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Solid Waste Management (SWM) Challenges and Solutions by using Zero Waste Strategy: Karachi as a Case Study

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ABSTRACT

This paper introduces an abridgment of solid waste conditions and their management issues in Karachi. Approach that can be used to reduce the municipal waste and the management of solid waste produce by the residents of Karachi city is Zero Waste Strategy. Zero waste strategy is a focused approach of conserving all the resources. This approach is beneficial by means of responsible production, valuable consumption, reuse and recovery of product, packaging and materials without burning and with the least discharge to air, water or land that cause an adverse effect on our environment and human health. The budget allocated by governmental bodies for solid waste management is adequate but not allocated properly to the local bodies. Bin services are provided throughout the city is enough but the locations selected for this purpose are not appropriate. Zero Waste Strategy (ZWS) helps to reduce the solid waste by providing proper route, with appropriate recycling plan, adequate management of resources and public behavior related to solid waste. The research concludes by proposing zero waste strategy (ZWS) as an effective solution of highlighted issues for management of solid waste in Karachi city. The current research is entirely unique and could affect the society in value added manner.

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INTRODUCTION

Solid waste management (SWM) has gained recognition as a crucial infrastructure that must be provided everywhere, just like freshwater, power, and telecommunications. Municipal waste is produced from the houses or trade provisions and services (Clift et al., 2000).

Solid wastes are now a common sight in our metropolitan setting. It is now without question that unprocessed solid waste is a significant challenge for our cities. As a result, urban people frequently have to deal with the danger to their overall health and safety. Although they have an impact that can be felt, the health effects of exposed and fermenting waste have not been quantified (Agwu, 2012).

LITERATURE REVIEW

Solid waste management in Estonia

Estonia is a Baltic country, a small member state of the European Union (EU), with an estimated population of about 1.325 million. Estonia has highlighted a shift in its waste management model, less reliance on dumping waste in landfills to produce valuable energy from that waste. Construction of incineration facilities started in 2013, and after this step, there was a diversified effect on reducing municipal waste to the landfills. As for 2013, 2014 and 2015, a total waste of 14%, 8% and 5%, respectively, have been reduced.

The introduction of tax rates to landfills depends upon the type of waste. The rate increases if the waste dumped into the landfills is larger than the permitted quantity, established according to the Environmental Charges Act. This step also led towards the reduction of waste dumped to the landfills.Figure 1 shows the acceleration of the production of the largest part of waste in 2004 to the lowest part of waste produced in 2015. While Figure 3 depicts that Estonia increased its recycling capacity from 18% in 2013 to 31% in 2014 (Eurostat, 2013).

Solid waste management in Poland

Poland, also known as the Republic of Poland, is a part of Central Europe with an estimated population of about 38,645,240 people. Poland also used recycling as a means to reduce waste dumped on the landfills. Figure 3 depicts the recycling rates in Poland obtained in previous years. While Figure 2 reveals the difference in waste management in the last years and interprets that there is an increase in the recovery and recycling of waste while the amount of waste disposed at the landfills decreases (Eurostat, 2019).

