Sirte University Scientific Journal Vol. 14, No. 2 (2024) 115-120

Sirte University Scientific Journal (SUSJ)

Journal home page: http://journal.su.edu.ly/index.php/SUSJ/index

DOI: 10.37375/susj.v14i2.3101

Determination of Heavy Metals content in Soil from Medical Waste Landfills and the Creation of Cement Capsules to Mitigate Pollution

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DOI: https://doi.org/10.37375/susj.v14i2.3101

ARTICLE INFO:

Received 03 October 2024.
Accepted 28 November 2024.
Available online 24 December 2024.

Keywords:

Landfill, Medical Waste, Cement Capsule, Pollution

A B S T R A C T

The objective of this study is to extract specific heavy metals (Pb^{2+}, Cd^{2+}, Ni^{2+}, and Cr^{2+}) from landfill soil and to ascertain their concentrations. Furthermore, the research involves the development of cement capsules designed to contain medical waste and to mitigate the leaching of heavy metals into the surrounding environment.

The findings indicate that the concentrations of these four heavy metals in the soil remained unchanged following the implementation of the capsules for medical waste storage. This outcome suggests that the capsules are effective in containing medical waste and preventing the leaching of heavy metals into adjacent soil.

This study contributes valuable awareness into the controlling of medical waste within public and private health facilities. The recent proliferation of clinics, health centers, and medical laboratories has significantly increased activities in this sector. Such expansion generates various toxic and organic wastes, which pose potential risks to the environment.

1 Introduction

Medical waste refers to potentially infectious or biodegradable waste generated from medical facilities, laboratories, and research centers. This includes items like contaminated blood, sharps (needles and scalpels), unwanted biological collections, discarded tissues, and used bandages. Sharps must be disposed of properly to prevent injuries and infection (World Health Organization: WHO, 2024). While hospitals play a vital role in patient care, they can also pose a risk of disease spread if waste is not managed correctly. Medical waste has raised global concerns due to its immediate dangers and long-term environmental impact, especially in countries like those in Central Africa, where international organizations aim to restrict hazardous waste transport (Chisholm et al., 2021).

The World Health Organization defines health-care waste as any materials generated by health institutions involved in diagnosis and treatment that may be contaminated. Such waste must be managed carefully to safeguard public health and the environment (World Health Organization: WHO, 2024). Medical waste management is the process of managing, storing, and treating waste generated by medical facilities such as hospitals, clinics, laboratories, and pharmacies. Medical waste includes used needles, catheters, surgical instruments, flammable chemicals, and medical instruments contaminated with blood and other bodily fluids (Dion et al., 2022).

Key methods for managing medical waste include:

i. Waste Separation: Medical waste should be separated from regular waste using specialized colored containers (Brown, 2024).

ii. Packaging: It must be securely packed in tightly sealed containers to prevent leakage and direct contact (Janagi et al., 2022).

iii. Temporary Storage: Properly packaged waste should be stored in restricted areas to avoid contamination (Chartier, 2014).

iv. Treatment: After storage, medical waste undergoes treatment, including sterilization and chemical processes, following strict guidelines for safe disposal (Chartier, 2014).

v. Final Disposal: Treated waste must be transported to approve disposal facilities, such as incinerators, in strict compliance with applicable local and international regulations (Filho et al., 2023).

These practices aim to protect public health and the environment from medical waste hazards. Institutions must adhere to relevant regulations regarding waste management.

Effective medical waste management starts with sorting hazardous waste from general waste in healthcare facilities. This crucial step occurs at the source, such as examination rooms or treatment areas .Nurses must dispose of waste properly: hazardous items that have contacted body fluids go into red or yellow bags marked for infectious waste (Andeobu et al., 2023). Non-hazardous items, like soft drink cans and food leftovers, should be placed in black bags for household waste; In contrast, non-hazardous waste, such as soft drink cans and food leftovers, should be disposed of in black bags designated for household waste (Rajalakshmi et al., 2023).

