

Challenges and Efforts of Environmental Management Toward Smart Environment in Ternate

Lely Adriani Nasution*, Yuni Andriyani Safitri, Eva Marthinu, Rohana Sufia

Geography Education, Faculty of Education and Teacher Training,
Universitas Khairun, Indonesia
*lely.adriani@unkhair.ac.id

Abstract

The implementation of the smart city concept involves the creation of a city that is digitally integrated. As a result, cities designated as smart cities undergo transformation, facing various challenges and efforts, particularly in environmental management. Ternate is one such city that is transforming its environmental management practices to develop a smart city focused on a smart environment. This research was conducted qualitatively, gathering data through focus group discussions (FGDs) and in-depth interviews with community members and relevant government agencies involved in implementing smart environmental initiatives. The findings indicate that the primary environmental challenge facing Ternate is waste management. Issues include low public awareness regarding proper waste disposal, a limited number of waste collection vehicles, and inadequate waste management and processing facilities. To address these challenges, it is essential to implement initiatives such as community outreach regarding waste banks, increasing the number of waste collection vehicles, and exploring collaborative opportunities with other parties to enhance waste management and processing in Ternate.

Keywords: Challenges and Efforts, Environmental Management, Smart Environment

DOI: [10.20527/jpg.v12i2.23832](https://doi.org/10.20527/jpg.v12i2.23832)

Received: 10 September 2025; **Accepted:** 30 September 2025; **Published:** 30 September 2025

How to cite: Nasution, L. A., Safitri, Y. A., Marthinu, E., Sufia, R. (2025). Challenges and Efforts of Environmental Management Toward Smart Environment in Ternate. *JPG (Jurnal Pendidikan Geografi)*, Vol. 12 No. 2.

<http://dx.doi.org/10.20527/jpg.v12i2.23832>

© 2025 JPG (Jurnal Pendidikan Geografi)

*Corresponding Author

JPG (Jurnal Pendidikan Geografi) is licensed under
a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License



1. Introduction

The development and implementation of technology in the current digitalization era can have positive impact on urban development, such as initiatives and innovations in

integrated technology-based urban programs (Michelle and Felasari, 2021). Through the integration of technological systems, a city is expected to facilitate forms of service to the community and lead to the concept of a smart city. A city is smart if its investment covers three aspects, there are human and social, infrastructure and technology that support growth and quality of life (Deloitte, 2015). Smart cities are formed with six pillars as a foundation, such as smart governance, smart people, smart environment, smart mobility, smart economy and smart living (Van Lendegem, 2011; Directorate General of Spatial Planning, Ministry of Public Works, 2015). The smart city concept also applies to a more advanced waste management and water management (Szpilko et al., 2023). This concept is a continuation of the smart environment pillar. As a dynamic and continuously innovative region, the urban environmental aspect is also an aspect whose relevance is taken into account in the development of the city, in addition to the industrial, health, information technology and communication (Scuotto et al., 2016). This is because the condition of the urban environment is dynamic both in terms of quantity and quality. To realize an environment that is directed by the direction with the goals of a smart city, urban areas need to pay attention to the indicators that are included in the scope of the smart environment as the table shows below:

Table 1. Key Driver Smart City

No	Indicator	Key Driver
1	Smart Governance	a. Democracy process and inclusion b. Interconnected and integrated governance administration c. Increased access to services
2	Smart People	a. Improving education patterns b. Controlling learning through remote e-education solution c. A better informed society
3	Smart Environment	a. Sustainable environmental management b. Reducing energy use through technological innovation c. Energy conservation and recycling
4	Smart Mobility	a. Smart and efficient transportation system b. Utilize and make the network more efficient for the movement of people and goods to reduce congestion c. Implementation of new social attitudes of using vehicle
5	Smart Economy	a. Regional or global competition b. Broadband access for all community to improve B2B chance c. Independent locations help manage populations within an independent area d. Electronic business transaction process in entire aspects
6	Smart Living	a. High quality access for healthy service b. Electronic management for healthy record c. Automatic housing and smartbuilding service d. Access for all social services

Source: Lendegem, 2011; Directorate General of Spatial Planning, Ministry of Public Works, 2015.

