THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Enormous Impact of Hospital and Clinical Waste Generation on Air Quality in Abakaliki, Southeastern Nigeria

Okoli Ifeyinwa, S
Graduate Researcher, Department of Soil Science and Environmental Management, Ebonyi State University, Abakaliki, Nigeria
Igboji, Paul Ola
Senior Lecturer, Department of Environmental, Estate Management, Urban and Regional Planning, Ebonyi State University, Abakaliki, Nigeria

Abstract:
The study was conducted at the FETHA 1 in Abakaliki, Southeastern Nigeria. It assessed the various hospital/clinical wastes generated in the various wards. The indoor and outdoor air quality of the wards was studied. The volume of waste generated in the morning and evening was studied for three months for two years. The indoor and outdoor air quality of the wards was also studied for three months for two years. The ambient concentrations of CO, NH_3, NO_2, H_2S were monitored using portable gas motors. At FETHA1, the highest volume of waste generated in the morning time in the month of June 2021 was 26.9 kg in the children's ward and the least value of 15.6 kg in the gynaecology theatre with a coefficient of variation (cv) of 26.7%; while in same morning of June 2022; the same children's ward gave the highest volume of wastes of 28.9 kg and least wastes of 16.7 kg in the same gynaecology theatre with a cv of 26.9%. In the evening period of June 2021, the highest waste of 27.5 kg was in the children's ward and the lowest value of 20.6 kg in the gynaecology theatre with a cv of 14.9%. In the morning of June 2022, the children's ward gave the highest volume of waste of 28.9 kg and the lowest value of 16.7 kg in the gynaecology theatre with a cv of 26.95, while in the evening period of June 2022, the same children's ward gave 30.1 kg and least value of 26.6 kg in gynaecology theatre with a cv of 6.3%. There were no statistically significant variations across wards, times of day and months for wastes generated at FETHA 1. The highest CO indoor gas concentration of 0.88 mg/l in 2021 was in the children's ward and the lowest CO indoor gas concentration of 0.40 mg/l and outdoor CO gas concentration of 0.28 mg/l with cv of 43.3%. For NH3, the highest concentration of 0.35 mg/l was in the same children's ward and the lowest concentration of 0.12 in the labour ward with a cv of 67.5%. Across wards, months and years, there were statistical variations in the indoor and outdoor gaseous concentrations of the various gases monitored. Although the concentrations of the gases indoors and outdoors passed the WHO and local standards, constant monitoring of wastes generated at all times, months, and years and their impact on air quality was recommended as the teaching hospital has high traffic of patients and customers to allay fears of gas poisoning.

Keywords: *Hospital/clinic, waste generation, indoor/outdoor air quality, gas poisoning*

1. Introduction

Hospital waste has been referred to as any discarded solid material generated from activities involving health protection, medical diagnosis, treatment, scientific research, and dental and veterinary services (Rao, 1994; Coker *et al.,* 2009; Hossain *et al.,* 2011). This type of waste has been considered potentially harmful to humans and requires special treatment. Non-hazardous waste from healthcare facilities is comparable to domestic waste and often ends up in the municipal solid waste stream discarded in landfills (Pruss *et al*., 1999). Hospital waste has remained a source of concern because of the potential to transmit diseases and contaminate soil, surface and groundwater with pathogenic microbes toxic and heavy metals often present in it (Pruss *et al*., 1999). Diseases associated with poor medical waste management include nosocomial diseases, typhoid, skin disorders, intestinal parasitosis and hepatitis (Bassey *et al.,* 2006).

Hospital wastes are categorized and each category can be generated in the hospital depending on the capacity and type of the hospital, such as maternity, general ward, clinic laboratory and specialist hospital. In each of these units, the level of waste generated varies relatively. However, the waste is better grouped into the following:

- Human blood and blood products,
- Cultures and stocks of infectious agents,
- Pathological waste,
- Sharps,
- Glassware/ broken glassware,
- Contaminated equipment/junk equipment,
- Chemical/radioactive

Some categories of hospital waste are regarded as biological waste. This group of waste disposal include non-human disease agent/equipment that has come in contact with the non-disease example, general zoonotic vectors used in research and culture used in plant pathology research, equipment such as petri-dishes and pipette as long as they do not contain human disease agent, are not regulated. Hospital is one of the complex institutions that are frequented by people from every walk of life in the society, without distinction between age, sex, race and religion.

Hospital waste may be infectious or non-infectious. The non-infectious wastes come from the hospitals' environments, like the grasses and flowers and are of less health risk. The infectious hospital waste, in addition to the risk for patients and personnel who handle it, poses threats to public health and the environment (Chaerul *et al.,* 2008). Due to the enormous health and aesthetic effects on our cities and towns, so many government agencies are set up to regulate and manage waste that is generated from different sources in our society, including those from hospital wastes. A few of these agencies include: Federal Environmental Protection Agency (FEPA), National Environmental Standard and Regulation Enforcement (NESRE), Municipal Solid Waste Management (MSWM), etc. These agencies and ministries made regulations and guidelines to safely guide and protect our environment and the health of the people. Hence, this study assessed the hospital and clinical waste generation and impact on air quality in Abakaliki, Southeastern Nigeria.

