EVALUATING MUNICIPAL SOLID WASTE SYSTEM AND PLASTIC WASTE LEAKAGE IN DONG HA CITY, VIETNAM

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Abstract - This study applied a waste flow diagram to clarify the status of municipal solid waste generation and waste flows, as well as model plastic waste leakage into the environment of Dong Ha City, Vietnam. Results denoted that the amount of municipal solid waste generation was about 0.66 kg/capita/day, being lower than estimated results of other Vietnamese cities. The majority of municipal solid waste generation was collected by formal collection service, at around 23,291 tonne/year, accounting for about 90% of total municipal solid waste generation. Around 5% of municipal solid waste (about 1,360 tonnes/year) was separated and recovered for recycling through the informal sector. Uncollected plastic waste (71%) and plastic waste leakage during collection and transportation (28%) were the two main sources contributing to plastic leakage. Thus, enhancement of the collection system plays the most important role in controlling plastic waste leakage.

Key words - Municipal solid waste; Plastic waste; Vietnam; Waste flow diagram

1. Introduction

Global increase in municipal solid waste generation (MSWG) and improper approaches to management, particularly in low and middle-income countries, have become notorious global environmental issues [1]. It was estimated that global MSWG would be 3.8 billion tonnes by 2050 if no appropriate action is taken [2]. Additionally, landfilling has been an omnipresent method for municipal solid waste (MSW) treatment in the world, particularly in developing countries, and the excessive burden on landfills was documented [3].

More importantly, countries in Southeast Asia, such as Vietnam, Indonesia, and Malaysia, are notorious for plastic leakage into the oceans [4, 5]. Vietnam, with an estimated plastic leakage of 0.28 to 0.73 million tonnes/year in 2010, has been one of the four countries with the largest amount of plastic leakage into oceans [5]. Similarly, another list denoted that Vietnam ranked eighth regarding top countries leaking plastic waste into oceans [4]. Due to the importance of plastic leakage control, the Vietnamese government has enacted a national strategy for controlling ocean plastic leakage in 2019, denoting national effort for plastic waste management [6]. However, a lack of monetary and personnel resources has led to inefficient control of municipal solid waste management (MSWM) and plastic waste leakage [7, 8].

Assessing the current status of MSWM system and modelling plastic waste leakage are the first steps for combating environmental issues from MSWM and plastic leakage. Municipalities, which are close to the hydrology system, would have the largest risk of plastic leakage into oceans. The Waste Flow Diagram (WFD) is one of the most popular for modelling plastic waste leakage in the world. Studies applied WFD to clarify the status of plastic leakage in coastal cities such as Hue City, Da Nang City, Hoi An City, and Tuy Hoa in Vietnam. However, the potential of plastic leakage in inland cities has been limited in Vietnam. Dong Ha City (DHC) is an inland City, located adjacent to the Thach Han river, which flows directly into the sea, being a potential source of plastic leakage into the ocean.

Thus, this study was an effort to clarify current characteristics of MSWG, waste flows, as well as analyse the status of unmanaged waste, including plastic waste leakage in DHC - inland City of Vietnam. This study aimed to contribute to the literature and data on global plastic waste leakage. Waste survey was conducted in April 2024 for data collection, including a waste audit in DHC, Vietnam.

2. Methodology

2.1. Waste audit

Household and non-household solid waste samples were collected at points of generation, just prior to collection by the garbage trucks. Samples were taken randomly and without replacement. Collected household solid waste samples were then labelled with source code and transported to a designated location for subsequent analysis - waste composition (classification) analysis based on the guidance of ASTM D5231 – 92 [9]. For other waste sources with larger volumes, the sample volume was determined by estimating the capaCity of the container (e.g., 60L bin, 120L bin, 240L bin). The total amount of waste generated was then estimated using the following formulas:

$$m_i = \frac{D_i}{V_i}$$

m_i: Total waste generated from source (waste generator) i; D_i: Density of MSW from source (waste generator) i; V_i: Volume of MSW from source (waste generator) i; Density of MSW by source (waste generator) was identified through waste survey.

Numbers of waste samples were denoted in Table 1.