Types of waste containers and bags includes (Figure 1):

- Red bag: This bag is designated for the disposal of syringes (without needles), contaminated gloves, catheter equipment, intravenous tubes, and similar items. These materials will undergo incineration following collection (Donuma et al., 2024).
- Yellow bag: Bandages and cotton swabs that have been contaminated with bodily fluids, blood bags, human anatomical waste, and body parts must be disposed of in yellow bags to ensure safe handling (Połomka et al., 2024).
- Cardboard box with blue label: Glass bottles and other glassware should be placed in a cardboard box that features a blue label. This helps to facilitate proper recycling and safety measures (Albizzati et al., 2023).
- Chemotherapy sharps container: This specialized container is meant for cytotoxic and genotoxic waste. It includes items such as chemotherapy needles, syringes, intravenous catheters, sutures, and eyeglasses, ensuring their safe disposal .

Figure 1 Types of waste containers and bags.

These measures are essential for maintaining a safe and compliant waste management system.

Medical waste and healthcare waste come from several key sources:

a. Hospitals and Medical Clinics: Significant waste sources include needles, blood-stained sheets, medical gloves, surgical masks, and hazardous chemicals (Bolan et al., 2023).

b. Medical laboratories: Labs generate waste such as contaminated tubes, glassware, petri dishes, and biological samples (Ranjbari et al 2022).

c. Home healthcare centers: Waste stems from supplies like needles, gloves, and bandages used in wound care.

d. Pharmacies: Pharmacies produce waste from expired medications, empty drug containers, and hazardous chemicals.

Healthcare waste poses a significant environmental threat due to its hazardous components and improper disposal practices (Janik-Karpinska et al., 2023). This includes materials such as needles, blood-stained materials, hazardous chemicals, leftover medications, radioactive substances, and infectious agents**.** Improper disposal can contaminate groundwater and surface water, harming ecosystems and water quality (Nwosu et al., 2024). Additionally, unsafe incineration releases toxic gases that pose health risks. The presence of infectious materials can also lead to disease transmission if not managed properly; to reduce these impacts, effective waste management practices are essential (Sidiq & Nurkayah, 2023).

Waste accumulation in landfills results in land pollution from harmful chemicals, which can contaminate groundwater and adversely affect local ecosystems. Liquids from landfills may seep into groundwater, compromising water quality and posing threats to organisms that rely on these water sources (Mor & Ravindra, 2023). The decomposition of waste in landfills releases gases such as carbon dioxide and methane, contributing to global warming, climate change, and air pollution. Landfills can lead to the destruction of natural habitats and attract wildlife, thereby disrupting the local ecological balance. Landfills can detract from the visual appeal of surrounding areas and produce unpleasant odors, diminishing the quality of life for nearby residents (Dabrowska et al., 2023).

The treatment and disposal of infectious medical waste pose health and environmental challenges. Some methods designed to reduce infection risks can inadvertently introduce other hazards. For example, incinerating waste with heavy metals or chlorine can release toxic substances if emission controls are insufficient. Additionally, improper landfill disposal can contaminate groundwater. It is crucial to evaluate treatment methods considering local conditions and potential toxic emissions (Singh et al., 2022).

Incineration is the primary method for disposing of hazardous medical waste, but it faces increasing scrutiny due to its impact on air quality. If exhaust is not properly filtered, harmful substances can be released, leading to a rise in the popularity of alternative disposal methods (Santoleri et al., 2000).

The cement capsule process (Fig. 2) treats hazardous medical and chemical waste by mixing it with cement to form a solid mass that traps harmful materials. This process effectively handles various waste types, such as expired medications and used sharp instruments, in compliance with environmental and health guidelines (Prüss et al., 1999).

2 Materials and Methods

2.1 Creating cement capsules

The management of hazardous medical and chemical waste involves several essential steps to create cement capsules:

1. Separation of Materials: Different types of waste must be systematically segregated to ensure safe handling and compliance with regulatory requirements.
2. Mixing: The medical waste is blended with cement in a precise ratio to ensure even distribution throughout the mixture.
3. Forming: The mixture is then placed into molds for secure transport and storage.
4. Curing: The capsules are allowed to cure adequately, which ensures they develop the necessary strength (Fig. 2).
5. Storage and Final Disposal: Once cured, the capsules are stored in accordance with local and international regulations to guarantee their safe disposal.

