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Healthcare Waste Generation at A Medium- To High-Complexity Academic Hospital in Colombia, 2022–2024

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Abstract:

Background: Healthcare facilities (HCFs) are the principal contributors to healthcare waste generation.

Objective:

To quantify the production of healthcare waste in an academic hospital in Colombia and to assess temporal trends in waste generation.

Methods:

A retrospective observational study was conducted in a medium-to high-complexity academic hospital located in Tuluá, Colombia. Waste was segregated at the source into three categories (ordinary, recyclable, and hazardous), collected daily, and weighed at the hospital's maintenance center. Data corresponding to the years 2022–2024 were obtained from institutional records. The generation rate was expressed as kilograms per bed per day (kg/bed/day), calculated based on annual production. Differences in annual averages were assessed using analysis of variance (ANOVA) with Bonferroni-adjusted post hoc comparisons. Temporal trends were evaluated through a generalized linear model (GLM). All statistical tests were conducted at a significance level of $\alpha = 0.10$.

Results:

All categories of healthcare waste demonstrated a statistically significant upward trend. The annual production of ordinary waste increased from 4.92 tons to 7.91 in 2024, representing an overall increase of 60.8%. Recyclable waste increased from 2.23 tons in 2022 to 4.46 in 2024, an overall increase of 100.0%. Hazardous waste rose from 9.82 tons in 2022 to 10.92 in 2024, an overall increase of 11.2%. The average generation rate across all categories was 0.27 kg/bed/day.

Conclusion:

The findings confirm an upward trend in healthcare waste generation at this Colombian academic hospital. Hospital authorities should strengthen protocols for hazardous waste handling to safeguard both healthcare workers and patients.

Key words: healthcare waste production; waste segregation; waste trend; academic hospital; generalized linear model; colombia.

Introduction:

Healthcare facilities (HCFs) represent the principal contributors to healthcare waste (HCW) generation. This waste is broadly categorized as hazardous or non-hazardous and further subdivided into infectious, non-infectious, or chemical components. Globally, approximately 85% of healthcare waste is classified as non-hazardous, whereas the remaining 15% comprises hazardous fractions, including infectious, radioactive, and toxic materials. In high-income countries, hazardous waste generation reaches up to 11 kg per hospital bed per day (kg/bed/day), while in low-income countries the rate is approximately 6 kg/bed/day. Nonetheless, inadequate segregation practices in many low-income settings often result in the commingling of hazardous and non-hazardous streams, thereby inflating the actual volume of hazardous waste reported [1-4].

Despite broad recognition of the risks associated with HCW, significant deficiencies in its management persist5,6. These challenges are particularly pronounced in developing countries, where HCW is frequently stored, transported, and disposed of alongside general waste streams [7]. According to the World Health Organization, approximately 10% to 25% of collected HCW is potentially hazardous to human health, primarily due to its capacity to harbor pathogens capable of causing infections in healthcare workers and patients alike [8].

Healthcare waste is defined as any waste generated during the diagnosis, treatment, or immunization of humans and animals. Hospitals are considered the primary sources of HCW, where inadequate management practices are frequently documented. Beyond its hazardous characteristics, HCW presents substantial health and safety risks due to the complex and heterogeneous composition of biomedical waste streams. This complexity has intensified public concern over the effectiveness of current strategies for its storage, treatment, transportation, and final disposal [9].

Several studies have demonstrated that the volume of solid waste generated by healthcare facilities varies depending on the type and scope of hospital services [10]. Solid waste management, and particularly the handling of medical solid waste, has emerged as a major global concern. Evidence indicates that approximately 33% of healthcare facilities do not manage their solid waste safely, while nearly 30% lack adequate systems for its segregation and proper disposal [11,12].

In Europe, the average rate of HCW generation is estimated at 2.61 kg per bed per day (kg/bed/day), ranging from 0.3 to 4.4 kg/bed/day. The highest volumes are reported in the Americas, with an average of 3.82 kg/bed/day (0.4–8.4 kg/bed/day). On a global scale, HCW generation is increasing at an estimated rate of 2–3% annually, with university hospitals identified as the primary contributors to hazardous waste [13].

