SUSTAINABLE WASTE MANAGEMENT USING BLOCKCHAIN TECHNOLOGY IN ASEAN NATIONS; CASE STUDY OF INDONESIA

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Abstrak: Artikel ini membahas ruang lingkup dan keterbatasan pengelolaan limbah yang ada di negara-negara ASEAN, seperti tempat pembuangan sampah yang meluap dan infrastruktur yang lemah. Ini membahas teknologi blockchain untuk membantu meningkatkan transparansi, efisiensi, dan akuntabilitas. Artikel ini akan menyelidiki inefisiensi pengelolaan limbah, hambatan investasi, dan peran pendidikan publik dalam mengubah sikap ini. Informasi dalam artikel ini didasarkan pada analisis data sekunder, serta laporan statistik dan dokumen yang diperoleh dari berbagai sumber dokumen yang relevan. Artikel ini merekomendasikan kebijakan mengenai tata kelola limbah diterapkan menggunakan blockchain, kampanye kesadaran publik dan program percontohan untuk menguji kemanjurannya dalam mengubah pengelolaan limbah menjadi kegiatan yang layak untuk memenuhi SDGs.

Kata Kunci: Pengelolaan Sampah, Implementasi Blockchain, Tata Kelola Sampah, Sampah Kota Padat Indonesia & Pengelolaan Sampah ASEAN.

Abstract: This article discusses the scope and limitations of waste management in ASEAN countries, such as overflowing landfills and weak infrastructure. It discusses blockchain technology to help improve transparency, efficiency, and accountability. This article will investigate the inefficiency of waste management, investment barriers, and the role of public education in changing these attitudes. The information in this article is based on secondary data analysis, statistical reports, and documents obtained from various relevant document sources. Finally, it would suggest that a policy regarding waste governance be implemented using blockchain, public awareness campaigns and pilot programs for testing its efficacy in transforming waste management into a viable activity to meet SDGs.

Keywords: Waste Management, Blockchain Implementation, Waste Governance, Indonesian Solid Municipal Waste & ASEAN Waste Management.

INTRODUCTION

Waste management is a critical environmental issue in today's world, and every country is struggling with it. Waste management refers to all the activities involved in handling waste, from production to final disposal. Waste management directly relates to the 12th Sustainable Development Goal (Responsible Consumption and Production), as it intensifies over time and contributes to environmental issues and their impacts. Focusing on the 12th Sustainable Development Goal (Responsible Consumption and Production), this study adopts advanced technologies and waste governance to promote sustainable consumption, production patterns, and recycling practices. By adopting waste governance and technology, ASEAN nations enhance the way they produce, consume, and dispose of the products for a more sustainable future and achieve the 2030 goals. The world is adopting blockchain technology for more sustainable waste management, as it offers potential solutions for enhancing transparency and efficiency in waste management. Blockchain is a transparent, safe digital ledger system that shares data chronologically throughout a decentralized network of computers by storing it in tamper-proof blocks. Several studies have explored the application of blockchain in various waste management scenarios, highlighting its impact.

Blockchain technology is revolutionizing secure transactions in the digital age. It functions as a shared, continuously growing database (blockchain) where each record (block) is cryptographically linked and secured. These blocks contain timestamps and transaction data, making them ideal for tracking events, managing assets, and even executing automated agreements ("smart contracts"[1]). Unlike traditional systems, blockchain operates without a central authority, granting all participants secure and transparent access to the entire transaction history. These foster trust and efficiency, with the potential to transform various industries beyond just cryptocurrency. The rising number of municipal waste management issues, fueled by rapid urbanization and population growth, is overwhelming traditional waste management systems, jeopardizing public health and environmental well-being.

