



Perspective

Hazardous Waste Management: Are Sustainable Development Goals Enough to Address Future Requirements? A Critical Perspective

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Abstract: Globally, over 400 million tons of hazardous wastes are generated per year, and are global problems to health, environment and economy. Despite enforcement of legislations and guidelines by World Health Organization, United Nations Environment Programme and countries, sustainable management of hazardous wastes is yet to be achieved. The present perspective based on expert commentary aimed to analyse whether current Sustainable Development Goals (SDGs) are enough to manage hazardous waste sustainably, and proposed a waste-to-SDG loop to achieve the same. Out of 17 SDGs, Goal 3 (good health and well-being), Goal 6 (clean water and sanitation), Goal 11 (sustainable cities and communities) and Goal 12 (responsible consumption and production) are relatively closer to waste management. So far, 18% progress on SDG achievement has been reported with 17% moderate progress and 48% marginal progress but 17% progress was even retrograde. Though some progress in SDG achievement has been documented in social protection, maternal and child mortality, women empowerment, still progress in hazardous waste management (HWM) is not properly recorded. HWM guidelines or policies focus more on technical aspects while giving less emphasis on other dimensions of sustainability i.e., environment and circular economy. In future, SDGs and legislations on HWM should go hand-in-hand, and considering SDG in a continuous loop with legislations, transboundary movement and other pertinent aspects would help achieve sustainable management of hazardous wastes.

Keywords: hazardous wastes; SDGs; waste-to-SDG loop

1. Introduction

Hazardous wastes are global threats to public health, ecology and economy as these possess diverse properties that are lethal to health and environment. Some of these properties are flammability, explosivity, oxidizing potential, irritancy, corrosivity, sensitization potential, acute specific target organ toxicity, carcinogenicity, mutagenicity, infectivity, air toxicity and ecotoxicity [1,2]. The United States Environmental Protection Agency (USEPA) categorised hazardous wastes into F, K, P and U lists. The F-list items are wastes from industrial processes and the K-list materials are also generated from specific manufacturing processes. Similarly, the P-list identifies commercial chemical products and the U-list items include pure or technical grade chemicals [2]. Hazardous wastes include several categories such as chemicals, e-waste, pharmaceutical and cytotoxic wastes, heavy metals, sharp wastes, and other [3,4]. These wastes can be in the form of solid, liquid, gas, sludge or leachate, and can be released into the environment if not properly encapsulated or immobilized [3]. Table 1 shows brief overview of categories of hazardous wastes and their health, environmental and economic hazards.



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Table 1. Categories of hazardous wastes [4,5].

