Medical Waste Management in Contemporary Health Systems: A Narrative Review

Abdulaziz S Alotaibi[1], Abdulaziz S. Algethami[2], Mohammed F. Alghannam[3], Modhi H. Alqahtani[4], Rehab S. Alsunaidi[5], Ahmed D. Alosaimi[6], Mohannad S. Alsowaida[7], Mohammed M. Alotaibi[8], Saleh A. Al Furhud[9], Ahmed Saeed Alrougi[10], Bandar F. Alaqeel[11]

[1]National Guard Health Affairs, Saudi Arabia, ALOTAIBIAB45@MNGHA.MED.SA
[2]Nuclear Medicine, National Guard Health Affairs Algethamiab2@mngha.med.sa
[3]Medical Imaging Department, National Guard Health Affairs, Alghannammo1@ngha.med.sa
[4]National guard health affairs, alqahtanimo24@mngha.med.sa
[5]National guard health affairs, rehabsa7@gmail.com
[6]Molecular Imaging Department, National Guard Health Affairs, Riyadh, Saudi Arabia, alosaimiah@mngha.med.sa
[7]Field Medicine, Ministry of National Guard, Alsowaidamo@mngha.med.sa
[8]National Guard Health Affairs, Riyadh, SA, Otibimo@mngha.med.sa
[9]National Guard Health Affairs, Riyadh, SA, Alfurhudsa@mngha.med.sa
[10]National guard health affairs, rougi2011_5@hotmail.com
[11]Pharmaceutical care, National Guard Health Affairs, aqeelb@mngha.med.sa

Abstract
Medical waste is a heterogeneous stream generated by hospitals, laboratories, blood banks, veterinary facilities, research centers, emergency services, and community-based care. Its management has direct implications for infection prevention, occupational safety, environmental protection, and health-system resilience. This narrative review synthesizes peer-reviewed evidence and official guidance on medical-waste classification, generation rates, management practice, treatment technologies, environmental and health impacts, and selected regulatory approaches. The reviewed evidence confirms that most health-care waste is non-hazardous, while a smaller hazardous fraction accounts for most infection, sharps-injury, toxic-exposure, and emission risks. Reported generation rates vary widely by region, income setting, service profile, and segregation quality. Across sources, the most consistent determinants of safe performance are segregation at source, puncture-resistant sharps containment, secure internal transport, staff training, vaccination, auditable records, and treatment selection according to waste type. Steam-based and other non-burn technologies are appropriate for many infectious waste streams when operation, validation, and downstream disposal are reliable, whereas modern high-temperature incineration remains relevant for selected pathological, pharmaceutical, and cytotoxic wastes. Poorly controlled burning, untreated disposal, and pharmaceutical leakage are associated with air pollution, water contamination, antimicrobial-resistance pathways, and preventable worker exposure. Sustainable improvement requires integrated regulation, routine measurement, trained personnel, and procurement practices that reduce avoidable waste while preserving infection-control standards.

Keywords: healthcare waste, biomedical waste, waste segregation, autoclaving, incineration, infection prevention, environmental health

Introduction

Medical waste, also termed health-care waste or biomedical waste, includes ordinary refuse generated in health-care facilities as well as regulated hazardous streams such as infectious waste, pathological waste, sharps, chemical waste, pharmaceutical and cytotoxic waste, and radioactive waste. Major sources include hospitals, primary-care centers, laboratories, mortuary and autopsy units, blood banks, research facilities, veterinary services, vaccination campaigns, and home-based care. This breadth of origin makes medical-waste management a multidisciplinary issue involving clinical practice, infection prevention, environmental health, occupational safety, procurement, transport, and public regulation (World Health Organization, 2024a; Ministry of Health, Kingdom of Saudi Arabia, 2019).