A smart environment is one of the pillars of the smart city concept, and it has the potential to experience dynamic changes due to complex activities in urban areas (Jacquez

et al., 2024). Smart environment seeks to increase knowledge related to environmental conditions and management in terms of energy, electricity and gas use as well as knowledge in reducing waste and growing environmental benefits for efficient use of resources (Aleta et al., 2017). Smart environment can also be described through natural conditions, climate, availability of green open space, pollution and management of resources to realize efforts to protect environmental functions (Alamsyah et al., 2016). All forms of development and activities in urban areas will always be in direct contact with the environment, including the implementation of smart city values. Therefore, the community must participate in supporting environmental management in order to create a good environment both physically and non physically (Zhang et al., 2020). The synergy of the community in managing the environment as a space they live in, including urban areas, can support preservation and prevent environmental damage or pollution (Law Number 32 of 2009). A good urban environment can represent the success of the role of government cooperation with the community (Bates et al., 2023).

Ternate city is the only city in North Maluku Province which selected to be one of city in Indonesia for Nawacita 100 Smart City (Erdian, 2023). The selection of Ternate city was marked by the submission of the smart city master plan document by the Ministry of Communication and Information to the Government of Ternate after a four stage technical guidance process from July to October 2022 (Diskominfo Sani Kota Ternate, 2022). From that selection, Ternate must be prepared to face and solve all of problems, including environmental problems, which are also one of part the smart city pillars. In Ternate, the most tangled environment issues can be found in problem waste. The problem of waste in Ternate city become a tangled thread that very difficult to solve until it causes polluted the sea. The lack of public awareness become the main factor which is contributing to the environmental problem, and its also increasing the impact of sea pollution, this condition became the serious threat that worsens the situation (Ichi, 2021). Since of the implementation of smart city in Ternate, environmental problems that caused by waste still have yet to be resolved, even though its implementation has been running for three years. The sight of waste can be found almost in all of areas, such as on the roadside, public facilities, under the bridge and even on the sea. It proofs that waste problem is the main cause of environmental problem that have yet to be resolved. Thus, this condition become an obstacle that must be overcome to truly achieve the goal of smart environment.

2. Method

This study uses a qualitative descriptive method through the FGD (Focus Group Discussion) approach and in-depth interview with several informants. Informants were selected purposively, considering their contribution to the environment in Ternate City. Informants in this study consisted of several communities, such as Ternate Creative Space, Ankam, Relawan Siaga, Eco Bhinneka, Bengkel Pulau, and representatives from the Provincial Environmental Service and the Head of the Ternate City Landfill Technical Implementation Unit (UPTD). The data analysis in this study uses triangulation. The sources of data in this study are consist of primary and secondary data. The primary data was getting by direct collection from FGD and in-depth interview and for secondary data was getting through by literature studies (See Fig 1 of data triangulation). This research design started with problem identification of smart environment in Ternate through out with observation, and then the next step was problem analysis which done by focus group discussion, and the finish step was formulating the challenges and efforts to smart

environment (see Fig 1 at the right side for flowchart design of the research).

