials can be used for biochar production. Such as household waste, crop residues, sewage sludge, forest residues, algal biomass, and animal litter. In addition, the biochar industries have to highlight the main physical & chemical properties, i.e., cellulose, hemicellulose, lignin, moisture content, and inorganic substances. We projected trees as the biochar raw materials and forest waste/litter, bamboo, shrub, and other vegetation as potential sources for the raw materials. For example, China is the most bamboo producer in the world, and bamboo waste can be made as biochar at a low cost. The annual increase in bamboo biomass is 10–30% compared with tree biomass of 2–5%. It means bamboo timber production in the same area is estimated to be 20 times more than trees (T. Xu et al., 2012).

Rural population refers to people living in rural areas defined by the Indonesia Central Bureau of Statistics (Badan Pusat Statistik); it was calculated as the difference between the total population and urban population. Indonesia rural population for 2017 was 119,995,396, a 0.29% decline from 2016. Based on the statistical data, the rural population from 1960–2022 declined yearly, including annual % change and % of the total population (Figure 10.1). The situation does not only happen in Indonesia but also worldwide. However, some countries still have high numbers of rural population, such as Austria,

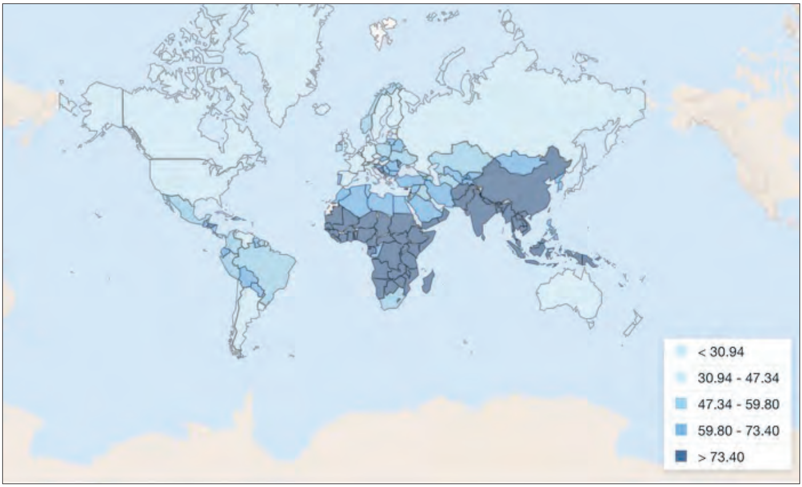


Sources: World Bank (2020)

Figure 10.1 Indonesia Rural Population 1960–2022

Barbados, Guyana, Samoa, and Tajikistan. Furthermore, an aggregated value for high-income, low and middle-income, low-income, lower-middle-income, middle-income, and upper-middle-income countries showed that the number of rural populations declined year by year. Based on the World Bank (2020), the world's rural population (% of the total population) in 1960 was 66.38%, and the latest data in 2020 was 43.84%.

In 1960, the rural population in Indonesia (Figure 10.2), China, and Africa were almost similar. More than 73.40% of people live in rural areas. Based on the history of Indonesia, during the President Suharto regime (1967–1998), urbanization significantly increased. The government also established policies to control the population in Java Island, the most populated island in Indonesia, such as transmigration program and rural area development. In the beginning, the program successfully impacted the Java Island population. However, the government did not regulate the details aspect livelihood aspects, natural resources, market, or transportation. Therefore, some locations

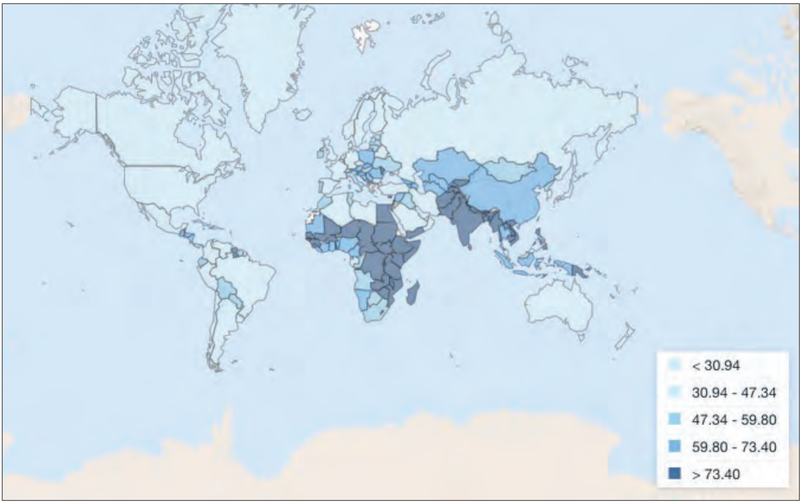


Sources: World Bank (2020)

Figure 10.2 Rural Population (% of the Total Population) in 1960

for transmigration program were misleading, and other problems were caused by the continuous number of people's arrival. Not only affect the natural resources, but some social conflict between the local society and newcomers became the most treacherous issue.

The Indonesian government must learn from those situations to implement a new regulation. Predicting the future is a more appropriate way to deal with future uncertainty. The scientific method is the key to deal with several complex problems. Therefore, the researcher should encourage the government to ensure that the to implement more accurate policies. As a democratic country, Indonesia must educate the people to be more concerned about the regulations. That means the government and the people are working together. Since the technology era has been growing faster for several decades, it will challenge the Indonesian government. If the regulation does not impact the people's participation in the policy, it will be hard to hook them into government plans in several decades.



Sources: World Bank (2020)

Figure 10.3 Rural Population (% of the Total Population) in 2020

As the fourth largest populated country (after China, India, and the USA), Indonesia has many potentials human resources; however, the human resources should be ensured enough quality to face the post-modern industry. The urban population grew yearly, which means the demand for food, electricity, water, transportation, and other bases increased. Compared with recent decades, some rural areas are changing into urban areas. These situations indicated that the people living in rural areas should prepare to be more independent as families and individuals. Because if the government did not have the option to keep rural areas with the program, rural society would still live in the owned system.

Regarding the demands of rural households, energy power has become essential, such as for for cooking, telecommunications, small industries, etc. To deal with that demand, the rural government should make an initiative. As an abundant resource, biomass has the potential to process into biochar. Usually, the rural area society is also familiar with biomass because, as a traditional method, the rural area society uses biomass for cooking. In subsequent decades, clean energy and technology are required to complete the IPCC requirement. Therefore, the rural area biomass sources can be processed into biochar through implemented technologies.

B. The Integrated Biochar Industry

1. Forest inventory and quantification

In recent decades, Indonesia had some regulations about forest quantification. However, not all forest areas have been measured. The problem is due to the accessibility, funding, and regulation. According to the IPCC and COP 26 at Glasgow, the Indonesia Minister of Environment and Forestry said that Forest and Land Use (FoLU) are the keys to Indonesia's sustainable forest management. However, the Indonesian government still has many tenurial conflicts and problems. Therefore, Indonesia must have deal with the tenurial issues in the following decades and should have an accurate number of Indonesia's forest cover, biomass, and other natural resources. To deal with carbon sequestration issues, forest biomass and carbon measurement have become significant issues to overcome.

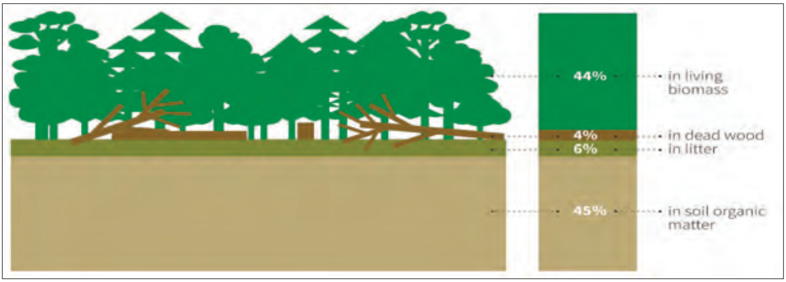
As the government and the people aim, the forests should contribute to the economy. Hence, the forests have become the object of people's economic growth. Such as the social forestry program (Sahide et al., 2020), simplified, gives people access to use the forest land. Besides, the program also does not guarantee a positive contribution to sustainable forest development because some evidence shows that the access only gives the land certificate, however, how those people use the land is not controlled by the government. Thus, there is no guarantee that the forest area will be kept in the function or changed into another function. This program, is a short mission without measuring for its long-term effect. To address this problem, the government and the academicians should have comprehensive planning and guidance, then duplicate it into society. Because Indonesia consists of many islands, one guidance is not enough to implement. Adaptation to the local characteristics is appropriate.

Accurate forest inventories, quantification, and estimation can improve the action to address climate change and develop sustainable forest management. In China, forest inventories have been quantified from 1977 to 2013 (Zhao et al., 2019). The program obtained the average biomass carbon sink, the biomass carbon stocks, and the biomass carbon density. This program's result could help validate and calibrate simulation model results and comprehensively investigate forest carbon budgets. Indonesia should have that kind of forest inventory to ensure that the program and planning are well-implemented.

2. Forest mapping

The proportions of carbon stock in forest carbon pools are: living biomass (44%), deadwood (4%), litter (6%), and soil organic matter (45%) (FAO, 2020). After the soil organic matter, living biomass is the largest forest carbon pool (Figure 10.4). The national commitments to reducing forest emissions in Indonesia are still ineffective (Meehan et al., 2019). The government is not seriously putting local and smallholder farmers together. However, the government always said that they have already collaborated with the local and smallholder farmers. Indonesia also has extensive tropical peatlands, and the smallholder farmers are essential in preventing forest fires, protecting the forests, and restoring the degraded peatlands (Merten et al., 2021). Indonesia reduced emissions target to NDCs is affected by some highlights emission sources: illegal land clearing, illegal logging, and forest fires (Tacconi & Muttaqin, 2019). Therefore, forest mapping in a new paradigm is pertinent to all elements needed to be targeted. Indonesia forests as tropical rain forests should be more effective in developing into a higher stage.

The forest mapping does not merely belong to the log potentials; the carbon stock is now more fundamental. The larger to smaller proportions are in soil organic matter, living biomass, deadwood, and litter (Figure 10.4). Furthermore, the forest carbon pools can also



Sources: FAO (2020)

Figure 10.4 The Proportion of Carbon Stock in Forest Carbon Pools, 2020

process onto biochar if sustainability management is implemented in all industrial processes. Besides, biochar is the key to increase nutrient content (Zhou et al., 2021). As an agricultural country, Indonesia has many farmers living closer to forests. Building the forest sustainable management mapping simultaneously with the biochar industry could be double robust to achieving a sustainable forest management plan for further decades.

3. Smart Forestry Station (SFS) Initiatives

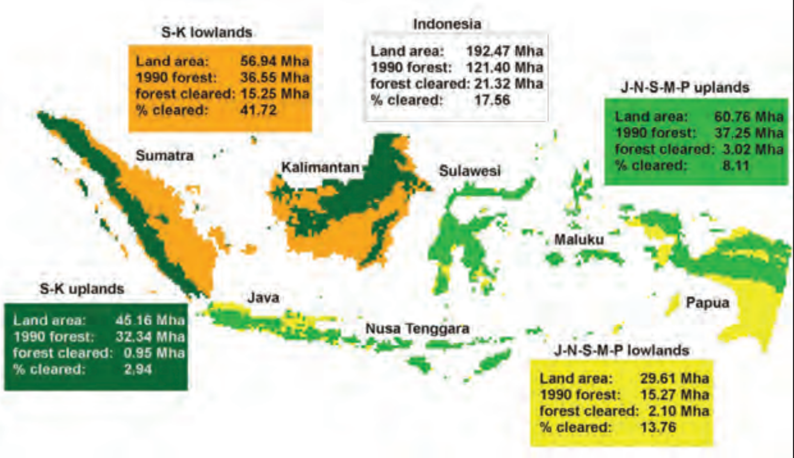
The Indonesian government has implemented the social forestry policy since 2014. Some experts argue that the social forestry policy goes to populist ideals, which means the boom expansion should be anticipated with several plans. The social forestry area increased from 653.311 ha in 2014 to 3.369.583 ha in 2019. Regarding the national goals that promote sustainability and social justice, management and monitoring system practices are the crucial management systems. The one map policy, digital data, and other relevant technology implementations have to promote to deal with the global industries.

Smart Forestry Station (SFS) initiatives are the idea needed to implement in this stage. Smart means the input, process, and outputs should use in the smart way, not only in technology but also the people's mindsets. The SFS integrated with previous enterprises, such as Perum Perhutani Group (Indonesia Forestry Enterprises Holding Group). Because in many ways, people are suitable with the usual system (business as usual), transformation and adaptation need takes time to implement. For example, a study proposed by Vicol et al. (2018) showed that key individual positions are essential to influence the social community. It would be better to build the infrastructures rapidly during the process. Therefore, social modal, social-economic engineering, and funding are fundamental requirements.

SFS is also essential for mitigating forest loss in Indonesia, such as providing real-time data and coordination between ecoregion, province, and island. As an country, Indonesia must coordinate rapidly to ensure the forest's real-time spatial condition on each island. From 2000–2005, dramatic forest clearing rates dropped last century (Figure 10.5). Moreover, Sumatra Island and Kalimantan Island are significant levels of forest clearing (Figure 10.6). The political and economic factors were highly related to forest clearing (Hansen et al., 2009). Therefore, the objective of SFS was to improve the forest management

Sources: World Resources Institute (2010)

Figure 10.5 Forest Cover Loss in Indonesia, 2000–2005



Private and civil society interests with the information needed to improve forest management. The forest clearing rate in Indonesia is among the highest reported by the United Nations Food and Agriculture Organization (FAO)

Source: Hansen et al. (2009)

Figure 10.6 Estimates of National and Sub-National Forest Extent and Loss

system, improve the socio-econometric, biodiversity conservation efforts, hydrological management, climate change mitigation, and forest biomass-carbon modeling efforts.

The SFS functions are to ensure the forestry bureau at a province level, even up to the rural level stay on track, and follow the national development targets. The SFS official office should close with the forestry bureau, but being independent in the monitoring function. A sustainable forestry management system must be achieved through innovative technology and competent personnel. The local younger people are also the keys to a better understanding of local society and forestry development. Moreover, a very ambitious team, transparency systems, objective goals, and aggressive path reflect the SFS role.

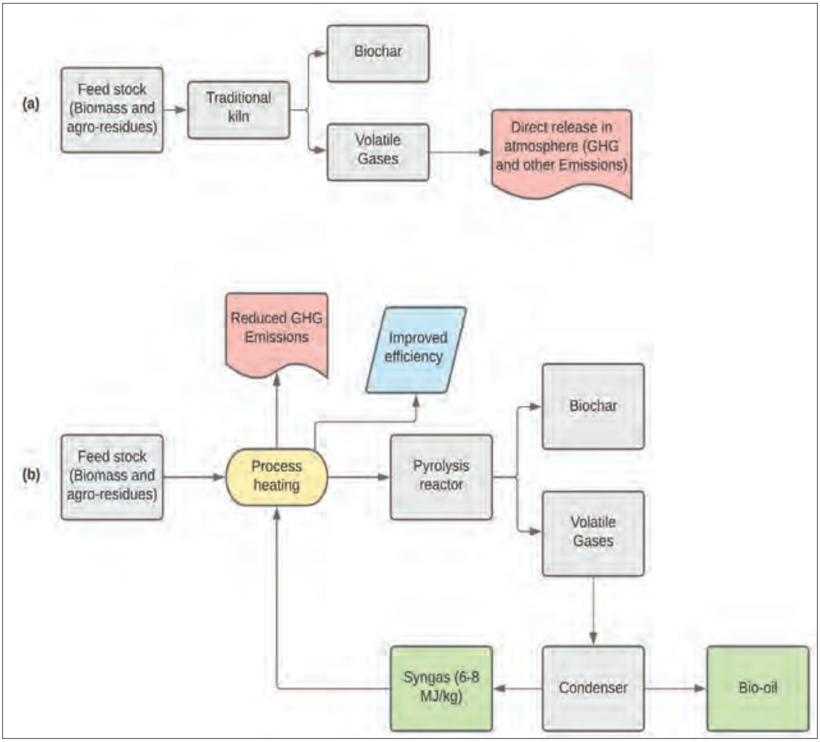
4. Biochar Industry

The previous study examined forest biomass as source of bio methanol (Kim, 2019; Sahoo et al., 2022; Suntana et al., 2009). However, Indonesia does not have many experiences using bio methanol in a large amount. From 2004 to 2005, rural and urban low-income Indonesian communities implemented energy conversion from kerosene into natural gases during the first SBY Presidency era. Before, many low-income communities depended on kerosene as their household's energy supplies. Since the energy conversion, 3 kg gas tube, including the gas stove and the pipe, has been distributed nationally. This program has been successfully implemented; however, several problems still appear, such as the subsidiary from the government was not implemented in the target communities.

Biochar has received greater attention from researchers since it has multiple functions, such as the color can indicate and predict biochar's properties (Fan et al., 2021). Biochar also can remove organic and inorganic contaminants from soil and water, even heavy metals (Kumar & Bhattacharya, 2021). The biochar industry using renewable resources can be the strategic solution to deal with environmental, livelihood, and economic growth. Indonesia, as a tropical country, has abundant biomass sources. As an Indonesian neighbor, Malaysia almost has a similar climate and resources in terrestrial areas (i.e., tropical rainforest, agriculture, and palm oil plantations). A study in Malaysia proposed by Kong et al. (2014) pointed out that producing biochar from oil palm has challenges, such as economic, logistical/transportation, and market acceptance. Acting as a carbon sink, while oil palm biomass is processed into biochar, an innovative integrated economic system was needed (Kong et al., 2014). Besides, biochar is also helpful for waste sludge reclamation. (Sun et al., 2021).

This chapter describes forest biomass in a different management unit in detail. However, other biomass resources such as agriculture/crop residues, and palm oil industry residues, also have the potential for the biochar industry. This chapter examined the key management of the biochar industry to help rural communities gain equitable energy. Nowadays, many rural communities use wood combustion, and even wood cooking stoves are not suitable for healthy living for the whole family, especially women and children.

Any renewable biological material can be used directly as a fuel, neither converted to another fuel or energy product; it is known as a feedstock. Good quality biochar also comes from a good quality of the feedstock. Biochar can also be divided into traditional and modern production systems, the schematic diagram shown in Figure10.7 (a) & (b), respectively. This chapter uses forest biomass residual processes in both traditional and modern systems. Although the modern systems are more appropriate than traditional ones, rural society must learn to simplify using biochar in the first stage. At the same time, the modern site has to build and make access to the local/rural society.



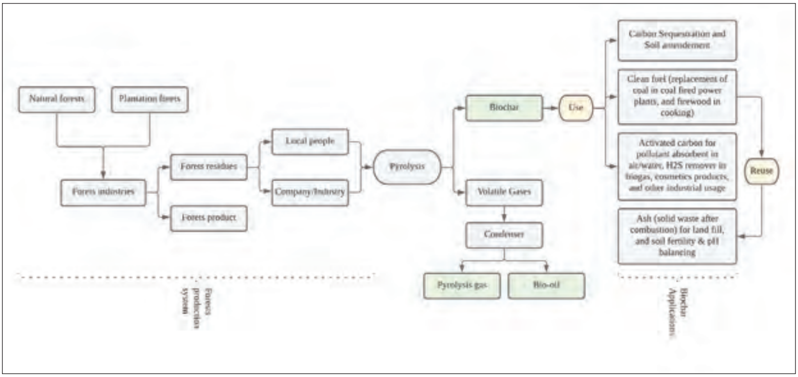
Source: Adapted from Anand et al. (2022)

Figure 10.7 (a) Traditional and (b) Modern Biochar Production System

The forestry production system comes from forest plantation and natural forest. Usually, the industry only accepts some parts, such as stems in specific diameters. Therefore, we can still use the branch, foliage, and root. The society can collect the forest biomass residues and work on the management. Thus, the biochar industry can create new job opportunities for rural people. In comparison, we reduce household carbon emissions and forest degradation through sustainable forest management.

5. The sustainable rural areas households

Rural population refers to people living in rural and maintaining the rural area. The stability number is also a fundamental issue the government needs to address. Rural areas have more flexible lifestyles as the buffer for the urban area because not all the economic systems are formal, such as farming, fishing, and rural livelihood, which do not need a more formal manner. Therefore, no high-risk damage will happen for those rural areas households as long as the family has access to the land, equipment, seeds, market, and other agriculture chain systems. Besides, in recent decades the modern economy and



Source: Adapted from Anand et al. (2022)

Figure 10.8 Forests Residue to Biochar Production and Application System the internet have already changed rural areas. That means sustainable rural areas and households must also be connected with the urban area.

There are two types of forest resources in typical forests: natural and plantation forests. Forest products also have residuals from this forest residue; the local people, companies, and industry can manage and produce biochar through pyrolysis. The standard products from pyrolysis are biochar, bio-oil, and pyrolysis gas. Moreover, biochar has functions like carbon sequestration and soil alteration, clean fuel, activated carbon for pollutant absorbent in air/water, ash for landfill, soil fertility, and pH balancing (Figure 10.8).

The biochar industry in rural areas needs to address rural economic growth, improve the government system, provide clean energy, enhance the small industry, and provide the supply chain for urban areas. Besides, the urban area needs to maintain a complex government system. In addition to reducing the urban area carbon emission, the comprehensive methods; technology solutions for e-governance order fulfillment. There are many ways to reduce carbon emissions. However, the implementation needs a strong government, private sectors, and social commitment. For example, due to reducing, a China study addresses climate change and promotes a low-carbon emissions (Wang et al., 2016). Therefore, a robust action plan was to examine sustainable rural areas households.

C. Conclusions

The integrated biochar industry for Indonesian rural area households has the potential to achieve the Nationally Determined Contributions (NDCs) implementation targets according to the Paris Agreement. Forest biomass and carbon sequestration also need to address through a comprehensive forest inventory and quantification, forest mapping, Smart Forestry Station (SFS) initiatives implementation, establishing biochar industry, and maintaining the sustainability of rural area households. Further study in the biochar industry and carbon emission estimation was needed.

References

Anand, A., Kumar, V., & Kaushal, P. (2022). Biochar and its twin benefits: Crop residue management and climate change mitigation in India. *Renewable and Sustainable Energy Reviews*, *156*, 111959. https://doi.org/10.1016/j.rser.2021.111959

Dong, L., Zhang, L., & Li, F. (2014). A compatible system of biomass equations for three conifer species in Northeast, China. *Forest Ecology and Management*, *329*, 306–317. https://doi.org/10.1016/j.foreco.2014.05.050

Fan, Y., Xiong, Y., Zhang, Y., Jiang, Z., Tang, H., Wu, L., Li, M., Xiao, X., Hu, C., & Zou, X. (2021). Method to characterize color of biochar and its prediction with biochar yield as model property. *Biochar*, *3*(4), 687–699. https://doi.org/10.1007/s42773-021-00119-w

Food and Agriculture Organization (FAO). (2020). Global forest resources assessment 2020-key findings. 2020-Key findings. *https://www.fao.org/3/CA8753EN/CA8753EN.pdf*

Hansen, M. C., Stehman, S. V., Potapov, P. V., Arunarwati, B., Stolle, F., & Pittman, K. (2009). Quantifying changes in the rates of forest clearing in Indonesia from 1990 to 2005 using remotely sensed data sets. *Environmental Research Letters*, *034001*. https://doi.org/10.1088/1748-9326/4/3/034001

Jagodziński, A. M., Dyderski, M. K., Gęsikiewicz, K., Horodecki, P., Cysewska, A., Wierczyńska, S., & Maciejczyk, K. (2018). How do tree stand parameters affect young Scots pine biomass? – Allometric equations and biomass conversion and expansion factors. *Forest Ecology and Management*, *409*, 74–83. https://doi.org/10.1016/j.foreco.2017.11.001

Khan, M. N. I., Shil, M. C., Azad, M. S., Sadath, M. N., Feroz, S. M., & Mollick, A. S. (2018). Allometric relationships of stem volume and stand level carbon stocks at varying stand density in Swietenia *macrophylla* King plantations, Bangladesh. *Forest Ecology and Management*, *430*, 639–648. https://doi.org/10.1016/j.foreco.2018.09.002

Kim, I. T. (2019). Simultaneous denitrification and bio-methanol production for sustainable operation of biogas plants. *Sustainability (Switzerland)*, *6658.* https://doi.org/10.3390/su11236658

Kong, S. H., Loh, S. K., Bachmann, R. T., Rahim, S. A., & Salimon, J. (2014). Biochar from oil palm biomass: A review of its potential and

challenges. *Renewable and Sustainable Energy Reviews*, *39*, 729–739. https://doi.org/10.1016/j.rser.2014.07.107
Kumar, A., & Bhattacharya, T. (2021). Biochar: a sustainable solution. *Environment, Development and Sustainability*, *23*(5), 6642–6680. https://doi.org/10.1007/s10668-020-00970-0
Kusmana, C., Hidayat, T., Tiryana, T., Rusdiana, O., & Istomo. (2018). Allometric models for above- and belowground biomass of *Sonneratia* spp. *Global Ecology and Conservation*, *15*, e00417. https://doi.org/10.1016/j.gecco.2018.e00417
Lei, X., Yu, L., & Hong, L. (2016). Climate-sensitive integrated stand growth model (CS-ISGM) of Changbai larch (*Larix olgensis*) plantations. *Forest Ecology and Management*, *376*, 265–275. https://doi.org/10.1016/j.foreco.2016.06.024
Meehan, F., Tacconi, L., & Budiningsih, K. (2019). Are national commitments to reducing emissions from forests effective? Lessons from Indonesia. *Forest Policy and Economics*, *108*, 101968. https://doi.org/10.1016/j.forpol.2019.101968
Merten, J., Nielsen, J. Ø., Rosyani, & Faust, H. (2021). Climate change mitigation on tropical peatlands: A triple burden for smallholder farmers in Indonesia. *Global Environmental Change*, *71* (November). https://doi.org/10.1016/j.gloenvcha.2021.102388
Parresol, B. R. (2001). *Additivity of nonlinear biomass equations.* Canadian Journal of Forest Research. 31(5), 865– 878. https://doi.org/10.1139/cjfr-31-5-865
Sahide, M. A. K., Fisher, M. R., Erbaugh, J. T., Intarini, D., Dharmiasih, W., Makmur, M., Faturachmat, F., Verheijen, B., & Maryudi, A. (2020). The boom of social forestry policy and the bust of social forests in Indonesia: Developing and applying an access-exclusion framework to assess policy outcomes. *Forest Policy and Economics*, *120*, 102290. https://doi.org/10.1016/j.forpol.2020.102290
Sahoo, K. K., Datta, S., Goswami, G., & Das, D. (2022). Two-stage integrated process for bio-methanol production coupled with methane and carbon dioxide sequestration: Kinetic modelling and experimental validation. *Journal of Environmental Management*, *301*, 113927. https://doi.org/10.1016/j.jenvman.2021.113927
Schneider, R., Franceschini, T., Fortin, M., & Saucier, J. P. (2018). Climate-induced changes in the stem form of 5 North American tree species. *Forest Ecology and Management*, *427*, 446–455. https://doi.org/10.1016/j.foreco.2017.12.026

Sun, H., Yang, J., Wang, Y., Liu, Y., Cai, C., & Davarpanah, A. (2021). Study on the removal efficiency and mechanism of tetracycline in water using biochar and magnetic biochar. *Coatings*, *11*(11), 1354. https://doi.org/10.3390/coatings11111354

Suntana, A. S., Vogt, K. A., Turnblom, E. C., & Upadhye, R. (2009). Bio-methanol potential in Indonesia: Forest biomass as a source of bio-energy that reduces carbon emissions. *Applied Energy*, *86*(SUPPL. 1), S215–S221. https://doi.org/10.1016/j.apenergy.2009.05.028

Tacconi, L., & Muttaqin, M. Z. (2019). Policy forum: Institutional architecture and activities to reduce emissions from forests in Indonesia. *Forest Policy and Economics*, *108*, 101980. https://doi.org/10.1016/j.forpol.2019.101980

Trautenmüller, J. W., Péllico Netto, S., Balbinot, R., Watzlawick, L. F., Dalla Corte, A. P., Sanquetta, C. R., & Behling, A. (2021). Regression estimators for aboveground biomass and its constituent parts of trees in native southern Brazilian forests. *Ecological Indicators*, *130*. https://doi.org/10.1016/j.ecolind.2021.108025

Vaughn, W. R., Taylor, A. R., MacLean, D. A., D'Orangeville, L., & Lavigne, M. B. (2021). Climate change experiment suggests divergent responses of tree seedlings in eastern North America's Acadian Forest Region over the 21st century. *Canadian Journal of Forest Research*, *51*(12), 1888–1902. https://doi.org/10.1139/cjfr-2021-0047

Vicol, M., Neilson, J., Hartatri, D. F. S., & Cooper, P. (2018). Upgrading for whom? Relationship coffee, value chain interventions and rural development in Indonesia. *World Development*, *110*, 26–37. https://doi.org/10.1016/j.worlddev.2018.05.020

Wang, X., Zhao, G., He, C., Wang, X., & Peng, W. (2016). Low-carbon neighborhood planning technology and indicator system. *Renewable and Sustainable Energy Reviews*, *57*, 1066–1076. https://doi.org/10.1016/j.rser.2015.12.076

Xiang, W., Li, L., Ouyang, S., Xiao, W., Zeng, L., Chen, L., & Lei, P.(2021). Effects of stand age on tree biomass partitioning and allometric equations in Chinese fir (*Cunninghamia lanceolata*) plantations. *European Journal of Forest Research*, *140*(2), 317–332. https://doi.org/10.1007/s10342-020-01333-0

Xu, K., Jiang, J., & He, F. (2021). Climate-based allometric biomass equations for five major Canadian timber species. *Canadian Journal of Forest Research*, 51(11), https://doi.org/10.1139/cjfr-2020-0485

Xu, T., Lou, L., Luo, L., Cao, R., Duan, D., & Chen, Y. (2012). Effect of bamboo biochar on pentachlorophenol leachability and bioavailability in agricultural soil. *Science of the Total Environment*, *414*, 727–731. https://doi.org/10.1016/j.scitotenv.2011.11.005

Zeng, W. S., Duo, H. R., Lei, X. D., Chen, X. Y., Wang, X. J., Pu, Y., & Zou, W. T. (2017). Individual tree biomass equations and growth models sensitive to climate variables for *Larix* spp. in China. *European Journal of Forest Research*, *136(2)*, 233–249. https://doi.org/10.1007/s10342-017-1024-9

Zhang, X., Wang, H., Chhin, S., & Zhang, J. (2020). Effects of competition, age and climate on tree slenderness of Chinese fir plantations in southern China. *Forest Ecology and Management*, *458, 117815*, 117815. https://doi.org/10.1016/j.foreco.2019.117815

Zhao, M., Yang, J., Zhao, N., Liu, Y., Wang, Y., Wilson, J. P., & Yue, T. (2019). Estimation of China's forest stand biomass carbon sequestration based on the continuous biomass expansion factor model and seven forest inventories from 1977 to 2013. *Forest Ecology and Management*, *448*(January), 528–534. https://doi.org/10.1016/j.foreco.2019.06.036

Zhou, S., Kong, F., Lu, L., Wang, P., & Jiang, Z. (2021). Biochar—An effective additive for improving quality and reducing ecological risk of compost: A global meta-analysis. *Science of the Total Environment*, *806(4)*, 151439. https://doi.org/10.1016/j.scitotenv.2021.151439

SECTION 3

FOOD DEFENSE AND SECURITY DEVELOPMENT

Chapter 11

Utilizing the Potential of Coastal Sand Marginal Land Resources in the Framework to Improve Food Security Post-COVID-19 Pandemic in Indonesia

Bhaskara Anggarda Gathot Subrata & Anugrah Abdillah Junaid

A. Food Security and Marginal Coastal Sandy Land Potential in Indonesia

Food security is achieved when everyone has access to sufficient, healthy, and nutritious food that is aesthetically pleasing and economically viable. Food security is concerned with providing food sources, especially for the poor, who often lack access to food and struggle to raise their standards above the poverty line. At the beginning of the COVID-19 pandemic, food availability became a serious issue, as it could jeopardize Indonesia's food security. According to the Global Hunger Index report (Grebmer et al., 2019), many people in Indonesia face severe hunger. Because Indonesia imports a variety of food commodities from many different countries, COVID-19 sig-

B. A. G. Subrata & A. A. Junaid
Ondokuz Mayis University, Turkey, e-mail: bhaskaraanggarda@gmail.com

Subrata, B. A. G., & Junaid, A. A. (2022). Utilizing the potential of coastal sand marginal land resources in the framework to improve food security post-COVID-19 pandemic in Indonesia. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and Technology Role for Indonesia Development* (175–190). DOI: 10.55981/brin.538.c510 ISBN: 978-623-7425-85-4 E-ISBN: 978-623-7425-89-2

nificantly impact Indonesia's trade activities, including food security and agricultural goods. This problem is caused by the slowdown in agricultural production, logistics transportation, and distribution due to movement restrictions.

On the other hand, due to land conversion and environmental factors such as climate change, the availability of productive land in Indonesia has decreased over time (Figure 11.1). Food production, food security, climate change, and the COVID-19 pandemic are inextricably linked and affect one another. Humanity's current challenges necessitate the development of novel agricultural strategies and approaches to resolve the issue of food security following the COVID-19 pandemic. Strategic decisions must be made to invest in natural capital and consider ecological, economic, and social factors when producing, distributing, and consuming food. Thus, policy must prioritize urgent food and public health needs, ensuring agriculture's long-term resilience and sustainability, and anticipating future outbreaks such as COVID-19.

While all countries have been affected by the COVID-19 pandemic, Indonesia struggles due to its large population and vast archipelago. All risks of future food crises resulting from a pandemic outbreak can be mitigated by maximizing the potential of marginal land resources, especially coastal sandy areas that are abundant in several parts of Indonesia. For example, the Special Region of Yogyakarta (DIY) Province has a coastal sand area of approximately 13,000 hectares, or 4% of the province's total area, stretching 110 km along the Indonesian ocean's southern coast (Subrata et al., 2016). This beach sand stretch extends between 1–3 km away from the coast. This land is suitable for cultivating food crops and horticulture, owing to the presence of large, shallow groundwater and abundant sunlight (Sunghening et al., 2013). Coastal sandy land, on the other hand, is marginal land with low productivity. The low productivity of coastal sandy land results from limiting factors such as limited water holding/storage capacity, high infiltration, very low organic matter, and inefficient water use.

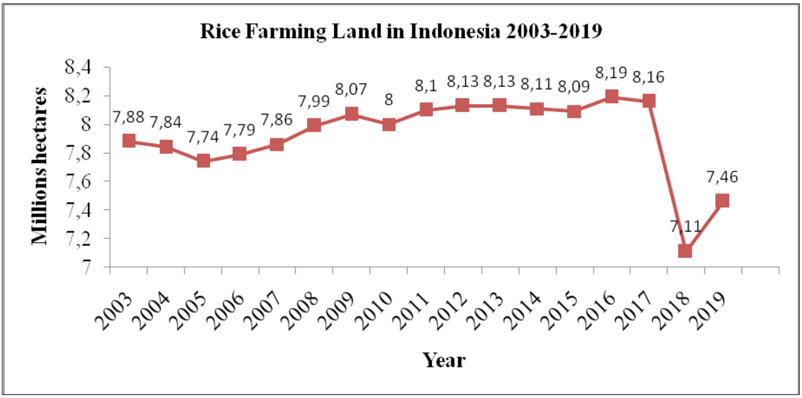
As a result, it is necessary to implement appropriate technology to convert coastal sandy land into productive agricultural land.

As a result, this chapter is expected to comprehensively present the potential of marginal coastal sandy land resources to support food security in Indonesia following the COVID-19 pandemic. This is in line with the primary objectives of the UN Research Roadmap for COVID-19 recovery, namely the need to develop strategies for preventing degradation and conserving land resources, particularly marginal coastal sands, to make them more integrated in the future to support Indonesia's food security.

B. The Difficulties and Dilemmas Associated with Indonesia's Agricultural Land Availability

Indonesia is one of the countries with the lowest average land per capita globally in terms of land resources. According to the FAO, Indonesia had 0.24 hectares of agricultural land per capita as of 2018. Meanwhile, the global average is 0.64 hectares, compared to 0.32 and 0.28 hectares in neighboring countries like Thailand and Malaysia (FAO, 2020). The land area per capita refers to the amount of agricultural land and pasture for cattle grazing. In Indonesia, land resources remain critically prioritized for social and economic development, frequently resulting in protracted agrarian conflicts.

Farmers and smallholders face a challenge related to agricultural land: agricultural land is becoming increasingly scarce as industry and settlements expand. Figure 11.1 depicts the land area used for rice production in Indonesia from 2003 to 2019. The figure demonstrates that the total productive land area has fluctuated yearly, with a significant decline in 2018 and 2019. For instance, one of the regions, Java Island, Indonesia's largest rice producer, has seen numerous changes in converting agricultural land to industry and settlements due to the country's growing population. Although several local governments have passed ordinances prohibiting the conversion of agricultural land, land conversion continues to increase year after year.



Source: Secretariat General Ministry of Agriculture (2020)

Figure 11.1 Rice Farming Land in Indonesia from 2003–2019

We still remember the massive land conversion incident in Kulon Progo area of DIY Province to construct the Yogyakarta International Airport (YIA). The construction of the YIA airport would then require 587 hectares in five villages in Kapanewon Temon, Kulon Progo, DIY Province. The problem is that agricultural land has been lost due to the construction of the Yogyakarta International Airport (YIA), resulting in the loss of several people's homes and livelihoods in favor of the airport construction area. This affects the environment's abiotic, biotic, and socioeconomic-cultural components. Among the ecological consequences are the loss of productive agricultural land and biodiversity. Economic effects include the loss of livelihoods for many Kulon Progo people, who rely on agriculture. Additionally, it is believed that the construction of the YIA airport made the people of Kulon Progo, especially the landless cultivators, the most vulnerable social group at the time. They possess a high probability of being "eliminated" from their life.