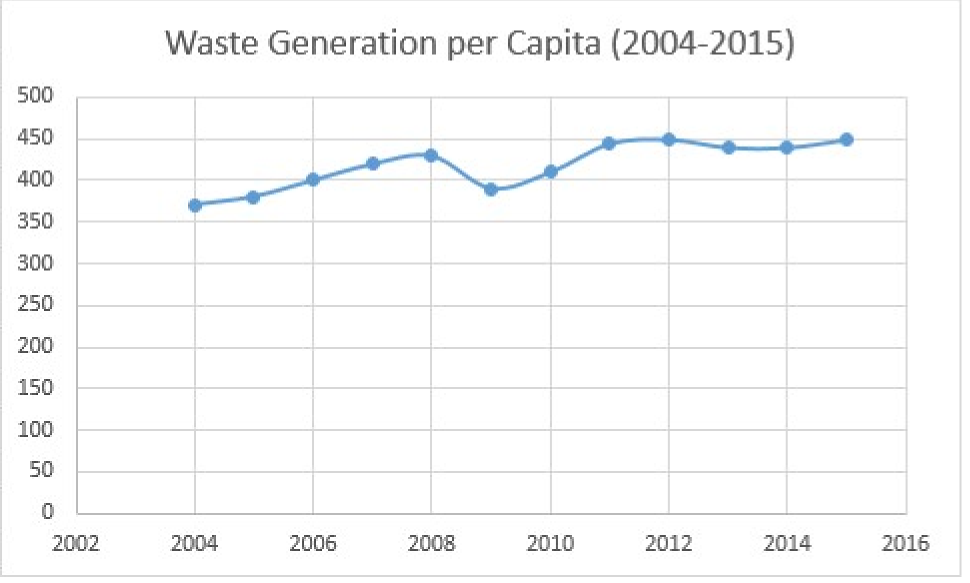

Figure 1: *Waste Generation per capita of Estonia (2004-2015).*

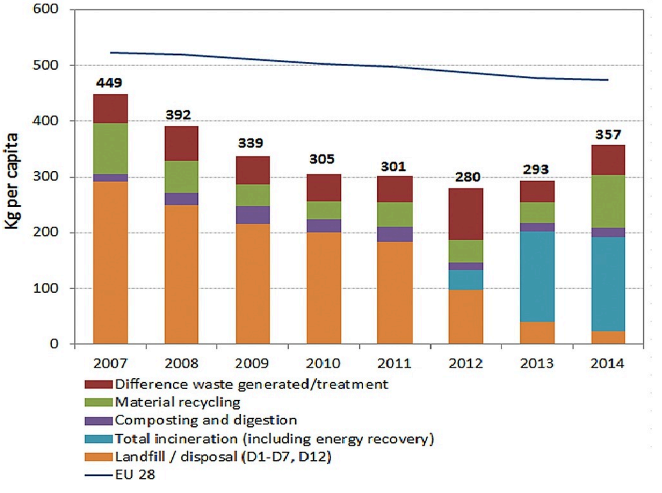

Figure 2: *Municipal Solid Waste treatment in Estonia (per capita).*

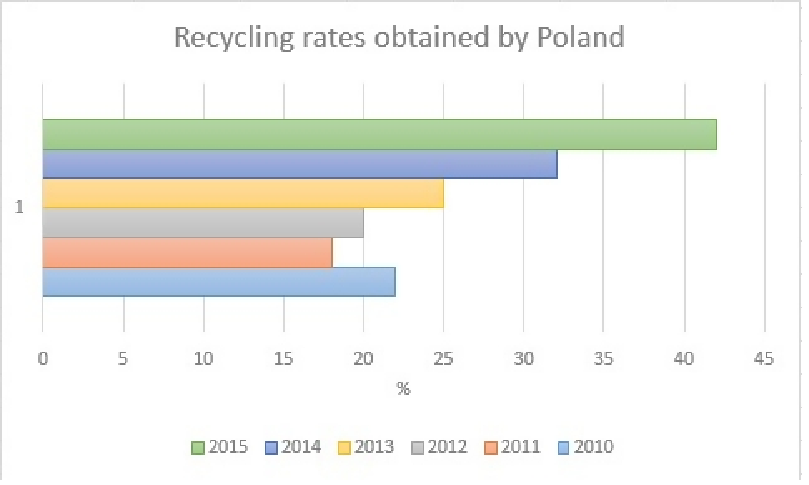

Figure 3: *Recycling rates (%) obtained by Poland.*

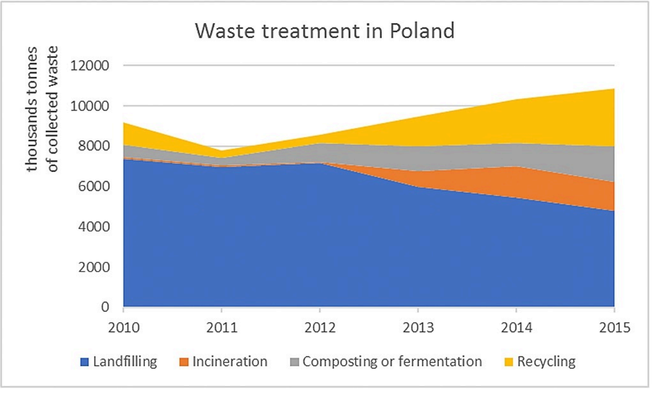

Figure 4: *Methods for treatment of waste in Poland for period (2010-2015).*

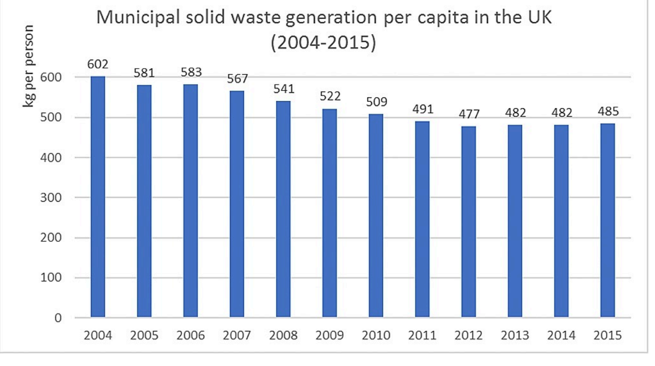

Figure 5: *Solid Waste generation in UK.*

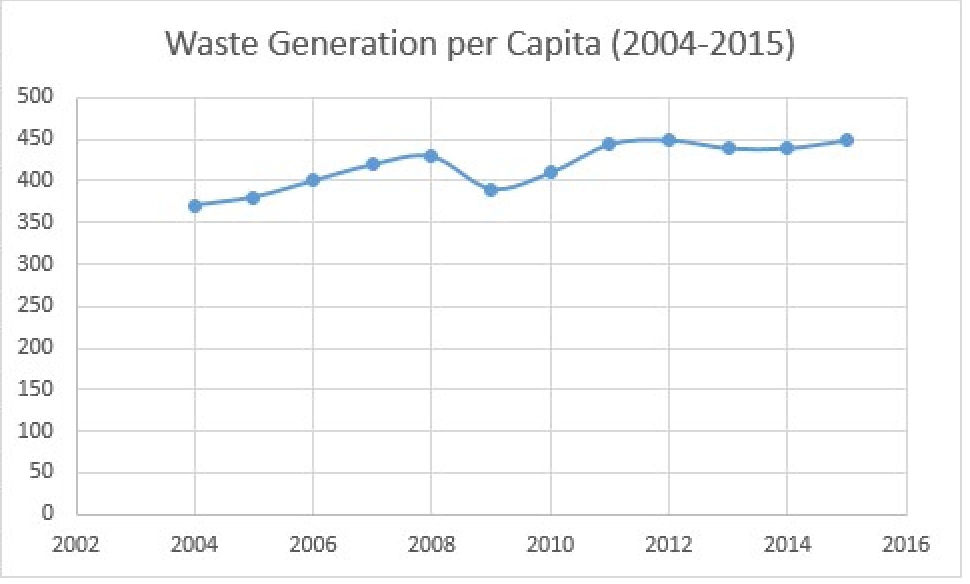

Figure 6: *Waste treatment in UK (2004-2015).*

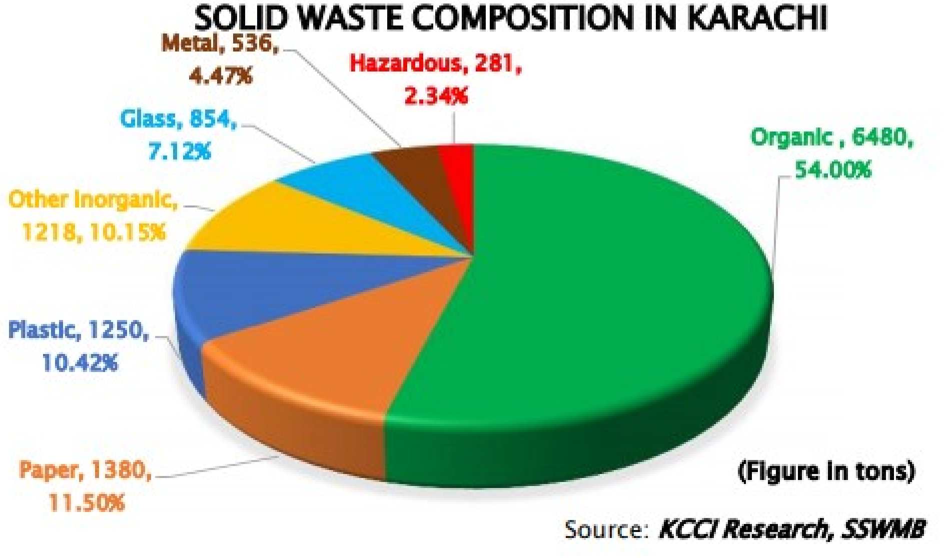

Figure 7: *Solid waste composition in Karachi.*

Municipal Solid Waste management in United Kingdom

The UK is a large European country with an estimated population of about 65.6 million, which is expected to increase to 79 million by the end of 2039 (Statistics, 2017). The current government tries its best to maintain the natural environment of the United Kingdom in a better and safe state as they found it (Eurostat, 2013). Figure 5 shows the gradual decrease in waste production from 2004 to 2012. There was a slight increase in waste in 2015, but the overall waste generation was 20%, less than in 2004.

The government of the UK introduced a national waste management plan aiming to raise efforts towards a zero-waste economy. High quality recycling techniques are introduced through which waste material is recycled and recovered before going to landfills, this technique reduces the amount of waste in landfills. Figure 6 shows the pre-treatment of solid waste before landfilling (DEFRA, 2017).

Solid Waste in Karachi

Karachi is the largest metropolis of Pakistan, located in the southern province of Pakistan named Sindh. It is the most populous city in Pakistan and the fifth most populous city in the world. This city is considered a premier financial and industrial hub and centre of the country because this city plays a central role in the economy of Pakistan (Kwenda et al., 2022). Many well-known industries (textile, pharmaceutical, steel mills, automotive manufacturers) and small and medium sized industries are located in this city, making this city crucial for the economy of Pakistan,