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[1] Smart contracts are self-executing agreements written in code, stored on a blockchain, that automatically trigger actions when predetermined conditions are met.
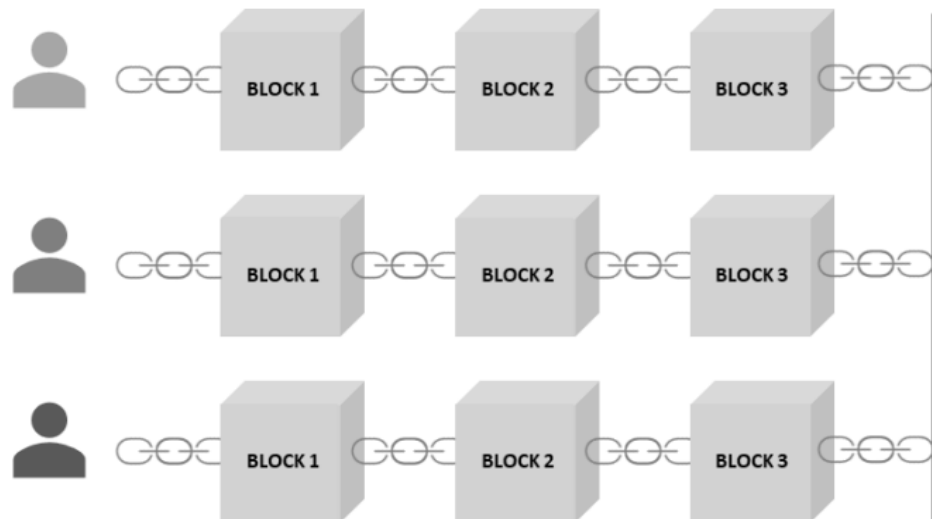
Figure 1: The Environment of Blockchain Technology
Source: (Bułkowska, 2023)

While established nations like Japan, South Korea, Singapore, Germany, Norway, and Australia have pioneered innovative strategies to struggle with these issues (Bukowska 2023), blockchain technology holds immense potential for the future sustainable world as previously described (R. Chithra 2024). Our planet is drowning in waste; increasing cities and a growing population are producing mountains of trash that traditional waste management systems simply can't handle. This mounting waste poses a serious threat to our environment, polluting our air, land, and water and endangering public health. We desperately need new solutions to overcome these issues and sustain the future. The proposed blockchain solution, coupled with secure data standards, aims to create a more accountable and transparent waste management system, ultimately leading to a healthier planet and a healthier population. Various types of waste management can lead to environmental issues. Some common types of waste management include hazardous waste, industrial waste, and electronic waste. However, we must first address the issue of municipal waste. Improper disposal of these wastes can lead to air and water pollution, landfill overflow, and harm to the green ecosystem, which causes a rise in temperature. These wastes are also injurious to the health of humans, sea life, and wildlife. It is important to properly dispose of these wastes to prevent further harm to the environment by adopting technology and sustainable waste

governance. Additionally, recycling these wastes can help reduce the demand for raw materials and decrease energy consumption.
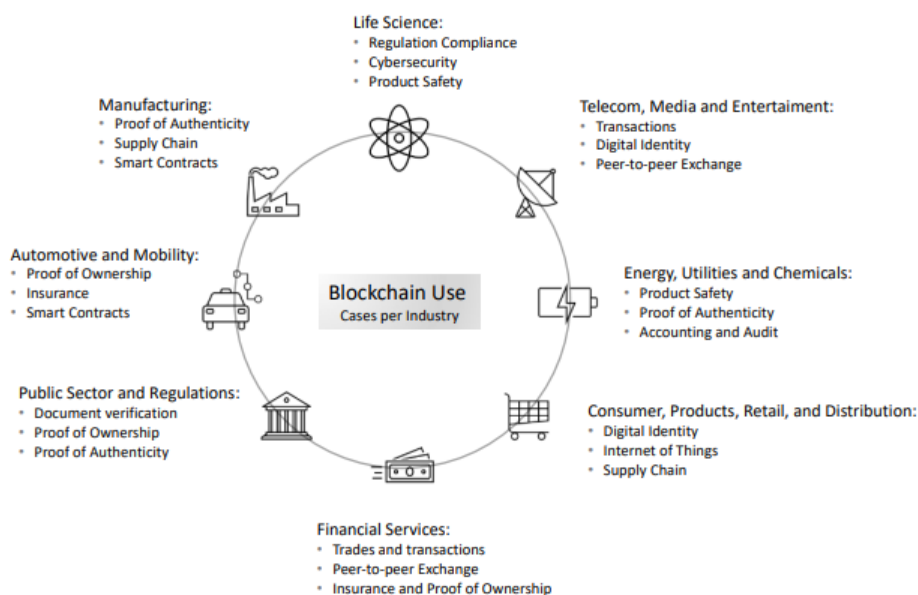