In Latin America and the Caribbean, the management of bio-contaminated waste remains inadequate, thereby heightening the risk of disease transmission among healthcare workers and the wider population¹4,15,16. Environmental pollution has become a critical concern worldwide due to its adverse effects on human health, with hazardous healthcare waste representing approximately 47% of total waste generated in some settings19,20. Continuous exposure of healthcare workers to biological, chemical, and physical waste significantly increases the risk of acquiring infectious and occupationally related diseases [21,22].

Within this framework, the active participation of healthcare workers is essential for implementing an effective hospital solid waste management system, thereby reducing potential risks to both human health and the environment.

Accordingly, the present study aimed to assess the production and trends of three categories of hospital waste, ordinary, recyclable, and hazardous, generated at a medium- to high-complexity academic hospital in Colombia between 2022 and 2024. In Colombia, hospital waste classification follows Resolution 1362 of 2020, which categorizes waste into hazardous healthcare waste, hazardous chemical/physical waste, and general (ordinary) waste [23,24]. We hypothesized that all waste categories would demonstrate a statistically significant upward trend during the study period.

Methodology:

Study Design and Setting. A retrospective observational study was conducted at the E.S.E. Hospital Departamental Tomás Uribe Uribe, a medium- to high-complexity academic hospital with 208 beds, located in Tuluá, Valle del Cauca, Colombia. The hospital provides a broad range of clinical services, including emergency care, surgery, internal medicine, obstetrics and gynecology, pediatrics, and intensive care, and serves as a teaching facility for medical and nursing students.

Waste Classification. Hospital waste is classified into three categories according to its characteristics: Group 1 comprises hazardous healthcare waste (HHCW) generated during medical care, most of which is contaminated with microorganisms and poses a high risk to individuals who encounter it. Group 2 also includes hazardous waste but refers to materials with physical or chemical properties that present potential dangers, such as toxicity, explosiveness, corrosiveness, or flammability, to exposed individuals, and Group 3, referred to as general waste, encompasses non-hazardous materials generated through administrative activities and the maintenance of hospital facilities [23,24].

According to institutional protocols, waste is segregated at the source, these materials are collected daily and transported to the maintenance center, where they are weighed and prepared for final disposal. In cases of misclassification, maintenance personnel are responsible for correcting the error. The analysis included data recorded monthly, yielding 36 complete monthly observations (January 2022–December 2024); no missing data were identified.

Calculation of Generation Rate. The generation rate of hospital waste, expressed as kilograms per installed bed per day (kg/installed bed/day), was calculated as follows: each type of waste across the three study years was summed, and the total was divided by three to obtain the average, expressed in tons, for the study period. This value was then converted into kilograms by multiplying by 1,000. The total kilograms were divided by 365 to estimate the daily waste generation, and the result was subsequently divided by 208 (the total number of hospital beds) to obtain the final kg/installed bed/day value. It is acknowledged that using installed beds rather than occupied bed-days may underestimate true waste generation intensity; occupied bed-day data were unavailable retrospectively.

Statistical Analysis Plan. The variation in the annual averages of waste production for each residue type during the study period was estimated, and to evaluate differences in mean annual waste generation across years and waste categories, an analysis of variance (Proc ANOVA) was performed. Given the homogeneity of variances, the Bonferroni adjustment was applied to control for type I error in multiple comparisons25.

In addition, a generalized linear model (Proc GLM) was employed to assess potential trends in waste generation over time [26,27,28,29]. All statistical tests were conducted at a significance level of $\alpha = 0.10$ to increase the statistical power, considering the sample size limitations [29]. Analyses were performed using SAS® software.

Ethical Considerations. The study was reviewed and approved by the Human Research Ethics Committee (HREC) of the Departmental Hospital Tomás Uribe Uribe, State Social Enterprise, Tuluá, as recorded in the minutes of meeting No. 2 of the Research Ethics Committee, dated [22 September 2025]. Given that the data were obtained from secondary sources, anonymized prior to analysis, and contained no personal identifiers, informed consent was not required in accordance with national regulations.