2. Materials and Methods

FETHA 1, also popularly known as Alex Ekwueme Federal University Teaching Hospital, Abakaliki, was established in the 1930s by the British Colonial Administration. It was a small health centre for the treatment of wounded soldiers and personnel during the Second World War (WW11). From then, the hospital was transformed; it changed its name from the casualty control centre to the Abakaliki General Hospital and then to the Federal Medical Centre before assuming its present status of a Federal Teaching Hospital Abakaliki.

The hospital ran into difficulties in the year 1973, which led to the deterioration of facilities and a shortfall in the number of consultant staff as the East Central State was split into many states by the Federal Military Government. Following an agreement between the Federal Government and the Ebonyi State Government, the hospital was made Federal Medical Center in March 1999 and was later made Federal Teaching Hospital Abakaliki (AE-FUTHA 1) by former President Good Luck Jonathan on 7th December 2011.

The Federal Government, through the Federal Ministry of Health, renamed Federal Teaching Hospital Abakaliki to Alex Ekwueme Federal University Teaching Hospital Abakaliki on 7th February 2019. It is now called AE-FUTHA 1.

The Hospital has 5,000 staff and is located in the centre of Ugah Street, Nsugbe Street, Prison, Udensi/Police quarters, very close to Nna Street CSMT Day secondary school Abakaliki. The last known population of Abakaliki was 915,438 (NPC, 2019). This was 0.253% of the total Nigerian population. If the population growth rate is the same as in the period 2006–2015 (+15.31%/year), it is estimated that the population of Abakaliki as of 2021 is about 1,179,280 (NPC, 2019). It enjoys a tropical climate with two seasons: the dry and rainy seasons. The geographical coordinates are: latitude $6^{o}.15^{1}$ N and Longitude $8^{o}.18^{1}$ E. There are two main hospitals in Abakaliki, both of which have training schools for health personnel and a range of departments offering services like: general consultation, eye care, dental care, surgical services, X-ray/ultrasound, pharmaceutical services, laboratory services, pediatrics services, gynecological, obstetric services, family planning, tuberculosis treatment units, vaccination and antenatal care, malaria prevention among others. One of the hospitals, in addition, has the only Cardio-Surgical Centre in Central/West Africa that offers cardiac surgery, diagnostic and interventional catheterization, coronary angiography, diagnostic coronarography, and pacemaker double and single chamber since 2009. Due to the growing trend of biomedical services in Abakaliki, there is a need to assess hospital/clinical waste management and disposal practices in the area to inform policy on the planning for an effective and sustainable waste management program.

2.1. Research Design and Methodology

Waste was sorted out and weighed in selected three (3) wards and 2 theatres in Completely Randomized Design (CRD) with three months serving as the replicates. A separate area outside the hospital served as the control. These wards were the Children's ward, Labor ward and Gynecology theatre. Air quality measurements were done with portable carbon monoxide, nitrogen dioxide, sulphur dioxide and hydrogen sulphide analyzer. The Models were: CO19256H, NO_2 19835H, NH_3 19736H; H_2S 19752H. The detection time was set by manufacturers at a range of 0-50ppm, with the alarm set at 3 pm. The four monitors were placed on a wooden platform in each ward, and Readings were taken on an hourly basis at 2,4,6,8,10,12 weeks intervals. Each reading was taken once a day between 8 am-12 pm. The three wards were visited daily for the measurement of waste generated weekly and monthly.

2.2. Data Analysis

The data generated were subjected to Analysis of variance (ANOVA) for Completely Randomized Design (CRD). Mean Separation and testing were done using Fisher's Least Significant Difference (F-LSD). Statistical Significant Difference was accepted at 5% Probability level (Steel and Torrie, 1980).

3. Results and Discussions

3.1. Hospital/Clinical Waste Generated at AE-FUTHA 1

3.1.1. Time Series Assessment of HCWs Generated across Wards (AE-FUTHA 1)

The Children's ward recorded the highest volume of waste in the morning in June 2021 with 26.9kg, with the lowest value of 15.6 kg in Gynaecology ward for the same time of Assessment.

In the same period in 2022, the same Children's ward recorded the highest HCW level of 28.9kg and the lowest value of 16.7kg in Gynaecology ward. (Table 1)

During the evening time of June 2021, the Children's ward recorded the highest volume of waste of 27.5 kg and the lowest in the Gynaecology ward, 20.6kg. At the same time, in 2022, the Children's ward also recorded the highest volume of waste at 30.1 kg and the lowest in the Gynaecology ward with 26.6kg. The coefficient of variation across wards in 2021 and 2022 were 26.7% and 26.94% in the morning and 14.99%| 6.27% in the evening. Throughout the year, the highest CV of 25.01% was in the Gynaecology ward and the lowest CV of 5.07% was in the Children's ward (Table 1).

In the morning of July 2021, the Children's ward recorded the highest volume of waste at 28.6 kg, while in the same period in 2022, it was also highest in the Children's ward with 29.5kg. In the evening time of 2021, it was the same Children's ward, leading with 30kg and the lowest in the Gynaecology ward with 25.9kg. In 2022, the Children's ward also led with 32.4 kg and the least in the Gynaecology ward with 28.7kg (Table 1).

