The Impact of Environmental Education and Awareness on the Effective Management of Solid Wastes Among Residents of Quetta: A review

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Abstract
The purpose of this study was to provide recommendations for enhancing environmental awareness and education in the region of Quetta, Pakistan, by investigating the influence of Environmental Education and Awareness on the Effective Management of Solid Wastes in the region. This was achieved by examining existing awareness on environmental policies, and how these influence people's attitudes towards SWM. This was accomplished by establishing a link between mindset and SWM strategies, and assessing the influence of individuals' environmental knowledge on how they address SW. Using a standardized survey, data were collected from 400 respondents from four zones: Kuchlack, Siryab, Kharot Abad and Nawakili, employing a systematic random sampling technique. The information gathered from the questionnaire was scrutinized. The findings revealed the presence of an environmental awareness policy in Quetta, Balochistan, as well as its effects on people's attitudes towards SWM. In addition, no association was found between attitudes and SWM practice. Also, environmental education did not influence Quetta people's attitudes towards SWM. Based on these findings, a collection of suggestions has been developed to assist practitioners, policymakers and especially academics in dealing with SWM.

Keywords: environmental awareness; SW; WM.

Introduction•

Anthropogenic activities have been releasing numerous trace elements into the environment, some of which are SW deposition from human operations. Waste generated by homes, businesses and factories, related to agriculture, mining and public sector operations, amongst others, is classified as SW [1]. SW is disposed of

•The abbreviations list is in page 261.

either in dumpsites within defined government or private land, and in unlawful burrow pits and empty places, in some cases. As a result, locals are concerned about the careless disposal of SW in crucial areas, which has resulted in piles of trash and widespread uncleanliness [2].

Herein, human attitudes regarding SWM were investigated. When garbage piles up and is not cleared, it produces filth and danger. Most environmental problems are caused by man-made pollution, which harms natural resources and living beings, since there are no effective regulations in place that support waste reduction, reuse and recycling [3].

The general population assumes that the government is largely responsible for SW collection and disposal. However, if the cleanup of the dumpsite is delayed or disregarded, the stench becomes unbearable [4]. Household garbage, junk, garden waste, business refuse, animal corpses, bulky debris, abandoned automobiles, medical waste, different sanitary remnants or weeds are examples of waste [5].

The care and handling of the specified SW becomes crucial as it accumulates. Most garbage generated in many developing countries is thrown indiscriminately on streets, marketplaces, dwellings, roadsides and open spaces. Waste products end up in rivers and channels, causing major environmental problems in the municipality, which is meant to be the state's master-planned area [6].

An effective approach to SWM by national, Local, State and regional authorities which is sustainable over bustling communities, can contribute to overall physical development [7]. This is required, since most cities in developing countries lack effective SWM programs.

Kuchlack may be found in latitude 09° 52′ N and longitude 008° 45′. It is connected to other cities in Quetta by air, train and road [8]. Although it is one of the planned towns, numerous residential neighborhoods in Quetta have degraded into slums, in recent years. The situation is likely to worsen until authorities commit to resolving the issue of urban waste management [9].

For this analysis, the institutional deficit hypothesis was applied. The concept is related to proper SWM in Pakistan's metropolis. Quetta's urban metropolis does not have enough public garbage cans. SW dumps are located beside the route, and when garbage accumulates, people and businesses dump it in the center of the major road, with no care for pollution [10]. This is mostly due to insufficient funding of institutions entrusted with waste generation and management, a lack of staff, bureaucratic bottlenecks, red tape and a high level of corruption [11].

This article's purpose was to investigate the level of education and environmental awareness about SWM in Kuchalack, Quetta. To build a framework on awareness about the environment and education, techniques on SWM in the city using a physical planning approach were taken into account [12].

Awareness about environment, SWM knowledge and practices

A survey about knowledge and awareness on environment and SWM techniques was undertaken to gain comprehension of the subject matter. The degree of knowledge and

practice on SWM by individuals and organizations, both businesses and government/public, was herein assessed [1]. Over the last two decades, extensive research has been undertaken worldwide on students' awareness, knowledge and behaviors towards WM. There was no research published in the international or Indian literature that examined the combined influence of schoolchildren's awareness, knowledge and combined practices on SW disposal [13]. The next sections will examine the literature on SW disposal understanding, comprehension and practices [14].
Awareness is the state or capacity to notice or be mindful of events, objects or sensory patterns. At this degree of consciousness, an observer can confirm sensory data without necessarily presuming knowledge [15]. Fig. 1 shows the steps of SWM.