Figure 2: The cement capsule process.

2.2 Determination of free heavy metal ion concentrations in soils

Heavy elements, specifically the ions of Pb^{2+}, Cd^{2+}, Ni^{2+}, and Cr^{2+}, were extracted from the waste using a methodology detailed by Yi et al. (2007b). Firstly, soil samples were dried at 70 °C for a duration of three days. Following this, the samples were thoroughly mixed to ensure homogeneity, and any suspended materials were removed. The dried samples were then ground using a ceramic mortar and sieved through a 64-micron sieve, after which they were stored in appropriately labeled polyethylene containers.

Subsequently, 2 grams of each dried sample were measured and placed in a Teflon beaker with a capacity of 50 ml. To this, 70 ml of concentrated hydrochloric acid (HCl) and nitric acid (HNO_3) were added, and the mixture was heated on a glass plate at 85 °C. Following the initial heating phase, 4 ml of concentrated hydrofluoric acid and perchloric acid were introduced, and the mixture was carefully evaporated to near dryness. After evaporation, the samples were separated using a centrifuge at a speed of 3000 rpm for 30 minutes. The concentrations of the heavy elements were then determined using a Flame Atomic Absorption Spectrophotometer (FAAS), in accordance with the testing methods established by the American Public Health Association (APHA, 2003).

3 Results and Discussion

3.1 Soil analysis results from the landfill in the industrial area:

The analysis conducted on chromium levels (Fig. 3) in the soil revealed a concentration of 0.23 mg/kg, indicating a low presence of this element. Chromium occurs naturally in soil, but its health and environmental effects can vary based on its concentration and chemical form. Typical natural levels of chromium in soil range from 10 to 50 mg/kg, making the recorded level of 0.23 mg/kg notably low. At this concentration, chromium is not anticipated to pose a risk to human health; exposure at this level is unlikely to result in health concerns.

The analysis of nickel in the soil reported a concentration of 4.30 mg/kg (Fig. 3), which is classified as moderate. Nickel is a naturally occurring metal found in soil and plays a role in various biological processes. Safe limits for nickel concentrations in soil vary by country; however, levels below 50 mg/kg are generally deemed safe for agricultural applications. Consequently, the observed concentration of 4.30 mg/kg is within acceptable parameters and does not warrant concern. For individuals who do not have sensitivity to nickel, this level typically does not present a significant health risk. Nevertheless, it is essential to note that nickel can cause skin irritation in sensitive individuals.

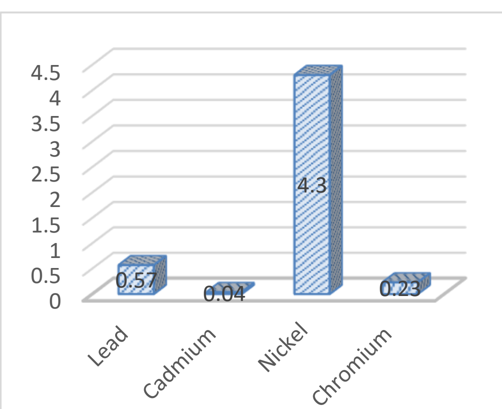

Figure3 : Results of soil samples collected from the landfill in the industrial area.

The analysis of cadmium in the soil yielded a result of 0.04 mg/kg, indicating a very low concentration of this element. While cadmium is classified as a heavy and toxic metal, this level is not considered harmful to the environment. Safe cadmium concentration limits vary by jurisdiction, but agricultural soil is generally regarded as safe when cadmium levels are below 1 mg/kg. The measured level of 0.04 mg/kg is well below this threshold. However, it is important to recognize that cadmium can pose health risks with prolonged exposure, making it advisable to avoid ingesting soil or coming into contact with contaminated soil, particularly before eating. Thorough handwashing after handling soil is recommended to mitigate potential risks. Long-term exposure to elevated cadmium levels can lead to accumulation in the body, potentially resulting in serious health issues, including kidney and bone damage, as well as an increased cancer risk.