Results:

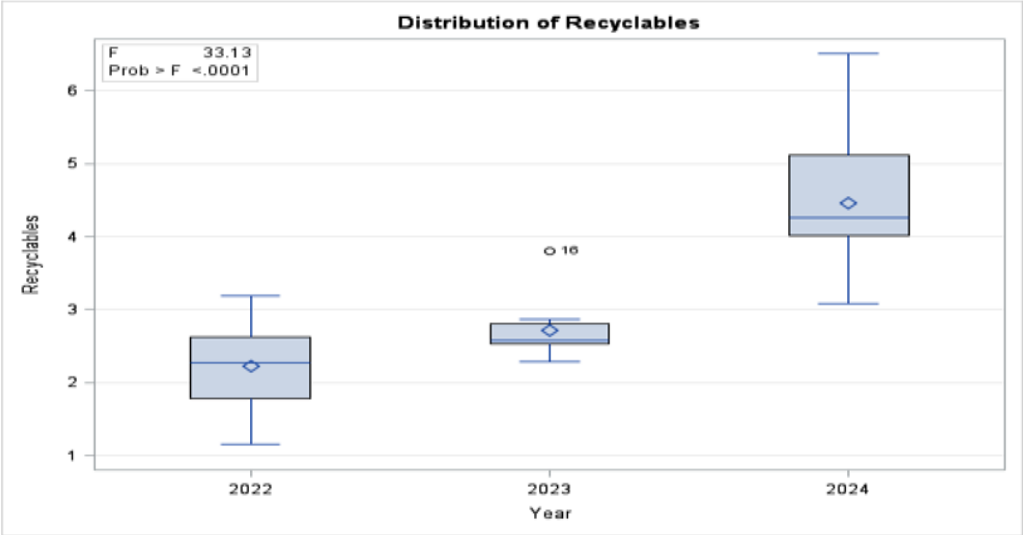
Waste Category	Year	Production (tons)	95% CI	% Change (2022-2024)	Daily Average (kg)	Kg/Bed/Day
Ordinary	2022	4.92	4.12–5.73	60.8%	13.5	0.065
	2023	8.99	7.47–10.51		24.6	0.118
	2024	7.91	7.74–8.09		21.7	0.104
Recyclable	2022	2.23	1.93–2.53	100.0%	6.1	0.029
	2023	2.71	2.53–2.89		7.4	0.036
	2024	4.46	4.01–4.92		12.2	0.059
Hazardous	2022	9.82	9.46–10.18	11.2%	26.9	0.129
	2023	10.41	10.03–10.79		28.5	0.137
	2024	10.92	10.54–11.30		29.9	0.144
Total	2022	16.97	–	37.2%	46.5	0.224
	2023	22.11	–		60.6	0.291
	2024	23.29	–		63.8	0.307

Source. Own estimation

Table 1: *Annual healthcare waste production by category, 2022-2024.*

The annual production of recyclable waste was 2.23 tons (95% CI: 1.93–2.53) in 2022, 2.71 tons (95% CI: 2.53–2.89) in 2023, and 4.46 tons (95% CI: 4.01–4.92) in 2024, representing a 100.0% across the study period. (Table 1).

The ANOVA procedure demonstrated significant differences in the average collection of recyclable waste across years $F = 33.1$, $df = 2,35$, $p = 0.0001$. Post hoc comparisons revealed statistically significant differences between 2024 and 2022 $p < 0.0001$, and between 2024 and 2023 $p < 0.001$. Both linear and quadratic trends were statistically significant; based on parsimony, the linear trend was selected $F = 59.8$, $df = 1$, $p < 0.0001$. (Figure 1)