Table 1. *Number of samples weighed to determine the amount of MSWG in DHC*

No	Waste source (waste generator)	Sample size
1	Household	270
2	School	12
2.1	Early childhood education	3
2.2	Primary school	3
2.3	Secondary school	4
2.4	High school	2
3	Accommodation	11
3.1	Guesthouses	5
3.2	2-3 star hotels	5
3.3	4-5 star hotels	1
4	Food and beverage establishments	10
5	Markets	5
6	Supermarkets / Retail stores	4
7	Offices	10
8	Public spaces	2
9	Informal recyclable waste collection facilities	5

2.2. Material flow analysis and waste flow diagram

Material flow analysis is popular method for examining municipal waste flow, which has been applied in many studies on MSWM in the world. WFD, based on principles of material flow analysis, has been built to illustrate MSW flow and, particularly, plastic waste leakage into the environment. Qualitative assessment is integrated into WFD to estimate the quantitative output of plastic waste leakage. Drawing on data from surveys, interviews, and observations, qualitative assessments are converted into quantitative factors to serve as inputs for the WFD. Using pre-defined equations, the quantitative output is then calculated based on these derived factors.

The WFD has been applied to clarify plastic leakage in many countries [10], having the capability to quantify the amount, sources, and fates of plastic leakage into nature and oceans. Tools for calculation (Excel file) and guidance of WFD can be accessed online through https://wfd.rwm.global/. In this study, SankeyMATIC platform was used to create figures of waste flows, while QGIS was used to create maps of junkshops and waste hotspots.

Quantifying plastic leakage presented significant challenges due to high data variability and resource constraints. Specifically, the informal sector's lack of transparency - evidenced by the refusal of junkshop owners to participate in waste audits - necessitated the use of modeled assumptions for collection ratios and recovery rates. All collection percentages were capped at 100%. Furthermore, to account for the inherent uncertainty in data from the informal sector data - social survey, a sensitivity range of ±20% was applied to check violations of model assumptions.

3. Result and discussion

3.1. Performance of the municipal solid waste management system

3.1.1. Solid waste generation

Average MSWG in DHC was approximately 25,835 tonne/year. Therefore, with a population of 107,971 people [11], the amount of MSWG was around 0.66 kg/capita/day (per person), being around the value of lower middle income country [1]. Moreover, about 12.3 tonnes of plastic waste were generated daily (Figure 2), from various sources, including households, schools, accommodation and food services, markets, supermarkets, retail stores, offices, and public activities.

The amount of MSWG in DHC was all lower than published estimated results of other Vietnamese cities (urban) such as Hue City (not expanded) of 0.83 kg/capita/day [10], Tuy Hoa City of 1.19 kg/capita/day [12], Da Nang City of 0.98 kg/capita/day [13], and Hoi An City of 1.19 kg/capita/day [14]. Moreover, the figure for DHC was also lower than the mean data of Phu Yen province (excluding Tuy Hoa City) of 0.73 kg/capita/day [15]. However, figure for DHC was larger than that of Can Gio district (0.3 kg/capita/day) [16]. The status of economic development would be one of the reasons, explaining the gap in the amount of MSW between DHC and other cities. Gross regional domestic product (GRDP) of Quang Tri province (DHC is the urban center of Quang Tri Province) was all lower than the provinces of the mentioned cities [17]. Economic status would be one of the strongest driving forces of MSWG [1, 18, 19]. With higher income, citizens tend to consume more, thus discharging more waste. Therefore, the economic development of DHC would be applied to explain the gap in MSWG between DHC and other research areas. Moreover, regarding the gap (MSWG) between DHC and Can Gio district, Can Gio district has been a rural area, while DHC can be considered as an urban area. Normally, urban areas generate a larger amount of municipal solid waste (per capita) in comparison with rural areas [20]. Thus solid waste generation of Can Gio district would be lower compared with DHC - urban area.

3.1.2. Waste collection and transportation

Every year, the amount of MSWG, captured by the formal collection service was around 23,291 tonnes/year, accounting for about 90% of total MSWG in DHC. Regarding plastic waste, about 4,005 tonnes/year of plastic waste was collected by a formal service company, accounting for about 88% of total plastic waste generation (Figure 2).

Collection and transportation of MSW within DHC were managed by Dong Ha environment and Urban Works Joint-Stock Company through a bidding process. The MSW was gathered in front of homes, waiting for collection vehicles. Most of MSW was contained in plastic bags, bins, or baskets. In small alleys, MSW was normally piled up on the pavement. Overload of bins would be a reason for the appearance of waste on the sidewalk before collection. This can lead to the uncontrolled release of MSW into the environment.