The soil analysis indicated that the lead concentration was 0.57 parts per million (ppm), which corresponds to 0.57 parts of lead per million parts of soil. This concentration is considered relatively low in comparison to environmental and health standards in various countries. At this level, lead is unlikely to significantly affect plant health or growth, as plants can tolerate small amounts of lead without exhibiting adverse effects. However, even at this low concentration, there remains a potential risk to human and animal health, particularly with direct and extensive exposure to the soil.

According to the analysis results of heavy metals in the soil as shown in Table 1.

Table 1: The analysis results of heavy metals in the soil

Heavy metal	Concentration value
Chromium	0.23 mg/kg
Nickel	4.3 mg/kg
Cadmium	0.04 mg/kg
Lead	0.57 mg/kg

3.2 Pure Soil Sample results before and after capsule placement:

The results indicate that the levels of heavy metals in the soil (chromium, lead, cadmium, and nickel) remained unchanged after the capsule was placed for the storage of medical waste. A summary of these results is presented in Table 2 and Fig. 4.

Table 2: Analysis of metal content in the soil before (a) and after capsule placement (b).

Heavy metal	Metal Content[a]	Metal Content [b]
Pb	0.5	**0.5**
Cd	0.05	**0.05**
Ni	0.7	**0.7**
Cr	0.6	**0.6**

The data suggests that the capsule successfully contained medical waste and effectively prevented the leaching of heavy elements into the surrounding soil.

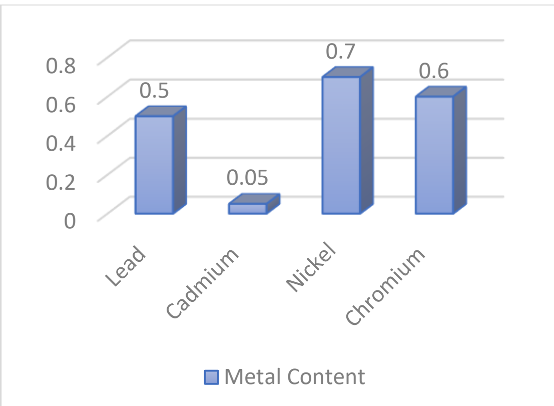

Figure 4: Results of soil samples collected before and after the placement of the capsules.

4 Conclusions

Medical waste management within healthcare facilities is a critical component of the healthcare system, serving to safeguard both public health and the environment. By adopting effective strategies for sorting, collecting, and treating medical waste, facilities can significantly mitigate the associated risks. The process of waste sorting enables proper handling based on the type and hazard level of the waste, thus streamlining the treatment and disposal processes. Additionally, proper collection methods are essential for reducing the likelihood of contamination and accidents among healthcare personnel. Implementing safe final disposal techniques, such as incineration, steam sterilization, and burial in designated sites, further diminishes the environmental impact of medical waste.

The effective management of medical waste is not only a measure of public health protection but also an urgent environmental imperative. Compliance with established procedures and environmental regulations enhances community safety and conserves ecosystems from pollution and degradation. As such, investing in comprehensive medical waste management systems and providing adequate training for staff in these protocols are vital steps toward fostering a healthy and sustainable environment.

Conflict of interest: The authors want to assure you that there are no conflicts of interest to report.

References

Albizzati, P. F., Cristobal, G. J., Antonopoulos, I., Egle, L., Foster, G., Gaudillat, P., Marschinski, R., Pierri, E., & Tonini, D. (2023). Harmonised labelling of waste receptacles with matching product labels. *JRC Publications Repository*. https://doi.org/10.2760/09021

American Public Health Association. Task Force on Correctional Health Care Standards. (2003). *Standards for health services in correctional institutions*. American Public Health Association.

Andeobu, L. (2023). Medical waste and its management. In *The Palgrave Handbook of Global Sustainability* (pp. 761-789). Cham: Springer International Publishing.

Bolan, S., Padhye, L. P., Kumar, M., Antoniadis, V., Sridharan, S., Tang, Y., ... & Bolan, N. (2023). Review on distribution, fate, and management of potentially toxic elements in incinerated medical wastes. *Environmental Pollution*, *321*, 121080.