The topic is increasingly important because health systems are expanding in scale and complexity while also adopting more disposable products for infection control and service efficiency. Single-use plastics, personal protective equipment, disposable syringes, laboratory consumables, diagnostic kits, and pharmaceutical residues can improve safety at the point of care, yet they also increase the quantity and complexity of waste requiring segregation, treatment, and final disposal. The COVID-19 pandemic illustrated this tension by generating abrupt increases in masks, gloves, gowns, test-kit plastics, chemical reagents, syringes, needles, and safety boxes, placing additional pressure on already uneven waste-management systems (World Health Organization, 2022).

The risk profile of medical waste arises not only from the inherent hazard of particular materials but also from failure at each operational step. Poor segregation can convert ordinary waste into a stream requiring hazardous-waste treatment. Inadequate sharps containment can expose nurses, physicians, cleaners, porters, waste handlers, and the public to

preventable injury. Poorly controlled combustion can release particulate matter, dioxins, furans, and metal-bearing emissions, while unsafe liquid or solid disposal may contribute to antimicrobial-resistance pathways and contamination of water, soil, and air (World Health Organization, 2014; Abosse et al., 2024; Zikhathile et al., 2022).

Medical-waste governance also differs substantially across jurisdictions. Some countries operate detailed national biomedical-waste rules, common treatment facilities, and annual reporting systems. Others rely on state or local regulation alongside federal worker-safety or transport standards. International guidance from WHO, UNICEF, UNEP, and treaty frameworks emphasizes segregation, minimization, environmentally sound treatment, worker protection, and continuous monitoring, but implementation depends on infrastructure, financing, training, enforcement, and institutional accountability (European Commission, 2025a; Centers for Disease Control and Prevention, 2024; Central Pollution Control Board, 2024).

The review focuses on four questions: how medical waste is currently classified, how much is generated in different settings, which management and treatment practices are most consistently recommended, and what lessons can be drawn from selected global, European, United States, Saudi Arabian, and Indian regulatory approaches.

Materials And Methods

This review paper was prepared as a structured narrative review of published evidence and official guidance. Searches were undertaken between 1 and 15 June 2026 across PubMed, publisher platforms, WHO publications and fact sheets, WHO/UNICEF Joint Monitoring Programme outputs, CDC guidance, OSHA regulations, EPA resources, PHMSA transport materials, European Commission webpages, Saudi Ministry of Health materials, and Indian Central Pollution Control Board documents. The main evidence window was January 2015 to June 2026, while older foundational documents were retained when they remained authoritative for waste classification, treatment selection, international law, or health-system policy.

Search terms combined synonyms for the waste stream with management and impact terms, including medical waste, health-care waste, healthcare waste, biomedical waste, infectious waste, sharps waste, waste segregation, treatment, autoclaving, microwave treatment, incineration, pharmaceutical waste, antimicrobial resistance, environmental impact, occupational safety, and regulation. Additional sources were identified by reviewing citations within official guidance and peer-reviewed reviews. Priority was given to official guidance, statutory or regulatory documents, systematic reviews, narrative reviews with clear methods, and original studies reporting generation rates, composition audits, treatment performance, environmental impacts, management practices, or regulatory implementation.

Records were screened for direct relevance to classification, generation, segregation, containment, internal transport, treatment, final disposal, worker protection, environmental pollution, antimicrobial-resistance pathways, or formal regulation. Excluded material comprised opinion pieces without primary or official evidence, documents focused solely on municipal solid waste, duplicate records, and sources lacking enough bibliographic information to support verification. Because this was a narrative review rather than a formal meta-analysis, findings were synthesized thematically and organized around classification, generation patterns, operational controls, treatment options, environmental and health impacts, pandemic-related waste surges, and governance frameworks.

Results

Classification and generation patterns

The reviewed evidence supports a stable classification framework across jurisdictions. WHO distinguishes infectious, pathological, sharps, chemical, pharmaceutical and cytotoxic, radioactive, and non-hazardous general waste streams. Saudi Arabian implementing regulations similarly distinguish non-dangerous medical waste from dangerous medical waste and identify subcategories including infectious, sharps, chemical, pharmaceutical, and radioactive wastes. Across sources, the distinction between general and hazardous waste was repeatedly identified as operationally important because it determines containment, labelling, transport, treatment, cost, and environmental controls (World Health Organization, 2024a; Ministry of Health, Kingdom of Saudi Arabia, 2019).

