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Assessment of the Impact of Sawmill Waste on the Environment

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Authors' contributions

This work was carried out in collaboration among all authors. Author HOS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JAN and CDO managed the analyses of the study. Author JAN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to assess the impact of sawmill wastes from selected sawmills in Port Harcourt on the environment. The physicochemical and microbiological features of the air at the sawmill sites were determined using air quality analyzer and settling plate technique respectively. Soil samples were analyzed for their physicochemical and microbiological properties. The study showed that of all the parameters monitored in the air samples at all the sampling sites, only noise level, volatile organic compounds and sulphur (IV) oxide exceeded the Federal Ministry of Environment limits. Results for microbiological analysis of air samples revealed that Total Heterotrophic Bacterial Counts (THBC) ranged from 2.5 x 10^4 (CFU/m^3) to 1.3 x 10^4 (CFU/m^3) while Total Fungal Counts (TFC) ranged between 1.7 x 10^4 (CFU/m^3) and 7.7 x 10^3 (CFU/m^3). The bacteria present in the air samples were identified as species of Staphylococcus, Micrococcus, Klebsiella, Serratia, Pseudomonas, Providencia and Bacillus while the fungi were identified as

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species of Penicillium, Aspergillus, Geotrichum, Cryptococcus, Rhizopus and Mucor. Results for microbiological analysis of soil samples revealed that THBC ranged from 2.06 x 10^6 (CFU/g) to 1.1 x 10^6 (CFU/g) while TFC ranged between 35 (CFU/g) and 1.4 x 10^2 (CFU/g). The bacterial isolates from the soil were identified as species of Pseudomonas, Salmonella, Aeromonas, Pseudomonas, Serratia and Aeromonas while the fungal isolates were identified as species of Penicillium, Aspergillus, Mucor and candida. The soil physicochemical properties monitored (pH, nitrate, lead, copper arsenic and mercury) where all within normal limits. The study showed that there are inhalable chemical and biological agents in the air at sawmills at the study locations. Measures should be put in place at sawmills to prevent occupational exposure and the waste should be properly managed.

Keywords: Sawmill wastes; air; soil; exposure; respiratory problems.

1. INTRODUCTION

Urban centres are fast springing up in Nigeria which has necessitated the increase in the establishment of sawmills in different parts of the country to satisfy the growing demand for timber commonly sourced from states within the rainforest belt of the country. Most of the sawmills in Nigeria are small-scale constituting about 81% of that sector [1]. Sawmill operations produce considerable amount of wastes which require management but nonetheless neglected among operators of small mills [2].

Timber processing produces powdery wood dust which form about 10-13% of the total volume of the wood log chopped off during milling operations [3,4]. Wood processing discharges various harmful substances laden in wood dust, such as terpenes, formaldehyde, fungi and their spores as well as bacteria growing on them into the environment [5,6]. These inhalable compounds can be allergenic, carcinogenic and immunotoxic [7]. Exposure to these compound has implication on respiratory health as they cause nasal irritation, nasopharyngeal cancer, bronchial hyper-responsiveness, allergic alveolitis, asthma, chronic bronchitis, rhinitis, contact dermatitis and general decline in lung function [5,8].

Control of exposure to wood dust and microbiological agents in woodworking environment is not easy [6]. In fact, various types of wood are commonly used and they generate complex mixtures of dusts and microorganisms which can pose various health risks upon inhalation.

Despite the fact that sawmill operations have been recognized has having potential to adversely impact on human health, much attention is not being paid to this sector in Nigeria in terms of managing their operation to r reduce the impact on human health and the environment. The sawmilling plants operating within the city of Port Harcourt, Rivers State, Nigeria for instance, are situated in highly dense residential areas, where dust and fumes from the mills drift freely into the environment. This study aims to study the microbiological and physicochemical parameters at some sawmilling sites within Port Harcourt, with the view to identify the possible allergenic and toxic chemical and microbiological agents present in the sawmilling environment in the study area.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted, in Port Harcourt Local Government Area (PHALGA) of Rivers State. Rivers State is part of the Niger Delta province, which lies within the rainforest belt in Nigeria and at the Southern end of country bordering the Atlantic Ocean. Three sawmills were sampled: sawmill at Rumuosi, sawmill at SARS Road and sawmill after SARS Road and their coordinate are 4°53'32.8"N 6°59'18.0"E; 4°89'28.6"N 6°97'46.8"E and 4°89'24.5"N 6°98'83.7"E respectively.