The coefficient of variation (CV) across wards in the morning of 2021 and 2022 were 26.19% and 8.89%, while the CV across wards in the evening of 2021 and 2022 were 7.37% and 6.14%. Across times of the day, the CV was highest in the Gynaecology ward, with 21.41% across 2021 and 2022 and least in the Children's ward, with 5.39% (Table 1).

In August 2021, the labour ward recorded the highest volume of waste at 26.5kg in the morning, with the lowest value of 20.9kg in the Gynecology ward. In the same month of 2022, the Children's ward again overtook the highest volume of waste generated, with 27.3kg in the morning, with the lowest value of 24.8kg in the Labour ward. In the evening of 2021, the Gynaecology ward recorded the highest waste of 30kg, with the lowest value of 26.9kg found in the Children's ward. In 2022, the Gynaecology ward recorded the highest waste of 32kg and the lowest value of 26.2 kg was found in the labour ward. The CV across wards in the morning of 2021-2022 was 12.36% and 4.87%, respectively, whereas, in the evening, they were 5.85% and 10.28%, respectively. Throughout the years, in August, the labour ward recorded the highest CV of 8.05%, while the children's ward recorded the lowest value of 3.87% (Table 1).

June						
Location	**Morning**	**Evening**	**Morning**	**Evening**		
	2021	**2021**	**2022**	**2022**	**SD**	**CV (%)**
Children's ward	26.9	27.5	28.9	30.1	1.44	5.07
Gynaecology theatre	15.6	20.6	16.7	26.6	4.97	25.01
Labour ward	21	26.5	26.6	29	3.39	13.14
SD	5.65	3.72	6.48	1.79	3.1	47.14
CV (%)	26.7	14.99	26.94	6.27	10	53.42
July						
Children's ward	28.6	30	29.5	32.4	1.62	5.39
Gynaecology theatre	16.7	25.9	24.9	28.7	5.16	21.41
Labour ward	25.6	28.5	26.1	30.1	2.11	7.64
SD	6.19	2.07	2.39	1.87	2.05	65.53
CV (%)	26.19	7.37	8.89	6.14	9.42	77.58
August						
Children's ward	25.6	26.9	27.3	28.1	1.04	3.87
Gynaecology theatre	20.9	30	26.5	32	2.02	7.56
Labour ward	26.5	29.6	24.8	26.2	2.17	8.05
SD	3.07	1.68	1.27	2.96	0.88	39.55
CV (%)	12.36	5.85	4.87	10.28	3.57	42.75

Table 1: Evaluation of Weight of Wastes Generated at FETHA1
Note: CV = Coefficient of Variability, SD = Standard Deviation,
AE- FUTHA= Federal Teaching Hospital Abakaliki

3.2. Time Series Assessment of HCWs Generated (Children's Ward AE-FUTHA 1)

Across the months of the year evaluated, August morning, 2021, recorded the highest volume of waste generated across wards with 26.8 kg, while the lowest value was in July at 24.9 kg. On the other hand, the same August recorded the highest waste of 28.3 kg in the evening and the lowest value of 26.9kg in the evening of June 2021.

In the morning of 2022, the month of August recorded the highest volume of waste with 27 kg and the lowest value of 21.4 kg in July. In the evening of 2022, the month of August recorded the highest waste value of 30.7 kg and the lowest in July, which gave 26.5kg. The CV across months for the morning of 2021 and 2022 were 3.72% and 12.25%, respectively, while the CV across months for the evening of 2021 and 2022 were 3.96% and 7.62%, respectively (Table 2).

Period	Morning	Evening	Morning	Evening	SD	CV (%)
June	25.6	26.9	26.3	29.8	1.59	5.88
July	24.9	29.1	21.4	26.5	2.78	10.95
August	26.8	28.3	27.0	30.7	1.55	5.51
SD	0.96	1.11	3.05	2.1	2.1	46.46
CV (%)	3.72	3.96	12.25	7.62	3.45	50.18

Table 2: Evaluation of Waste Generated (kg) at (Children's Ward) FETHA 1
Note: CV = Coefficient of Variability, SD = Standard Deviation, FETHA= Federal Teaching Hospital Abakaliki

3.3. Time Series Assessment of HCWs Generated (Gynaecology Ward-AE-FUTHA 1)

Across the months of the year evaluated, August morning 2021 recorded the highest volume of waste generated across wards with 20.9 kg, while the lowest value was in June at 15.6 kg. On the other hand, the same August recorded the highest waste of 26.5kg in the evening and the lowest value of 20.6 kg in June 2021 evening.

In the morning of 2022, the month of August recorded the highest volume of waste with 29.6 kg and the lowest was 26.6 kg in June. In the evening of 2022, the month of August recorded the highest waste value of 31.2 kg and the lowest in June, which gave 27.4kg. The CV across months for the morning of 2021 and 2022 were 15.77% and 5.38%, respectively, while the CV across months for the evening of 2021 and 2022 were 13.34% and 6.58%, respectively (Table 3).