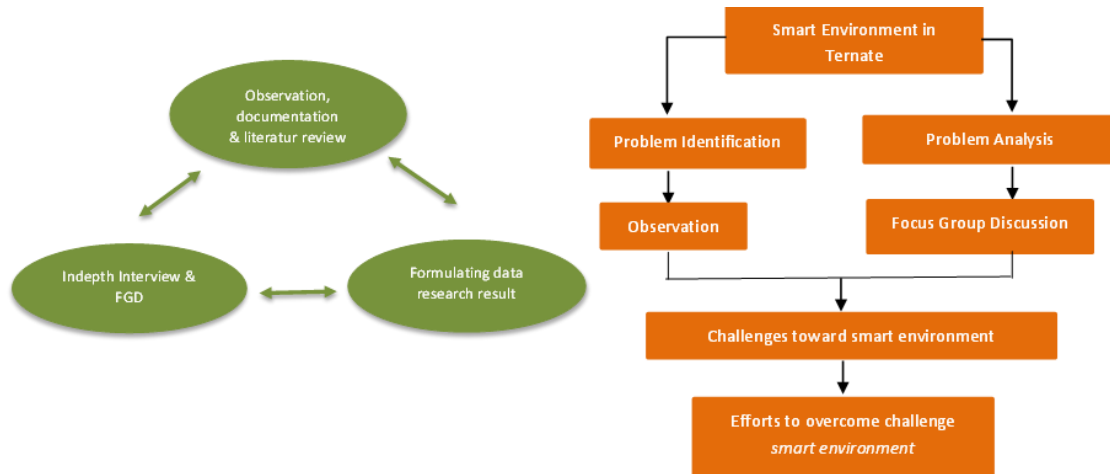


Figure 1. Data triangulation and Flowchart design of research

3. Result and Discussion

A. Result

To achieve the success of smart environment implementation, there needs to be an indicator as a reference and guideline for its implementation. There are several indicators that can be used as a pilot for smart environment implementation, these indicators was formulated from the smart environment research by Harian Kompas, PT Perusahaan Gas Negara and Institut Teknologi Bandung (ITB) in 2015. These indicators are derived from the key driver of smart city implementation, which combines the us of integrated technology and the concept of sustainability in carrying out environmental management, which includes the following (Rachmawati & Pertiwi, 2017):

1. Availability of public open space
2. Good waste management
3. Slum management
4. River revitalization
5. Reduce wasteful building construction
6. Alternative energy
7. Reducing CO₂
8. Urban agriculture

Based on those indicators, the second indicator is the most priority thing to pay attention when implementing the smart environment in Ternate. The determination of that indicators as a focus is based on problem that occur and happen in Ternate and the determination also based on the result of the Ternate City-Wide Assessment in 2018. The Ternate City-Wide Assessment. Based on analysis results from City-Wide Assessment in 2018, there are several problems that can be a threat for Ternate city, such as fires, earthquake, landslide, land floods, volcanic eruptions, sea water intrusion and garbage.

From that results, we can see that garbage is the only problem which is not included to problem in natural disaster category and besides of that garbage is also can be threat or problem that has an impact in public health and the environment and can be indirect impact for society.

Related to threat or problem that had explain before, the garbage rises as a problem or threat for Ternate caused by waste that happen for most of the area in Ternate. The amount of waste in Ternate specifically increasing along with the increasing of population. This condition is getting worse by the lack of public awareness, especially for who those living in upstream areas and also this condition happens because there is a change for people consumption. People more likely an instant way for their living and it can be seen from the increasing purchasing power for various types of necessities as the background to the emergence if many new shops and shopping centers that emerged, so this condition can be contribute to the increase in waste product. In addition to being the main focus of the smart environment indicator, the waste problem also has an impact on other aspects such as water, ecosystems, and especially health. The prevalence of diarrhea caused by environmental conditions in Ternate City has increased from 2011 to 2015, namely from 3259 cases to 3990 cases. The cause is the condition of polluted water due to waste disposal around water sources in random places, which affects water quality. The waste problem in Ternate City is complex. The complexity of this waste problem is caused by the lack of supporting facilities in dealing with waste, the lack of public awareness in disposing of waste, and also the inaccessibility of locations by waste collectors (City Wide Assessment, 2018).



Figure 2. The complexity of waste problem in Ternate (Ternate City-Wide Assessment, 2018)

B. Discussion

The waste problem in Ternate City is a major obstacle to implementing a smart

environment. Based on the identification results, it is necessary to formulate challenges and possible measures to address these issues. The challenges and measures in addressing a smart environment include aspects that need to be addressed and the efforts that can be made to address them.