Karachi's social, economic and political conditions are disturbed, due to the ongoing pandemic which has ruined this city's position. One of the main problems raised is solid waste, which has ruined this city's position, and Karachi has become famous as the dirtiest city in Pakistan. This issue arises because of improper solid waste management by city and provincial authorities like KMC (Karachi metropolitan city) and SSWMB (Sindh Solid Waste Management Board) (Jerin et al., 2022). If not managed timely and effectively, it will raise various other unrepairable critical issues (E. Singh et al., 2022).

Municipal waste means any unproductive debris or garbage. The primary sources from which solid waste is generated in Karachi include household, commercial, industrial waste, institutions or office sweeping and street sweeping. The estimated waste generated in Karachi city is between 12000 to 15000 tons/day. Out of which, the garbage street picker picks 3105 tons/day of waste, and about 1350 tons/day is the amount of waste which housewives separate at the sources. The amount mentioned above of garbage is collected from five districts of the municipals corporation (DMCs) of Karachi and transported to KMC (Karachi Metropolitan Corporation) landfill sites, where this waste or residue is not properly disposed of or not segregated into its components (DEFRA, 2017). The waste generated in Karachi comprises of the material mentioned in Figure 7. Many challenges or factors affect the progress of solid waste management in Pakistan (Kissan Engineering). In 2021, PepsiCo launched Pakistan's largest plastic waste collection program and collected and recycled over 16000 tons of plastic.This study aims to provide a facilitating framework for adopting smart waste management in the context of CE for Pakistan (Khan & Ali, 2022).