Characteristics of MSWM system - collection and transportation - would be similar to other cities in Vietnam, where formal service companies were in charge of MSW collection. Notably, the application of electric carts was denoted in formal MSW collection in DHC, Vietnam, being similar to Hue City [21] and Hoi An City [22]. Operation of electric carts would have the potential to mitigate greenhouse gas emissions (GHG), contributing to climate action [23, 24]. Thus, due to the global trend of utilisation of electric vehicles, the application of electric vehicles within MSWM system would be one of the solutions for MSWM system toward climate action.

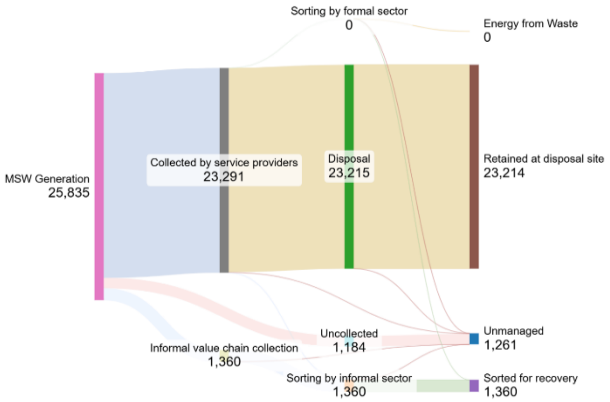

Figure 1. *General MSW flow in DHC, Vietnam (tonne/year)*

3.1.3. Waste treatment

Approximately 90% of MSW (approximately 23,215 tonnes/year) was managed at the Dong Ha landfill (Figure 1). Moreover, 3,929 tonnes/year of plastic waste was also managed at Dong Ha landfill, accounting for about 86% of total municipal plastic waste generation (Figure 2).

Dong Ha MSW landfill accepted urban waste from all sources, with a significant proportion of household waste. The MSW was transported to the landfill, where final separation of recyclable materials was performed by scavengers. Landfill technology would not be proper as a sanitary landfill. Deodorising spray and soil covering were not frequently applied. There was a risk of leakage of MSW from the landfill due to strong winds and extreme weather events.

Moreover, due to the projection of the population trend of DHC, there would be a gradual increase from 101,249 people (2022) [11] to 180,000 people (2030) [25]. The amount of MSWG in Dong Ha would also increase, so that the current MSWM system in DHC will be put under greater pressure. Thus, a well-defined plan for waste management would be needed in the near future.

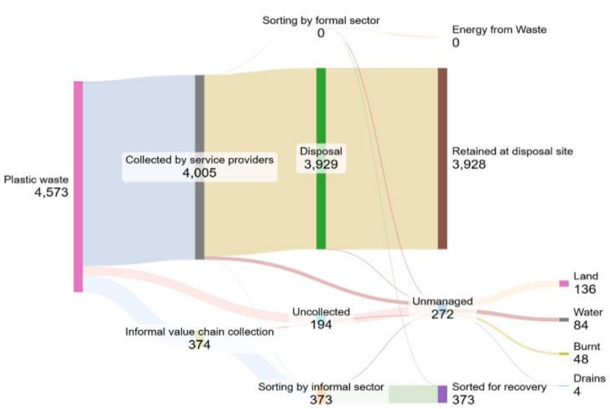

Figure 2. *General municipal plastic waste flow in DHC, Vietnam (tonne/year)*

3.1.4. Recycling activities

Around 5% of MSW (about 1,360 tonnes/year) was separated and recovered for recycling through the informal sector (Figure 1). An estimation of 374 tonnes/year of plastic waste was re-collected by the informal sector, accounting for about 8% of total municipal plastic waste generation (Figure 2).

Informal collection of high-value recyclable materials was conducted concurrently with the formal MSWM system (Figure 3). Accordingly, recyclables would also be sorted by waste generators and sold (or donated) to scrap buyers and collection staff. Separation of recyclables from the mixed waste stream, by collection staff (handy carts, three-wheeled electric vehicles, and compactor trucks), as well as by urban scavengers, was also observed. While formal collection workers recovered recyclables to supplement their wages, informal actors - such as waste pickers, scavengers, and itinerant buyers - relied on waste recovery as their primary source of subsistence. Consequently, economic incentives served as a fundamental driving force behind dual involvement of both sectors and their functional co-existence within the recycling value chain.