The aforementioned issue is only one of Indonesia's numerous examples of agricultural land conversion. The construction of a cement factory has contaminated agricultural land in the Kendeng area of Central Java. Agricultural land has been converted to develop the mineral mining industry in the Sangatta area of of East Kalimantan. There are numerous other agricultural land conversions to non-agricultural uses throughout Indonesia. The study indicated that Indonesia lost between 1,800 and 2,000 tons of rice yields yearly (Food Security Council Indonesia et al., 2015). Indeed, the government is not simply silent; it has expanded land to several areas throughout Indonesia via the food estate program. The food estate in Merauke Regency, Papua Province, with a target area of 1.2 million hectares, has converted more than half of its function to oil palm industries. Meanwhile, we have been surprised by the food estate program in Central Kalimantan Province in recent years, specifically in the Kapuas and Pulang Pisau Regencies. However, a few months after Indonesian President Joko Widodo led the initial planting, the farmers encountered crop failure. This is because inadequate technology was applied to the area's specific conditions, resulting in financial losses for many farmers.

Meyer and Früh-Müller (2020) demonstrate that the transition from land use to settlements or infrastructure has been quite extraordinary in the last few decades. Settlement development will outperform agriculture in affluent areas without prompt interventions, such as zoning planning or payments for farmland maintenance. Eventually farmers will abandon agriculture for economic reasons. According to Chrisendo et al. (2020), land-use change is common in tropical countries, with profound environmental and socioeconomic consequences. Thus, it is necessary to identify the potential for new land resources and investigate appropriate technology sources to achieve the best results possible during land conversion and agricultural land expansion.

C. Coastal Sand Marginal Land Resources: Opportunities and Challenges

Land resources are one factor contributing to an agricultural business system's success. Due to limiting factors, not all land can be planted with crops. Land subject to these limitations is frequently referred to as marginal land. Some land resource experts define marginal land are "characterized by land uses that are at the margin of economic viability" and "lands unsuitable for continuous tillage or lands where there were major constraints to economical use of industrial inputs" (Scherr & Hazell, 1994; Strijker, 2005). There are potential marginal land resources in Indonesia, one of which is coastal sand. Several islands are covered in millions of hectares of marginal land made up of coastal sand. The prospects for agricultural development are favorable, but they are currently being mismanaged. Due to the low fertility of these lands, technological innovation is required to increase productivity.

Indonesia is an archipelagic state with the world's second-longest coastline, after Canada (Gumbira & Harsanto, 2019). A country's vast coastline is a valuable asset to optimize. With 17,504 islands and a sea area of 7.9 million km^2, or 81% of Indonesia's total land area, coastal sandy land resources can be used to expand agricultural land. According to Samantha (2013), the Geospatial Information Agency estimates Indonesia's coastline total of 99,093 km. Coastal sandy land can be developed into agricultural land, given the vast amount of coastal land that has been underutilized.

Source: Lahan Pasir Pantai (2017). *Lahan pasir pantai.* https://pxhere.com/id/photo/1183739

Figure 11.2 Coastal Sand Marginal Land

Table 11.1 Some of the Characteristics of the Coastal Sandy Land at Bugel Beach, Kulon Progo, DIY Province

Soil characteristics	Value	Description
Soil dry moisture content (%)	0.68	-
pH (H2O) (1:2,5)	6.7	(neutral)
Electrical Conductivity (mS)	0.20	(very low)
Soil C-organic content (%)	0.23	(very low)
Soil Organic Matter (%)	0.40	(very low)
N-total (%)	0.02	(very low)
P-availability (ppm)	16.67	(high)
K-availability (me 100 g^{-1})	0.03	(very low)
Ca-availability (me 100 g^{-1})	0.63	(very low)
Na-availability (me 100 g^{-1})	0.29	(low)
Mg-availability (me 100 g^{-1})	0.18	(very low)
Cation Exchange Capacity (me 100 g^{-1})	3.81	(very low)
Sand fraction (%)	98.5	
Dust fraction (%)	1.5	Sandy land
Clay fraction (%)	1.0	
Soil volume weight (g cc^{-1})	1.79	(bit high)
Soil density (g cc^{-1})	2.75	(bit high)

Source: Kertonegoro et al. (2007); Subrata et al. (2016)

As shown in Table 11.1, coastal sandy land is marginal land with low productivity characteristics, including sandy texture, loose structure, low nutrient content, low cation exchangeability, low water holding capacity, very high evaporation rate, and very minimal nutrients, containing clay and dust (Budiyanto et al., 2020; El Sayed Said et al., 2020; Xue et al., 2016). As a result, the buffering capacity for water and fertilizer is deficient (Minasny & McBratney, 2018). The sandy soil easily drains water at around 150 cm per hour, affecting the root system and water depth (Basso et al., 2013). On the other hand, sandy soils have a limited capacity to store water, storing only about 1.6–3% of available water (Yost & Hartemink, 2019). The coastal area's wind is powerful, ranging between 4.9–5.1 m sec^{-1} (Table 11.3). At that speed, the wind easily uproots roots and knocks plants over, and it can carry salt particles that can obstruct plant growth (Downs & Hellmers, 1975).

Temperatures in coastal areas can reach 43°C during the day, with humidity reaching 39% (Table 11.2), while rainfall is extremely low, around 86–378 mm year^{-1} (Table 11.3). This results in groundwater loss due to extremely high evaporation rate.

Table 11.2 Average Temperature (°C) and Humidity (%) for 3, 6, 9, and 12 Months

Time	Temperature (°C)				Average	Humidity (%)				Average
	3	6	9	12		3	6	9	12	
Morning (06.00–07.00)	28	30	28	29	28.75	69	65	69	67	67.50
Noon (12.00–13.00)	45	43	45	42	43.75	39	38	39	40	39.00
Afternoon (17.00–18.00)	34	34	35	31	33.50	58	58	61	63	60.00

Source: Subrata et al. (2016)

Additionally, coastal sandy land is defined by a soil composition predominantly composed of sand (>80%). The availability of plant nutrients, particularly nitrogen, is extremely low. Coastal dunes are also highly porous. As a result, chemical fertilizers are easily washed out of the root zone and lost. Another characteristic is cation exchange capacity, and soil biota has a very low standard of living.

Table 11.3 Average Rainfall (mm), Long Sunshine (%), and Wind Velocity (m sec-1)

Time	Rainfall (mm)				Long Sunshine (%)				Wind Velocity (m sec^{-1})			
	2019	2018	2017	2016	2019	2018	2017	2016	2019	2018	2017	2016
Jan	427	334	249	227	92	89	94	90	4.84	4.3	5.78	5.04
Feb	226	175	208	521	89	94	87	88	4.85	5.08	4.29	5.1
Mar	511	133	137	594	94	90	88	86	5.16	5.17	4.83	5.29
Apr	89	59	149	461	90	91	89	94	4.54	5.97	4.1	4.73
May	8	14	74	48	91	87	94	83	4.96	6.5	5.03	4.35
Jun	0	9	29	416	89	88	89	94	4.29	5.04	5.09	5.29
Jul	0	0	2	84	94	89	94	90	4.83	4.64	5.08	5.17

Time	Rainfall (mm)				Long Sunshine (%)				Wind Velocity (m sec^{-1})			
	2019	2018	2017	2016	2019	2018	2017	2016	2019	2018	2017	2016
Aug	2	0	0	41	94	94	90	91	4.1	4.6	4.3	5.08
Sep	0	5	62	407	94	90	89	94	4.83	5.03	6.5	5.04
Oct	0	0	65	372	90	94	94	90	5.04	4.35	5.29	4.87
Nov	99	202	447	808	91	90	90	88	5.78	4.29	4.83	4.1
Dec	270	102	124	566	87	91	88	82	6.5	6.2	6.7	6.9
Ave	136.0	86.8	128.8	378.7	91.2	90.5	90.5	89.1	4.9	5.1	5.2	5.1

Source: Meteorology, Climatology, and Geophysical Agency Indonesia (2022)

D. Innovation in Management Technology Coastal Sandy Lands

Coastal sandy lands in the south of Java have not been yet used extensively as agricultural land in the last decade. This is because the land is made of sand, has a high wind speed, and contains salt, making it unsuitable for agriculture, particularly food crops. However, coastal land is potential as agricultural land for food crops and horticulture in the last decade, despite its low productivity (Kurniasih et al., 2021; Parwata et al., 2013; Putra et al., 2017a). This demonstrates the potential for developing coastal sandy lands throughout Indonesia as an option for agricultural land expansion programs.

Through technology and community empowerment, efforts can be made to utilize, improve, and increase the fertility of agricultural land in naturally less productive coastal sand areas. The first step toward using this arid land is to manipulate the soil by adding soil enhancers such as clay, lime, zeolite, manure, or compost to improve the soil's physical, chemical, and biological properties. Soil improvement services can be provided at least once a year, if not more frequently. Adding clay has increased clay content, and soil aggregation in coastal sandy areas. According to Putra et al. (2020), applying organic manure at a rate of 30 tons $hectare^{-1}$ can increase the C-organic content by 7.8%. Meanwhile, zeolite application can improve soil characteristics by increasing clay content, between pF 4.2 and 2.54, moisture-holding capacity, volume weight, specific gravity, soil pH, nitrogen, phosphorus, and potassium availability from 11.25% to 23.9%, respectively (Rajiman et al., 2021).

Due to the low biological fertility of coastal sandy soil, biological fertilizers are the best technology to apply. Soybean plants increased the number of root nodules by up to 120% and seed yield by 68% when inoculated with *Rhizobium japonicum* bacteria (Purwaningsih et al., 2019). *Trichoderma asperellum* and *Trichoderma* spp., free-living fungi found in soil and root ecosystems, have also been studied in coastal sandy areas. Trichoderma inoculation of shallots in sandy coastal soils can increase fresh shallot yields by 21–25% (Setyaningrum et al., 2019).

Irrigation of the coastal sand area will require the construction of several communal wells (Figure 11.3). Communal wells are a network of irrigation wells and water reservoirs connected approximately 10 m apart. Pumps deliver well water directly to the land via pipes connected in an open and closed system. With the availability of shallow water sources, it is possible to anticipate drought when conducting plant cultivation (Yuwono, 2009). Maintaining soil moisture requires careful management that considers the presence of freshwater sources. Micro-irrigation can also be used to conserve water. Micro-irrigation is a type of irrigation that delivers water directly to the root zone of plants. Drip irrigation, micro sprays, mini sprinklers, and subsurface irrigation are all types of micro-irrigation. Micro-irrigation systems are more effective and efficient in water use than conventional irrigation systems. Micro-irrigation using various models has been shown increased shallot yields from 2–4 tons ha^{-1} to approximately 7–9.4 tons ha^{-1}. Chili commodities can increase crop yields from 8 tons ha^{-1} to 17 tons ha^{-1} by extending the harvest season from 12 to 19 times (Indradewa et al., 2021).

Tree planting in the zone adjacent to the beach must occur concurrently with the rest of the coastal area (0–200 m). Planting trees can generate biomass that can be used to replenish the soil's

Source: Amelia (2012); Department of Soil Science-Universitas Sebelas Maret (2021)

Figure 11.3 Communal Wells System in Coastal Sandy Land

organic matter, improve the microclimate, break wind from the sea, and prevent the spread of salt carried by the wind (Yuwono, 2009). Wind speed reduction alters the microclimate within the protected zone. The temperature will drop, and the air humidity will rise, decreasing water loss via evapotranspiration (Sunaryo & Darini, 2010). Numerous plant species that grow along the coast and act as a barrier include pandan laut (*Populneatectorius*), pandan wong (*Pandanus* sp.), keben (*Barringtonia asiatica*), ketapang (*Terminalia catappa*), waru laut (*Hibiscust iliacerus*), borogondolo (*Hernandia peltata*), nyamplung (*Calophyllum inophyllum*) and cemara laut (*Casuarina equisetifolia*) (Mile, 2007).

Cropping patterns are appropriate for coastal sand farming due to the season and low rainfall. Cropping patterns enhance crop productivity during certain seasons, and farmers can forecast the types and varieties of crops that will thrive during that season. Crop rotation or relay cropping can effectively control pests, diseases, and weeds, and improve soil fertility (He et al., 2019). Additionally, cropping patterns can be used to determine the optimal variety to harvest at the optimal price-to-profit ratio (Pandit et al., 2018).

Coastal sand farming can also benefit from multiple cropping systems. Due to coastal sandy land's relatively rapid drainage rate, watering must be more intensive. Fertilizer application is also increased due to the fertilizer's increased evaporation rate. Intercropping has been shown to increase the Land Equivalent Ratio (LER). The best LER value was 1.47 for intercropping upland rice and mung beans (Subrata et al., 2016), 1.89 for intercropping upland rice and soybeans (Putra et al., 2017b), and 1.13 for tomatoes and cabbage (Rusbiyati et al., 2018). Multiple cropping can increase crop efficiency in fertilizer, watering, and pesticide use. Additionally, even with a small land area, farmers can maximize their harvests because they can plant two or more crops in a single planting season, increasing farmers' income.

E. Conclusion

Although the end of the COVID-19 pandemic is unknown, its impact has been felt thus far. This will directly affect the community's food security, such as purchase power eroding, food prices increasing, and there may be a food shortage or insufficient supply. On the other hand, with its enormous population, Indonesia needs to reconsider efforts to increase the availability of high-quality food ingredients in both quantity and quality. Increasing cultivation on marginal coastal sandy land is the best option for increasing food availability in Indonesia's declining productive land. Indonesia, which has the world's second-longest coastline, can capitalize on the potential of coastal sandy land as a new chapter in agricultural production following the COVID-19 pandemic and into the future.

References

Amelia, K. (2012). *Potensi tersembunyi pantai selatan Yogyakarta*. https://reispirasi.wordpress.com/2012/02/25/potensi-tersembuyi-pantai-selatan-yogyakarta/

Anonim. (2017). *Lahan pasir pantai*. https://pxhere.com/id/photo/1183739

Basso, A. S., Miguez, F. E., Laird, D. A., Horton, R., & Westgate, M. (2013). Assessing potential of biochar for increasing water-holding capacity of sandy soils. *GCB Bioenergy*, *5*(2), 132–143. https://doi.org/10.1111/gcbb.12026

Budiyanto, G., Aini, L. N., & Sari, S. A. (2020). Land suitability for soybean (*Glycine max* (L.) Merill) in sandy coastal land of Parangtritis, Bantul

Regency. *IOP Conference Series: Earth and Environmental Science*, *458*(1), 012007. https://doi.org/10.1088/1755-1315/458/1/012007

Chrisendo, D., Krishna, V. V., Siregar, H., & Qaim, M. (2020). Land-use change, nutrition, and gender roles in Indonesian farm households. *Forest Policy and Economics*, *118*, 102245. https://doi.org/10.1016/j.forpol.2020.102245

Department of Soil Science-Universitas Sebelas Maret. (2021). *Automasi irigasi di lahan pasir pantai Kabupaten Bantul untuk meningkatkan produktivitas tanaman budidaya.* https://ilmutanah.fp.uns.ac.id/automasi-irigasi-di-lahan-pasir-pantai-kabupaten-bantul-untuk-meningkatkan-produktivitas-tanaman-budidaya/

Downs, R. J., & Hellmers, H. (1975). *Environment and the experimental control of plant growth*. Academic Press. https://doi.org/10.1016/B978-0-12-221450-9.X5001-8

El Sayed Said, M., Ali, A. M., Borin, M., Abd-Elmabod, S. K., Aldosari, A. A., Khalil, M. M. N., & Abdel-Fattah, M. K. (2020). On the use of multivariate analysis and land evaluation for potential agricultural development of the northwestern coast of Egypt. *Agronomy 10*(9), 1318. https://doi.org/10.3390/agronomy10091318

Food and Agriculture Organization (FAO). (2020). *Agricultural land per capita*. https://ourworldindata.org/grapher/agricultural-area-per-capita?country=Southeast+Asia~IDN~THA~MYS~VNM~SGP~OWID_WRL

Dewan Ketahanan Pangan, Kementerian Pertanian (Food Security Council, Ministry of Indonesia Agriculture) and World Food Programme (WFP). (2015). *Food security and vulnerability atlas of Indonesia 2015.* https://reliefweb.int/sites/reliefweb.int/files/resources/wfp276251.pdf

Grebmer, K. von, Bernstein, J., Patterson, F., Wiemers, M., Chéilleachair, R. N., Foley, C., Gitter, S., Ekstrom, K., & Fritschel, H. (2019). *Global hunger index: The challenge of hunger and Welthungerhilfe and Concern Worldwide*. https://www.globalhungerindex.org/pdf/en/2019.pdf

Gumbira, G., & Harsanto, B. (2019). *Decision support system for an eco-friendly integrated coastal zone management (ICZM) in International Journal on Advanced Science, Engineering and Information Technology, 9(4), 1177–1182*. DOI:10.18517/ijaseit.9.4.9484

He, H., Liu, L., Munir, S., Bashir, N. H., Wang, Y., Yang, J., & Li, C. (2019). Crop diversity and pest management in sustainable agriculture. *Journal of Integrative Agriculture*, *18*(9), 1945–1952. https://doi.org/10.1016/S2095-3119(19)62689-4

Indradewa, D., Alam, T., Suryanto, P., Kurniasih, B., Wirakusuma, G., Sartohadi, J., Ilmiah, H. H., Rogomulyo, R., Respatie, D. W., & Setiawan, A. B. (2021). *Inovasi teknologi agronomi di lahan pasir pantai*. Gadjah Mada University Press.

Kertonegoro, B. K., Shiddieq, D., Sulakhudin, S., & Dariah, A. (2007). *Optimalisasi lahan pasir Pantai Bugel Kulon Progo untuk pengembangan tanaman hortikultura dengan teknologi inovatif berwawasan agribisnis*. Seminar Nasional Sumberdaya Lahan dan Lingkungan Pertanian, 10.

Kurniasih, B., Hasanah, U., Muflikhah, N., & Tohari. (2021). Rice cultivars responses to different salinity levels at coastal agricultural land of Yogyakarta. *IOP Conference Series: Earth and Environmental Science*, *686*(1), 012026. https://doi.org/10.1088/1755-1315/686/1/012026

Meteorology Climatology and Geophysical Agency Indonesia. (2022). *Data online - pusat database - BMKG*. https://dataonline.bmkg.go.id/akses_data

Meyer, M. A., & Früh-Müller, A. (2020). Patterns and drivers of recent agricultural land-use change in Southern Germany. *Land Use Policy*, *99*, 104959. https://doi.org/10.1016/J.LANDUSEPOL.2020.104959

Mile, M. (2007). Pengembangan spesies tanaman pantai untuk rehabilitasi dan perlindungan kawasan pantai pasca tsunami. *Info Teknis*, *5*(2), 1–8.

Minasny, B., & McBratney, A. B. (2018). Limited effect of organic matter on soil available water capacity. *European Journal of Soil Science*, *69*(1), 39–47. https://doi.org/10.1111/EJSS.12475

Pandit, N. R., Mulder, J., Hale, S. E., Zimmerman, A. R., Pandit, B. H., & Cornelissen, G. (2018). Multi-year double cropping biochar field trials in Nepal: Finding the optimal biochar dose through agronomic trials and cost-benefit analysis. *Science of The Total Environment*, *637–638*, 1333–1341. https://doi.org/10.1016/J.SCITOTENV.2018.05.107

Parwata, I. G. M. A., Indradewa, D., Yudono, P., Kertonegoro, B. D., & Kusmarwiyah, R. (2013). Physiological responses of *jatropha* to drought stress in coastal sandy land conditions. *Makara Journal of Science*, *16*(2), 115–121. https://doi.org/10.7454/MSS.V16I2.1406

Purwaningsih, O., Kusumastuti, C. T., Nugroho, Y. S., & Morib, C. Y. (2019). The effect of *Rhizobium japonicum* on the growth of soybean cultivars in coastal area. *Ilmu Pertanian (Agricultural Science)*, *4*(1), 33–39. https://doi.org/10.22146/IPAS.36371

Putra, F. P., Yudono, P., & Waluyo, S. (2017a). Growth and yield of upland rice under intercropping system with soybean in sandy coastal area.

Ilmu Pertanian (Agricultural Science), *2*(3), 130–136. https://doi.org/10.22146/ipas.25215

Putra, F. P., Yudono, P., & Waluyo, S. (2017b). *Pertumbuhan dan hasil tanaman serta komposisi gulma di berbagai proporsi populasi pada sistem tumpangsari padi gogo + kedelai di lahan pasir pantai* [Thesis, Gadjah Mada University]. http://etd.repository.ugm.ac.id/penelitian/detail/128681

Putra, S. S., Putra, E. T. S., Widada, J., & Sulistyaningsih, E. (2020). *Aplikasi pupuk kandang dan mikoriza pada budidaya cabai keriting (*Capsicum annum *L.) secara organik di lahan pasir pantai* [Thesis, Gadjah Mada University]. http://etd.repository.ugm.ac.id/penelitian/detail/187060

Rajiman, R., Yekti, A., & Munambar, S. (2021). Pengaruh dosis zeolit terhadap karakteristik tanah dan hasil cabai merah di lahan sub optimal pasir pantai. *Jurnal Penelitian Pertanian Terapan*, *21*(2), 99–107. https://doi.org/10.25181/JPPT.V21I2.2009

Rusbiyati, A., Rogomulyo, R., Muhartini, S. (2018). Pengaruh proporsi tanaman terhadap pertumbuhan dan hasil tumpangsari kubis (*Brassica oleracea* var. *Capitata* L.) dengan tomat (*Lycopersicum esculentum* Mill.). *Vegetalika*, *7*(4), 26–38. https://doi.org/10.22146/VEG.41164

Samantha, G. (2013). *Terbaru: Panjang garis pantai Indonesia capai 99.000 kilometer*. https://nationalgeographic.grid.id/read/13218380/terbaru-panjang-garis-pantai-indonesia-capai-99000-kilometer

Saputro, T.E., Rahmawati, N. & Azizah, R. (2015). *Agriculture research center di lahan pasir pantai baru Yogyakarta (dengan pendekatan Green Architecture)*. (Skripsi, Universitas Muhammadiyah Surakarta), 1–14. http://eprints. ums.ac.id/id/eprint/38659

Scherr, S. J., & Hazell, P. B. R. (1994). *Sustainable agricultural development strategies in fragile lands.* https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/125535/filename/125566.pdf

Secretariat General Ministry of Agriculture. (2020). *Statistik data lahan pertanian tahun 2015-2019*. https://satudata.pertanian.go.id/assets/docs/publikasi/Buku_Statistik_Data_Lahan_tahun_2015-2019.pdf

Setyaningrum, T., Indradewa, D., Priyatmojo, A., & Sulistyaningsih, E. (2019). *Pertumbuhan dan hasil bawang merah di lahan pasir pantai dengan penambahan pupuk kandang dan inokulasi* Trichoderma asperellum [Dissertation, Gadjah Mada University]. http://etd.repository.ugm.ac.id/penelitian/detail/170230

Strijker, D. (2005). Marginal lands in Europe—causes of decline. *Basic and Applied Ecology*, *6*(2), 99–106. https://doi.org/10.1016/J.BAAE.2005.01.001

Subrata, B. A. G., Yudono, P., & Waluyo, S. Putra, E.T.S (2016). *Pengaruh proporsi populasi padi gogo dan kacang hijau dalam tumpangsari terhadap hasil dan komposisi gulma di lahan pasir pantai* [Thesis, Gadjah Mada University]. http://etd.repository.ugm.ac.id/penelitian/detail/103173

Sunaryo, Y., & Darini, M. T. (2010). Crop cultvation strategies in coastal sandy area especially in Yogyakarta. *The International Seminar on "Development of Coastal Sandy Area Towards Sustainable Agriculture*, 13–14.

Sunghening, W., Tohari, T., & Shiddieq, D. (2013). Pengaruh mulsa organik terhadap pertumbuhan dan hasil tiga varietas kacang hijau (Vigna radiata L. Wilczek) di lahan pasir Pantai Bugel, Kulon Progo. *Vegetalika, 1*(2), 54–66.

Xue, S., Lewandowski, I., Wang, X., & Yi, Z. (2016). Assessment of the production potentials of *Miscanthus* on marginal land in China. *Renewable and Sustainable Energy Reviews*, *54*, 932–943. https://doi.org/10.1016/J.RSER.2015.10.040

Yost, J. L., & Hartemink, A. E. (2019). Soil organic carbon in sandy soils: A review. *Advances in Agronomy*, *158*, 217–310. https://doi.org/10.1016/BS.AGRON.2019.07.004

Yuwono, N. W. (2009). Membangun kesuburan tanah di lahan marginal. *Jurnal Ilmu Tanah dan Lingkungan*, *9*(2), 137–141.Chapter 12

Chapter 12

IoT and Smart Packaging: A Novel Approach for Managing Food Waste

Hilmy Prilliadi

A. Introduction

It has long been known that massive losses arise in our agricultural supply chain of rising, cultivating, handling, and delivering food to consumers. Food wastes start mostly on the farm, during production, and proceed through handling and wholesaling. Numerous early phase losses are unavoidable, such as weather, pest infestations, molds, wastages, rodent harm, and stockpiling, handling, and shipping failures.

Food waste is a major challenge in developing countries such as Indonesia. The recycling bins and wastes generated are evidence of these conditions. Office and home premise eateries, large and small streetside food stalls, public get-together gatherings, and celebratory

H. Prilliadi
Atatürk University, Turkey, e-mail: prilliadi97@gmail.com

Prilliadi, H. (2022). IoT and smart packaging: a novel approach for managing food waste. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and technology role for Indonesia development.* (191–207). DOI: 10.55981/brin.538.c511 ISBN: 978-623-7425-85-4 E-ISBN: 978-623-7425-89-2

events can generate a huge amount of food waste. Food waste is a common sign of pollution to the world's environmental factors, and causes significant financial loss. According to current research, half of food is wasted globally; each year, approximately one-third of all food produced globally—approximately 1.3 billion tons—is lost or wasted (UNEP, 2020). This figure is expected to rise even further in the future, which is a concern.

The COVID-19 pandemic has compelled many restaurants, coffee shops, bars, and other food warehouses to shift from on-site selling to e-commerce with non-contact delivery or roadside pick-up. Many food production lines, particularly meat production plants, were forced to close given the high rates of infection caused by close working distances and long hours of work. For instance, over a thousand cases of COVID-19 were confirmed from a meat factory in northwest Germany in the summer of 2020 (Deutsche Welle, 2020). As a result of the disruption, there has been an increase in food waste and economic losses. According to Andre Laperriere, Executive Director of Global Open Data for Agriculture and Nutrition (GODAN), the pandemic has increased food waste in developed countries by 30% to 40%. Similarly, when supply chains fail and restaurants and other infrastructures (schools, universities, and the hotel industry) are forced to close, several farmers are left with massive amounts of unsellable harvests (fruits and vegetables), resulting in economic losses, high waste (disposal dairy, meat, and fresh produce), and a decrease in sustainable development (Kawamura, 2020). These problems highlight the importance of strategy and systemic changes that encourage food supply diversion when the supply chain is disrupted.

Amidst large increases in environmental consciousness in the world's developing countries in recent years, there seems to be little real consideration given to food waste as an environmental problem, nor any endeavor to secure it within a broader sustainability perspective. Indonesia lost annually 115–184 kilograms of food per capita on average, which was concluded by the National Development Planning Agency (BAPPENAS) in partnership with the World Resources Institute and the management advisory firm Waste for Change. According to their study, yearly food waste causes economic losses of IDR 213–551 trillion, equivalent to 4–5% of Indonesia's GDP. In the same period, this generation also produces greenhouse gases (GHG) emissions of 1,702.9 megatons CO^2, equivalent to 7.29% of Indonesia's average annual GHG emissions. The impact of food waste at the retail and consumer levels adds to the global footprint of food emissions. If food waste were a nation, it would be world's third-largest producer of greenhouse gases, according to Flanagan et al. (2018). The total energy loss from food waste is equivalent to the food portion of 61–125 million people per year. The data also show that grains account for the majority of food loss and waste, while vegetables are the least efficiently processed, accounting for 62.8% of Indonesia's total domestic supply of vegetables (BAPPENAS, 2021).

Consumers gave more than 30 causes for wasting food, the most frequent being cooking food excessively, not making proper food plans, purchasing too much, shifting objectives, not eating meals at the proper time, and not being interested in the meals cooked. Consumer uncertainty over date coding was also commonly discussed in the WRAP (Waste and Resources Action Programme) studies, with one in five consumer robustly dismissing meals near to its 'best before' date, even though it was still good to eat. Consumers have failed to keep up with food, such as what it is, where it comes from, and how it has been managed to produce. Consumers believe that food is cheap and readily available, so they could sometimes make a strong disconnect, allowing them to throw uneaten food apart while claiming that they do not waste food (WRAP, 2009). Since most consumers are in neglect regarding food waste and are unaware of its ecological consequences, they have the opportunity to educate themselves to improve the situations, for instance by generating awareness about the environmental impact of food packaging, creating an environmental-friendly food packaging system, and providing the food waste solution through the Internet of Things (IoT).

B. Food Waste and Food Packaging

The primary function of packaging is to protect the goods from the harmful effects of exposure and use in the external environment. Furthermore, packaging can be an important promotional platform to communicate with customers. It emerges in a number of various forms and, as a user interface, offers consumers simplicity and efficiency of use. Product packaging has four primary functions: protection, communication, convenience, and containment. For instance, packaging used in food products typically functions as follows:

a. To keep the product from leakage or breaking and safe from contamination.
b. To convey critical knowledge about food products and their nutrient content, as well as to give food preparation directions.
c. To make life easier for customers, such as allowing them to heat it in the microwave.
d. To assist in the facilitation of transportation and handling.

Conventional packaging, however, is no longer adequate due to high consumer expectations, increasing product diversity, and, most lately, national and international development to promote a circular economy and reduce the carbon footprint of consumer products. To meet the diverse needs of consumers, innovative and smart packaging with increased functionality is undoubtedly required. Some examples are worth trying, such as offering packaged foods with fewer preservatives, creating products that meet higher regulatory standards, and designing package system that enables traceability from inception to delivery, representing protection against lawsuits. Furthermore, smart packaging can facilitate market expansion in the global context, aid in implementing more strict domestic and international food safety standards, and even safeguard against potential food bioterrorism threats.

Smart Food Packaging

Smart packaging is a concept that has emerged in the literature over the last two decades and is frequently used. It refers to the packaging systems used for perishable goods such as food, beverages, pharmaceuticals, cosmetics, and etc. According to Vanderroost et al. (2014), smart packaging can be refers to intelligent and active. Smart packaging provides a complete packaging solution that, on the one hand, monitors and responds to changes in the product or the environment.

In smart packaging, chemical sensors or biosensors control the quality and safety of food from the producer to the consumer. Smart packaging, like the other innovations discussed thus far, employs a variety of sensors to control food quality and safety, including identifying and evaluating freshness, bacteria, spillages, carbon dioxide, oxygen, total acidity, time, and temperature.

A smart packaging platform's specific functionality varies and depends on the product being packaged, such as food, beverage, medicine, or many health and household supplies. Consequently, the precise circumstances for monitoring, delivering, or adjusting would differ. Smart packaging allows producers, resellers, or consumers to follow a product's life cycle and evaluate it. It also helps mitigate the environmental impact within or outside the packaging by providing real-time information to the producer, reseller, or consumer about the product's status.

Application of Smart Packaging

Smart packaging innovation has a variety of uses, from food quality and drug consumption monitoring to postal mailing tracking via embedded security labels. The possibility is viewed as a value-added benefit from the consumer's perspective. In today's world, where people are always connected to the internet, a new approach to monitoring and controlling purchased items via linked apps has emerged as a significant commercial opportunity for businesses looking to increase customer satisfaction. Smart packaging can also reveal supply chain waste and inefficiency, save expenses, improve product quality, and increase profitability.

The challenge in implementing smart packaging is that food waste can be generated at various stages in the food supply chain. Once food reaches the supply chain, packaging becomes vital in maintaining its security, freshness, and high quality. Developing integrated packaging sensors can help amidst the handling of recovered packaging and thus hopefully reduce food waste. Such sensors can retain data such as packaging material, food expiry date, oxygen concentration, temperature, and pH level. Through the new technology known as Internet of Things, this data may be shared with food producers, distributors, and even packaging recycling companies.

Food waste can occur at any point along the food supply chain. Consumer behavior, for example, has contributed significantly to the increased amount of food waste at the end-of-life stage. Contamination and damage due to inadequate safety procedures, overstocking items in shops, incorrect tagging, and missing product details are just a few of the main causes of food waste in the supply chain. Perishable bakery and culinary products account for a significant portion of food waste, with repercussions throughout the supply chain (Mena et al., 2011). The major cause of this issue is frequently an excess excessive supply that surpasses demand, a shorter product shelf life, or inadequate storage conditions. It is also worth noting that the root causes of food loss and waste differ between developed and undeveloping countries. For instance, in developing countries, roughly 40% of food is lost during the production phase, while in developed countries, 40% of food waste is generated throughout the transportation, selling, and consuming stages (Wunderlich & Martinez, 2018). Attention has been drawn to the increasingly alarming rates of food loss and waste (FLW. Food waste also connects with public health issues regarding food security, safety, and nutrition, negatively influencing socioeconomic development. Food waste, for example, can result in higher food prices, reduced incomes, and increased poverty. Furthermore, wasteful activities can harm the environment, including land, freshwater, oceans, forests, and wildlife.

- The Impact of Smart Packaging on Food Waste
  The term "smart packaging" is frequently used interchangeably or incorrectly when discussing packaging systems. The term "smart packaging" refers to both intelligent and active packaging. Smart packaging can detect external and internal shifts in a product and respond (actively) by interacting with an external interface (electric or optical). The main goal of smart packaging development is to improve the shelf life of the product and its health, transfer factual information to consumers, optimize safety, and enhance product traceability as it moves through the supply chain. The primary alternative to traditional packaging is active packaging, which aims to encourage and maintain high quality while extending food product freshness. To accomplish this, various components can be combined to form a scheme capable of releasing and absorbing materials from and into food products, thereby reducing waste. Smart packaging, on the other hand, is used primarily to monitor and check the status of packaged foods, as well as to collect and provide data on product conditions during storage and transportation procedures. As a result, a smart packaging system employs some common components, such as gas detectors, freshness and maturation indicators, temperature-time indicators (TTI), and radio frequency identification (RFID) devices.

Technological advancement in food safety issues is one of the most important steps in preventing food waste. Examples include energy-efficient and temperature-controlled storage solutions, new packing material and design features, and sophisticated tracking systems. Improved and innovative techniques, in particularly active packaging and smart packaging, have proven to be valuable tools for food waste reduction while also ensuring food safety and fulfilling customer demands. Even though devices for smart packaging, such as electrochemical sensors, E-Tongues, and E-Noses, have advanced significantly, today's devices are typically complicated and costly, and are not even prepared to be integrated with actual packaging. The statements "best used before" and "sold by" or "used by" have become the norm in today's food industry, but they struggle to provide data on the status of the food within the packet, so "dynamic shelf-life systems" must be initiated for easier understanding. In this regard, the environmental sustainability of food packaging is a concern; thus, research on mapping the ecologic performance evaluation of packaging is critical to deliver guidelines to packaging design experts.

Advanced inventions are being developed urgently for food and nutrition security. The use of modern technology in smart packaging has appeared. It has lately been accepted by the food and pharmaceutical applications as a tool to extend shelf life of food. It can be used for manufacturing operations, reducing food waste, eliminating additives, and, most importantly, offering better quality and availability to ensure safety and consumer satisfaction. Developing advanced food packaging systems, specifically targeting chemical and biological markers in food remains a significant challenge. The selection of a target marker is influenced by prior knowledge of the specific microbial agent and its presence under diverse circumstances in different food products, including the transmission of reactants generated during the spoilage stage.

Food contamination is a delicate system that can be triggered by a variety of physical, chemical, or enzymatic processes, as well as pathogenic activity. pH changes, as well as the presence of toxic materials, toxic fumes, gases, and mucus, may be caused by microbial population and metabolic activity. Chemical reactions such as oxidation, irradiation, and lipolysis can generate unwanted flavors and side effects. In addition to intrinsic parameters, external variables (temperature, pH, and humidity) can influence food waste chemically, physically, and biologically (physicochemical and structural). Food spoilage Food spoilage, ripeness, rancidity, microwave maturity and RFID are just a few technologies available to help reduce food spoilage.

Smart RFID tags are intended to assess the quality of food products using a combination of sensing elements. These RFID tags could identify changes in food properties, such as food volatiles, permeability, pH, viscosity, dielectric constant and gases using chemical equipment such as responsive coatings, optical labels, litmus paper, and pH or conductivity electrodes. Some examples include applying various food volatile responsive films to RF constructions and sensing the change in response through color changes of certain dyes caused by volatiles from food or due to changes in food pH for colorimetric sensing, as well as checking variants in the dielectric constant of food due to spoilage (Potyrailo et al., 2014). As a byproduct of degradation, food naturally emits volatile components. Byproducts of microbial activity that can be used as predictors of food contamination include trimethylamine, ammonia, dimethylamine, carbon, sulfate substances, histamine, and ethanol. Solid-phase microextraction was combined with gas chromatography-mass spectrometry, UV-VIS spectroscopy, and near-infrared spectroscopy to detect and quantify volatile compounds in foods. Nonetheless, these tools are expensive, complicated, and time-consuming, especially when compared to smart sensor-enabled RFID, a cost-effective, unobtrusive, and user-friendly food packaging technique. Furthermore, because it contains identifiers that can interact with food ingredients and metabolic products in extrinsic environmental factors, this packaging system can potentially be a powerful tool for reducing food waste.