Figure 1: Steps of SWM.

Education and public awareness have evolved into key components of any country's WM program. The same can be said about Pakistan's integrated WM plan, which is part of the country's garbage management policy. According to them, "environmental consciousness components may be divided into two categories: perception combined behavior, which includes an understanding of present ecological problems along with behavioral willingness to protect the atmosphere" [16].
People's objective information, perception and environmental reality all have a role in their view of environmental concerns. According to several studies, learning about the environment is an important component in developing a sense of responsibility among its citizens [17]. Understanding would increase their consciousness and comprehension of their surroundings, helping them to make educated informed and accountable decisions when becoming adults.
According to worldwide literature, raising knowledge and attitudes regarding garbage generation and disposal is vital to assisting the human race in addressing the present landfill management crisis. There is a shortage of material on children's environmental awareness [18].

Thus, it is advised that environmental curricula at educational institutions be reviewed, while also developing awareness and competence. Furthermore, a comparable study was undertaken in other areas of Balochistan.

It was later established that a thorough grasp of the repercussions of waste disposal systems should begin from the start of school education [1]. It is also critical to commit time to environmental education to inculcate in children a suitable and acceptable ecological culture. According to the report, knowledge of how to dispose of electronic waste is poor. Hence, there is an urgent need to bridge this understanding and practice gap [19].

Knowledge refers to the familiarity in perceiving someone or something, which may involve facts, information, descriptions or skills acquired through experience or training. It may refer to a subject's theoretical or practical comprehension [22]. It may be implicit (as with practical competences or skills) or explicit (as in theoretical understanding of a subject), formal or extensive.

Education in a certain topic is intrinsically linked to the knowledge of that subject. Teaching has been viewed as having the potential to address these challenges by increasing knowledge and information about different environmental problems, changing people's attitudes, encouraging innovative thinking and action, and working towards sustainable development [20]. Teaching ought to strive to increase the public's understanding of environmental challenges and solutions, and provide essential skills and knowledge. However, knowledge alone will not transform people's attitudes. The knowledge learning, its delivery, the trustworthiness of the communicator and the circumstances in which it was received all influence the recognition of a new attitude [21].

Studies in sociology have also shown that, while individuals' perspectives may change when they receive information on a particular problem, the path to improved behavior and routine is based on the complex combination of psychological and social factors [22]. It has been reported that people's understanding of the environment is extremely specific depending on the topic and geographic scale, which has been validated by research. It has also been argued that a lack of a basic environmental understanding is one of the reasons for poor environmental decision-making [23].

As a result, knowledge can be considered an important component in developing a person's understanding of environmental concerns and environmental consciousness that leads to action. A more recent study has concluded that knowledge may account for 40% of environmental activism [24].

SWM practices

Practice, as opposed to theories about implementation or use, is the actual application or usage of an idea, belief or method. All inhabitants on Earth's surface, in an ideal

world, would demonstrate high levels of environmental stewardship and accountability on WM [25].

It should be emphasized that research has shown that, while people's awareness and comprehension of environmental concerns may increase and their attitudes may change, the critical steps to transform behavior and practice are based on a wide range of cultural and psychological variables [26].

However, it is vital to put this knowledge, understanding and perspective into practice, so that actual outcomes for solving complex and interlinked problems such as handling waste will materialize [27]. As a result, there must be a continuing push to develop and promote an understanding of proper WM and sustainable environmental practices through education.

Schoolchildren all across the world have poor WM habits. Some articles have investigated the association between poor WM practices and characteristics, including awareness, behavior and knowledge. In most cases, these studies showed obvious correlations between poor WM practices and a lack of environmental knowledge and awareness [28].

Researchers also have claimed that, to achieve sustainable development, a more active and concentrated strategy is required to put all of the theories from ecological research into reality. All study efforts will be meaningless if the word is not followed by action, and incorrect WM will be a continual issue for the future human race [29].

This deliberate endeavor to translate insights from environmental studies into great practices for long-term development is especially important for Pakistan. Accepting the contribution that each country's citizens can give for achieving sustainable progress is essential. Fundamentals in WM comprehension and experience can lead to a more ecologically sound future [30].

Effectiveness of SWM authorities

Depending on the category or context in which it is used, SW can be defined in a variety of ways (Table 1).

Table 1: SW sources and varieties [37].