Period	Morning	Evening	Morning	Evening	SD	CV (%)
June	15.6	20.6	26.6	27.4	4.79	21.27
July	16.7	25.9	28.5	30.0	5.16	20.43
August	20.9	26.5	29.6	31.2	3.93	14.54
SD	2.79	3.24	1.52	1.94	0.68	28.70
CV (%)	15.77	13.34	5.38	6.58	4.39	42.82

Table 3: Evaluation of Weight of Waste Generated (kg) at (Gynaecology Theatre) FETHA 1
Note: CV = Coefficient of Variability, SD = Standard Deviation, FETHA= Federal Teaching Hospital Abakaliki

3.4. Time Series Assessment of HCWs Generated (Labour Ward AE-FUTHA 1)

Across the months of the year evaluated, June Morning, 2021, recorded the highest volume of waste generated across wards with 29.0 kg, while the lowest value was in July, which was 25.6 kg. On the other hand, the same June recorded the highest waste generated of 30.1 kg in the evening and the lowest value of 29.4 kg in the evening of July 2021.

In the morning of 2022, the month of August recorded the highest volume of waste with 27.2 kg and the lowest 25.8 kg in July. In the evening of 2022, the month of June recorded the highest waste value of 30.6kg and the lowest in August, which recorded 29.2 kg waste value. The CV across the months for the morning of 2021 and 2022 were 6.24% and 2.71%, respectively, while the CV across months for the evening of 2021 and 2022 were 1.21% and 2.34%, respectively (Table 4).

Period	Morning	Evening	Morning	Evening	SD	CV (%)
June	29.0	30.1	26.8	30.6	1.46	5.02
July	25.6	29.4	25.8	29.9	1.98	7.16
August	27.6	29.9	27.2	29.2	1.11	3.91
SD	1.71	0.36	0.72	0.70	0.50	57.70
CV (%)	6.24	1.21	2.71	2.34	1.87	60.16

Table 4: Evaluation of Weight of Wastes Generated (Kg) at (Labor Ward) FETHA 1
Note: CV = Coefficient of Variability, SD = Standard Deviation, FETHA= Federal Teaching Hospital Abakaliki

3.5. Time Series Indoor Air Quality across Wards (AE-FUTHA 1)

Across wards in the month of June, the highest concentrations of CO (0.88mg/l) and (0.89mg/kg) were recorded in June 2021 and 2022 at the children's ward, while the lowest concentration of CO (0.40mg/kg) and (0.44mg/l) was recorded in the Gynaecology theatre. The coefficient of variation of CO across wards in 2021 and 2022 were 43.25% and 39.47%. Throughout the years, the highest CV of 0.43% was in the children's ward and the lowest CV of 0.15% was in the labour ward (Table 5).

The highest concentration of NH_3 (0.35mg/l) and (0.43mg/l) was recorded in June 2021 and 2022 at the children's ward, while the least concentration of NH_3 (0.12mg/l) and (0.15mg/l) was recorded in the Gynaecology theatre and labour ward in 2021 and labour ward in 2022. The coefficient of variation for NH_3 across wards in 2021 and 2022 were 67.52% and 64.39%.

The highest concentration of NO_2 (0.55mg/l) and (0.58mg/l) was recorded in June 2021 and 2022 at the children's ward, while the least concentration of NO_2 (0.36mg/l) and (0.4mg/kg) was recorded in the labour ward in 2021 and 2022. The coefficient of variation for NO_2 across wards in 2021 and 2022 were 20.12% and 19.57% respectively.

The highest concentration of H_2S (0.02mg/l) and (0.02mg/l) was recorded in June 2021 and 2022 at the children's ward, while the least concentration of H_2S (0.01mg/l) and (0.01mg/l) was recorded in the labour ward and Gynaecology theatre in 2021 and 2022. The coefficient of variation of H_2S across wards in 2021 and 2022 were 45.93% and 33.33% respectively.

In July 2021 and 2022, CO (0.86mg/l) and (0.88mg/l) recorded the highest concentration in the children's ward, while the lowest concentrations of CO (0.65mg/l) and (0.73mg/l) were recorded in the labour ward. The coefficients of variation of CO in July 2021 and 2022 are 23.73% and 20.28%, respectively.

The highest concentration of NH_3 (0.18mg/l) and (0.22mg/l) in the ward was recorded in July 2021 and 2022 at the children's ward, while the least concentration NH_3 (0.09mg/l) and (0.11mg/l) was recorded in the labour ward in 2021 and 2022 July. The coefficient of variation for NH_3 across wards in 2021 and 2022 were 39.12% and 36.84%, respectively.

The highest concentration of NO_2 (0.32mg/l) and (0.35mg/l) was at the children's ward in July 2021 and 2022, while the lowest concentration of NO_2 (0.14mg/l) and (0.15mg/l) was recorded at Gynaecology theatre in July 2021 and 2022. The coefficient variation of NO_2 across wards in 2021 and 2022 were 37.33% and 35.58%, respectively.