Quantitative findings showed that most health-care waste is not hazardous. WHO estimates that approximately 85% of health-care waste is non-hazardous and 15% is hazardous. WHO also reports that high-income settings generate up to 0.5 kg of hazardous waste per bed per day on average, compared with about 0.2 kg per bed per day in low-income settings, although under-segregation and weak measurement may obscure the true hazardous fraction in resource-limited settings. A global meta-analysis across 78 countries reported an average medical-waste generation rate of 2.04 kg per bed per day, with a range from 0.3 to 8.4 kg per bed per day (World Health Organization, 2024a; Singh, Ogunseitan and Tang, 2022).

Regional patterns varied markedly. Singh, Ogunseitan and Tang (2022) reported lower mean generation rates in Africa and Asia and higher means in Europe and the Americas. Mol et al. (2022) reported continent-level medians showing particularly high total hospital waste generation in North America and lower values in Africa. At hospital level, Kaposi et al. (2024) found that hazardous volumes were higher in units such as surgery, intensive care, and emergency services, indicating that service mix and clinical intensity influence both total waste and hazardous fractions.

Operational controls and service readiness

Management practices were consistent across official guidance in emphasizing segregation at source, appropriate containment, marked storage areas, staff protection, internal transport controls, and documented handover. CDC guidance specifies leak-resistant biohazard bags for regulated medical waste and puncture-resistant sharps containers located at the point of use. OSHA requires contaminated sharps not to be bent, recapped, or broken by hand and requires sharps containers

to be closable, puncture-resistant, leak-proof, and labelled or color-coded. These requirements place risk control close to the point of generation rather than at the end of the waste pathway (Centers for Disease Control and Prevention, 2024; Occupational Safety and Health Administration, n.d.).

Service-readiness data showed persistent infrastructure gaps. WHO reported that only 61% of hospitals had basic health-care waste services in 2021. The WHO/UNICEF 2024 update found that, in 2023, basic waste-management service coverage was 26% in sub-Saharan Africa, 40% in Northern Africa and Western Asia, 42% in landlocked developing countries, and 25% in fragile contexts. The global meta-analysis by Singh, Ogunseitan and Tang (2022) also reported that only 38.9% of medical waste was segregated for proper management and only 41% of workers had in-service training, indicating that infrastructure and workforce capacity remain major barriers to safe performance.

Waste audits and routine measurement were presented in the literature as practical tools for identifying over-classification, under-segregation, high-risk departments, and opportunities for waste reduction. Slutzman et al. (2023) found that waste audits can reveal mismatches between actual waste composition and institutional assumptions. Such audits are particularly relevant where facilities pay for hazardous-waste treatment by weight or volume, because misclassification increases cost and may lead to unnecessary use of high-emission treatment methods.

Treatment technologies

Treatment technologies reported across the reviewed sources included steam sterilization, microwave treatment, chemical disinfection, modern high-temperature incineration, encapsulation, inertization, and controlled disposal routes. The evidence did not identify a single universal best method. Instead, sources emphasized matching the technology to the waste stream, facility scale, technical capacity, validation requirements, emissions controls, and downstream disposal arrangements (World Health Organization, 2014; Centers for Disease Control and Prevention, 2024; United States Environmental Protection Agency, n.d.).

Table 1. Treatment options for selected medical-waste streams

Treatment option	Principal waste streams	Reported strengths	Reported limitations
Autoclave or steam-based treatment	Many infectious and microbiological wastes; selected sharps after containment	Mature technology; effective microbial reduction; avoids combustion emissions when properly operated	Not suitable for all anatomical, cytotoxic, or pharmaceutical streams; depends on maintenance, validation, and downstream disposal
Microwave treatment	Selected infectious waste streams	Non-burn option; can achieve high disinfection efficiency; useful where incineration is undesirable	Requires technical reliability, stable power supply, and validated operating conditions
Modern high-temperature incineration	Pathological, anatomical, pharmaceutical, and some cytotoxic wastes	Major volume reduction; destroys waste streams unsuitable for steam treatment	Air-emission and ash risks if poorly designed or operated; requires strict pollution control
Chemical disinfection	Selected liquid infectious wastes and some infectious solids	Useful for targeted streams and some point-of-generation applications	Chemical-handling risks; effluent control needed; effectiveness reduced by high organic loads in some settings
Encapsulation or inertization plus controlled disposal	Sharps residues, some pharmaceutical residues, and treated remnants	Useful as a downstream containment step where advanced options are limited	Not a substitute for segregation or decontamination; landfill and leachate controls remain necessary