Bureaucratic hurdles

Solid waste management (SWM) has been the main agenda of the provincial government and many different political parties in Karachi for the last few years. The budget allocated for this purpose by Asian Development Bank's (ADB) was about $400 million to work on Infrastructure and Service delivery Reform Program. Still, this budget was not allocated to the district and local authorities and became part of the corruption committed by government officials. The provincial government faces difficulty in this epidemic because of inappropriate policies and incompetent bureaucratic engines.

Lack of urban planning

The urban planning of Karachi city is not up to the mark, because the city is continuously expanding. The small disposal sites are located in the middle of many societies, and the major disposal sites also become a part of the city because of the expansion. Major disposal sites are few and cover about 9500 tons/day out of 12000 tons/day (Prinsen, 2022).

Table 1.
Karachi's landfilling site damp data (KCCI Research, SSWMB).

Solid Waste Dumped At Karachi's Landfill Sites		
No	Name of Landfill sites	Waste handling capacity (tons/day)
1.	Jam Chakro,near Surjani town	Around 8000 tons
2.	Gondpass	Around 1500 tons
3.	Dhabeji(Under Progress)	Not commissioned

Inadequate waste management equipment

The waste management equipments used by the SSWB (Sindh Solid Waste Management Board) and KMC (Karachi Metropolitan Corporation) were outdated and not properly used for waste collection and disposal, creating many hurdles in the path towards waste management in Karachi. The identified zero waste strategy could benefit society and the environment positively and effectively. The mentioned factors or challenges target the primary waste management strategy to solve multiple criticalities of the region. The zero waste strategy could be beneficial and problem solving in managing waste (Zaman, 2016).

STRATEGIES TO MANAGE SOLID WASTE IN KARACHI

The methodology proposed to cope with the solid waste management (SWM) problem is zero waste strategy (ZWS) (Hemidat et al., 2022).

Zero Waste Strategy

Zero waste strategy is a focused approach of conserving all the resources through responsible production, consumption, reuse and recovery of product, packaging and materials without burning and with the least discharge to air, water or land that could cause an adverse effect on our environment and human health (Pant & Joshi, 2022). This strategy iterates along three cycles mentioned in the Figure 8. These combined cycles proposed a zero waste solution and economic business model. These zero-waste solutions and business models can give value to the availability of the steps into an arranged sequence of regenerative systems that benefit human health and nature (Tian et al., 2022).

Biological cycles

The cycles include the nutrients and minerals, which are the input of life that depends upon food, clean water, biodegradable chemicals and building blocks for the materials (Jarju & Cato, 2022). This cycle consists of two domains, upstream and downstream. Upstream includes the location of minerals and nutrients cultivated by the farmers, downstream consists of the location of conversion of inputs into outputs, products and by-products. This cycle focused on the balance of input taken and brought back from the land (Jainapur et al., 2022).

Manufacturing cycles

This cycle includes the fabrication processes interaction with the humans, which transforms inputs into outputs. To maximize production, the fabrication process must be efficient for reusing and recycling waste materials (Al-Salem et al., 2009).

Ecological cycles

This cycle includes the application of basic laws and principles of Physics, Chemistry and Biology. It defines the effect of room temperature, pressures, etc., on the system's functioning and easy access to the sources for effective system functioning (Gana et al., 2022).

The zero waste model not only mention cycles but also provides economics business model with zero waste solutions which includes useful steps that can be implemented into every cycle as per the requirements. These steps are reduced, reuse, recycle and recovery to landfill (Korai et al., 2016).

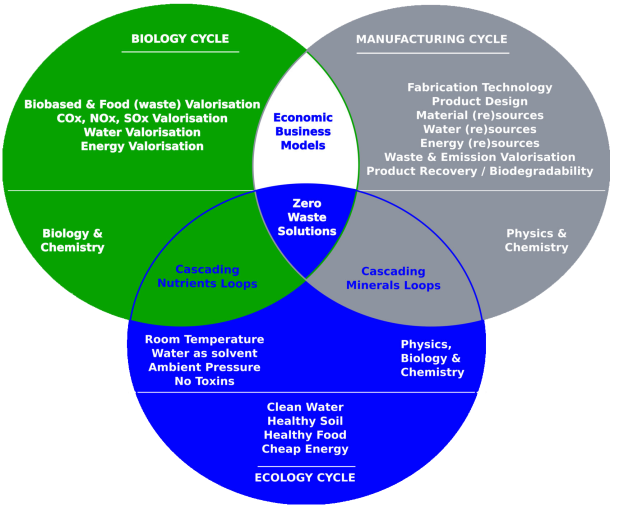

Figure 8: *The Zero Waste Model (Prinsen, 2022)*

Reduce

Means bringing solid waste to a less desirable state or converting it into a minimum amount so that the least material can be disposed of at landfills.

The following step can be taken to reduce solid waste.