| Categories | Brief Description | Examples | Hazards |
|--|--|--|--|
| 1. Chemical wastes | | | |
| a. Corrosive wastes | Can corrode metals at pH ≤ 2 or pH ≥ 12 | Acidic or alkaline chemicals, battery acids, rust removers, halogenated and non-halogenated solvents, disinfectants and antiseptics | |
| b. Reactive wastes | Can react violently with water or air and release toxic gases | Explosives, lithium-sulphur batteries, peroxides, perchloric acid, toxic gases (e.g., hydrogen cyanide, hydrogen sulphide) | Health hazards Tissue damage, respiratory problems (e.g., pulmonary oedema), systemic toxicity |
| c. Oxidizing wastes | Can promote combustion and increase flammability through oxidation | Bleaching agent, nitrates, peroxides, perchlorates | Environmental hazards Ecotoxicity, air pollution, soil and water contamination |
| d. Ignitable or flammable wastes | Can catch fire below 60 °C | Alcohols, aerosols and pressurised containers, organic solvents, paint thinners | Economic hazards Costs of infrastructure damage, remediation and management costs |
| e. Toxic wastes | Can harm humans or environment if absorbed, ingested or inhaled | Asbestos, heavy metals (e.g., cadmium, lead, mercury), insecticides, herbicides and pesticides (e.g., carbamates, dichloro-diphenyl-trichloroethane, organophosphates) | |
| 2. E-wastes and automobile wastes | | | |
| | Expired electrical or electronic items | Computers, phones, televisions, antifreeze, car batteries, motor oils | Health hazards Respiratory and neurological damage, cancers with dioxins and furans, reproductive and developmental delays Environmental hazards Ecotoxicity leading to biodiversity loss, air pollution, soil and water contamination, greenhouse gas emission leading to acid rain, ozone layer depletion and global warming Economic hazards Loss of precious metals (e.g., gold, silver, cobalt), reduced agricultural productivity, increased expenditure on public health |
| 3. Hazardous healthcare wastes | | | |
| a. Infectious wastes | Can transmit or spread diseases (e.g., HIV, hepatitis B, hepatitis C) | Laboratory wastes, used dressings, wastes from hospital wards | Health hazards Disease transmission, needlestick injuries, cancers and systemic toxicities |
| b. Pathological wastes | Can contain bacteria, viruses, parasites and cause diseases (e.g., tuberculosis, anthrax, skin infections) | Amputated body parts, placentas, blood and body fluids | (e.g., respiratory problems, neurotoxicity, antimicrobial resistance, birth defects) Environmental hazards |
| c. Pharmaceuticals and cytotoxic wastes | Expired, unused or contaminated medicines | Antibiotics, anti-inflammatory drugs, controlled drugs, anticancer drugs, genotoxic chemicals | Environmental contamination via release of carcinogens (e.g., dioxins and furans) during incineration, contamination of soil and water source through leachate and wastewater, ecotoxicity |
| d. Sharp wastes | Can puncture or cut skin and body tissues | Blades, broken glasses, syringes and needles, infusion sets, scalpels | Economic hazards |
| e. Nuclear or radioactive wastes | Can emit ionizing radiations (e.g., alpha particles, beta particles, gamma rays, X-rays) | Syringes and vials contaminated with radionuclides, liquids contaminated with radiotherapy | Financial burden for treatment and disposal and environmental remediation |
| 4. Universal wastes and medical devices | | | |
| | Frequently generated hazardous materials | Batteries, mercury-containing equipment (e.g., thermometers) | Health hazards Injuries and spread of blood-borne diseases (e.g., HIV, hepatitis B, hepatitis C), release of carcinogens (e.g., dioxins, furans), antimicrobial resistance, respiratory and cardiovascular problems Environmental hazards Air, water and soil pollution, plastics and microplastics pollution Economic hazards High management costs with incineration or autoclaving, reduced health productivity and increased healthcare burden |
| 5. Household hazardous materials | | | |
| | | Aerosols and pressurised containers, cleaning fluids, paints, personal care products, cleaners | Health hazards Acute injuries (e.g., skin burns, respiratory and eye diseases, nervous system damage) Environmental hazards Air pollution, soil and water contamination, bioaccumulation in food chain Economic hazards Increased treatment and disposal costs, high environmental remediation costs |

The globally acknowledged concept of sustainable development refers to the development that meets the requirements of the current time without compromising the needs of future generations [6]. Sustainable

development is considered as the universal strategy to eradicate poverty, conserve the planet and ensure that all people live in peaceful and prosperous environment by 2030 [7]. The 17 Sustainable Development Goals (SDGs), 169 targets and 232 indicators were adopted as the Global Goals to contribute to four main dimensions of sustainability i.e., social inclusion, environmental sustainability, economic prosperity and good governance [8].