Figure 2: The usage of blockchain in other sectors
Source: (Pandey 2022)

In ASEAN countries, rapid urbanization is disabling traditional municipal waste management systems, leading to overflowing landfills, limited recycling capabilities, and inadequate infrastructure. A lack of investment in waste management technologies and public awareness about responsible waste disposal intensifies these problems. The consequences are terrible, as air pollution from improper waste disposal pollutes the air we breathe and jeopardizes human health. Water pollution harms marine ecosystems and has the potential to infiltrate drinking water sources. Wildlife also suffers due to environmental issues such as food sources threatened by pollution and heatwaves caused by wildfires. Addressing these interconnected issues is crucial for achieving sustainable waste management in ASEAN countries (Indonesia) and protecting the environment. This study aims to explore the inefficiencies of municipal waste management in ASEAN countries, focusing on limitations in infrastructure and recycling the waste, and how we can improve sustainability in the environment by overcoming air and water pollution, wildlife and sea life damages, public health risks, and landfill issues. This study will analyze barriers to investment in new technologies and the role of public education in promoting responsible waste disposal. This study will identify

actionable solutions and foster municipal and regional waste governance collaboration for a more sustainable waste management future in ASEAN nations (Indonesia). Research Questions: How blockchain technology be a viable solution to enhance transparency and efficiency in waste management systems across ASEAN countries. The information in this article is based on secondary data analysis, statistical reports, and documents obtained from various relevant document sources

CONCEPTUAL FRAMEWORK

The rapid increase in population and economic development sweeping across the globe is generating extraordinary volumes of municipal waste. Traditional waste management systems around the world struggling with inefficient resources and advancement. This leads to overflowing landfills, limited recycling capabilities, and improper waste disposal practices, all of which have a devastating impact on the environment for humans, wildlife, and sea life. In this context, blockchain technology emerges as a potential game-changer. Its secure, transparent, and tamper-proof nature offers a novel approach to revolutionizing waste management practices in the world. This study will delve into the potential of blockchain technology to address the critical challenges of municipal waste management, exploring its impact due to inefficient resources and technology and the overall sustainability of waste management systems in ASEAN, with a special emphasis on Indonesia.

RESULTS AND DISCUSSIONS

Houses, offices, and markets primarily generate organic and inorganic waste, such as food, paper, and plastic waste, which contributes to the environmental and landfill issues associated with municipal waste management. All this waste has a more significant impact on climate change through methane emissions, which are more threatened than CO_2 and chlorofluorocarbon emissions. Globally, organic waste dominates, accounting for 61% of household waste. As per (Jain 2017) report, Indonesia generates the most municipal plastic waste annually