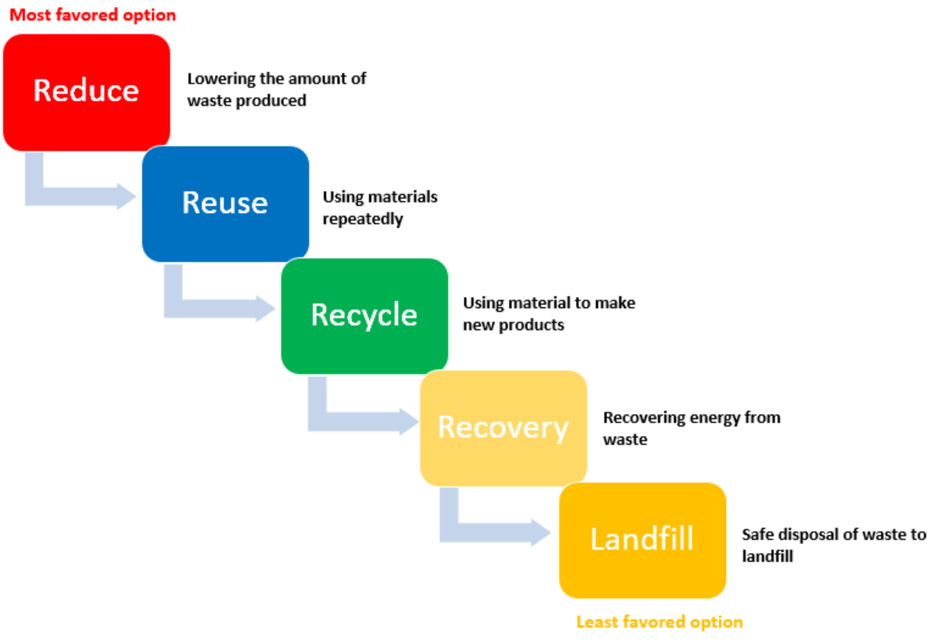

Figure 9: *Schematic diagram illustrates steps in Zero Waste*

- Use bags made of compost materials that can be returned to the ground to fertilise the yard or garden.
- Avoid the use of plastic bag, because plastic is a non-biodegradable material and can't be decayed by an attack of microorganism when buried underground and have a life of several years.
- Use cloth bags to hold or carry materials or groceries.
- Use sponge and cloth towers instead of paper or plastic for dish or hand washing (N. Singh et al., 2021).

Reuse

Reuse refers to using material again and again instead of being disposing of. The materials like plastic bottles, that water purification companies use to sell their water, can be reused after collecting from various sources instead of disposal. This practice is also helpful in reducing the number of plastic waste at dumpsites (Ranjbari et al., 2022).

Recycling

In Karachi, recycling activities are expensive and connected at all the stages of solid waste management. The private sector runs the recycling activities in Karachi, and recycling helps a lot in reducing the waste amount and earning environmental and economic benefits as this sector employs most of the poverty-ridden garbage pickers in Karachi. There are two main divisions of the recycling sector in Karachi (Muheirwe et al., 2022).

1. Packers and sweepers collect waste from street, community and society bins and disposal sites. After passing through several dealers and reaching the small-scale recycling industry, this stream deals with most of the poor quality waste, also known as the dirty stream. These include papers, plastic bags, broken glasses, plastic bottles, and bones.
2. Separation of waste at the source of generation was sold to the buyers who travelled from place to place in search of good quality waste and reached small-scale recycling industries. This is called a clean stream (Younes et al., 2016).

Following is the technique used for recycling:

Mechanical recycling technique is used to recover plastic constituents of solid waste into a new product for reuse by using mechanical means. This technique becomes world known back in the 1970s. This technique helps recycle single polymer plastic because more complex the plastic structure would be, more challenging to recycle it mechanically. It is feasible to separate, wash and prevent waste for producing high-quality end products before recycling. The mechanical method involves several steps mentioned below:

- Shredding involves converting significant plastic parts into small chopped forms.
- Contaminant separation involves separating paper, dust and other impurities from plastic.
- Floating involves the separation of plastic flakes in a floating tank based on density difference.
- Milling involves the milling of single polymer plastic.
- Washing and drying involve washing plastic waste at the beginning. The actual washing occurs after the first if further treatment is required and usually can be done by water. Still, sometimes chemicals like caustic soda and surfactants are used.

- Agglutination involves collecting products for storage and further processing after adding additives and pigments.
- Extrusion involves the extrusion of plastic into strands and then production in palletised form.
- Quenching involves cooling plastic to be granulated and sold as a final product (Bikash & Ichihashi, 2022).

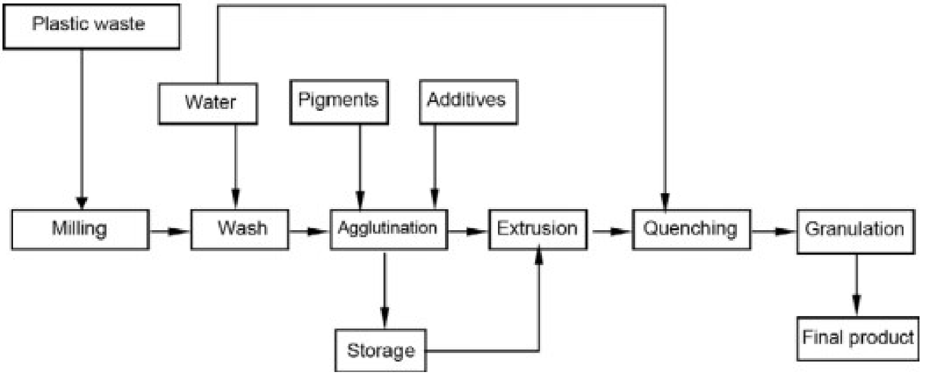

Figure 10: *Description of mechanical recycling steps Aznar et al. (2006).*

Recovery

Recovery involves the production of energy from solid waste.