Note: The treatment comparison synthesizes WHO, CDC, EPA, UNEP, ICRC, and recent review evidence on microwave and autoclave performance (World Health Organization, 2014; World Health Organization, 2024a; Centers for Disease Control and Prevention, 2024; United States Environmental Protection Agency, n.d.; United Nations Environment Programme, 2012; International Committee of the Red Cross, 2011; Kollu, Kumar and Gautam, 2022; Zikhathile et al., 2022).

Health, environmental, and pandemic-related findings

Environmental and health impacts clustered around infection, sharps injury, toxic exposure, pharmaceutical leakage, air pollution, and antimicrobial-resistance pathways. WHO reports that a single needlestick injury from an infected source carries approximate transmission risks of 30% for hepatitis B virus, 1.8% for hepatitis C virus, and 0.3% for HIV. WHO

also links poor waste management to exposure to antibiotics, cytotoxic drugs, mercury, dioxins, furans, particulate matter, radiation burns, and thermal injuries (World Health Organization, 2024a).

The antimicrobial-resistance literature identified unsafe storage, treatment, wastewater discharge, and disposal of health-care residues as pathways through which resistant organisms, antibiotics, and disinfectant residues may enter the environment. Abosse et al. (2024) reported that poorly managed health-care waste and wastewater can contribute to environmental reservoirs of antimicrobial resistance, particularly where segregation, treatment, and effluent controls are weak.

Pandemic-era waste surges were quantitatively large in official evidence. WHO's 2022 analysis estimated that approximately 87,000 tonnes of PPE procured through a UN emergency initiative would likely become waste. The same analysis associated more than 140 million shipped test kits with about 2,600 tonnes of mostly plastic waste and 731,000 litres of chemical waste, and linked global vaccination activities to about 144,000 tonnes of additional syringes, needles, and safety-box waste. WHO also reported that 30% of health-care facilities worldwide, and 60% in least developed countries, were not equipped to handle existing waste loads, let alone pandemic additions (World Health Organization, 2022).

Regulatory frameworks showed similar operational building blocks but different governance architectures. The European Union emphasizes the waste hierarchy, hazardous-waste controls, permitting, and emissions limits for relevant installations. The United States relies primarily on state medical-waste regulation, supported by federal infection-control, worker-safety, and transport requirements. Saudi Arabia defines dangerous and non-dangerous categories, assigns roles to health and environmental authorities, requires approvals for treatment and disposal facilities, and permits emergency amendments during epidemics and disasters. India uses national Bio-Medical Waste Management Rules, annual reporting, state and national oversight, and a common treatment-facility model that restricts on-site treatment where a common facility is available within a defined distance (European Commission, 2025a; European Commission, 2025b; Ministry of Health, Kingdom of Saudi Arabia, 2019; India, 2016; Central Pollution Control Board, 2024).

Discussion

The reviewed evidence indicates that the pivotal management problem is not simply the existence of hazardous medical waste, but the inflation of hazardous volumes through poor classification and weak source segregation. Because most clinical waste is actually general waste, every mis-sorted item increases the cost, environmental burden, and treatment complexity of the whole stream. This finding explains why WHO emphasizes minimization and segregation first, and why institutional classification guidance can produce measurable reductions in hazardous-waste volumes. In practical terms, classification accuracy functions simultaneously as an infection-control intervention, an environmental intervention, and a cost-control intervention (World Health Organization, 2024a; Singh, Ogunseitan and Tang, 2022; Ministry of Health, Kingdom of Saudi Arabia, 2022).