According to a Boston Consulting Group (BCG) report, there are already slow actions to reduce food waste throughout the supply chain due to a lack of technology, effort, regulatory frameworks, and collaboration across the value chain. Infrastructure upgrades and supply chain efficiency are only estimated to save US$ 270 billion (in value) or US$ 1.5 trillion by 2050. Smart packaging systems can help with this by reduce food waste and enable more sustainable supply chain management. For example, data carriers will aid in linking information in the supply chain to improve process efficiency and ensure traceability, automation, theft prevention, or counterfeit protection. RFID will help with inventory control and traceability, improving food quality and safety throughout the logistics system. TTI will also aid in precise temperature characteristics or cold storage tracking throughout the supply chain. As a result, smart packaging will not only drastically reduce waste and loss by improving supply chain distribution efficiency and accurately detecting food spoilage, but it will also address health and safety concerns. Moreover, not only can smart packaging reduce the period and content costs associated with analyzing packaged foods, but it will also save cost due to its capability to eliminate food waste. The proposed bioactive smart packaging is expected to become a future trend, creating new opportunities, increasing market demand, and gaining acceptance from more food producers.

Continuous improvement in food waste data collection is expected to aid in the decision-making and promotion of this packaging design. Furthermore, modern manufacturing innovations are designed to decrease factory production costs and improve the integration of smart devices into today's packaging lines. Additional research into the issue of safety and feasibility, as well as the prospect of inclusion in various applications, is required. Finally, customer must be well educated about these innovative packaging systems, including their costs and benefits, as well as their willingness to shop.

C. Internet of Things-Based Food Waste Management

The term "Internet of Things" is used as a catch-all phrase to refer to various aspects of the physical extension of the internet and the web via the massive implementation of spatially distributed equipment with integrated recognition, detection, and/or actuation functionality. The Internet of Things envisions a world where physical and digital objects can be connected using suitable information communication technologies, allowing for the development of innovative class applications.

The Internet of Things (IoT) is an exchange of information in which everyday items use technology to electronically connect and engage with one another and their users for the advantage of the users (Deokar et al., 2018). The Internet of Things (IoT) comprises physical components with digital counterparts and virtual representations. In this way, things gain context awareness and can sense, connect, communicate, and exchange data, information, and knowledge. The use of virtual elements as a central planning, interoperation, and coordination tool has the potential to transform food supply chains.

IoT in supply chain management is very appealing because ineffective supply chain processes cannot respond appropriately to a constantly changing situation caused by globalized society (Ben-Daya et al., 2019). Efficiency, which is highly important in the Food Supply Chain (FSC), can help reduce and prevent resources-food waste.

Smart packaging with sensors could alert users to the use of IoT technology while also reducing food waste. Smart packaging technologies can detect the absence or presence of glucose, ethanol, volatile gases such as ammonia in fish, pathogenic substance, color degeneration, and other contaminants. Packaging labels with a variety various time-temperature indicators (TTI) have been developed. However, the greatest barrier to this technology implementation, is a lack of technical understanding of smart packaging and IoT, and the cost of implementation. Intelligent fridges have been developed alongside smart packaging, smart mobile devices, and the associated applications (Vanderroost et al., 2014), so this is now regarded as a in greater concern.

Organizational food waste management is difficult for anyone in the food service industry. This problem could be well managed using the Internet of Things (IoT) This innovation has progressed from the stage of scientists to the phase of implementation, making it a critical application technology with the potential to deliver smart services.

As the Internet of Things (IoT) and devices have grown in popularity, security has become increasingly important. As more end items or organizations are connected to the Internet of Things (IoT), more generated data must be transmitted over the server. The information is then analyzed and evaluated to be effectively used. Because of the resource constraints of Internet of Things (IoT) tools, different security has been highlighted for various end tools. The Internet of Things (IoT) is gaining traction in the focused intelligent transport system, in which the vehicles connect smartly with one another. When the vehicles connect smartly, there is a much lower risk of a fatal collision. The Internet of Things (IoT) assigns a different IP address to each device, it is very difficult to hack.

Physical entities in an IoT environment are intelligent items that have the following characteristics:

1. Possess a physical embodiment as well as a set of physical characteristics (e.g., size, shape).
2. Use a basic communication skills, including the opportunity to discover, recognize, and respond to new messages.
3. Have a unique identifier associated with at least one name (human-readable description) and at least one address (machine-readable number or string).
4. Device can detect observed processes (for example, temperature and humidity) or trigger actions affecting physical reality (actuators).

Since smart technologies generate a large amount of data, data capture is essential. Data collecting hardware with capability to input and gathering data is a critical component of an IotT device. The following are some notable examples (Lehmann et al., 2012):

a. Data collection during the "food cycle," which includes agricultural production, post-harvest storage and handling, food manufacturing, and utilization. This information can be gathered using sensor networks, providing detailed information about processing measurements such as relative humidity, temperature, fertilizer and pesticide usage, farm machine driving lanes, and etc.

b. Capturing transport data, such as position and ambient information from inside and outside the truck, allowing logistics management to evaluate the current situation.

c. Collecting data of product quality indicators such as oxygen, humidity, nitrogen content, or ethylene content in the air around a product as an indicator of perishing fruits and vegetables, which is relevant in storage facilities and during transportation, as well as with users and their perception of food product quality class.

d. Capturing data from a product's packaging (for example, the manufacturer's name) to help with cloud retrieval.

To realize IoT implementation, network access infrastructure must be well-designed. The developed IoT applications would also share connectivity, network components, and a common service platform. These applications are classified into three categories:

Table 12.1 Realization Process of IoT Implementation

Collection	• Processes for observing the real world, collecting actual tangible data on food and the environment, and recreating a common perception of it.
Transmission	• The transmission phase includes mechanisms for delivering recorded data to applications and external servers. As a result, this phase require techniques for connecting to the network through gateways and various techniques (e.g., wired, wireless, satellite), addressing, and routing.
Management and Application	• The managerial and application stage is concerned with analyzing and processing information flows, transmitting data to a DLSP model based on the kinetic Arrhenius model because it is temperature dependent, providing feedback to control applications, and alerting users to potential hazards (short period of time in which food product must be used).

Source: Ostojic et al. (2017)

The first step in IoT implementation is to collect data about the physical environment in which the food product is currently stored (e.g., temperature, humidity) or about objects (e.g., identity of crop, meat, etc.). Data gathering is achieved from the use of multiple sensor systems attached to sensors, cameras, and Global Positioning System (Global Positioning System) terminals, while data collection is normally accomplished through quick connectivity, which may be conducted using open source basic solutions (e.g., ZigBee, Bluetooth) or proprietary solutions (e.g., Z-Wave).

Effective food waste management based on Internet of Things framework not just bring valuable information on the condition of food products at each stage of its life, but also predicts their shelf life. As a result, each participant in the life cycle can forecast the remaining shelf life in the time frame that is important to them. As a result, the consumer can decide whether to stick with the current strategy or modify it to reduce food waste. For instance, if a truck breaks down during the delivery process and the temperature rises above a predetermined threshold, the supplier can recognize shelf life and decide whether to continue with the strategy and make deliveries to department stores or bring it back it to the manufacturer.

D. Summary and Conclusion

This chapter explored the influence of application domains like smart packaging and larger IoT development in reducing food waste. These platforms enable the extension of storage and the transition of duration and product life communication from static coding systems to more real-time applications, albeit at a cost. It could be achieved using effective packaging solutions or IoT systems in smart-enabled packaging technologies. While intelligent applications have the potential to reduce end-user food waste, as discussed in this chapter, there are some drawbacks to consider, such as privacy protection or the threat of hacking, as well as aspects about if the possibility of a knowledgeable entity will influence current behavior in the household, when buying or planning consumption of food.

Packaging has a significant strong involvement in treating food waste, both in terms of delivering food to consumers and providing consumers with better methods of handling their food stock, going resulting in less waste. Food packaging should be reduced in the quest for a less wasteful society, but this can only go so far before having a negative impact. Lighter packaging may be preferable, but only if it results in greater product loss elsewhere. There is a contentious discussion about introducing more packaging if it helps consumers reduce food waste by a more significant factor in the home. The battle to reduce food and packaging waste has evolved beyond simple considerations intended to reduce the immediate weight of packaging.

The packaging alone would not fix the food waste problem. Food-saving packaging efforts indicated in previous sections should certainly help, but consumer awareness and changes in consumer behavior will be the most significant considerations in resolving the problem. Packaging is vital because it communicates how we view our food products to consumers. If food is cheaply packaged, frequently produced in mass amount, and poorly secured, it sends a clear message to the consumer that this is a product with little intrinsic value and can thus be discarded without concern.

Food waste can occur at any point in the food chain, which includes agricultural production, post-harvest handling and storage, manufacturing, delivery, utilization, and disposal. An IoT system can be used to mitigate the severity of this occurrence. This chapter describes an IoT system that predicts interactive shelf life using the kinetic Arrhenius model. One limitation of this model is that shelf life determination is only accurate for the relevant product structure, packaging, and handling condition variety.

However, inside this novel frame of mind, it is feasible to reorient the packaging industry as a strong pro-environmental force with significant sustainability influence and power of product protection and aiding in the prevention of waste. In this worldview, numerous opportunities for true packaging advancement can be coupled with IoT technology, some of which have already been mentioned and recommended here, that are coherent with a long-term sustainable society.

References

BAPPENAS. (2021, Juni 28). *Pengelolaan limbah makanan yang berkelanjutan berkontribusi pada pembangunan rendah karbon di Indonesia*. Indonesia Green Growth. Retrieved December 2021. https://bit.ly/3qzvNKs

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: A literature review. *International Journal of Production Research*, *57*(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140

Deokar, A., Pandhare, A., Patare, A., Lakhwani, N., & Pande, S. (2018). Smart recipe: An innovative way to cook. *International Research Journal of Engineering and Technology (IRJET)*, *5*(3), 531–533.

Deutsche Welle. (2020). *Coronavirus: German slaughterhouse outbreak crosses 1,000*. Deutsche Welle. Retrieved August 30, 2021, from https://www.dw.com/en/coronavirus-german-slaughterhouse-outbreak-crosses-1000/a-53883372

Flanagan, K., Clowes, A., Lipinski, B., Goodwin, L., & Swannell, R. (2018). *SDG target 12.3 on food loss and waste: 2018 progress report*. An annual update on behalf of Champions 12.3, September, 1–28. http://www.https://champions123.org/publication/sdg-target-123-food-loss-and-waste-2018-progress-report

Kawamura, A. G. (2020). *Perspectives on COVID-19 and the food and agricultural system*. Presented at COVID-19 and the Food and Agricultural System, June 19. Retrieved December 23, 2021, from https://www.nationalacademies.org/event/06-19- 2020/COVID-19-and-the-food-and-agricultural-system

Lehmann, R. J., Reiche, R., & Schiefer, G. (2012). Future internet and the agri-food sector: State-of-the-art in literature and research. *Computers and Electronics in Agriculture*, *89*, 158–174. https://doi.org/10.1016/j.compag.2012.09.005

Malik, A., Erginkaya, Z., Ahmad, S., & Erten, H. (2014). Value addition and preservation by fermentation technology. In A. Malik, Z. Erginkaya, S. Ahmad, & H. Erten (Eds.), *Food Engineering Series*. Springer US. https://doi.org/10.1007/978-1-4939-1378-7_13

Mena, C., Adenso-Diaz, B., & Yurt, O. (2011). The causes of food waste in the supplier-retailer interface: Evidences from the UK and Spain. *Resources, Conservation and Recycling*, *55*(6), 648–658. https://doi.org/10.1016/j.resconrec.2010.09.006

Ostojic, G., Stankovski, S., Tegeltija, S., Dukić, N., & Tejić, B. (2017). *Implementation of IoT for food wastage minimisation*. XVII International Scientific Conference on Industrial Systems, 116–121.

United Nation Environment Programme. (2020, November 12). *Worldwide food waste*. Retrieved December 2021, from https://www.unep.org/thinkeatsave/get-informed/worldwide-food-waste

Vanderroost, M., Ragaert, P., Devlieghere, F., & De Meulenaer, B. (2014). Intelligent food packaging: The next generation. *Trends in Food Science and Technology*, *39*(1), 47–62. https://doi.org/10.1016/j.tifs.2014.06.009

Waste and Resources Action Programme (WRAP). (2009, November). *Household food and drink waste in the UK 2009*. Retrieved December 2021, from https://wrap.org.uk/sites/default/files/2020-12/Household-Food-and-Drink-Waste-in-the-UK-2009.pdf.

Wunderlich, S. M., & Martinez, N. M. (2018). Conserving natural resources through food loss reduction: Production and consumption stages of the food supply chain. *International Soil and Water Conservation Research*, *6*(4), 331–339. https://doi.org/10.1016/j.iswcr.2018.06.002

Chapter 13

Smart Food Supply Chain: Recommendations after COVID-19 Pandemic in Agricultural Industry

Nanda Aulia Putri & Fachri Rizky Sitompul

A. Overview of Current Food Crisis

Many countries compete in the food crises resilience period due to the COVID-19 pandemic. To prevent further pandemic, several countries have implemented lockdowns or regulated some areas. This option requires the availability of food in large quantities in each country, which can disrupt the global food supply. Many food-producing countries directly restrict or close the export market of certain commodities to ensure their needs. The World Food Agency (FAO) has warned that the COVID-19 pandemic has paralyzed various sectors so that the economy can trigger a food crisis in multiple countries from April–May 2020 (WFP, 2020). In this situation, the world food market is getting tighter. For instance, countries with largest global wheat

N. A. Putri & F. R. Sitompul
Lunghwa University of Science and Technology, Taiwan, e-mail: nandaauliaputri29@gmail.com

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production, such as Russia, Kazakhstan, and Ukraine, announced the export of basic ingredients for bread. Likewise with rice, the country in Southeast Asia that called the rice granary retains the importance and availability of supplies in his country. In Indonesia, since the government implemented Restrictions Large-Scale Social (PSBB), the policy triggers such condition that force many stalls and shops to be closed and affects the limitation of food access points from production center in agricultural areas to cities. This situation results in agricultural production in upstream and can lead to a drop in food prices, which directly cause harm to farmers, ranchers, and fishermen.

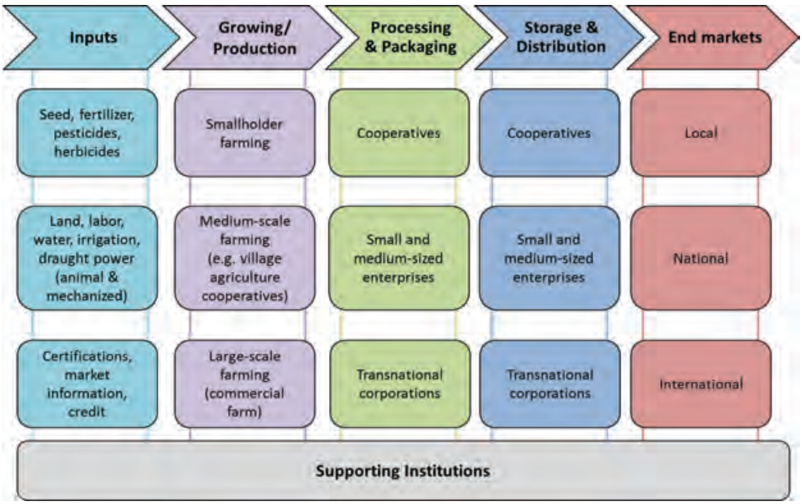
For example, most Indonesian consumers (about 60%) reside in the Jabodetabek region (Jakarta, Bogor, Depok, Tangerang, and Bekasi). At the same time, agricultural commodity producers, husbandry, and fisheries are spread throughout Indonesia. To overcome the long-distance obstacle, a good logistics system is needed by providing good infrastructures (roads, ports) and modern cold chain system for perishable foods. Inter-island trade and inter-regional trade should also be encouraged to take place efficiently. Another problem is the most primary suppliers of food products (farmers, fishers, and ranchers) are small-scale businesses. The relationship between farmers and stakeholders of the value chain is limited to make transactions. Consequently, the primer suppliers find it difficult to change their state to compete.

B. Logistics Situation during COVID-19 Pandemic

There are several food security challenges during the period of the pandemic and post-COVID-19, unevenly distributed food products between regions, consumers (quantity and quality), distribution between provinces and islands, price tends to be unpatterned price, and drought problems.

Based on data produced by Central Statistics Agency (BPS), in 2019, the current year's surplus reached 2.28 million tons, in 2020 the current year surplus reached 1.95 million tons, and in 2021 the current year surplus was estimated to reach 2.21 million tons. The production surplus is safe enough to cover the production deficit in January of around 1.29 million tons. In February 2022, it is estimated that there will be a surplus in the current month because production has exceeded the demand, which is around 1.17 million tons.

In the COVID-19 pandemic, the government, through the Food Security Agency, has a national food logistics system as a development strategy to stabilize food supply and prices throughout Indonesia. This strategy includes first, increasing production in deficit areas, and bringing production closer to consumers. The strategy consists of adding new planting areas "Perluasan Areal Tanam Baru" (PATB) in deficit areas, providing production inputs (seeds, fertilizers), and the provision of production facilities and infrastructure (agricultural machinery aid, irrigation networks). Second, improving distribution system, namely improving the smooth distribution of food. This strategy includes simplifying supply chain and intervention distribution,



Source: Abdulsamad et al. (2013)

Figure 13.1 Agricultural Value Chain developing National and Regional food hubs in each province, and establishing e-commerce. Third, institutional development, namely coordinating and synergizing between logistics actors. This strategy includes strengthening the role of logistics actors (farmers, traders, logistics service actors), establishing a central food logistics institution and regions (BUMN/BUMD) in each province, and synchronizing logistics system regulations and national policies (central and regional). Fourth, encourage local food consumption, namely carrying out food development locally. This strategy includes developing local food industry areas and campaigning to promote local food consumption.

The latest report, mentioned that more than 3 million people worldwide had been tested positive for COVID-19. That is a huge number for a pandemic, at least after the Spanish flu pandemic, infected 500 million people worldwide. This pandemic also has a tremendous impact on all aspects of human life. Public places such as plazas, schools, and markets should be closed, and human mobilization is limited only to essential business, such as logistics, food, and health. This phenomenon will globally affect the economy and food availability. The crisis is imminent. Forecasts from various world economic research institutes indicate that it certainly all countries in the world will experience a recession, minus economic growth, massive budget cuts, and reduction of workers number. This information is not intended to frighten, but it is a fact, the path that humanity will face in the future. So how should we respond to the crisis that is very likely to occur.

C. Some Options to Stabilize Logistics Stocks during COVID-19

One of the efforts that can be done is to build a logistics supply chain in each region. A typical pandemic that comes from urban areas, and then spreads throughout the world, gives hope to suburban areas that with plenty of agriculture land and food barns. This does not mean pandemic should spread to urban areas, but at least the suburbs are far from population density and mobility susceptible to the quick spread of COVID-19, and thus can avoid this situation that will be much more dangerous. Therefore, the suburban area must be guarded with a social safety net regarding food availability. Many countries are predicted to experience a recession or minus economic growth during the pandemic. JP Morgan and the IMF predict world economic growth in 2020 to at -1.1% and -3% (https://bondsloans.com/news/em-currencies-local-bonds-top-picks-for-2020-jp-morgan-asset-management-1). Negative economic growth will directly impact food availability.

The Food and Agriculture Organization of the United Nations (FAO) has even warned that the global coronavirus pandemic could trigger a "threatening food crisis," as many restrictions have hampered production patterns during the pandemic. Rapid action must be taken to protect the most vulnerable asset, keep the global food supply chain alive, and reduce the impact of the pandemic on the entire food system, and Indonesia is no exception.

In fact, Indonesia is currently facing the threat of an agricultural crisis caused by a crisis in the number of farmers, massive conversion of agricultural land, and high urbanization. Indonesia's agricultural sector cannot speak much. Meanwhile, based on data from the Ministry of ATR/BPN in 2018, the raw area of rice fields in Indonesia was only 7.1 million hectares (ha) or decreased compared to 2013 which was still 7.75 million hectares. BPS also launched that in 2018, the number of workers in the agricultural sector were recorded at 35.7 million people or 28.79% of total population, but most of them had entered old age. Meanwhile, only 10% of the total number of farmers came from groups of young farmers (19–39 years old). If this condition persists, in the next 10 years, the threat of a food crisis will certainly occur.

In this context, the spotlight must be focused on the size and portion of the budget for handling the pandemic and economic recovery of 110 trillion that is used to build social safety nets. At least with the support of the funding and human resources from various task forces for handling COVID-19, food availability, food accessibility, and food affordability (the three pillars) for realizing food security are expected to be discovered.

D. Strategies for Food Supply Chain

Before the pandemic, one-third of all food produced for human consumption was lost or wasted across the food supply chain that which includes many stages, such as production, postharvest handling, processing, distribution, and consumption. Therefore, food waste has gained more attention in the era of coronavirus. A study by Aldaco et al. (2020) indicated that COVID-19 had a minor impact on the overall food loss and waste generation, but resulted in 12% higher production of food waste on household level.

Valuable bioactive components such as phenols, carotenoids, pectins, flavonoids, essential oils, glucosinolates, isothiocyanates, and whey protein isolate can be derived from food waste in order to be reutilized in the food chain. These functional compounds can be used as preservatives, gelling agents, food, or nutritional supplements. Conventional or innovative techniques can be applied in the extraction, fractionation, and isolation stages of bioactive components from food wastes. However, additional collection and processing centers are required to recover food wastes generated during the production, processing, or consumption stages.

The European Food Safety Authority indicated that food itself is not a source of coronavirus as viruses cannot be transmitted through food consumption. Nonetheless, various environmental surfaces such as doorknobs, light switches, or foods contaminated with the COVID-19 virus remain at potential risk of become transmission media of virus (Thevenard, 2020). In addition, the latest study by Mathilde et al. (2020) showed that SARS-CoV-2 could be transmitted via air. Therefore, people should always care about handwashing. In addition, retailers must follow the hygiene requirements when handling food. Food preparation workers must wear masks and gloves and change them frequently during cutting, slicing, or packaging foods. Consumers are also responsible for preventing contamination by not touching foods other than what they are willing to purchase in the stores (Morawska & Cao, 2020).

E. Implementation of Smart Food Supply Chain

Various robot systems can be used to ensure food safety in food facilities by preventing the transmission of microorganisms by humans. The Industry 4.0 era now plays a vital role by making a data-driven autonomous decision in production. Automation opens new opportunities to increase productivity by 25% and complete tasks such as loading/unloading, placing, and packaging more efficiently than human beings. Robots can also help us serve the foods to consumers in the food-serving industry. In addition, Cyber-Physical System (CPS) can monitor the unsafe or low-quality products in the food supply chain (Iqbal et al., 2017).

The COVID-19 pandemic also resulted in onerous requirements for human resource management. These challenges include changing working conditions by adopting new workplace policies and actions to reduce physical contact. Therefore, organizations must respond to the challenges by some measures. First, COVID-19 symptoms of the workers, visitors, suppliers, and contractors should be monitored before entering the facility. The food safety or HACCP teams can perform temperature screening of all staff at the plant entrance. Ensuring workers to wear face protection equipment and gloves is essential, too. Second, facilities should consider reducing working hours and rotating employees. The overall number of workers in each shift should be divided into three or four groups and their break time should be adjusted to avoid overcrowding. Finally, warehouses and processing facilities should be redesigned to implement social distances among employees. Building dividers or barriers which cover the upper part of the body of workers can be used to maintain social distance. A diagonal arrangement should be used if employees use two-side engagement in food processing. Robotic machines also can be used to lower the risk associated with COVID-19-infected workers during the coronavirus pandemic.

Furthermore, robots can replace humans in food-processing operations to maintain social distancing by reducing the number of food workers. These precautions against the COVID-19 will stabilize international market mechanism. Countries should maintain the balance between the production quantity and the safety of workers.

Decentralization of food manufacture might also be used to avoid drawbacks and risks associated with the centralization paradigm in COVID-19. Low-scale facilities near the consumers can significantly reduce the storage and transportation costs and minimize the environmental impacts. Building the production facilities closer to consumers helps shorten the supply chain and decrease emissions and energy consumption during transportation and storage. Decentralization provides flexibility in supply chain and allows customers to get fresh and natural products. It also simplifies the administrative procedures in order to reach poor and disadvantaged people in certain areas (Almena et al., 2019a; Almena et al., 2019b; Lai & Cistulli, 2005).

The industry also should determine which transportation routes are blocked (potential alternatives should be sought) and how many workers cannot work due to restrictions. The local labor force should be trained and activated in cross-border restrictions. It would be an opportunity to ensure a reliable and long-term workforce for the future by training and increasing the skills of local employees. Agricultural workers were now identified as essential people, which ensured them to work under better conditions with higher wages. At the same time, agricultural inputs should be considered as essential products to ensure food production. Collection centers should be selected and planned considering their distance to the manufacturer. Integration of small producers closer to collection centers with high capacity can also decrease mobility.

Changes in demands are another factor affecting supply chain performance. Therefore, the demands should be determined using forecasts and simulations. Especially, the products essential for daily life, such as sanitizers and food items, gained more demand at the beginning of the crisis. However, the perishable nature of food products makes them more susceptible to the impacts of COVID-19 on the supply chain. Therefore, the manufacturer can apply statistical models to propose optimal solutions for supply and demand disruptions due to the COVID-19 pandemic. Using those results, production, processing, and distribution can be adapted appropriately (Paul & Chowdhury, 2020).

In addition, it is necessary to use the logistics facilities in the most optimum way, especially the logistics vehicles should not return empty to the starting point. The concept of 'Urban Distribution Center' can allow us to use better capacity with consolidating the number of deliveries by one or more vehicles. It also improves the effectiveness of the collection or transportation process. In addition, food protection should be ensured by coordinating the supply chain members. Private or government institutions need to invest in storage centers. Consumers should have access to markets, and attention should be paid to the needs of low-income consumers. The relationship between buyer and seller should be strengthened by establishing web-based food distribution systems. Web-based supply chain management system can be referred to as an internet-enabled system that allows information flow among suppliers, facilities, collection centers, and retailers. This system enables faster and more flexible collaboration between producer and customer (Morganti & Gonzalez-Feliu, 2015; FAO, 2020b; Ngai et al., 2004).

Digital commerce services play an integral role in the interaction and trading activities among food supply chain actors. E-commerce provides opportunities to reduce costs and increase demand. In addition, for a long time, small farmers are considered disadvantaged in the food supply chain due to many challenges they face in accessing market. Higher transaction charges in all deals do not allow small farmers to stand in benefit positions due to their small scale. Therefore, digitalization of procedures enables small farmers to sell their crops at a higher price and helps them reach more customers directly and effectively bypassing intermediaries. The largest e-commerce companies can collaborate with the government to digitalize the services of rural markets and encourage them to be part of the e-commerce economy. These platforms offer mostly organic fertilizers to the market at a reasonable cost.

Supply Chain Management (SCM) Data Science' can be used by governments and private sectors to solve SCM problems and forecast the outcomes by performing quantitative and qualitative methods owing to the data quality and data availability. Therefore, data availability and dissemination should be improved. Access to correct data at the right time is important for the efficient functioning of the supply chain. The availability of reliable information reduces uncertainties in the market and allows private and public organizations to determine sources of potential disruptions and risks. Correct data also provide better decision-making and enhanced profitability. In addition, a collaboration between a government agency and a private sector can be more effective by easily accessible data. Sharing data and information across the food supply chain can reduce the negative impacts and strengthen flexibility in the long run.

F. Suggestions for Government and Businesses in Indonesia

First, a crisis committee should be established to focus on the effect of COVID-19 on the food value chain without waiting too long to implement of specific strategies and interventions. This committee should act as a key actor in observing the progress and recommend actions to reducing COVID-19 effects on agricultural production and food supply cuts. To ensure adequate and full implementation of the strategies, the committee must collaborate with the private sector. In Turkey, the Ministry of Agriculture and Forestry has formed the COVID-19 commission consisting of seven academicians and two members from the Ministry of Agriculture and Forestry for measures and recommendations to be taken in the field of agriculture and food within the scope of the pandemic Ministry of Agricultural and Forestry, 2020.

In the aftermath of the pandemic, governments worldwide announced response plans to help the agriculture industry reduce the effect of the COVID-19 pandemic. In Turkey, the Ministry of Agricultural and Forestry announced the precautions and funding assistance programs for farmers and manufacturing facilities/stores such as slaughterhouses, greenhouses, and bakery stores. In addition, the Ministry of Internal Affairs issued the lockdown guidelines allowing the farmers and food production plants to continue their operations during lockdown (MAF, 2020; MIA, 2020).

In Canada, Agriculture Response Program was designed for 50–75% funding assistance which does not have to be paid back regarding health protocol, marketing and product movement, distribution, strategic projects, abattoir efficiency, and development (Novascatia, 2020).

In the USA, the Department of Agriculture committed programs and flexibilities such as food assistance, dumped milk, crop insurance, farm loan, commodity loan, crop acreage, animal mortality, paycheck protection, and economic injury disaster loan to help agricultural producers whose business are affected by the COVID-19 pandemic (USDA, 2020).

Governments should also establish and operate emergency provisioning strategies to support production. Temporary input subsidy programs should protect the regions most affected by the pandemic. Timely support is essential for planting season for the following spring. Data collection and assessment programs for migrant workers should be able to determine when and where the migrants are needed. Facilitating the cross-border movement of migrant workers is vital because movement restrictions and border closures have a strong negative influence on the agricultural labor supply.

In Canada, the government announced a US$ 50 million financial aid program for small farmers who hired temporary foreign employees through the COVID-19 pandemic. The program allowed employers to receive US$ 1,500 per foreign worker who had to self-isolate for 14 days upon entry into Canada (Ker, 2020). The resulting labor shortage can be reduced by policies that classify agricultural workers as critical persons and exempt them from travel limitations. In the USA, the government highlighted the importance of people employed in agricultural production and considered them as 'critical infrastructure workers'. It should also be focused on giving more extended stay permits by changing the country's visa and residence regulations for seasonal workers. In some countries such as Canada and Belgium, governments allowed employers to postpone recruitment or offer long-term contracts. Commission of European Union (EU) introduced 'the green lanes' for vehicles carrying agri-food products to ensure free and fast movement on borders. EU measures also highlighted the free movement of agri-food and seasonal workers by enabling them to reach their workplace and exercise their activities. In addition, the commission extended the farmers' application deadline to receive income support, known as Common Agricultural Policy (CAP) payments. A temporary framework for state aid measures was approved to support farmers and agri-food businesses to ensure liquidity. However, it is necessary to encourage the local population to become agricultural workers.

Local populations and unemployed people can be trained to work in actual farming practices like sowing, weeding, or harvesting to minimize the effect of the restriction on migrant workers. Online platforms should facilitate connections between local residents and the agriculture sector. Unemployed people or local workers should be encouraged to be agricultural laborers by adding a premium reward to their wages since local workers do not seem interested in farming due to the possibility of finding better non-agricultural alternatives. COVID-19 pandemic showed that labor-replacing mechanization policy is the best way to solve the labor shortage over the medium to longer-term (Troskie, 2020).

Employment contracts between the food value chain actors should be fair to all parties. They should be clear about the rights and responsibilities of each of the party, since public and private standards define the minimum requirements for food safety and quality. However, personal measures involve more stringent regulations than public standards and affect the producers' prices and produce quantity. In addition, these standards significantly impact their income and market access. In addition, legal frameworks can regulate the rights of producers and vulnerable groups affected by supply and demand changes and the need to adapt in accordance with these changes. In emergencies such as the COVID-19 pandemic, these regulations can contribute to safe transactions and problem-free operation.

Moreover, it is necessary to strengthen the capacities of legal regulations, including ensuring the proportionality and necessity of restrictive measures, and providing flexibility in implementing certain administrative requirements to face the challenges caused by the new situation. Providing flexibility in licensing requirements for direct selling, e-commerce, and food transport can also help small producers and agricultural businesses find alternative market opportunities since flexibility is relatively associated with the weak/strong position of farmers and the presence of long/short food supply chains. Customers sometimes believe supply chain challenges can impose the food choice.

Logistic operations are also critical to maintaining food delivery. Therefore, some regulations are needed to be maintained appropriately. For instance, some investments in infrastructure should be established to upgrade monitoring and supervision methods, sanitation systems, digital documentation use, and operations. Countries should follow rigid hygienic control in the distribution sector to prevent virus transmission. The health and safety of the logistic employees who carry tradable products should be maintained. For instance, Logistic Sub-Group developed three work streams in the UK: safe passage programs; crisis management, accommodation, and transportation; and shore base logistics and freight management. These work streams were intended to provide safe passage (health issues) and assurance to personnel and their families. It also ensures the movement of staff effectively and consistently. Lastly, it provides guidelines and raises awareness in the logistic sector.

Rapid yield prediction and determination of national food stocks need to define shortages or surpluses, particularly because of import prohibition or export restrictions. Better management of food stocks in different regions should be considered, and farm products' non-food uses (e.g., biofuel) should be reduced. Crop yield information models can help governments decide on food security or grain marketing. Local models can use intensive data techniques appropriate for small areas, whereas regional models use extensive data techniques suitable for larger areas. Therefore, a proper modeling method should be carefully selected to understand the impacts of policy decisions. The duration of the COVID-19 pandemic is uncertain. Agricultural firms have begun to change their business models. For example, it is important to address crucial issues, such as promoting understanding of the virus transmission, creating reporting system for positive cases, establishing progressive investment and resource plans covering the next three years, planning business continuity, alternating input source channels, increasing focus on stock management, reviewing personnel occupational health and safety practices, limiting travel, and preparing human resource in the face of increasing demand or absenteeism (Clift & Court, 2020; ICC & WHO, 2020). However, companies also need to cooperate with competing companies on some issues, e.g., raw material supply. Small companies need to be more organized, using the crisis as a driving force. Firms should care about developing the information and communication technology infrastructure that can be used for the agriculture and food sector. It is also necessary to benefit from financial incentive packages according to the needs of the enterprises.

G. Conclusion

During a pandemic, continuing the supply flow in the and food sector, which is one of the most important sectors together with health, is vital to prevent the food crisis and reduce the negative impact on the global economy. Although no major problems have been observed in the food supply chains, it remains uncertain in the future. As a result, each country has to realize the severity of the situation and sometimes should tighten or loosen the measures flexibly according to the spread of the pandemic. The supply chain also should be flexible enough to respond to the challenges in the food supply chain.

To mitigate the impact of COVID-19 on the availability and stability of food prices in Indonesia, the government must ensure facilities and assistance in all lines of food, starting from production to consumption, running accordingly as it supposed to. Coordination between Ministries and State Institutions is the key to implement this food policy strategy. The trend of food commodity trade restrictions and logistical disruptions is inevitable due to pandemic. Therefore, the government needs to optimize the potential for domestic food production and improve the national food logistics system.

Valid data related to the food balance in Indonesia need to be reviewed immediately and all ministries and state institutions are required to use the same food data. If several food commodities need to be imported to meet domestic food needs, it is necessary to obtain granting for import facilities, before the rise of food trade restrictions in several nations' food commodity suppliers. However, if it is not required to import, therefore domestic supply chain should be optimized. Domestic food must be a top priority so there is no disruption to resilient food in Indonesia.

References

Abdulsamad, A., Brun, L. C., & Gereffi, G. (2013). *Realizing the potential of African agriculture: Innovations and market access for smallholder farmers*. Center on Globalization, Governance, & Competitiveness, Duke University. https://doi.org/10.13140/RG.2.1.1197.3600

Aldaco, R., Hoehn, D., Laso, J., Margallo, M., Ruiz-Salmón, J., Cristobal, J., Kahhat, R., Villanueva-Rey, P., Bala, A., Batlle-Bayer, L., Fullana-i-Palmer, P., Irabien, A., & Vazquez-Rowe, I. (2020). Food waste management during the COVID-19 outbreak: A holistic climate, economic, and nutritional approach. *Science of the Total Environment 742*, 140524. https://doi.org/10.1016/j.scitotenv.2020.140524

Almena, A., Fryer, P. J., Bakalis, S., & Lopez-Quiroga, E. (2019a). Centralized and distributed food manufacture: A modeling platform for technological, environmental, and economic assessment at different production scales. *Sustainable Production and Consumption 19*, 181–93. https://doi.org/10.1016/j.spc.2019.03.001

Almena, A., Lopez-Quiroga, E., Fryer, P. J., & Bakalis, S. (2019b). Towards the decentralisation of food manufacture: Effect of scale production on economics, carbon footprint, and energy demand. *Energy Procedia*, *161*, 182–89. https://doi.org/10.1016/j.egypro.2019.02.080

Clift, K., & Court, A. (2020). *How are companies responding to the coronavirus crisis?* World Economic Forum. https://www.weforum. org/agenda/2020/03/how-are-companies-responding-to-the-coronavirus-crisis-d15bed6137/

Food and Agriculture Organization (FAO). (2020a). *Impacts of coronavirus on food security and nutrition in Asia and the Pacific: Building more resilient food systems*. http://www.fao.org/3/ ca9473en/CA9473EN.pdf

Food and Agriculture Organization (FAO). (2020b). *Policy responses to keep input markets flowing in times of COVID-19*. https://doi.org/10.4060/ca8979en

International Chamber of Commerce (ICC) and the World Health Organization (WHO). (2020). *ICC-WHO joint statement: An unprecedented private sector call to action to tackle COVID-19. https://www.who.int/news/item/16-03-2020-icc-who-joint-statement-an-unprecedented-private-sector-call-to-action-to-tackle-covid-19*

Iqbal, J., Khan, Z. H., & Khalid, A. (2017). Prospects of robotics in food industry. *Food Science and Technology, 37*(2), 159–65. https://doi.org/10.1590/1678-457X.14616

Lai, K. C., & Cistulli, V. (2005). *Decentralized development in agriculture: An overview.* EASYPol, Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/3/am379e/am379e.pdf

Ker, A. P. (2020). *Risk management in Canada's agricultural sector in light of COVID-19, 68*(2), 251–58. https://doi.org/10.1111/cjag.12232

Mathilde, R., Kok, A., de Meulder, D., Bestebroer, T. M., Lamers, M. M., Okba, N. M. A., van Vlissingen, M. F., Rockx, B., Haagmans, B. L., Koopmans, M. P. G., Fouchier, R. A. M., & Herfst, S. (2020). SARS-CoV-2 is transmitted via contact and via the air between ferrets. *Nature Communications, 11*(1), 3496. https://doi.org/10.1038/s41467-020-17367-2

Ministry of Agricultural and Forestry, Republic of Turkey (MAF). (2020). *COVID-19 precautions.* https://www.tarimorman.gov.tr.