2.2 Sample Collection

Air samples were analyzed *in situ* at the three sawmills. Soil samples were collected from three locations in sterile plastic containers and transported immediately to the laboratory. Composite samples were obtained by mixing 5 grams of soil collected from different five different areas and a portion of the composite soil (1 g) was then placed in sterile bottles for physicochemical and microbiological analysis.

2.3 Physicochemical Analyses of Air Samples

Hand held air quality monitor (CW-HAT 200) was used to analyze for temperature, relative humidity, wind speed, and suspended particulate matter. MultiRAE IR meter was used to measure volatile organic compounds (VOCs), carbon monoxide (CO) carbon dioxide (CO_2), nitrogen oxide (NO_2), sulphur oxide (SO_2), and noise was measured using CEL 269.

2.3.1 Determination of microorganism present in air samples

The settling plate technique as described by Mbakwem-Aniebo et al. [9] was used for the isolation of microorganism in the air. In this technique, standard 90 mm diameter Petri dishes containing 18 ml of sterile culture media [Nutrient Agar (NA) and Potato Dextrose Agar (PDA)] were opened at the sawmill sites for 20 minutes, after which the Petri dishes were closed and placed in the incubator at 37^{o}C for 24 hours for possible bacterial growth in NA while the PDA plates were incubated at room temperature for five days for the determination of fungi. Enumeration was done using the Omeliansky's formula: N=5a x 104/bt (where a is actual plate count, b is the surface area of the Petri dish and t is the exposure time in minutes) and expressed in CFU/m^3.

2.3.2 Determination of microorganism present in soil samples

The spread plate method was used for the determination of microorganism in soil samples. In this procedure, 0.1 ml from 10^{-4}-10^{-5} dilutions of the soil sample was aseptically transferred into sterile plates of nutrient agar (NA) in duplicates. The inoculum was spread evenly on the surface of the agar plates with sterile glass spreader and allowed to dry. The NA plates were incubated at 37^{o}C for 24-48 hours and observed for bacterial colonies. For the isolation of fungi, 0.1 ml each from 10^{-2}-10^{-3} dilutions of the soil samples was transferred into sterile plates of PDA in duplicates. One milliliter (1 ml) of lactic acid was added to the plates to inhibit the growth of heterotrophic bacteria. The plates were incubated at room temperature for 76-96 hours and observed for fungal colonies. At the end of the incubation period the plates were examined for growth and pigmentation. Enumeration was done using the formula: Average no. of colonies/Volume plated (ml) × Dilution factor, and expressed as CFU/g.

2.4 Characterization of Isolates

The bacterial and fungal colonies formed on the media were repeatedly sub-cultured on NA to obtain pure isolates which were later subjected to a battery of biochemical tests, morphological and cultural characteristics, with reference to Bergey and Holt [10] Cheesbrough [11], Abbey [12] and McCance [13].

2.5 Physicochemical Analyses of Soil Samples

The pH of soil was measured *in situ* using a pH meter JENWAY 3071, model pH 82 (degree of accuracy 0.01) equipped with a temperature probe (924001). Nitrate was measured following the method of Agarry et al. [14]. Heavy metal content of the samples was determined using atomic absorption spectrophotometer (AAS).

2.6 Statistical Analysis

Data obtained from the study were subjected to one way analysis of variance (ANOVA) to determine levels of significance.

3. RESULTS

3.1 Physicochemical Parameters of Air Samples

The results from the analysis of air quality using the air quality analyzer are presented in Table 1. The noise level ranged from 78.7-83.5 db; temperature from 30.5-33.7^{o}C; relative humidity 60.5-67.5; wind speed 0.1-1.2 m/s; volatile organic compounds (VOCs) 6-6.2 ppm; suspended particulate matter (SPM) 59-60; carbon monoxide (CO) 2.3-3.6 ppm; carbon dioxide (CO_2) 1985- 2249 ppm; sulphur (IV) oxide (SO_2) 0.13-0.14 ppm and nitrogen dioxide (NO_2) 0.028-0.034 ppm.

3.2 Microbiological Parameters of Air Samples

Fig. 1 presents the results for the Total heterotrophic bacterial counts (THBC) and total fungal counts (TFC) after 20 minutes of exposure. Air sample from SARS Road had the highest THBC and TFC of 2.5 x 104 (CFU/m^3) and 1.7 x 10^4 (CFU/m^3) respectively, while After

SARS Road had the least THBC of 1.3 x 10^4 (CFU/m^3) and Rumuosi had the least TFC of 7.7 x 10^3 (CFU/m^3).