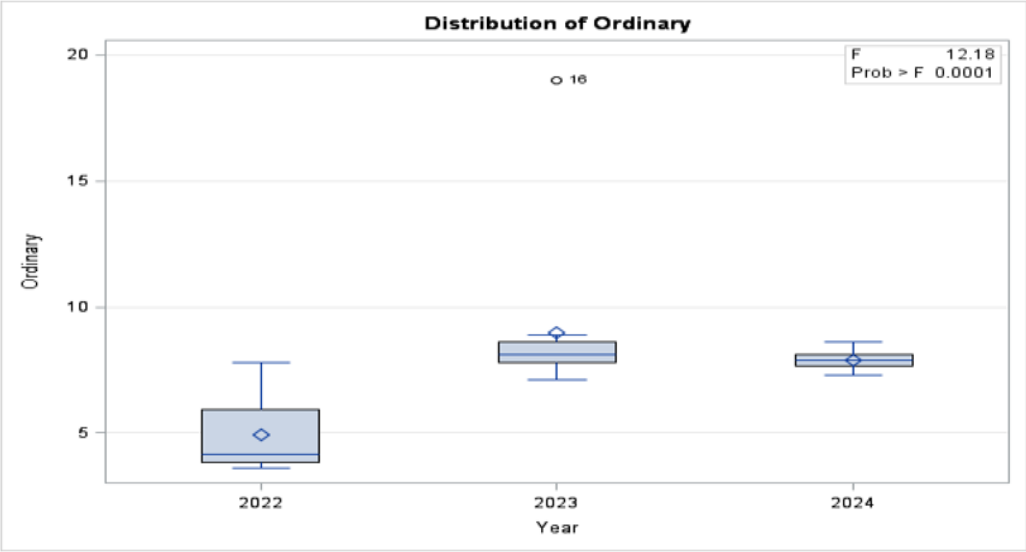


Source. Own estimation

Figure 1: *Average annual tons of recyclable sanitary waste collection, 2022-2024.*

The annual production of ordinary waste was 4.92 tons (95% CI: 4.12–5.73) in 2022, 8.99 tons (95% CI: 7.47–10.51) in 2023, and 7.91 tons (95% CI: 7.74–8.09) in 2024. Overall, ordinary waste increased by 60.8% across the study period.

Analysis of variance (Snedecor's F test) indicated significant differences in the average collection of ordinary waste among the three years $F = 12.2$, $df = 2,35$, $p < 0.0001$. Post hoc comparisons revealed statistically significant differences between 2022 and 2023, $F = 22.7$, $df = 1$, $p < 0.0001$, and between 2024 and 2022 $F = 12.2$, $df = 1$, $p < 0.001$. Both linear and quadratic trends were statistically significant; however, based on the principle of parsimony, the linear trend was selected, $F = 12.8$, $df = 1$, $p < 0.01$. (Figure 2)



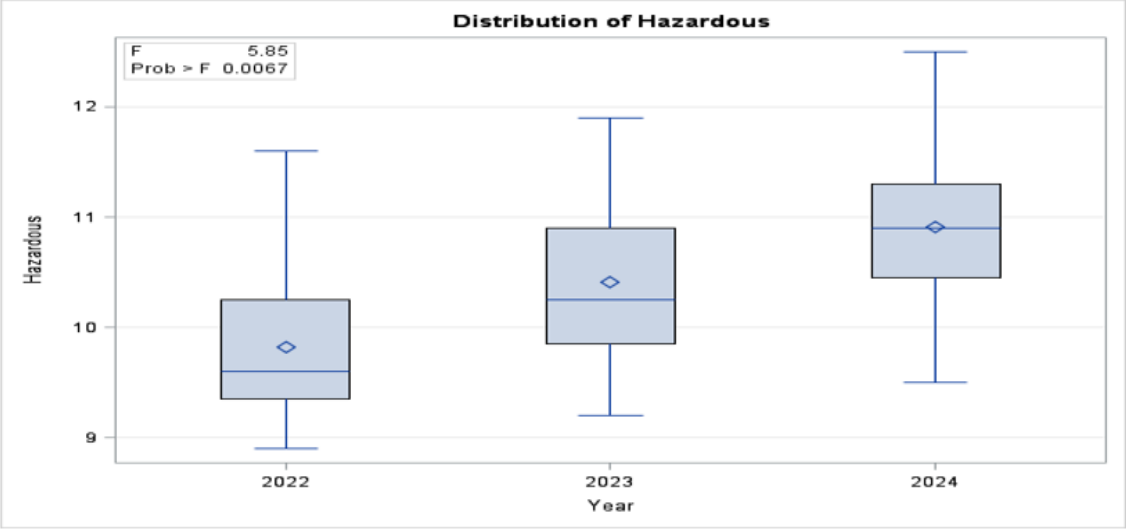
Source. Own estimation

Figure 2: *Average annual tons of ordinary sanitary waste collection, 2022-2024.*

The annual production of hazardous waste was 9.82 tons (95% CI: 9.46–10.18) in 2022, 10.41 tons (95% CI: 10.03–10.79) in 2023, and 10.92 tons (95% CI: 10.54–11.30) in 2024 (Table 1). This represents an overall increase of 11.2% in hazardous waste generation.

