



Assessment of Medical Waste Disposal and Environmental Implications in Uyo City Metropolis

NDIFREKE, E. I.^{1,*} , IMOHO, I. E.¹ , EYO, S. A.² 

¹Department of Mechanical Engineering, Akwa Ibom State, Polytechnic, Nigeria.

²Department of Electrical Engineering, University of Cross River State, Nigeria.

ARTICLE INFO

Received: x/x/2023

Accepted: x/x/2024

Keywords

Elemental composition, Environmental implications, Medical waste, Waste management

ABSTRACT

Indiscriminate dumping of infectious and toxic medical wastes generated from the hospital as well as open burning of these wastes are becoming prevalent in recent times. This usually result in several health and environmental problems. The objective of this study was to determine the soil elemental compositions in hospital waste disposal sites in Uyo metropolis. The study areas, included Uniuyo Teaching Hospital, St. Luke's Hospital, Uniuyo Medical Centre and Children Hospital. Underlying soil samples in the waste disposal sites were collected in a cellophane bag and tied properly to prevent air ingress. Atomic absorption spectrophotometer was employed to determine trace metals present in the waste disposal sites which were compared to World Health Organization Standards. The results were analyzed using statistical analysis, ANOVA. Results obtained from the atomic absorption spectrophotometer revealed that each of the samples contained one of the following elements such Pb, Ni, Cr, As, Cd, Al. The ANOVA results showed that mean values of the heavy metals were within WHO permissible limit, like lead Pb (1.302) at the children hospital site, Nickel Ni (0.448) at Uniuyo Teaching Hospital site, Aluminum Ai (0.486333) at the Uniuyo Medical Centre site, Arsenic As (0.239333) at the control site. Except chromium Cr (0.343667) at the children hospital site that was above the WHO standard. From the result of the statistical analysis, it was observed that medical wastes had a significant effect on the environment of Uyo metropolis. Based on the findings, it is recommended that effective method of waste segregation and disposal should be implemented, and designated sites should be used as dump sites.

1. INTRODUCTION

According to Borowy (2020), a medical waste is defined as tissues removed from surgery rooms, morgues, laboratories or other medical facilities. The term may also apply to bedding, bandages that have been used in diagnosis/treatment in clinics or research institutes. Medical wastes are generated as a result of patient's diagnosis and treatment or immunization of human beings or animals. The term "hospital

wastes" has many subsets examples are hazardous wastes and infections wastes. Wrongly managed medical waste is one of the most toxic wastes known in science. Medical waste disposal is a critical aspect of healthcare management that requires careful attention to prevent adverse environmental implications. Uyo City Metropolis, located in Akwa Ibom State Nigeria, is a rapidly growing urban area facing challenges in the proper disposal of medical waste. The current state of medical

*Corresponding author, e-mail:author@fupre.edu.ng

DIO

©Scientific Information, Documentation and Publishing Office at FUPRE Journal

waste disposal in Uyo City Metropolis is concerning, as there is a lack of proper infrastructure and guidelines for the safe disposal of medical waste (Ukpong and Udofia, 2011; Mbina and Edem, 2015). The absence of designated disposal sites and the inadequate segregation of medical waste from general waste contribute to the improper handling and disposal of hazardous materials. This situation poses significant risks to public health and the environment. Improper medical waste disposal practices in Uyo City Metropolis have severe environmental implications (Hassan, 2008; Morenikeji et al., 2017). Firstly, the release of hazardous chemicals and pathogens from improperly disposed medical waste can contaminate soil, water bodies, and air, leading to the spread of diseases and ecological imbalances. Secondly, the burning of medical waste, a common practice in the absence of proper disposal facilities, releases toxic gases and particulate matter, contributing to air pollution and respiratory problems (Ezeudu et al., 2022). Lastly, the improper disposal of sharps and needles poses a direct threat to waste handlers and the general public, increasing the risk of injuries and infections (Ramadhan, 2014; Zherka, 2020; Afesi-Dei et al., 2023). Municipal Solid Waste (MSW) generation is one of the most significant environmental problems bedeviling cities and the wellbeing of its inhabitants particularly in developing countries (Ikpe et al., 2019; Ikpe et al., 2020a). Ikpe et al. (2020b) employed a questionnaire based survey to assess the risks posed by open waste dumping on the physical environment and health of individuals in Benin City Metropolis. The findings revealed that open waste dumping is responsible for outbreak of diseases such as Cholera, Diarrhoea, Malaria, Tetanus, Lassa fever, Typhoid and Yellow fever, Hookworm, and other parasite infestation.