1) Challenges to a Smart Environment in Ternate

A) Awareness of Protecting the Environment from Waste

Awareness of the long-term impacts of littering is still lacking among the society. As a result, many people intentionally litter without considering their surroundings or the potential negative impacts. In Ternate City, this practice is common. People often dump their trash in the barangka (rivers that flow into the sea), causing it to pile up. Waste should be processed before being disposed of in landfills or recycled (Rachmawati & Pertiwi, 2017). During the rainy season, empty barangka fill with rainwater, carrying large amounts of trash, filling streets and clogging drainage channels, causing flooding. People not only dump trash in barangka, but also intentionally dump it into the ocean, even though waste thrown into the ocean is very dangerous because it does not decompose easily. The most common type of waste found in the ocean is plastic waste.



Figure 3. Waste A collection of plastic waste that was washed away by the rain in barangka, Soa Sio, Ternate City

Plastic waste that is not managed properly on land is known as Mismanaged Plastic Waste (MPW) and ends up in the ocean. The largest amount of MPW in Indonesia is found on the island of Java, at 129.3 ktons/year, and on the island of Sumatra, at 99.1 ktons/year. However, in percentage terms, approximately 66.6% of MPW dumped into the sea originates from rural areas. The largest percentage of MPW originating from rural areas is found in eastern Indonesia, with 80-90% distributed across the Maluku Islands and Papua. Meanwhile, in Sumatra, Bali, and Kalimantan, 70-75% of MPW is dumped into the ocean, and around 55% in Java (World Bank, 2021). In fact, according to Purba et al. (2021), areas significantly impacted by marine waste are in northern Indonesia, such as the Riau Islands, West Kalimantan, East Kalimantan, North Maluku, and Raja Ampat. Based on these data, it can be seen that North Maluku really needs to pay attention to the waste problem as a major challenge in environmental conditions. The problem of waste polluting the oceans also poses a challenge in achieving SDGs goal 14 on marine

ecosystems. The sustainability of marine ecosystems depends on the health and cleanliness of the marine environment, which serves as a habitat for marine life.

B) Minimal Waste Processing and Management

The majority of waste discarded by the public is household waste. Household waste is a type of waste that is difficult to manage and process due to its high quantity and frequent lack of prior separation. Managing and processing household waste remains a significant challenge, as the waste management system is still limited to collection, transfer, and disposal to landfills (Tamyiz et al., 2018). If waste management and processing continue to be suboptimal, it will lead to environmental problems such as pollution, the spread of disease outbreaks, environmental degradation, flooding, soil degradation, and even accelerated global warming (Isaiah & Blessing, 2020). Furthermore, the accumulation of waste in open areas can lead to groundwater pollution because leachate seeps into the soil pores, contaminating the groundwater quality (Utami et al., 2023). Apart from that, considering that Ternate City has a target for waste management which is stated in regional regulations, there needs to be an improvement in waste management.

II. Targets for handling household waste and household-like waste at the provincial and district/city levels

Indicator	Year							
	2018	2019	2020	2021	2022	2023	2024	2025
Potential of household waste and household-like waste in Jakstrada (tons/year)	31.832	32.469	33.118	33.780	34.456	35.145	35.848	36.565
Target for handling household waste and household-like waste in Jakstrada	73%	80%	75%	74%	73%	72%	71%	70%
Targets for handling household waste and household-like waste at the provincial and district/city levels	23.237	25.975	24.839	24.998	25.153	25.305	25.452	25.596

Figure 4. household waste and similar waste management targets in Ternate city

Source: Ternate Mayor Regulation No. 19 of 2018 about Regional Policies and Strategies for Managing Household Waste and Household-Like Waste

In order to reduce the impacts caused by the lack of waste management and processing by the community, the community needs to be educated about the impacts of waste and the utility values that can be optimized from waste management and processing efforts. The community needs to know and be directly involved in processing waste into materials that are still usable. For example, plastic waste can be recycled into shopping bags, carpets, flower vases, and other materials that still have economic value. Therefore, community involvement in managing and processing waste needs to be increased in order to maintain environmental sustainability and can increase the value of products from waste materials that can still be processed (Mutaqin, 2018).