The bacteria present in the air samples were identified to belong to the genera Staphylococcus, Micrococcus, Klebsiella, Serratia, Pseudomonas, Providencia and Bacillus (Table 3) while the fungi were identified to belong to the genera Penicillium, Aspergillus, Geotrichum, Cryptococcus, Rhizopus and Mucor based on the cultural morphology (Table 2) and their biochemical characteristics (Table 3).

3.3 Microbiological Parameters of Soil Samples

The THBC and TFC results for the soil samples are presented in Fig. 2. Soil sample from After SARS Road had the highest THBC of 2.1 x 10^6 (CFU/g) and Rumuosi had the least THBC of 1.1 x 10^6 (CFU/g), while the highest TFC of 1.4 x 10^2 (CFU/g) was detected SARS Road and After SARS Road and Rumuosi had the least TFC of 35 (CFU/g).

The bacterial isolates from the soil were identified to belong to the genera Pseudomonas, Salmonella, Aeromonas, Pseudomonas, Serratia and Aeromonas (Table 5) while the fungal isolates were identified to belong to the genera Penicillium, Aspergillus, Mucor and candida (Table 6).

3.4 Physicochemical Parameters of Soil Samples

Table 7 shows the physicochemical parameters of the soil samples. The nitrate, copper, arsenic and mercury concentrations in soil samples from SARS Road were higher than in soil samples from After SARS Road. However, After SARS Road had higher pH value and lead concentration than SARS Road.

4. DISCUSSION

Sawmilling operations generate a lot of waste which pollute the air. The most significant part of monitoring ambient air quality data in any industry is to ensure its validation with the acceptable standards, as all industrial activities are known to have environmental footprints and occupational hazards. In the present study, only the estimates of concentrations of VOCs, noise level and SO_2 exceeded the FMEv standard of 0.5 ppm, 65 db and 0.01-0.1 ppm respectively.

The VOCs in the air at all three sawmills sampled ranging from 6-6.2 exceeded the FMEv limit of 0.5 ppm. Wood processing activities at sawmills include the use of many chemical preservatives and other chemicals discharged from the machineries. These chemicals are released into the ambient air. If the air at sawmilling sites is not collected and purified, the concentration of VOCs in the surrounding environment will be high. The elevated VOCs presented in this study, especially in terms of occupational health of workers in the study area is alarming, although consistent with results obtained from previous works. Two separate studies conducted in Ilorin Kwara by Olalekan et al. [16] and Rami et al. [17] similarly reported high VOCs concentrations in sawmills within the city. Elevated levels of VOCs could lead to respiratory problems and may cause distress to asthmatics among industrial workers.

Table 1. Physicochemical parameters of air in the study area

S/No	Parameter	Location			FMEv [15]
		Rumuosi	SARS Road	After SARS Road	
1	Noise level (db)	78.7±12.02	83.5±21.26	79.5±13.24	65
2	Temperature (^oC)	30.5±1.14	33.7±3.26	33.4±2.9	29.5-36.9
3	Relative humidity	67.5±10.53	60.5±8.32	61.4±15.41	4.90-75.9
4	Wind speed (m/s)	0.9±0.1	0.1±0.08	1.2±0.2	-
5	VOC (ppm)	6±0.4	6.2±1.22	6±2.02	0.50
6	SPM (ppm)	60±20.45	60±11.26	59±25.06	115-150
7	CO (ppm)	3.6±0.1	2.7±0.1	2.3±1.3	50
8	CO_2 (ppm)	2249±85.23	2107±56.21	1985±29.14	-
9	SO_2 (ppm)	0.14±0.02	0.13±0.01	0.13±0.01	0.01-0.1
10	NO_2 (ppm)	0.028±0.001	0.029±0.002	0.034±0.007	0.04-0.06

VOCs=volatile organic compounds; SPM=suspended particulate matter; SARS=Special Anti Robbery Squad; FMEv=Federal Ministry of Environment