SN	Some sources	Different kinds of waste involving SW
1	Residence	Waste food, garbage, smoke, cardboard, paper goods, plastic bottles, fabrics and other specific SW.
2	Commercial/municipal affairs	Food particles, garbage, dust, deconstruction, cardboard, paper, other plastic materials, glass, glassware, wood, metals and construction materials.
3	Industry	Demolition and construction waste, specialized waste, sometimes hazardous waste, household waste, packaging and food waste.
4	Wide regions	Specialized waste, waste, plastics, paper and glassware.
5	Location of treatment equipment	Waste from treatment plants, primarily residual sewage.
6	Agricultural sector	Food waste, agricultural waste, garbage and toxic waste.

Waste is commonly defined as any material that is considered useless, implying that it is no longer necessary for its intended function. It can be viewed from two perspectives, based on their two primary functions [31].

In terms of a primary function, everything becomes a waste when it fails to perform its intended function. When something is no longer useful to one person, it may be valuable to another, so that and so one person's rubbish could become another one's raw goods [32].

SW is made up of organic and inorganic waste materials that are no longer needed and must be eliminated, due to their value reduction to users. Its resulting indiscriminate disposal harms the environment, and may cause diseases such as pneumonia, sickness and diarrhea, among others [33, 34].

As shown in Table 1, trash is created from a variety of sources, including home, industrial, commercial, agricultural, construction and demolition SW. Sewage generated from a range of resources in Pakistani metropoles contains 40% more carbon than that of many wealthy locations [35].

Unmanaged waste dumps, especially landfill sites, release significant amounts of methane gas, which is linked to greenhouse gas emissions. Furthermore, the issues related to e-waste, which is created by abandoned electronic equipment, have become a serious citywide issue [36].

*Sustainable industrialization and SW manag*ement

Waste disposal has emerged as one of humanity's most pressing issues in the modern era. Urbanization/industrialization of the world has resulted in the development of trash amounts that are now increasing to the point in which they are significantly affecting earth’s environmental systems [37].

The development of huge amounts of garbage is unable to continue since it results in the entire devastation of environmental systems, which has a severe influence on the well-being of people [38].

The notion of ecologically friendly growth has risen in response to this menace to the environment [39]. “Our Practical Future: Provide of the World Committee on Environment as well as Development”, the definition of viable growth, was originally issued in 1987 by the United Nations, which offered which is now one of the oldest and most widely recognized definitions: “Sustainable development is an expansion that meets the requirements of the present without first sacrificing the ability of the future generations in satisfying their individual needs” [40].

Hierarchy of WM

Everybody is responsible for preserving the health of the planet by limiting trash generation. This obligation has resulted in a WM hierarchy to reduce waste (Fig. 2) [41].

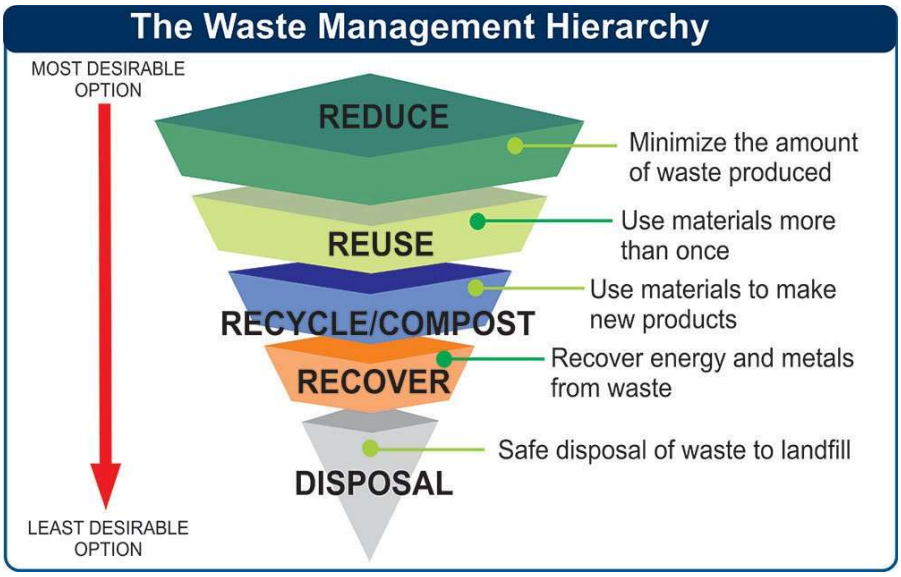

Figure 2: Hierarchy of WM [42].

