A Review of Municipal Waste Management with Zero Waste Concept: Strategies, Potential and Challenge in Indonesia

Edza Aria Wikurendra*, Nour Salah Abdeljawad, and Imre Nagy

***Abstract*—Municipal waste management is still a significant problem for solid waste issues in Indonesia. Only 60 to 70% of the waste generated is disposed of in landfills, the rest is dispersed in different areas. The potential for leachate pollution, greenhouse gases, and a waste of non-renewable natural resources can occur due to municipal waste management problems not being optimal. Municipal waste management needs a holistic concept that would include upstream to downstream stages. This paper comprehensively reviews municipal waste management with a zero waste concept based on management, development, measuring, implementations, strategies, potentials, and challenges in Indonesia. The zero waste concept offers waste management, starting with waste elimination, recycling, reduction, and recovery of used goods. Several municipalities around the globe, such as Canberra, Adelaide (Australia), Stockholm (Sweden), Nova-Scotia (Canada), and San Francisco (United States), have decided on targets for zero waste cities. Indonesia is still implementing waste management that accentuates disposal in landfills, so there needs to be a literature study related to the management, development, measuring, implementations, strategies, potentials, and challenges of Indonesia's zero waste concept.**

***Index Terms*—Municipal waste management, zero waste, landfills**

I. Introduction

According to national statistics, only 60 to 70 % of overall municipal waste can be carried to landfills by government organizations [1]. The Indonesian government passed Law Number 18 of 2008 on Solid Waste Management as national legal protection in early May 2008 [2]. Within a maximum of five years, local governments was required close any landfills used for open dumping (until 2013) [3]. New landfills will be created to replace it in the same period. According to current standards and laws, constructing a new landfill must employ a sanitary landfill system [4]. Even though they are constructed as sanitary landfills, most are operated as controlled open dumping landfills [5]. As a consequence, this practice has resulted in, among other things, the emission of leachate, which contains organic pollutants and nitrogen and greenhouse gases (GHG) [6].

For the Indonesian government, waste management remains a major concern. These issues include a lack of community knowledge, particularly among those who sell at the market, a lack of garbage collection facilities, a shortage of cleaning staff, and the extension intensity is still relatively low [7]. Every year, Indonesia produces 64 million tons of waste. Most of this waste is household waste, accounting for 44.5% of the total waste transported without processing at landfills. Based on data from the Ministry of Environment, it is stated that 60% of landfills in Indonesia have reached their maximum capacity limit in 2015 [8].

Global warming and climate change, and their diverse effects on humanity, prompted people to consider the availability of sustainable natural resources [9]. Natural resources (non-renewable resources) are in short supply, forcing people to think carefully about conserving them [10]. The waste management system with zero waste is a comprehensive approach to managing waste and sources in a city in a viable kind [11].

Although many review papers discussing municipal waste management with the zero waste concept have been reported in the literature, articles that focus on management, development, measuring, implementations, strategies, potentials, and challenges in Indonesia are challenging to find. As a result of the needs above, this paper comprehensively reviews municipal waste management with a zero waste concept regarding management, development, measuring, implementations, strategies, potentials, and challenges in Indonesia. This review can be a good strategy for designing municipal waste management with a zero waste concept for the waste problem, which is still a significant problem in Indonesia, especially from another perspective.

II. Management

Waste is considered useless by society including industry. This understanding has taken shape around the world as waste impacts climate change, including loss of biodiversity, increased contamination of air, water, soil, deforestation, and depletion of resources and materials resulting from over-consumption of unsustainable production [12]. This involves waste minimization measures and the concept of "waste elimination from processes and products" [13, 14].

Every year, the world's waste is predicted to surpass four billion metrics, of which barely 20% can be reprocessed or recovered [15]. If we consider cities as living ecosystems with a "closed-loop" managing cycle, as indicated in Fig. 1, the problem of growing waste output is critical [16]. The zero waste concept rejects incinerators, landfills, eliminates throwaway societies, and creates sustainable communities

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[17]. Nandy *et al*. (2022) said do not expect to reach the zero waste state next year, but can plan for a situation very close to the zero waste state in 2030 [18].