The ANOVA procedure demonstrated statistically significant differences in mean hazardous waste levels among years $F = 5.85$, $df = 2,35$, $p = 0.007$. Post hoc comparisons revealed a significant borderline increase between 2023 and 2022 $F = 3.39$, $df = 1$, $p = 0.07$, and a significant increase between 2022 and 2024 $F = 11.68$, $df = 1$, $p < 0.001$. Trend analysis indicated that only the linear component reached statistical significance $F = 11.68$, $df = 1$, $p < 0.001$, suggesting a steady upward trajectory in hazardous waste production. (Figure 3)

The average combined generation rate across all three categories was 0.27 kg/bed/day (range: 0.224–0.307 kg/installed bed/day across years). Hazardous waste constituted 47.8% of total production on average, followed by ordinary waste 34.5% and recyclable waste 17.7%.



Source. Own estimation

Figure 3: *Average annual tons of hazardous sanitary waste collection, 2022-2024.*

Discussion:

For ordinary waste, the annual amounts produced were 4.92 tons (4.12–5.73) in 2022, 8.99 tons (7.47–10.51) in 2023, and 7.91 tons (7.74–8.09) in 2024. The Analysis of variance procedure indicated significant differences in average production across the study period $F = 12.2$, $df = 2,35$, $p < 0.0001$. Post hoc comparisons showed that 2024 differed significantly from both 2022 and 2023. Trend analysis revealed a statistically significant linear component $F = 12.8$, $df = 1$, $p < 0.01$, suggesting a sustained upward trajectory in the generation and disposal of ordinary waste. Notably, ordinary waste exhibited the largest overall increase among the waste categories, rising by 60.8% over the study period. (Figure 2.)

Regarding recyclable waste, 2.23 (1.93–2.53), 2.71 (2.53–2.89), and 4.46 (4.01–4.92) tons were produced annually during each year of the study period. The ANOVA procedure result was $F = 33.1$, $df = 2.35$, $p < 0.0001$, indicating that there are differences related to the year's average collection of recyclable waste, a difference was found between the years 2023 and 2024 compared to the year 2022. The linear trend was statistically significant, $F = 59.8$, $df = 1$, $p < 0.0001$, indicating a continued increase in the collection and final disposal of this type of waste. Recyclable waste showed an increase of 100.0%. (Figure 1).

In relation to hazardous waste, the annual production was 9.82 tons (9.46–10.18) in 2022, 10.41 tons (10.03–10.79) in 2023, and 10.92 tons (10.54–11.30) in 2024. The Analysis of variance procedure revealed significant differences in mean production across the study period $F = 5.85$, $df = 2,35$, $p = 0.007$. Post hoc comparisons indicated that both 2023 and 2024 differed from 2022. Trend analysis confirmed a significant linear component $F = 11.68$, $df = 1$, $p = 0.001$, demonstrating a consistent increase in the generation and disposal of hazardous waste. Overall, hazardous waste rose by 11.2% over the study period. (Figure 3.)

The observed increases across all waste categories may reflect multiple concurrent factors, including expanding clinical and academic activities, increased use of single-use medical devices, post-pandemic recovery in elective services, and potentially improved segregation practices. However, the retrospective design precludes definitive attribution of the observed trends to specific causal mechanisms. The 100% increase in recyclable waste suggests enhanced environmental awareness, though concurrent increases in absolute material consumption cannot be excluded. The steady rise in hazardous waste, while consistent with global trends in academic hospitals, warrants monitoring of treatment capacity to ensure safe disposal.

A study conducted in a hospital in Ghana reported daily waste generation of 5.1 kg of sharps, 24.46 kg of infectious waste, and 59.45 kg of general waste. In the present study, daily production averaged 9.45 kg of recyclable waste, 22.9 kg of ordinary waste, and 29.8 kg of hazardous waste. When combining sharps and infectious waste in the Ghanaian study, the total was 29.56 kg/day—comparable to the hazardous waste levels observed here. Conversely, when ordinary and recyclable waste from this study is considered together, the total of 32.5 kg/day was slightly lower than the general waste reported in Ghana30.

In Iran, a six-month intervention aimed at reducing general and contaminated waste successfully decreased general waste from 95.5 to 73.1 kg/day and contaminated waste from 57.5 to 39 kg/day, figures considerably higher than those observed in this study31.

In Qatar, hazardous waste production in hospitals ranged between 2.6 and 3.1 kg per bed per day and demonstrated a continuous upward trend32. In comparison, the average in the present study was 0.27 kg per hospital bed per day, which falls within the World Health Organization's global estimate of 0.2–0.5 kg per hospital bed per day32. This lower rate may partly reflect the use of installed beds rather than occupied bed-days as the denominator; cross-institutional comparisons should consider denominator differences.