It was also reported that open waste dumping can also result in water contamination, land pollution, emission of obnoxious odour as well as climate changes and global warming through the release of Green House Gases (GHGs). Ekanem et al. (2021) conducted a descriptive cross-sectional study among 158 health workers in St. Luke's Hospital, Anua, in Uyo, Akwa Ibom State, Nigeria. Data was collected using a structured questionnaire, checklist for a facility walk-through assessment and a key informant interview and analysed using STATA statistical software version 10.0. Majority (88.6%) of the respondents had good level of knowledge of Health Care Waste (HCW) management and its effect on health. More than half (58.9%) of the respondents had good HCW management practices. Predictors of poor knowledge of HCW management had limited training on HCW management. All wards had sharp containers and waste bins which were not of the standard colour coding. About 30% of the waste bins had lids. Olorunsola and Adje (2017) studied the waste disposal pattern of domestic, medical and pharmaceutical waste in Uyo metropolis, Southern Nigeria. Majority of wastes disposed were medical and pharmaceutical, and were disposed without segregation. The proportion of medical waste disposed ranged from 85% to 96.67% while 73.34% to 82.5% represent the proportion of pharmaceutical waste disposed. Only a small proportion disposed medical waste by burning or burying. Disposal by incineration was not practiced at all in the population surveyed. Ikpe et al. (2019) investigated the effects of waste dumpsites on geotechnical properties of the underlying soils in wet season. It was observed that chemical composition and pH of dumpsite underlying soils indicated high level of soil contaminants with pH of 3.3 and 3.5 which are very acidic unlike pH of

other soil-food waste samples which were in the neutral range (6.8-7.1). The study also revealed that the interaction between food waste and the toxic contaminant in dumpsites can significantly alter the geotechnical properties of the underlying soil, damage plant root, affect soil fertility etc. whereas, pH obtained from soil-food waste indicated a valuable product for compost manure. Ngouakam et al (2012) studied the characterization and management strategies as well as the infectious disease associated with solid clinical waste in general hospital, Ikot Ekpene, Akwa Ibom State. Six categories of HCW identified were infectious, pathological, sharps, pharmaceutical, chemical and radioactive wastes. Physical, chemical and biological hazards were also identified. A total of 33.4 kg/day (0.0334 tons/day) of solid HCW were generated. Open dumping, incineration, burying and open burning were the different methods of waste disposal practices observed. The study revealed that HCWs were poorly managed. Singh et al. (2021) reviewed the current challenges and future opportunities of medical waste for sustainable management. Results obtained highlighted the importance of knowledge and awareness of best practices for infection and injury prevention for waste management among health care workers. An average of 38.9% of medical waste was segregated for proper management and only 41% of workers were trained in-service for medical waste disposal. Plastic materials constituted approximately 35% of medical waste, presenting an opportunity for sustainable resource recovery and recycling. The study revealed that approximately 40% of health workers were injured during waste handling, including musculoskeletal disorders, eye injury, skin infection, and disability. In this study, medical waste disposal and environmental

implications in Uyo city metropolis was assessed. The field survey was conducted in St. Luke's Hospital, Anua in Uyo City Metropolis, Akwa Ibom State.

2. RESEARCH METHODOLOGY

2.1. Study Area

The study area is Uyo metropolis the capital of Akwa Ibom State. Uyo being the State capital of Akwa Ibom State is located on latitudes and longitudes. It lies in the central portion of Akwa Ibom State. Uyo, the capital city of Akwa Ibom State is located on the North West of the state. It extends from latitudes 7⁰47' to 8⁰03' North and from longitudes 4⁰52' to 5⁰07' East. By 1991, the population of Uyo Urban was 118,250. Recently, studies conducted by Ottah et al (2023) observed that the population of Uyo metropolis has exceeded 1.5 million people representing 7.5 % growth from UNDP and SDG report of 2017.

2.2. Population of the Area

The population of the area in 1991 was 244,762. This consisted of 120,875 male and 123,887 females. To determine the population of the area in 2019, this figure was projected at 3.5% growth rate (3.5% of growth rates is used to project the population to 2019 because National Population Commission allows 3.5% growth rate for urban area (Essien and Cyrus, 2019) Using the formula in Equation 1, statistical population projected to 2019 is presented in Table 1.

$$P_t = P_o (I+r)^n \quad (1)$$

Where, P_t is the year population is projected to (2019), P_o is the population of the base year, I is a constant value, n is the period between the base year and the future year and r is the growth rate.

Thus, for males we have:

$$Pt = 123887 + 1 \left(\frac{3.5}{100}\right)^{26}$$

$$Pt = 123887 + 1(0.035)^{26}$$

$$Pt = (1.035)^{26}$$

$$Pt = 303022$$

For female we have:

$$Pt = 120875 + 1 \left(\frac{3.5}{100}\right)^{26}$$

$$Pt = 120875 + 1(0.035)^{26}$$

$$Pt = 295655$$

Table 1: Population statistics (Field Survey, 2023)

Category	1991	2019
----------	------	------

Males	123,887	303022
Females	120,875	295,655
TOTAL	244.762	598,677

From Table 1, the 2019 population estimates for the study area is 598,677 persons. This figure will be used throughout the study. Uyo City Metropolis as it appears on the Map of Akwa Ibom State is presented in Figure 1. Also, the health centers as it appears on the Map of Uyo City Metropolis is presented in Figure 2.