There have been seven facilities for purchasing high-value recyclables operating in DHC (Figure 4). While located in proximity to residential zones, informal recycling facilities are predominantly concentrated in peri-urban fringes. These areas function as convenient areas for informal junkshops [26], offering a balance between spatial availability for waste storage and relative lack of institutional surveillance or community-led social control. Primary high-value recyclables collected and purchased were metals, paper (cardboard, printing paper, books, newspapers), and high-value plastic waste. Plastic bag was also a type of product being collected; however, only large, flexible plastic bags were recovered and sold to recycling facilities. Due to their low mass density, the economic viability of collecting plastic bags was significantly limited. Consequently, the quantity of plastic bags recovered was notably lower than that of other types of recyclables.

In DHC, the recycling system - collection and transportation of recyclable waste - was operated by the informal sector. This phenomenon was similar to other cities in Vietnam, namely Hue City [21, 27], Da Nang City [13], Tuy Hoa City, Hoi An City [14], and Can Gio district [16]. However, the operation of the informal sector would normally cause a negative impact on the environment as well as fire and explosion risk [7, 28, 29]. Moreover, contamination of soil and groundwater was also denoted due to the operation of the informal sector in developing countries [30]. Regarding working environment and conditions, health-related problems, social stigmatisation, and low income were also mentioned in developing countries [31]. Integration of the informal sector has been expected as a proper action for problems and challenges from the operation of the informal sector, such as health-related problems and potential social inequality [31-33]. Moreover, integration of the informal sector is also considered as an approach to control plastic waste leakage [34]. Importantly, an effort was conducted to identify factors contributing to the dynamics of the informal sector - informal recycling stations in central Vietnam. Population as well as availability of space and proper social control were factors contributing to the dynamic change of the informal recycling system [26]. Thus, integration and proper planning for an informal recycling system into a formal MSWM system should be emphasised, particularly in heading to the circular economy in the context of urban areas of Vietnam and other developing countries.

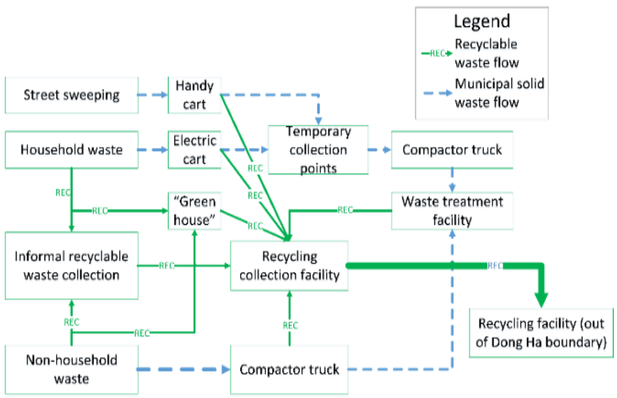

***Figure 3.** Schematic of high-value recycled materials flow in DHC*

3.1.5. Unmanaged municipal solid waste

Potential leakage of MSW into the environment would occur throughout the daily waste stream, from collection and transportation to treatment and disposal. An estimated 1,261 tonnes of MSW were lost to the environment annually from urban activities, representing about 5% of total MSWG (Figure 1). Waste collection process was considered the primary cause of MSW leakage into the environment, accounting for about 94% of total potential unmanaged waste (Figure 1). Collection of MSW in bags and containers that lack proper covering or secure sealing would pose a significant risk of waste leakage into the environment. Furthermore, transfer of MSW to compactor trucks at temporary collection points, without a fully enclosed system, would be another source of waste leakage into the environment.

The MSW hotspots were identified as locations with persistent, long-term waste accumulation and repeated illegal dumping, despite numerous cleanup campaigns by local authorities. Four potential waste hotspots were identified (Figure 5). These hotspots were predominantly situated in sparsely populated areas, which facilitated illegal dumping due to minimal institutional surveillance. Absence of formal waste management at these sites, compounded by extreme weather events, significantly heightened the risk of environmental leakage, particularly regarding the transport of plastic debris into sensitive local ecosystems. Total volume of waste at these hotspots was 30 m³. Main components of waste were construction and demolition waste, such as rubble, gypsum, wood, and household items from cleanup or demolition activities. Waste from industrial and service activities, such as plastic foam sheets and plastic-based furniture materials, constituted a significant proportion. A small amount of MSW was also discarded alongside these piles of construction waste.