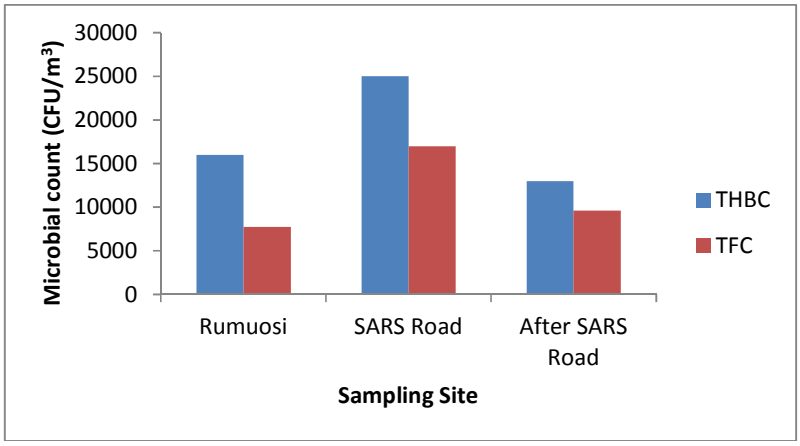

Fig. 1. Microbial counts in air

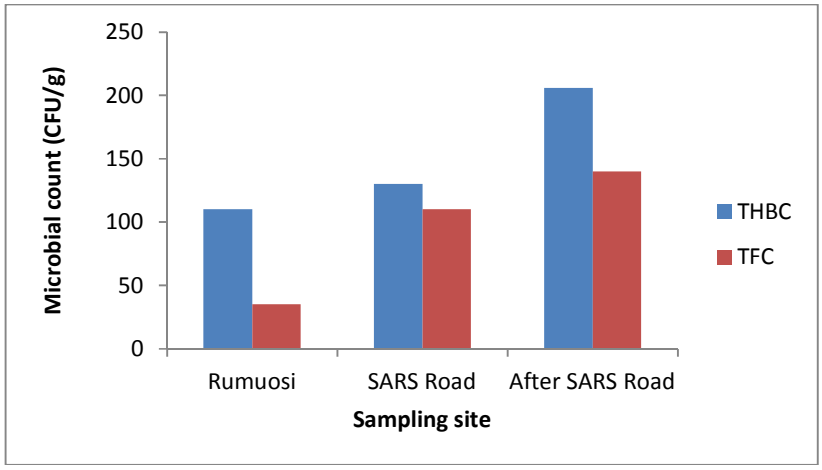

Fig. 2. Microbial counts in soil

Table 2. Cultural morphology of bacterial isolates from air samples

Sample	Code	Cultural Morphology
A	Q_1	White flat circular serrated rough and dry 0.3cm
	Q_2	Orange raised entire circular smooth and shiny 0.2cm
	Q_3	Cream raised entire circular smooth and shiny 0.4cm
	Q_4	Cream rough flat smooth and dry surface irregular 0.3cm
	Q_5	White smooth and dry raised circular entire 0.2cm
B	Q_6	Brown red raised circular entire smooth and shiny 0.1cm
	Q_7	White raised circular entire smooth and dry 0.2cm
	Q_8	White flat circular serrated rough and shiny 0.3cm
	Q_9	Cream smooth and shiny entire raised circular
C	Q_{10}	White irregular flat dull and rough surface 0.3cm
	Q_{11}	Orange raised circular entire smooth and shiny
	Q_{12}	White circular dry rough serrated flat and rough 0.4cm
	Q_{13}	Rough flat smooth and dry surface irregular 0.4cm
	Q_{14}	Yellow circular entire raised smooth and shiny
	Q_{15}	Brownish circular raised entire smooth and shiny

A: Rumuosi; B: SARS Road; C: After SARS Road

Table 3. Biochemical test for isolates from air samples

Isolate Code	Catalase	Citrate	Glucose	Lactose	Sucrose	Mannitol	Indole	oxidase	MR	VP	Butt	Slant	Gas	H_2S	Motility	Gram reaction rea reaction staining	Possible genera
Q_1	+	+	+	-	-	+	-	-	+	-	A	B	-	-	-	-	*Aeromonas* sp.
Q_2	+	-	+	+	+	+	-	-	-	+	A	A	-	-	-	+	*Staphylococcus* sp.
Q_3	+	+	D	-	-	-	+	-	-	-	B	B	-	-	+	-	*Pseudomonas* sp.
Q_4	+	+	+	+	+	+	+	-	+	-	A	A	-	-	-	+	*Staphylococcus* sp.
Q_5	+	+	+	-	-	-	+	-	+	-	A	B	-	-	+	-	*Providencia* sp.
Q_6	+	+	+	-	-	-	+	+	-	+	A	B	-	-	-	+	*Micrococcus* sp.
Q_7	+	+	+	+	+	-	+	-	-	+	A	B	-	-	-	+	*Staphylococcus* sp.
Q_8	+	+	+	-	-	-	+	-	-	+	A	B	-	-	-	+	*Bacillus* sp.
Q_9	+	+	+	+	+	+	+	-	+	-	A	A	+	-	+	-	*Klebsiella* sp.
Q_{10}	+	+	+	+	-	-	+	-	-		A	A	-	-	-	+	*Micrococcus* sp.
Q_{11}	+	+	+	-	+	-	+	-	-	+	A	B	-	-	-	-	*Serratia* sp.
Q_{12}	+	+	D	-	-	-	+	-	-	+	A	B	-	-	-	+	*Bacillus* sp.
Q_{13}	+	+	+	-	-	-	+	-	-	+	A	B	-	-	-	+	*Bacillus* sp.
Q_{14}	+	+	+	+	-	-	+	-	+	+	A	B	-	-	-	+	*Micrococcus* sp.
Q_{15}	+	+	-	-	-	-	+	+	+	+	B	B	-	-	-	-	*Pseudomonas* sp.