C) Limited Garbage Collection Fleet

The garbage collection system in Ternate City is managed by the Environmental Services. Garbage collection is part of waste management, aiming to transport garbage

from the source to the final disposal site (Law Number 18 of 2008). Garbage collection in Ternate City uses a fleet of motorcycles and trucks. Unfortunately, these collections have no fixed schedule and are limited in number, so they do not reach all areas. Some resident who cannot be reached by waste collection vehicles often dispose of their waste in dumpsters located on the side of main roads. This leads to garbage accumulation, which can detract from the aesthetics and cause unpleasant odors for road users passing by. The limited number of garbage collection vehicles can also impact suboptimal service, resulting in waste accumulation (Shafa & Darwin, 2022).



Figure 5. Garbage deliberately placed on the side of the road by the public due to the uncertain schedule of the garbage collection fleet.

2) Efforts to Address Challenges Towards a Smart Environment in Ternate

A) Waste Bank Socialization

The still-minimal waste management is related to the existence of waste banks in Ternate. According to Regulation of the Minister of State for the Environment of the Republic of Indonesia Number 13 of 2012, a waste bank is a place for sorting and collecting waste that can be recycled and/or reused, thus having economic value. Referring to this definition, waste banks play a crucial role in maintaining environmental sustainability and addressing waste issues (Afdhal, 2024). Based on an in-depth study with the Ternate City Environmental Service, there are still very few in the community, even though their existence can optimize waste management and processing efforts. Public outreach regarding the establishment of waste banks can be one way to address the waste problem in Ternate City. This outreach can begin with an introduction to waste banks and how they work to manage and process waste to increase economic value and be more effective and efficient in addressing existing waste problems in the community (Adiyanto et al., 2022). This effort is an effort with a long-term goal, so that its implementation is a process and requires time, but if it is sustainable and consistent, the existence of a waste bank can improve environmental cleanliness efforts in Ternate City as one step in overcoming the challenges towards a smart environment.

B) Increasing the Number of Garbage Collection Vehicles

The role of waste collection vehicles in Ternate City is crucial to prevent waste from piling up at landfills. The increasing volume of waste must be accompanied by efficient collection and transportation operations from waste collection vehicles. Furthermore, expanding service areas must be supported by adequate equipment systems

(Pratama & Sururi, 2023). The issue of irregular waste collection schedules can also be addressed by having sufficient fleets. Increasing the number of waste collection vehicles also needs to prioritize locations that are currently less accessible and difficult to reach, ensuring equitable waste collection. Therefore, in efforts to increase the number of waste collection vehicles, it is important to consider the type of vehicle that best suits the needs and road conditions, as not all locations in Ternate City are easily accessible due to steep terrain and limited road width.

C) Opening Cooperation in Waste Management and Processing

In accordance with Article 26, Paragraph 1 of Government Regulation of the Republic of Indonesia Number 81 of 2012 concerning the Management of Household Waste and Household-Like Waste, local governments can establish waste management institutions and partner with businesses/communities in the transportation, processing, and final processing of waste. This regulatory framework can strengthen efforts to address waste issues by opening opportunities for open collaboration with communities, the public, and the private sector. Cooperation in waste management and processing is necessary to accelerate the achievement of smart environment goals in Ternate City. This collaboration can take the form of lending equipment for waste management and processing, collaboration in outreach and education on waste management and processing, and opening investment opportunities for relevant parties to implement technological breakthroughs that can increase efficiency in waste processing. This effort can also be a way to achieve the SDGs goal in point 11 regarding sustainable cities and settlements.