Despite enforcement of legislations and guidelines by international agencies such as World Health Organization (WHO), United Nations Environment Program (UNEP) and countries, sustainable management of hazardous wastes is yet to be achieved. Globally, over 400 million tons of hazardous wastes are generated per year [9]. The average costs of managing hazardous wastes range from USD 450 per ton for waste acids, alkalis and solvents and industrial sludge to USD 6020 per ton for discarded chemical reagents, polychlorinated biphenyls and chlorine-containing hazardous wastes. The laboratory wastes, medical wastes and hazardous wastes with high organic matter cost USD 1020 to 1200 per ton for the management [9]. It has already been a decade since the adoption of SDG in 2015, and now, it is the time to evaluate the progress SDG achievement in hazardous waste management (HWM), which has been uniquely advocated in this perspective. Research publications exist on HWM and SDGs as separate topics but literature advocating the integration of HWM into SDGs remains limited. Therefore, this study has raised this knowledge gap that HWM should be integrated into SDGs, and proposed a novel way to do achieve this through the ‘waste-to-SDG loop’. The present perspective paper based on expert commentary aimed to explore the need of assessing SDGs progress in terms of HWM and suggest a way forward for the same. This research is novel in discussing the need of the inter-connection of HWM with SDGs and proposing the ‘waste-to-SDG loop or circle’ to achieve sustainable management of hazardous wastes. The previous research discussed only about SDGs progress in terms of overall economy, poverty reduction, gender equality and other social issues but not HWM. The current perspective would sensitise policy makers and SDG advocates in rethinking the existing SDG framework and associated targets to address the full spectrum of HWM challenges.

2. Current Status of SDG Achievement

The SDGs aimed to emphasise five broader aspects of people, planet, prosperity, peace and partnership [10]. However, the SDG Progress Report 2025 stated critical situation of progress in achieving the target by 2030, showing only 18% progress on track and 17% moderate progress. While there was 48% marginal progress on SDG achievement, remaining 17% progress is even retrograde [11]. The status of SDG achievement is insufficient in Africa compared to other regions [12]. Some progress in SDG achievement has been seen social protection, child marriage, maternal and child mortality, women empowerment, access to electricity and internet connectivity, and management of communicable diseases (e.g., HIV, malaria, etc.). Still more than 800 million people live in extreme poverty and hunger, and the world is facing great climatic calamity with the highest records of carbon dioxide levels over two million years [13]. However, the report does not fragment the progress status on HWM and other associated issues such as health and environmental impacts, and costs of managing these. The disaggregated data by region, income group of hazardous waste producers or waste category are lacking in the report. Previously, the EASIER framework gave equal weighting to six dimensions (i.e., stakeholder engagement, accessibility, scalability and replicability, inclusiveness, economic impact, and resilience and environmental impact) that are vital to achieving and advancing SDGs but still lacks the contexts of HWM [14]. In traditional linear model, economic growth and environmental sustainability cannot go parallel as these are based on the foundation of other. The traditional approach of economic growth was mainly based on exploitation of available resources without considering the needs for future generations, which is against the norms of SDGs. This linear modality of economic growth threatened environmental sustainability and necessitated adoption of circular economy or circularity in economic development giving due consideration to the environmental preservation and protection for the present and future [15]. The same issues of environmental sustainability and circularity are relevant to HWM as well. Hence, future SDG reports should give space to the progress status of region-wise hazardous wastes generation, their health and environmental impacts, costs of management and hurdles and their solutions in achieving sustainable HWM.

3. Methodology

The current perspective research was grounded on the expert commentary covering the issues of SDG progress in terms of HWM, and integrating SDGs and associated targets with HWM. The existing literature pertinent to SDG and HWM were searched on large databases such as Scopus, Science Direct and PubMed/Medline using the string of keywords (“hazardous waste management” AND “sustainable development goals”). The articles which had descriptions of both components (i.e., SDGs and HWM) were included whereas those lacking any of the components or both components were excluded from the study. Other data sources to

extract relevant literature were websites of various agencies such as USEPA, United Nations, UNEP and other. The SDGs and associated targets and existing status of SDGs progress in achieving HWM were extracted from the United Nations database [11].