The proportion of hospital hazardous clinical waste (HHCW) identified in this study averaged 47.8%. This figure closely aligns with findings from a study conducted in Hungary, which reported 46.42%33. However, it markedly exceeds the World Health Organization's global estimate of 10–25%. A plausible explanation for this discrepancy is the additional volume of hazardous waste generated through academic and research activities commonly undertaken in university hospital settings.

In contrast, a study conducted in a referral hospital in Uganda revealed that general waste accounted for 72% of total waste, while clinical waste represented 28%. The average solid waste generation rate was 111.4 kg per day, with hospital wards being the primary contributors34. These values are considerably higher than those observed in the present study.

Similarly, research conducted in the department of Norte de Santander, Colombia, reported that 53.92% of waste was classified as non-hazardous, whereas 46.08% corresponded to hazardous waste35. This distribution is consistent with the proportions documented in our findings, reinforcing the observation that hazardous waste in certain hospital contexts can reach levels significantly above global estimates.

The present study documented a statistically significant upward trend in the generation of all three categories of healthcare waste—ordinary, recyclable, and hazardous-at a medium- to high-complexity academic hospital in Colombia over a three-year period. These findings are consistent with global reports indicating that healthcare waste generation is increasing at an estimated rate of 2–3% annually, and that university hospitals are among the primary contributors to hazardous waste [36].

These findings underscore the institutional commitment to mitigating potential health risks by ensuring the systematic removal of residues, particularly those classified as hazardous, from the hospital environment. While improved segregation practices may contribute to the observed increases in separately collected waste categories, other factors such as expanding clinical activity and increased use of disposable materials cannot be excluded. Additionally, the sustained increase in recyclable waste collection suggests not only improved environmental practices but also the potential for generating supplementary economic benefits through recycling initiatives [37].

Study Design Limitations:

This study has several limitations that should be acknowledged. First, the single-center design limits the generalizability of the findings to other healthcare institutions with different characteristics, sizes, or service portfolios. Second, the analysis did not incorporate hospital occupancy rates, patient-days, or procedure volumes as denominators, which would have enabled a more nuanced understanding of waste generation relative to clinical activity. Third, the retrospective design precluded the collection of detailed information on potential confounding factors, such as changes in clinical practices or infection occurrences. Fourth, the classification of waste relied on institutional protocols and the judgment of maintenance personnel, which may have introduced some degree of misclassification bias.

Future Research Directions:

Future studies should adopt a multi-center design to compare waste generation patterns across hospitals with varying levels of complexity and geographic locations. The inclusion of activity-based denominators (e.g., occupied bed-days, admissions, surgical procedures) would enhance the comparability of waste generation rates. Additionally, prospective designs incorporating waste audits at the ward or departmental level would provide actionable insights for targeted interventions. The environmental and economic impacts of recycling programs and waste minimization strategies also warrant further investigation.

Data Availability:

The data that supports the findings of this study are available from the GECOI office upon reasonable request. Due to institutional policies, the raw monthly waste generation data cannot be publicly deposited; however, de-identified summary statistics and supplementary methodological details are available upon request.

References:

1. Chartier Y, (2014) World Health Organization. Safe Management of Wastes from Health-Care Activities. 2nd ed. Geneva, Switzerland: World Health Organization;.
   View at Google Scholar | ***View at Publisher***
2. Hasan MM, Rahman MH. (2018) Assessment of Healthcare Waste Management Paradigms and Its Suitable Treatment Alternative: A Case Study. J Environ Public Health. 2018:6879751.
   View at Google Scholar | ***View at Publisher***