1. Solid waste samples collected from the various commercial and residential areas were used for quantification and composition. We weighed the components (plastic, paper, cloth, cardboard, food waste, glass, etc.) in the collected sample using physical balance. As per consumption equation,Equation (1) can be used for estimating quantities along with potential components by considering a 2.4% solid waste growth rate (Shahab et al., 2022).
2. Various characteristics of solid waste, including moisture content (MC), total solids (TS), volatile matter (VM), fixed carbon (FC), ash content (AC), calorific value (CV), and element analysis, were determined by adopting standard methodologies. The theoretical biogas potential of the collected waste sample was estimated by using Equation (2).

3. By considering various special characteristics of solid waste like Calorific value (CV), Ash content (AC), Fixed carbon content (FC), theoretical bio gas potential (TB_P), were estimated for different waste to energy technologies as per the procedures described below: (Bhat et al., 2022)

$$X_{SW} = (Gr_{SW} \times Pq_{SW} \times N) + Pq_{sw} \tag{1}$$

Whereas;

X_{sw}=Estimated quantity of solid waste

Gr_{sw}=Growth rate

Pq_{sw}=Present quantity of solid waste

N=Number of years

$$TB_P = \left(\frac{\left(\frac{4n+x-2y-3z}{8}\right) CH_4 \times Sp.Wt\ of\ CO_2 + \left(\frac{4n-x+2y+z}{8}\right) CO_2 \times Sp.Wt\ of\ CH_4}{C_n H_x O_y N_z \times Sp.Wt\ of\ biogas} \right) \times 1000 \tag{2}$$

Thermochemical conversion process In this process, biodegradable and non-biodegradable materials contribute to energy output. Equation (3) andEquation (4) were used for estimating the energy recovery and power generation potential of Solid waste, respectively.

$$ERP = 1.16 \times NCV \times SW_{dq} \tag{3}$$

$$PGP = \frac{(0.048 \times NCV \times SW_{dq} \times Y]}{1000} \tag{4}$$

Whereas;

ERP = Energy recovery potential(KWh/ton day).

PGP = Power generation potential(MW/ton day).

NCV = Net calorific value(kcal/kg).

SW_{dq} = Dry waste quantity.

Y = Thermochemical conversion efficiency. N. Singh et al. (2021).

Biochemical conversion process In this process, a biodegradable portion of organic matter contributes only to the energy output. Equations (5), (6) and (7) were used to estimate energy recovery and energy generation potential of Solid waste and methane generation, respectively.

$$ERP = MG \times NCV/0.042 \tag{5}$$

$$PGP = \frac{[MG \times NCV \times Y]}{1008} \tag{6}$$

$$MG = TM_P \times Y_d \times OBF \times VM \times SW_{dq} \times 1000 \tag{7}$$

Whereas;

ERP = Energy recovery potential (KWh/ton day).

PGP = Power generation potential (MW/ton day).

NCV = Net calorific value (kcal/kg).

SW_{dq} = Dry waste quantity.

Y = Thermochemical conversion efficiency.

MG = Methane generation (m^3/day).

TM_P = Theoretical methane potential(m^3/kg VM).

VM = Volatile matter in percentage.

Y_d = Digestion efficiency.

OBF = Organic biodegradable fraction.

In solid waste, there are several degradable components (food waste and yard waste) and less degradable (plastic, wood, cloth etc), which is why, solid waste is a heterogeneous mixture. There is a need to develop different scenarios for optimisation of energy from solid waste shown in Figure 11 (Pal & Bhatia, 2022).

Whereas;

Mix-MSW=Mixed municipal solid waste includes leather, card board, rubber, paper, wood, textile, glass, ash, dirt etc.

Mix-OFMSW=Mixed organic fraction of municipal solid waste like wood,leather, paper etc.

BCs-MSW=Biodegradable component of municipal solid waste.

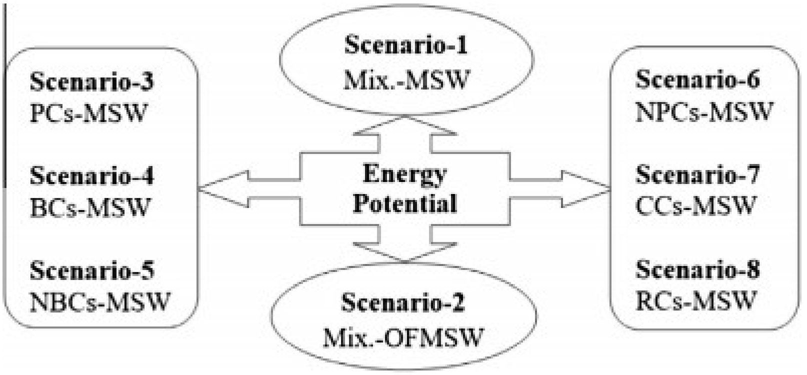

Figure 11: *Scenarios for energy recovery potential of solid waste.*

NBCs-MSW=non-biodegradable component of municipal solid waste.