The highest concentration of H_2S (0.02mg/l) and (0.02mg/l) was recorded in the children's ward in July 2021 and 2022, while the lowest concentration of H_2S (0.01mg/kg) was recorded in 2022 and zero H_2S was recorded in 2021 July. The coefficient variation of H_2S across wards in 2021 and 2022 were 45.93% and 33.33%, respectively.

In August 2021 and 2022, the CO (0.88mg/l) and (0.89mg/l) were recorded the highest in the children's ward, while the lowest concentration of CO (0.68mg/l) and (0.72mg/l) was recorded in Gynaecology theatre. The coefficient of variation for CO in August 2021 and 2022 were 10.14% and 8.62%, respectively.

The highest concentration of NH_3 (0.12mg/l) and (0.17mg/l) was recorded in the children's ward, while the least concentration of NH_3 (0.08mg/l) and (0.10mg/l) was recorded in the labour ward in August 2021 and 2022. The coefficient of variation for NH_3 was 2.00% and 3.51% in August 2021 and 2022, respectively.

The highest concentration of NO2 (0.25mg/l) and (0.31 mg/l) was recorded in the children's ward in 2021 and 2022 August, while the lowest concentrations of NO_2 (0.14mg/l) and (0.21mg/l) were recorded in the Gynaecology theatre. The coefficient of variation for NO_2 across wards in 2021 and 2022 were 5.57% and 5.13% respectively.

The concentrations of H_2S (0.01mg/l) in August 2021 and 2022 were equal. The coefficient of variation for H_2S was 0.58% and 0.58% in 2021 and 2022, respectively (Table 5).

June										
Location	**CO**	**NH_3**	**NO_2**	**H_2S**	**CO**	**NH_3**	**NO_2**	**H_2S**	**SD**	**CV (%)**
	2021	**2021**	**2021**	**2021**	**2022**	**2022**	**2022**	**2022**		
Children's Ward	0.88	0.35	0.55	0.02	0.89	0.43	0.58	0.02	0.43	0.43
Gynaecology Theatre	0.40	0.12	0.54	0.01	0.44	0.16	0.57	0.01	0.16	0.16
Labour Ward	0.49	0.12	0.36	0.01	0.51	0.15	0.40	0.01	0.15	0.15
Outdoor	0.28	0.17	0.20	0.01	0.34	0.35	0.22	0.01	0.35	0.35
FARM EBSU	0.19	0.10	0.18	0.01	0.28	0.12	0.19	0.01	0.28	0.28
SD	0.59	0.19	0.48	0.01	0.61	0.24	0.51	0.01	0.24	0.24
CV (%)	43.25	67.52	22.12	43.30	39.47	64.39	19.57	43.30	64.39	64.39
July										
Location	**CO**	**NH_3**	**NO_2**	**H_2S**	**CO**	**NH_3**	**NO_2**	**H_2S**	**SD**	**CV (%)**
	2021	**2021**	**2021**	**2021**	**2022**	**2022**	**2022**	**2022**		
Children's Ward	0.86	0.18	0.32	0.02	0.88	0.22	0.35	0.02	0.36	95.20
Gynaecology Theatre	0.81	0.15	0.14	0.01	0.82	0.17	0.15	0.01	0.28	119.39
Labour Ward	0.65	0.09	0.22	0.00	0.73	0.11	0.26	0.01	0.26	108.92
Outdoor	0.79	0.26	0.21	0.01	0.80	0.27	0.20	0.01	106.09	0.29
FARM EBSU	0.60	0.07	0.16	0.01	0.77	0.13	0.18	0.01	104.02	0.27
SD	0.17	0.09	0.13	0.09	0.15	0.11	0.13	0.01	63.41	0.06
CV (%)	**23.73**	**39.12**	**37.33**	**45.93**	**20.28**	**36.84**	**35.58**	**33.33**	**25.65**	**48.13**
August										
Location	**CO**	**NH_3**	**NO_2**	**H_2S**	**CO**	**NH_3**	**NO_2**	**H_2S**	**SD**	**CV (%)**
	2021	**2021**	**2021**	**2021**	**2022**	**2022**	**2022**	**2022**		
Children's Ward	0.88	0.12	0.25	0.01	0.89	0.17	0.31	0.01	0.33	108.50
Gynaecology Theatre	0.68	0.10	0.14	0.01	0.72	0.13	0.21	0.01	0.28	115.36
Labour Ward	0.81	0.08	0.18	0.01	0.61	0.10	0.24	0.01	0.28	122.54
Outdoor	0.69	0.11	0.29	0.03	0.83	0.21	0.15	0.01	0.29	114.97
FARM EBSU	0.54	0.09	0.20	0.01	0.69	0.11	0.13	0.01	0.27	110.31
SD	0.10	0.02	0.06	0.01	0.09	0.04	0.05	0.01	0.04	78.68
CV (%)	10.14	2.00	5.57	0.58	8.62	3.51	5.13	0.58	4.52	78.68

Table 5: Assessment of Air Quality Sampling Concentration at FETHA 1
Note: SD = Standard Deviation, CV (%) = Percentage Coefficient of Variability,
CO = Carbon (IV) Oxide, NH_3 = Ammonia Gas, H_2S = Hydrogen Sulphide

3.6. Time Series Indoor Air Quality (Children's Ward AE-FUTHA 1)

Across the months of the year evaluated, July was the highest with CO (0.87mg/l) in 2021, while August recorded the highest CO (0.84mg/l) in 2022. The coefficient of variation across months for CO was 11.29% and 6.86% in 2021 and 2022, respectively. Throughout the year, the highest CV of 108.4% was recorded in August, while the lowest CV of 80.52% was recorded in June.