3.2. Plastic waste leakage

Regarding plastic waste, an estimated 272 tonnes/year was unmanaged, accounting for about 6% of total municipal plastic waste generation. Uncollected plastic waste (71%) and plastic waste leakage during collection and transportation (28%) were the two main sources, contributing to plastic leakage in DHC (Figure 2 and Table 2). The majority of plastic waste was assumed to retain on land with 136 tonnes/year, accounting for about 50% of total plastic waste leakage in DHC, followed by plastic leakage through the water system (84 tonnes/year, 31% of total mismanaged plastic waste) (Table 2). More than one tonne of plastic waste was leaked into the environment during the management process at the landfill (Figure 2).

While the percentage of plastic waste remaining on land was largest in DHC (50%), other cities in Vietnam would have significantly lower proportions in central Vietnam, such as Hue City (25%-33%) [10], Hoi An City (30%) [14], and Da Nang City (31%) [13]. While Hue City, Da Nang City, and Hoi An City are coastal areas with a complex hydrology system, DHC is situated inland, characterized by two rivers coursing along its administrative borders. Thus, it would be reasonable that the majority of plastic leakage was estimated to retain on land. These results would contribute to the Vietnamese strategy of plastic leakage control that inland areas should focus on strict control of illegal dumping sites (hotspots). For example, utilisation of a closed-circuit television system could be a solution for controlling waste hotspots, indirectly combating plastic leakage retaining on land. Coastal cities with extensive river networks must prioritize mitigating plastic leakage into canals, lakes, rivers, and beaches, with a strategic emphasis on enhancing public awareness and fostering behavioral change.

Amount of plastic waste accumulated in soil and water environments would pose a risk of dispersal into rivers and oceans, particularly during unexpected natural disasters or extreme weather conditions such as strong winds and heavy rain. More importantly, these estimations were based on normal conditions without a natural disaster. The DHC is located in central Vietnam, where many natural disasters occur yearly. Plastic waste leakage would be extremely large due to the negative impacts of natural disasters such as typhoons and floods. Thus, in Central Vietnam, efforts to mitigate plastic waste leakage into the environment should consider not only human cooperation and technical aspects, but also characteristics of regional weather and climate conditions. These factors collectively present a considerable challenge to the MSWM system, and control of plastic waste leakage into the environment.

Potential waste hotspots were also locations where plastic waste from industrial and commercial service activities accumulates in the environment (Figure 5). The plastic waste found at these hotspots was mainly furniture materials and waste from the advertising and printing industries. About 48 tonnes/year of plastic waste were burnt, accounting for 18% of total mismanaged plastic waste (Table 2 and Figure 2). This phenomenon would be a result of ordinary behaviour or a low level of awareness of local people. Thus, campaigns aimed at raising awareness and changing behaviour should be implemented. However, long-term consideration should be given to the frequency, intensity, and sustainability of these environmental initiatives. Behavioural change is typically the outcome of a prolonged and continuous process in a holistic fashion, considering systematic interventions [35], particularly in the context of waste management and plastic waste management [36].

Table 2. *Detailed information on unmanaged plastic waste in DHC*

Content	Value	Unit
Unmanaged plastic waste	**272**	**tonne/year**
Unmanaged plastic waste	**6%**	**% of plastic waste generation**
Contribution from uncollected waste	71%	% of mismanaged plastic waste
Contribution from collection service	28%	% of mismanaged plastic waste
Contribution from informal value-chain collection	0.3%	% of mismanaged plastic waste
Contribution from disposal facilities	0.5%	% of mismanaged plastic waste
Plastic waste retained on land	**136**	**tonne/year**
Plastic waste retained on land	**50%**	**% of mismanaged plastic waste**
Plastic waste openly burnt	**48**	**tonne/year**
Plastic waste openly burnt	**18%**	**% of mismanaged plastic waste**
Plastic waste cleaned from drains	**4**	**tonne/year**
Plastic waste cleaned from drains	**1%**	**% of mismanaged plastic waste**
Plastic waste to water systems	**84**	**tonne/year**
Plastic waste to water systems	**31%**	**% of mismanaged plastic waste**
Plastic waste to water systems	**2%**	**% of plastic waste generation**
Contribution directly entering water systems	81%	% of plastic in water systems
Contribution entering via storm drains	19%	% of plastic in water systems
Plastic to water systems per person	0.8	kg/capita/year