Table 4. Identification of fungal isolates from air samples

Isolate code	Macroscopy	Microscopy	Possible Isolate
R_1	Blue-greenish convex, circular, dry and rough surface with margin	Presence of conidiophore in transparent hyphae looking like brush in cluster	*Penicillium* sp.
R_2	Highly dense fluffy mycelia that produces dark spores with age	Presence of sporangium and long hyphae	*Rhizopus* sp.
R_3	Cracked yellow reverse, black surface with white border	Presence of hyphae with sporangium	*Aspergillus* niger
R_4	Yellow raised entire circular smooth and dull surface	Purple large cocci	*Cryptococcus* sp.
R_5	Dense cottony white mycelia that turns brown with age	Broad non-septate hyphae	*Mucor* sp.
R_6	Presence of white dry powdery-like colonies that look like yeast with loped center with rough surface	Presence of hyphae with conidiospores	*Geotricum* sp.

Table 5. Biochemical identification isolates from soil samples

Isolate Code	Catalase	Citrate	Glucose	Lactose	Sucrose	Mannitol	Indole	oxidase	MR	VP	Butt	Slant	Gas	H_2S	Motility	Gram reaction rea reaction staining	Possible genera
S_1	+	+	D	-	-	-	+	-	-	-	B	B	-	-	+	-	*Pseudomonas* sp.
S_2	+	+	+	-	-	-	+	-	+	-	A	A	-	-	-	-	*Salmonella* sp.
S_3	+	-	+	-	-	-	+	-	+	-	B	B	-	-	-	-	*Aeromonas* sp.
S_4	+	+	-	-	-	-	+	+	+	+	B	B	-	-	-	-	*Pseudomonas* sp.
S_5	+	+	+	-	+	-	+	-	-	+	A	B	-	-	-	-	*Serratia* sp.
S_6	+	+	+	-	+	-	+	-	-	+	A	B	-	-	-	-	*Serratia* sp.
S_7	+	-	+	+	+	-	+	-	+	-	A	B	-	-	+	-	*Aeromonas* sp.

Table 6. Identification of fungal isolates from soil samples

Isolate code	Macroscopy	Microscopy	Possible Isolate
SS_1	Blue-greenish convex, circular, dry and rough surface with margin	Presence of conidiophore in transparent hyphae looking like brush in cluster	*Penicillium* sp.
SS_2	Cracked yellow reverse, black surface with white border	Presence of hyphae with sporangium	*Aspergillus* niger
SS_3	Dense cottony white mycelia that turns brown with age	Broad non-septate hyphae	*Mucor* sp.
SS_4	Cream colour colony	Blastoconidia and pseudohyphae strongly gram positive	*Candida* sp.

Table 7. Physicochemical parameters of the soil samples

S/No	Parameter	Sampling Site	
		SARS Road	**After SARS Road**
1	pH	4.98	5.26
2	Nitrate (mg/kg)	10.74	7.03
3	Cu (mg/kg)	18.03052	16.62115
4	Pb (mg/kg)	14.96734	19.13291
5	As (mg/kg)	4.37351	3.85430
6	Hg (mg/kg)	0.18628	0.39106

The noise level at all three sawmills sampled ranging from 78.7-83.5 db exceeded the FMEv limit of 65 db. High noise level ranging from 76-114 db was reported within 100-400m from sawmills sampled in Ile-Ife, Osun State in the study by Olawuni and Okunola [18]. Boateng and Amedofu [19] in their study carried out in Kumasi Ghana, ascertained that noise pollution from sawmill industries has a great impact on the hearing capabilities of worker. Ideally, sawmill industry is not supposed to be sited within residential areas; rather it ought to be located in a given zone, usually, at the outskirt of residential areas [20]. Boateng and Amedofu [19] asserted that the farther the distance from the sawmill industry, the lower the environmental problems like noise associated with sawmilling activities.