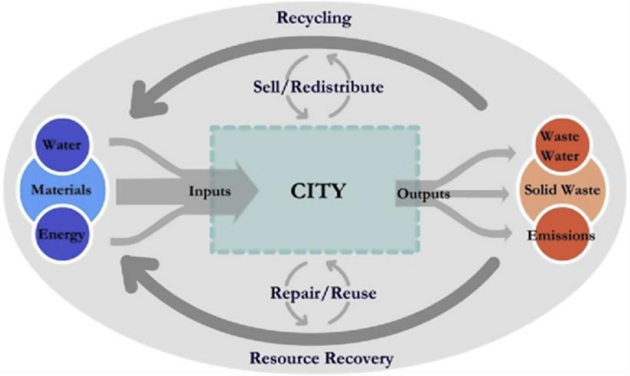

Fig. 1. The material flow rate in a city of zero waste.
Source: Zaman and Lehmann (2011) [14]

Waste management is consistently one of the top five most concerning aspects of city management, yet surprisingly, it receives the least attention compared to other city challenges [19]. One sign of successful city governance is the quality of waste services [20]. Waste avoidance is the primary priority for reducing the amount of waste eventually disposed of in a landfill or burned in an incinerator, followed by recycling and material engineering.

Non-renewable natural resources are increasingly limited in number due to over-exploitation. Exploitation of finite resources will continuously cause uncertainty in the future. This must be avoided, therefore society should use a sustainable amount of waste monitoring system that emphasizes on 1) waste prevention, 2) material productivity, and 3) resource extraction [21].

Although urban areas comprise only around 2% of the earth's surface, they utilize greater than 75% of its raw materials and produce 70% of worldwide waste [22]. Creating waste means diminishing natural resources, consuming energy and water, putting tension on land, contaminating the ecosystem, and in the end, adding to the expense of waste management. We must progress to a point where there is no longer any waste, and the whole lot should be replaced; this is known as zero waste.

Zero waste is one of the most forward-thinking approaches to waste management [23]. Several major towns worldwide, including Adelaide, San Francisco, and Stockholm, have declared zero waste. They are attempting to meet the set goal of becoming the first cities to implement zero waste policies. However, applying the zero waste concept in a city and analyzing a city's success based on the zero waste concept is equally crucial [14].

III. Development

Cities produce around 1.3 billion tonnes of solid waste per year, which is anticipated to rise to 2.2 billion tonnes by 2025 [24]. In low-income countries, waste generation will more than treble in 20 years [25]. According to the Indonesian Ministry of Environment and Forestry, the country's overall waste output is 64 million tons per year [8]. Plastic waste accounts for up to 14% of total waste [26]. Palmer was the first to apply zero waste principles to chemical waste recovery in 1973 [27]. To meet the 2010 aim, some cities across the world enacted zero waste laws in 1995, and Canberra turned out to be the first city in the globe to realize the goal [14].

TABLE I: Key Milestones and Events on the Zero Waste Development

Year	Country	Milestones/ events
1970s	USA	The term 'Zero Waste' was coined by Paul Palmer.
1986	USA	The National Coalition against Mass Burn Incineration was formed.
1988	USA	Seattle introduced the Pay-As-You-Throw (PAYT) system.
1989	USA	The California Integrated Waste Management Act was passed to achieve 25% waste diversion from landfill by 1995 and 50% by 2000.
1990	Sweden	Thomas Lindhqvist introduced "Extended Producer Responsibility".
1995	Australia	Canberra passed the 'No Waste by 2010' bill.
1997	New Zealand, USA	• The Zero Waste New Zealand Trust was established. • The California Resource Recovery Association (CRRA) organized conference on zero waste.
1998	USA	Zero waste was included as guiding principles in North Carolina, Seattle, Washington, and Washington DC.
1999	USA	The CRAA organised zero waste conferences in San Francisco.
2000	USA	The Global Alliance for Incinerator Alternatives was formed.
2001	USA	GrassRoots Recycling Network published "A Citizen's Agenda for Zero Waste".
2002	New Zealand, USA	• The book Cradle-to-Cradle was published. • Zero Waste International Alliance was established. • The First ZW Summit was held in New Zealand.
2004	Australia, USA	• ZWIA gives a working definition of zero waste. • GRRN adopts ZW business principles. • Zero Waste SA was established in South Australia.
2008	USA	The Sierra Club adopted a zero waste producer responsibility policy.
2012	USA	• The documentary film Trashed premiered at the Cannes Film Festival. • The Zero Waste Business Council was established in the USA.