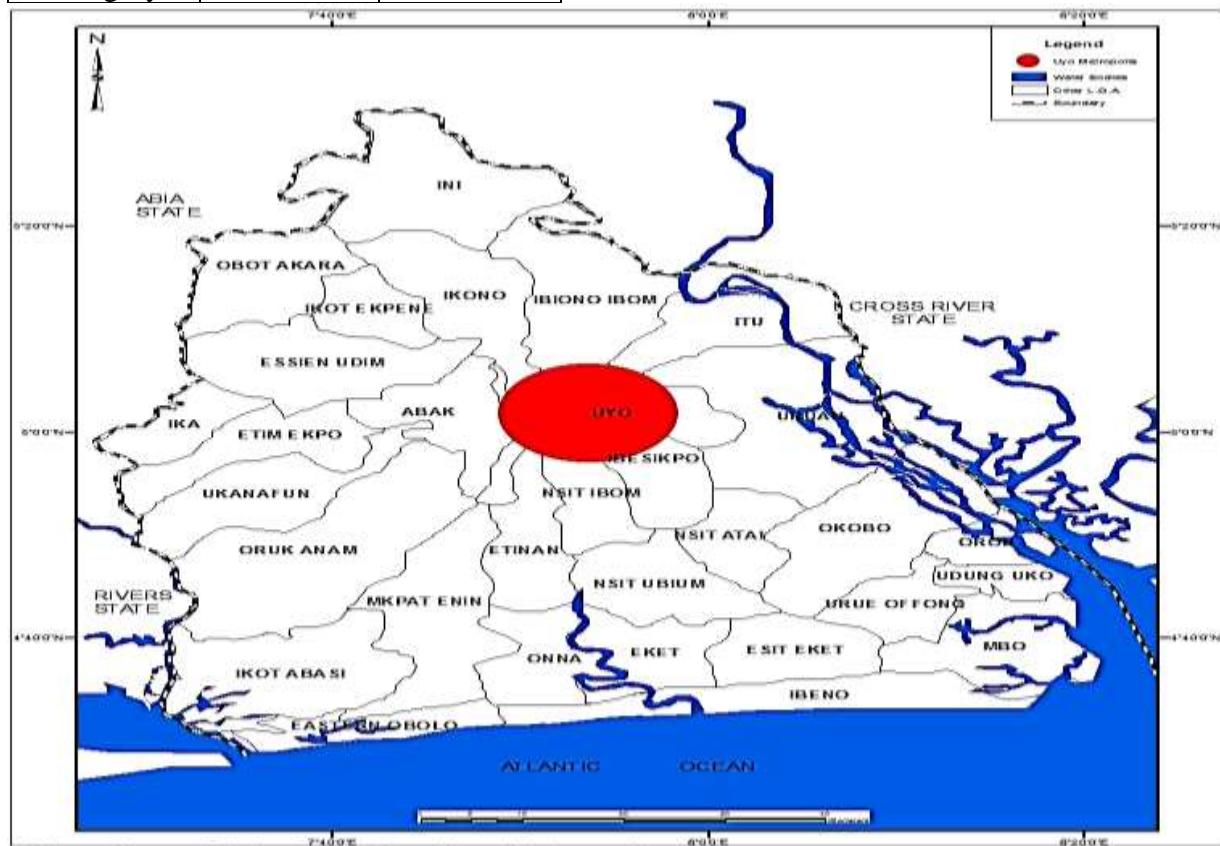


Figure 1: Uyo Metropolis on the map of Akwa Ibom State

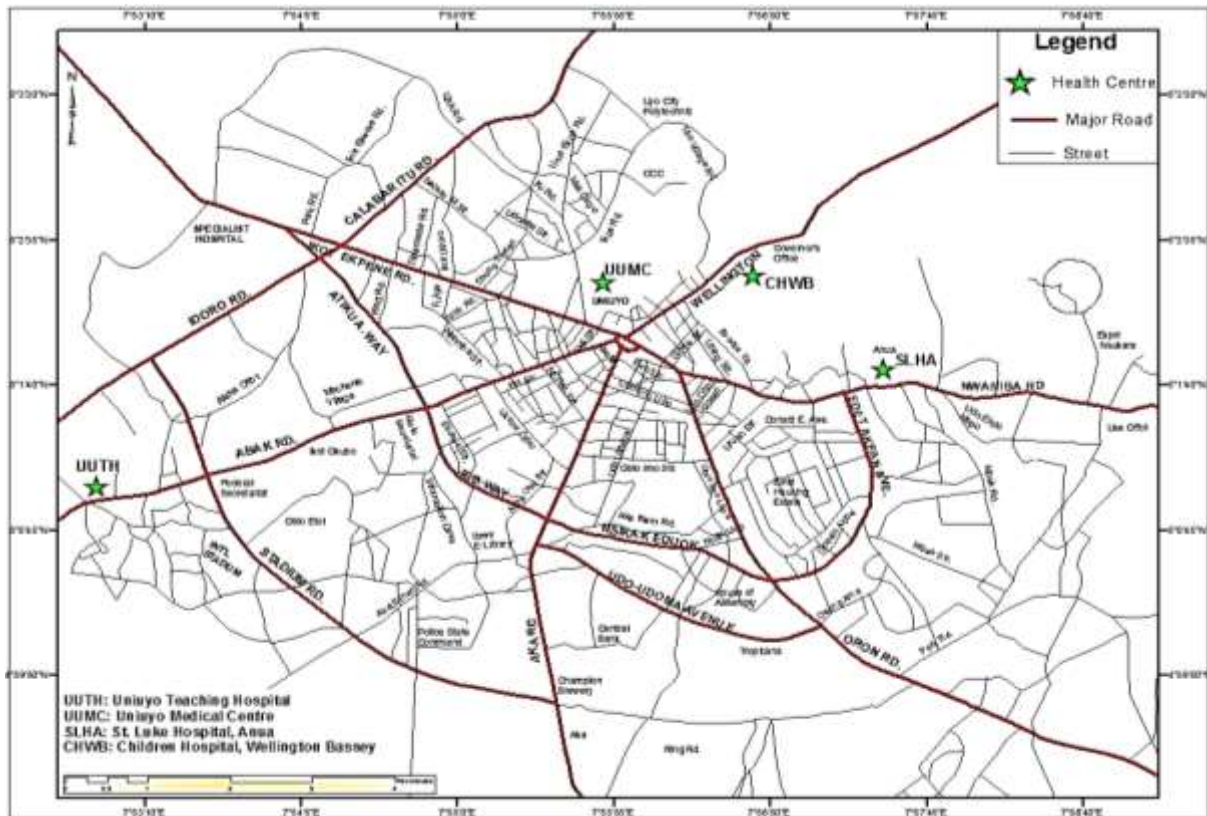


Figure 2: Health institution on the map of Uyo City Metropolis

2.3. Research Design

The research methodology that was used in this research was experimental. The experimental samples that were used in the laboratory to detect or checks the effect of heavy metals on soil were purposely collected using instrument e.g. (Augur, Shovel, nylon, scalper and measuring tape) the quantity of soil collected was 50g. They were collected from four (4) different hospital dump site namely; University of Uyo Teaching Hospital, St. Luke's Hospital, University of Uyo Medical Centre and Children Hospital.

2.4. Data Requirement

The data for this study were derived from the number of soil samples from the hospitals disposal sites, three samples of soil were collected from each hospital site. The data were basically primary and secondary. The primary data include soil from hospital disposal sites. The soil samples were collected from University of Uyo Teaching Hospital, University of Uyo

Medical Centre, St. Luke's Hospital and Children Hospital all within Uyo Metropolis. The control site was 200m from disposal site. The soil samples were collected, preserved and taken to the laboratory for analysis of heavy metals in the University of Uyo. The secondary sources of data included textbooks, journals, magazines and articles, pilot studies as well as the ministry of Environment, World Health Organization (WHO) and NESREA for comparing of standards.

2.5. Sample Collection/Sampling Technique

