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Effects of Seasonal Variation on Air Quality and Microbial Composition around Sawmilling Sites in South East Nigeria

V. Obike-Martins [a], M. S. Fashola [a], N. C. Oji [a], V. O. Nwaugo [b], F. U. Uchenna [a], I. N. Okwy-Irokanulo [a] and E. Enya [a*]

[a] *Department of Microbiology, College of Natural Sciences, Michael Okpara University of Agriculture Umudike, Abia State, Nigeria.*
[b] *Department of Microbiology, Abia State University Uturu, Abia State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: The demand for wood and wood products for use in construction and building has resulted in a surge in sawmilling activities especially in Nigeria with resultant incessant emissions into the environment.
Aims: This study was therefore aimed at investigating the air quality status and microbial composition of air around two different sawmill facilities.
Place and Duration of Study: This study was carried out within sawmilling sites at the Ahiaeke and Okigwe Timber markets in Abia and Imo states of Nigeria respective during the dry and rainy seasons.
Methodology: Air quality determination was done in–situ using hand held environmental sensor meters (HANNA Air Monitors, Rhodes Island, USA). Bacterial and fungal concentration (cfu/m^3) in the air of saw-mill sites were evaluated by passive air sampler. Petri dishes containing nutrient agar, MacConkey and Sabouraud dextrose agar were exposed at intervals of 10 minutes, 20 minutes and 30 minutes at four designated points as 0m, 50m, 100m and 500m (control).
Results: Seasonal trends were observed in the levels of air pollutants from both sites in this study. $PM_{2.5}$ and PM_{10} were at the peaks during the dry season at both sites (Ahiaeke and Okigwe)

**Corresponding author: E-mail: emmy_enya12@yahoo.com;*

reaching 134ppm and 275ppm respectively for Ahiaeke whilst it was 39ppm and 65ppm respectively for Okigwe at ground level (0m). There was a continual decline in the values observed for H_2S and CH_4 as the distances decreased at both sites during dry seasons at 100m while at 500m (control) nothing was detected. It was determined that sampling times of 10minutes yielded countable bacterial growth of 7.4cfu/m^3 and 6.2cfu/m^3 at the 0m and 50m distances respectively at the Ahiaeke site. A sampling time of 30minutes yielded increased bacterial load of 9.9cfu/m^3 and 8.4cfu/m^3 at the 0m and 50m distances respectively at same site. A similar trend was observed for total bacterial, coliform and fungal counts at the Okigwe site. Nucleotide sequences of bacterial 16S rRNA gene fragments retrieved from bacterial isolates in this study were deposited in the GenBank nucleotide sequence database under accession nos. MK621199, MK621103, MK621201, MK640631, MK640622, MK640625, MK640623, MK640628, MK640630, MK621201, MK643270, MK621195, MK640785, MK640842 and MK640843 for the bacterial isolate whereas the fungal isolates were deposited with MK621199, MK621202, MK640642 and MK640638.

Conclusion: The results obtained in this study are not only useful in providing information on the prevailing air quality but also justify the need for epidemiological research in the area to ascertain the level of impact of continuous gaseous emission from the sawmill on the pollution of the sites.

Keywords: Air quality; bioaerosol; wood; sawmill; particulates.

1. INTRODUCTION

Sawmill by its nature generates a lot of wastes such as; saw dusts, plain shavings, wood rejects, as well as several emissions. With increased demands for wood and its products, the volume of wastes being generated is bound to also increase. In the absence of proper disposal methods, these wastes are burnt in the open air. Hence, one of the greatest environmental problems facing the Sawmill industry today is pollution. These environmental issues range from degrading the urban environment, producing offensive odours during the rains and polluting the air with smoke when the wastes are burnt uncontrollably. They also constitute health hazards when they are not timely disposed. They also pose bad working environment for those working in the area, due to accumulation of wastes over a period of time most especially during raining season. Some studies show that the greatest air pollution problem in the Nigerian environment is atmospheric dust arising from many industrial processes including Sawmill industries [1]. The establishment of Sawmill industry in different parts of the country has been in high increase due to the fast growth recorded in the building construction sector, to satisfy the growing demand for wood [1,2].