The technology findings point toward a hierarchy of appropriateness rather than a universal best method. Non-burn systems such as autoclaving and microwave treatment are supported for many segregated infectious waste streams because they avoid combustion-related emissions and can achieve reliable microbial reduction when properly validated. However, the literature does not support eliminating incineration altogether. Some pathological, pharmaceutical, and cytotoxic wastes require destructive treatment or specialized routes that steam-based systems cannot replace. The choice of technology should therefore be based on waste composition, scale, energy availability, staff skill, maintenance capacity, emissions controls, and the safety of residual disposal (Centers for Disease Control and Prevention, 2024; Kollu, Kumar and Gautam, 2022; Sharifi et al., 2024).

Sustainability considerations should begin before waste is generated. Procurement policies can reduce avoidable packaging, select reusable products where clinically appropriate, and avoid unnecessary single-use items when safe alternatives exist. At the same time, waste reduction must not compromise infection prevention, particularly in high-risk care settings. A balanced strategy requires collaboration between clinicians, infection-control teams, supply-chain managers, environmental-health officers, and waste contractors so that waste minimization is aligned with patient safety rather than treated as a separate administrative target.

Training and occupational protection are recurring themes across the evidence. Waste handlers, cleaners, nurses, laboratory staff, and transport workers often face the highest exposure risk while having the least influence over clinical procurement and waste-generation decisions. For this reason, training should not be limited to waste personnel alone. Clinicians and students also need practical instruction on color coding, sharps disposal, pharmaceutical separation, spill response, and reporting of injuries or near misses. Vaccination, post-exposure protocols, and safe container placement are essential complements to classroom training.

Regulatory comparison suggests that policy texts are necessary but insufficient without implementation capacity. The EU model emphasizes prevention, producer responsibility, and emissions control; the United States combines state waste rules with federal worker-safety and transport obligations; Saudi regulations define institutional responsibilities and environmental approvals; and India uses a common treatment-facility model with annual reporting. Despite these differences, the core operational logic is similar: define waste categories clearly, segregate at the point of generation, protect workers, control transport, match treatment to waste type, monitor emissions and residues, and keep auditable records.

Low-resource and fragile settings require particular attention because the absence of basic waste-management services can turn routine care into an environmental and occupational hazard. The WHO/UNICEF service-readiness figures show that many facilities still lack basic systems for safe segregation, treatment, and disposal. In such contexts, incremental

improvements may be more realistic than rapid installation of expensive technology. Practical priorities include reliable color-coded containers, sharps boxes at the point of care, temporary secure storage, staff training, contracts with licensed treatment providers where available, and simple waste audits to identify high-risk departments.

The antimicrobial-resistance dimension further strengthens the case for integrated management. Medical waste, wastewater, antimicrobial residues, disinfectants, and resistant organisms can interact outside the clinical setting when disposal is unsafe. Although the direct contribution of medical waste to antimicrobial resistance varies by context and requires more measurement, the pathway is plausible enough to justify stronger control of pharmaceutical residues, laboratory waste, and health-care effluents. This area also links medical-waste policy to broader One Health approaches involving human health, animal health, and environmental protection (Abosse et al., 2024).

This narrative review has several limitations. It is a structured synthesis of published and official sources rather than original experimental or field research, and direct comparison across jurisdictions was constrained by differences in terminology, legal design, reporting metrics, and document accessibility. The reliance on accessible official and peer-reviewed sources may have limited coverage of local implementation experiences. Even so, the convergence of WHO, CDC, EPA, EU, Saudi, Indian, and peer-reviewed sources on segregation, sharps safety, treatment selection, training, documentation, and regulation strengthens confidence in the main conclusions. Future work would benefit from harmonized reporting of kg per bed per day, outpatient-adjusted metrics, waste-composition audits, treatment validation data, cost analyses, and antimicrobial-resistance monitoring linked to solid and liquid medical-waste pathways.