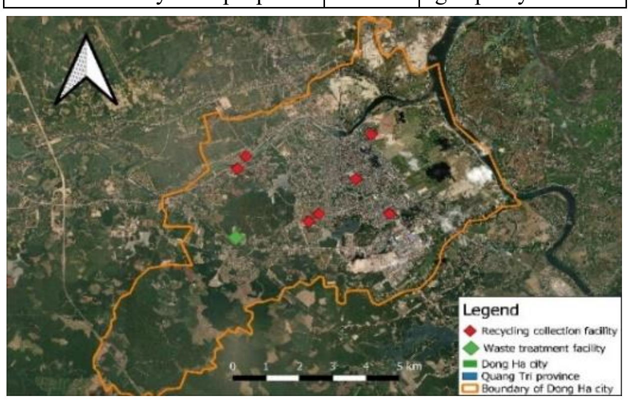

Figure 4. *Spatial distribution of informal recycling facilities in DHC. Base map: Google Earth*

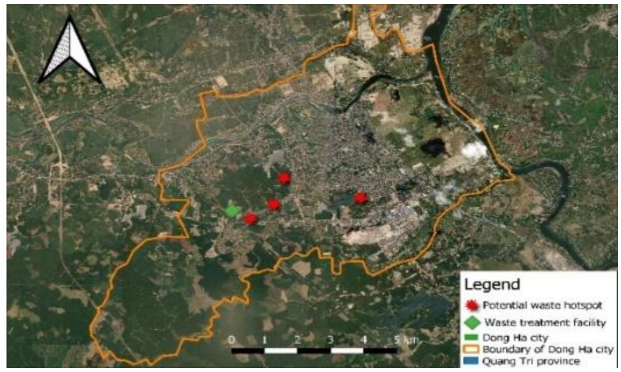

Figure 5. *Spatial distribution of potential waste hotspots in DHC. Base map: Google Earth*

4. Conclusion

This study provided unique insights into the global picture of applying WFD to clarify the performance of MSWM system and the status of plastic leakage in DHC - inland City of a developing country. This has been one of the first efforts to integrate GIS and WFD to clarify the status of waste flow and plastic leakage in an inland City in Vietnam, a developing country. This study applied GIS to mitigate bias during data collection - as qualitative input for WFD. Moreover, the application of GIS also helped enrich information on the recycling system and the status of waste hotspots.

Application of WFD denoted amount of MSWG was about 0.66 kg/capita/day, being lower than other municipal areas of Vietnam. Being similar to other Vietnamese cities, the majority of MSWG was collected by the formal collection service (90% of total MSWG) while around 5% of MSW was separated and recovered by the informal sector in DHC. The mechanism of plastic leakage was also similar to other Vietnamese cities, where uncollected plastic waste (71%) and plastic waste leakage during collection and transportation (28%) were the two main sources, contributing to plastic leakage (272 tonnes/year). The majority of plastic waste was assumed to retain on land. These results denote that the collection system plays the most important role in enhancing MSWM to control plastic leakage. Thus, next studies on the optimisation of the collection system are needed to control plastic leakage. Moreover, due to a lower rate of MSWG, experiences and lessons from other Vietnamese municipal areas could be applied with modifications for the context of DHC. Particularly, utilisation of a closed-circuit television system could be a solution for controlling plastic waste leakage (hotspots) in inland cities such as Dong Ha while enhancement of public awareness and fostering behavioral change would be proper for coastal cities with complex hydrology systems. This study was a cross-sectional study, so the capaCity to illustrate the trend of waste flows and plastic leakage would be limited. Thus, next efforts are needed to conduct this type of study annually or monthly to capture changes in waste flow.

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REFERENCE

[1] S. Kaza, L. C. Yao, T. P. Bhada, and F. Van Woerden, "*What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*", D. W. B. Urban Development;. Washington, Washington, DC, USA, 2018.