D) Community and Government are Committed Together for Waste Problem

The government is evaluating existing regulations to monitor their effectiveness. In Ternate City, there were two regulations address waste issues, such are Ternate Mayor Regulation No. 19 of 2018 about Regional Policies and Strategies for Managing Household Waste and Household-Like Waste, and Ternate Mayoral Instruction No. 800.2.2/41 of 2024 about "Si Lisa Movement," a waste management strategy to increase economic value in Ternate City. Unfortunately, these two regulations have not yet demonstrated the government's success in addressing waste in Ternate City. By comparing the implementation of smart environments in several cities in Indonesia, the Ternate city government's commitment to achieving the program's success is still lacking. In several other cities in Indonesia, the government's commitment can be seen in programs created to support the achievement of smart environment goals, such as

Table 2. Comparison of committed government in some cities when implementing smart environment

Semarang	Tangerang	Jakarta
Provide green open space with wifi and automatic watering system	Slum area development policy	Refuse-Derived Fuel (RDF) is an alternative fuel obtained through the processing of waste with specific calorific values and specifications, which can be used as a substitute for coal. This processing takes place at the Bantargebang Integrated Waste Processing Site (TPST).
Semarang City has two climate resilience plan	Development of pedestrian areas	Colaboration between government and community with website

documents: the Regional Action Plan for Climate Change Mitigation and the Regional Action Plan for Climate Change Adaptation.		https://ksbbpersampahan.com which contain a catalog of aid packages such as the Waste Bank as a means of providing waste management tools,
Renewable energy development consists of five types: Solar Power Plants (PLTS), Wind Power Plants (PLTB), biogas, Waste-to-Energy Power Plants (PLTSa), and Solar-Powered Street Lighting (PJUTS)	issuance of government regulations and policies regarding environmental management (Nurlukman & Basit, 2023)	Provide technology to flood detection with measuring water level and rainfall
Semarang has Silampah application (Sistem Lapor Sampah) that integrate between waste and technology (Sari et al., 2024)	-	Samtama program (Sampah Tanggung Jawab Bersama) and Jakarta Recycle Center (JRC) (Rahdiana et al., 2024)

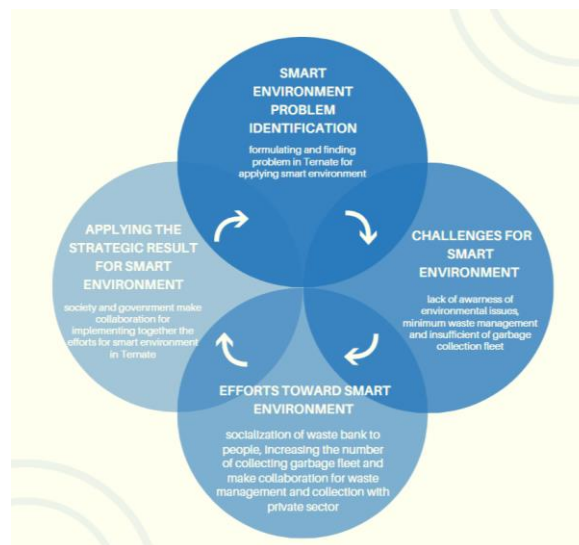


Figure 6. Thematic framework research

Therefore, a joint evaluation and commitment with the community is needed, providing an open space for the public to voice complaints about waste issues as a form of government performance evaluation. Furthermore, this joint commitment is expected to accelerate Ternate City's path to becoming a smarter city.

4. Conclusion

Optimizing a smart environment in Ternate City still faces several challenges, particularly regarding waste. Waste management in Ternate City is a major environmental issue that must be addressed immediately. These issues include waste accumulation, a lack of public awareness of proper waste disposal, and a shortage of waste collection

vehicles. These issues represent challenges that must be addressed in achieving a smart environment. To address these challenges, several efforts can be made, including increasing the number of waste collection vehicles, promoting waste banks, and establishing collaborations with other parties to manage and process waste more optimally and efficiently.