Brown, K. (2024, September 26). *How to properly manage medical waste*. Medassureservices. https://medassureservices.com/how-to-properly-manage-medical-waste/

Chartier, Y. (Ed.). (2014). *Safe management of wastes from health-care activities*. World Health Organization.

Chisholm, J. M., Zamani, R., Negm, A. M., Said, N., Abdel daiem, M. M., Dibaj, M., & Akrami, M. (2021). Sustainable waste management of medical waste in African developing countries: A narrative review. *Waste Management & Research*, *39*(9), 1149-1163.

Dabrowska, D., Rykala, W., & Nourani, V. (2023). Causes, types and consequences of municipal waste landfill fires—literature review. *Sustainability*, *15*(7), 5713.

Dion, H., Evans, M., & Farrell, P. (2022). Hospitals management transformative initiatives; towards energy efficiency and environmental sustainability in healthcare facilities. Journal of Engineering Design and Technology, 21(2), 552–584. https://doi.org/10.1108/jedt-04-2022-0200

Donuma, K. U., Ma, L., Bu, C., George, L. Y., Gashau, M., & Suleiman, A. O. (2024). Environmental and human health risks of indiscriminate disposal of plastic waste and sachet water bags in Maiduguri, Borno State Nigeria. *Waste Management Bulletin*, *2*(2), 130-139.

Janagi, R., Shah, J., & Maheshwari, D. (2015). Scenario of management of medical waste in US and UK: a review. *J. Glob. Trends Pharm. Sci*, *6*(1), 2328-2339.

Janik-Karpinska, E., Brancaleoni, R., Niemcewicz, M., Wojtas, W., Foco, M., Podogrocki, M., & Bijak, M. (2023, January). Healthcare waste—a serious problem for global health. In *Healthcare* (Vol. 11, No. 2, p. 242). MDPI.

Leal Filho, W., Lisovska, T., Fedoruk, M., & Taser, D. (2023). Medical waste management and the UN sustainable development goals in Ukraine: an assessment of solutions to support post-war recovery efforts. *Environmental Challenges*, 100763.

Mor, S., & Ravindra, K. (2023). Municipal solid waste landfills in lower- and middle-income countries: Environmental impacts, challenges and sustainable management practices. *Process Safety and Environmental Protection*, *174*, 510–530. https://doi.org/10.1016/j.psep.2023.04.014

Nwosu, I. A., Ekpechu, J. O., Njemanze, V. C., Semidara, B., Eyisi, E. C., Ohuruogu, B., ... & Okoli, C. N. (2024). Assessment of awareness, attitude, and consequences of healthcare waste among health workers at health facilities in southeast Nigeria. *Sage Open*, *14*(1), 21582440241229598.

Połomka, J., Jędrczak, A., & Myszograj, S. (2020). Risk and opportunity of using plastics from waste collected in a yellow bag. *Polymers*, *12*(8), 1815.

Prüss, A., Giroult, E., & Rushbrook, P. (Eds.). (1999). *Safe management of wastes from health-care activities*. World Health Organization.

Rajalakshmi, S., Amzad Basha, K., & Asif Jamal, G. A. (2023). A Manual on Waste Management Audit. *Laser Park Publish House, Coimbatore, Tamil Nadu, India. 163p*.

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

Santoleri, J. J., Reynolds, J., & Theodore, L. (2000). *Introduction to hazardous waste incineration*. John Wiley & Sons.

Sidiq, A. N., & Nurkayah, N. (2023). Analysis of the Impact of Hospital Medical Waste on the Surrounding Environment. *Innovative: Journal of Social Science Research*, *3*(6), 7188-7199.

Singh, N., Ogunseitan, O. A., & Tang, Y. (2022). Medical waste: Current challenges and future opportunities for sustainable management. *Critical Reviews in Environmental Science and Technology*, *52*(11), 2000-2022.

World Health Organization: WHO. (2024, October 24). *Healthcare waste*. https://www.who.int/news-room/fact-sheets/detail/health-care-waste

Yi, L., Hong, Y., Wang, D., & Zhu, Y. (2007b). Determination of free heavy metal ion concentrations in soils around a cadmium rich zinc deposit. *Geochemical Journal*, *41*(4), 235–240. https://doi.org/10.2343/geochemj.41.235