Three samples were collected from each hospital disposal site, while same was collect from the control site. The sample were stored in sterile containers and preserved before transferring to the laboratory for analysis. Fifteen (15) different samples of soil the hospital wastes were collected randomly at three different locations within the different hospitals. The

control site was at Uruan Local Government Area. The samples were collected using soil Augur and placed in a sterile polythene bag, before transferring to the soil science laboratory Uniuyo, for the analysis of heavy metals. The technique employed in this research was soil sample collected around a particular dump site, blended (mixed) to obtain a representative sample. These samples were obtained from the depth of 10 – 12cm by the use of Augur, trowel for fetching and the meter rule for measurement the samples collected were packaged in polythene bags and then taken to the laboratory for preparation and analysis.

2.6. Sample Preparation

The wet soils were air dried by spreading on sheets of papers and allowed to dry for 72 hours. Samples were mixed frequently to expose fresh surface to dryness. The samples were grinded after drying and sieved through a 2mm mesh sieve and coarse particles discarded. The powdered form was stored for digestion and subsequent analysis.

2.7. Determination of pH

The pH meter was calibrated using a standard buffer solution of pH 4.0 and 9.2. The pH was determined with – soil to water ratio of 1:2:5 i.e. log of soil to 25ml of distilled water.

2.8. Method

Log of 2mm served air dried soil was put into a 50ml plastic beaker and 25ml of distilled water and the mixture was stirred several times for 30 minutes. The soil suspension was then immersed into the beaker but prevented from touching the bottom of the beaker. The pH reading will be taken after 30 seconds, so as to allow steady reading (Seyoum, 2006). The experiment was repeated for all the fifteen (15) samples.