4. Emphasis of SDGs on Hazardous Waste Management

A total of 10 papers were extracted from Scopus, 241 articles in Science Direct and 2 papers in PubMed/Medline database by keeping the aforementioned keywords (dated 13th March 2026). However, none of these papers were directly pertinent to address the topic matter i.e., SDGs and HWMs and their co-integration. SDGs should give due emphasis on safe and sustainable management of diverse categories of hazardous wastes. Usually, the management approach varies depending on the categories of hazardous wastes. Some approaches (e.g., non-incineration technology) emphasise environmental sustainability while compromising rest of the pillars of SDGs (i.e., social, economic, technological and governance). On the other hand, incineration or thermal combustion technology shows meagre profile of environmental sustainability due to the emission of carcinogens like dioxins and furans, and other persistent organic pollutants (POPs), which have high bio-accumulation and bio-magnification. Therefore, POPs from hazardous wastes generated by preceding generations and present generation would be transferred to succeeding generations, and severely affect them. Therefore, exact trajectory of hazardous wastes and their sustainable management and status of SDGs progress in terms of HWM are warranted. Out of 17 SDGs, Goal 3 (good health and well-being), Goal 6 (clean water and sanitation), Goal 11 (sustainable cities and communities) and Goal 12 (responsible consumption and production) are relatively closer to waste management. Still, it is not clearly documented in literature whether these SDGs and targets are enough to manage health and environmental concerns of hazardous wastes. Table 2 details the SDGs and targets that are aligned with waste management, and their progress reported by the United Nations Report [11]. Though the progress status simply indicated three categories i.e., ‘on track’, ‘stagnation’ and ‘regression’, these do not specifically report the progress status on HWM. Therefore, current SDG Report still lacks objective evaluation of SDG achievement towards sustainable HWM targeting their broader aspects such as health, environmental and economic aspects. Hence, based on the available SDG Report, it can be inferred that SDGs should be extended to encompass all essential aspects of HWM.

Table 2. SDGs and targets closer to waste management [11].

| SDGs | Targets | Domain | Progress Status |
|---|---|---|-----------------|
| Goal 3: Ensure healthy lives and promote well-being | Target 3.9: Reduce the number of illnesses and deaths from hazardous chemicals and pollutions in air, water and soil | Health impact of pollution | On track |
| Goal 6: Ensure sustainable management of water and sanitation | Target 6.3: Improve water quality by reducing pollution and minimizing release of hazardous chemicals and materials | Water quality | Stagnation |
| | Target 6.a: Expand capacity-building in wastewater treatment, recycling and reuse technologies | International cooperation on water and sanitation | Regression |
| Goal 11: Make cities safe, resilient and sustainable | Target 11.6: Reduce adverse environmental impact of cities by paying attention to air quality and municipal and other waste management | Urban air quality and waste management | On track |
| Goal 12: Ensure sustainable consumption and production | Target 12.3: Halve global food waste and reduce food losses in production and supply chains | Food waste and losses | Regression |
| | Target 12.4: Achieve environmentally sound management of chemicals and wastes throughout their lifecycle, and reduce their release to air, water and soil to minimise their adverse impacts on health and environment | Managing chemicals and wastes | Stagnation |
| | Target 12.5: Reduce waste generation through prevention, reduction, recycling and reuse | Reduction in waste generation | Regression |
| | Target 12.c: Rationalise inefficient fossil-fuel subsidies to minimise waste and environmental impacts and to protect the poor and the affected communities. | Fossil fuel subsidies | Regression |