Environmental education on SWM

Lack of schooling and understanding of effective handling of waste practices is one of the major problems in developing countries. Individuals lack interest in the environment when they are poorly informed, which affects their actions and excludes them from SWM decision making [42].

Legislation governing waste in Quetta

Pakistani Constitution is the most important source of law in Pakistan, and it is pertinent to this research in two respects. First, it comprises an environmental justice which includes administrative freedoms that establish a duty for waste regulation. Second, it establishes a regulatory framework for protecting everyone's ability to enjoy life in harmony with nature [43]. As a result, the constitution establishes a wide framework for environmental governance and preservation. Waste in Pakistan has been regulated by a variety of laws, including Pakistani Garbage Information Centre. WM Legislative Acts encompass major strategies designed to reach various aims, as mentioned in the sections below [44].

Based on waste hierarchy concepts, these techniques aim waste elimination. Pakistan's waste regulation structure previously outlined shows there is significant legislative heterogeneity that needs to be addressed by Pakistani government, since it is detrimental to long-term economic and governance activities, as demonstrated by [46]. According to the research, fragmented and disorganized laws may be connected to historical events, which meant that a developing country like Pakistan was not geared toward long-term prosperity. Therefore, it is consequently proposed that legislative heterogeneity be given priority in all Pakistani environmental laws [45].

Level of awareness and attitudes towards SWM

Along with appropriate regulations, proper technical help and adequate funding, public knowledge and engagement are critical components of any waste disposal strategy. Waste is a result of human activity and, without a thorough understanding of garbage disposal issues, even the absolute best-conceived disposal management strategy seems ineffective [46, 47].

General public's awareness and attitudes towards waste can influence all parts of the SWM process. This affects household waste segregation and storage spaces. Related issue is reusing materials, collector frequency, littering and fly-tipping, willingness to make payments for the disposal of waste solutions and volume and character of criticism directed at waste disposal and treatment [48].

In general, Imran Khan administration sought to educate everyone. However, some people have a negative attitude towards how to dispose of trash. Those who work with SW are often considered unclean, impoverished and inferior. Carrying household rubbish to bins or waste collection places is frequently viewed as a child's responsibility. It is not only the government's job to raise public awareness of the need for public information regarding environmental management procedures, since individuals also play a vital role [49].

SW in Quetta

The problem with WM is quite broad, since it involves all aspects of SW, including its handling, whether directly or indirectly. Quetta's municipality institution lacks the resources and technical expertise to satisfy the needs of the city's rising population. Poor people in rural areas are often interested in self-help programs like SWM and regeneration. Nearly every paper, plastic, metal and glass is collected and recycled [50]. As a result, disadvantaged populations in rural regions play a significant role in trash recycling (Fig. 3).

Organic rubbish is the only waste left on sidewalks and pickup locations, which may be used to generate fertilizer. However, municipalities and the business sector have taken the greatest possible use of this opportunity [51].

Figure 3: Waste collection from dumps.

Potential for waste recycling in Quetta

Quetta does not engage in any form of recycling operation under the current system. People retain key recyclable commodities, such as paper, glass and metals, which are then sold to street hawkers for reuse [52]. Scavengers gather up recyclables mixed with abandoned waste, making two to three trips to various dumps, and earning $150/300 per day.

Informal/formal division

The involvement of the private sector in waste disposal is divided into official and unofficial categories. The formal sector includes governmental and non-governmental entities. The informal sector is substantial, consisting of thousands of nomad traders (known as *Kabari walls*) dispersed around the municipality who gather various forms of garbage [53].

Private companies can initiate organic and inorganic WM programs. Organic fertilizer is made from organic waste. Paper, tin, plastic and other inorganic debris are first separated. Then, it is sold to industries and recycled into products such as plastic wood composite tetra sheets. Unforeseen urbanization, inadequate sanitation and drainage structure, insufficient human and capital resources for waste collection, a lack of legally binding dumping sites, shortage of weight bridges for accurate waste measurement on-site and the lack of recycling procedures have all affected WM within Quetta [54].

In Quetta, waste has the potential to be transformed into a lucrative economic resource for many NGO, including business entities. These groups may collect garbage and recycle it into fertilizer, plastic bottles and tetra pack products. A privately held business can establish a recycling facility in Quetta and begin producing fuel derived from refuse based on the waste-to-energy concept. NGO may also motivate people to sell waste to them, since it can be recycled into soil-purifying nutrients [55].