Ministry of Internal Affairs, Republic of Turkey (MIA). (2020). *COVID-19 precautions.* https://www.icisleri.gov.tr/.

Morawska, L., & Cao, J. (2020). Airborne transmission of SARS-CoV-2: The world should face the reality. *Environment International*, *139*, 105730. https://doi.org/10.1016/j.envint.2020.105730

Morganti, E., & Gonzalez-Feliu, J. (2015). City logistics for perishable products. The case of the Parma's food hub. *Case Studies on Transport Policy, 3*(2), 120–128. https://doi.org/10.1016/j.cstp.2014.08.003

Ngai, E. W. T., Cheng, T. C. E., & Ho, S, S, M. (2004). Critical success factors of web-based supply chain management system using exploratory factor analysis. *Production, Planning, & Control*, *622–630.* https://doi.org/10.1080/09537280412331283928

Nova Scotia. (2020). *COVID-19 agriculture response program*. Canadian Agricultural Partnership. https://nsfa-fane.ca/wp-content/uploads/2020/06/Agriculture-Response-Program-Guidelines-2.pdf

Paul, S. K., & Chowdhury, P. (2020). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *International Journal of Physical Distribution & Logistics Management*, *51*(2), 104–125. https://doi.org/10.1108/IJPDLM-04-2020-0127

Thevenard, E. (2020). *European commission directorate-general for health and food safety crisis management in food, animals, and plants: Food hygiene, COVID-19, and food safety questions and answers.* https://food.ec.europa.eu/system/files/2020-04/biosafety_crisis_covid19_qandas_en.pdf

Troskie, D. P. (2020). *Impact of COVID-19 on agriculture and food in the Western Cape.* Western Cape Department of Agriculture.

U.S. DEPARTMENT OF AGRICULTURE (USDA). (2020). *Coronavirus and USDA assistance for farmers*. https://www.famers.gov/coronavirus

World Food Programme (WFP). (2020). *COVID-19 will double number of people facing food crises unless swift action is taken.* https://www.wfp.org/news/covid-19-will-double-number-people-facing-food-crises-unless-swift-action-taken

SECTION 4

HUMAN RESOURCE AND PUBLIC SERVICE DEVELOPMENT

Chapter 14

Establishing Knowledge Management System to Support the Education System

Rahmat Trialih

A. Pandemic Hits Current Educational System

The emergence of the COVID-19 pandemic in late 2019 has disrupted the world's economy and forced many people to restrict many activities. At first, this did not disturb human civilization, as people were still optimistic that this situation would improve soon. However, the pandemic does not yet seem to take any favorable turn as time goes by. Due to the uncertain situation, many sectors finally realized that they had to adapt by changing their activities. Luckily, everything has become more accessible because of current technology development, making this change possible. However, this change cannot be implemented and applied immediately, as it requires many adjustments and

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R. Trialih
University College Cork, Ireland, e-mail: rtrialih@gmail.com

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elaborations to deal with existing problems and limitations, including in the educational sector.

Education can develop a human civilization and create many unprecedented innovations and changes. This fact indicates that education has an essential role in human life, and even though the pandemic has not yet ended, education must still continue as it should be. We already know that the COVID-19 pandemic has disrupted the ideal and effective learning process. This situation will undoubtedly impede education's main purpose, namely creating competitive and knowledgeable human resources. Ma et al. (2016) stated that education could significantly improve human resources' behavior, salary, and quality. However, the COVID-19 pandemic, which has been occurred worldwide, has had a tremendous impact. As reported by WHO data in 2020, COVID-19 has significantly affected 213 countries, with more than 3 million cases worldwide and resulted in more than 200 thousand victims (Kerbl & Zepp, 2021). A report also revealed that the COVID-19 pandemic impeded the learning process in universities and schools. This education sector changed its learning and teaching methods into an online system, and some closed their services, such as the library and labs (UNESCO, 2020). Before the pandemic, online learning received positive feedback and was expected by many people to be the future method of education rather than traditional education (Gaur et al., 2015). Nevertheless, several reports indicated that online learning was not showing a good prospect as expected.

By referring to the Indonesian law no 20-year 2003, we can see that the goal of Indonesian education is developing the student's potency so they can be excellent human, believe in God's greatness, have noble character, healthy, knowledgeable, capable, creative, independent, democratic, and responsible citizens. Based on this goal, we can conclude that the Indonesian education goals are basically align with the global education goals. Global education is affected by pandemics, including in Indonesia, and forced the education sector to embrace changes due to new normal conditions, such as by establishing online learning.

Meanwhile, current Indonesian education usually uses traditional face-to-face learning systems. The COVID-19 pandemic ruined the process even though the Indonesian Ministry of Education and Cultures has already implemented learning portal like "Rumah Belajar" and the others (Permata & Dhoehaeni, 2021). However, universities or schools in Indonesia are forced to face many challenges, especially in finding practical online learning without diminishing students' knowledge acceptance (Zalat et al., 2021). Another challenge with online learning is that the educators seem to find it difficult to properly formulate the teaching method to evoke students' interest and engage their participation, as well as reduce their boredom (Aguilera-Hermida et al., 2021; Aguilera-Hermida, 2020). We commonly see jokes on social media, such as Instagram or TikTok, where a teacher or lecturer explains the course materials. However, the student kept turning off the camera so the educator did not know what the student were doing. This condition is likely due to students' low awareness of learning, or their acceptance that online learning experience is not as attractive as offline.

Additionally, this situation has worsened because the education institution does not have good online learning tools, and Indonesia's infrastructure may be far from ideal. Meanwhile, one of the success factors in online learning is providing appropriate infrastructures, such as adequate internet connection and affordable internet quotas (Salehudin et al., 2021). Besides, the teaching-learning process problem is related to the knowledge management process. By implementing the activity in the knowledge management process, the learning process can be expected to run smoothly.

This chapter discusses how technology, mainly through knowledge management, is essential to improve education and the other basic foundations to implement quality education.

B. Education Challenge in Indonesia

The COVID-19 pandemic gives understanding and the big picture regarding how technology can facilitate education performance in the future. Several studies discussed this idea, but online education's effectiveness is still widely questionable. The Indonesian Ministry of Education website stated that technology has grown rapidly nowadays. However, it still could not replace the role of teacher, lecturer, and offline learning interaction between educator and student. It happened because, in traditional learning, we refer to obtain knowledge theoretically while learning other values such as teamwork, competition, creativity, and humanity. Therefore, the global pandemic made online learning quite challenging for students and educators (Hendriyanto, 2021; Pengelola Web Kemdikbud, 2021).

From students' perspectives, online learning forced them to become more self-motivated and mature in managing time. While from the educator's perspective, online learning requires them to become more creative to ensure the learning process runs effectively and interestingly, not dull the students. A recent study conducted in Indonesia showed that online learning in Indonesia is usually effective but still inefficient in many ways (Bahasoan et al., 2020). Online learning in Indonesia is inefficient because of the network problem and quota constraints. The study found that the cost of an adequate internet quota may discourage the students, as they need to purchase many top-ups.

Additionally, a good internet provider has not yet covered all areas in Indonesia, making the situation more complicated. For this problem, Indonesian Ministry of Education has given a free internet quota. However, this scheme is not practical because it cannot be used optimally due to the diverse requirement of education methods (Sajida, 2020). This situation is just one example of many challenges Indonesia needs to face.

This section discusses the problem and challenges faced by the education sector in Indonesia.

1. Learning Loss

Based on the international student program assessment report in 2018, Indonesia's ranking was relatively low compared to other countries.

Indonesia ranked ten lowest among 80 countries (OECD, 2019). The phenomenon has seemingly become more urgent because Indonesia's scores in reading, mathematics, and science are declining from 400 to 380 points. In brief, we can conclude that this situation is one of the challenges for the Indonesian education sector, especially during the pandemic situation. The pandemic causes the education process to be conducted at a distance without educators' adequate supervision, thus leading to dangerous learning loss circumstances.

Learning loss can be defined as the decline of students' competence, which can occur due to online learning in a certain period. Preventing learning loss is not easy for educators because their role cannot function as optimally as before due to social distancing policy. Nevertheless, there is a crucial need for supporting roles from parents as people who are close to students, and more importantly, self-motivation from students themselves (Bączek et al., 2021).

The standard solution used by educators is to give students many tasks, and students must complete them. However, we must be aware that many tasks cannot be expected to effectively increase student learning quality, and instead potentially impede the learning process, even though studies show that homework can stimulate student's academic performance. Therefore, it depends on self-motivation (Bembenutty & White, 2013). Quoted from the news report, many students also complain about online learning because they are burdened with more tasks than before. This situation will negatively affect students as they will not enjoy the learning process and perceive that studying is not fun (Galloway et al., 2013).

2. Technology Usage

Online learning cannot be done without the support of technology. Technology act as essential element to smoothen the online learning process. Recently, many learning platforms and applications have appeared a choice to help students and educators allow the learning process to run smoothly. However, the success of online learning is not only determined by how sophisticated the technology itself, but more by the user's capability to utilize technology optimally. In Indonesia, at least three stakeholders need to properly understand online learning technology: educators, students, and parents (Li, 2007). These three stakeholders hold the key to conduct successful learning process. One of the current challenges is to educating parents and educators born in the 70s or 80s to utilize technology.

On the other hand, this technological challenge is certainly attributed to the unequal economic conditions. We know that Indonesia is a big country, and Indonesia's technology standardization is unequal. It would probably be fine for wealthy people or families in the big city or wealthy because they can afford good internet access and adequate devices. This condition contradicts people or families who live in small-town or unwealthy people because they probably cannot afford good internet access and adequate devices.

3. Learning Culture

It is not a secret that Indonesia has a school culture without an actual learning culture, meaning that we go to school daily, but obtain almost nothing from school. Many factors drive this situation, such as how students are distracted by their mobile phones or sleep, rather than pay attention to the teacher. We can prevent this phenomenon happened by establishing a learning culture. The learning culture focuses on methods that develop fundamental knowledge and allow students to implement it after school.

Learning culture is a series of activities in doing learning tasks. Creating a learning culture needs a long process and can be started by planting the interest to study and making it a natural behavior rather than a forced action. Students with good learning culture will feel like they are violating a norm if they are not studying. Ideally, when students think that studying is fun, they will receive more knowledge and increase inner motivation, thus impacting productivity. In the large picture, learning culture will become the key to determine a society's identity (Jenert, 2011).

4. Another Challenge

Implementing a knowledge management system is difficult, since it can have many challenges. Several studies tried to map the challenges of implementing knowledge management (Mishra, 2012; Petrides & Nguyen, 2006). They argued that even if we plan what we think best, it still would have weaknesses and distract our focus. Due to this reason, we still need to plan to counter it. The following are some other common challenges we might face and need to be tackled properly:

a. Inability to recognize knowledge
b. Geographical distance
c. Limitations of information and communication technologies
d. Loosely defined areas of expertise
e. Constantly changing regulation
f. Internal conflicts
g. Lack of incentives or performance management goals
h. Poor training or mentoring programs
i. Cultural barriers

C. Knowledge Management

Knowledge management is gaining acceptance in education because knowledge is a concept of utilizing the information from many sources and potentially used as learning strategies (Oye & Salleh, 2013). Knowledge management is a set of practices to improve the use and sharing of data and information in decision-making. However, many educational institutions have already acknowledged and used knowledge management to improve their learning system recently. Using knowledge management in the education sector will benefit education stakeholders (Saide & Sheng, 2020). For example, it will give external and internal quality improvement, provide more accessible information gathered by educators and school administrators, and prevent excess information.

Good education needs a good teacher, and a good teacher needed must be made, not found. A good teacher will be assessed by standard assessment, tests, and certification in the current system. However, these things are not entirely correct because the practical side can differ from their tests and certification. Qualifying in the certification and tests are crucial because educators cannot leave their students like leaving a missing child behind, and educational institutions need to be flexible with time development. At the same time, teachers must remain abreast of a wide variety of changing standards, curricula, and pedagogical methods.

The faculties and universities have a more complex situation because many tasks need to be done by the lecturer. Faculties face increasing information and innovation in their field, and it is difficult to align with these consistently. Moreover, faculties and universities also need to adjust their budget to hire good quality staff, develop the faculty infrastructures, and other things such as conference fees. Additionally, they have to teach a much broader population and determine which teaching methods are most suitable for demographic groups. Moreover, they also need to be more involved and persistent about student assessment issues from college entrance and placement to value-added issues related to the degree.

This section will discuss the knowledge management cycle and how each step will help the education field. A function in knowledge management has four following steps in a cycle. This cycle is created because knowledge will be refined over time. The knowledge in a good knowledge management system (KMS) is never finished because the environment changes over time, and the knowledge must be updated to adapt to the changes. The cycle works as follows:

1. Knowledge Acquisition

Knowledge acquisition is the process of collecting and obtaining knowledge from various sources. Through this process, people can add new knowledge to knowledge basee. When this situation happens, the knowledge will be refined and improved. The acquisition can be defined as expanding the capabilities or improving performance at a specified task. The goal of this process will focus on creating and refining the current knowledge. In the educational sector, we can use this process to get a source of knowledge from textbooks, technical papers, database reports, journals, and the environments that might be presented as facts, rules, concepts, procedures, heuristics, formulas, relationships, statistics, or any other helpful information. Knowledge acquisition is not a one-time process but can be repeated many times because knowledge will constantly develop.

2. Knowledge Store

Knowledge store uses technology to store structured and unstructured information in the database. This process takes place in the expert system that contains the facts about the world and ways of reasoning related to those facts or highlights the inconsistencies. In the educational sector, the knowledge store can be a place to submit and gather a lot of knowledge or information which may be accessed later by stakeholders in the educational sector.

3. Knowledge Distribution

Knowledge distribution is a process of distributing knowledge to all stakeholders involved in the educational sector. The knowledge can be provided by educators or anyone who wants to distribute their knowledge. Later, this process will ease teachers and lecturers to teach their students, to understand the lesson easily.

4. Knowledge Usage

Knowledge usage is usually used in the business sector to make business decisions or gain opportunities. The educational sector can facilitate students in implementing their knowledge in class. This process is usually recursive and continually generates feedback that improves comprehension and can be integrated into other knowledge activities. For example, educators can monitor this process to evaluate how students apply the knowledge in real life, like during internships or apprenticeships.

5. Type of Knowledge

Generally, in knowledge management, there are two categories of knowledge: explicit knowledge and tacit knowledge. Polanyi (1958) first conceptualized the difference between explicit and tacit knowledge of an organization. Explicit knowledge deals with more objective, rational, and technical knowledge (e.g., data, policies, procedures, software, documents) (Polanyi, 1958). On the other hand, tacit knowledge is usually subjective, cognitive, and empirical learning; it is highly personal and difficult to formalize. Later, Alavi and Leidner (2001) provided a taxonomy of knowledge. They defined a spectrum of different types of knowledge, going beyond the simple binary classification of explicit versus tacit.

Explicit knowledge comprises the policies, procedural guides, white papers, reports, designs, products, strategies, goals, mission, and core competencies of an enterprise and its IT infrastructure. The knowledge has been codified (i.e., documented) in a form that can be distributed to others or transformed into a process or strategy without requiring interpersonal interaction. For example, a description of how to process a job application would be documented in a firm's human resources policy manual. Explicit knowledge has also been called leaky knowledge due to its ease of handling, allowing an individual or an organization to readily and accurately document it.

On the contrary, tacit knowledge is the cumulative store of experiences, mental maps, insights, acumen, expertise, know-how, trade secrets, skillsets, understanding, and learning that an organization has. It also consists of the organizational culture embedded in the past and present experiences of the organization's people, processes, and values. Tacit knowledge, also called embedded knowledge, is usually localized within an individual's brain or in group interactions within a department or branch office. Tacit knowledge typically involves expertise or high skill levels.

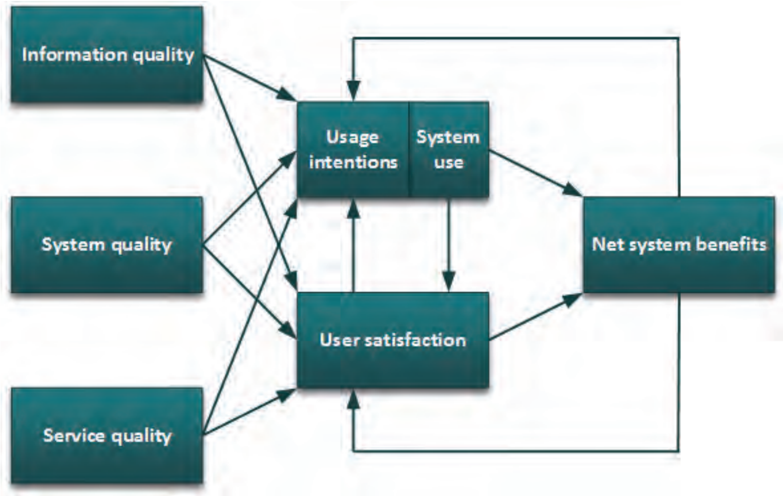
Sometimes tacit knowledge could easily be documented but has remained tacit simply because the individual housing the knowledge does not recognize its potential value to others. Other times, tacit knowledge is unstructured, without tangible form, and therefore difficult to codify. It is difficult to put some tacit knowledge into words. For example, explaining how to ride a bicycle would be challenging to be documented explicitly and thus categorized as tacit knowledge. Successful transfer or sharing of tacit knowledge usually occurs through associations, internships, apprenticeships, conversations, other means of social and interpersonal interactions, or even simulations. Tacit knowledge also claimed that intangibles such as insights, intuitions, hunches, gut feelings, values, images, metaphors, and analogies are the often-overlooked assets of organizations. Harvesting these intangible assets can be critical to meet a firm's bottom line to achieve its goals. Tacit knowledge sharing requires a particular context or situation to be facilitated because it is less commonly shared under normal circumstances.

D. Information System Success Factor

Creating a knowledge management system cannot be separated from successfully implementing an information system (IS). Delone and McLean explained in their model that information system success could be seen from their information quality, service quality, and system quality (Delone & McLean, 1992; DeLone & McLean, 2016). These three variables will be of why people use technology for a long time to improve performance.

1. Information Quality

Information quality is the quality of the information that the system can store, deliver, or produce. Information quality is one of the most common dimensions to evaluate IS success. In IS concept, the information quality impacts both user's intentions to use the system and user's satisfaction with the system, which, in turn, determines the extent to which the system can yield benefits for the user and organization.



Source: Delone and McLean (2003)

Figure 14.1 IS Success Factor Information Quality

2. System Quality

Along with information quality, the overall quality of a system is also one of the most crucial dimensions commonly evaluated. System quality indirectly impacts how the system can deliver benefits through mediational relationships through the usage intentions and user satisfaction constructs.

3. Service Quality

Along with information quality and system quality, information systems are also commonly evaluated according to the quality of service they can deliver. Service quality directly impacts usage intentions and user satisfaction with the system, affecting the system's net benefits.

4. System Use/Use Intentions

Intentions to use an information system and actual system use are well-established constructs in the information systems literature. The

IS success model has three cores: information quality, system quality, and service quality, affecting system use and intentions. System use is conditioned to influence a user's satisfaction with the information system, which, in turn, affects usage intentions. Along with user satisfaction, system use directly affects the net benefits the system.

5. User Satisfaction

Like actual system use, user satisfaction directly influences the net benefits provided by an information system. Satisfaction refers to the extent to which a user is pleased or contented with the information system and is conditioned to be directly affected by system use.

6. Net Benefits

The net benefit that can be delivered by an information system is a critical facet of the system's overall value to its users or the underlying organization. In the IS success model, net system benefits are affected by system use and user satisfaction with the system. System benefits would influence user satisfaction and a user's intentions to use the system.

E. Recommendation

The pandemic is challenging, but we must find a solution to facilitate education and learning. Previous studies showed that implementing a knowledge management system (KMS) can help people increase productivity and deliver a consistent knowledge asset. Based on these findings, we are eager to utilize the KMS benefit, especially for the educational sector. Implementing KMS requires us to consider many things, such as project management, data mining, blogging, and forum, and without calculating these correctly, we are planning to fail. We need to understand how to adopt KMS to formulate educational objectives and follow the best practices for managing knowledge as an asset before finally disseminating it to students or stakeholders.

1. Investment in Five Cores to Implement KMS for E-Learning

To implement and consider building a proper KMS, we need to develop five cores so the KMS will run smoothly and all stakeholders can benefit from the impact.

a) People

People are the essential core in implementing KMS technology. The technology potency cannot be maximized without a good attitude and skill. To build people, we need to establish the training and class materials to give them insight and prevent the situation where the students/employee gives resistance and bends the school's/organization's rules. The main problem in Indonesia is that we are usually capable of creating good and high-end technology but forget the people element as the actor. It explains why security can be easily hacked because there is a human factor that manipulates and exploits it. In education, there is always a possibility that people will try to disregard the official system and instead find their solution. Shortly, we should prepare the people to build their skills and knowledge to implement the official system comprehensively (Hosseini et al., 2014; Wiig, 2004).

b) Process

The process is the second essential core in implementing the KMS technology. We should understand that the goal of technology is refining the current process and make learning and working more efficient. If we learn how technology transforms everything, we know that technology may replace and transform the traditional system. In other words, when we apply the new technology, we should also change the process and erase unnecessary activity. Shortly, we should prepare the best resources to create the process inside the organization to become more efficient and yield better result than before (Lee & Choi, 2003).

c) Technology

Technology is the third essential core in implementing KMS technology. We should know that we will need the right technology to move from traditional to advanced. In this part, the organization should understand the current technology and how the technology will be developed in the future (Saide et al., 2018). Choosing the right technology is an easy because we have to analyze the risks and benefits of each technology. For example, there will be great technology with high-price and good features, but the features cannot be used fully. The organization should consider this (Ho, 2009; Lee & Choi, 2003; Saide et al., 2018; Yeh et al., 2006).

d) Structure

The structure is the fourth essential core in implementing the KMS technology. There is a possibility that we need to change the structure. A leader with a good understanding of technology can become a great problem solver. If we cannot find it, the leader can choose the right people with a good understanding of KMS to lead the project (Claver-Cortés et al., 2007; Mahmoudsalehi et al., 2012; Saide et al., 2019).

e) Culture

The culture is the fifth essential core in implementing the KMS technology. Culture has the power to influence the environment in accepting and building good technology conditions in the organization. Some previous studies indicated that people could be changed because an excellent organizational culture influences them. In other words, when we want to rebuild education, we should never forget to give good examples or create conducive culture for the people (Adeinat & Abdulfatah, 2019; Ahmady et al., 2016; al Saifi, 2015).

2. Steps in Building Knowledge Management System for Education

We recommended at least eight steps to help education sector or organization face the challenge, reduce the risks, and maximize the potential rewards. This approach was inspired by ITIL v3 and COBIT approach in IT governance (Choi & Yoo, 2009; Nabiollahi & Sahibuddin, 2008). The following are the steps we recommend:

Step 1: Establish Knowledge Management Program Objectives

Before we enter further steps such as selecting a tool, defining a business process, developing the organization's workflows, and imagining and implementing the ideal end state of KMS, first we should establish the appropriate objectives of KMS itself. In this step, we must identify and document the current business problems. This business problem can become our starting point and business drivers to gain momentum and proper foundation for implementing KMS later. We need to note that the objectives can be short-term and long-term. Both of them should address the business problems and support the business continuity. Short-term objectives should ensure that the program is on the right path, while long-term objectives will help create and communicate the big picture.

Step 2: Preparing Change Management Roadmap

When we talk about knowledge management, we cannot only focus on technology application, as it needs a culture change. Employees and organizations must rethink how they develop, create, and share knowledge. That's the reason why people, processes, and culture are the essential core in implementing KMS. For example, knowledge is not free, and some employees are reluctant to share their knowledge. We can prepare a solution such as giving a reward for their contribution. This practice can form a "knowledge is power" behavior that contradicts a knowledge-sharing, knowledge-driven culture.

When we want to successfully implement a new knowledge management program, the organization may require changes, which can be the organization's norms or shared values. We should understand that every movement or change cannot run smoothly. There will be some people who might resist or even attempt to quash the change. To anticipate and minimize the negative impact, we need to manage cultural change. An example of good solution in the organization is to recruit knowledge-management experts who can encourage knowledge-sharing behaviors within their departments and provide valuable feedback for the implementation team.

Step 3: Formulate and Map the High-Level Process for Starting Point

Mapping out a high-level knowledge management process is vital for effective implementation. Working with a high-level process will help the organization develop and hone detailed procedures throughout the following steps progressively. It should be noted that we need to understand the people who will be the users and contributors of knowledge. This part cannot be skipped and should be part of this process because in developing the KMS, we must include everything and ensure the needs will be covered.

In preparing proper KMS, we can use the KMS best practices of some previous organizations, such as mapping and formulating the knowledge strategy, creation, identification, classification, capture, validation, transfer, maintenance, archival, measurement, and report.

Step 4: Determine and Prioritize the Needs

We need to assess what technology can enhance and automate knowledge management-related activities in this step. Based on the program objectives established, we should determine and prioritize requirements in knowledge management technology. We also need to understand that the knowledge management solutions on the market are extensive and varied. It is essential to know the background of each service provider, then analyze the costs and benefits of each type of technology and find out which solution can help us for achieve our goals.

Besides that, understanding what employees use today and what is working and not working for them can become an excellent approach to understanding the needs. Choosing the right technology cannot be done appropriately without determining the current technologies which may meet the organization's needs.

Step 5: Assess Current Condition

After we established the program objectives, prepared for the cultural changes management, defined a high-level process, and determined and prioritized the technology needs, we must assess our organization's current state of knowledge management. This assessment should cover the five core components of knowledge management: people, processes, technology, structure, and culture. It should be noted that the assessment should usually provide an overview of three aspects: the current state, the gap between the current condition and desired condition, and recommendations to fill the gaps. The results of this assessment will be used as foundation for establishing the roadmap.

Step 6: Create the To-Be Condition and Milestone to Achieve the Ideal Situation

After assessing the current-state condition, it can be said that we comprehend all information about the current condition. Then, we must build the implementation roadmap as our guidance in realizing the knowledge management program. However, before going too far, we have to confirm and re-confirm if we got the senior leadership's support, commitment, and funding to implement and maintain the knowledge management program until it can be deployed. Without leadership support, the efforts and project will not run smoothly and are more likely to become futile. Solid evidence of the organization's shortcomings via the assessment may drive the urgency rate up and open the leader's eyes.

In addition, we need a strategy to address the critical shortfalls in gaining leadership support and obtaining the funding we need. This strategy can be presented as a related project roadmap, addressing the gaps identified during the current state assessment. We can create a roadmap in the form of monthly, quarterly, semi-annually, or annually, and it is also important to illustrate the key milestones and dependencies. A good roadmap will be a great start to support the next steps.

As time progresses, we continue reviewing and evolving the roadmap based on changing economic conditions and business drivers. This action should be taken because sometimes we have to face an unpredictable situation. We also need to make the schedule to manage the project continuity. Later, this step will give us additional insight through the lessons learned and may be applied in future projects.

Step 7: Implementation of KMS

Implementing a KMS program and maturing the organization's overall effectiveness will require significant personnel resources and funding contribution. We have to prepare for the possibility of the long haul, but make sure that we have to make incremental advances and celebrate them. We should remember that the organization recognizes the value and benefits of the developing program to reduce the resistance and continue investing in knowledge management.

After that, it is time for the rubber to meet the road, as we understand the objectives clearly. We already have a proper solution to mitigate cultural issues. We can also determine what technologies are appropriate to launch the knowledge management program. Further, we know the gaps and have a roadmap to tell how to address them. When we advance through each step of the roadmap, we need to ensure the completion of our short-term objectives and report it. Failing to do this will bring consequences for our program to lose momentum and support from key stakeholders.

Step 8: Measure, Evaluate, and Improvement

This step is critical because we should understand how well our knowledge management investments work. We need to provide the framework to measure the effectiveness and compare it to anticipated results. Before implementing the knowledge management program, we must establish baseline measurements to capture the organization's performance. Then, after implementation, we need to compare the new results to the old results to see how well performance has been done.

The value resulting from the knowledge management system cannot be seen immediately. Sometimes the process will take time. So, if the results are not meet our expectation, we can always make the corrections and adjustments along the way.

We must determine the appropriate methods to measure our organization's progress, for example establishing a balanced scorecard that provides performance, quality, compliance, and value metrics. The key point behind establishing a knowledge management balanced scorecard is that it may provide valuable insight into what is working and what is not. Based on this result, we can then take the necessary actions to correct any mistakes to ensure high compliance, performance, quality, and reduce value gaps, thus improving the overall efficacy of the knowledge management program.

F. Conclusion

Implementing a comprehensive knowledge management system (KMS) takes considerable time and resources. However, the results will undoubtedly be worth the effort. We can also minimize risk by taking a phased approach that gives beneficial returns at each step. Education organizations that have invested in knowledge management must realize that they cannot get tangible results immediately. In other words, this investment is designed to be fruitful in the long-term.

As we already stated, in building KMS, we must ensure the eight knowledge management steps have been performed thoroughly. We do not need to make it directly once a time, as it should be executed step-by-step. When building KMS, we also need to pay special attention to three success factors in information system: service quality, information quality, and system quality. These factors can generate proper system usage and high user satisfaction, which will later help students and educators gain more benefits than before.

References

Adeinat, I. M., & Abdulfatah, F. H. (2019). Organizational culture and knowledge management processes: Case study in a public university. *VINE Journal of Information and Knowledge Management Systems*, 49(1), 35–53. https://doi.org/10.1108/VJIKMS-05-2018-0041

Aguilera-Hermida, A. P. (2020). College students' use and acceptance of emergency online learning due to COVID-19. *International Journal*

of Educational Research Open, *1*, 100011. https://doi.org/10.1016/j.ijedro.2020.100011
Aguilera-Hermida, A. P., Quiroga-Garza, A., Gómez-Mendoza, S., del Río Villanueva, C. A., Avolio Alecchi, B., & Avci, D. (2021). Comparison of student's use and acceptance of emergency online learning due to COVID-19 in the USA, Mexico, Peru, and Turkey. *Education and Information Technologies, 26*(6), 6823–6845. https://doi.org/10.1007/s10639-021-10473-8
Ahmady, G. A., Nikooravesh, A., & Mehrpour, M. (2016). Effect of organizational culture on knowledge management based on Denison model. *Procedia - Social and Behavioral Sciences*, *230*, 387–395. https://doi.org/10.1016/j.sbspro.2016.09.049
al Saifi, S. A. (2015). Positioning organizational culture in knowledge management research. *Journal of Knowledge Management*, *19*(2), 164–189. https://doi.org/10.1108/JKM-07-2014-0287
Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly: Management Information Systems*, *25*(1), 107–136. https://doi.org/10.2307/3250961
Bączek, M., Zagańczyk-Bączek, M., Szpringer, M., Jaroszyński, A., & Wożakowska-Kapłon, B. (2021). Students' perception of online learning during the COVID-19 pandemic: A survey study of Polish medical students. *Medicine*, *100*(7), e24821. https://doi.org/10.1097/MD.0000000000024821
Bahasoan, A N., Ayuandiani, W., Mukhram, M., & Rahmat, A. (2020). Effectiveness of online learning in pandemic COVID-19. *International Journal of Science, Technology & Management, 1*(2), 100–106. https://doi.org/10.46729/ijstm.v1i2.30
Bembenutty, H., & White, M. C. (2013). Academic performance and satisfaction with homework completion among college students. *Learning and Individual Differences*, *24*, 83–88. https://doi.org/10.1016/j.lindif.2012.10.013
Choi, W., Yoo, D. (2009). Assessment of IT Governance of COBIT Framework. *International Conference on U- and E-Service, Science and Technology.* UNESST 2009. Communications in Computer and Information Science, vol 62. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-10580-7_13
Claver-Cortés, E., Zaragoza-Sáez, P., & Pertusa-Ortega, E. (2007). Organizational structure features supporting knowledge management

processes. *Journal of Knowledge Management*, *11*(4), 45–57. https://doi.org/10.1108/13673270710762701

Delone, W. H., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable. *Information System Research*, *3*(1), 60–95. https://doi.org/10.1287/isre.3.1.60

DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems*, 19(4), 9–30. http://www.jstor.org/stable/40398604

DeLone, W. H., & McLean, E. R. (2016). Information systems success measurement. *Foundations and Trends® in Information Systems, 2*(1), 1–116. https://doi.org/10.1561/2900000005

Galloway, M., Conner, J., & Pope, D. (2013). Nonacademic effects of homework in privileged, high-performing high schools. *Journal of Experimental Education*, *81*(4), 490–510. https://doi.org/10.1080/00220973.2012.745469

Gaur, S., Chaudhary, A., & Mittal, M. (2015). A comparative study of e-learning technique with traditional teaching techniques. *International Journal of Innovative Research in Electrical, Electronics, Instrumentation, & Control Engineering, 3*(8), 23–25. https://doi.org/10.17148/ijireeice.2015.3806

Hendriyanto. (2021, August 26). *Tantangan dan terobosan pendidikan di era digitalisasi. Direktorat Sekolah Dasar, Direktorat Jenderal PAUD Dikdas dan Dikmen, Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.*. https://ditpsd.kemdikbud.go.id/artikel/detail/tantangan-dan-terobosan-pendidikan-di-era-digitalisasi

Ho, C.-T. (2009). The relationship between knowledge management enablers and performance. *Industrial Management and Data Systems*, *109*(1), 98–117. https://doi.org/10.1108/02635570910926618

Hosseini, M. R., Tahsildari, H., Hashim, M.T., & Tareq, M. A. (2014). The impact of people, process, and technology on knowledge management. *European Journal of Business and Management*, *6*(28), 230-241. https://www.iiste.org/Journals/index.php/EJBM/article/view/16022/0

Jenert, T. (2011). *Learning culture as a guiding concept for sustainable educational development at higher education institutions.* Red-Conference Proceedings. https://www.researchgate.net/publication/230672889

Kerbl, R., & Zepp, F. (2021). Coronavirus disease 2019. *Monatsschrift Fur Kinderheilkunde*, *169*(4), 308–311. https://doi.org/10.1007/s00112-021-01158-0

Lee, H., & Choi, B. (2003). Knowledge management enablers, processes, and organizational performance: An integrate view and empirical examination. *Journal of Organizational Computing and Electronic Commerce*, *20*(1), 179–228. https://doi.org/10.1080/07421222.2003.11045756

Li, Q. (2007). Student and teacher views about technology: A tale of two cities? *Journal of Research on Technology in Education*, *39*(4), 377–397. https://doi.org/10.1080/15391523.2007.10782488

Ma, J., Pender, M., & Welch, M. (2016). *Education pays 2016. The college board trends in higher education series* (pp. 1–44). College Board. https://files.eric.ed.gov/fulltext/ED572548.pdf

Mahmoudsalehi, M., Moradkhannejad, R., & Safari, K. (2012). How knowledge management is affected by organizational structure. *Learning Organization*, *19*(6), 518–528. https://doi.org/10.1108/09696471211266974

Sinha, P., Mishra, N. M., & Arora, M. (2012). Challenges and prospects of knowledge management practices in higher education institution. *Radix International Journal of Research in Economics & Business Management*, *1*(8), 1–21. https://www.researchgate.net/profile/Monika-Arora-9/publication/232697621_CHALLENGES_AND_PROSPECTS_OF_KNOWLEDGE_MANAGEMENT_PRACTICES_IN_HIGHER_EDUCATION_INSTITUTION/links/5a9e923baca272e66bf71546/CHALLENGES-AND-PROSPECTS-OF-KNOWLEDGE-MANAGEMENT-PRACTICES-IN-HIGHER-EDUCATION-INSTITUTION.pdf.