5. Transboundary Movement of Hazardous Wastes and SDGs

Hazardous waste problem is a cross-border issue, which necessitates that its transboundary movement be regulated and restricted as much as possible. Some international legislations have been enforced to regulate their transboundary movement. For instance, Basel Convention was enacted in 1989 to tackle hazardous waste imports in African and other developing countries. This stated that transboundary shipment of toxic wastes be permitted

only with the written consent of all States to achieve environmentally sound management of hazardous wastes. The Convention also made the State of waste generation to re-import in case these were illegally transported, and dispose of safely in their own country [16]. A case in point is the ban in incinerating pharmaceutical wastes in New Zealand, which necessitated that these be exported overseas for incineration [17]. Similarly, Rotterdam Convention was endorsed in 1998 to protect public health and environment from the potential hazards of chemicals through environmentally sound use and information exchange among Parties [18]. So far, SDGs do not appear to focus directly on these sensitive issues of transboundary movement of hazardous wastes. Thus, there is a high possibility that hazardous wastes generated in one country can pollute and contaminate water course and air system in other countries as well. One of the hurdles is ineffective implementation of the Conventions as such. Therefore, future amendments in Conventions should emphasise sustainability through responsible implementation of the provisions of transboundary movement of hazardous wastes. The problem can be managed by integrating SDGs with legislations pertinent to transboundary movement of hazardous wastes.

6. The Waste-to-SDG Loop or Circle, and the Way Forward

In future, legislations, policies or guidelines for HWM should give due priorities to SDGs to make the Earth liveable for generations to come. The issues of hazardous wastes and progress on their sustainable management should be transparently reflected in future SDG reports. Besides, harmonisation of legislations, regulations or policies are imperative to ensure effective and homogeneous management of hazardous wastes across the countries. For instance, legislations such as Acts, regulations, policies and guidelines for pharmaceutical waste management, one of the categories of hazardous wastes, were not found harmonised among ASEAN (Association of South East Asian) countries [19]. The lack of harmonisation would create confusion among the Member States in managing hazardous wastes properly and following the established guidance such as Basel Convention, Stockholm Convention, which are essential for regulating transboundary movement of hazardous wastes. Similar scenario can be projected for other categories of hazardous wastes besides pharmaceutical wastes, which represents critical condition of SDG achievement. Hence, harmonised two-way intersection of HWM policies and legislations would help achieve SDGs in all countries. In future, national legislations as well as HWM guidelines of WHO, UNEP and other agencies should emphasise SDGs, and the reverse is also true.

Figure 1 below shows outline of interaction between legislations and HWM via schematic ‘waste-to-SDG loop or circle’. It shows how HWM is inter-connected with legislations, guidelines or policies, and SDGs and how this regulates transboundary movement of hazardous wastes through their representative components. This loop revolves the cycle from HWM to SDG in bidirectional or continuous manner to facilitate uninterrupted management of hazardous wastes and SDG achievement. The components shown are representative only and in practice, context-specific components should be operationalised based on the categories of hazardous wastes, legislations for their management, region and volume of the hazardous wastes generated, and other. The implementation of this newly proposed loop would facilitate current SDGs to encompass context-specific components pertinent to HWM, which would remove shortcomings in achieving SDGs in HWM. The loop reflects that legislations, regulations and Acts on HWM should emphasise all pillars of sustainability i.e., social or socio-cultural dimension, environmental or ecological dimension, economic or circularity dimension and technological dimension, and SDGs in return should facilitate sustainable HWM by encompassing guidance from these legislations. The procedures mentioned in the Basel Convention, Bamako Convention, Rotterdam Convention and Waigani Convention should be liaised with SDGs to achieve sustained progress in HWM. The current SDGs do not specifically focus on regulating transboundary movement of hazardous wastes, which underscores a need of two-way harmonisation among these conventions and SDGs for the same. In principle, Figure 1 highlights that all these nodes of loop (i.e., hazardous wastes, legislations, SDGs and transboundary movement of hazardous wastes) are inter-dependent and should foster each other.

So far, guidelines or policies appear to focus more on technical aspects while giving less emphasis on other dimensions of sustainability. The loop shows that there should be continuity in sustainability achievement in HWM in a circular pattern encompassing legislations and other related concerns. The loop can be ensured in case HWM legislations, policies or guidelines encompass all aspects of sustainability along with transboundary regulation of hazardous wastes as per various conventions. Besides incorporating pillars of sustainability in the legislations or policies, these should also take into consideration the determinants of slow and even retrograde progress in SDG achievement.