The introduction of zero waste legislation in New Zealand in 1997 aided the push to reduce waste beyond the zero waste movement. This movement advocates for a "closed-loop materials economy, one in which items are designed to be reused, mended, recycled, an economic system that minimizes and eventually eliminates waste" [28]. Del Norte County, California, was recognized as the first county in the United States to realize the zero waste strategy in 2000 entirely. The zero waste target was endorsed as a strategic waste management plan by the California Integrated Waste Management Board in 2001 [27]. Table I depicts achievements and events connected to zero waste development [29].

Zero waste implies removing all trash from the soil, water,

and air that poses a hazard to the earth, human health, animals, or plants [30]. The San Francisco Department of the Environment describes zero waste as not using landfills or incinerators and enacting regulations that reduce trash and expand recycling and composting opportunities [14]. Zero waste in the United Kingdom is defined as "A simple way of summarizing the targets as far as possible to reduce the impact of waste on the environment. It is a visionary goal that prevents waste from occurring, conserves resources, and restores material value" [31].

Fig. 2. Drivers for transforming current cities into zero waste cities.
Source: Allam (2018) [32]

Zero waste means removing all unneeded and undesired debris from all products at all stages of their life cycles [32], [33]. The many concepts proposed for a viable waste management system are evading, decreasing, using again, revamping, restoring, salvaging, refurbishing, remanufacturing, selling back, and dispersing waste resources. The concept of zero waste is still evolving, with limited recycling and product redesign helping to reduce trash formation at an early stage [34]. Fig. 2 shows the principles of a zero waste city, which, if implemented correctly, can transform the city into a zero waste town [32].

IV. Measuring

Several issues must be considered when transforming a waste management system into a zero waste strategy, including geographic frontlines, waste avoidance at design stage, behaviour modification, waste decrease through reprocessing and reshaping, and so on [35]. The fields of geo-administrative, socio-cultural, management, environment, economy, organization, government, and policy are divided into seven major categories (see Fig. 3) [36].

Designing a performance appraisal tool in indicators is critical to comprehend and analyze zero waste management [37]. Various stakeholders have produced solid waste management indicators based on their areas of interest, such as social, economic, environmental, or technological [38]. Researchers also conducted some studies on standards of sustainable waste management [39].

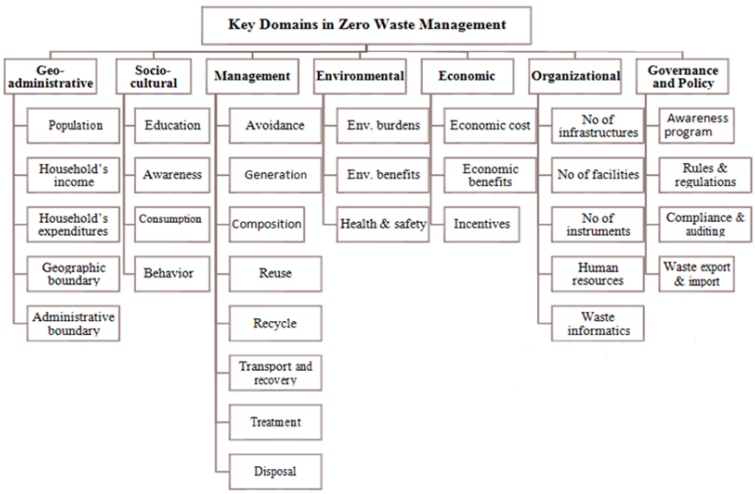

Fig. 3. Domain schemes in zero waste management system.

No single solution to the present waste problem, to intelligently create a city of zero waste, a general attempt to municipal waste management and the notion of long-term sustainability are possible. Understanding the local context and the global market scenario will allow maximal zero waste adaptation. Build future zero waste initiatives, it is necessary to identify major priority areas. Questions about city governments' plans to improve recovery performance (as measured by waste production per capita, landfill per capita, and resource recovery degree associated with internationally fruitful applies), for instance what resource conveniences are desirable to meet countless goals, how much venture is required, and where the Advanced Waste Treatment (AWT) ability will be built, will be answered. What can be done to boost productivity? More material could be extracted from the trash stream to satisfy the increased target if the waste generation rate rises as expected.

V. Example of Implementations

A. Canberra

In 1996, Canberra became the world's first city to pass a Zero Waste Law. "Beginning of 2010, the government will not produce garbage," says the law. Garden waste and building debris trash have become more diverse as a result, Canberra's city reached 70 per cent waste diversification in 2004 (Construction & Demolition). One of Canberra's city plans is the creation of a "Resource Recovery Park" to assist businesses in producing items from a variety of materials and reused market commodities [40].