5. References

- Adiyanto, O., Mohamad, E., Irianto, Jaafar, R., Faishal, M., & Rasyid, M. I. (2023). Optimization of PET Particle-Reinforced Epoxy Resin Composite for Eco-Brick Application Using the Response Surface Methodology. *Sustainability*, 15(5), 4271. <https://doi.org/10.3390/su15054271>.
- Afdhal. (2024). Peran bank sampah dalam memperkuat ekonomi lokal dan membangun lingkungan berkelanjutan. *Saskara: Indonesia Journal of Society Studies*. 4(1), 134-154.
- Alamsyah, N., Susanto, T. D., & Chou, T. C. (2016). A comparison study of smart city in taipei and surabaya. Conference: 2017 Internasional Conference on ICT for smart society (ICISS). <https://doi.10.1109/ICTSS.2016.7792859>.
- Aleta, N. B., Alonso, C. M., & Ruiz. R. M. A. (2017). Smart mobility and smart environment in the spanish cities. *Transportaion Research Procedia*, 24, 163-170. <https://doi.org/10.1016/j.trpro.2017.05.084>.
- Bates, G., Hasan, M. N., Barnfield, A., & Bondy, K. (2023). Urban policies and the creation of healthy urban environments: A review of government housing and transport policy documents in the United Kingdom. *Journal of Urban Affairs*, 47(6), 1942–1960. <https://doi.org/10.1080/07352166.2023.2260029>.
- Deloitte. (2015). Smart cities how rapid advances in technology are reshaping our economy and society. Govlab. <https://www.deloitte.nl/govlab>.
- Direktorat Jenderal Penataan Ruang Kementerian Pekerjaan Umum. (2015). *Laporan Akhir Kajian Pengembangan Smart City di Indonesia*. Jakarta: Kementerian Pekerjaan Umum.
- Diskominfosandi Kota Ternate. (2022). “Wujudkan ternate smart city, pemkot ternate gelar bimtek masterplan smart city. *Online*. Diakses melalui: <https://ternatekota.go.id/news/wujudkan-ternate-smart-city-pemkot-ternate-gelar-bimtek-masterplan-smartcity>. Pada 07 September 2025.
- Erdian. (2023). “Kemkominfo serahkan master plan smart city untuk ternate”. *Online*. Diakses melalui: <https://kumparan.com/ceritamalukuutara/kemkominfo-serahkan-master-plan-smart-city-untuk-ternate-1zZtlZna6yk/full>. Pada 07 September 2025.
- Ichi, M. (2021). “Sampah, ancaman serius laut ternate”. *Online*. Diakses melalui: <https://mongabay.co.id/2021/09/26/sampah-ancaman-serius-laut-ternate/>. Pada 25 Agustus 2025.
- Isaiah, O. O., & Blessing, A. G. (2020). Environmental and Biochemical Implication of Solid Waste Dumpsites in Ondo State, Nigeria. *American Journal of Environment and Sustainable Development*, 5(4), 64–71.