3. Dehghani MH, Ahrami HD, Nabizadeh R, Heidarinejad Z, Zarei A. (2019) Medical Waste Generation and Management in Medical Clinics in South of Iran. MethodsX. 6: 727-733.
View at Google Scholar | ***View at Publisher***
4. Janik-Karpinska E, Brancaleoni R, Niemcewicz M, Wojtas W, Foco M, Podogrocki M, Bijak M. (2023) Healthcare Waste—A Serious Problem for Global Health. Healthcare. 11(2):242. *https://doi.org/10.3390/healthcare11020242*
View at Google Scholar | ***View at Publisher***
5. Singh N, Ogunseitan OA, Tang Y. (2022) Medical waste: Current challenges and future opportunities for sustainable management. Crit Rev Environ Sci Technol. 52(11):2000-2022. *https://doi.org/10.1080/10643389.2021.1885325*
View at Google Scholar | ***View at Publisher***
6. Cook E, Woolridge A, Stapp P, Edmondson S, Velis CA. (2023) Medical and healthcare waste generation, storage, treatment and disposal: a systematic scoping review of risks to occupational and public health. Crit Rev Environ Sci Technol. 53(15):1452-1477. https://doi.org/10.1080/10643389.2022.2150495
View at Google Scholar | ***View at Publisher***
7. Harhay MO, Halpern SD, Harhay JS, Olliaro PL. (2009) Health care waste management: a neglected and growing public health problem worldwide. Trop Med Int Health. 14(11):1414-1417. https://doi.org/10.1111/j.1365-3156.2009.02386.x
View at Google Scholar | ***View at Publisher***
8. World Health Organization. Safe Management of Wastes from Health-Care Activities. 2nd ed. Geneva: WHO; 2014.
View at Google Scholar | View at Publisher
9. Ramaganesh M, Shiny Rebekka S, Watson V, et al. (2021) Measurement of hospital efficiency in biomedical waste management. Mater Today Proc. https://doi.org/10.1016/j.matpr.2021.10.415
View at Google Scholar | View at Publisher
10. Ministerio de Salud del Perú (MINSA). (2018) Integral Management and Solid Waste Management in Health Establishments, Support Medical Services and Research Centers. Lima: MINSA; 1-88.
View at Google Scholar | View at Publisher
11. Suarez Rivadeneira JE, et al. (2024) Generation rate of hospital solid waste from different services: A case study in the province of Bagua, northern Peru. Heliyon. 10:e31814. https://doi.org/10.1016/j.heliyon.2024.e31814
View at Google Scholar | ***View at Publisher***
12. MINSA, Peru. N° 217-2004. 2004. ISBN 9972851141. https://doi.org/10.1016/j.heliyon.2024.e31814
View at Google Scholar | ***View at Publisher***
13. Herrera Rojas M, Lazo Ramos RS.(2020) Hospital Solid Waste Management System to reduce environmental impact in a social security hospital in Tacna—2018. Veritas Et Scientia Magazine—UPT. 8:1192-1201. https://doi.org/10.47796/ves.v8i2.136
View at Google Scholar | ***View at Publisher***
14. Khan BA, Cheng L, Khan AA, Ahmed H. (2019) Healthcare waste management in Asian developing countries: a mini review. Waste Manag Res. 37:863-875. https://doi.org/10.1177/0734242X19857470
View at Google Scholar | ***View at Publisher***
15. World Health Organization (WHO). Solid waste. https://www.paho.org/es/temas/residuos-solidos
View at Google Scholar | View at Publisher
16. Ticona-Casani GM, Sutta-Huamán LD. (2021) Hospital Waste in Latin America: Systematic Review. 9(2):17-27.
View at Google Scholar | View at Publisher
17. Kaposi A, et al. (2024) Analysis of healthcare waste and factors affecting the amount of hazardous healthcare waste in a university hospital. J Mater Cycles Waste Manag. 26. https://doi.org/10.1007/s10163-024-01890-1
View at Google Scholar | ***View at Publisher***
18. Abarca D, Escobar F. (2018) Health waste management: an educational program from knowledge to practice. J High Andean Res. 20:315-324. https://doi.org/10.18271/ria.2018.395
View at Google Scholar | View at Publisher
19. Nkonge Njagi A, Mayabi Olowe A, Kithinji J, Kithinji M, et al. (2012) Knowledge, attitude and practice of health-care waste management and associated health risks in the two teaching and referral hospitals in Kenya. J Community Health. 37:1172-1177.
View at Google Scholar | ***View at Publisher***
20. Choudhury M, Sahoo S, Samanta P, Tiwari A, Tiwari A, Chadha U, Bhardwaj P, Nalluri A, Eticha TK, Chakravorty A. (2022) COVID-19: An Accelerator for Global Plastic Consumption and Its Implications. J Environ Public Health. 2022:1066350. https://doi.org/10.1155/2022/1066350
View at Google Scholar | ***View at Publisher***
21. Rupani PF, Delarestaghi RM, Abbaspour M, Rupani MM, El-Mesery HS, Shao W. (2019) Current status and future perspectives of solid waste management in Iran: a critical overview of Iranian metropolitan cities. Environ Sci Pollut Res. 26(32):32777-32789.