NPCs-MSW=Non-putrescible components of municipal solid waste like wood, plastic, rubber, textiles and cardboard.

PCs-MSW=Putrescible component of municipal solid waste like food and yard waste.

CCs-MSW=Combustible component of municipal solid waste like leather, rubber, textile and wood.

RCs-MSW=Recyclable components of municipal solid waste like card board, paper, glass, metals and plastics.

Waste disposal area needs to be estimated on the prediction of solid waste generation. The capacity of the proposed landfill area can be estimated by using Equation (8).

$$landfill\ area = \frac{(R \times L \times P \times 1.5)}{\rho_{bulk} \times H} \tag{8}$$

Whereas;

R=waste generation rate (kg/capita year).

L=landfill life span (years).

P=population (number of persons).

ρ_{bulk} waste bulk density (kg/m^3).

H=height of the waste disposal at the landfill (m) (Bafail & Abdulaal, 2022).

BENEFITS OF USING THE ZERO WASTE STRATEGY

Two main benefits of using the Zero Waste Strategy for the government or local bodies exist, and these benefits the environment and community as described (Jerin et al., 2022).

Zero waste benefits for our environment

Reducing, reusing, and recycling can play a vital role in reducing the release of greenhouse gases and carbon content in the atmosphere. Zero waste strategy helps conserve natural resources and reduces the pollution caused by extrusion, manufacturing and disposal. Recycling focuses on keeping the waste out of landfills and incinerators and providing recycled material for the manufacturers to make new products instead of raw materials (Kwenda et al., 2022).

Zero waste benefits for the community

It helps to protect the community's health and provides community building capacity. Zero waste practices like composting at the community garden, tool sharing and skills sharing to reuse and repair build capacity to reduce waste and cost. Zero waste practice ensures community health by reducing air pollution, land pollution and water pollution by keeping toxic gases and waste out of landfills and air (Bafail & Abdulaal, 2022).

CONCLUSION

The problem of waste is not only complicated but also becomes expensive to be managed efficiently and sustainably. Solid waste is increasing at a higher rate, so there is a dire need to consider the severe practice of reducing waste by reusing and recycling waste to get energy and make use of economic and environmental benefits. The main challenge for solid waste performance measures, is the lack of up-to-date data and reliability. Data quality is also an issue in predicting the righteous performance measure for future direction. Recent studies show that green house gases can be reduced by using different landfill approaches in Karachi, namely open dumps, sanitary landfills, and aerated and anaerobic bioreactor landfills for specific compositions.

This research tried to shed some light on solid waste management. Also, it provides the practice to reduce waste. It gives a new direction for reusing and recycling waste to produce new products instead of disposing of them. This study also guides on "how to reduce waste in landfills by gaining energy recovery from the waste". Such directions will become helpful to improve, not only the economy of Karachi city, but also its environmental condition by reducing pollution.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interests.

REFERENCES

Agwu, M. O. (2012). Issues and challenges of solid waste management practices in port-harcourt city, Nigeria-a behavioural perspective. *American Journal of Social and Management Sciences*, *3*, 83–92. https://doi.org/10.5251/ajsms.2012.3.2.83.92

Al-Salem, S. M., Lettieri, P., & Baeyens, J. (2009). Recycling and recovery routes of plastic solid waste (PSW): A review. *Waste management*, *29*, 2625–2643. https://doi.org/10.1016/j.wasman.2009.06.004

Aznar, M., Caballero, M., et al. (2006). Plastic waste elimination by co-gasification with coal and biomass in fluidized bed with air in pilot plant., *87*(5), 409–420. Retrieved from https://sci-hub.hkvisa.net/10.1016/j.fuproc.2005.09.006 https://doi.org/doi:10.1016/j.fuproc.2005.09.006

Bafail, O. A., & Abdulaal, R. M. (2022). A Combined BWM-TOPSIS Approach Versus AHP-TOPSIS Approach: An Application to Solid Waste Management. *The 3rd International Conference on Industrial Engineering and Industrial Management*, 27–33. https://doi.org/10.1145/3524338.3524343

Bhat, R. A., Singh, D. V., Qadri, H., Dar, G. H., Dervash, M. A., Bhat, S. A., & Yousaf, B. (2022). Vulnerability of municipal solid waste: An emerging threat to aquatic ecosystems. *Chemosphere*, *14*(4), 1–13. https://doi.org/10.1016/j.chemosphere.2021.132223

Bikash, B., & Ichihashi, M. (2022). Household Preferences for Improved Solid Waste Management (SWM) Services: A Randomised Conjoint Analysis in Kathmandu Metropolitan Ward No. 10. *Sustainability*, *14*, 2251. https://doi.org/10.3390/su14042251

Clift, R., Doig, A., & Finnveden, G. (2000). The application of life cycle assessment to integrated solid waste management: Part 1-Methodology. *Process Safety and Environmental Protection*, *78*, 279–287. https://doi.org/10.1205/095758200530790

DEFRA. (2017). *Litter Strategy for England.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/727987/litter-strategy-annual-report-2017-2018.pdf

Eurostat. (2013). *Municipal waste generation and treatment, by type of treatment method.* Retrieved from https://www.eea.europa.eu/data-and-maps/data/external/municipal-waste-generation-and-treatment

Eurostat. (2019). *Recycling rate of municipal waste.*

Gana, B. A., Babanyara, Y. Y., & Abdulkadir, A. (2022). Prospects of the Involvement of Stakeholders in Solid Waste Processing in Developing Nations. *Journal of Environmental Treatment Techniques*, *10*, 81–91.