at 64 million tons; of these, 3.2 million tons end up in the sea, followed by Thailand at 26 million tons, Vietnam at 22 million tons, the Philippines at 14 million tons, and Malaysia at 12 million tons. Interestingly, Singapore and Brunei Darussalam have the highest per capita waste generation, highlighting potential lifestyle differences within the region. This not only harms individual animals, leading to over 100,000 marine mammals deaths annually, but also disrupts the delicate balance of marine ecosystems. The economic impact as plastic pollutes beaches and fishing grounds, reducing tourism and fisheries income. New study found 12 kinds of micro-plastics in 47 canines and 23 human testis with higher levels in humans. While the type of plastic varied some were linked to lower testis weight in both dogs and humans, suggesting a potential negative impact on male fertility and sperm quality (Chelin Jamie Hu 2024)
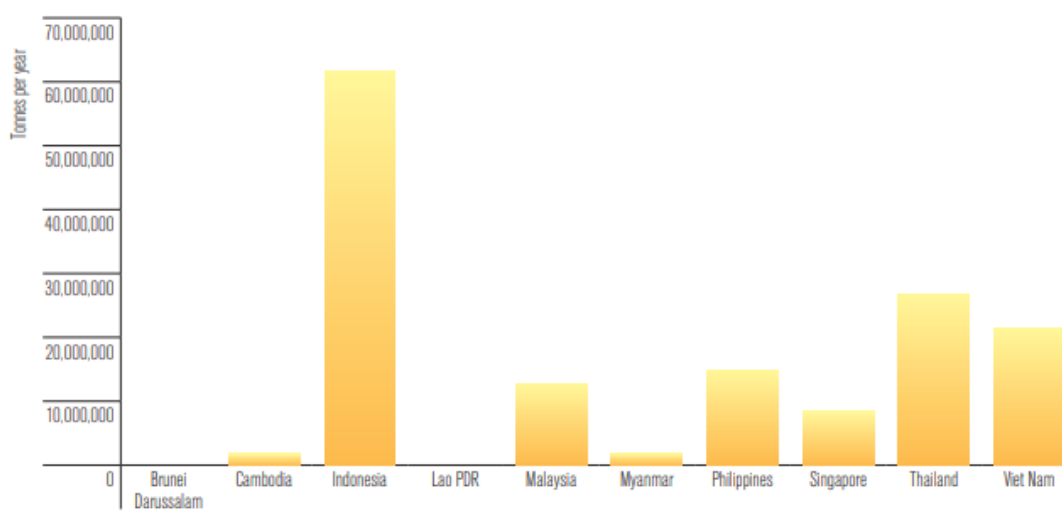
Figure 3: Municipal Solid Waste (MSW) generated annually in ASEAN countries
Source: (Jain 2017)

While many nations are becoming more aware of their contributions to climate change, Indonesia has to do more. By 2025, the government hopes to have cut plastic trash by up to 70%. This is an ambitious aim. In order to facilitate this goal, the government has pledged to provide US$ 1 billion each year for the project. (Lotulung 2023).

Figures 4: The largest once-used plastic rebound action occurs in Indonesia

Source: (aliansizerowaste.id, 2020)

Hamish Forbes (2021) stated that Indonesia generates a staggering 23 million to 48 million metric tons of food waste per year. Estimates suggest that food waste accounts for 8% to 10% of global greenhouse gas emissions. This uneaten food decomposes in landfills, releasing methane, a powerful greenhouse gas 25 times more dangerous than carbon dioxide at trapping heat. These emissions contribute to climate change, leading to rising temperatures, extreme weather events, and disruptions to agricultural production, potentially creating a vicious cycle in which food waste exacerbates food insecurity.

Electronic waste, also known as E-waste, is a growing concern in this digital age and contributes significantly to waste management. Many people are unaware that their online activities cause a carbon footprint due to energy consumption. Indonesia is the 4th largest internet user-based country, where the combined digital footprint of its 202.7 million users (As per 2021) significantly contributes to global carbon emissions, and E-waste contributes 3.7% of the world's carbon emissions (Saraswati 2022). Improper disposal of electronics, often containing toxic substances like lead and mercury, contaminates soil, water, and air, harming ecosystems and contributing to wider environmental issues. This toxic exposure also poses severe health risks, particularly for children and informal recycling

workers, leading to respiratory problems, skin conditions, and even neurological damage.

Table 1: Amount of Waste Generation

No.	Countries	Per Capita MSW Generation (kg/capita/day)	Annual MSW Generation (In ton)	Annual Hazardous Waste Generation (In MT)	Annual E-waste Generation (In Metric Kiloton ton)
1	Brunei Darussalam	1.4	210480		
2	Cambodia	0.55	1089429		
3	Indonesia	0.70	64000000		
4	Lao PDR	0.69	77380		8.00
6	Malaysia	1.17	12840000	1517434.06	
5	Myanmar	0.53	841508		
7	Philippines	0.69	14660000	1693856.72	39000
8	Singapore	3.763	7514500	411180	110
9	Thailand	1.05	26770000	3300000	368.314
10	Viet Nam	0.84	22020000		1609.775

Source: (Jain 2017)

The municipal solid waste produced in the ASEAN nations is composed mainly of organic waste, plastic, paper, glass, and metal, but specifically in Indonesia, the major waste is organic/food waste, which is 60%, plastic 14%, paper 9%, metal 4.3%, glass 1.7%, textile 3.5%, and rubber 5.5%, as described in **Table 2.**