[2] UNEP, "*Global Waste Management Outlook 2024: Beyond an age of waste – Turning rubbish into a resource*", U. N. E. Programme, Nairobi, Kenya, 2024.

[3] A. L. Patrício Silva, J. C. Prata, A. C. Duarte, D. Barcelò, and T. Rocha-Santos, "An urgent call to think globally and act locally on landfill disposable plastics under and after covid-19 pandemic: Pollution prevention and technological (Bio) remediation solutions," *Chemical Engineering Journal,* vol. 426, p. 131201, 2021.

[4] L. J. J. Meijer, T. van Emmerik, R. van der Ent, C. Schmidt, and L. Lebreton, "More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean," *Sci Adv,* vol. 7, no. 18, Apr 2021.

[5] R. Jambeck Jenna *et al.*, "Plastic waste inputs from land into the ocean," (in English), *Science,* vol. 347, no. 6223, pp. 768-771, 2015.

[6] TTCP, *Decision No. 1746/QD-TTg of the Prime Minister, dated December 4, 2019, on Issuing the National Action Plan for Marine Plastic Waste Management until 2030*, 2019.

[7] MONRE, *National State of Environment Report 2019 - Thematic Report: Municipal Solid Waste Management*, 2019.

[8] MONRE, *National State of Environment Report*, 2021.

[9] *Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste*, 2016.

[10] A. Whiteman *et al.*, "The Waste Flow Diagram: Identifying Leakages from Municipal Waste Management Systems", Z. G. GmbH, Dag-Hammarskjöld-Weg 1 - 5 65760 Eschborn, Germany, 2023.

[11] DHCSY, *Dong Ha City Statistical Yearbook*, 2023.

[12] D. Tosi Robinson *et al.*, "Land-based plastic leakage into the aquatic environment from municipal solid waste - Waste flow diagram applied to Tuy Hoa City, Phu Yen, Vietnam," *Waste Management,* vol. 186, pp. 226-235, Sep 15 2024.

[13] C. Le Dinh, T. Fujiwara, and S. T. P. Phu, "Plastic Leakage Pattern and Municipal Solid Waste Management Toward Circular Economy," *Process Integr Optim Sustain,* 2025.

[14] C. Le Dinh, T. Fujiwara, and S. T. P. Phu, "Municipal solid waste system of a tourism destination toward circular economy – Understanding plastic leakage into water system," *Environ Res Technol,* vol. Article in press, 2025.

[15] D. Tosi Robinson, T. T. Le, H. T. T. Ngo, T.-H. T. Hoang, C. Zurbrügg, and T. H. T. Nguyen, "Regional land-based plastic leakage into the aquatic environment – Waste Flow Diagram applied to the Phu Yen province, Vietnam," *Marine Pollution Bulletin,* vol. 217, p. 118058, 2025.

[16] T. H. T. Nguyen, T.-T. T. Nguyen, N.-H. Ha, K. L. P. Nguyen, and T.-K. L. Bui, "Toward a circular economy for better municipal solid waste management in Can Gio district, Ho Chi Minh City," *Sustain Chem Pharm,* vol. 38, 2024.

[17] TVPL, "The Latest Ranking of Vietnam's 63 Provinces and Centrally-run Cities by Gross Regional Domestic Product (GRDP) in 2024", *thuvienphapluat.vn,* 2024. [Online]. Available: https://thuvienphapluat.vn/chinh-sach-phap-luat-moi/vn/ho-tro-phap-luat/chinh-sach-moi/81173/bang-xep-hang-grdp-63-tinh-thanh-viet-nam-xep-hang-kinh-te-63-tinh-thanh-moi-nhat-2024 [September 19, 2025].

[18] M. Noufal, L. Yuanyuan, Z. Maalla, and S. Adipah, "Determinants of Household Solid Waste Generation and Composition in Homs City, Syria," *Journal of Environmental and Public Health,* vol. 2020, no. 1, p. 7460356, 2020.

[19] C. Magazzino and P. M. Falcone, "Assessing the relationship among waste generation, wealth, and GHG emissions in Switzerland: Some policy proposals for the optimization of the municipal solid waste in a circular economy perspective," *Journal of Cleaner Production,* vol. 351, 2022.