Data gathered from liquid waste might be sold on the marketplace as liquid nutrition for plants. Despite the government's long-standing commitment to bring opportunities for converting trash into electricity and other useful uses, a lack of suitable infrastructure hinders the industry from growing. Although Baluchistan government recognizes the importance of WM industry it is required a more successful and reasonable methodology, most likely based on partnerships, for encouraging this industry to create a cleaner environment and contribute to economic growth [56].

Thus, it is highly encouraged that Baluchistan's authorities develop a public-private collaboration policy, in addition to a study on the privatization of SW disposal, to formalize the process of addressing sustainability challenges, while also providing local governments with revenue-generating capabilities [57].

Legal framework regarding MSWM in Quetta

All states should develop a policy for sustainable disposal of SW that meets public health, hygiene and environmental quality concerns. The approach should emphasize

long-term trash dump availability for future generations of people. Pakistan's hazardous waste legislation and regulations are insufficient and out of date. It is urgent to enact SWM legislation which should include measures related to MSW management [58].

A strategy outlining the roles of public and private players is essential. It was recently observed that legal documents may be established to assign responsibilities, of which scope must be expanded. The legislative structure should ensure that policies are met within a set timeframe. There should be a policy framework in place to enable the preparation and execution of MSWM approaches and systems [59].

Conclusion

This article investigated the degree of knowledge and instruction on the handling of SW in Pakistan, to provide a framework for environmental awareness and education throughout the country. The goal was accomplished by carefully examining the existing policy on environmental awareness and its impact on public perceptions of SWM handling. According to several researches and personal experiences, the main issues of SWM in Quetta include lack of disposal systems, resources and competent staff members, and a poor complaint mechanism for communities. All of these gaps may be filled if the government of Baluchistan wishes to develop policies and implement them. There ought to be community-wide awareness campaigns about garbage separation from the household level. It is required to determine the relationship between SWM knowledge and practices, and assessing how the residents' perception of environmental awareness influences the latter.

Hence, it was found that there was a high level of awareness about SWM in Quetta, Pakistan. However, the question remains, why is the city in a not constant state of cleanliness?

Recommendations

In light of the findings, the following recommendations were made: there is a need to develop an environmental awareness policy for SWM in the Jos metropolis. It is necessary to establish and implement a corresponding and appropriate policy. There remains a continuing need for attention to guarantee sustainable SWM practices. Because there is a lack of environmental education on SWM in Quetta, a continual campaign to guarantee frequent updates for sustainability should be implemented.

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Conflict of interest

The authors revealed no competing interest regarding the study activity.

Authors' contributions

N. Karamat: wrote the manuscript. **A.A. Bhutto**: helped with figures, tables and grammar mistakes. **M.Asif**: corrected all paper sequence in the manuscript. **M. Siddique**: helped in doi and references. **S. K. Suri**: improved abstract and conclusion. **M. Abas**: improved plagiarism. **M. S. Aamir:**did all paper proofreading.

Abbreviations

MSW: municipal solid waste
MSWM: municipal solid waste management
SW: solid waste
SWM: solid waste management
T: temperature
WM: waste management

References

1. Moghadam MA, Mokhtarani N, Mokhtarani B. Municipal solid waste management in Rasht City, Iran. Waste Manag. 2009;29:485-9. https://doi.org/10.1016/j.wasman.2008.02.029
2. Grangxabe XS, Madonsela BS, Maphanga T et al. An overview of waste management practices of street vendors in sub-saharan africa: A meta-analysis. J Environ Manag. 2024;364:121464. https://doi.org/10.1016/j.jenvman.2024.121464
3. Ahmed SA, Ali SM. People as partners: Facilitating people's participation in public-private partnerships for solid waste management. Habit Int. 2006;30(4):781-96. https://doi.org/10.1016/j.habitatint.2005.09.004
4. Khoshnodifar Z, Ataei P, Karimi H. Recycling date palm waste for compost production: A study of sustainability behavior of date palm growers. Environ Sustain Indic. 2023;20:100300. https://doi.org/10.1016/j.indic.2023.100300
5. Singh RP, Singh P, Araujo AS et al. Management of urban solid waste: Vermicomposting a sustainable option. Resour Conserv Recycl. 2011;55(7):719-29. https://doi.org/10.1016/j.resconrec.2011.02.005
6. Srivastava V, Ismail SA, Singh P et al. Urban solid waste management in the developing world with emphasis on India: challenges and opportunities. Rev Env Sci Bio/Tech. 2015;14(2):317-37. https://doi.org/10.1007/s11157-014-9352-4
7. Sharholy M, Ahmad K, Mahmood G et al. Municipal solid waste management in Indian cities – A review. Waste Manag. 2008;28(2):459-67. https://doi.org/10.1016/j.wasman.2007.02.008
8. Ambulkar AR, Shekdar AV. Prospects of biomethanation technology in the Indian context: a pragmatic approach. Resour Conserv Recycl. 2004;40(2):111-28. https://doi.org/10.1016/S0921-3449(03)00037-5