The highest concentration of NH3 (0.23mg/l) and (0.29mg/kg) were recorded in the month of June 2021 and 2022, respectively. While the lowest concentrations of NH3 (0.12mg/l) and (0.16mg/l) were recorded in August 2021 and 2022. The coefficients of variation for NH3 across months of the year were 31.01% and 29.13%.

The highest concentrations of NO2 (0.35mg/l) and (0.39mg/l) were recorded in June 2021 and 2022, while the lowest concentrations of NO_2 (0.23mg/l) and (0.26mg/l) were recorded in August 2021 and July/August 2022. The coefficients of variation for NO_2 across months of the year in 2021 and 2022 were 23.24% and 24.74%, respectively.

The highest concentration of H2S (0.06mg/kg) was recorded in July 2021, while H2S (0.02 mg/l) was recorded in August 2022. The lowest concentration of H2S was 0.01mg/l in June 2021 and in June/July 2022, it was H2S (0.01mg/l). The coefficient of variation for H2S across the month of the year were 88.19% and 43.30% (Table 6).

Location	CO	NH_3	NO_2	H_2S	CO	NH_3	NO_2	H_2S	SD	CV (%)
	2021	2021	2021	2021	2022	2022	2022	2022		
June	0.70	0.23	0.35	0.01	0.74	0.29	0.39	0.01	0.27	80.52
July	0.87	0.20	0.25	0.06	0.83	0.22	0.26	0.01	0.33	97.42
August	0.84	0.12	0.23	0.02	0.84	0.16	0.26	0.02	0.34	108.4
Outdoor	0.68	0.14	0.21	0.01	0.80	0.15	0.37	0.01	0.31	94.20
FARM EBSU	0.61	0.12	0.20	0.01	0.70	0.13	0.21	0.01	0.32	90.77
SD	0.09	0.05	0.06	0.03	0.06	0.07	0.08	0.01	0.02	49.19
CV (%)	11.29	31.01	23.24	88.19	6.86	29.13	24.74	43.30	25.31	78.55

Table 6: Time Series Indoor Quality (Children's Ward AE-FUTHA1)
Note: SD = Standard Deviation, CV (%) = Percentage Coefficient of Variability, CO = Carbon (IV)

3.7. Time Series Indoor Air Quality (Gynaecology Theatre AE-FUTHA 1)

The highest CO (0.65mg/l) was recorded in 2021 June/August and CO (0.69mg/l) was recorded in 2022, while the lowest concentration of CO (0.57mg/l) and (0.61mg/l) was recorded in July 2021 and 2022. The coefficient of variation of CO across the months of the year 2021 and 2022 were 7.40% and 6.60%. Throughout the year, the highest CV of 99.43% was recorded in July and the lowest CV of 81.04% was recorded in June. (Table 7)

The highest concentration of NH_3 (0.15mg/l) was recorded in August 2021, while NH_3 (0.20mg/l) was recorded in June 2022. The lowest concentrations of NH_3 (0.11mg/l) and (0.14mg/l) were recorded in July 2021 and 2022, respectively. The coefficient of variation for NH_3 across months of the year in 2021 and 2022 were 15.61% and 17.63%.

The highest concentration of NO_2 (0.52mg/l) and (0.55mg/l) were recorded in June 2021 and 2022, while the least concentration of NO_2 (0.15mg/l) and (0.18mg/l) were recorded in July 2021/August 2022, respectively. The coefficient of variation for NO_2 across months of the year for 2021 and 2022 were 52.83% and 65.59%.

The highest concentration of H_2S (0.05mg/l) was recorded in July 2021, while in June 2022, an H_2S concentration of (0.03mg/l) was recorded. The lowest concentration of H_2S (0.01mg/l) was recorded in the three months of June, July and August of 2021 and July/August of 2022. The coefficient of variation for H_2S across the months of the year were 98.97% and 69.28%, respectively.