2.9. Sample Digestion

Method conventional aqua regia (i.e. solution of HCL and HNO₃ with a ratio of

3:1) digestion was employed. This was performed in 250ml glass beaker covered with watch glasses. A well –mixed sample of 0.500g was digested in 2ml of aqua regia on a hot plate for 3 hours at 110^oC. After evaporation to near dryness, the sample was distilled with 20ml of 2% (v/v with H₂O) nitric acid and transferred into a 100ml volumetric flask after filtering through Whatman no. 42 paper and diluted to 100ml with distilled water. The extract was then taken for subsequent analysis of heavy metals (Iyama et al., 2022; Alam et al., 2023).

2.10. Determination of Trace Metals (Pb, Ni, Cr, As, Cd, Al)

Atomic absorption spectroscopy is based on the ability of an “excited” atom of an element to absorb energy from wavelength of light of the same frequency as the element. This creates a decrease in the initial signed energy and this difference is proportional to the concentration. Each element has its own series of specific characteristics for sensitivity; noise and linearity define the range in which calibration curve was accurate.

The optical system was set up with hollow cathode lamp for element of interest. The appropriate slit and wave length were selected for the element (heavy metal). A solution of known concentration of the analyzed samples were aspirated and the absorbance reading was rational to the standard and a sample concentration was interpolated from the intensity of the reading. Atomic absorption spectrophotometer (AAS) has various models but for this analysis the buck model was used because the model had advantage over other models, it operates in three (3) modes: direct measurement, deuterium background correction (dz), and variable giant pulse correction (gp). The two correction modes allowed the chemist to analyze samples that have complex or “dirty” matrices’, which would normally give significant interference in the

analytical determination (Asemave and Anhwange, 2013).

2.11. Method of Data Analysis

Data collected were analyzed using the ANOVA to test the hypotheses formulated for the study state the hypotheses again. The result obtained from the laboratory analysis were subjected to statistical analysis of related variables of heavy metal in the environment using ANOVA.

ANOVA analysis of variance is a statistical method used to test differences between two or more means. ANOVA is also a statistical technique that is used to check if the means of two or more groups are significantly different from each other. ANOVA checks the impact of one or more factors by comparing the means of different samples. ANOVA is the statistical technique that was used to check or test differences in properties of soil at different hospital disposal sites. To achieve this goal, the total group variance within the groups and between group variance was investigated.

The within group variance represents the sampling error in the distribution while the

between group variances represent the influence of the variable being observed. If the between group is not substantially greater than the within group variance, the difference between the mean is probably a reflection of sampling error but if it is substantially greater than one, there is the indication that the difference is not a chance occurrence as sampling error (Awodele, 2016). H_0 : Hypothesis which states that there is no significant effect of medical waste on the soil in Uyo metropolis was tested. The model used for statistical analysis was SPSS (statistical package for social sciences) Version 2015.

3. RESULTS AND DISCUSSION

This section presents the data generated from the analyses on medical wastes disposal and its effect on the soil of the four hospitals disposal dump sites in Uyo metropolis. The raw data gathered and the laboratory analyses results are presented. These data are presented in line with the stated objectives of the study. Therefore, elemental compositions present in each of the four underlying soil samples are presented in Table 2.

Table 2: Soil Elemental compositions in hospital waste disposal sites (Field Survey, 2023)

Elemental Compositions	Uniuyo Teaching Hospital			St. Luke's Hospital			Uniuyo Medical Centre			Children Hospital			Control Site Sample		
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Ph	7.250	7.640	8.220	6.480	7.560	7.450	8.750	6.250	7.800	7.780	8.930	7.690	7.560	8.630	8.650
Pb	0.592	0.350	0.602	1.220	0.680	0.032	0.324	1/503	1.363	0.193	2.524	1.189	1.22	0.59	1.350
Ni	0.392	0.350	0.602	0.009	0.00	0.019	0.0987	0.072	0.278	0.36	0.427	0.239	0.37	0.062	0.024
Cr	0.242	0.029	0.005	0.002	0.472	0.078	0.274	0.091	0.471	0.029	0.628	0.374	0.361	0.011	0.656
Ai	0.092	0.083	0.495	0.503	0.023	0.0605	0.082	0.049	0.623	0.438	0.293	0.115	0.372	0.215	0.872

Cd	0.075	0.070	0.493	0.036	0.025	0.067	0.556	0.002	0.921	0.372	0.720	0.020	0.066	0.070	0.7510
As	0.005	0.047	0.055	0.466	0.037	0.038	0.023	0.046	0.367	0.0112	0.00	0.037	0.046	0.062	0.610