Hemidat, S., Achouri, O., Fels, L. E., Elagroudy, S., Hafidi, M., Chaouki, B., & Guo, J. (2022). Solid Waste Management in the Context of a Circular Economy in the MENA Region. *Sustainability*, *14*(1), 480. https://doi.org/10.3390/su14010480

Jainapur, S., Ahirwar, V., Pandit, S., Bambardekar, M., & Mulay, M. (2022). Solid waste management and ux: A sustainable experience. *International Journal of Research in Engineering*, *5*, 182–191.

Jarju, A. M., & Cato, S. (2022). The environmental health risk effect and the possible renewable energy potential of the solid waste dump site in Riverton City. *International Journal of Innovation and Applied Studies*, *36*, 306–312.

Jerin, D. T., Sara, H. H., Radia, M. A., Hema, P. S., Hasan, S., Urme, S. A., Audia, C., Hasan, M. T., & Quayyum, Z. (2022). An overview of progress towards implementation of solid waste management policies in Dhaka, Bangladesh. *Heliyon*, *8*(2). https://doi.org/10.1016/j.heliyon.2022.e08918

Khan, F., & Ali, Y. (2022). A facilitating framework for a developing country to adopt smart waste management in the context of circular economy. *Environmental Science and Pollution Research*, *29*, 26336–26351. https://doi.org/10.1007/s11356-021-17573-5

Korai, M. S., Mahar, R. B., & Uqaili, M. A. (2016). Optimisation of waste to energy routes through biochemical and thermochemical treatment options of municipal solid waste in Hyderabad Pakistan. *Energy Conversion and Management*, *124*, 333–343. https://doi.org/10.1016/j.enconman.2016.07.032

Kwenda, P. R., Lagerwall, G., Eker, S., & Van Ruijven, B. (2022). A mini-review on household solid waste management systems in low-income developing countries: A case study of urban Harare City. *Waste Management & Research*, *40*, 139–153. https://doi.org/10.1177/0734242X21991645

Muheirwe, F., Kombe, W., & Kihila, J. M. (2022). The paradox of solid waste management: A regulatory discourse from Sub-Saharan Africa. *Habitat International*, *119*, 102491. https://doi.org/10.1016/j.habitatint.2021.102491

Pal, M. S., & Bhatia, M. (2022). Current status, topographical constraints, and implementation strategy of municipal solid waste in India: a review. *Arabian Journal of Geosciences*, *15*, 1–26. https://doi.org/10.1007/s12517-022-10414-w

Pant, S., & Joshi, J. (2022). Solid waste management processes and problems in Almora municipal area of Uttarakhand. *IJAR*, *8*, 353–358.

Prinsen, A. (2022). *The Zero Waste Consultant. Zero Waste Consultant*. Rotterdam, Netherland.

Ranjbari, M., Esfandabadi, Z. S., Shevchenko, T., Chassagnon-Haned, N., Peng, W., Tabatabaei, M., & Aghbashlo, M. (2022). Mapping healthcare waste management research: Past evolution, current challenges, and future perspectives towards a circular economy transition. *Journal of hazardous materials*, *422*, 126724. https://doi.org/10.1016/j.jhazmat.2021.126724

Shahab, S., Anjum, M., & Umar, M. S. (2022). Deep learning applications in solid waste management: A deep literature review. *International Journal of Advanced Computer Science and Applications*, 13–13. https://doi.org/10.14569/IJACSA.2022.0130347

Singh, E., Kumar, A., Mishra, R., & Kumar, S. (2022). Solid waste management during COVID-19 pandemic: Recovery techniques and responses. *Chemosphere*, *288*, 132451. https://doi.org/10.1016/j.chemosphere.2021.132451

Singh, N., Ogunseitan, O., & Tang, Y. (2021). Medical waste: Current challenges and future opportunities for sustainable management. *Critical Reviews in Environmental Science and Technology*, *52*. https://doi.org/10.1080/10643389.2021.1885325

Statistics, N. (2017). *Overview of the UK population: March 2017.* Retrieved from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/mar2017

Tian, T., Liu, G., Yasemi, H., & Liu, Y. (2022). Managing e-waste from a closed-loop lifecycle perspective: China's challenges and fund policy redesign. *Environmental Science and Pollution Research*, 1–12. https://doi.org/10.1007/s11356-022-19227-6

Younes, M. K., Nopiah, Z. M., Basri, N. A., Basri, H., Abushammala, M. F., & Younes, M. Y. (2016). Landfill area estimation based on integrated waste disposal options and solid waste forecasting using modified ANFIS model. *Waste Management*, *55*, 3–11. https://doi.org/10.1016/j.wasman.2015.10.020

Zaman, A. U. (2016). A comprehensive study of the environmental and economic benefits of resource recovery from global waste management systems. *Journal of cleaner production*, *124*, 41–50. https://doi.org/10.1016/j.jclepro.2016.02.086