Nabiollahi, A., & Sahibuddin, S. bin. (2008). Considering service strategy in ITIL V3 as a framework for IT governance. *International Symposium on Information Technology.* DOI: 10.1109/ITSIM.2008.4631631

Organization for Economic Co-operation and Development (OECD). (2019). *Programme For International Student Assessment (PISA) 2018*. oecd.org/pisa/publications/pisa-2018-results.htm

Oye, N. D., & A.Iahad, N. (2011). *E-learning barriers and solutions to knowledge management and transfer. Information Management and Business Review, 3*(6), pp. 366-372. https://doi.org/10.22610/imbr.v3i6.953

Pengelola Web Kemdikbud. (2021, October 19). *Adaptasi teknologi bagi sektor pendidikan dalam menjawab tantangan masa depan.* Kementerian Pendidikan dan Kebudayaan Republik Indonesia. https://

www.kemdikbud.go.id/main/blog/2021/10/adaptasi-teknologi-bagi-sektor-pendidikan-dalam-menjawab-tantangan-masa-depan

Permata, V. J., & Dhoehaeni, H. (2021). *Rumah belajar as online learning model for early childhood education*. Proceedings of the 5th International Conference on Early Childhood Education (ICECE 2020). DOI:10.2991/assehr.k.210322.067

Petrides, L., & Nguyen, L. (2006). Knowledge management trends: Challenges and opportunities for educational institutions. In Metcalfe, A. (Ed.), *Knowledge management and higher education: A critical analysis* (pp. 21–33). IGI Global. https://doi.org/10.4018/978-1-59140-509-2.ch002

Polanyi, M. (1974). *Personal knowledge: Towards a post-critical philosophy* (Vol. 20, Issue 3). University of Chicago Press. https://philpapers.org/rec/POLPKT

Saide, S., Indrajit, R. E., Trialih, R., Ramadhani, S., & Najamuddin, N. (2019). A theoretical and empirical validation of information technology and path-goal leadership on knowledge creation in university: Leaders support and social media trend. *Journal of Science and Technology Policy Management*, *10*(3), 551–568. https://doi.org/10.1108/JSTPM-06-2018-0067

Saide, S., & Sheng, M. L. (2020). Knowledge exploration–exploitation and information technology: crisis management of teaching–learning scenario in the COVID-19 outbreak. *Technology Analysis and Strategic Management*, *33*(8), 927–942. https://doi.org/10.1080/09537325.2020.1854714

Saide, Trialih, R., Indrajit, R. E., Putri, A., Fazri, P. N., & Hafiza, W. (2018). The influence of information technology infrastructure and leadership style on knowledge management implementation. *2017 IEEE International Conference on Industrial Engineering and Engineering Management.* https://doi.org/10.1109/IEEM.2017.8289877

Sajida, & Ranjani. (2020). Examining the internet quota subsidy policy in Indonesia. IAPA Proceedings Conference. https://doi.org/10.30589/proceedings.2020.411

Salehudin, M., Zulherman, Z., Arifin, A., & Napitupulu, D. (2021). Extending Indonesia government policy for e-learning and social media usage. *Pegem Journal of Education and Instruction*, *11*(2), 14–26. https://doi.org/10.14527/pegegog.2021.0

UNESCO. (2020). *COVID-19 impact on education*. UNESCO. https://en.unesco.org/covid19/educationresponse

Wiig, K. M. (2004). *People-focused knowledge management: How effective decision making leads to corporate success.* Routledge. https://doi.org/10.4324/9780080479910

Yeh, Y. J., Lai, S. Q., & Ho, C. T. (2006). Knowledge management enablers: A case study. *Industrial Management and Data Systems*, *106*(6), 793–810. https://doi.org/10.1108/02635570610671489

Zalat, M. M., Hamed, M. S., & Bolbol, S. A. (2021). The experiences, challenges, and acceptance of e-learning as a tool for teaching during the COVID-19 pandemic among university medical staff. *PLoS ONE*, 16, 1–12. https://doi.org/10.1371/journal.pone.0248758

Chapter 15

Public Transportation Transformation Towards a Smart, Efficient and Inclusive System

Ulin Nuha

A. Overview of Public Transportation Transformation

Transportation has been vital for human civilization from centuries BC until today. Transportation is a means to move goods or people's needs from one place to another for an objective (Adeniran & Olaniyi, 2016). Through transportation, the development of the economic sector is highly supported for the distribution of products. A transportation unit also significantly helps the accessibility of civilization movement to fulfill daily needs. The first significant revolution in transportation occurred in Europe from 1760 to 1850, affecting human life worldwide. Society previously utilized animals to assist the primary transportation need. When the industrial revolution came,

U. Nuha
National Kaohsiung University of Science and Technology, Taiwan e-mail: ulinpoenya@gmail.com

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they changed transportation to trains which used coal as the primary energy source. This displacement impacted human mobilization more efficiently and faster. Today, we must prepare to face the fifth industrial revolution as known society 5.0. Undoubtedly, it affects the growth of the applied science faster and more sophisticated increases.

Transportation has made various contributions to society living in urban and rural areas. Good transportation infrastructure can accelerate the productivity of the economic sector (Kutty et al., 2020). The existence of transportation can impact the development and sustainability of an area's economic, environmental, and social of the society. Through modern transportation, an industrial economy exceeds various territorial boundaries, even different continents. More significantly, transportation has a vital role in industrial activities for fast and efficient logistics distribution. The transportation component of the industrial sector consists of warehousing (distribution centers), trucking, trains, and specific supporting industries. Transportation plays an important role in running the economy in the community's welfare because there is a facility that can move people and goods from one area to another to obtain core needs and build the socio-economic capabilities of the community.

Moreover, the existence of transportation provides facilities as a mode of support for the community's daily life. The mobility of residents in their daily activities, especially to work, is highly dependent on public or private transportation facilities. For instance, BPS, The Central Bureau of Statistics (BPS) in Indonesia, states that train passengers in November 2021 experienced a 15.60% increase in commuters compared to October 2021 (Dihni, 2022). On the other hand, transportation infrastructure influences the environment directly and indirectly. The direct impacts are land taken for building infrastructure, visual disturbance, noise during construction, and infrastructure utilization. Then, the indirect impact is environmental pollution which is the biggest impact on climate change (Gudmundsson et al., 2016).

For government policy, a good transportation facility accelerates the goal of developing infrastructure in various areas. Building facilities in rimland areas requires distributing labor and materials from other places. Indonesia's government objective to develop regions such as Papua first requires good transportation both for pathway and conveyance. Government services also need the service of transportation to be optimal in executing their program. Moreover, the transportation system also impacts social interaction, especially in Indonesia, which has a tradition of gathering and visiting each other. Therefore, infrastructure development is highly strategic to improve the welfare of a country.

However, to build a modern transportation system and infrastructure, procurement of infrastructure systems not only focuses on massive quantities but also pays attention to the system's sustainability. Sustainability in the transportation system must achieve a condition that the presenting needs are gained without compromising the ability of the next generations to attain their desires and concern for the natural resources, the prosperity of society, availability of future resources, and conforming the human values (Shiftan et al., 2003). To realize the sustainability of transportation systems, planning management requires integrating various components while considering a comprehensive procedure (Maheshwari et al., 2015).

One of the most critical transportation systems is the public transportation unit. Public transportation allows more people to travel along a defined route, such as buses, trains, and cars, and the period of services operates on a set schedule. The advances in technology and science contribute novel systems to public transportation through applying artificial intelligence and big data. Many countries have developed their public transportation to achieve a sustainable transportation system. In a developing country such as Indonesia, transportation public has lack in providing excellent services than private transport for society. The success of public transportation management indicates that the government's policies are working effectively. Moreover, currently we face a post-pandemic situation, so an analysis of the current needs and prospect needs to be done.

To realize society 5.0, we must comprehend this idea's pillars. One of its pillars is the public transportation system which significantly impacts society's goals and values. Public transport facilities lead to various impacts and advantages to society locally. It gives references for the policy to make decisions where transport sustainability corresponds to society's needs (Stjernborg & Mattisson, 2016). To realize a sustainable public transportation system, we initially analyze several issues related to public transportation in Indonesia as follows:

B. Traffic Congestion

As the fourth most populated country in the world, traffic congestion still becomes a problem faced by residents in Indonesia. According to data from TomTom in 2021, the capital city of Indonesia, Jakarta, got the traffic index of the top 10 in the world.

INRIX, a company engaged in the data analysis, states that Surabaya is the most congested city in 2021, achieving 62 hours as the amount of time wasted in a year due to traffic as seen in Table 15.1 (INRIX, n.d.). Then, the congested cities in Indonesia are followed by Jakarta, Denpasar, Malang, and Bogor, where the percentage decreases compared to the previous year. However, these cities still have high traffic jam, which have many impacts.

Table 15.1 The Top Five Most Congested Cities in Indonesia

Ranking	City	Global ranking (2020)	Global ranking (2021)	Hours lost during traffic jam*	Hour lost percentage pre-Covid
1	Surabaya	361	58	62	72%
2	Jakarta	55	409	28	-81%
3	Denpasar	142	359	31	-48%
4	Malang	46	394	29	-49
5	Bogor	1014	861	7	-224%

*During one year in 2021

Source: INRIX (n.d.)

One factor influencing the traffic congestion of big cities in Indonesia is a traffic system that still mixes up all types of transportation modes, both local and regional (Wijanarko & Ridio., 2019). Some big cities have regulated the mode of transportation in a pathway, but it is not applied extensively. The traffic congestion also cannot be separated from a large number of private vehicle users compared to the number of public transport users.

BPS record that the number of motorcycles owned by residents is 115 million units, while cars achieve a 21 million units (BPS, n.d.). Private transportation still becomes the first choice for residents. This paradigm must be changed while the government must provide good public transportation. The impact of traffic congestion not only affects the mobility of the society but also the cost of environmental prolusion. Especially during the period of leaving and returning from work, traffic jams occur in almost all big cities in Indonesia.

C. Inadequate Public Transportation

The large number of residents who have private vehicles shows that the role of public transportation is not yet utilized for community mobility. Based on BPS data, the number of users of motorbikes and private cars each year has increased in percentage compared to the previous years. We take Jakarta as the capital city as an example. The number of motorcycle users in 2020 is 20 million people, while the number of car owners reached 3 million, both of which have increased in percentage from previous years (BPS Jakarta, 2021). Even the Governor of Jakarta once said that the total number of vehicles in Jakarta is more than the total population of around 11 million people (Muryono, 2021).

In contrast, a statistic from BPS shows that the number and growth of Transjakarta Bus Passengers by Corridor in 2020 decreased 52,1 % compared to the previous that had 264 million passengers for one year (Rizaty, 2021). The number of train passengers decreased in 2020 to only 80 million compared to the previous year. This data may be biased because in 2020, pandemic began in Indonesia. However, Jakarta has a mission to turn back and improve the function of public transportation as the main mode of citizen mobility. On the other hand, we take Salatiga City, a small city and not the center of the economy in Central Java, as a comparison. The number of motorcycles in this city in 2020 was 120 thousand increasing from the previous year. Then, the number of cars in 2020 was 19 thousand (BPS Jateng, n.d.). If we compare to the population of Salatiga City in September 2020, which was 192,322 people, more than 70% of the population own a private vehicle (BPS, n.d.). While the number of in-city transportation in 2020 was 421 vehicles, it noted that in Salatiga City, there is no train (BPS Salatiga, 2021). The analysis above shows that many cities in Indonesia still need to increase the quantity and quality of public transportation.

Moreover, the existing public transportation system in Indonesian cities still does not integrate. There are still many modes of public transportation in some cities that stop at any place, opening a special point. Public transportation generally picks up passengers where they stand and drops passengers where they want. In addition, access from the airport to the train station is still far in some cities. Then, one of the reasons that people prefer choosing choose the private vehicles is that important points from every corner of the area do not have easy access to go. For instance, a resident who wants to use public transportation from his home to the sub-district office sometimes has to wait an hour for the departure time or the difference between the arrival of certain public transportation routes and the next vehicle.

D. Conventional System

If we look at Indonesia's transportation problem, we must differentiate between metropolitan and non-metropolitan cities. The availability or quantity of public transportation in metropolitan cities can be considered sufficient compared to non-metropolitan cities. Besides the quantity that needs to be increased the transportation system is not yet fully technology-based. Payment mechanism commonly is based on conventional payment, even using money directly as a transaction tool. The ticketing mechanism is still not fully implemented on public transportation, especially for using the e-money card as a payment method.

Jakarta may be the first city that promotes Jak Lingko as electronic payment for public transportation payment. However, it needs to be expanded again for all kinds of existing transportation modes and not only for the Jakarta area but also can be operated in other cities. Then, the big data concept does not fully enter the public transportation system. Take Jakarta as an instance, people only know the table schedule of arrival and the route based on poster paper, and the schedule sometimes may be late. It needs a real-time information system that informs passengers how many minutes the bus will arrive at a certain point. So, the position of every public vehicle, be it a bus or train, is recorded by a system that can be seen in real-time.

In some non-metropolitan cities, *angkot* or shared taxi is still the main mode of transportation. *Angkot* are private cars that are used as public transportation. Take Semarang city as an example, *angkot* still become the main public transportation besides the bus. As the capital city of Central Java, the transportation system of Semarang city is still lagging behind Jakarta. Sustainable and advanced transportation infrastructure needs to be implemented in several cities in Indonesia besides Jakarta, especially big cities that are still experiencing traffic congestion. The infrastructure development that will be carried out also needs to be studied in-depth so that the existing infrastructure is effective and not just frenetic.

E. Not Inclusive and Comfortable Environment

One of the factors of public interest in using public transportation that is the convenience factor that has not been obtained. Service, accessibility, safety, and cost can indicate how well the transportation system is (Aminah, 2018). For instance, disabled people do not get comfortable facilities in entry or space in the mode of transportation. Public transportation such as buses in many cities in Indonesia is not yet friendly for people with disabilities by providing special spaces.

Likewise, the public transportation infrastructure does not provide toilets for disabilities, for example. Then, detailed designs such as seats sometimes still do not consider comfort for passengers. The easiest example is a seat for economy class train passengers. The design of the long seats facing each other in the economy class train makes the long-distance passengers feel less comfortable a detailed design needs to get attention.

Moreover, based on the Jakarta Transportation Safety Board (DKTJ) report, one of the common complaints about Jakarta transportation throughout 2021 is the length of the headway of public transportation, which affects the accumulation of passengers at the bus stop or station (Wibowo, 2021). Before the pandemic, the Minister of Transportation stated that the percentage of public transportation passengers was about 33%, still much less than private transportation users (Wiryono, 2017). This problem requires innovation and strategy from policymakers on how to change the paradigm in society to have a desire to use public transportation instead of private, accompanied by an increase in the quality of service and comfortable facilities.

F. Solution and Recommendation for the Public Transportation System in Indonesia

1. Sustainable Transportation System

Transportation infrastructure has a critical role in the economic development of Indonesia. The transportation system is not only a social means that connects people from one place to another but also a means to open their territory from isolation and backwardness (Qodriyatun, 2012). A sustainable transportation system and infrastructure cannot only overcome various problems such as congestion, vehicle accidents, environmental pollution, and so on, but also stimulate development and encourage equitable regional development in Indonesia.

Jakarta achieved the Sustainable Transport Awards (STA) 2021 in MOBILIZE 2020 virtual conference (Sandiputra & Inggita, 2020). This achievement of course deserves to be appreciated. However, the fact of daily traffic congestion still appears. Let's talk about Indonesia as a country. We also must pay attention to other cities. Through smart mobility, the goal is to reduce the use of private vehicles. Initially, it needs government policy to regulate the number of owned vehicles. In 2020, the Bureau of Statistics (BPS) recorded that the total population of vehicles in Indonesia was more than 133 million units (BPS, n.d.). Take Singapore as an example. The government regulates that before buying a car, people need to have a Certificate of Entitlement (COE), a license to own a car issued by the Land Transport Authority (LTA). It may be challenging to apply to all cities in Indonesia, but we can imitate this policy in big cities with a high percentage of private vehicles.

To implement sustainability of transportation systems and infrastructure, several points affect the sustainability foresight based on IPE or Infrastructure Performance Enhancement, such as accountability, certainty, cost-effectiveness, participation transparency, and others taken by stakeholders (Gharehbaghi et al., 2020). One of the indicators of sustainable transportation infrastructure is built based on public transportation using electric energy such as buses and trains to mobilize people far more efficiently than private vehicles, where an electric vehicle has less pollution and carbon footprints (Mead, 2021). To realize a sustainable transportation infrastructure, there are some breakthroughs:

a) Smart Mobility

There are some innovations or based-technology solutions that can be implemented in smart mobility:

1) Congestion Traffic Detection
   Traffic signs are critical equipment affecting the traffic congestion in the roadway. The traffic congestion will happen long during busy periods, especially departure and return from the workplace. Through a congestion detector, it can set the traffic sign based on the congestion. The length of time for changing traffic signs in congested and lost traffic conditions can be adjusted differently to

avoid prolonged congestion. Many cities in Indonesia have applied CCTV near the traffic sign. This camera can detect congestion by image processing using computer vision and deep learning, as shown in Figure 15.1. Through this technology, vehicles passing a crossroads can also be counted. Many studies have proposed various technologies to achieve this goal. This concept may not yet be applicable in many points and cities, but at least we start at some points prone to traffic congestion in big cities.

The congestion traffic detection algorithm can be seen in Figure 15.2 as an instance. First, we have a video sequence as the input of vehicle number detection. Then, image processing utilizes image processing to estimate the number of vehicles and traffic density. The image processing result can classify the traffic congestion to apply a dynamic traffic sign based on the traffic congestion degree.

2) Emergency Routing

As previously mentioned, the number of private vehicles in Indonesia is huge, and congestion in traffic often occurs. As a

Source: Zhang et al. (2019)

Figure 15.1 Vehicle's Detector Using Image Processing

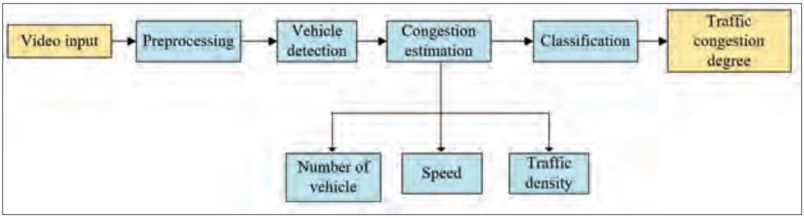
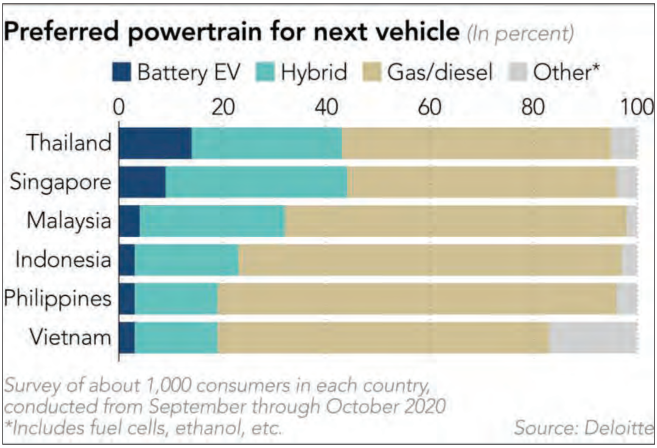


Figure 15.2 Vehicle's Detector Algorithm

follow-up to previous technology, the government can create an information system to give alternative path references in cities when there is congestion or accident. This technology can be combined with the Google Maps feature where Google Maps has a drawback drawback of giving information about congestion from devices if the devices activate their GPS in smartphones. This proposed technology can provide adapted route guidance and dynamic traffic signal timing.

b) Sustainable Vehicle Promotion

The Ministry of Transportation of Indonesia stated that in mid-2021, there were 14 thousand electric vehicles (Primadhyta, 2021). The electric vehicles consist of 1,656 cars, 262 three-wheeled vehicles, 12,464 electric motorcycles, 13 buses, and five freight cars. It is still below 1% of the percentage of vehicles spread in Indonesia. In contrast, the number of public electric vehicle charging stations has reached 187 units spread over 155 locations on Java, Sumatra, and Sulawesi. The government needs to make a policy that supports the use of electric vehicles. At least the buses or cars that the government uses as public transportation and government operational service vehicles use electric vehicles. In tIndonesia, the largest country in the ASEAN region, still depends on gas or diesel for the powertrain. The use of battery EV based on a survey around the end of 2020 is below than Thailand, Singapore, and Malaysia as shown in Figure 15.3. The government policy can accelerate the use of electrical energy



Source: Loh & Sugiura (2021)

Figure 15.3 Powertrain Sources in ASEAN Countries

for powertrain through lower taxes on the sale and ownership of low-emission vehicles.

2. Integrated Public Transportation

The transportation system of big cities in Indonesia is still fragmented, which causes passenger journeys to be longer, less comfortable, and more expensive. The operating path of each type of public transportation mode is still independent. Even every transportation mode stops carelessly because there is no standard stopping place except in some big cities like Jakarta. Here we will map out several points that need to be carried out by policymakers ito realize the integration of public transportation.

a) Establishment of Public Transportation Stops

The majority of landmass transportation in Indonesia is *angkot*, bus, train, and MRT as shown in Figure 15.4 However, *angkot* and buses are almost in all cities in Indonesia. The government needs to make regulations that not all types of mass public transportation can stop

Source: Kominfo (n.d.)

Figure 15.4 Mass Transportation

recklessly. They can only stop at a certain point according to what has been determined. For instance, each *angkot* with a certain route can only stop at 50 points where passengers are waiting. When there is no passenger, the car keeps going. Each stopping point is made as a marker regarding transportation that passes through the place accompanied by the route and time of arrival as shown in Figure 15.5. The problem is that individuals own public transportation in Indonesia, but not all public transportation modes are owned or under the government. To this end, the government may create a regulation that only transportation modes obtaining official permission from the government can operate. The income they get must be submitted to the government and they will get a fixed income every month regardless of how many passengers they get.

3. Integrated Route and Schedule

People need integrated public transportation to get an effective route and time. Stakeholders must provide a certain schedule of specific public transportation. Integrated public transportation is designed based on how demand-responsive services are arranged and the

Figure 15.5 Stopping Point with Its Schedule and Route in Taiwan

frequency of a route from public transportation modes to a certain point (Hall et al., 2008). First, they can map the busy time route of specific public transportation. On busy routes or with many passengers, a type of public transportation passes the more stopping point each hour. Instead of having a long route not integrated with other modes of transportation, it is very important to rearrange the modes of transportation that are integrated. Each city in Indonesia needs to design integrated public transportation, including buses, and MRT as shown in Figure 15.6.

4. Centralized Data Information

Public information about transportation services is not yet easily accessed by the community. The government needs to build an information system for public transportation. This information system includes all information about the route and schedule of public transport in all cities in Indonesia, including buses, trains, or

Source: klia2.info (n.d.)

Figure 15.6 Integrated Transit Map in Malaysia

MRT. In Google Maps, we may find a route from Senayan to Monas using some transportation such as Bus or MRT. However, if we see from Magelang Square to the mayor's office, you will not find public transportation route. Centralized information about the schedule and route of all public transportation is critical to be defined through digital information such as smartphone applications.

One of the problems is that not all public transportation in Indonesian cities has a specific route code Therefore, all types of public transportation in various cities must be attached to a code for easy identification. Figure 15.7 shows digital information system for public transportation in Taiwan. This application allows us to find buses by route number or the stopping point name. Moreover, this information is real-time, so public transportation informs its current location to be detected by the information system. This application system gives information about real-time schedules for buses and MRT, regular trains, and LRT.

Afterward, most payment conducted in public transaction uses cash in non-big cities in Indonesia. Big cities such as Jakarta, Surabaya, and others may apply non-cash payments or smart cards. Jakarta may

Figure 15.7 Example Digital Information System for Public Transportation

lead to public transportation payment through the *Jak Lingko* card as shown in Figure 15.8, but it only can be used and applied in Jakarta area. We need a smart card such as *Jak Lingko* in Jakarta to be able to be used and applied in all cities in Indonesia and for all transportation. The Indonesian Ministry of Transportation needs to serve smart cards for public transportation payments for buses, trains, MRT, and etc. Take Taiwan as an instance, they have smart cards such iPass and EasyCard for all transactions, not only for transportation payment but these cards can also be used for minimarket payment and others. This card can be used not only for short-distance public transportation but also for long-distance or inter-city transportation.

These smart cards can help people whenever they travel and avoid the *calo* (broker) that is still rife in the sale of transportation tickets in Indonesia. The balance can be topped up through minimarkets or authorized agents near public transportation stations. It can also give precise information about the pattern of community use when using public transportation every day in various modes and regions.

Source: Arjanto (2019)

Figure 15.8 Jak Lingko Card

5. Inclusive and friendly public transportation

Based on data from the 2015 Inter-Census Population Survey (SUPAS), BPS recorded 8.56% of the population with disabilities (BPS, 2016). It indicates that we should pay attention to them, especially their mobility in public transportation. Indonesia may be far in facilitating disabilities compared to developed countries. However, we can start to make them comfortable when using public transportation. Many public transportations do not provide a space or seats for people with dis. In-city and inter-city buses must provide easy access from the bus stopping point to enter transportation. Likewise, the intercity destination train modes managed by the Indonesian Railways (KAI) must be more inclusive in providing easy and convenient access. Some points in big cities like Jakarta may already provide these services, but they need to be improved and augmented in other cities. Each

Source: Alamy Stock Photo (n.d.)

Figure 15.9 A Bus with Inclusive Access for Disabilities bus or train should be accessible for parents, pregnant women, and disabilities as shown in Figure 15.9.

Table 15.2 Glossary of Terms Used

Term	Explanation
Society 5.0	A society centered on balance and integration through technological advancement to solve social and economic problems
Artificial intelligence	Systems or machines imitate human intelligence to do tasks and improve their abilities iteratively
Big data	A study to analyze and extract information systematically from massive data sets
Commuter	Workers who regularly travel through a route each day
Image processing	A method to process digital images through an algorithm to obtain valuable information or perform some operation

G. Conclusion

Indonesia, a country with a big population and wide area, has huge mobility for society. However, traffic congestion often occurs in everyday lives, especially in big cities. It denotes that public transportation services are not satisfactory or do not yet attract the interest of citizens to use them. Based on the various problems that have been analyzed, this chapter proposes several ideas that can serve as references for a sustainable and progressive public transportation system. We map them with several points such as the development of sustainable transportation system designs, integrated public transportation, centralized data information, and inclusive and friendly public transportation. The existence of well public transportation system will help the mobility of citizens in an efficient and environmentally friendly manner and can be a long-term investment for the government.

References

Adeniran & Olaniyi, A. (2016). Impacts of the fourth industrial revolution on transportation in the developing nations. *International Journal of African and Asian Studies, Vol 26*. https://www.iiste.org/Journals/index.php/JAAS/article/view/33447

Aminah, S. (2018). Transportasi publik dan aksesibilitas masyarakat perkotaan. *Jurnal Teknik Sipil, 9*(1): 1142–55. http://journal.unair.ac.id/filerPDF/Transportasi%20 Publik%20dan%20Aksesibilitas.pdf

Alamy Stock Photo. A city bus extends a handicapped ramp for a wheelchair user at a bus stop on central park west in New York city. [Photo]. Accessed February 23, 2022. https://www.alamy.com/stock-photo-a-city-bus-extends-a-handicapped-ramp-for-a-wheelchair-user-at-a-bus-139257632.html

Arjanto, D. (2019, February 21). Transjakarta Jak Lingko buka 3 rute baru, ini cakupan koneksinya. *Tempo*. [Photo]. Accessed February 23, 2022. https://metro.tempo.co/read/1178102/transjakarta-jak-lingko-buka-3-rute-baru-ini-cakupan-koneksinya

BPS. (n.d.). Perkembangan Jumlah kendaraan bermotor menurut jenis (unit), 2018-2020. Accessed February 23, 2022. https://www.bps.go.id/indicator/17/57/1/jumlah-kendaraan-bermotor.html

BPS. (n.d.). Perkembangan Jumlah kendaraan bermotor menurut jenis (unit), 2018-2020. Accessed February 23, 2022b. https://www.bps.go.id/indicator/17/57/1/jumlah-kendaraan-bermotor.html

BPS Jakarta. (2021, November 23). Statistik transportasi provinsi DKI Jakarta 2020. Accessed February 23, 2022. https://jakarta.bps.go.id/publication/2021/11/23/1aaaa91a6dd67d24ffeed6cd/statistik-transportasi-provinsi-dki-jakarta-2020.html

BPS Jateng. (n.d.). Jumlah kendaraan bermotor menurut kabupaten/kota dan jenis kendaraan di provinsi Jawa Tengah (unit), 2018–2020. Accessed February 23, 2022. https://jateng.bps.go.id/indicator/17/1006/1/jumlah-kendaraan-bermotor-menurut-kabupaten-kota-dan-jenis-kendaraan-di-provinsi-jawa-tengah.html

BPS Salatiga. (2021, June 10). Hasil sensus penduduk 2020 di kota Salatiga. Accessed February 23, 2022. https://salatigakota.bps.go.id/pressrelease/2021/06/10/168/hasil-sensus-penduduk-2020--di-kota-salatiga--.html

BPS Salatiga. (2021, December 30). Number of city transportation by route in Salatiga municipality, 2020. Accessed February 23, 2022. https://

salatigakota.bps.go.id/statictable/2021/12/30/672/banyaknya-angkutan-dalam-kota-angkota-menurut-trayek-yang-dilayani-2020.html

Dihni, V. A. (2022, January 5). Penumpang kereta api naik 15,6% per November 2021. *Databoks*. https://databoks.katadata.co.id/datapublish/2022/01/05/penumpang-kereta-api-naik-156-per-november-2021

Gharehbaghi, K., Robson, K., & Rahmani, F. (2020). Mega transportation infrastructure: A sustainable foresight. *Transportation Research Procedia 48*, 3996–4002. https://doi.org/10.1016/j.trpro.2021.04.001

Gudmundsson, H., Hall, R. P., Marsden, G., & Zietsman, J. (2016). *Sustainable transportation: Indicators, frameworks, and performance management*. Economics. Springer. DOI:10.1007/978-3-662-46924-8. http://www.springer.com/series/10099

Häll, C. H., Lundgren, J. T., & Värbrand, P. (2008). Evaluation of an integrated public transport system: A simulation approach. *Archives of Transport*, *20*, (1–2), 29–46.

INRIX. (n.d.). INRIX 2021 global traffic scorecard. Accessed February 23, 2022. https://inrix.com/scorecard/

klia2.info. (n.d.). Greater Kuala Lumpur/Klang Valley Integrated Transit System, the backbone of seamless connectivity in the Kuala Lumpur region. [Photo]. Accessed February 23, 2022. https://klang-valley-kl-transit-map.soft112.com/

Kominfo. (n.d.). Membangun transportasi umum, mengurangi kemacetan. [Photo]. Accessed February 23, 2022. https://kominfo.go.id/content/detail/5197/membangun-transportasi-umum-mengurangi-kemacetan/0/infografis

Kutty, A. A., Yetiskin, Z., Abraham, M. M., Nooh, M. A., Kucukvar, M., & Abdella, G. M. (2020). An empirical assessment on the transportation sustainability indicators and their impact on economic productivity. In *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management Detroit*. http://www.ieomsociety.org/detroit2020/papers/534.pdf

Loh, D. & Sugiura, E. (2021, September 21). Slow charge: ASEAN aims to bring lofty EV goals within range. *NIKKEI Asia*. [Photo]. Accessed February 23, 2022. https://asia.nikkei.com/Spotlight/Asia-Insight/Slow-charge-ASEAN-aims-to-bring-lofty-EV-goals-within-range

Maheshwari, P., Kachroo, P., Paz, A., & Khaddar, R. (2015). Development of control models for the planning of sustainable transportation systems.

Transportation Research Part C: Emerging Technologies 55, 474–85. https://doi.org/10.1016/j.trc.2015.03.024

Mead, L. (2021). The road to sustainable transport. *International Institute for Sustainable Development*. https://www.iisd.org/system/files/2021-05/still-one-earth-sustainable-transport.pdf

Muryono, S. (2021, March 17). Anies: Jumlah kendaraan di Jakarta lebih banyak dari warga. *Antara News.* Accessed February 23, 2022. https://www.antaranews.com/berita/2047502/anies-jumlah-kendaraan-di-jakarta-lebih-banyak-dari-warga

Primadhyta, S. (2021, November 23). Kemenhub catat jumlah kendaraan listrik RI baru 14.400 unit. *CNN Indonesia.* Accessed February 23, 2022. https://www.cnnindonesia.com/ekonomi/20211123124819-92-724887/kemenhub-catat-jumlah-kendaraan-listrik-ri-baru-14400-unit

Qodriyatun, S. N. (2012). Saatnya beralih ke sistem transportasi berkelanjutan. Info Singkat Kesejahteraan Sosial, IV(16), 9–12. Pusat Penelitian Badan Keahlian DPR RI, 2012. http://berkas.dpr.go.id/puslit/files/info_singkat/Info%20Singkat-IV-16-II-P3DI-Agustus-2012-19.pdf

Rizaty, M. A. (2021, November 29). Blok M - kota jadi rute Transjakarta dengan penumpang terbanyak pada 2020. *Databoks*. Accessed February 23, 2022. https://databoks.katadata.co.id/datapublish/2021/11/29/blok-m-kota-jadi-rute-transjakarta-dengan-penumpang-terbanyak-pada-2020

Sandiputra, R. & Inggita, M. (2020, October 31). Jakarta won the sustainable transport award (STA) 2021. *Berita Jakarta*. Accessed February 23, 2022. https://www.beritajakarta.id/en/read/37146/jakarta-won-the-sustainable-transport-award-sta-2021#.YhYDEN9BxjU

Shiftan, Y., Kaplan, S., & Hakkert, S. (2003). Scenario building as a tool for planning a sustainable transportation system. *Transportation Research Part D: Transport and Environment, 8*(5), 323–42. https://doi.org/10.1016/S1361-9209(03)00020-8

Stjernborg, V. & Mattisson, O. (2016). The role of public transport in society—A case study of general policy documents in Sweden. *Sustainability, 8*(11), 1120. https://doi.org/10.3390/su8111120

Tomtom. Jakarta Traffic. Accessed 2021. https://www.tomtom.com/en_gb/traffic-index/jakarta-traffic/

Wibowo, W. (2021, June 12). 10 masalah layanan transportasi yang sering diadukan warga Jakarta selama pandemi COVID-19. *Sindo News*. Accessed February 23, 2022. https://metro.sindonews.com/

read/453868/171/10-masalah-layanan-transportasi-yang-sering-diadukan-warga-jakarta-selama-pandemi-covid-19-1623510372
Wijanarko, I. & Ridio, M. A. (2017). Faktor-faktor pendorong penyebab terjadinya kemacetan studi kasus: Kawasan sukun Banyumanik kota Semarang. *Jurnal Planologi, 14*(1), 63. https://doi.org/10.30659/jpsa.v14i1.3859
Wiryono, S. (2017, March 28). Warga Jabodetabek lebih minati moda transportasi publik. *Republika*. Accessed February 23, 2022. https://www.republika.co.id/berita/oni418384/warga-jabodetabek-lebih-minati-moda-transportasi-publik
Zhang, F., Li, C., & Yang, F. (2019). Vehicle detection in urban traffic surveillance images based on convolutional neural networks with feature concatenation. *Sensors, 19*(3), 594. [Photo]. https://doi.org/10.3390/s19030594

Chapter 16

A Decentralized File Storage for Effective E-Government

Ahmad Fajar, Rahmat Trialih, & Fitria Wulandari Ramlan

A. Overview of Decentralized File for Goverment

Countries with fast population growth will lead to various problems related to population. The most central is the issue of data security. The theft of personal data is becoming more common. Even in 2021, President Joko Widodo's vaccination certificate is circulating on social media. This certificate is allegedly derived from the PeduliLindungi application by obtaining an Identity Number from the General Election Commission.

Apart from the president's data, there have also been leaks before. Around 279 million BPJS Health participant data are traded on RaidForums. Also, about 91 million Tokopedia users, then 1.2 million users of Bhineka.com, and 2.3 million voter data from the

A. Fajar, R. Trialih, & F. W. Ramlan
King Abdulaziz University, Saudi Arabia, e-mail: ahmad.fajar@outlook.co.id

Fajar, A., Trialih, R., & Ramlan, F. W. (2022). A decentralized filestorage for effective e-government. In R. Trialih, F. E. Wardiani, R. Anggriawan, C. D. Putra, & A. Said (Eds.), *Indonesia post-pandemic outlook: Environment and technology role for Indonesia development* (279–295). DOI: 10.55981/brin.538.c497 ISBN: 978-623-7425-85-4
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General Election Commission have been traded on the internet. This fact indicates that the protection of personal data still needs to be a concern by the government.

Personal data protection is increasingly important, especially during a pandemic when transactions begin to switch to digital or online due to restrictions on people's mobility. The cyber police recorded that the public reported 182 cases of data theft. This figure increased by 27.3% compared to the previous year, with 143 reports. Over the last five years, the increase in reports of data theft increased by 810% from 20 reports in 2016 (Jayani, 2021). The public must also protect personal data by not spreading personal and confidential information. In addition, the public needs to read the privacy policy when accessing social media to avoid unwanted incidents.

Those things can happen because the data storage system is still centered in one location or server. This term is called the centralized server. Storing and accessing files containing sensitive data such as medical records, financial history, personal information, and legal papers is difficult since it involves file system administration and authorization of those data. We have gone far from the inflexible and unreliable paper-file storage method to today's digital alternatives. Cloud-based centralized storage technology has outperformed local physical storage devices such as hard drives and servers during the last decade. About 94% of all enterprises now adopt centralized cloud solutions for data storage. Users may store data over the internet and access it remotely using centralized storage systems everywhere. Major organizations centrally hold data in a cloud storage system.

Cyberattacks and other security issues are made possible by such data. Decentralized storage solutions rely on a peer-to-peer network of users who individually store tiny, encrypted chunks of the actual data. Consequently, a reliable data storage and sharing system have been created. It might be built on a blockchain or any other peer-to-peer network. Enabling this technology for government or other sensitive data can minimize stealing those data.

B. The Blockchain

1. Technology behind Decentralization

We need to explain this term thoroughly. Before we go through it in detail, let us know each part related to the blockchain.

In daily life, people use computers to read and change data. It is possible to buy a computer of many different types. These types include laptops, desktop computers, tablets, and smartphones. Data is information in various forms, from videos and photos to text. In the past, we kept things like paper or film. Our computer can keep this data digitally. It has a lot of different parts that work together to make it easy for us to get and change all that data quickly and easily in a digital format.

If our data is saved on a local computer, it means no connection to the internet. Suppose we keep our data on the internet. The computer is called a server. Servers host websites, databases, files, or other services. It comes physically, but only authorized person or organization can access it directly. When we want access to a website, we access the server that stores it. For instance, when we want to send a message on Facebook Messenger, we access a Facebook server providing the messenger's service.