In line with the objectives of the study, Table 2 shows the composition of medical wastes element in the various hospitals in Uyo metropolis. pH of soil around the various disposal sites in Uyo Metropolis ranges from 6.25 to 8.930). The result indicates that all the samples are in alkaline medicine i.e. pH above 6.50. Sample from Uniuyo Teaching Hospital shows the concentration (mg/kg), of heavy metals as follows; Pb (0.514667) NI (0.448kg/mg). Cr (0.092kg/mg), Al (0.223333kg/mg), Cd (0.21266kg/mg), As (0.052333kg/mg), Cd (0.212667kg/mg), As (0.052333kg/mg) while samples from Children Hospital Wellington Bassey Way, Uyo, indicate the concentration mg/kg. As: Pb (1.302mg/kg)

Ni (0.342mg/kg), Cr (0.343667), Al (0.282mg/kg), Cd (0.370667mg/kg), As (0.016067mg/kg). The result from University of Uyo Medical Centre indicates the concentration (mg/kg) as: Pb (1.062433mg/kg), Ni (0.149567mg/kg), Cr (0.278667mg/kg), Al (0.251333mg/kg), Cd (0.042667mg/kg), As (0.180333mg/kg). The results from Uyo Metropolis (control site) indicates the concentration (mg/kg) of heavy metals show: Pb (1.05333mg/kg), Ni (0.152mg/kg), Cr (0.342667mg/kg), Ai (0486333mg/kg), Cd (0.212667mg/kg), As (0.239333mg/kg). The mean elemental values of the four hospital dumping underlying soils are presented in Table 3.

Table 3: Mean values of soil parameters across the four hospital waste dumpsites (Field Survey, 2023)

Elemental compositions	Uniuyo Teaching Hospital	St. Luke’s Hospital	Uniuyo Medical Centre	Children Hospital	Control Site
pH	7.703333	7.163333	7.6	8.133333	8.28
Pb	0.514667	0.644	1.062433	1.302	1.053333
Ni	0.448	0.009333	0.149567	0.342	0.152
Cr	0.092	0.184	0.278667	0.343667	0.342667
Al	0.223333	0.1955	0.251333	0.282	0.486333
Cd	0.212667	0.042667	0.493	0.370667	0.295667
As	0.052333	0.180333	0.145333	0.016067	0.239333

Pb was detected in all the dump sites as also observed by Ojekunle et al. (2015) and Onwukeme et al. (2021). It appears to be higher as found in Table 3 and the respective figures. This can be attributed to the availability of lead containing wastes at the dumpsite which are eventually leached into the underlying soils. Lead is known to have harmful health effects even at lower levels and there is no save exposure level. It is pertinent to note that exposure to any amount of lead bout 0.01mg/kg is detrimental to health. As it may result in possible neurological damage to fetuses,

abortion and other complication in children under three years old (Schupf and Ottman, 2001; Dommergues, 2023). Nickel (Ni) was found in small concentration except in University of Uyo teaching Hospital as shown in Table 3. This implies that wastes carrying Ni are present in a very small quantity in hospital wastes in Uyo metropolis. ANOVA Table for the soil values is presented in Table 4.

Table 4: ANOVA: Soil Values (Field survey, 2023).

	Sum of Squares	df	Mean Squares	F	Sig.
Between Groups	238.564	6	39.761	701.170	.000
Within Groups	1.588	28	.057		
Total	240.152	34			

Chromium (Cr) was also detected in all the dump sites, though generally low and thus can also be attributed to the dump sites carrying waste of low Cr concentration. Chromium₃ is less damaging to the health due to their absorption by the body (<1%), but Cr +6 is actually poisonous and allergies and imitations. thus, considered as carcinogenic to humans (Asemave et al., 2012). Al and Cd were also in all the dump sites as shown in Table 2. But their concentration was low. This can also be as a result of leaching or low Al and Cd carrying wastes. The absence of Ni in St. Lukes Hospital can be explained. It is because of massive erosion taking place along the dump site. Most of the element Ni could be leached into the gully eroded part of the land. This is low compared to WHO standard of Al = 6-3.500mg/kg and Cd = 0.02 – 8.2mg/kg (Uba et al., 2008) report that, Cd has highest tended bioavailability in dump sites. In general, the concentration of Cd and Al may be attributed to various sources, some of which include hospital wastes, automobile tyre dust, burning of oil and tyre, plastic wrap pings which include general waste form hospitals, points, dyes and especially, refuse dumps and commercial activities (Parida et al., 2022). The levels of these heavy metals detected in these dumpsites are within acceptable limits sets by the World Health Organization WHO (Ohiagu et al., 2020). Arsenic (As) was detected in all the site, but relatively low as compared to WHO standard (As =0.009 – 1.5mg/kg) for heavy metals concentration in the soil. The results of heavy metals obtained from the analysis of soil around hospital wastes concentrations were relatively low. The low concentration

could be as a result of the wet period, this analysis was carried out as a result of hospital waste carrying less concentration of these metals. (Pb, Ni, Al, Cd, Cr and As) in Uyo metropolis.