Location	CO	NH_3	NO_2	H_2S	CO	NH_3	NO_2	H_2S	SD	CV (%)
	2021	2021	2021	2021	2022	2022	2022	2022		
June	0.65	0.14	0.52	0.01	0.69	0.20	0.55	0.03	0.28	81.04
July	0.57	0.11	0.15	0.05	0.61	0.14	0.21	0.01	0.23	99.43
August	0.65	0.15	0.47	0.01	0.68	0.18	0.18	0.01	0.27	93.10
Outdoor	0.42	0.13	0.48	0.01	0.64	0.16	0.19	0.02	0.25	86.39
FARM EBSU	0.39	0.10	0.18	0.01	0.62	0.13	0.17	0.01	0.20	0.78
SD	0.05	0.02	0.20	0.02	0.04	0.03	0.21	0.01	0.08	111.72
CV (%)	7.40	15.61	52.83	98.97	6.60	17.63	65.59	69.28	34.65	83.00

Table 7: Time Series Indoor Air Quality (Gynaecology Ward Ae-Futha1)
Note: SD = Standard Deviation, CV (%) = Percentage Coefficient of Variability,
Co = Carbon (IV) Oxide, Nh_3 = Ammonia Gas, H_2s = Hydrogen Sulphide

3.8. Time Series Indoor Air Quality (Labour Ward AE-FUTHA 1)

Across the three months of the year 2021 and 2022, the highest concentrations of CO (0.82mg/l) and (0.85mg/l) were recorded in July 2021 and 2022, while the least concentration of CO (0.56mg/kg) and (0.59mg/l) were recorded in June 2021 and 2022, respectively. The coefficient of variation for CO across the months of the years were 18.77% and 17.99%. Throughout the year, the highest CV of 107.13% was recorded in July and the lowest CV of 86.33% was recorded in June (Table 8).

The highest concentrations of NH3 (0.14mg/l) and (0.17mg/l) were recorded in June 2021 and 2022, while the lowest concentrations of NH_3 (0.07mg/l) and (0.10mg/l) were recorded in July 2021 and 2022. The coefficient of variation for NH3 across the months of the year 2021 and 2022 were 33.99% and 26.34%.

The highest concentrations of NO_2 (0.28mg/l) and (0.31mg/l) were recorded in June 2021 and 2022, while the lowest concentrations of NO_2 (0.17mg/l) and (0.21mg/l) were recorded in July 2021 and 2022. The coefficient of variation for NO_2 across months of the years 2021 and 2022 were 24.37% and 19.59%.

The highest concentration of H_2S (0.24mg/l) and (0.02mg/l) were recorded in July 2021 and 2022, while the least concentration of H_2S (0.01mg/l) and (0.01mg/l) were recorded in June/August 2021/2022. The coefficient variation for H_2S across the month of the year was 153.2% and 43.30%.

Location	CO	NH_3	NO_2	H_2S	CO	NH_3	NO_2	H_2S	SD	CV (%)
	2021	2021	2021	2021	2022	2022	2022	2022		
June	0.56	0.14	0.28	0.01	0.59	0.17	0.31	0.01	0.22	86.33
July	0.82	0.07	0.17	0.24	0.85	0.10	0.21	0.02	0.33	107.13
August	0.70	0.10	0.25	0.01	0.73	0.13	0.29	0.01	0.29	103.78
Outdoor	0.69	0.11	0.24	0.80	0.62	0.12	0.27	0.01	0.26	97.62
FARM EBSU	0.60	0.08	0.18	0.01	0.57	0.14	0.26	0.01	0.24	79.26
SD	0.13	0.04	0.06	0.13	0.13	0.04	0.05	0.05	0.05	70.38
CV (%)	18.77	33.99	24.37	153.2	17.99	26.34	19.59	43.30	45.68	108.27

Table 8: Time Series Indoor Air Quality (Labor Ward Ae-Futha1)
Note: SD = Standard Deviation, CV (%) = Percentage Coefficient of Variability,
Co = Carbon (IV) Oxide, Nh_3 = Ammonia Gas, H_2s = Hydrogen Sulphide

Nigeria has policies and regulations that protect public health and the environment, including a national policy on the environment and a national environmental sanitation policy. (National policy on environment, Nigeria, 2011). Nigeria is also a signatory to an international treaty called the Basel Convention, which regulates the movements of hazardous waste between nations (Basel declaration of environmentally sound management of waste, 1999). According to WHO guidelines, the development of a national policy for managing healthcare waste is the first step that a government should take in addressing its management.

There are several studies on waste management practices in health facilities in Nigeria. According to the results from the 2004 baseline assessment of injection safety and healthcare waste management conducted by the Making Medical Injections Safe (MMIS) project in Nigeria, 0% of hospitals used color-coded bins for waste segregation (Rao, 1994). In another study on healthcare waste management in Jos, Nigeria, it was reported that waste segregation was not performed in any of the surveyed health facilities (Babatola, 2008). In a similar study in Lagos, Nigeria, only 16.9% of health facilities segregated waste (Awodele *et al.,* 2016). Another study in Nigeria found that healthcare waste disposal was carried out by open-air burning or burying at the facility site without prior treatment (Babatola, 2008). Furthermore, in a study at a tertiary facility in Nigeria, researchers found that no designated person or unit was responsible for healthcare waste management, indicating that responsibility for it was not clearly defined (Babatola, 2008).