[20] G. Hoang Minh, T. Fujiwara, and S. T. Pham Phu, "Municipal waste generation and composition in a tourist City - Hoi An, Vietnam," *Journal of Japan Society of Civil Engineers,* vol. 5, no. 1, pp. 123-132, 2017.

[21] WWF Vietnam, "*Technical assessment of solid waste management system in Hue City*", Hue City, Vietnam, 2021.

[22] C. Le Dinh, T. Fujiwara, M. Asari, and S. T. Pham Phu, "Solid waste collection system in tourism destination – the status, problems, and challenges," *Chemical Engineering Transactions,* vol. 83, pp. 43–48, 2021.

[23] G. Simpkins, "Benefits of electric vehicle adoption," *Nature Reviews Earth & Environment,* vol. 4, no. 7, pp. 432-432, 2023/07/01 2023.

[24] Y. Zhu, E. F. Choma, K. Wang, and H. Wang, "Electric vehicle adoption delivers public health and environmental benefits," *Eco-Environment & Health,* vol. 2, no. 4, pp. 193-194, 2023.

[25] UBNDQT, *Decision No. 1234/QD-UBND dated June 15, 2023, on Approving the Adjustment to the General Planning of Dong Ha City up to 2045*, 2023.

[26] C. Le Dinh, T. Fujiwara, and S. T. Pham Phu, "Spatial Analysis of Informal Recyclable Station System for Integration to Formal Solid Waste Management System and Circular Economy–Proposing Integrated Methodology of GIS, Remote Sensing, and Statistical Learning," *Environmental Quality Management,* vol. 34, no. 3, p. e70043, 2025.

[27] WWF-Viet Nam, *The plastic reduction journey of Hue City*, Hue City, Vietnam: Hue University Publishing House, 2024.

[28] Y. D. Tong, D. X. Huynh Thi, and T. D. Khong, "Understanding the role of informal sector for sustainable development of municipal solid waste management system: A case study in Vietnam," *Waste Management,* vol. 124, pp. 118–127, Apr 1 2021.

[29] S. Jerie, "Occupational Risks Associated with Solid Waste Management in the Informal Sector of Gweru, Zimbabwe," *Journal of Environmental and Public Health,* vol. 2016, no. 1, p. 9024160, 2016.

[30] K. Owusu-Sekyere, D. A. Aladago, D. Leverenz, M. Oteng-Ababio, and M. Kranert, "Environmental Impacts on Soil and Groundwater of Informal E-Waste Recycling Processes in Ghana," *Sustainability,* vol. 16, no. 11, 2024.

[31] M. M. a. Harfadli, B. S. Ramadan, I. Rachman, and T. Matsumoto, "Challenges and characteristics of the informal waste sector in developing countries: an overview," *Journal of Material Cycles and Waste Management,* vol. 26, no. 3, pp. 1294-1309, 2024.

[32] R. Fidelis, E. D. R. Guerreiro, D. J. Horst, G. M. Ramos, B. R. de Oliveira, and P. P. de Andrade Junior, "Municipal solid waste management with recyclable potential in developing countries: Current scenario and future perspectives," *Waste Management & Research,* vol. 41, no. 9, pp. 1399-1419, Sep 2023.

[33] N. Silva de Souza Lima and S. D. Mancini, "Integration of informal recycling sector in Brazil and the case of Sorocaba City," *Waste Management & Research,* vol. 35, no. 7, pp. 721-729, Jul 2017.

[34] C. A. Velis, B. D. Hardesty, J. W. Cottom, and C. Wilcox, "Enabling the informal recycling sector to prevent plastic pollution and deliver an inclusive circular economy," *Environmental Science & Policy,* vol. 138, pp. 20-25, 2022.

[35] P. Cash, A. Wrobel, A. Maier, and J. P. Hansen, "Understanding long-term behaviour change techniques: a mixed methods study," *Journal of Engineering Design,* vol. 34, no. 5-6, pp. 383-410, 2023.

[36] H. Rau, S. Nicolai, and S. Stoll-Kleemann, "A systematic review to assess the evidence-based effectiveness, content, and success factors of behavior change interventions for enhancing pro-environmental behavior in individuals," *Frontiers in Psychology,* vol. 13, 2022.