Table 2: Composition of MSW

Food/ Organic Waste	Paper	Plastic	Metal	Glass	Textile	Rubber	Grass/Wood etc. waste	Construction Debris	Others
36	18	16	4	3					
60	9	15		3	1	1			
60	9	14	4.3	1.7	3.5	5.5			2.4
64	7	12	1	7	5	3			
45	8.2	13.2		3.3					27.3
73	2.24	17.75		0.45	1.14				5.15
52	8.70	10.55	4.22	2.34	1.61				
10.5	16.5	11.6	20.8	1.1	2.1		8.6	16.9	11.9
64	8	17.62	2	3	1.4	1	1		
55	5	10	5	3		4			

Source: (Jain 2017)

The alarming rise in municipal waste worldwide necessitates urgent solutions, approaches, and policies to address environmental issues and safeguard the global ecosystem. This study delves into the potential solutions for a more sustainable future. The entire world, including ASEAN nations with their growing and emerging economies and increasing urbanization, is grappling with these challenges. ASEAN nations, particularly Indonesia, formulate green growth-oriented environmental strategies through the implementation of policies and frameworks such as the National Action Plan 2007, the Indonesia Climate Change Sectoral Roadmap 2009, and the National Action Plan for greenhouse gas emission reduction 2011. Indonesia has air, water and waste management legislation in addition to a fundamental environment act. Hazardous and toxic materials waste are all defined under this legislation.

Major Municipal Solid Waste (MSW) policies, programs, strategies, plans, and initiatives are in place in Indonesia. However, they are not now adequately enforced or implemented at all levels of government. The collection, recycling rate, and resource recovery from MSW are all below average as a result. Although there are national targets for trash minimization and collection, local government policy frameworks have not effectively incorporated these standards Jain (2017). Based on waste management and technology profiles, policy, regulatory and institutional profiles for every nation and waste stream, gap analyses have been conducted. Based on national reports and presentations, these gaps have been evaluated at the policy, program, plan/strategy and project levels in response to the objectives stated at the UNCRD's [2]3R[3] forum as per **Figure 3 data.** Apart from ASEAN, Indonesia has not clear policy framework and regulation for E-Waste (Jain 2017), which is the raising concern with the increasing population and advancement of technology and Projects and plans related to e-waste are in the design and development stages. It is included in the ten-year Extended Producer Responsibility (EPR) implementation roadmap. Since hazardous waste management regulations involve health care waste, Indonesia does not have any special policies or regulations on the subject. Coordination across mandated departments can be improved, much like

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[2] United Nations Centre for Regional Development.
[3] The 3R Initiative aims to promote the "3Rs" (reduce, reuse and recycle) globally so as to build a sound-material-cycle society through the effective use of resources and materials.