Conclusion

Medical-waste management is a core component of safe and sustainable health-system performance. The evidence reviewed in this paper shows that the largest share of health-care waste is non-hazardous, but unsafe handling of the smaller hazardous fraction can create disproportionate risks for patients, workers, communities, and the environment. The most important intervention is not a single technology, but a complete management system beginning with correct segregation at the point of generation and continuing through containment, internal transport, storage, treatment, final disposal, documentation, and oversight.

For many facilities, the most achievable improvements are practical and operational: consistent color coding, sharps containers at the point of use, staff training, routine audits, vaccination and post-exposure procedures, and clear accountability for each step of the waste pathway. Treatment technologies should be selected according to waste type and operational capacity. Autoclaves, microwaves, and other non-burn technologies are suitable for many infectious streams when properly operated and validated, while modern high-temperature incineration or specialized routes remain necessary for selected pathological, pharmaceutical, and cytotoxic waste.

Sustainable progress requires integration between infection prevention, environmental regulation, occupational safety, procurement, and health-care governance. Policies should move beyond disposal alone and address waste minimization, purchasing decisions, data reporting, emissions control, and resilience during emergencies. For hospitals and health authorities, the central lesson is clear: safe medical-waste management is not an optional housekeeping function, but a measurable public-health responsibility that protects workers, reduces pollution, improves resource use, and supports the credibility of modern health care.

References

1. Abosse, J.S., Megersa, B., Zewge, F. and Eregno, F.E. (2024) 'Healthcare waste management and antimicrobial resistance: a critical review', Journal of Water and Health, 22(11), pp. 2076-2093. doi:10.2166/wh.2024.232.
2. Basel Convention (2003) Technical guidelines on the environmentally sound management of biomedical and healthcare wastes. Geneva: Secretariat of the Basel Convention.
3. Basel Convention (2025) Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Geneva: Secretariat of the Basel Convention.
4. Centers for Disease Control and Prevention (2024) 'I. Regulated medical waste', Infection Control. Atlanta, GA: CDC. Available at: https://www.cdc.gov/infection-control/hcp/environmental-control/regulated-medical-waste.html (Accessed: 15 June 2026).
5. Central Pollution Control Board (2024) Annual report on biomedical waste management for 2023. New Delhi: CPCB.
6. European Commission (2025a) Waste Framework Directive. Brussels: European Commission. Available at: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en (Accessed: 15 June 2026).
7. European Commission (2025b) Industrial and Livestock Rearing Emissions Directive. Brussels: European Commission.
8. India (2016) Bio-Medical Waste Management Rules, 2016. New Delhi: Ministry of Environment, Forest and Climate Change.
9. International Committee of the Red Cross (2011) Medical waste management. Geneva: ICRC.
10. Janik-Karpinska, E., Brancaleoni, R., Niemcewicz, M., Wojtas, W., Foco, M., Podogrocki, M. and Bijak, M. (2023) 'Healthcare Waste-A Serious Problem for Global Health', Healthcare, 11(2), 242. doi:10.3390/healthcare11020242.
11. Kaposi, A., Nagy, A., Gomori, G. and Kocsis, D. (2024) 'Analysis of healthcare waste and factors affecting the amount of hazardous healthcare waste in a university hospital', Journal of Material Cycles and Waste Management, 26(2), pp. 1169-1180. doi:10.1007/s10163-024-01890-1.
12. Kenny, C. and Priyadarshini, A. (2021) 'Review of current healthcare waste management methods and their effect on global health', Healthcare, 9(3), 284. doi:10.3390/healthcare9030284.