Every computer has an IP address (internet protocol address), effectively its mailing address. A website's name is just an IP address code. When you enter Facebook into your browser search box, it sends you to the Facebook server.

The next question is where we store our data? A database is a place that can keep our data saved. The database is on servers that can be easily accessed, managed, and updated. A small system only needs a small database on its server. On the other hand, big companies like Google and Facebook use massive servers to run or store their applications and users' data. It consists of many servers called data centers. Only those companies can manage the data center. Therefore, the user's data will depend on the company. Because of fires and hacks, data could be lost or leaked at the data center. Hackers will find places to attack because the system is in one place. Because of this, some databases are distributed across servers in different areas; this kind of database is called distributed databases.

Distributed databases are databases that are stored on several servers with different locations. If one server goes down, it can continue running to serve the application or request. From this checkpoint, we can get the rough meaning of distribution. We are almost to the blockchain.

The main things that make them different are what kind of data, how it is stored, who can access it, and who can see it. Once data is created on a blockchain, it cannot be changed or deleted.

A blockchain is a database shared by all the computers in a computer network. As a database, a blockchain stores information digitally in a form that can be read and used. Blockchain is best known for its important role in cryptocurrency systems, such as Bitcoin, where they keep a record of secure and independent transactions. A new thing about a blockchain is that it makes people trust each other without needing a third party.

In the blockchain, data is stored in blocks linked together via cryptography. It is one transaction. Another case is when there are too many transactions for a block. It will be added to a long chain of transactions called "blockchain". Besides, when you do this, you will get a chronological record of transactions, like a ledger. This situation goes from the first transaction in the first block to the last transaction in the most recent block. The blockchain stores these blocks in a way that allows us to see a perfectly-recorded history of the Bitcoin transactions that took place over the past year (Conway, 2021).

C. Usage Ideas and Examples of Blockchain

However, blockchain technology has a lot of potential applications than merely serving as the fuel for Bitcoin. The "business intelligence" article highlighted some of its emerging uses in banking, business, government, and other fields below (Intelligence, 2022).

(1) Blockchain in Banking and Finance

(a) **International Payments**

Blockchain technology enables the secure and rapid development of a tamper-proof record of sensitive activity. As a consequence, it is well-suited for international payments and money transfers.

(b) **Regulatory Compliance and Audit**

Blockchain is very safe, making it a good tool for accounting and auditing because it reduces the risk of human error and ensures the integrity of the records. When the account records are locked in with blockchain technology, no one can change them, even those who own them. In this case, the trade-off is that blockchain technology could eventually do away with the need for auditors and cut down on the number of jobs.

(c) **Money Laundering Protection**

Again, the encryption so important to the blockchain makes it very good at stopping money laundering. The technology that allows businesses to keep track of their customers' identities is "Know Your Customer (KYC)." Companies use this process to discover their customers and verify their identities.

(d) **Insurance**

Smart contracts are most likely the best approach to leverage Blockchain in insurance. These contracts enable consumers and insurers to process claims simply and securely. All contracts and claims may be stored on the blockchain and authenticated by the network, preventing anyone from making fraudulent claims. The blockchain would reject several claims for the same accident since it would not allow more than one.

(e) **Peer-to-Peer Transaction**

Venmo and other P2P payment services are easy to use but have limitations. Some services do not allow transactions based on where you live. For other people, you must pay a fee to use them. Many of them can be hacked, which is unsuitable for people who put their personal financial information. Blockchain technology could also solve these problems with all the benefits it has.

(2) Blockchain Application in Business

(a) **Supply Chain Management**

Blockchain is a good choice for tasks like real-time tracking of goods as they move and change hands through the supply chain. Using a blockchain gives companies a lot of different ways to move these goods. A blockchain can put events in a supply chain in order. For example, when goods arrive at a port, they can be put into different shipping containers. Blockchain is a new way to organize and use data. It is a way to keep track of things and use them.

(b) **Healthcare**

Health data that can be used on the blockchain includes general information like your age and gender and essential medical history data, like your immunization history or vital signs. On its own, none of this information would be able to identify any person, which is why it can be stored on a shared blockchain that many people can access without worrying about privacy.

If you have many specialized medical devices connected to your health record, blockchain can help you link those devices to your record. There will be a way for devices to store the data made on a healthcare blockchain and add it to people's medical records. Connected medical devices have a big problem because the data they produce is split up into different places. Blockchain could be the link that connects those other places.

(c) **Real Estate**

Most people will move about 12 times throughout their lives. The average home is sold by a homeowner every five to seven years. Using blockchain could benefit the real estate market because it moves so often. It would speed up home sales by quickly verifying finances, reducing fraud thanks to encryption, and making the selling and buying process more transparent.

(3) Blockchain Applications in Government

(a) **Record Management**

The government keeps people's birth and death dates, marriage status, and property transfers. However, keeping track of all this information can be challenging, and some of these records are still on paper. Sometimes, people must go to their town hall to make changes, which is time-consuming, unnecessary, and frustrating. Using blockchain technology could make this record-keeping a lot easier and safer.

(b) **Identity Management**

Blockchain technology can be useful if it has enough information, especially in identity management cases. It will help people's activity by showing or providing their special authentication code. For example, The World Food Programme used a similar Blockchain-guided approach for their biometric ID and digital payments. It allows refugees in a Jordanian camp to reserve funds and purchase goods without physical documents or valets. Furthermore, with the advent of Schengen II, the European Union (EU) is considering digital identity and working on the mobility of identity-related credentials in its member states through the eIDAS Directive (EU Regulation No 910/2014). A trend is shifting "control" of identity away from governmental institutions and corporate actors and toward "self-sovereign individuals" who can now manage their digital selves autonomously.

(c) **Voting**

Blockchain technology can make it easier for people to vote while also being more secure. Because even if someone were to get into the terminal, they would not be able to do anything to other nodes. Each vote would be linked to a single ID, and with the ability to make a fake ID impossible, government officials would be able to count votes more quickly and effectively.

(d) **Taxes**

Experts in technology and tax from the private and public sectors join forces to investigate the potential of blockchain. Much information could be stored on the blockchain to make the time-consuming and prone to human error process of filing taxes much more efficient.

(e) **Non-Profit Agencies**

Blockchain could help charities fight antitrust by making them more transparent. The technology can show donors that NPOs use their money the way they say they are. Blockchain technology could also help those NPOs give those funds more quickly, manage their resources better, and improve their ability to track them.

(4) Blockchain Applications in Information, Communication, and Technology (ICT)

(a) **Record Management**

As previously stated, encryption based on blockchain makes it very effective for record management by preventing duplicates, false entries, and other errors.

(b) **Cybersecurity**

Blockchain is a big help in cybersecurity because it does not have a single point of failure. Another benefit of blockchain technology is that it can be used to keep your information safe and secure from start to finish.

(c) **Big Data**

Because the information on the blockchain cannot be changed, and every computer on the network continuously checks its information, blockchain is a great way to store big data.

D. Interplanetary Filesystem (IPFS): Advance Technology for Sharing File

Blockchain uses smart contracts running on a decentralized virtual machine. Users might create a decentralized application (dApps) using this second generation of technology (Wood, 2022). Additionally, the Interplanetary File System (IPFS), a peer-to-peer distributed file system, is an intriguing architecture to consider in conjunction with blockchain. It combines various previously successful methods that use a content-addressed block storage paradigm to store data. IPFS aims to enhance HTTP, the most widely used file-sharing protocol (Hsiao-Shan et al., 2020).

It allows us to learn more about IPFS. Assume we wish to download a photograph from the internet. We instruct the computer where to look for the picture when we do this. In this example, the picture's location is an IP address or domain name, such as *http://websitename.com/tiger.jpg*. This method is known as "Location-Based Addressing." We tell the computer where to retrieve the information, but you will not get the picture if the location is inaccessible, or the server is unavailable. However, if this occurs, there is a good probability that someone else has already downloaded that image and still has a copy. The computer will be unable to get a copy from that person. To overcome this, IPFS switches from "location-based" to "content-based" addressing (Drake, 2015). Instead of mentioning/where/to look for the resources, you say/what/we need.

There is a hash for every file. This hash is like a fingerprint. To get a file, we ask the network: "Who has the file with this hash?" Someone in the IPFS network will give it to us, and we will use it. They might ask how we know that person has not changed the file. Because we used a hash to ask for the file, we can check to see what we got. We ask for a file with a certain hash. When we get the file, we check to see if the hash is the same as we asked. It is safer than before now. Use hashes to find content that does not have to be repeated. When many people put the same file on IPFS, it will only be made once, making the network easier to use.

How does IPFS work? Files are kept within IPFS objects, which may hold up to 256kb and include connections to other IPFS objects. For example, we save a "Hello World" text file that is relatively short and is saved in a single IPFS object. But what about files greater than 256kb? As an example, consider a photograph or video. Those are divided into numerous IPFS objects of 256kb each, and the system then creates an empty IPFS object that connects to the other parts of the file. IPFS's data architecture is simple, yet it may be quite powerful. This design enables us to utilize it as a filesystem. For example, we have a basic directory structure with a few files. We can transform this into IPFS objects and construct one for each file and directory. IPFS employs content-based addressing. Once anything is introduced, it cannot be removed. It is an immutable data repository, similar to a blockchain.

How do we edit things on that file if modified or updated? IPFS supports the versioning of files. We are working on a critical document that will be shared with everyone through IPFS. IPFS will generate a new commit object for us. This object is critical since it informs IPFS which commit came before it and relates to our file's IPFS object. After a time, we would like to update this file. We upload our changed file to the IPFS network, and the program generates a new commit object for us. This commit object now refers to the previous commit. This method may be repeated indefinitely. IPFS will ensure that our file and its history are available to all network nodes.

The most challenging issue that IPFS confronts is keeping files accessible. Every node on the network maintains a cache of downloaded files and helps others distribute them if needed. However, if these four nodes host a certain file - and those nodes go down, that file becomes inaccessible, and no one can get a copy of it.

This dilemma may be solved in two ways. We can either incentivize individuals to keep files and make them accessible or proactively distribute files and ensure that there are always a specific number of copies available on the network.

In this case, the government has many institutions and should have at least one data center. We can use those data centers as nodes or use other people's spaces on their computers and pay for that space.

E. Decentralized Storage for Sensitive File

Data breaches and loss usually become the real deal, and the most common problem happens in many organizations, including countries. Today's data can be accessed on the internet quickly, and there is no perfect protection in protecting data, especially for sensitive files that may contain important information. This situation allows the data to be transferred freely in the business network, cloud, and devices, raising the risks of data breaches. Data breaches were mentioned as severe threats to organizations, which may cause great harm, including significant reputational damage and financial losses (Long et al., 2017). By referring to IBM and the Ponemon Institute's recent studies, many companies and organizations have suffered data breaches more than 17,000 times annually. It is possible if sensitive data related to the government is in it (IBM, 2021).

Most of these breaches resulted in a significant data leak that may have caused a loss in productivity, decreased public confidence, trust, and increased costs associated with government response (Waind, 2020). Due to the growing number of security threats, data loss and data leakage in government have become significant concerns because public data are secret and not allowed to be disseminated freely. In general, the process of sharing data for business-related activities, both internally and externally requires good safety. The possibility of data theft and misuse is rising, and the government should prevent their action. Therefore, the government can utilize distributed ledger technology known as blockchain to prevent and secure sensitive organizations' data (de Haro-Olmo et al., 2020).

F. Utilizing Blockchain to Protect Sensitive Data

We must understand that governments need to save and share sensitive data with their underlings' departments internally and externally. When this action is taken, it may be shared through email or cloud service. Based on this situation, we can suggest that the data is usually unprotected and leaked to unsupervised people. It will be dangerous if such action is taken using the stolen data. For example, it is used to deceive an easily fooled person. Blockchain technology can prevent this situation from happening because it uses a peer-to-peer method that allows all participants in the network to have an identical copy of the ledger. When any changes happen to the ledger, it will also reflect in all copies in minutes or some cases, seconds. We argue that distributed ledger technologies can help the government protect sensitive data and ensure the integrity of data records.

G. Implementation for the Government

The main problem we would like to solve is securing personal data. Many companies or the government try to protect the users' data. Nevertheless, their system can still be hacked. Therefore, it is not enough to only protect the algorithm in code. Also, the storage of these data is still centered in one place. The system is easily penetrated and even more dangerous if the government does not have a backup.

We want to emphasize that blockchain applications are still in their infancy and represent an incredibly fast-paced subject with no established theory, few recognized specialists, and no clear solutions. Scholarly discussion on this topic is still in its infancy, with the majority of attention focused on Bitcoin's technological, financial, and legal aspects. As a result, a thorough examination of the influence of blockchain technology on political governance and democracy, in general, is sorely missing at the moment (Atzori, 2017).

The combination between Blockchain and IPFS could be the best solution for this matter (Hsiao-Shan et al., 2020). Previous research has already adopted this approach. They proposed a design model for a permission-less sharing system. The member in the system could create a group or join an existing group and send the file to it. Otherwise, the member can also request a file from that group. Sending and receiving the file needs a key generated in the IPFS proxy, Shah et al (2020). also proposed a similar solution for securing the storage. The IPFS protocol is then used to distribute and store encrypted data across network peers.

To make our sensitive data well protected. We can use this technology to secure our data, especially in Indonesia, with many institutions spread over several areas. We are trying to specify the implementation. For instance, we want to apply IPFS and Blockchain in Social Security Administrator for Health (BPJS Kesehatan). The people who want to open a new account in BPJS Kesehatan usually need to come to the office. The office here is a branch office or smaller office. Staff will input the personal data using his computer, then store it in the database through software.

However, the software will store that data in a database using a relational database management system (RDBMS) stored on one server. Could you imagine we changed how the software puts the applicant data? As we mentioned before, we can use the benefits of Blockchain and IPFS. The data will not be saved in the central database but distributed to the network nodes.

We can implement this matter in real life. We can make it a node for the computer used by the front liner staff. For instance, five staffs are in one branch office, so we have five nodes. Then, multiply by the total branch office that BPJS Kesehatan has. Do not worry about data security in one computer; a key protects the data from IPFS proxy. Furthermore, the user or staff who need that data should request a decrypt key through the network security builds in.

How about the trend that people no longer need to come to the office, just use their smartphones? The basic idea is the same; we only change how to save and access the data. From centralized storing and accessing, it becomes decentralized. Not limited to storing or accessing the files, it also tracks the file's history. Who was the creator? Who is trying to access that file and all updated versions?

H. Recommendations

1. Involving Stakeholders

Consider the objectives: What technology feature gives the essential advantage or benefit to a specific technical architecture product, service, or component? Examine whether distributed ledgers are the best vehicle for your objectives.

Collaborate with all internal stakeholders; Decentralized blockchain technology should not be confined to the innovation laboratory or the technical team. Collaborate immediately with the many stakeholders within your company to ensure that the solution is planned from the start to satisfy the regulatory, commercial, and technological issues that will undoubtedly occur.

Obtain executive approval; Board-level buy-in would be required to meet aggressive targets. Educate to close technological gaps and make the realm of public blockchains less intimidating.

Deal with legal issues head-on; Certain use of distributed ledger technology will undoubtedly generate legal concerns. According to some experience, regulators are becoming more pragmatic when evaluating innovation and regulation that predates certain technology.

We advocate starting early with regulators and educating them about the solution and its benefits. It is critical to ensure that you have evaluated the potential legal challenges before proceeding.

2. Government

We want to see a government working group define key investigation areas and, potentially, controlled pilots. It is not about attempting to solve everything at once but about taking small steps that, over time, may make a difference.

A decentralized record of transactions will enable anything of worth and decide whether it includes trade securely, straightforwardly, and without the threat of trying to interfere. This situation could have been what society has been looking for exactly. It can deliver real-time, reliable information to many people and create a system, for example, in which taxpayers and tax authorities have equal trust in the factuality of the data obtained. It may make it easier to pay taxes and for governments to close the tax gap.

3. Society

Recommendations for society could be divided into several fields:

(a) On Research:

We can encourage collaboration and collaborative work among specialists from different fields of the research world. This action will increase the value and interest in Indonesian language competence. In addition, it can increase Indonesia's research efforts on privacy. In addition, we can concentrate on the part of the software engineering capabilities on the blockchain infrastructure and application difficulties. Then, we need to investigate the establishment of an international interdisciplinary Blockchain Institute.

(b) On the Digital Trust:

Begin a certification reflection using blockchain to develop new certification skills for products and services. Begin work on a project to create a scalable, modular digital identification service for individuals and businesses.

(c) On the Public Policy Support:

Create a public research advisory council to advise the state on blockchain-related technology concerns.

4. Academic

Establish master's level specialist training, specialized R&D engineers, and application engineers by higher education organizations. Encourage work-study programs at the field's research and development facilities.

Design a MOOC (Massive Open Online Courses) to offer and support current efforts on the subject, for example, offer hosted on the platform, and create specific technologies that allow for a high level of learner involvement.

I. Conclusion

We know that blockchain technology gives benefits, and previous research has already discussed how this technology can be used in governments and other countries' sectors. However, we are sure that this technology should be implemented carefully. We see this as an opportunity, and by considering the risk, we ought to recommend a top-down approach to implementing blockchain in government. Moreover, we should remember that implement blockchain is not an easy task. Besides using the government or representative council to create the policy, it will be wiser to involve other stakeholders. We can use the triple helix approach of government, society, and academia. We are sure that if the communication between these three stakeholders runs smoothly, it will help Indonesia create a better government environment with good safety.

References

Atzori, M. (2017). Blockchain technology and decentralized governance: Is the state still necessary? *Journal of Governance and Regulation*, *6*(1), 45–62. https://doi.org/10.22495/jgr_v6_i1_p5

Cheng et al. (2017). Enterprise data breach: Causes, challenges, prevention, and future directions. In *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 7(5)*. Wiley-Blackwell. https://doi.org/10.1002/widm.1211

Conway, L. (2021). What is a blockchain? The simple explanation - The street crypto: Bitcoin and cryptocurrency news, advice, analysis and more. *The Street*. https://www.thestreet.com/crypto/bitcoin/what-is-a-blockchain-the-simple-explanation de Haro-Olmo, F. J., Varela-Vaca, Á. J., & Álvarez-Bermejo, J. A. (2020). Blockchain from the perspective of privacy and anonymization: A systematic literature review. *Sensors (Switzerland)*, *20*(24), 1–21. https://doi.org/10.3390/s20247171

Drake, K. (2015). HTTP is obsolete. It's time for the distributed, permanent web. *IPFS.IO*. https://ipfs.io/ipfs/QmNhFJjGcMPqpuYfxL62VVB9528NXqDNMFXiqN5bgFYiZ1/its-time-for-the-permanent-web.html

Huang et al. (2020). A secure file sharing system based on IPFS and blockchain. In *Proceedings of the 2020 2nd International Electronics Communication Conference,* 96–100. Association for Computing Machinery. https://doi.org/10.1145/3409934.3409948

International Business Machines Corporation (IBM). (2021). Cost of a data breach report 2021. https://www.ibm.com/security/data-breach

Intelligence, I. (2022). The growing list of applications and use cases of blockchain technology in business and life. Business Insider. https://www.businessinsider.com/blockchain-technology-applications-use-cases?r=US&IR=T

Jayani, D. H. (2021). Pencurian data pribadi makin marak kala pandemi. *Databoks*. https://databoks.katadata.co.id/datapublish/2021/09/07/pencurian-data-pribadi-makin-marak-kala-pandemi

Shah, M., Shaikh, M.Z., Mishra, V., & Tuscano, G. (2020). Decentralized Cloud Storage Using Blockchain. *2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)(48184)*, 384-389.

Waind, E. (2020). Trust, security and public interest: Striking the balance a narrative review of previous literature on public attitudes towards the sharing, linking and use of administrative data for research. *International Journal of Population Data Science, 5(3).* Swansea University. https://doi.org/10.23889/IJPDS.V5I3.1368

Wood, G. (2022). Ethereum: A secure decentralized generalized transaction ledger eip-150 revision. https://gavwood.com/paper.pdf

Chapter 17

Brief Introduction to Hospital Information System

Cendra Devayana Putra

A. Overview of Hospital Information System

A Hospital Information System (HIS) is not a novel piece of healthcare technology. Large hospitals have adopted mainframe computers since the 1960s, mainly focused on business and administrative needs. Then, the development of inexpensive minicomputers in the 1970s enabled the installation of smaller, specialized clinical application systems in various hospitals, followed by subsequent technological advancements until today. One of the systems innovation goals is to aid the hospital's operational departments to become more efficient and structured. For instance, an internal medicine specialist may require an interesting radiological report. Hospitals frequently rely on staff to provide patient records without a HIS. Delivering docu-

C. D. Putra
National Cheng Kung University, Taiwan, e-mail: cendradevayanaputra@gmail.com

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ments takes time, depending on the distance between the source and destination of the information. The condition contrasts with hospitals that utilize HIS. The physician may readily access the required item via the HIS. Compared to nurses, the time necessary to provide the patient medical record through the system significantly decreases. This decreased time would undoubtedly result in reduced patient wait times and increased patient satisfaction. Therefore, this chapter will intensely discuss hospital information systems deeper. In more detail, I briefly present hospital information systems worldwide in this chapter. The reader would learn about hospital information systems' definition, importance, and application. This chapter helps students know hospital information systems and use quickly learned words in the hospital and information system domain.

B. The Importance of Hospital Information Systems

Almost all sectors have implemented information systems for over two decades to support their operations since 1991. Many researchers have published their information system innovations to satisfy humans. The first research on an information system that we track was created by Thomas Haigh, then followed by considerable research that covers many other sectors like Economy (Uribe-Toril et al., 2022), Social (Thomas et al., 2022), Government (Aggarwal et al., 2012), Education (Bourcier et al., 2022), and Health (Aggarwal et al., 2012). The need for information systems is still increasing until now. Moreover, with global social developments that have influenced social 5.0, information systems have integrated into our daily lives.

Currently, information systems innovations have also become a part of hospitals. Almost all big hospitals require a plethora of data, and it is critical for the quality of patient care and hospital management that these information needs are met. Moreover, aligned with an ever-growing patient, the information system and hospital cannot be separated.

When a patient is admitted to a hospital, a physician or nurse must first get information regarding their purpose for admission and

Source: Penn Medicine (2022)

Figure 17.1 Musculoskeletal Imaging

medical history. Later, they will require the findings of clinical, laboratory, and radiologic investigations, among the most often performed diagnostic procedures. In general, clinical patient information should be accessible on a timely basis and be accurate and current (e.g., the recent lab report should be available on the ward within 2 hours). If this is not the case, if the information is received too late, outdated, or even incorrect, patient care quality is jeopardized (e.g., an inaccurate lab report may lead to erroneous and even harmful treatment decisions). Health care expenses may rise if this results in repeated tests or costly information searches. Therefore, information should be accurately documented by machines or humans to enable healthcare practitioners to obtain the necessary information and make intelligent decisions quickly.

Machines or humans must highly inform health professionals and paramedics to do their duties. For example, administration staff in cashiers should be notified promptly and with up-to-date information.

If information flow is insufficient, bills are generated days, if not weeks, after the patient is discharged; the patient may be dissatisfied or get away from the account. Moreover, if required information is lacking, payable services cannot be billed, reducing the hospital's revenue.

Hospital administration also has a sizable information requirement. Current cost and revenue information is required to run the organization. Equally critical is information about the quality of patient treatment, such as the nature and severity of patients' illnesses, nosocomial infections, and complication rates of therapeutic procedures. Without accurate, timely, and complete information, the hospital's operations cannot be appropriately controlled, raising the risk of management errors. Thus, information processing is critical to the quality of health care, particularly in hospitals.

In particular, in Indonesia, information exchange is seen as critical for the benefit of hospitals. Since 2013, the Ministry of Health has mandated that all hospitals keep at least one HIS, called SIMRS, to assist with hospital operations. The Indonesian Ministry of Health (Kemenkes) urges hospitals to modernize their information systems to increase efficiency and effectiveness (Bureau, 2013). The big intuitive is a promising advancement for future hospital operations in Indonesia.

C. The Massive Cost of Information Processing

Not only is information critical, but processing it incurs high costs. Based on data, in 2018, private hospitals in the United States (US) spent approximately $732.2 billion on operating expenses, and 44% of that operation was related to information exchange. Specifically, spent worth to maintain information is follows: administrative and general (21.4%); pharmacy (4.8%); operational plan (2.3%); nursing and administration (1.3%); and others (14.2%) (Bai & Zare, 2020). In 2019, The European Union (EU) spent 3,476.433 euros per capita on healthcare, with approximately 3,026 hospitals. European Union spent cost represents 9.916% of the total gross domestic product (GDP) of the European Union (Health Care Resources: Hospitals, n.d.). In 2018, the Australian government also spent $195.7 billion on Healthcare, covering 1,339 hospitals (Health Care Resources: Hospitals, n.d.). In 2018, the Indonesian government spent $336,726 per capita on health care, including individual and collective services. The amount spent on costs increased significantly from the previous year, 2017, when the Indonesian government spent $316,239 per capita (Penn Medicine, 2022). Even though fees for managing information appear to be relatively high, they can only be estimated as a minimum. Additional expenses for managing other information may not be calculated, resulting in the total costs exceeding the written estimate. Also, the total percentage of information processing, on the other hand, can only be estimated (Wackers et al., 2021).

D. Information: A Factor in Productivity

Numerous societies in the nineteenth century were characterized by increased in industry and industrial production. By the latter half of the twentieth century, the concept of communicating and processing data via computers and computer networks had already begun to take shape. Today, we refer to the twenty-first century as the information technology century or the "information society." It is anticipated to be defined by informatics and information and communication technology (ICT). People shall have access to information bound to a medium of matter or energy but is mainly independent of place and time and in any position imaginable. The information must find its way to people, not the other way around.

Today, data is one of the most critical factors affecting a hospital's productivity. The hospital information system must make complete and accurate information available for high-quality patient care and cost-effective hospital management. HIS is also becoming increasingly critical for hospitals' competitiveness (Tiankai et al., 2018).

1. The Information Processing System Should Provide a Comprehensive View of the Patient and the Hospital

Information processing should provide a comprehensive, holistic perspective of the patient and the hospital. "holistic" in this context refers to a comprehensive view of a patient's treatment, regardless of where the patient has been or will be treated in the hospital. This holistic approach to patient care can help mitigate the negative impacts of highly specialized medicine, which involves several departments and healthcare specialists. Despite the highly diverse diagnosis and therapy and the diversity of people and regions inside a hospital, appropriate information processing (and a well-designed hospital information system) may assist in making all patient information accessible. As specialization in medicine and healthcare expands, so does fragmentation of knowledge, making it increasingly vital to combine data into a holistic picture. However, it must be apparent that only authorized workers have access to patient data and information about the institution.

2. A Hospital's Information System Serves as its Memory and Nervous System.

Over 100 billion patients visit hospitals annually, including routine checkups, recovery, treatment, etc. The number of patients varies

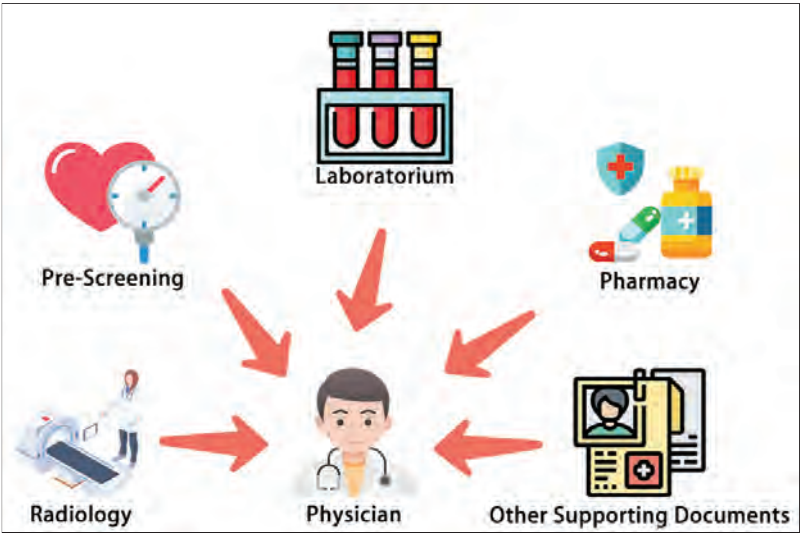


Figure 17.2 General Patient Diagnosis Scheme

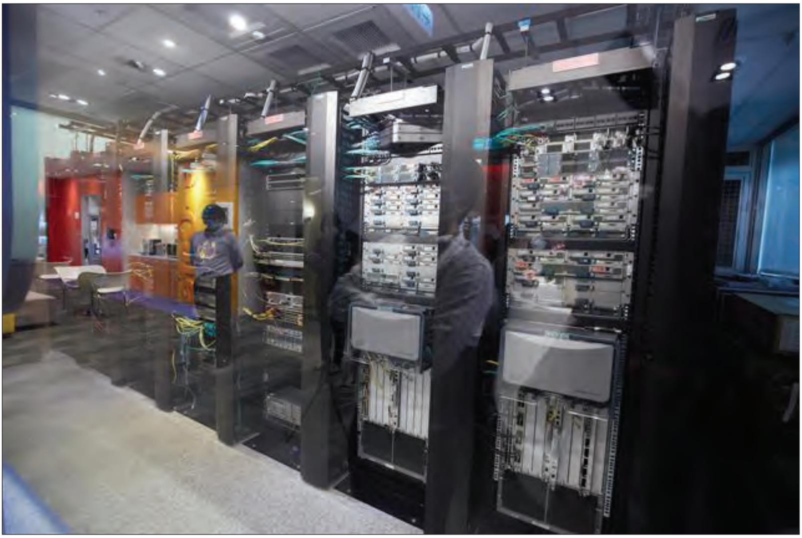
according to the hospital's class and services, and the more benefits and hospital classes available, the more patients will come. Due to many patients, hospitals must maintain patient data regularly, as it is impossible to remember all patient information individually.

Traditionally, hospital information has been stored on paper-based medical records. The traditional method frequently uses paper and patient indexing. This method is simple because it only requires a small amount of space and a few people to organize it regularly. However, this traditional method has several disadvantages, including flammability, the requirement of a large area as the number of patients increases, and susceptibility to damage. As a result, some hospitals are in the process of transitioning to computer-based medical records.

In keeping with technological advancements, computer-based medical records, later dubbed electronic medical records (EMR), have grown in popularity among hospital information system administrators. The EMR performs the same function as its predecessor, namely patient data storage. The distinction is that EMR stores data with the assistance of a system (software) and a server (hardware). This method

Source: Astorino (2019)

Figure 17.3 Paper-Based Medical Record



Source: Digitimes (n.d.)

Figure 17.4 Server in Hospital

necessitates the aid of an information management expert to ensure that the information distribution process is not redundant and runs smoothly. Again, the quality of an organization's information system is critical to its ability to recognize and store facts correctly, recall them, and act on them (Tiankai Wang et al., 2018).

E. The Advancement of Information and Communication Technologies in Hospital

Every business, from banking to healthcare, has incorporated technology. This advancement is necessary to improve an organization's efficiency and effectiveness. Technology is well suited for use in health, particularly in hospitals. We saw in the previous subchapter that information is critical for hospitals, and that subsection demonstrates how news affects the hospital's cost, productivity, view, and memory. This subchapter illustrates how information technology is transforming the hospital paradigm, commonly used modules, and research that has the potential to alter the future image of hospitals.

1. Basic Modules of Hospital Information System

Hospital information system modules vary significantly in functionality and cost, depending on the hospital's needs and finances. I use the standards established by the Ministry of Health in Indonesia (Kemenkes) in this chapter to make the hospital information system module easier to understand.

The Indonesian Ministry of Health's (Kemenkes) information management process is divided into two major components. This division operates following the hospital's established business procedures. *The front office* is the primary service provided by the hospital. These significant components assist patients with all aspects of their care, including registration, diagnosis, appointments, and pharmacies. On the other hand, *the back office* is a service section that supports primary services. This significant component manages physical

Source: Bureau (2013)

Figure 17.5 Minimal Hospital Information System Architecture in Indonesia hospital resources, including people, money, tools, assets, reagents, and stationery.

This Ministry of Health policy must be tailored to each hospital since every hospital has a different policy and treatment procedure. Additionally, this policy is still far too broad to be effective. I want to take a different, more detailed approach in this book to help readers understand the hospital information system's components. I divide a hospital information system into several standard modules for most hospitals.

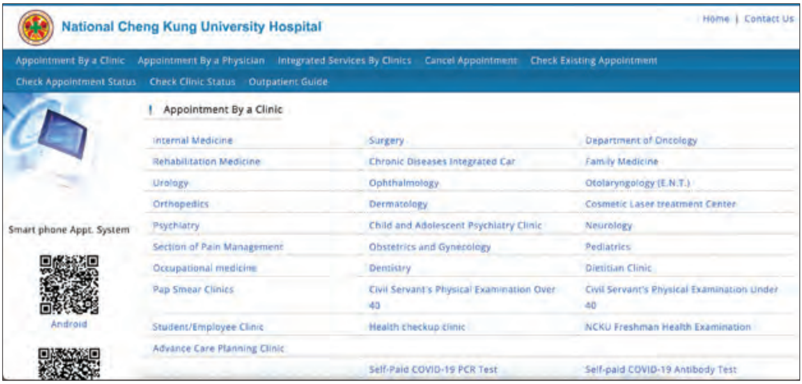
a) Online Appointment Module

Since 1991, healthcare information systems have incorporated an online appointment module as a significant advance. Online appointment scheduling enables the automated scheduling of patient appointments, follow-ups, and any special procedures that may be necessary. The online appointment module allows the hospital to manage medical professionals' availability at the optimal time, ensuring that the appropriate patient is loaded at the optimal time via services such as appointments, bulk cancellations, appointment rescheduling, and scheduling history management (Collen, 1991).

Patients can book physical or virtual appointments quickly, and doctors receive the patient's complete health history before the visit via healthcare provider solutions. The Online appointment modules can be customized by the hospital's need to assist patients in booking lab tests and radiology appointments through patient engagement systems. Directly affecting patient wait times will increase patient engagement and trust in hospital administration. According to a study, online meetings can minimize the likelihood of patients not showing up by 39% and boost patient satisfaction by 29% when automated (Hasvold & Wootton, 2011).

b) Payment Module

The Hospital payment module is a part of a complex hospital system responsible for managing patient payments. Payment is a critical



Source: Huey-Jen Jenny Su (2022)

Figure 17.6 Online Appointment Modules

module because it has a wide range of effects on the hospital, including the cost of care, admission and readmission rates, and patient satisfaction. However, specific payment module systems may require hospital, insurance, and government policy adaptations. These payment systems must integrate with third-party insurance, appointment scheduling, banking, and pharmacy systems. As a result, hospitals typically include the payment module as one of the information system modules that must be available, costly, and monitored properly.

Although many hospitals have struggled to integrate their financial management, the hospital system continues to lose money. According to a survey by the American Hospital Association, 26.4% of hospital finances in America are lost each year[2]. According to recent data, hospitals lose an average of $50 billion per month[3]. This loss is caused by various internal and external factors, including patient cancellations, service changes without proper documentation, and poor management patterns. Combined with COVID-19, which requires

2 https://www.cnbc.com/2020/05/05/hospitals-losing-millions-of-dollars-per-day-in-covid-19-pandemic.html

3 https://www.itij.com/latest/news/us-hospitals-losing-around-50-billion-month-due-covid-19

hospitals to take extra precautions when treating patients, hospitals risk losing more money. The cost may also be why healthcare institutions in the United States of America have declared a financial crisis.

Therefore, the payment module needs to be placed in the general module of the hospital system, which is essential to consider. However, the system's accuracy still needs to be studied more deeply in related research (American Hospital Association, 2017).

c) Laboratory Integration module

Laboratory Integration Module is a critical component of the hospital's information management system. The laboratory management module provides access to patient test results, uploads reports and findings, and manages hospital blood banks. Staff can access laboratory data and generate reports for patients. It is frequently integrated with other hospital information system modules to improve overall system functionality and streamline patient registration. When a physician orders a specific test panel, the information is updated in the healthcare system and transmitted directly to the diagnostic laboratory. This interface assists in minimizing human error. Because all data is entered into the clinical information system, previous medical reports can be retrieved and reviewed.

d) Pharmacy Integration Module

HIS may include document management modules for documenting and managing each patient's Electronic Health Records (EHR) and Electronic Medical Records (EMR), which may include doctor's notes, supporting documents, scans, x-rays, claims, and billing-related information as demographic data. The pharmacy data management system also incorporates audit requirements, billing updates, and modifications. Through integration with healthcare automation, hospital management information systems can combine the pharmacy's compounding capabilities and multiply them to create customized medication packages for each patient based on their unique needs. The success of this method is critical to the hospital's overall revenue generation, as it provides patients with a value-based caregiving experience tailored to their unique needs.

e) Emergency Department Module

For many patients, the hospital entrance is not through the lobby but the through the swinging doors of the emergency department. As the initial stop on any patient's journey, it is self-evident that a hospital's emergency department, or ED, must be fully optimized to provide the best possible initial medical care in emergent situations.

Historically, hospitals have struggled to automate clinical processes and documentation in the ED. In contrast to an inpatient or outpatient setting, with the emphasis on longitudinal care, a typical ED scenario is episodic, focusing on individual encounters and complex clinical workflows. Speed and accuracy are critical when triaging patients, capturing clinical data, communicating with clinicians and hospital staff, or processing admissions and discharges.

Historically, hospital emergency departments have provided emergent care to patients using manual processes and tools, such as communicating verbally, using paper charts, or using whiteboards for patient tracking purposes. However, as the number of ED patient visits continues to grow, hospital administrators have recognized the proportionately increasing need to improve emergent care within the organization by streamlining processes, workflows, and documentation. A widely believed condition can be met using clinical information systems, such as an Electronic Health Records (EHR) system.