B. Adelaide

One of South Australia's most populous cities, Adelaide has devised and executed a zero waste strategy to maximize waste resource recovery. The cornerstones of waste management in Adelaide are garbage recycling and composting. The trash composting program has grown dramatically, and by 2015, the composting capacity must be more than the waste delivered to landfills [14].

As a result, Adelaide's waste composting facility is still being developed. This city has a high rate of waste diversification, with an overall rate of 82%. For decades, the city has been successful in executing the CDL system.

C. Stockholm

Stockholm is one of Europe's most important cities, with high environmental standards and aspirations to improve environmental quality. The government is in charge of the capital's waste management system. The Stockholm City Government has launched a development named "Vision Stockholm 2030" to plan for Stockholm's long-term sustainability. Stockholm has set a goal to become a fossil-free city by 2050 [41]. The transformation of Stockholm into a resource-efficient zone is one of the 2030 vision's main goals [42].

D. Halifax-Nova Scotia

In the mid-1990s, Halifax, Nova Scotia, Canada, attempted to enlarge the landfill area. This plan prompted public outcry, with residents complaining about a bad odour emanating from the property. The city authorities then planned a big incinerator with a 750-ton-per-day capacity. Similarly, this idea sparked objections, and the project was halted. In the end, the government left the matter to the people and said, "You don't want landfills, and you don't want incinerators, tell us what you want. Please design the program".

The people accepted the challenge, and the government stepped in to help, such as with the consultant's report. Citizens chose one of the initiatives based on information provided by Seattle-based sound resources. This service entails separating and collecting recyclable, organic, and other waste from residents' homes. In their reports, citizens made two paradigm adjustments: 1) They always use the word "resources" instead of "waste" in their pronouncements; 2) Residents requested that no waste be put into the landfill without first being processed due to previous adverse experiences with landfills [43]. As a result, a construction waste filtering facility was built.

Halifax has achieved a 60% diversification rate. This scheme also provides 1000 jobs in the waste collecting and processing industry. In addition, the second-hand collection industry sector added 2000 employment. In Nova Scotia, almost all separated materials are reused by industry [44].

E. San Fransisco

San Francisco, with a population of 850,000 people, is the most progressive city in the USA, with a waste diversification rate of 77%, the highest in the country, thanks to a three-pronged tactic that includes coercing harsh waste decrease laws, affiliating with waste management firms to develop new programs, and working to promote recycling and composting through encouragements and community outreach [45]. Because this city has little territory, residents are working to reach the zero waste target, which will be attained by 2020 [46].

VI. Strategies

Waste must be managed to have added value, reused, and not pollute the environment. Historically, waste management has been identified with an engineering function [47]. Increased production has created a problem that requires landfills. The flow of material in the community is schematically depicted in Fig. 4 [48]. Waste is generated at the stage of extracting raw materials and during the production process. After the raw materials are obtained, more waste is produced during the processing of goods which the community will then consume. The most effective way to reduce the waste problem is to reduce the amount and toxicity of the waste generated [49]. But with the increasing desire for a better standard of living, humans have become more likely to consume higher levels of consumption and produce more waste. Consequently, the community must look for effective waste management methods and ways to reduce the amount of waste that needs to be disposed of in landfills [50]. Following Law No. 18 of 2008, waste management aims to improve public health and environmental quality and make waste a resource [51].

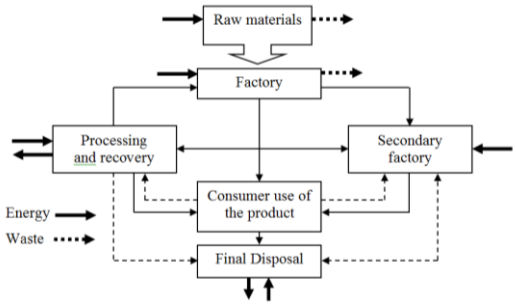

Fig. 4. The flow of materials and waste in industrial society.
Source: Tchobagnoglous and Kreith (2002) [48]

The increase in waste has resulted in increasingly complex problems for managing waste. Solid waste management is complex because it includes many technologies and disciplines. Includes technology associated with control over the generation, storage, collection, transfer and transportation, processing and disposal of waste, which is acceptable and by the principles of public health, economics, engineering, aesthetics and other environmental considerations, including responsiveness to the general public [52].