9. El-Fadel M, Findikakis AN, Leckie JO. Environmental impacts of solid waste landfilling. J Environ Manage. 1997;50:1-25. https://doi.org/10.1006/jema.1995.0131
10. Adekunle IM, Adetunji MT, Gbadebo AM et al. Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. Int J Environm Res Pub Health. 2007;4:307-18. https://doi.org/10.3390/ijerph200704040007
11. Mkandawire T. Quality of groundwater from shallow wells of selected villages in Blantyre District, Malawi. Phys Chem Earth, Parts A/B/C. 2008;33(8-13):807-11. https://doi.org/10.1016/j.pce.2008.06.023
12. Talang RP, Sirivithayapakorn S. Comparative analysis of environmental costs, economic return and social impact of national-level municipal solid waste management schemes in Thailand. J Clean Prod. 2022;343:131017. https://doi.org/10.1016/j.jclepro.2022.131017
13. lo Storto C. Measuring ecoefficiency of municipal solid waste management in Apulia to account for governance heterogeneities. Clean Waste Syst. 2024;7:100131. https://doi.org/10.1016/j.clwas.2024.100131
14. Luo L, Guo S, Shen D et al. Characteristics and release potential of microplastics in municipal solid waste incineration bottom ash. Chemosphere. 2024;364:143163. https://doi.org/10.1016/j.chemosphere.2024.143163
15. Asif M, Siddique M, Abbas A et al. Production of Sustainable Bioplastic Derived from Renewable Lignocellulosic Agricultural Biomass: A Comprehensive Review. Front Wat Environ. 2024;4(1):1-4. https://doi.org/10.37934/fwe.4.1.114
16. Soomro SA, Ahmad H, Asif M. Lignin used as a green and sustainable agriculture biomass for renewable application. A comprehensive review. J Chem Nutr Biochem. 2023;4(1):47-55. https://doi.org/10.48185/jcnb.v4i1.731
17. Soomro SA, Ahmad H. A comprehensive review of nocellulosic biomass and potential production of bioenergy as a renewable resource in Pakistan. J Chem Nutr Biochem. 2021;2(2):46-58. https://doi.org/10.48185/jcnb.v2i2.408
18. Beaudin N, Caron RF, Legros R et al. Cocomposting of weathered hydrocarbon-contaminated soil. Compost Sci Utiliz. 1996;4:37-45. https://doi.org/10.1080/1065657X.1996.10701828
19. Raschid-Sally L. City waste for agriculture: emerging priorities which influence agenda setting. Aqua Proced. 2013;1:88-99. https://doi.org/10.1016/j.aqpro.2013.07.008
20. Muhammad T, Jiang C, Li Y et al. Impacts and mechanism of coal fly ash on kitchen waste composting performance: The perspective of microbial community. Chemosphere. 2024;350:141068. https://doi.org/10.1016/j.chemosphere.2023.141068
21. Nelles M, Gruenes J, Morscheck G. Waste management in Germany–development to a sustainable circular economy? Proced Environ Sci. 2016;35:6-14. https://doi.org/10.1016/j.proenv.2016.07.001