Hospitals successfully implemented EHRs in inpatient and outpatient settings and have realized significant benefits. However, even for the most technologically savvy clinical staff, implementing these EHRs in the ED has proven challenging. The emergency department environment is unique, with the full spectrum of disease relentlessly arriving on the doorsteps of overburdened emergency clinicians without warning. Workflows are intricate and vary by patient, and the pace is frenetic. The EHRs being used across these hospitals are not designed for the ED, necessitating the need for a more specialized solution—an Emergency Department Information System (EDIS).

According to the HL7 Emergency Care Special Interest Group's 2007 EDIS Functional Profile document, an Emergency Department Information System is "an extended EHR system used to manage data in support of Emergency Department patient care and operations." While the primary purpose of an EDIS is like that of a basic HER, it aims to support and document the patient's direct care in a patient record, and EDIS focuses on specific core functionalities (Rothenhaus et al., 2007).

f) Intensive Care Unit Module

Intensive care is becoming more necessary as the population ages, and socioeconomic factors influence health interventions. Several issues in the Intensive Care Unit (ICU) must be addressed, including the following: a shortage of beds and skilled personnel, high medical costs, a high mortality rate, severe nosocomial infections, low adherence to standards, low quality of care and improvement, an epidemic of medical and medication errors, and poor coordination of inpatient care. Additionally, several factors should be considered, including the inability of an automated scoring system to predict disease severity and mortality, the inefficiency of integrated clinical alerts, clinically significant workflow disruption, and resource constraints.

The following are some issues that may arise from insufficient information exchange within the hospital. Every decision-maker requires factual and accurate information, such as a physician who needs information about a patient's condition or a nurse who requires information about bed availability. Otherwise, the treatment process of the patient will lose.

g) Electronic Medical Record (EMR) Module

Typically, patient health information is stored on physical media such as notes, images, or other media. However, these media have high operational and maintenance costs. As a result, the Electronic Medical

Record (EMR) is considered a more efficient method of storing patient health information such as the following: 1. Allergies; 2. Diagnosis; 3. Medications; 4. Medical history; 5. Immunization date; 6. Radiology Image; 7. Treatment plan; 8. Laboratory Result; 9. Other Important Information. An EMR can manage medical records and patient care in a single practice. Electronic Medical Records (EMRs) have several advantages over traditional paper medical records. For instance, electronic medical records enable physicians to:

1. Conduct periodic data monitoring.
2. Quickly identify patients who will undergo examination or screening.
3. Evaluate their patients' performance on specific measures—for instance, blood pressure readings or vaccinations.
4. Monitor and improve the practice's overall quality of care.

2. Advanced Modules of Hospital Information System

We already discussed several operating system modules required by hospitals in the preceding subsection. With the knowledge of that chapter, we can conclude that the fundamental module required by hospitals facilitates information exchange between doctors or units within the hospital. Of course, the operating system leverages only a fraction of the technology available in healthcare era 4.0.

Healthcare 4.0 enables health technologies to leverage industry 4.0 advancements such as IoT, cloud manufacturing, big data, and artificial intelligence. This is a challenge and opportunity for all parties to form a comprehensive hospital information system in Indonesia. Therefore, this chapter tries to summarize some research on hospital information systems to discover the future of hospital information systems worldwide (Jiangshan Li & Carayon, 2021).

a) Patient Engagement

A disease is not always present because of an incident soon, but also because of a poor long-term lifestyle. For example, consider a father who smoked for decades and then developed cancer at 50 or an adolescent who drank alcohol and then developed the liver disease at 30. These are two examples of diseases that develop because of an unhealthy lifestyle. Indeed, diseases can be avoided if individuals have a sincere desire to maintain a healthy body. However, hospitals' continued perception as a place to cure patients ensures that such diseases continue to occur frequently in society.

Hospital information systems utilize digital technologies to increase patient engagement and promote positive patient behavior. Mobile applications, interactive patient portals, text messaging, and e-mails all help to improve patient health outcomes. These channels provide critical information to patients, such as their health records and education about their specific medical conditions. Additionally, they enable patients to manage their care plans, schedule appointments, manage medications, and take an active role in treatment decision-making.

According to study in 2018, several hospitals have recently implemented patient engagement initiatives (Asagbra et al., 2018). This could be because the hospital is structured so that it is not only a place of healing but also a place that enables patients to maintain their health independently. When patients become aware of their bodies, hospital revenue will remain stable and may even increase, as will the overall quality of care provided to their patients (Asagbra et al., 2019).

b) Health Analytics

The unprecedented rise of medical data created by HIS has ushered in a new era of healthcare analytics and artificial intelligence. The collection and analysis of data from patient records, drug administrations, operational data, insurance billing, and regulatory sources can result in various benefits:

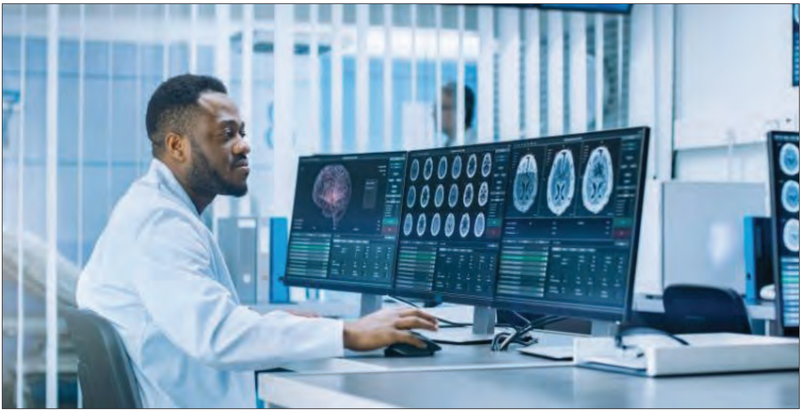
1. **Performance management**: Analyzing a hospital's performance using key metrics (related to outcomes and financials) to better understand its clinical, operational, and financial performance by department/clinical condition/physician, to identify and drive performance improvement initiatives. For instance, research on

the ordering and operational distribution of medical supplies. If this material is not correctly handled, it will result in cost inefficiency for storage or losses owing to a lack of inventory. To solve this problem, a dash of artificial intelligence is required to improve logistics (Ying Yang et al., 2021).

2. **Pathway management**: By coordinating treatment across settings, optimize patient paths across the network and clinical pathways within the hospital. A clinical pathway is a procedure and standard-based diagnosis and treatment plan based on Evidence-Based Medicine and/or doctor physician experience to standardize medical service behaviors and eliminate recovery delays and resource waste so that patients can get the best possible medical care (Xinyu Wang et al., 2021; Wind et al., 2021).
3. **Clinical decision support system (CDSS)**: Clinical, physiological, and longitudinal patient data are used to inform clinical personnel and physicists about the most appropriate diagnostic and treatment choices. Today's decision-making is not only informed by physicians' expertise but may also be aided by specific artificial intelligence technologies. For instance, a physician seeking to diagnose a patient can utilize a clinical decision support system to advise physicians on the medications, dosages, and therapies that are most appropriate for the patient. To begin, CDSS will get information about patients such as their age, duration of therapy, etc. The data will then be utilized parallel to feed into artificial intelligence models such as decision trees. Finally, the system can predict the appropriate medicine, dosage, and course of therapy for the patient. (Kharat et al., 2014; Sutton et al., 2020).
4. **Population health management**: Using analytics in epidemiology, for example, by connecting Electronic Medical Records to geographic information systems to determine healthcare patterns in specific areas (Hebert & Root, 2019).

c) Biosensing Wearables

Wearables with biosensing allow continuous monitoring of a wide range of variables, and recent technological advances have made them



Source: Cote (2021)

Figure 17.7 Implemented Health Analytics Tool

inexpensive. These wearables come in a variety of forms, including watches and clothing, as well as digestible and smart implants. These biosensors monitor and track various parameters, including movement, heart rate, sleeping quality, temperature, and glucose level, and offer critical data points to users and healthcare practitioners who previously needed a disruptive way to access. However, the sheer number of sensors and applications accessible has created software integration problems for healthcare providers. These wearable sensors can be used to help a cloud-based digital healthcare platform connect doctors, pharmaceutical companies, payers, healthcare providers, and healthcare systems to more than 400 home devices, wearables, and patient care applications (Sharma et al., 2021).

d) Telemedicine

Hospitals increasingly rely on telemedicine as they shift to a patient-centered strategy. Historically, hospitals followed a centralized model, resulting in huge increases in operational expenses and significant transport challenges for patients living outside of major cities. Thanks to the usage of telemedicine, patients and healthcare practitioners may now connect in real-time via several communication channels, the transfer, and storage of medical data, as well as remote monitoring. Telemedicine enables physicians to give care remotely via computers and mobile devices. This system allows for clinicians to interact with patients and coworkers in realtime, using the same workflow tools they use to write charts, access patient information, and manage treatment. Telemedicine helps hospitals to save money by reducing their need for additional staff and space while boosting their ability to treat more patients (Jnr, 2020).

F. Conclusion and Recommendations

Information is a critical component of the hospital that cannot be ignored. Hospitals squander a significant amount of money on their information management because the information contained within the hospital is intrinsically linked to the patient. Additionally, information plays a role in the productivity of a hospital's operating activities. This information must be supplied holistically to ensure that the patient diagnostic process is not harmed. As a result, a hospital information system is required.

Hospital information systems have become a critical component of hospitals worldwide, particularly in Indonesia. The Indonesian Ministry of Health has enacted laws governing hospital information systems, requiring that each hospital have at least one. Additionally, the Ministry of Health has recommended a hospital information system adaptable to the hospital's capabilities.

I reduced the hospital system's components for study purposes by dividing it into seven critical parts: online appointments, payment modules, laboratory integration, pharmacy integration, emergency department integration, intensive care unit modules, and electronic medical record modules. The seven modules are typical components found in hospital information systems. The module's primary objective is to assist operational and middle management workers in completing their responsibilities.

Since AI, big data technologies, and the Internet of Things have become widely employed, hospital information systems are evolving in operational areas and other areas of analysis. The author included various development modules that the hospital information system may use. The first consideration is patient engagement. Patient engagement is a method of increasing patient awareness to avert the onset of illness (preventive). The second type of analysis is health analytics. AI and analytics are inextricably linked. Health analysis simplifies complex processes such as resource allocation, clinic routes, disease prediction, and geographic information systems. Then there are biosensing wearables. Biosensing wearables are often third-party devices linked to patients that are not integrated into the hospital information system. These tiny devices collect patient monitoring data for doctors, such as heart rate, respiratory rate, and other bodily conditions. Some researchers have attempted to include this biosensing into a component of the hospital information system to obtain holistic data. Finally, there is telemedicine. Telemedicine is a technological advancement in hospital information systems that enables patients and doctors to communicate over distances utilizing a reliable connection. The advantage of this technology is that no interaction is necessary because not all patients can walk (disabled).

Technology has become an integral component of Indonesian life, from waking up to sleeping. The phenomenon was seen in the number of gadgets we carry daily. Regrettably, some hospital information systems in Indonesia continue to play a minor role and cannot completely replace the paper-based system. The drawback might result from a shortage of in-depth research on usage, user acceptability, and security in hospital information systems.

References

Abhinav, B., Sumaiya, A., Oommen, J., Vivekanand, J. (2020). An overview of mobile applications (apps) to support the coronavirus disease 2019 response in India. *Indian Journal of Medical Research, 151*(5), 468–473. doi: 10.4103/ijmr.IJMR_1200_20

American Hospital Association. (2017). *Fact sheet: Hospital billing explained.* https://www.aha.org/system/files/2018-01/factsheet-hospital-billing-explained-9-2017.pdf

Asagbra, O. E., Burke, D., & Liang, H. (2018). Why hospitals adopt patient engagement functionalities at different speeds? A moderated trend analysis. *International Journal of Medical Informatics*, 123–130. https://doi.org/10.1016/j.ijmedinf.2017.12.023

Asagbra, O. E., Burke, D., & Liang, H. (2019). The association between patient engagement HIT functionalities and quality of care: Does more mean better? *International Journal of Medical Informatics*, *130*(May), 103893. https://doi.org/10.1016/j.ijmedinf.2019.05.029

Astorino, D. (2019). Here's how to find and track your medical history. [Photo]. Retrieved March 29, 2022. https://www.huffpost.com/entry/finding-medical-history_l_5cc30a0de4b0817069685427

Bai, G., & Zare, H. (2020). Hospital cost structure and the implications on cost management during COVID-19. *Journal of General Internal Medicine*, *35*(9), 2807–2809. https://doi.org/10.1007/s11606-020-05996-8

Bourcier, D., Collins, B. W., Tanya, S. M., Basu, M., Sayal, A. P., Moolla, S., Dong, A., Balas, M., Molcak, H., & Punchhi, G. (2022). Modernising physician resource planning: a national interactive web platform for Canadian medical trainees. *BMC Health Services Research*, *22*(1), 1–15. https://doi.org/10.1186/s12913-021-07366-4

Bureau, E. 2013. (2013). Peraturan Menteri Kesehatan Republik Indonesia nomor 82 tahun 2013. *55*, 1–37. [Photo].

CNBC. (2020). *U.S. hospitals are losing millions of dollars per day in the midst of the Covid-19 pandemic — and recovery may take years.* Published may 5 2020. from https://www.cnbc.com/2020/05/05/hospitals-losing-millions-of-dollars-per-day-in-covid-19-pandemic.html

Collen, M. F. (1991). A brief historical overview of hospital information system (HIS) evolution in the United States. *International Journal of Bio-Medical Computing*, *29*(3–4), 169–189. https://doi.org/10.1016/0020-7101(91)90036-E

Cote, C. (2021). 3 applications of data analytics in health care. [Photo]. Retrieved February 18, 2021. https://online.hbs.edu/blog/post/data-analytics-in-healthcare

Digitimes. (n.d.). Server in Hospital. [Photo]. Retrieved March 29, 2022, from https://www.digitimes.com/newsshow/20200729PD200_files/1_b.jpg

Hasvold, P. E., & Wootton, R. (2011). Use of telephone and SMS reminders to improve attendance at hospital appointments: A systematic review. *Journal of Telemedicine and Telecare*, *17*(7), 358–364. https://doi.org/10.1258/jtt.2011.110707

Health Care Resources: Hospitals. (n.d.). Retrieved March 29, 2022, from https://stats.oecd.org/index.aspx?queryid=30182#.

Hebert, C., & Root, E. D. (2019). Repurposing geographic information systems for routine hospital infection control. *Advances in Health Care Management*, *18*, 61–73. https://doi.org/10.1108/S1474-823120190000018003

Jingshan, Li. & Carayon, P. (2021). Health care 4.0: A vision for smart and connected health care. IISE Transactions on Healthcare Systems Engineering, 11(3), 171–180. https://doi.org/10.1080/24725579.2021.1884627

Jnr, B. A. (2020). Use of telemedicine and virtual care for remote treatment in response to COVID-19 pandemic. *Journal of Medical Systems, 44*(132). https://doi.org/10.1007/s10916-020-01596-5

Kharat, A. T., Singh, A., Kulkarni, V. M., & Shah, D. (2014). Data mining in radiology. *Indian Journal of Radiology and Imaging, 24*(2), 97–102. https://doi.org/10.4103/0971-3026.134367

Penn Medicine. (2022). Musculoskeletal Imaging. [Photo]. Retrieved March 29, 2022, from https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.pennmedicine.org%2Ffor-patients-and-visitors%2Ffind-a-program-or-service%2Fradiology%2Fmusculoskeletal-imaging&psig=AOvVaw06jci8p6jiDElwvUySg7sy&ust=1644414986349000&source=images&cd=vfe&ved=0CAsQjRxqF

Rothenhaus, T. C., Kamens, D., Faaem, F., Mcclay, J., & Coonan, K. (2007). Emergency department information systems (EDIS) functional profile. *HL7 Emergency Care Special Interest Group Co-chairs.* http://providersedge.com/ehdocs/ehr_articles/HL7_2007_EHR-S_FM_R1-Example_Functional_Profile_EDIS.pdf

Sharma, A., Badea, M., Tiwari, S., & Marty, J. L. (2021). Wearable biosensors: An alternative and practical approach in healthcare and disease monitoring. *Molecules*, *26*(3), 748. https://doi.org/10.3390/molecules26030748

Sutton, R. T., Pincock, D., Baumgart, D. C., Sadowski, D. C., Fedorak, R. N., & Kroeker, K. I. (2020). An overview of clinical decision support systems: benefits, risks, and strategies for success. *Npj Digital Medicine*, *3*(17), 1–10. https://doi.org/10.1038/s41746-020-0221-y

Thomas, H. M., Runions, K. C., Lester, L., Lombardi, K., Epstein, M., Mandzufas, J., Barrow, T., Ang, S., Leahy, A., Mullane, M., Whelan, A., Coffin, J., Mitrou, F., Zubrick, S. R., Bowen, A. C., Gething, P. W., & Cross, D. (2022). Western Australian adolescent emotional wellbeing during the COVID-19 pandemic in 2020. *Child and Adolescent Psychiatry and Mental Health*, *16*(4), 1–11. https://doi.org/10.1186/s13034-021-00433-y

Wang, T., Wang, Y., & McLeod, A. (2018). Do health information technology investments impact hospital financial performance and productivity? *International Journal of Accounting Information Systems*, *28*, 1–13. https://doi.org/10.1016/j.accinf.2017.12.002

Uribe-Toril, J., Ruiz-Real, J. L., Galindo Durán, A. C., Torres Arriaza, J. A., & de Pablo Valenciano, J. (2022). The circular economy and retail: Using deep learning to predict business survival. *Environmental Sciences Europe*, *34*(2). https://doi.org/10.1186/s12302-021-00582-z

Wackers, E., Stadhouders, N., Heil, A., Westert, G., van Dulmen, S., & Jeurissen, P. (2021). Hospitals bending the cost curve with increased quality: A scoping review into integrated hospital strategies. *International Journal of Health Policy and Management*. https://doi.org/10.34172/ijhpm.2021.168

Wind, A., van der Linden, C., Hartman, E., Siesling, S., & van Harten, W. (2021). Patient involvement in clinical pathway development, implementation and evaluation – A scoping review of international literature. *Patient Education and Counseling, 105(6), 1441–1448.* https://doi.org/10.1016/j.pec.2021.10.007

Xinyu, W., Jie, C., Fang, P., & Jingtai, L. (2021). Construction of clinical pathway information management system under the guidance of evidence-based medicine. *Journal of Healthcare Engineering*, *2021*. https://doi.org/10.1155/2021/4425449

Ying, Y., Limin, D., Hua, R., & Jing, W. (2021). Optimization on medical material distribution management system based on artificial intelligence robot. *Journal of Healthcare Engineering*. https://doi.org/10.1155/2021/5511299

Chapter 18

Electronic Health Record

Ahmad Said & Cendra Devayana Putra

A. Overview of Electronic Health Record

During today's technological advances, information spreads quickly and becomes an advantage for people who use it. Moreover, technology is used to disseminate useful information to the community, one of which is in the world of health. Health information available in hospitals is very important for public safety. Therefore, it is necessary to have a health information system such as electronic health records. Electronic Health Records (EHRs) can be broadly defined as representing longitudinal data (in electronic format) that are collected during routine delivery of healthcare (Jackson et al., 2016). Electronic Health Records (EHRs) provide opportunities to enhance

A. Said & C. D. Putra
Universiti Sains Malaysia, e-mail: ahmad_said@ymail.com

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patient care, embed performance measures in clinical practice, and facilitate clinical research (Cowie et al., 2017).

Legally, the data in the EHRs is a legal record of patient services and the hospital has the right to store such data. EHRs generally contain demographic, vital statistics, administrative, claims, clinical, and patient-centered data. EHRs can be accessed and owned by patients and the data can be used in other healthcare centers for subsequent treatment purposes. EHRs emerged largely to improve healthcare quality and capture billing data. EHRs may be used to assess study feasibility, facilitate patient recruitment, streamline data collection, and conduct entirely EHR-based observational, embedded pragmatic, post-marketing randomized registry studies, or comparative effectiveness studies. EHRs are mostly used for observational studies, safety surveillance, clinical research, and regulatory purposes.

B. The Benefits

There are several benefits of using EHRs: general benefit, operational benefits, and organizational benefits. For the general benefits, EHRs will improve the professionalism and performance of hospital management. Stakeholders such as patients will enjoy the convenience, speed, and convenience of health services. Furthermore, EHRs makes each unit work according to its functions, responsibilities, and authorities. Operational Benefits, when EHRs are implemented, at least four operational factors will be felt. The first factor is the completion speed of administrative tasks. This speed has an impact on increasing work effectiveness. The second is the accuracy factor, especially data accuracy. In the past with manual systems, people had to check one file at a time, but now with the manual system. For example, if the same patient is registered twice at different times, the system will reject it. EHRs will warn if the same action for the same patient is recorded two times. This keeps the data more accurate and more thorough. The third is the efficiency factor. Because the speed and accuracy of data increases, the time needed to do administrative work is reduced considerably so that employees can focus more on their main work.

Fourth is the ease of reporting, the number of reporting cases could be more because the data is in non-physical form.

Organizational Benefits, because Hospital Information System (HIS) requires discipline in data entry, timeliness and correctness of data, the work culture that previously suspended such things has changed. For example, a drug prescription written in the EHRs will be very much needed by the drug department, while all actions taken at the hospital will be required. So EHRs create increased coordination between units. Often people claim that with the computerization of administrative costs increased.

In Indonesia, EHRs have been used since the late 2000s. The use of technology in the health care system in Indonesia was initially limited to recording patient data. In addition, EHRs are also used in communication and exchange of information between health facilities, such as in Central Java, where each puskesmas (Public Health Center) can access integrated electronic medical records to track the history of patients who come for treatment. Not infrequently patients have to undergo various examinations from the beginning again because of the unavailability of health data first.

C. Function

Accordingly, an EHRS system should offer the following basic functions. First, Health Information and Data. It should store and provide access to patient's health information such as patient's history, allergies, laboratory reports, diagnosis, current medications, and so on to healthcare providers for appropriate clinical decisions for better patient care. It should integrate data from various sources and make it available to the people involved in patient care. The second is to Replicate the Workflow. It should be able to work in sync with the original workflow of the healthcare organization. The third is Efficient Interaction. It should be able to work effectively, saving care providers' time by keeping things concise.

Fourth is Clinical Decision Support (CDS). It should support the provision of reminders, prompts, and alerts. Such features help improve clinical and preventive practices and reduce the frequency of adverse events. Fifth is Patient Support. It should empower patients to access their health information, enabling them to be involved in their healthcare. Sixth is Messaging and Data Processing Capability. It should allow an exchange of data in known/standard formats for the interoperability of healthcare applications.

Additionally, it should enable the processing of incoming data in known/standard formats. Seventh is Administrative Tools. It should provide administrative tools, such as scheduling systems, to improve clinical practices' efficiency and timely patient services.

1. Significance of EHR

In addition, there is significance in the EHR. First, Ease of Maintaining Health Information of Patients. The EHR system minimizes the use using paper in storing data and has good backups, reducing operating, upgrading, and maintaining costs. Second, Efficient in Complex Environments. EHRs help improve work processes and efficiency in healthcare. For example, quickly finding patient data, overcoming patient problems, and making it easier for researchers to analyze the efficacy of drugs in patients. Next, Better Patient Care. Most of the time, multiple healthcare providers are involved in the treatment of a patient.

Moreover, it enables point-in-time data insertion, retrieval, and update. Thereby, providing immediate access to patient data from any specialty center whenever required. Availability of health information, such as past medical history, family medical history, and immunization through EHR helps take preventive measures and manage chronic diseases more effectively.

The Fourth is Improve Quality of Care. EHR helps decrease reporting and charting time during treatment, hence, improving care quality. EHR also helps improve risk management and accurate diagnosis, improving the quality of care. Fifth, is Reduce Healthcare

Delivery Costs. Due to the availability of health information data from all healthcare organizations, a healthcare provider can refer to the required test reports, thus avoiding the repetition of expensive tests. Next is Accelerates Research and Helps Build Effective Medical Practices. EHR provides an extensive database in one place, promoting its use for disease surveillance for providing preventive measures. It also helps analyze treatment patterns of medicine in decision support with EHR enabling effective medical practices. The last is Better Safety. An EHR system provides safer patient health records than paper based system through access, audit, and authorization control mechanisms.

2. Factors Affecting Implementation of EHR

There are also several factors affecting the implementation of EHR. First, the design of the system needs the involvement of clinical staff with the to include the organization's policies and workflow processes. Then, an EHR system must also meet the privacy and security regulations for health data imposed by regulatory bodies in the country. It provides assures patients and providers that the health data is securely stored and privacy is maintained while healthcare applications deliver appropriate services. Next, the duplication of EHR records of a patient in the same EHR system is an important issue in EHR usage. In the process, different organizations assign different identifiers to the same patient.

EHR system consolidates patients' healthcare data generated from various healthcare systems. Hence, it should be capable of integrating data from all such systems. Additionally, these applications usually do not consistently use security and data integrity standards. An EHR system must, therefore, consistently use standards and upgrade to newly developed standards for addressing these issues. An EHR system must also carefully handle ethical and legal issues linked to the accuracy, confidentiality, and access rights of healthcare data. These include improved quality and patient care, patient safety, more efficient patient data tracking, improved documentation, and better audit of accessed information. Indeed, an EHR system also provides some financial ROI, such as increased income with expanded patient load due to time efficiency and reduced material costs, such as paper, charts, and printing supplies. Some healthcare providers find it more difficult and time-consuming to use computers for data entry than handwriting. Additionally, paper-based records have some advantages over EHR. Also, reading text on paper is 40% faster than reading on a computer screen.

The system's speed is reported to be the most important, with sub-second (screen flips) recommended. Users' familiarity with computer systems affects the ease of use, perhaps favoring younger users in developed countries. When training staff uses EHR system, it has been reported that educational efforts should ensure that staff understands why the system is being implemented and how to use all relevant features. Problems with EHR integration arose when staff training started too late in the implementation phase. It is important to address infrastructure issues earlier, such as identifying appropriate spaces for computer installment and use and ensuring that sufficient backup and technical support exists in case of computer malfunctions.

Even after the iimplementing EHR system, significant use was still made of paper documentation. Despite access to computers in these hospitals, nurses still relied on paper documentation and personalized scraps of paper to organize nursing activities. Thus documentation was fragmented (Baumann et al., 2018). However, there are some evidences from studies that over a more-extended period with full implementation of the system, documentation time may ultimately decrease, accompanied by improved work and information flow, significant decreases in multitasking, and improved patient safety.

D. Some Cases Using EHR in Indonesia

Based on research, Budiyanti et al. (2018) talk about the development of EHR using cloud-based HER. Cloud based-electronic medical record (cloud-based-EHR) has been developing in Indonesia. These services have some benefits, such as lower costs, more user-friendly features, potential for data sharing, and support for clinical decision-making. Nevertheless, the implementation has implications for ethical and legal issues such as data and network security, cloud service provider, data sharing procedures, and medical privacy.

Research conducted by Andriani et al. (2017) on satisfaction with EHR implementation at Gadjah Mada University Hospital foundthat satisfaction with information from EHR had a positive effect on overall satisfaction with performance expectations and attitudes that had an impact on overall benefit satisfaction. For further development of the EHR, the output of the report produced by the EHR needs to be adjusted to the format of the Ministry of Health. In addition, IT staff also need to provide training for new employees.

In Indonesia, various techniques are used in the implementation of EHR. One of them is using data security techniques that can be done using cryptographic methods, firewalls, access control, and other security techniques. This method has been proven to be very promising and successful in keeping privacy and security from EHR (Ningtyas & Lubis, 2018).

From a legal aspect in Indonesia, there is no special law about electronic medical records. However, at this moment, preparation for using EHR can be enforced based on regulations legislation and policies among others; Law No. 29 of 2004 concerning Medical Practice, Law No.36 of 2009 concerning Health, Law No. 11 of 2008 concerning Electronic Information and Transactions, and Regulation of Ministry of Health (Permenkes) No. 269 of 2008. However, several laws and regulations governing electronic medical records can be retrieved show that that EHR can also be used as evidence in court related to problems in health services (Gunawan & Christianto, 2020).

E. Some Cases using EHR in The World

Baumann et al.'s research (2018) shows that pooled meta-analysis results indicated that pre-EHR interns had the largest proportion of total workload spent on documentation tasks, followed by physicians, and nurses who had the smallest proportion out of all hospital staff examined. Post-EHR, physicians had the largest proportion of total workload spent on documentation tasks, by interns, and nurses. The large variation in documentation times between studies could be partly explained by the varying allocation of tasks between medical staff in different countries. For example, the role played by nurses in the coordination and planning of patient care may differ between Europe, Australia, and the US.

Differences in national guidelines around documentation about patient safety and quality standards and varying definitions of tasks defined as documentation tasks between studies could also contribute to variations in results. EHR implementation use of paper and electronic documentation was frequently observed, suggesting duplication of work processes. In contrast, full implementation of EHR for documentation appeared to be associated with decreased time in documenting. Thus, after an initial transition phase, exclusive utilization of electronic records rather than paper records could potentially lead to a more efficient system, allowing improved information flow between different disciplines and medical institutions and more time for direct patient care and communication.

A finding of concern is that over one-fifth of physicians' and almost half of the nurses' workload is spent multitasking in pre-EHR settings. In addition, physicians were reported to be frequently interrupted in their work. Multitasking and interruptions may adversely affect patient safety by increasing the possibility of mistakes in documentation and prescription, staff cognitive overload, and medical errors. Interestingly, time spent multitasking was only 9% for physicians in the one post-EHR study that examined multitasking.

In the USA, while EHR adoption has increased steadily since 2010, it is unclear how providers that have not yet adopted will fare now that federal incentives have converted to penalties. Finally, hospitals most often reported up-front and ongoing costs, physician cooperation, and complexity of meeting meaningful-use criteria as challenges. Our findings suggest that nationwide hospital EHR adoption is in reach but will require attention to small and rural hospitals and strategies to address financial challenges, particularly now that penalties for lack of adoption have begun (Adler-Milstein et al., 2015).

F. Conclusion and Recommendations

EHR, or electronic health record, is a valuable technology in the medical field. EHR is beneficial because it allows healthcare workers to focus more on their work. Doctors who focus on patient diagnosis, for example, do not need to be bothered with many physical documents that may differ in type depending on the test site. If doctors must check document formats, they should focus on this less important task. The EHR can assist in the standardization of patient reporting.

Several Indonesian hospitals have attempted to deploy EHR. The use of an EHR has several advantages for hospitals, including lower costs, more user-friendly features, the ability to share data, and support for clinical decision-making. However, in Indonesia, the adoption of EHR technology is not going so well. Data and network security, cloud service providers, data sharing processes, and medical privacy were among the ethical and legal challenges. This issue arises because EHR development in Indonesia is still in its early stages.

Through this chapter we expect a widespread response from many sectors to ensure that EHR is fully implemented in Indonesia as soon as possible. We hope all hospitals in Indonesia use EHR since technology advancements in Indonesia are relatively rapid. To do this, specifically, we need (1) more operational government legislation addressing EHR, (2) network cooperation between Internet Service Provider (ISP), the government, and hospitals, and (3) the realization of Indonesia's "Satu Data" dream. "One Data" is a government program to unify (integrated) data so as to reduce data redundancy, data loss, and be more structured.

References

Budiyanti, R. T., Arso, S. P., & Herlambang, P. M. (2018). Rekam medis elektronik berbasis cloud dalam perspektif etika dan hukum di

Indonesia. *Cermin Dunia Kedokteran*, *45*(9), 695–698. http://dx.doi.org/10.55175/cdk.v45i9.617

Adler-Milstein, J., DesRoches, C. M., Kralovec, P., Foster, G., Worzala, C., Charles, D., Searcy, T., & Jha, A. K. (2015). Electronic health record adoption in US hospitals: Progress continues, but challenges persist. *Health Affairs*, *34*(12), 2174–2180. https://doi.org/10.1377/hlthaff.2015.0992

Andriani, R., Kusnanto, H., & Istiono, W. (2017). Analisis kesuksesan implementasi rekam medis elektronik di RS Universitas Gadjah Mada. *Jurnal Sistem Informasi*, *13*(2), 90. https://doi.org/10.21609/jsi.v13i2.544

Baumann, L. A., Baker, J., & Elshaug, A. G. (2018). The impact of electronic health record systems on clinical documentation times: A systematic review. *Health Policy, 122*(8), 827–836*)*. https://doi.org/10.1016/j.healthpol.2018.05.014

Cowie, M. R., Blomster, J. I., Curtis, L. H., Duclaux, S., Ford, I., Fritz, F., Goldman, S., Janmohamed, S., Kreuzer, J., Leenay, M., Michel, A., Ong, S., Pell, J. P., Southworth, M. R., Stough, W. G., Thoenes, M., Zannad, F., & Zalewski, A. (2017). Electronic health records to facilitate clinical research. *Clinical Research in Cardiology, 106*(1), 1–9. Dr. https://doi.org/10.1007/s00392-016-1025-6

Gunawan, T. S., & Christianto, G. M. (2020). Rekam medis/kesehatan elektronik (RMKE): Integrasi sistem kesehatan. *Jurnal Etika Kedokteran Indonesia*, *4*(1), 27. https://doi.org/10.26880/jeki.v4i1.43

Jackson, N., Atar, D., Borentain, M., Breithardt, G., van Eickels, M., Endres, M., Fraass, U., Friede, T., Hannachi, H., Janmohamed, S., Kreuzer, J., Landray, M., Lautsch, D., le Floch, C., Mol, P., Naci, H., Samani, N. J., Svensson, A., Thorstensen, C., … Kirchhof, P. (2016). Improving clinical trials for cardiovascular diseases: A position paper from the Cardiovascular Round Table of the European Society of Cardiology. *European Heart Journal*, *37*(9), 747–754. https://doi.org/10.1093/eurheartj/ehv213

Ningtyas, A. M., & Lubis, I. K. (2018). Literatur review permasalahan privasi pada rekam medis elektronik. *Jurnal Pseudocode, 5*(2), 12–17. https://doi.org/10.33369/pseudocode.5.2.12-17

Chapter 19

Conclusions and General Recommendations Regarding Environment and Technology as the Foundation for National Development

Rahmat Trialih, Fefi Eka Wardiani, Rendy Anggriawan, Cendra Devayana Putra, & Ahmad Said

As discussed in the articles in this book, one significant conclusion can be drawn that the environment and technology are vital in building Indonesia's sustainable development. The COVID-19 pandemic has affected the entire world and has threatened the economic situation and people's lives. We should look at this situation as an opportunity to take advantage. Therefore, this situation can be our starting point to focus on national development through nature and the power of technology. This concept is certainly in line with the national recovery program that the government has designed.

We see that this national recovery strategy is very focused on economic recovery. However, we understand that building a sound economy requires foresight in seeing business opportunities and needs

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R. Trialih, F. E. Wardiani, & A. Said
University College Cork, Ireland, e-mail: rtrialih@gmail.com

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to build a foundation by leveraging this country's advantages and combining them with current technological developments. We need to involve at least five parties, namely the government, academia, industry, society, and the community, to realize this (Sukarno et al., 2019). This concept is known as the Penta helix concept. Communication between these five parties will help us understand what we have planned faster because of the balanced integration and synergy. Here we see that these five parties need to understand our power. We believe that Indonesia is endowed with a great natural environment in this concept. If we can take advantage of this, we will have momentum that other countries do not necessarily have. In addition, current technological developments have reached a point where they can transform people's lives in various sectors. Through this, if we can see the potential of technology and use it properly, the lives of Indonesian people can be well supported, and society 5.0 can be realized.

We note that at least some essential points are critical to the success of the Penta helix concept, especially in the technology and environmental sectors (Caraka et al., 2021; Upe et al., 2021). First, in building disaster prevention and greening management. We can take advantage of nature-based solutions, remediation of heavy metals, and geomorphological watersheds. Second, we will need the technology to solve the wastewater, air pollution, and textile to achieve the ideal waste and pollution management development. We also need to regulate microplastic and reduce carbon emissions. Third, we see that building food defense and security development requires an understanding of new technologies such as the internet of things (IoT) or the concept of supply chain management (SCM), then linking it to the target of the UN research roadmap. Lastly, we propose the idea of human resource and public service development which consists of services to the community through education technology, transportation technology, data security technology, and adequate health service technology. In general, we feel that this achievement will require the involvement and synergy of all stakeholders.

Other than that, we also offer recommendations for the relevant stakeholders in this chapter. These recommendations and suggestions are closely related to the role of the environment and technology in the sustainable development of Indonesia after the COVID-19 pandemic. The following are recommendations for the environment and technology as the foundation for sustainable development.

1. Environment Role

For Sustainable Development, there are some points from the various multidiscipline backgrounds.

a. Mitigating the climate threat requires comprehensive undertakings from all contributing sectors. Regrettably, the chemical industry is one area that tends to be overlooked by many. As the global transition to the green industry is inevitable, the Indonesian government must act post-haste to prepare the country's infrastructure and human resources. Besides, this pandemic can kick off a momentous shift toward developing a greener economic system.
b. The harmony of the self-prevention movement and the role of the community is essential in reducing the number of microplastics in the environment. Furthermore, the government should pay attention to the distribution of microplastics and start evaluating and monitoring their existence while it is still in the early stage to prevent bigger impacts in the future. There is no harm in educating, outreaching, and preventing microplastics to minimize the possible effects of their existence.
c. The sustainability of the land is in our collective hands, so we must protect this limited resource for the sake of future generations' continuity. Land restoration based on bioremediation, which combines the principles of nature-based solutions and the circular economy, will generate a long-term benefit. Harmonization of environmental standards requests to assist fathom important natural goals worldwide. New, cheap, and proficient remediation strategies ought to be looked for.

d. Although the end date of the Covid-19 pandemic is unknown, its impact has been felt thus far. This will have a direct effect on the community's food security. Indonesia needs to reconsider some efforts to increase the availability of high-quality food ingredients in quantity and quality. Extensification of cultivation on marginal coastal sandy land is the best option for increasing food availability in Indonesia's declining productive land. Furthermore, Improving agricultural land ecosystems necessitates positive collaboration from diverse stakeholders and society. Smart packaging and larger IoT development help reduce food waste. This platform enables the extension of storage and the transition of duration and product life communication from static coding systems to more real-time applications, albeit at a cost.

e. The RUSLE model has proven a good method for estimating soil erosion supported by GIS software and satellite image data. Based on the soil loss calculation, the area with high or severe risk needs further attention for mitigation purposes. Moreover, the integrated biochar industry for Indonesian rural area households has the potential to achieve the Nationally Determined Contributions (NDCs) implementation targets according to the Paris Agreement.