Today, there is a growing awareness across the world that waste is a resource that should not be abandoned and left to landfilling sites. The literature is replete with studies concerning waste treatment and recycling techniques and procedures. However, there are certain types of waste that are considered too hazardous to be recycled and reused without pretreatment (Awodele et al., 2016). Infectious healthcare waste is one such kind of waste. According to World Health Organization (WHO), around 75% to 90% of the waste generated across healthcare facilities can be considered non-hazardous, while the remaining 10–25% cannot be ignored (Chartier, 2013). This may consist of infectious, radioactive, toxic or genotoxic items. Such waste items pose environmental and occupational health risks. In recent years, the generation of hospital waste has increased significantly owing to an increase in population, the number of healthcare facilities and the use of disposable medical products (Arab *et al*., 2008; Mohee, 2005). Many developed countries enforce strict guidelines regarding healthcare waste segregation, storage and transportation (Marinkovic *et al*., 2008; Tudor *et al*., 2005). Developing countries, on the other hand, are found to be resource-constrained when it comes to effective hospital waste management (HWM) (Caniato *et al*., 2015; Hossain *et al*., 2011). Here, poor sanitation practices might result in the mixing of hazardous waste with general waste, which may exacerbate the problem of waste management by increasing the cost of treatment and disposal (Patwary *et al*., 2009a). Moreover, poor nutrition, inadequate healthcare and lack of vaccination may increase the susceptibility of the public to infection from untreated medical waste (Patwary *et al*., 2009b).

4. Conclusion

As civilization grows, so do global services and goods, including those pertaining to health and healthcare. The rising trend in local, regional and global population calls for matching provision of health and healthcare. Most times, the outcome of activities of civilization, including waste generation and effects on environmental and human health, tend to be ignored or overbearing. As we provide health and healthcare, attention should also be paid to waste arising from such trends. In hospitals and clinics, patients, workers, and visitors need adequate protection from harmful substances, including those from waste. The air patients, workers, and visitors breathe in hospital wards and surroundings need to be safe and healthy. Hence, the present findings will be useful to health and environmental managers and other stakeholders in health and healthcare provision.

5. References

i. Arab, M., Baghbani, R.A., Tajvar, M., Pourreza, A., Tajvar, M., Omrani, G. and Mahmoudi, M. (2008). Report: The assessment of hospital waste management: a case study in Tehran. Waste Management and Research, 26: 304–308.

ii. 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.

iii. Babatola, J.O (2008). Comparative study of Biogas yield pattern in some Animal and Household waste. African Research Review, 2, 54–68. https://doi.org/10.43/4/afrrev./2/4.4/08/

iv. Basel Declaration of Environmentally Sound Management of Waste (1999). Declarations and Resolutions. Accessed online via: digWatch.com on 22.08.2023.

v. Bassey B.E, Benka-coker M.O, H.S.A Aluyi and Afri Health. Sci (2006). Characterization and management of solid medical wastes mar; 6(1): 58–63.

vi. Caniato, M., Tudor, T. and Vaccari, M. (2015). International governance structures for healthcare waste management: A systematic review of scientific literature. Journal of Environmental Management, 153: 93–107.

vii. Chaerul, M. and Tnaka, M. (2008). A system dynamics approach for hospital waste management. Waste Management, **28**, 442–449.

viii. Coker, A., Sangodoyin, A., Sridhar, M., Booth, C., Olomolaiye, P. & Hammond, F. (2009). Medical waste management in Ibadan, Nigeria: Obstacles and prospects. Waste Management, 29: 804–811.

ix. Hossain, M.S., Santhanam, A., Norulaini, N.N. and Omar, A.M. (2011). Clinical solid waste management practices and its impact on human health and environment–A review. Waste Management, 31: 754–766.

x. Marinković, N., Vitale, K., Holcer, N.J., Džakula, A. and Pavić, T. (2008). Management of hazardous medical waste in Croatia. Waste Management, 28: 1049–1056.

xi. Mohee, R. (2005). Medical waste characterization in healthcare institutions in Mauritius. Waste Management, **25**, 575–581.

xii. National Policy on Environment (2011). National Environmental (Coastal and Marine Area Protection). Regulations, 2011. Environmental (Coastal and Marine Area Protection). Federal Republic of Nigeria Gazette, No 5, vol 19, 13th May, 2011.

xiii. NPC (2019). Population of Abakaliki. National Population Commission of Nigeria.

xiv. Patwary MA, O'Hare WT and Street G, et al. (2009a). Health and safety perspective on medical waste management in a developing country: A case study of Dhaka city. In: 19th international FAIM conference. Gemini International Limited, pp. 282–290.

xv. Patwary MA, O'Hare WT and Street G, et al. (2009b). Quantitative assessment of medical waste generation in the capital city of Bangladesh. *Waste Management* 29: 2392–2397.

xvi. Pruss A, Giroult E & Rushbrook D (1999). Safe management of waste from healthcare activities. Geneva: World Health Organization.

xvii. Rao A.S, Prabhu, U.H, Sampath, S.R and Schiere J.B (1994). The effect of level of allowance on the intake and digestibility of finger millet (Eleusine coracana)strew in crossbred heifers. Anim feed sci.Technol, 49(1-2): 37–41.

xviii. Steel, R. G. and J. H. Torrie, (1980). *Principles and Procedures of Statistics, 2nd Ed*, New York; p 63.

xix. Tudor TL, Noonan CL and Jenkin LET (2005). Healthcare waste management: A case study from the Cornwall NHS, UK. Waste Manage, 25: 606–615.