22. Korai MS, Mahar RB, Uqaili MA. The feasibility of municipal solid waste for energy generation and its existing management practices in Pakistan. Renew Sustain Ener Rev. 2017;72:338-53. https://doi.org/10.1016/j.rser.2017.01.051
23. Imran M, Haydar S, Kim J et al. E-waste flows, resource recovery and improvement of legal framework in Pakistan. Res Cons Rec. 2017;125:131-8. https://doi.org/10.1016/j.resconrec.2017.06.015
24. Fidelis R, Guerreiro ED, Horst DJ et al. Municipal solid waste management with recyclable potential in developing countries: Current scenario and future perspectives. Waste Manag Res. 2023;41(9):1399-419. https://doi.org/10.1177/0734242X231160
25. Naveenkumar R, Iyyappan J, Pravin R et al. A strategic review on sustainable approaches in municipal solid waste management and energy recovery: Role of artificial intelligence, economic stability and life cycle assessment. Biores Technol. 2023;379:129044. https://doi.org/10.1016/j.biortech.2023.129044
26. Roy H, Alam SR, Bin-Masud R et al. A review on characteristics, techniques and waste-to-energy aspects of municipal solid waste management: Bangladesh perspective. Sustainability. 2022;14(16):10265. https://doi.org/10.3390/su141610265
27. Kumar A, Samadder SR. A review on technological options of waste to energy for effective management of municipal solid waste. Waste Manag. 2017;69:407-22. https://doi.org/10.1016/j.wasman.2017.08.046
28. Asif M, Laghari M, Mukwana KC et al. Pretreatment of Lignocellulosic Waste Material Conversion into Biofuel and Environmental Impact: A Comprehensive Review. Port Electrochim Acta. 2025;43(03):153-164. https://doi.org/10.4152/pea.2025430301
29. Asif M, Laghari M, Abubakar AM et al. Review on Municipal Solid Waste, Challenges and Management Policy in Pakistan. Port Electrochim Acta. 2025;43(04):249-258. https://doi.org/10.4152/pea.2025430404
30. Brunhara JP, Macedo KG, Das TK et al. A driving force-pressure-state-impact-response (DPSIR) tool to help waste pickers' cooperatives self-evaluate their environmental and economic performance. Hyg Environ Health Adv. 2023;6:100054. https://doi.org/10.1016/j.heha.2023.100054
31. Sha W. Literature review on waste management of online food delivery industry in China. Chin J Pop Res Environ. 2023;21(3):197-202. https://doi.org/10.1016/j.cjpre.2023.09.009
32. Awasthi P, Chataut G, Khatri R. Solid waste composition and its management: A case study of Kirtipur Municipality-10. Heliyon. 2023;9(11):e21360. https://doi.org/10.1016/j.heliyon.2023.e21360

33. Ahsan A, Alamgir M, Imteaz M et al. Municipal solid waste generation, composition and management: Issues and challenges. A case study. Environ Prot Eng. 2015;(3):43-59. https://doi.org/10.5277/epel50304
34. Alwedyan S. The urban household solid waste generating factors and composition study—A case study: Irbid City–Jordan. Environ Qual Manag. 2022;(4):235-48. https://doi.org/10.1002/tqem.21808
35. Rupani PF, Maleki Delarestaghi R, Asadi H et al. Current scenario of the Tehran municipal solid waste handling rules towards green technology. Inter J Environ Res Publ Health. 2019;(6):979. https://doi.org/10.3390/ijerph16060979
36. Pitakaso R, Srichok T, Khonjun S et al. Optimization-driven artificial intelligence-enhanced municipal waste classification system for disaster waste management. Eng Appl Artif Intell. 2024;133:108614. https://doi.org/10.1016/j.engappai.2024.108614
37. Taouahria B. Predicting citizens municipal solid waste recycling intentions in Morocco: The role of community engagement. Waste Manag Bull. 2024;2(1):316-26. https://doi.org/10.1016/j.wmb.2024.02.008
38. Alam S, Rokonuzzaman M, Rahman KS et al. Techno-economic and environmental analysis of organic municipal solid waste for energy production. Heliyon. 2024;10(11):e361670. https://doi.org/10.1016/j.heliyon.2024.e31670
39. Dehghanifard E, Dehghani MH. Evaluation and analysis of municipal solid wastes in Tehran, Iran. MethodsX. 2018;5:312-21. https://doi.org/10.1016/j.mex.2018.04.003
40. Malmir T, Tojo Y. Municipal solid waste management in Tehran: Changes during the last 5 years. Waste Manag Res. 2016;34(5):449-56. https://doi.org/10.1177/0734242X16632056
41. Phillips J, Gholamalifard M. Quantitative evaluation of the sustainability or unsustainability of municipal solid waste options in Tabriz, Iran. Inter J Environ Sci Technol. 2016;13:1615-24. https://doi.org/10.1007/s13762-016-0997-0
42. Behrooznia L, Sharifi M, Hosseinzadeh-BH. Comparative life cycle environmental impacts of two scenarios for managing an organic fraction of municipal solid waste in Rasht-Iran. J Clean Prod. 2020;268:122217. https://doi.org/10.1016/j.jclepro.2020.122217
43. Meena MD, Dotaniya ML, Meena BL et al. Municipal solid waste: Opportunities, challenges and management policies in India: A review. Waste Manag Bull. 2023;1(1):4-18. https://doi.org/10.1016/j.wmb.2023.04.001
44. Sandoval-RM, He R, Semeano R et al. Mathematical optimization of waste management systems: Methodological review and perspectives for application. Waste Manag. 2024;174:630-45.https://doi.org/10.1016/j.wasman.2023.10.006