13. Kollu, V.K.R., Kumar, P. and Gautam, K. (2022) 'Comparison of microwave and autoclave treatment for biomedical waste disinfection', Systems Microbiology and Biomanufacturing, 2(4), pp. 732-742. doi:10.1007/s43393-022-00101-y.
14. Ministry of Health, Kingdom of Saudi Arabia (2019) Implementing Regulations of the Uniform Law for Medical Waste Management. Riyadh: Ministry of Health.
15. Ministry of Health, Kingdom of Saudi Arabia (2022) Acute Hazardous Medical Waste Classification Guidelines Released. Riyadh: Ministry of Health.
16. Mol, M.P.G., Zolnikov, T.R., Neves, A.C., dos Santos, G.R., Tolentino, J.L.L., de Vasconcelos Barros, R.T. and Heller, L. (2022) 'Healthcare waste generation in hospitals per continent: a systematic review', Environmental Science and Pollution Research, 29(28), pp. 42466-42475. doi:10.1007/s11356-022-19995-1.
17. Occupational Safety and Health Administration (n.d.) Bloodborne pathogens, 29 CFR 1910.1030. Washington, DC: OSHA. Available at: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1030 (Accessed: 15 June 2026).
18. Pipeline and Hazardous Materials Safety Administration (n.d.) Transporting infectious substances overview. Washington, DC: U.S. Department of Transportation. Available at: https://www.phmsa.dot.gov/transporting-infectious-substances (Accessed: 15 June 2026).
19. Secretariat of the Stockholm Convention (2023) Stockholm Convention on Persistent Organic Pollutants. Geneva: United Nations Environment Programme.
20. Sharifi, S., Yaghmaeian, K., Golbaz, S., Nabizadeh, R. and Baghani, A.N. (2024) 'Economic evaluation of hazardous healthcare waste treatment systems', Scientific Reports, 14, 21764. doi:10.1038/s41598-024-69940-0.
21. Singh, N., Ogunseitan, O.A. and Tang, Y. (2022) 'Medical waste: current challenges and future opportunities for sustainable management', Critical Reviews in Environmental Science and Technology, 52(11), pp. 2000-2022. doi:10.1080/10643389.2021.1885325.
22. Slutzman, J.E., Bockius, H., Gordon, I.O., Greene, H.C., Hsu, S., Huang, Y., Lam, M.H., Roberts, T. and Thiel, C. (2023) 'Waste audits in healthcare: a systematic review and description of best practices', Waste Management & Research, 41(1), pp. 3-17. doi:10.1177/0734242X221101531.
23. United Nations Environment Programme (2012) Compendium of technologies for treatment/destruction of healthcare waste. Osaka/Shiga: UNEP.
24. United States Environmental Protection Agency (n.d.) Medical waste. Washington, DC: EPA. Available at: https://www.epa.gov/rcra/medical-waste (Accessed: 15 June 2026).
25. World Health Assembly (2019) Water, sanitation and hygiene in health care facilities. Resolution WHA72.7. Geneva: World Health Organization.
26. World Health Organization (2014) Safe management of wastes from health-care activities. 2nd edn. Geneva: WHO. Available at: https://www.who.int/publications/i/item/9789241548564 (Accessed: 15 June 2026).
27. World Health Organization (2022) Global analysis of health care waste in the context of COVID-19: status, impacts and recommendations. Geneva: WHO. Available at: https://www.who.int/publications/i/item/9789240039612 (Accessed: 15 June 2026).
28. World Health Organization (2024a) Health-care waste. Geneva: WHO. Available at: https://www.who.int/news-room/fact-sheets/detail/health-care-waste (Accessed: 15 June 2026).
29. World Health Organization (2024b) A review of health-care waste management policies in the Western Pacific Region: key findings from selected countries and areas. Manila: WHO Regional Office for the Western Pacific.
30. World Health Organization (2024c) Universal water, sanitation, hygiene, waste and electricity services in health care facilities: global framework for action 2024-2030. Geneva: WHO.
31. World Health Organization and UNICEF (2024) WASH in health care facilities 2023 data update: special focus on primary health care. Geneva/New York: WHO/UNICEF Joint Monitoring Programme. Available at: https://data.unicef.org/resources/jmp-wash-in-health-care-facilities-2024/ (Accessed: 15 June 2026).
32. Zikhathile, T., Atagana, H., Bwapwa, J. and Sawtell, D. (2022) 'A review of the impact that healthcare risk waste treatment technologies have on the environment', International Journal of Environmental Research and Public Health, 19(19), 11967. doi:10.3390/ijerph191911967.