Waste management will fail when there is too much waste, in the wrong place, not close enough to where to sell waste, or not recycled enough [53]. The solution lies in redesigning products, packaging, and processes suitable for input into the value chain. Initiatives and tools can also support successful sustainable waste management strategies. Some examples of tools and initiatives have been carried out in several cities to support sustainable waste management [54]:

1) **Providing information and education to popularize recycling programs.** Greater Vancouver Regional District, BC published the book "101 Uses for Your Old Shoes and Other Stuff" in 1996 containing how to recycle and repair household goods as a source of business and organizational direction for recycling, by repairing and renting items in the area.
2) **Cooperation and partnerships.** The community composting program in Switzerland consists of nearly 600 composting environments. Suitable venues, educational information and support are provided by the city. The maintenance/maintenance of the compost pile is shared with the participating households. Nearly 10% of the city's population participates in this program.
3) **Mastery of knowledge in the field of composting.** In Seattle, Washington, interested residents can join the composter program training. Participants who have mastered it then enter the community to train residents. In Indonesia, training or mastery of education in waste technology is still low, with establishing a compost mastery school as a significant waste management effort.
4) **Waste reduction award program.** One form of award related to waste in Indonesia is Adipura. The Adipura award is applied to encourage local governments and the community to create a clean and well-shaded city by applying the principles of good governance in environmental management. For Adipura, waste is one of the leading environmental issues. For this reason, Adipura's assessment includes the cleanliness of the city and the condition of the landfill.
5) **Eco-labelling.** Refers to labelling on products that provide information about the percentage of content recycled in a product that can help consumers choose environmentally friendly products.

In addition to the strategic approach through tools and initiatives, the term waste hierarchy is known in waste management as concept and priority tool that can develop waste management strategies to reduce resource consumption and protect the environment [55]. Tchobanoglous & Kreith [48] reveal four options for waste management (reduction of waste from source, recycling, waste into energy and landfilling) that can be done interactively or hierarchically (Fig. 5a, 5b).

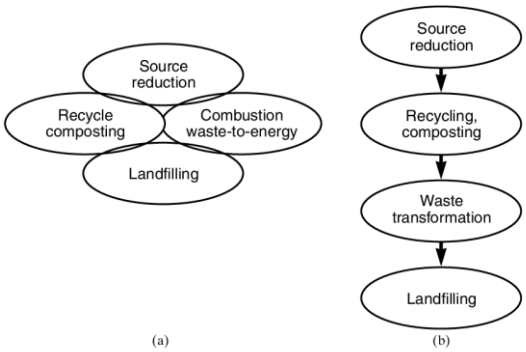

Fig. 5. Relationship between compiled waste management options and integrated waste management: (a) interactive, (b) hierarchy.
Source: Tchobagnoglous and Kreith (2002) [48]

In areas with no emphasis on economic aspects, tools for waste management are selected based on the level of clarity of environmental acceptance [56]. Reducing waste from the source will be the most important level to prevent waste problems. Recycling, including composting, will be the next management option because it can return the resources to be commercial after the original product no longer has any benefits. Energy waste is the next option because waste can produce energy rather than just being burned or buried. Landfilling is the last option which is not better or even worse than incineration [57]. United Nations Environmental Programme, 2010 lists a waste hierarchy similar to Zhang *et al.* (Fig. 6) [58, 59]. With the increasing problems in waste management, waste management cannot be solved with only one waste management option but with a comprehensive and integrated management system.

Fig. 6. Waste hierarchy according to the United Nations Environment Program (UNEP) waste climate and change.
Source: Zhang *et al*. (2022) [58, 59]

VII. Potentials and Challenges in Indonesia

Compared to the 2000 population census, which amounted to 205.1 million residents, the 2010 population census shows that Indonesia's total population is 237.5 million residents [60]. Across the last ten years, Indonesia's population has grown by around 32.5 million residents at an increased rate of 1.49% per year. Difficulties occur at every stage of solid waste management, including collection, transfer, transportation, and processing, with these issues increasing at the conclusion, especially landfills [61].

According to a study of waste management done by the United Nations Environment Programme (UNEP) in 2004, the government only meets 33% of solid waste management service indicators [58]. This shows that the Indonesian government's waste management services are still inadequate. Several things influence this low quality of service. Indonesia's existing waste management law was ineffective, resulting in inefficient waste management. This law does not assertively regulate the management of solid waste [62].