with other waste streams. Technology is lacking in Indonesia for managing the three types of rising waste streams. Although only 20% of hospitals have their own incinerators, most garbage is disposed of in landfills or in illegal hotspots where it is disposed of with MSW.
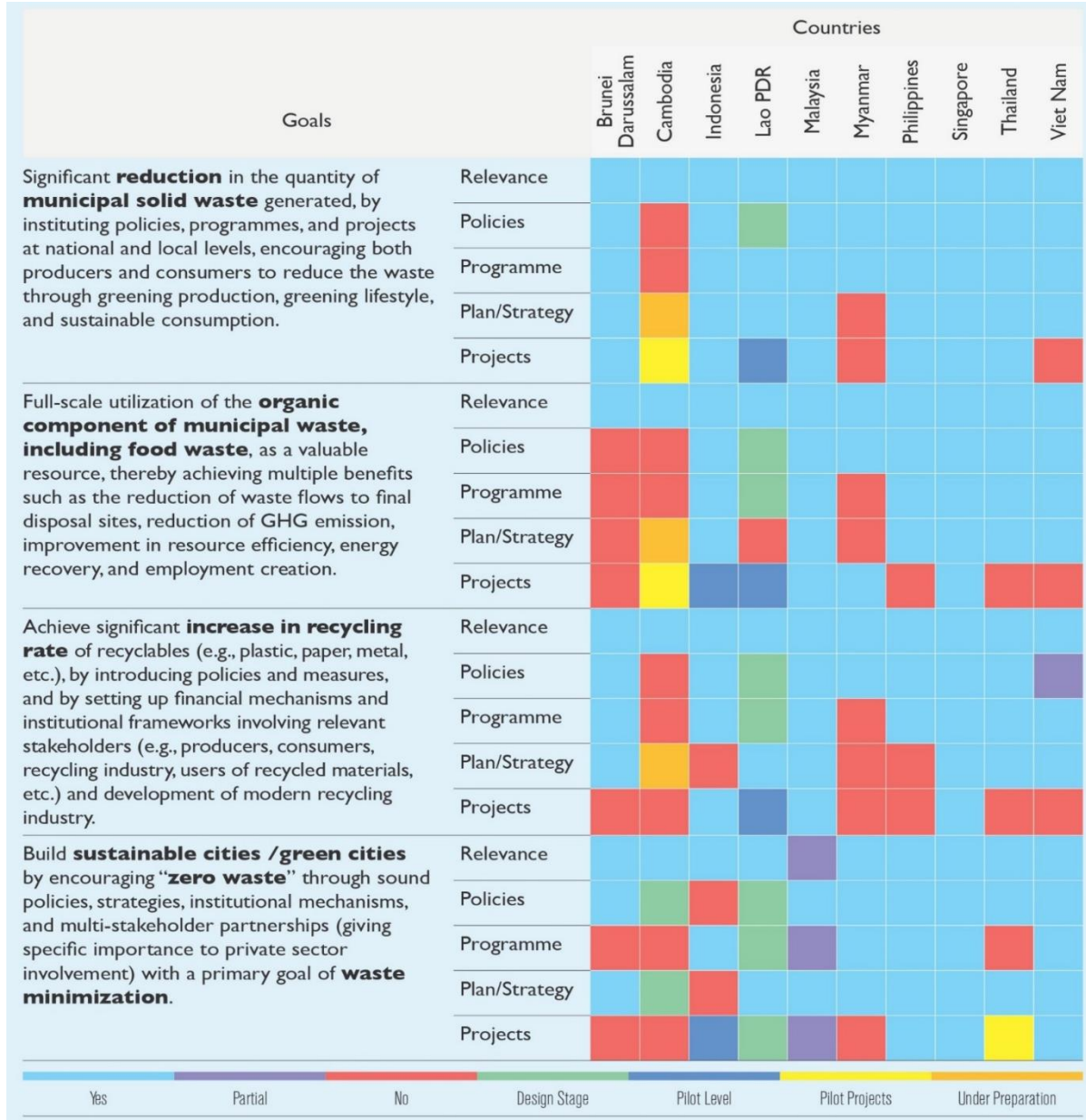

Figure 5: Municipal Solid Waste
Source: (Jain 2017)

CONCLUSIONS

Firstly, the government should develop a waste governance policy framework by using blockchain technology which is low carbon technology and gather the all stakeholders and partners on the same platform to achieve the sustainable goal and gather the international support to overcome the challenges. Governments should have an emerging awareness campaign among the public so they can well aware about climate challenges and also can contribute to achieving the sustainable waste management goals. The Indonesian government should come up with more projects like National Blue Economy Roadmap 2023-2045 which was launched in July 2023, this project specifically develops for the enhancement of marine resources. United Nations Environment Program (UNEP) support fell under the High Impact Initiative on Nature Driving Economic Transformation, part of a broader UN effort to supercharge progress on the SDGs. All world well aware that there will be a number of limitations to implement the blockchain technology in waste management but we recommend to implement the blockchain technology on partially and municipal level for testing purpose so it will be easily to eliminate the risk and limitations of technologies. Because of its special qualities, blockchain technology has the potential to significantly influence how many different economic sectors develop in the future. A smart contract might automatically confirm that an individual is accurately sorting rubbish and award them appropriately if a waste management system gives benefits for recycling (Sen Gupta 2022).