4. CONCLUSION

The study assesses medical waste and its health implication in Uyo metropolis in Akwa Ibom State – Nigeria. The results indicate that most of the areas studied had concentrations of heavy metals; though some heavy metals could not be detected in some dumpsite e.g. (Ni in E, As in K). It was observed that some dumpsites have higher concentration of heavy metals such as (Pb, 524 in K) than others, and this could be attributed to harmful metals present in hospital wastes. Other sites had low concentration of these heavy metals due to topography or soil type or as a result of low contaminated wastes from the hospital because of proper sorting of harmful wastes from the general wastes. These dump sites have concentration of heavy metals within the allowable limit by WHO; as a result may not appear to pose very serious environmental problems at the moment. However, there is cause for some concerns as continuous accumulation in the levels of heavy metals many occur with time and may result in serious health challenges. The assessment of medical waste and its health implication in Uyo metropolis in Akwa Ibom State, statistically was not significant as shown in table 5.3 (ANOVA table) with these the (No) hypothesis is accepted. This study has contributed immensely to knowledge in the following ways. To address the challenges associated with medical waste disposal, it is crucial to implement comprehensive healthcare waste management guidelines and policies in Uyo City Metropolis. These guidelines should include proper segregation of medical waste at the source, the establishment of designated disposal sites equipped with appropriate technologies, and the training of healthcare workers on safe waste handling practices. Additionally, regular

monitoring and enforcement of these guidelines are essential to ensure compliance and accountability. This study has elaborated how medical wastes from hospital affect the environment.

- i. This study has shown that medical wastes should be properly sorted to reduce contamination with other non-tonic waste from hospital.
- ii. This study has provided an insight to students, lectures and researchers who could consider it in the course of carrying out similar research work.

The following suggestions are made for further researches in the area.

- i. The assessment of medical wastes on water should be carried out.
- ii. The assessment of medical waste on air should also be done.
- iii. Similar studies should be carried out at local government health facilities.

Further studies should also be made on plants that are growing in and around medical wastes dump sites to assess its effect on human health.

References

- Afesi-Dei, C., Appiah-Brempong, M. and Awuah, E. (2023) Health-care waste management practices: The case of Ho Teaching Hospital in Ghana. *Heliyon*, 9(4), e15514.
- Alam, M., Rohani, M. F. and Hossain, M. S. (2023) Heavy metals accumulation in some important fish species cultured in commercial fish farm of Natore, Bangladesh and possible health risk evaluation. *Emerging Contaminants*, 9(4), 100254.
- Asemave, K. and Anhwange, B. A. (2013) Evaluation of Heavy Metals in Waste Dumpsites: An Assessment of Heavy Metals. Lambert Academic Publishing, ISBN: 978-3-659-37380-0.
- Asemave, K., Ubwa, S. T., Anhwange, B. A and Gbaamende, A. G. (2012). Comparative Evaluation of Some Metals in Palm Oil, Groundnut Oil and Soybean Oil from Nigeria. *International Journal of Modern Chemistry*, 1(1), 28-35.
- Awodele, O., Adewoye, A. A. and Oparah, A.C. (2016) Assessment of medical waste management in seven hospitals in Lagos, Nigeria. *BMC Public Health* 16(269), 1-11.
- Borowy, I. (2020). Medical waste: the dark side of healthcare. *História, Ciências, Saúde-Manguinhos*, 27, 231-251.
- Dommergues M. (2023) Termination of pregnancy for fetal neurological abnormalities. *Child's Nervous System*, 19(7-8), 600-604.
- Ekanem, A. M., Ijezie, A. E., Undie, M. U., Etuk, J. J., David, A. E., Peter, O. I., Paul, U. M. and Agwu, C. E. (2021) Assessment of knowledge and practices of healthcare waste management among health workers in a general hospital in southern Nigeria. *Ibom Medical Journal*, 14(1), 34-45.
- Essien, E. and Cyrus, S. (2019) Detection of Urban Development in Uyo (Nigeria) Using Remote Sensing. *Land*, 8(6), 102.
- Ezeudu, O. B., Ezeudu, T. S., Ugochukwu, U. C., Tenebe, I. T., Ajogu, A. P., Nwadi, U. V. and Ajaero, C. C. (2022) Healthcare Waste Management in Nigeria: A Review. *Recycling* 2022, 7(6), 87.
- Hassan, M. M., Ahmed, S. A., Rahman, K. A. and Biswas, T. K. (2008) Pattern of medical waste management: existing scenario in Dhaka City, Bangladesh. *BMC Public Health* 8(36), 1-10.