45. Soares S, Serralha F, Paz MC et al. Unveiling the data: An analysis of plastic waste with emphasis on the countries of the E³UDRES2 alliance. Heliyon. 2024;10(7): e28375. https://doi.org/10.1016/j.heliyon.2024.e28375
46. Cui W, Wei Y, Ji N. Global trends of waste-to-energy (WtE) technologies in carbon neutral perspective: Bibliometric analysis. Ecotoxicol Environ Safe. 2024;270:115913. https://doi.org/10.1016/j.ecoenv.2023.115913
47. Milbrandt A, Zuboy J, Coney K et al. Paper and cardboard waste in the United States: Geographic, market and energy assessment. Waste Manag Bull. 2024;2(1):21-8. https://doi.org/10.1016/j.wmb.2023.12.002
48. Saranga H, Roy S, Chowdhury S. Charting a sustainable future: Transformative policies for India's energy, agriculture and transport sectors. IIMB Manag Rev. 2024;36(1):21-38. https://doi.org/10.1016/j.iimb.2024.02.005
49. Karthikeyan PK, Bandulasena HC, Radu T. A comparative analysis of pre-treatment technologies for enhanced biogas production from anaerobic digestion of lignocellulosic waste. Industr Crops Prod. 2024;215:118591. https://doi.org/10.1016/j.indcrop.2024.118591
50. Haither AH, Anjali G. Sustainable urban development: Evaluating the potential of mineral-based construction and demolition waste recycling in emerging economies. Sustain Fut. 2024;7:100179. https://doi.org/10.1016/j.sftr.2024.100179
51. Shafiei-AR, Aghbashlo M, Tabatabaei M et al. A critical review of sustainable biorefineries utilizing high-solid processing for industrial crop lignocellulosic wastes valorization. Indust Crops Prod. 2024;211:118236. https://doi.org/10.1016/j.indcrop.2024.118236
52. Trushna T, Krishnan K, Soni R. Interventions to promote household waste segregation: A systematic review. Helyon. 2024;1082):e24332 https://doi.org/10.1016/j.heliyon.2024.e24332
53. Hu J, Miao L, Han J et al. Waste separation behavior with a new plastic category for the plastic resource circulation: Survey in Kansai, Japan. J Environ Manag. 2024;349:119370. https://doi.org/10.1016/j.jenvman.2023.119370
54. Kumar M, Bhujbal SK, Kohli K et al. A review on value-addition to plastic waste towards achieving a circular economy. Sci Tot Environ. 2024;921:171106. https://doi.org/10.1016/j.scitotenv.2024.171106
55. Manzoor S, Fayaz U, Dar AH et al. Sustainable Development Goals Through Reducing Food Loss and Food Waste: A Comprehensive Review. Fut Foods. 2024;9:100362. https://doi.org/10.1016/j.fufo.2024.100362
56. Haque A, Nath ND, Johnston TV et al. Harnessing biotechnology for penicillin production: Opportunities and environmental considerations. Sci Tot Environ. 2024;946:174236. https://doi.org/10.1016/j.scitotenv.2024.174236

57. Piadeh F, Office I, Behzadian K et al. A critical review for the impact of anaerobic digestion on the sustainable development goals. J Environ Manag. 2024;349:119458. https://doi.org/10.1016/j.jenvman.2023.119458
58. Archana K, Visckram AS, Kumar PS et al. A review on recent technological breakthroughs in anaerobic digestion of organic biowaste for biogas generation: Challenges towards sustainable development goals. Fuel. 2024;358:130298. https://doi.org/10.1016/j.fuel.2023.130298
59. Bakari R, Asha R, Hossein M et al. Converting Food Waste to Biofuel: A Sustainable Energy Solution for Sub-Saharan Africa. Sustain Chem Environ. 2024;7:100126. https://doi.org/10.1016/j.scenv.2024.100126