Smart contracts and self-executing agreements can revolutionize waste management. Imagine a tiny Radio Frequency Identification (RFID) chip embedded in a trash bag like an invisible tag with a secret code. This chip, along with the sensor in the bin itself (part of the internet of things/ IoT), would track the type and amount of waste generated and also track from where your garbage came from and where it goes. IoT devices can collect real-time data on waste generation, location, and type. They may guarantee that waste is sent to the proper treatment facilities and is not dumped in unapproved areas by bringing transparency to the recycling process (Jennifer Li, 2021). Smart contracts can use this code to reward

recycling the material or waste, and at the same time, these tags can help to fine the companies that polluted the environment. Participants in a network construct these contracts together. They are used to make peer-to-peer or remittance transactions easier (Wang 2019). This "trash tracking" system could be made possible by blockchain technology, the same system behind some cryptocurrencies. It could make waste management cheaper, cleaner, and fairer for everyone. Re-engineering and supply-chain process management are using the smart contracts (Kouhizadeh 2019). A smart contract might also be connected with other systems, like waste collection truck fleet management systems, to optimize the overall process by enabling route optimization and better resource management (J. Amato Neto 2019). The combination of the Internet of Things (IoT) and blockchain technology has the potential to revolutionize waste management in smart cities. It can also incentivize responsible waste management by rewarding participants and identifying areas for improvement. Overall, blockchain technological integration offers a promising approach to creating a more sustainable waste management system in smart cities (Bułkowska 2023).

Bibliography

Aliansi Zero Waste Indonesia. 11 Oktober 2020. "Monster Plastik Muncul dan Ancam Bumi." https://aliansizerowaste.id/2019/07/21/monster-plastik-muncul-dan-ancam-bumi/

Bułkowska, Katarzyna. 2023. "Implementation of Blockchain Technology in Waste Management." *MDPI* 18.

Chelin Jamie Hu, Marcus A Garcia, Alexander Nihart, Rui Liu, Lei Yin, Natalie Adolphi, Daniel F Gallego, Huining Kang, Matthew J Campen, Xiaozhong Yu. 2024. "Microplastic presence in dog and human testis and its potential association with sperm count and weights of testis and epididymis." *Toxicological Sciences*.

Hamish Forbes, Tom Quested, Clementine O'Connor. 2021. *FOOD WASTE INDEX REPORT*. United Nations Environment Programme.

J. Amato Neto, A.S.L. França, R.F. Gonçalves, C.M.V.B. Almeida. 2019. "Proposing the use of blockchain to improve the solid waste management in small municipalities." *Journal of Cleaner Production*.

Jain, Amit. 2017. *WASTE MANAGEMENT IN ASEAN COUNTRIES*. Thailand: United Nations Environment Programme.

Jennifer Li, Mohamad Kassem. 2021. "Applications of distributed ledger technology (DLT) and Blockchain-enabled smart contracts in construction." *Automation in Construction.*

Kouhizadeh, Mahtab. 2019. "At the Nexus of Blockchain Technology, the Circular Economy, and Product Deletion." *Applied Sciences.*

Lotulung, Garry. 2023. *INDONESIA IS DROWNING IN PLASTIC. BUT WITH ACTION COMES HOPE.*https://www.fairplanet.org/story/indonesia-plastic-crisis-river-jakarta/#:~:text=Based%20on%20data%20obtained%20from,end%20up%20in%20the%20sea.

Pandey, S., & Sen, C. 2022. "Blockchain Technology in Real-Time Governance: An Indian Scenario." *Indian Journal of Public Administration.*

Phillip Taylor, Katrien Steenmans, Ine Steenmans. 2020. "Blockchain Technology for Sustainable Waste Management." *Sec. Politics of Technology.*

R. Chithra, P Kishorekumar, M Manojkumar, S S Praveen. 2024. "Sustainable Waste Management using Block Chain Techniques for Smart City." *2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA).* Bengaluru: IEEE.

Saraswati, Aviaska Wienda. 2022. *The Threat of Indonesian Waste Management Problem.* Feburary 3. https://greeneration.org/en/publication/green-info/the-threat-of-indonesian-waste-management-problem/.

Sen Gupta, Y., Mukherjee, S., Dutta, R. 2022. "A blockchain-based approach using smart contracts to develop a smart waste management system." *Int. J. Environ. Sci. Technol.*

Wang, Shuai. 2019. "Blockchain-Enabled Smart Contracts: Architecture, Applications, and Future Trends." *IEEE.*