- Ikpe, A. E., Ebunilo, P. O. and Sadjere, G. E. (2019b) Effects of waste dumpsites on geotechnical properties of the underlying soils in wet season. *Environmental Engineering Research*, 24(2), 289-297.
- Ikpe, A. E., Imonitie, D. I. and Ndon, A. E. (2019a) Investigation of Biogas Energy Derivation from Anaerobic Digestion of Different Local Food Wastes in Nigeria. *Academic Platform Journal of Engineering and Science* 7(2), 332-340.
- Ikpe, A. E., Ndon, A. E. and Etim, P. J. (2020) Assessment of the Waste Management System and Its Implication in Benin City Metropolis, Nigeria. *Journal of Applied Research on Industrial Engineering*, 7(1), 79-91.
- Ikpe, A. E., Ndon, A. E. and Etim, P. J. (2020) Fuzzy Modelling and Optimization of Anaerobic Co-Digestion Process Parameters for Effective Biogas Yield from Bio-Wastes. *The International Journal of Energy & Engineering Sciences*, 5(2) 43-61
- Iyama, W. A., Okpara, K. and Techato, K. (2022) Assessment of Heavy Metals in Agricultural Soils and Plant (*Vernonia amygdalina* Delile) in Port Harcourt Metropolis, Nigeria. *Agriculture* 2022, 12(1), 27.
- Mbina, A. A. and Edem, E. E. (2015) Challenges of urban waste management in Uyo Metropolis, Nigeria. *Civil and Environmental Research*, 7(2), 196-205.
- Morenikeji, O. A., Inyang, A. B. and Udobia, I. U. (2017) Hospital Waste Management Practice Alertness among Health Practitioners in Secondary and Tertiary Care Facilities in Uyo Metropolis, Akwa Ibom State. *European Journal of Research in Medical Sciences*, 5(2), 44-53.
- Ngouakam, H., Atanga, M. B., Onojeta, A., Essienobong, J. A. and Konlak, G. D. (2012) Generation and disposal of solid clinical waste in general hospital and infectious disease hospital, Ikot Ekpene, Akwa Ibom State, Nigeria: characterization and management strategies." *Journal of Emerging Trends in Engineering and Applied Sciences*, 3, 165-169.
- Ohiagu, F. O., Lele, K. C., Chikezie, P. C., Verla, A. W. and Enyoh, C. E. (2020) Bioaccumulation and health risk assessment of heavy metals in *Musa paradisiaca*, *Zea mays*, *Cucumeropsis manii* and *Manihot esculenta* cultivated in Onne, Rivers State, Nigeria. *Environmental Analysis Health and Toxicology*, 35(2), e2020011.
- Ojekunle, Z. O., Ojajuni, K. O., Sangowusi, R. O., Oyebanji, F. F., Ojekunle, V. O., Adekitan A. A. and Odjegba, E. E (2015) Evaluation of Soil Contaminant Level at Dumpsites in Nigeria. *Elixir Agriculture*, 80, 30995-31001.
- Olorunsola, E. O. and Adje, D. U. (2017) The disposal pattern of domestic medical and pharmaceutical waste in Uyo metropolis, Southern Nigeria. *West African Journal of Pharmacy*, 28(1), 15-22.
- Onwukeme, V. I. and Eze, V. C. (2021) Identification of heavy metals source within selected active dumpsites in south-eastern Nigeria. *Environmental Analysis Health and Toxicology* 2021, 36(2), 1-18.
- Ottah, U. N., Okokon, E. O., Okoi, N. O., Akpan, U. B., Etokidem, A. J., Asibong, I. U., & Asibong, U. E. (2023). Use of the partograph

- among obstetric care providers in government healthcare facilities in Uyo Senatorial District, Akwa Ibom State, Nigeria, 23(3), 34-42
- Parida, V. K., Sikarwar, D., Majumder, A. and Gupta, A. K. (2022) An assessment of hospital wastewater and biomedical waste generation, existing legislations, risk assessment, treatment processes, and scenario during COVID-19. *Journal of Environmental Management*, 15(308), 114609.
- Ramadhan, M. M. (2014) Sharps Waste Management at Kidongo-Chekundu National Mental Hospital - Zanzibar Tanzania. University of Tanzania, Zanzibar.
- Schupf, N. and Ottman, R. (2001) Risk of epilepsy in offspring of affected women: association with maternal spontaneous abortion. *Neurology*, 57(9), 1642-9.
- Seyoum, B. (2006) Introduction to Medical Laboratory Technology. Ethiopia Public Health Training Initiative, Haramaya University.
- Singh, N., Ogunseitan, O. A. and Tang, Y. (2021) Medical waste: Current challenges and future opportunities for sustainable management, 52(11), 1-23.
- Uba, S., Uzairu, A., Harrison, G. F. S., Balarabe, M. L. and Okunola, O. J. (2008) Assessment of heavy metals bioavailability in dumpsites of Zaria Metropolis, Nigeria. *African Journal of Biotechnology*, 7(2), 122-130.
- Ukpong, I. E. and Udofia, E. P. (2011) Domestic Solid Waste Management in a Rapidly Growing Nigerian City of Uyo, *Journal of Human Ecology*, 36, 229-235.
- Zherka, A. (2020) When Improper Disposal Leads to More Than Hospital Visits: The Need for a National Standard for Used Medical Sharps. 44(2), *William & Mary Environmental Law and Policy Review*, 649-668.