Due to a lack of available land, many towns suffer landfill issues. Sanitation measures, such as land cover, leachate collecting, and environmental contamination treatment systems through CH_4 releases and leachate infiltration into shallow soil water, are not available at open dumping sites [63]. Table II depicts the evolution of different waste management indicators in Indonesia [39]. This means that, since 1999, four areas of municipal solid waste management have been satisfactory, and just one feature has improved since the UNEP study.

TABLE II: Municipal Waste Management Aspect Implementation in Three Periods

Waste Management Aspect	Before decentralization in 2019	1999–2004 (UNEP)	2005–now
1. Policy on integrated waste management	NA	NA	NA
2. Policy on solid waste management	NA	NA	NA
3. Institutional arrangement to handle/ manage wastes	A	A	A
4. Regulatory framework for waste management	A	A	A
5. Budget support for waste management	NA	NA	NA
6. Training program for waste management	NA	NA	A
7. Private sector participation	NA	NA	NA
8. Community participation	A	A	A
9. Information system	NA	NA	NA
10. Economic instrument	A	A	A

NA: Not Available, A: Available
Source: *Wibisono* et al. (2020) [39]

Training programs for capacity building in municipal solid waste management have been organized by the Ministry of Environment and the Ministry of Settlements and Infrastructure. Endeavours to enhance indicators should commence by viewing current situations as challenges and developing them using this potential. Table III depicts the potential and constraints of using the zero waste concept in municipal trash management in Indonesia [64].

TABLE III: Potentials and Challenges for Municipal Waste Management with zero Waste Concept in Indonesia

Potentials	Challenges
1. Waste Law No. 18/2008 accommodates greater role in municipal waste management for local government. 2. Community participation has been actually practiced although indirectly. It can be improved into direct involvement such as waste separation. 3. Incentives and disincentives scheme including in Waste Law can encourage law enforcement. 4. New recycling policy in 3R can increase the possibility in waste reduction, material recovery and revenue. 5. High organic content waste is a source for composting treatment. 6. Projected plastics consumption increase can be potentials in achieving added value from the waste since it can be a material input for recycling plant and incinerator in the future.	1. Enactment of Waste Law No 18/2008, forced Local government to propose plan and implementation for open dumping closing at the latest 1 year and 5 year from the waste law enactment (May 2008). 2. Landfill developer is obliged to build waste separation system. 3. Millenium Development Goals achievement target in waste sector is 70% community is provided by municipal waste management by 2015. 4. Low public awareness in separating waste. 5. Low priority in the local government's annual budget allocation. 6. Low private sector participation. 7. Lack of infrastructure. 8. Though the enactment of waste law, there is no policy on solid waste management since most municipal waste is solid waste.

In the current situation, household inorganic and hazardous/ toxic waste is not correctly managed since householders predominantly dispose of this waste and organic waste [65]. According to the waste composition survey, kitchen waste or food scrap is the highest fraction (52%), followed by recyclable inorganic waste such as plastic (14%), paper, and cardboard (12%). While the kitchen waste is valuable as feedstock to compost, plastic, paper, and cardboard can be recycled. Meanwhile, the presence of hazardous waste is low, with only 4% of metal waste and 2% of the waste classified as other waste, which includes e-waste such as batteries and used electronic products [66].

Among the top fractions of inorganic waste from households, nearly all are recyclable, except dense plastic that is unrecyclable scraps. Other wastes, such as food packaging (18%), refused plastic sacks (15%), clear plastic beverage bottles/ PET bottles (11%), and aluminium beverage cans (8%), can be recycled and would, therefore, have significant economic values in scrap dealing. Although there are valuable household waste resources, most respondents dispose of recyclable waste and other types of waste, including organic waste [66].

VIII. Conclusion

Several inferences can be derived from the results of the literature review as indicated above:

1) Cities in Indonesia have experienced overcapacity in handling urban waste management, so new initiatives are needed.

2) Zero waste is a notion that stems from preventing the development of garbage from upstream to downstream, rather than only processing waste in the end pipe, it could be a novel concept in Indonesia's waste management.
3) The zero waste concept has been implemented successfully in numerous cities worldwide thus it is not hard to implement.

It requires the participation of all participants in the implementation of the zero waste idea, beginning with the government, education, and commercial sector.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

EAW analyzed the data and wrote the paper; NSA editing and reviewing the paper; IN supervised and reviewed the paper. All authors had approved the final version.

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