The SO_2 concentration at all three sawmills sampled which was 1.4 ppm for Rumuosi and 1.3 ppm for SARS Road and after SARS Road, all exceeded the FMEV limit of 0.01-0.1 ppm. Adelagun et al. [21] also reported high SO_2 concentrations ranging from 0.23 – 0.60 ppm in a study of sawmill industry in Ebute-Meta, Lagos State. Areas with high SO_2 concentrations are susceptible to acid rain and other associated hazards.

Although, temperature has been rising on average, in the world and can be used as a surrogate for the meteorological factors influencing surface ozone formation [22], temperature measured in this study were well within tolerable limit of 29.5-36.9^{o}C according to FMEv [15], consistent with a tropical climate. The temperature range in this study (30.5-33.7^{o}C) is within temperature range of 21.00-46.40^{o}C reported by Olalekan et al. [16].

The measured concentrations of CO, NO_2 and SPM in air around sawmills investigated were within FMEv ambient air limits. Elevated values CO and SPM in the environment affect human health and also have climatic effects. Prolonged exposure to high levels of PM_{10} may cause irritation of the respiratory tract and bronchitis [16]. Adeoye et al. [23] in a descriptive cross-sectional study carried out in 84 sawmills in Osun State reported high SPM in the sawmill environments which they argued could cause various degrees of pulmonary impairment. NO_2 is also implicated in respiratory diseases. Carbon monoxide is muscle paralyzing, neurotoxic and can lead to death presumably due to asphyxiation.

Sawmills produce bioaerosol which can cause respiratory health problems upon exposure [24]. In the present study TFC from air sample ranged from 9.6 x 10^3 - 1.7 x 10^4 (CFU/m^3). An occupational exposure limit (OEL) of 1-10^5 spores/m^3 has been proposed on the basis of the experimental and epidemiological evidence of the lowest-observed-effect level (LOEL) for exposure to general fungal spores [25]. The fungal count at the sawmilling sites in this present study is low, probably because the working area is semi-enclosed, which could allow for air current to disperse the airborne spores further from the operating sites.

Endotoxin-producing Gram-negative bacteria pose the greatest risk among bacteria present in wood processing sites [7]. Gioffre et al. [26] reported that people working in wood factories may be exposed to high levels of inhalable endotoxins. The Gram-negative bacteria isolated from the air in this study belong to the genera Klebsiella, Serratia, Pseudomonas and Providencia. *Pseudomonas aeruginosa* is known to cause respiratory infections.

In the present study the fungi present in the air samples were identified to belong to the genera *Penicillium*, *Aspergillus*, *Geotrichum*, *Cryptococcus*, *Rhizopus* and *Mucor*. Allergenic fungi developing on bark of logs or stored wood products pose great risk for respiratory diseases [7]. Species of *Penicillium* and *Aspergillus* are reported to cause symptoms of allergic respiratory diseases. *Geotrichum* sp. was the most frequently isolated fungi from the air. However, Duchaine and Mériaux [24] in their study of eastern Canadian sawmills, reported *Penicillium* species as the most frequently isolated microfungi. *Penicillium* sp. was however the most frequently isolated fungi from the soil.

The nitrate, copper arsenic and mercury concentrations in soil samples from SARS Road were higher than in soil samples from After SARS Road. However, After SARS Road had higher pH value and lead concentration than SARS Road. The heavy metals detected in soil were Pb, Ar, Cu and Mercury. Okonkwo et al. [27] similarly detected Pb and Cu in sawmill dumpsite in Abakaliki, Ebonyi State. The heavy metals values obtained in both sites were found to be within normal range in soil (2 – 300 mg/Kg) as presented by Kabata-Pendias and Pendias [28].

5. CONCLUSION

The present study has shown that the sawmill environment in Port Harcourt harbor wood dust, produce noise, heavy metals, toxic gases and microorganisms that can be injurious to health and the environment. Measures need to be put in place by operators of sawmills in Port Harcourt to cut down on their pollution and better manage the sawmill waste.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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