- Jacquez, E., Junior, A. N., De Paris, S., Francescatto, M., & Siluk, J. (2024). Smart cities and innovative urban management: Perspectives of integrated technological solution in urban environment. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2024.e27850>.
- Menteri Lingkungan Hidup. (2012). *Peraturan Menteri Negara Lingkungan Hidup Nomor 13 Tahun 2012 tentang Pedoman Pelaksanaan Reduce, Reuse dan Recycle Melalui Bank Sampah*. Indonesia: Jakarta.
- Michelle, B., & Felasari, S. (2021). Smart city implementation in bekasi city. *Architecture & Environment*, 20(1), 31-44. <https://dx.doi.org/10.12962%2Fj2355262x.v20i1.a8600>.
- Mutaqin, A. Z. (2018). Pengelolaan sampah organik rumah tangga dalam penanggulangan pencemaran lingkungan di desa bumiwangi kcamatan ciparay kabupaten bandung. *Jurnal Geoarea*, 1(1), 32–36.
- Nurlukman, A. D., & Basit, A. (2023). Implementasi smart environment city dalam tata Kelola lingkungan di kota Tangerang. *Moderat : Jurnal Ilmiah Ilmu Pemerintahan*, 9(4), 769-784.
- Palang Merah Indonesia & American Red Cross. (2018). *City wide asesment program kota tangguh dari kota ternate (maluku utara)*. Indonesia. Jakarta.
- Pemerintah Pusat. (2008). *Undang-Undang Nomor 18 Tahun 2008 tentang Pengelolaan Sampah*. Indonesia. Jakarta.
- Pemerintah Pusat. (2009). *Undang-Undang Nomor 32 Tahun 2009 tentang Perlingungan dan Pengelolaan Lingkungan Hidup*. Indonesia. Jakarta.
- Peraturan Pemerintah. (2012). *Peraturan Pemerintah Nomor 81 Tahun 2012 tentang Pengelolaan Sampah Rumah Tangga dan Sampah Sejenis Sampah Rumah Tangga*. Indonesia. Jakarta.
- Pratama, P. S., & Sururi. M. R. (2023). Evaluasi teknik operasional pengumpulan dan pengangkutan sampah dalam sistem pengelolaan sampah di kabupaten subang (studi kasus: kecamatan subang). *Envirotek: Jurnal Ilmiah Teknik Lingkungan*, 15(2), 186-193.
- Purba, N. P., Faizal, I., Cordova, M. R., Abimanyu, A., Afandi, N. K. A., Indriawan, D., & Khan, A. M. A. (2021). Marine debris pathway across Indonesia boundary seas. *Jurnal of Ecological Engineering*, 22(3), 82-98. <https://doi.org/10.12911/22998993/132428>.
- Rachmawati, T., & Pertiwi, P. D. (2017). Smart environment program, smart way to smart city. *Policy & Governance Review*, 1(1), 26-36. <https://doi.org/10.30589/pgr.v1i1.24>.
- Rachdiana, F. P., Putri, N. D. R., Maharani, N. A., & Darmawan, I. (2024). Implementasi inovasi dalam pengelolaan lingkungan berbasis smart environment untuk mendorong terwujudnya smart city di kota jakarta. *Triwikarma: Jurnal Ilmu Sosial*, 5(10).
- Sari, D. A. H., Rahayu, M. J. & Pujiyanto, B. S. (2024). Kajian kesesuaian penerapan konsep smart environment sebagai bagian dari smart city (studi kasus: kota semarang). *Desa-Kota Jurnal Perencanaan Wilayah, Kota dan Permukiman*, 6(1) ,

154-170.

- Scuotto, V., Ferraris, A., & Bresciani, S. (2016), "Internet of Things: applications and challenges in smart cities. A case study of IBM smart city projects.". *Business Process Management Journal*, 22(2). <http://dx.doi.org/10.1108/BPMJ-05-2015-0074>.
- Shafa, S. Z., & Darwin, I. S. (2022). Kajian optimalisasi sistem pengangkutan sampah di kecamatan subang. *Bandung Conference Series: Urban & Regional Planning*.
- Szpilko, D., Gallegos, A. D. L. T., Naharro, F. J., Rzepka, A. & Remiszewka, A. (2023). Waste management in the smart city: current practices and future directions. *Resources*, 12(10), 115. <https://doi.org/10.3390/resources12100115>.
- Tamyiz, M., Hamidah, L. N., Widiyanti, A., & Rahmayanti, A. (2018). Pelatihan pengelolaan sampah rumah tangga di desa Kedungsumur, Kecamatan Krembung, Kabupaten Sidoarjo. *Journal of Science and Social Development*, 1(1), 16–23.
- Utami, A. P., Pane, N. N. A., & Hasibuan, A. (2023). Analisis dampak limbah/sampah rumah tangga terhadap pencemaran lingkungan hidup. *Cross-Border: Journal of International Border Studies, Diplomacy and International Relation*, 6(2), 1107-1112.
- World Bank. (2021). Plastic waste discharges from rivers and coastline in Indonesia. *In Marine Plastic Series*. <http://doi.org/10.1596/35607>.
- Zhang, Y., Xiao, X., Cao, R., Zheng, C., Guo, Y., Gong, Zongcai, W. (2020). How important is community participation to eco-environmental conservation in protected areas? From the perspective of predicting locals' pro-environmental behaviours. *Science of The Total Environment*, 739. <https://doi.org/10.1016/j.scitotenv.2020.139889>.