View at Google Scholar | ***View at Publisher***

22. Iyer M, Tiwari S, Renu K, et al. (2021) Environmental survival of SARS-CoV-2—A solid waste perspective. Environ Res. 197:111015. ***View at Google Scholar*** | ***View at Publisher***
23. Ministerio de Salud y Protección Social de Colombia. Resolución 1362 de 2020. Por la cual se adopta el Manual de Gestión Integral de Residuos Generados en la Atención en Salud y otras Actividades. Bogotá: Ministerio de Salud; 2020. ***View at Google Scholar | View at Publisher***
24. World Health Organization. Safe management of wastes from health-care activities. 2nd ed. Chapter 2: "Categories of health-care waste". Geneva; WHO, 2024. ***View at Google Scholar*** | ***View at Publisher***
25. Kirk RE. Experimental Design: Procedures for Behavioral Sciences. 2nd ed. Pacific Grove, CA: Brooks/Cole Publishing Company; 1982. ***View at Google Scholar | View at Publisher***
26. Checkoway H, Pearce N, Crawford-Brown DJ. Research Methods in Occupational Epidemiology. New York: Oxford University Press; 1989. ***View at Google Scholar | View at Publisher***
27. Kleinbaum DG, Kupper LL, Muller KE. Applied Regression Analysis and Other Multivariable Methods. Belmont, CA: Duxbury Press; 1988. ***View at Google Scholar*** | ***View at Publisher***
28. Mendenhall W, Wackerly DD, Scheaffer RL. Mathematical Statistics with Applications. 4th ed. Boston: PWS-KENT Publishing Company; 1990. ***View at Google Scholar | View at Publisher***
29. Ryan TP. Sample Size Determination and Power. Hoboken, NJ: John Wiley & Sons; 2013. ***View at Google Scholar | View at Publisher***
30. Abanyie SK, Amuah EEY, Douti NB, et al. (2021) Healthcare waste management in Tamale Central Hospital, Northern Ghana. An assessment before the emergence of the COVID-19 pandemic in Ghana. Environ Challenges. 5:100320. ***View at Google Scholar*** | ***View at Publisher***
31. Azami-Aghdash S, et al. (2023) Improving the hospital waste management at the Farabi hospital in Malekan—Iran: An action research study. Heliyon. 9(7):e17695. https://doi.org/10.1016/j.heliyon.2023.e17695 ***View at Google Scholar*** | ***View at Publisher***
32. Al NH, Izuka K, Edquibal C, et al. (2021) Quantitative assessment of medical waste management in Hamad Medical Corporation, Qatar. Occup Dis Environ Med. 9. https://doi.org/10.4236/odem.2021.93009 ***View at Google Scholar*** | ***View at Publisher***
33. Kaposi A, et al. (2024) Analysis of healthcare waste and factors affecting the amount of hazardous healthcare waste in a university hospital. J Mater Cycles Waste Manag. 26. https://doi.org/10.1007/s10163-024-01890-1 ***View at Google Scholar*** | ***View at Publisher***
34. Christine Katusiime. (2018) Making Healthcare Waste Management A Priority: The Reality of Solid Waste Disposal at Mulago National referral Hospital. International Journal of Environmental Sciences & Natural Resources. 15(5). 10.19080/IJESNR.2018.15.55921 ***View at Google Scholar*** | ***View at Publisher***
35. Nieto-Sánchez ZC, Moreno-Sánchez YM, Fernández-Nieto EL. (2022) Management of hospital waste in a Service Provider Institution in the municipality of Los Patios, Norte de Santander, Colombia. Rev Salud Pública. 24(5):1-8. ***View at Google Scholar*** | ***View at Publisher***
36. World Health Organization. Safe Management of Wastes from Health-Care Activities. 2nd ed. Geneva: WHO; 2014. ***View at Google Scholar | View at Publisher***
37. Nematollahi H, Tuysserkani M, Nematollahi A. (2025) Medical waste management in the modern healthcare era: A comprehensive review of technologies, environmental impact, and sustainable practices. Results Eng. 28:107210. ***View at Google Scholar*** | ***View at Publisher***