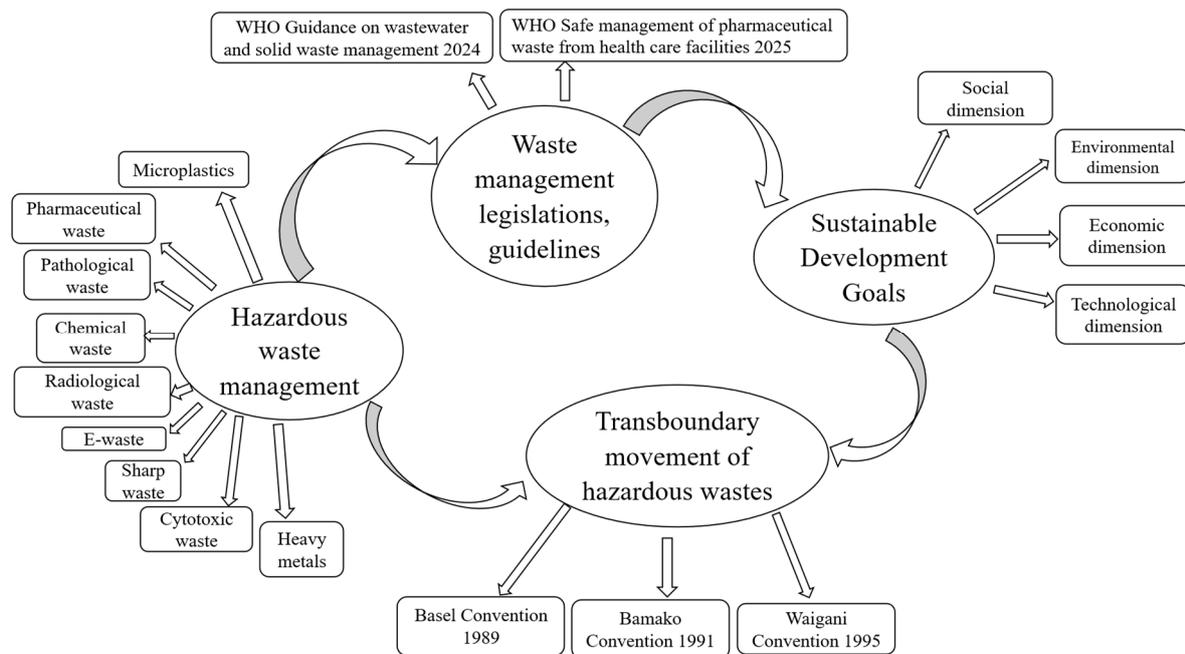


Figure 1. Waste-to-SDG loop or circle.

7. Conclusions

Though some mentions of waste management are in Goal 3 (good health and well-being), Goal 6 (clean water and sanitation), Goal 11 (sustainable cities and communities) and Goal 12 (responsible consumption and production), still HWM-related components are not well incorporated in the current SDGs. Some progress in SDG achievement has been seen in social protection, child marriage, maternal and child mortality, women empowerment, but the progress status on HWM and its health and environmental impacts, and circular economy of managing these is still not properly documented. Therefore, this perspective has raised the issue of incorporating components of HWM, transboundary movements and legislations in upcoming SDGs by proposing ‘waste-to-SDG loop’. In future, this newly proposed loop can facilitate sustainable HWM by regulating these components in a continuous circular pattern to achieve satisfactory outputs in all pillars of sustainability i.e., economic, environmental, social and technological dimensions.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflicts of Interest

The author declares no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

Abbreviations

HWM: hazardous waste management; POPs: persistent organic pollutants; SDGs: Sustainable Development Goals; UNEP: United Nations Environment Programme; USEPA: United States Environmental Protection Agency; WHO: World Health Organization.

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