2. Technology Role

a. For Sustainable Development in Education Sector

   1) Implementing KMS requires investment and development in five supporting elements, namely people, process, technology, structure, and culture
   2) It is necessary to have a good roadmap in the development of KMS, starting from the establishment of objective programs to the framework for evaluation and measurement as a primary material for improvement

3) In building an adequate information system, it is necessary to consider the system, the quality of information, and service because these can affect the sustainability of use and user satisfaction.

b. For Sustainable Development in Medical Sector

1) In Hospital information systems, information is a critical component that cannot be replaced, so this system must provide accurate, updated, and secure information.
2) In the development of hospital information systems, it is hoped that there will be a system that is adaptable and flexible to changes and developments in hospital capabilities
3) A hospital information system needs to have seven core components, namely online appointments, payment modules, laboratory integration, pharmacy integration, emergency department integration, intensive care unit modules, and electronic medical record modules
4) The development of AI technology, big data, and the internet of things enables the transformation of the hospital system in Indonesia
5) Building electronic health records in Indonesia requires the involvement of stakeholders from clinical staff, changes in organizational policies, and workflow processes
6) Electronic health records must ensure that this system is built according to security and privacy standards and provides no redundancy of patient data even in different hospital environments.

c. For Sustainable Development in Transportation Sector

1) Building a quality transportation system should be started by having transportation infrastructure with smart mobility and sustainable vehicle promotion

2) In encouraging public awareness to use public transportation, it is necessary to build an integrated transportation facility between types of vehicles and routes and schedules that run in harmony
3) The use of a centralized data system for transportation needs to be considered by the government as the foundation for the development of excellent and reliable public transportation

d. For Sustainable Development in Agriculture Sector
1) Data is an essential element in building a food balance in Indonesia, and of course, food data is needed starting from the data of suppliers, and the data of imports until import facilities
2) The development of a food supply chain in the post-pandemic era may involve the use of robotic systems to replace human labor
3) It is necessary to develop an optimal food transportation route so that it can save costs and maximize the delivery time of staple foods

e. For Sustainable Development in Government Sector
1) In building a blockchain system in government, it is necessary to involve relevant stakeholders, especially from the government, academia, and the community
2) The use of blockchain for government can help current government systems such as voting, taxes, non-profit agencies, cybersecurity, and big data

We cannot deny that natural wealth is one of Indonesia's gifts. In addition, technological developments have also become an enabler for a country to transform into a developed country. The progress of a country can not only rely on the government's efforts, but there needs to be a good synergy among all related stakeholders. Good harmony and synergy between the government, academia, society, community, and industry is the key to Indonesia's ability to survive and become a better country, especially after the COVID-19 pandemic era. This pandemic can be either a threat or an opportunity in challenging situations. Therefore, related stakeholders need to turn this threat into an opportunity. Moreover, they all need to continue understanding technological advances actively and maximizing our country's potential, such as natural resources and the environment. Based on this, we believe that the environment and technology can be the primary weapons for Indonesia in carrying out sustainable development, especially in this post-pandemic.

References

Caraka, R. E., Noh, M., Chen, R. C., Lee, Y., Gio, P. U., & Pardamean, B. (2021). Connecting climate and communicable disease to penta helix using hierarchical likelihood structural equation modelling. *Symmetry, 13(4), 657.* https://doi.org/10.3390/sym13040657

Sukarno, G., Rasyidah, R., & Saadah, K. (2020). Improve creative industry competitiveness penta helix and human capital in digital era. Advances in Social Science, Education and Humanities Research. *Proceedings of the 2nd International Media Conference 2019*. https://doi.org/10.2991/assehr.k.200325.014

Upe, A., Ibrahim, Z., Arsyad, M., Sumandiyar, A., & Jabar, A. S. (2021). Strengthening of social capital through penta helix model in handling Covid-19 pandemic. *International Journal of Pharmaceutical Research, 13*(1), 4243–4248. https://doi.org/10.31838/ijpr/2021.13.01.635

Abbreviations

BPA	Bisphenol-A
BTX	Benzene, toluene, and xylenes
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization, and storage
CCS	Carbon capture and storage
CO_2	Carbon dioxide
COVID-19	Corona virus disease 2019
CRI	Carbon Recycling International
EG	Ethylene glycol
GHG	Greenhouse gas
IEA	International Energy Agency
IPPU	Industrial processes and product use
LB	Lignocellulose biomass
LDPE	Low density polyethylene
LTS-LCCR	Long-Term Strategy for Low Carbon and Climate Resilience
Mton-CO_2e	Megaton of carbon dioxide (CO_2) equivalent
MTBE	Methyl *tert*-butyl ether

NDC	Nationally Determined Contribution
NLG	Natural liquid gas
PAA	Polyacrylic acid
PE	Polyethylene
PEG	Poly(ethylene glycol)
PES	Poly(ethylene succinate)
PET	Poly(ethylene terephthalate)
PHAs	Polyhydroxyalkanoates
PLA	Polylactic acid
PP	Polypropylene
PS	Polystyrene
PU	Polyurethane
PVC	Poly(vinyl chloride)
SRB	Styrene-butadiene rubber
TPA	Terephthalic acid
TRL	Technological readiness level

Glossary

Abiotic Components : Non-living chemical and physical parts of the environment that affect living organisms and the functioning of ecosystems.

Absorption : Phenomenon where the molecules are accumulated throughout another substance by diffusion or osmosis.

Adsorption : A wastewater purification technique for removing a wide range of compounds from industrial wastewater.

Adsorption : Phenomenon where the molecules form a layer on a surface of a substance.

Aerobic : A process that requires the presence of oxygen or air.

Ammonia : The gas is colorless, has a pungent odor, consists of the elements of nitrogen and hydrogen, is easily soluble in water, and its compounds are widely used in fertilizers, medicines, etc.

Anaerobic : A process that occurs in the absence of oxygen.

AOPs : Advanced oxidation processes (AOPs) are treatment technologies aimed at degrading and mineralizing recalcitrant organic matter from wastewater through reaction with hydroxyl radical (•OH).

Archipelago : A group of islands, or an area of sea with many islands.

Azo dyes : Organic compounds bearing the functional group R–N=N–R′, in which R and R′ are usually aryl. They are a commercially important family of azo compounds, i.e. compounds containing the linkage C-N=N-C. Azo dyes are widely used to treat textiles, leather articles, and some foods.

Biodiversit : A term used to describe the enormous variety of life on Earth.

Bioeactor : A vessel on which chemical process is carried out that involves organism or biochemically active substances derived from such organisms.

Bio-fixation : Method to capture CO_2 mediated by photo- or chemo-autotrophic microorganisms.

Biomass : Biomass refers to the mass of living organisms, including plants, animals, and microorganisms, or, from a biochemical perspective, cellulose, lignin, sugars, fats, and proteins. Biomass includes both the above- and belowground tissues of plants, for example, leaves, twigs, branches, and boles, as well as roots of trees and rhizomes of grasses.

Biotic Components: : The living components in an ecosystem.

Capital intensive : A business operation that requires a significant investment to generate a good or service and, thereby, has a high fixed asset percentage.

Carbon Sequestration	:	Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere to reduce global climate change.
Carbon	:	A chemical element that is contained in all animals and plants, an important part of other substances such as coal and oil, and exists in its pure form as diamonds and graphite.
Cation Exchange Capacity (CEC)	:	The total capacity of soil to hold exchangeable cations.
Chemical precipitation	:	The process of conversion of a solution into solid by converting the substance into insoluble form or by making the solution a super saturated one.
Circular carbon economy	:	Closed-loop system where carbon emissions are reduced, reused, and recycled (3R).
Circular economy	:	The production and consumption model, which involves sharing, renting, reusing, repairing, updating, and recycling existing materials and products for as long as possible. In this way, the product life cycle is extended.
Climate Change	:	A long-term change in the average weather patterns that define Earth's local, regional and global climates.
CO_2e	:	Metric scale used to compare the emissions from numerous greenhouse gases based on their global-warming potential (GWP) by converting levels of other gases to an equal amount of carbon dioxide with a similar GWP.

Coagulation	:	A chemical process used to neutralize charges and form a gelatinous mass to trap (or bridge) particles, thus forming a mass large enough to settle or be trapped in a filter. The words “coagulation” and “flocculation” are often used interchangeably, but they refer to two distinct processes.
Coastal Land	:	Describe the interface or transition area between land and sea.
Coastal Sandy Land	:	Marginal land with low productivity characteristics, including sandy texture, loose structure, low nutrient content, low cation exchangeability, low water holding capacity, very high evaporation rate, and very minimal nutrients, containing clay and dust.
Communal Well	:	A well that services more than one home for residential or irrigation purposes.
Crop Rotation	:	The practice of planting different crops sequentially on the same plot of land to improve soil health, optimize nutrients in the soil, and combat pest and weed pressure.
Decarbonization	:	Process to reduce or remove the emission of CO_2 into the atmosphere.
Decolorization	:	Refers to the process of removing brightly colored organic impurities from the sample mixture. The procedure is usually carried out in the solution phase after the solid product and impurities are dissolved in a suitable solvent. The removal of color from something; bleaching.
Defossilization	:	Process to reduce or remove the fossil-resource-origin emission into the atmosphere.

Dimethylamine	:	An organic compound with the chemical formula (CH3)2NH. This secondary amine is a colorless, flammable gas with an ammonia-like odor.
Direct job	:	Employment generated directly by core activities.
Disruption	:	The era of innovation and massive change that fundamentally changes all existing systems, arrangements, and landscapes in new ways.
Drainage Rate	:	The rate at which water can move through the soil to the drains.
Drip Irrigation/ Trickle Irrigation	:	A type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface.
Dynamic shelf-life systems	:	Discounting old products or applying dynamically adjustable expiration dates.
Electrical Conductivity	:	The measure of the amount of electrical current a material can carry or its ability to carry a current.
Electrochemical destruction:		A cerium-catalyzed electrochemical oxidation process, the CerOx Process, is one electrochemical means of destroying organic waste material. Cerium, as the oxidised Ce(IV), is a potent oxidizing agent that removes electrons from virtually any organic compound with which it comes in contact (except fluorocarbon materials). The process uses Ce(IV), produced is produced in electrochemical Cells that utilize Platinum-plated titanium electrodes. Operating at atmospheric pressure, the process can convert organic hazardous waste materials into carbon dioxide and water.

E-Noses	:	The tools used to characterize different gas mixtures and consist of sensing and signalling system processing system.
E-Tongues	:	An analytical instrument containing a series of chemical sensors capable of characterizing complex liquid samples electronic nose
Evapotranspiration (ET)	:	A term used to refer to the combined processes by which water moves from the earth's surface into the atmosphere.
Flocculation	:	A process by which a chemical coagulant added to the water acts to facilitate bonding between particles, creating larger aggregates which are easier to separate. The method is widely used in water treatment plants and can also be applied to sample processing for monitoring applications.
Flotation	:	Separation of suspended solids, oils, greases and undissolved particles. This technique can be used as a preliminary treatment method for further purification, but at the same time the wastewater treatment can be limited to the flotation technique only. The most used flotation technique is D.A.F. (Dissolved Air Flotation), by which compressed air is dissolved in the wastewater, to be treated.
Food Crops	:	Subsistence crops that are meant for human consumption
Food cycle:	:	A group of food chains that are all or an important part of the food relationships that allow the survival of the population of a community.
		Food Security: A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Forest inventory	: Forest inventory is the systematic collection of data on the forestry resources within a given area. It allows assessment of the current status and lays the ground for analysis and planning, constituting the basis for sustainable forest management.
Fungal Degradation	: A beneficial activity of fungi in carrying out biodegradation using chemical substances as carbon and energy source for metabolism, thereby breaking down larger molecules into smaller ones.
Gas chromatography-mass spectrometry	: An analytical method that combines the features of gas chromatography and mass spectrometry to identify different substances in the test sample.
Greenhouse gas (GHG)	: An atmospheric gas, such as water vapor, carbon dioxide, methane, and nitrous oxide that absorbs and emits radiation produced by solar warming of the Earth's surface. Human activities, primarily the burning of fossil fuels and clearing of forests, have increased greenhouse gas emissions, causing global warming.
Horticulture	: The branch of plant agriculture dealing with garden crops, generally fruits, vegetables, and ornamental plants.
Households	: Individuals who comprise a family unit and live together under the same roof; individuals who dwell in the same place and form a family, sometimes encompassing domestic help; all those who are under the control of one domestic head.
Indirect job	: Employment generated from supporting tasks, such as purchasing goods and services, from other sectors.
Intercropping	: A multiple cropping practice that involves growing two or more crops in proximity.

Isoelectronic point	: The pH of a solution at which the net charge of a molecule carries becomes zero or is neutral.
Land Equivalent Ratio (LER)	: The sum of the fractions of the intercropped yields divided by the sole-crop yield.
Land Use Change	: A process by which human activities transform the natural landscape, referring to how land has been used, usually emphasizing the functional role of land for economic activities.
Marginal Land	: Land with little or no agricultural or industrial value and often has poor soil or other undesirable characteristics.
Microbial remediation	: Can be simply defined by employing microorganisms to lower the bioavailability of pollutants (especially organic contaminants) so as to make less toxic to the ecosystem. These microorganisms can break down (or metabolize) contaminants by using them as a food source.
Microclimate	: A local set of atmospheric conditions that differ from those in the surrounding areas, often with a slight difference but sometimes with a substantial one.
Micro-irrigation	: A type of irrigation that delivers water directly to the root zone of plants.
Mineralization	: The process by which chemicals present in organic matter are decomposed or oxidized into easily available forms to plants. Transformation of organic molecules in soil is mainly driven by microbiota, such as fungi bacteria, and earthworms.
Moisture Holding Capacity	: The mass percent of moisture in a coal sample is specially equilibrated under reduced pressure at 96% relative humidity and 30°C.

Nationally Determined Contributions (NDCs)	:	Nationally determined contributions (NDCs) are at the heart of the Paris Agreement and the achievement of these long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change.
Near-infrared spectroscopy	:	A spectroscopic technique that uses the infrared wavelength region of the electromagnetic spectrum (around 800 to 2500 nm).
Olefin	:	Hydrocarbon containing one or more double bonds (also known as alkene).
Paris Agreement	:	The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels.
Pathogenic	:	Any organism tend to cause disease, for instance viruses, bacteria, spores, etc.
pF Value	:	A quantity indicates the quality of water (which is a culture solution in hydroponic culture) contained in soil.
pH Value	:	A measure of how acidic/basic water is.
Physician	:	A physician is a health care practitioner who performs medicine. Medicine is concerned with promoting, maintaining, and restoring health via the investigation, diagnosis, prognosis, and treatment of illness, injury, and other physical and mental impairments.
Product life cycle	:	The length of time a product is introduced to consumers until it is removed from the market.

Productive Land	:	Land used by households for crop production, animal production or perennial crops and trees.
Radio Frequency Identification	:	The small electronic device consisting of a chip and an antenna.
Root Zone (of plants)	:	The area of soil and oxygen surrounding the roots of a plant.
Rural area	:	A rural area is a geographic area located outside cities and towns.
Semipermeable	:	One types membrane which only let solvents, for example water pass through them. Unlike permeable that can also let solvents and solutes, such as ions and molecules pass through the membrane.
Soil Aggregation	:	Arrangement of primary soil particles (sand, silt, clay) around soil organic matter and through particle associations. Aggregate stability is a good indicator of soil health.
Soil Biota	:	The biologically active powerhouse of soil, such as micro-organisms (bacteria, fungi, and algae) and soil "animals" (protozoa, nematodes, mites, springtails, spiders, insects, and earthworms).
Soil Dry Moisture Content	:	The ratio of the mass of water held in the soil to the dry soil.
Soil Enhancers/Soil Amendments	:	The practices used to improve mine soil quality in terms of its stru cture and biochemical function.
Soil Organic Matter (SOM)	:	The organic component of soil, consisting of three primary parts including small (fresh) plant residues and small living soil organisms, decomposing (active) organic matter, and stable organic matter (humus).

Supercritical fluid	:	Phase where the district boundaries between liquid and gas phases no longer exist as the gas has surpassed its critical temperature and pressure.
Supply Chain Management	:	The process of handling the entire production flow of a good or service — from raw components to delivery of the final product to the consumer. A company creates a network of suppliers ("links" in the chain) that move products from suppliers of raw materials to organizations that deal directly with users.
Synthetic biology	:	A field of science that involves redesigning organisms for useful purposes by engineering them to have new abilities. Synthetic biology researchers and companies around the world are harnessing the power of nature to solve problems in medicine, manufacturing and agriculture.
Trimethylamine	:	Trimethylamine (TMA) is an organic compound with the formula N(CH3)3. It is a colorless, hygroscopic, and flammable tertiary amine. It is a gas at room temperature but is usually sold as a 40% solution in water.
UV-VIS spectroscopy	:	A measurement of light absorption in the ultraviolet (200-350 nm) and visible (350-800 nm) region by a compound.
Volatile	:	Easily turns into gas or vapor
Wastewater	:	Liquid waste that includes water from domestic, industrial, commercial or agricultural activities. It also contains any solids or particulate matter in certain concentration.

Waterless dyeing	:	The process by which dyeing is performed without water. It is a process without water and requires less energy than traditional dyeing method, while still achieving impressive colors in solids and prints. Waterless dyeing process required less process, time, chemicals, & auxiliaries.
Zero-valent iron degradation	:	An effective reducing agent for azo dyes and it is less costly than chemical methods, effective and environmentally friendly

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Biography of Editors

RAHMAT TRIALIH

Born in Malang City, East Java, Indonesia, on January 21, 1991. Has a life motto "Just walk the path you believe; don't forget you are the main character in your own life story. In 2014, he successfully completed his undergraduate studies majoring in Computer Science at the Information Technology and Computer Science Program (now known as the Faculty of Computer Science (FILKOM)) Universitas Brawijaya (UB) Malang. Then, he continued his Master's study majoring in Information Systems at the Sepuluh Nopember Institute of Technology (ITS) Surabaya and completed it in 2016. He is currently pursuing a doctoral program at University College Cork (UCC), Ireland, majoring in Business Information Systems armed with a scholarship from UCC and currently conducting research related to the phenomenon of workaround and shadow IT. Broadly speaking, he has research interests in the fields of IT governance, knowledge management, and social issues in IT/IS usage. Previously, he had been an adjunct lecturer at the Faculty of Computer Science and the Faculty of Administrative Sciences UB from 2016 to 2020. In 2020, he acted as PPI Ireland's Head of Studies and Education. Currently, he is mandated to become the chairman of the technology commission under the OISAA's The Directorate of Research and Policy Studies (Ditlitka) for 2021–2022.

FEFI EKA WARDIANI

Born in East Java, Indonesia, in 1997. Fefi lives in Taiwan with her husband. Fefi got an undergraduate degree in Biology from National Jember University, Indonesia. After that, just to shake things up, she went to the Global master's program of Life Sciences at the National Chiayi University, Taiwan, and graduated cum laude. She is now a doctoral student at Chung Yuan Christian University, Taiwan. Currently, she is also active as a Chairman of Overseas Indonesian Students Association Alliance in Environmental Commission. She is also Climate Reality Leader in Indonesia (Climate Reality Indonesia). Visit Fefi's LinkedIn to find out more about her at https://www.linkedin.com/in/fefiekaw/.

RENDY ANGGRIAWAN

Rendy Anggriawan has completed his master's program with a concentration in soil science from IPB-University Indonesia. His research interests focus on soil health issues and related agricultural production issues. He joins several professional organizations as a form of seriousness in the knowledge they are engaged in, such as the Indonesian Peat Society Association (HGI). Since 2018, he has been actively teaching as a teaching assistant at several universities in the city of Jember. Currently, he is pursuing a doctoral program with a concentration in Hydrology at IIT Roorkee, India.

CENDRA DEVAYANA PUTRA

Born in Surabaya, East Java, Indonesia, on February 02, 1999. He has a life motto "live is to share." He graduated as bachelor in the Information Systems study program, Faculty of Science and Technology, Universitas Airlangga in 2020, with titled highest GPA student. He has been in the world of health information systems in various places, such as the Airlangga University Hospital since 2020 and Widodo Hospital since 2021. He is currently pursing his master's degree at Institute of Information Management, College of Management, National Cheng Kung. Besides, he also serves as vice-chair of the technology commission at the Directorate for Research and Policy Studies OISAA. If you want to know him more, please contact him at https://www.linkedin.com/in/cendra-devayana-putra-0b7898137/.

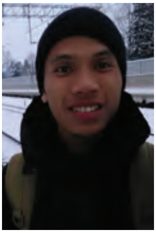
AHMAD SAID

Born in Jakarta, Indonesia, on March 18, 1986. He won 1st place in the LKTI competition from the PLN Group and contributed to the creation of the "Project Management Body of Knowledge" Ver7 Project Management Institute. He has experiences working as a Project Manager in the field of IT-artificial intelligence in the financial services industry and holder of a Project Management Professional certification issued by the Project Management Institute. Currently, he is pursuing his doctoral degree in Business Information Technology, Universiti Sains Malaysia, Malaysia. Currently serving on the technology commission staff at the Directorate for Research and Policy Studies OISAA.

Biography of Authors

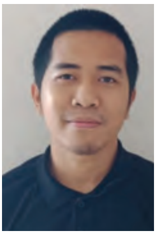
ADE BRIAN MUSTAFA

Ade Brian Mustafa obtained a Bachelor of Science in Agriculture from Bogor Agricultural University (located in Bogor, Indonesia) in the Soil Science and Land Resources Department, Faculty of Agriculture (2012–2017). He is currently pursuing a Master of Science in Environmental Science and Engineering from Shanghai Jiao Tong University (located in Shanghai, China) in the School of Environmental Science and Engineering (2019–2022). Moreover, he actively engaged in various positions under such some organizations, namely Waste Solution Hub, Indonesia Resources Development Institute, and Sprout Academy. Previously, he contributed to the International Indonesian Scholars Association or *Ikatan Ilmuwan Indonesia Internasional* (I–4) as an Event, Promotion, and Communication Assistant from 2018 to 2020. Besides his activities on these platforms, he also published several academic scientific and popular science articles, participated in training programs and competitions, and was invited as a speaker in an online discussion. He is passionate about sustainable development goals, especially nexus sustainability, nature-based solutions, climate mitigation and adaptation, circular economy, renewable energy, community resilience, and so forth.



AHMAD FAJAR

Ahmad Fajar (28) is known as an unpretentious person with a life motto "the more we learn, the more we earn, the more we have to return". He has enthusiasm for Web Technology and Artificial Intelligence, Social Activities, Public Policy, and International Relations. He also joins several communities to increase his experience and sharpen his thinking. He graduated from the University of Muhammadiyah Prof. DR. HAMKA (UHAMKA) Jakarta with the title of the Best Activist. During his undergraduate studies, he received various scholarships, including the Jakarta Scholarship and Student Achievement Scholarship. He was active as Chair of the 2013–ß2014 Faculty of Engineering BEM and UHAMKA Student President for the 2014–2015 period. He is currently working as a software engineer at a startup in Indonesia. Apart from working as a professional, he is continuing his studies on a fully-funded scholarship at the Top University in the Middle East, King Abdulaziz University. He is also preparing to release his own startup with his friends.



ANUGRAH ABDILLAH JUNAID

Currently an undergraduate student in Environmental Engineering Department, Ondokuz Mayis University, Türkiye. He serves as a member of the Student Representative Assembly of the Indonesian Student Association in Türkiye (PPI Türkiye) in Commission IV of Public Relations and Aspirations. Apart from being involved in the organization, he is also interested inscientific writing.

ASEP MUHAMMAD HIDAYATULLOH

Born in Sumedang, West Java. He graduated from Geophysical Engineering ITB in 2015. In 2020, he continued his master's degree at the Department of Hydrology and Water resources management, King Abdulaziz University, Saudi Arabia. He as a staff external division of PPMI Jeddah period 2020–2021. He loves writing, and until now, he has published two papers in the ISI journal as first author and second author, and two other papers as the first author are under review.

AULIA NUR MUSTAQIMAN

Aulia Nur Mustaqiman was born in Jakarta in 1989. After getting a bachelor's degree in agricultural engineering from Universitas Brawijaya in 2011 and a master's degree with a master of environmental science from Universitas Gadjah Mada in 2016, he began working in Universitas Brawijaya as a lecturer in the environmental engineering study program. Currently, he is pursuing his Ph.D. in Environmental Engineering in Chung Yuan Christian University, Taiwan, from 2020 until now. His research topic is conducting about air quality and pollution, especially persistent organic pollutants emitted from engine emissions, under the supervision of Professor Lin Chi Wang.

BHASKARA ANGGARDA GATHOT SUBRATA

Graduated with Bachelor of Agriculture in Agrotechnology Department, Jenderal Soedirman University, Purwokerto, in 2014. He then graduated from Master of Science in Agronomy Department, Gadjah Mada University, Yogyakarta, in 2016. He is now a doctoral student in Agronomy Department, Ondokuz Mayis

University, Türkiye, and a lecturer in Agronomy Department, Amal İlmiah Yapis Wamena University, Indonesia. Has been active in the Overseas Indonesian Student Association in the 2019–2020 Food Commission Study Division. Furthermore, he is actively writing in printed and digital media, various scientific journals, book chapters, and has been a speaker in several seminars and webinars.

DYAH WAHYU UNTARI

She is from Surabaya and was born on March 10, 1995. She received her diploma in Civil Engineering at the Institute of Technology Adhi Tama Surabaya in 2017. During her second year of school, she works in Surabaya for a general contractor and consulting firm. She is now pursuing a master's degree in environmental engineering at Chung Yuan Christian University in 2020. The research focuses on extracting rare earth elements from hazardous fly ash utilizing membrane technology. She has been a member of the Overseas Indonesian Students Association Alliance at the Directorate of Research and Studies since 2020.

FACHRI RIZKY SITOMPUL

Born in Medan City, North Sumatra Province, Indonesia, on April 4, 1995. Has published scientific papers entitled “Digitalization of Agri-food Supply Chains: Facts and Promises of Blockchain Technology” and “Measurement and Proposed Improved Supply Chain Performance approach With PDCA framework. He has served as a member of the OISAA Felari Scholarship Sub-Sector for 2020–2021 and Head of the Indonesian Student Association Hungary Strategic Research Division for 2020–2021. Currently, he serves on the technology commission staff at the Directorate for Research and Policy Studies of OISAA.

FAHIR HASSAN

Born on December 15, 1991. He received his undergraduate and master's degree in Environmental Engineering at the Sepuluh Nopember Institute of Technology, Surabaya, in 2010 and 2016. He has been active as a practitioner in drinking water design and lecturer at the Department of Environmental Engineering University of Jember since 2017. Currently, He is pursuing his doctoral degree at Chung Yuan Christian University since 2020 with Microplastic research. He is active as PPI CYCU for the period 2021–2022. He can be contacted by e-mail at fahirhassan@unej.ac.id.

FAHRUDIN SIDIK

He completed his bachelor's degree in Environmental Engineering at Institut Teknologi Sepuluh Nopember Surabaya in 2019. He is currently in his sophomore year in Environmental Engineering Chung Yuan Christian University, Taiwan. Despite the research focusing on the Electrocoagulation process in water and wastewater treatment, he consistently writes in academic (papers, book chapters) and non-academic fields (blogs, online articles). He also joins several online courses, webinars, conferences, and the Indonesian Student Association of CYCU as Head of the Home Affairs Department. For further information, he can be reached through email at (fahrudin_sidik@yahoo.com)

FITRIA WULANDARI RAMLAN

Born in Medan, North Sumatra, Indonesia, on April 15, 1991. Has a life motto as Mahatma Gandhi said: "Live as if you were to die tomorrow and Learn as if you were to live forever". She obtained her bachelor degree from Harapan University Medan, Indonesia, majoring in Informatics Engineering in 2014; then in 2016, she joined as a Research Assistant at the Intelligent Robot Lab at Kyungpook National University, South Korea. Furthermore, she continued her master's education at Kyungpook National University, in the electronics engineering department in 2018–2020 with the KNU International Scholarships (KINGS) scholarships for tuition fees; Brain Korea 21 (BK21) scholarship for living expenses; and also joined in a special project of the National Research Foundation (NRF) of South Korea in collaboration with the LG Company by involving five well-known universities in South Korea. Currently pursuing her doctoral education at the National University of Ireland Galway (NUIG), Ireland, through a Science Foundation Ireland (SFI) scholarship in the Center for Research Training in Artificial Intelligence (CRT-AI) program. In Korea, she is active as a member in the activities of Rumaisa (Community of Indonesian Muslimah Houses in South Korea) and KNU-INA (Indonesian Students at Kyungpook National University, South Korea). She is active within Indonesian Student Association Ireland's IT division and a member of the OISAA's technology commission.

HILMY PRILLIADI

Graduated from the University of Muhammadiyah Yogyakarta with a bachelor's degree in agribusiness in 2019. Throughout his undergraduate education, he served as Chairman of the Student Executive Board of the Faculty of Agriculture for the 2017–2018 period and Student Vice President at the University of Muhammadiyah Yogyakarta for the 2018–Í2019 period. Furthermore, he received winning awards as outstanding students and the best graduates of the university. He is currently undertaking a master's degree in agricultural economics at Atatürk University, Erzurum, on a Türkiye Bursları scholarship. During his master's education, he served as the Head of Commission on Food in Overseas Indonesian Students Association Alliance for the 2020–2021 period and Vice

Chairman of the Indonesian Student Association in Turkey for the period 2021–2022. Some of his recent publications: "The Impact of COVID-19 on the Global Economy Today and Post-pandemic" in the Sabah Il Bulletin, "Urban Food Center: Washington DC Food Access Problems and Solutions", "Glocalization: Post-pandemic Sustainable Lifestyles", as well as author and editor of the book *Sustainable Golden Indonesia 2045: A Collection of Thoughts from Indonesian Students Around the World. 10th Series: Food* published by LIPI Press.

JIHAN NABILAH HANUN

Has completed her bachelor's degree in Waste Treatment Engineering at Politeknik Perkapalan Negeri Surabaya in 2019. Besides that, she completed her master's degree in Environmental Engineering at Chung Yuan Christian University in 2020. Her focused research was in the field of waste utilization and microplastics, which correlated to the soption behaviors towards Contaminant of Emerging Concerns (CECs). Despite the research focusing on the waste utilization and microplastics, she consistently writes in academic fields (papers, book chapters). She also joins several online courses, webinars, conferences, and supports several occasions held by the Indonesian Student Association of CYCU and Overseas Indonesian Students Association Alliance (OISAA).

LATONIA NUR ADYANIS

born in Jakarta on October 2, 1997. She graduated from the Institute of Technology Sepuluh Nopember in 2019 in the Department of Environmental Engineering. In her undergraduate thesis, she studies the water supply improvement in Malang City, East Java, to raise 100% service goals and drinking water quality levels. After graduation, she directly pursues a master's degree at Chung

Yuan Christian University under the same department. After two years, she graduated from Chung Yuan Christian University, focusing on persistent organic pollutants monitoring and control. She is currently pursuing a postgraduate in Chung Yuan Christian University under Professor Lin-Chi Wang, studying controlling strategies of persistent organic pollutants generation during the combustion of solid recovered fuel by using waste.

NABILLA DEWI SEPTIANI

Graduated from undergraduate study in Chemical Engineering Department at Institut Sains & Teknologi AKPRIND Yogyakarta in 2019. She is currently a master's student in the Chemical Engineering Department at Indian Institute of Technology Madras, India, and an awardee of ICCR Scholarship (Indian Council for Cultural Relations). Her research interests are in Environment, Energy, and Materials.

NANDA AULIA PUTRI

Born in Medan City, North Sumatra Province, Indonesia, May 22, 1999. She got the Best Of The Best Arithmetic Competition National Level 2015, Batam, Indonesia; Runner Up International Arithmetic Competition 2016, Malaysia; 1st Place in Poetry Writing at Medan State Polytechnic Level, Indonesia 2017; 3rd Place in the Essay Competition at Medan State Polytechnic, Indonesia 2018; 2nd Place in General Outstanding Student at Medan State Polytechnic Level, Indonesia 2018; Pass the Government-funded Entrepreneurial Student Program; 3rd Winner of the General Outstanding Student at the Medan State Polytechnic Level, Indonesia 2019

1st Place in Singing Competition at Lunghwa University Of Science and Technology, Taoyuan, Taiwan 2020. Additionally, she also has served as Treasurer staff of the PPI LHU Election Committee in 2021. Just graduated as Bachelor of Science in the Department of Electronics Engineering, Lunghwa University of Science and Technology, Taiwan. Currently studying Master of Science at the Department of Electrical Engineering, Lunghwa University of Science and Technology, Taiwan. And act as a staff of the technology commission at the Directorate for Research and Studies OISAA.

RADITYO PANGESTU

Born in Bandar Lampung, Indonesia, in 1995. Radityo Pangestu is a researcher in Indonesia's National Research and Innovation Agency (BRIN). He is now also pursuing a Ph.D. in Chemical Science and Engineering at Kobe University, Japan. His expertise lies in biorefinery topics, particularly those exploring the bio-based production technologies for a sustainable industry. His current work is related to the production of biodegradable plastics from renewable sources using genetically engineered microbial hosts as a biocatalyst. He is also a member of the Overseas Indonesian Student Association Alliance and Indonesian Student's Association in Japan. Email: pangestu.radityo@gmail.com

SURYA BAGUS MAHARDIKA

He graduated from the Bogor Agriculture University, Indonesia, in March 2019 with a bachelor's degree in Forest Management. While on campus, he had a preeminent role as the chief of Student's Executive Board of Faculty of Forestry, Bogor Agriculture University in 2016 to 2017, and as vice president of

Student's Executive Board of Bogor Agriculture University from 2017 to 2018, leading for more than 24.000 students in the whole university. Besides, he earned the National Activist Scholarship (Baktinusa) Batch 8 and other national-level awards. In September 2019, he received a Chinese Government Scholarship for a master's degree at Forest Management, Northeast Forestry University, Harbin, China, and is expected to graduate in July 2023. His current activity is as a university laboratory team member, a speaker in national seminars and webinars, a trainer for several organizations, writing journals, books, and other media. Since January 2020, he and his team have built a non-government organization named Indonesian Resources Development Institute (IRDI).

ULIN NUHA

Born in Magelang, Central Java Province, Indonesia, on May 9, 1996. He once won 1st place in the National Scientific Work Week. He previously served as staff at PPI Taiwan and Indonesian Student Association Yunlin City. Have one publication in Journal of Information Technology (JIT). He is currently taking a first-year doctoral degree in Electronic Engineering, National Kaohsiung University of Science and Technology, Taiwan. In addition, he is currently on the staff of the technology commission at the Directorate for Research and Policy Studies OISAA.

ZAHRATURRAHMI

She graduated with a bachelor's degree in Agribusiness studies from Syiah Kuala University, Banda Aceh, Indonesia, in 2017. She is currently pursuing a master's degree in Agricultural Economics with a concentration in management at Isparta Uygulamalı Bilimler Üniversitesi, Turkey. She is active as a staff in Marketing and Communication at a Paragraphs Publishing Company. Currently, she is also active as a staff in the field of Education in Turkey's Islamic Economic Society (MES) region. In 2021 she published three international publications in the field of science. Furthermore, she was active as a staff of the Commission on Food-Directorate of Research and Policy Studies (OISAA) 2020–2021. In 2021, she was awarded the best presentation at the International Congress "Agriculture on the World" in Alanya, Turkey. In 2020, she won first place in a photography competition organized by the Indonesia Embassy in Ankara, Turkey. In 201,7 she was a Special Effort Agricultural Instructor (Upsus) for Food Self-Sufficiency in Aceh Province, organized by the Ministry of Agriculture of Indonesia.

INDONESIA

POST-PANDEMIC OUTLOOK:

Environment and Technology Role for Indonesia Development

COVID-19 has disrupted all aspects of human life. To mitigate the impact of the pandemic, several efforts have been taken, including by Indonesian scholars abroad. This book entitled *Indonesia Post-Pandemic Outlook: Environment and Technology Role for Indonesia Development* explores environment and technology issues and topics related to the COVID-19 pandemic and discusses post-pandemic recovery efforts in Indonesia.

Comprising of 19 chapters, this book is divided into four sections. *The first section,* disaster and greening management development, discusses insights for a better solution in disaster prevention and development of greening management. *Second,* waste and pollution management development, explores options in development of waste and pollution management such as potentials uses of membrane technology, remediation of textile dyes, biochar industry, and also discussion on persistent organic pollution and microplastics. *Third,* food defense and security development, explores the potentials of food security and management in utilizing the potential of coastal sand marginal land resources, IoT and smart packaging, and smart food supply chain. *The last part*, human resource and public service development, discuses developments on management of education system, public transportation, e-government, and health information system.

We hope that this book can be a valuable reference for stakeholders, policymakers, as well as society to recover from the pandemic crisis and find better solutions to benefit future generations.

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