Microorganisms easily develop in wood and, during wood processing, microorganisms are released into the air and high concentrations of aerosolised microorganisms may be present inside sawmills. Airborne microorganisms were identified as a cause of occupational pulmonary disease for woodworkers [3]. Akinbode and Olujimi [4] reported that the prevalence of cough, phlegm, chronic bronchitis, nasal symptoms, frequent headaches, and eye and throat irritations was significantly higher among woodworkers than the control group.

Sawane and Sawane [5] reported that in large-scale industrial composting plants, since exposures to microorganisms and organic dust in the compost industry can be substantial, in-creasing the number of workers and occupational exposures of those compost workers may cause acute and possibly chronic inflammatory reactions in their upper airways, presumably induced by non-allergic pro inflammatory agents like endotoxins and (1-3)-β-D-glucans.

It has been generally recognized that exposures to biological agents in occupational and residential environment predispose people to a vast array negative health disorders including contagious infectious diseases, acute toxic effects, allergies, and cancer having significant impact in public health [6]. The pollution of air in saw-mills with microorganisms results from the primary or secondary infection of timber with bacteria and fungi, respectively. It is often characterized by abundant growth of molds. Thus, sawmill workers may be exposed at work to the inhalation of various allergenic and immunotoxic agents, comprising wood derivatives and microorganisms associated with timber [7]. This exposure to bioaerosols in work environment presents hazards of allergy and respiratory symptoms.

Wood smoke is an aerosol comprising of hazardous gases, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons, heavy metals and soot, which is made visible by the presence of particulate matter (PM) [8,9]. The adverse health effects from particulate matter exposure are often not immediately noticed [10]. Particulates can accumulate in the lungs after repeated long-term exposure causing respiratory distress and other health problems [11]. Epidemiological studies have long recognized increased mortality and morbidity in susceptible populations during high air pollution episodes [12,13]. The hazardous substances embedded on PM especially $PM_{2.5}$ are carried deeper into alveoli where they cause harm and interfere with gaseous exchange [14].

The objective of this study is to investigate air quality status and microbial composition of air around two different sawmill facilities.

2. METHODS

2.1 Air Quality Determination

This was done using the standard methods described in the laboratory manual of air pollution by the National ambient air quality guidelines [15]. Air borne particulate matter ($PM_{2.5}$ and PM_{10}) was determined using handheld environmental sensor meters (HANNA Air Monitors; Rhodes Island, USA). The meters were switched on at the various sampling points and allowed to stabilize within 20-30 minutes before taking the reading. The particulate matter was measured by counting and sizing the number of particles in the air. The instrument was held at 0m, 50m, 100m and 500m above ground level of each sawmill site and the air particulates concentration of the sample location determined.

Other parameters measured were; Temperature, hydrogen sulphur (H_2S), methane (CH_4), sulphur oxide (SOx), nitrogen oxide (NOx). Similarly, readings were taken from both sawmill sites at distances of 0m, 50m, 100m and 500m above ground level of each sawmill site.

2.2 Isolation/Enumeration of Total Heterotrophic Bacterial and Fungal Count

Petri dishes containing freshly prepared nutrient agar, MacConkey and Sabouraud dextrose agar were exposed and held at interval of 10 minutes, 20 minutes and 30 minutes at 0m, 50m, 100m and 500m above ground level of each sawmill site to capture aerosolized microorganisms. The culture plates were subsequently incubated at $37^oC/25^oC$ for 24hours/48hours for bacteria and fungi respectively. Upon establishment of growth, viable colonies between 25 – 250 colonies were counted and microbial population density expressed in colony forming unit/plate/minutes by passive air sampling technique [16]. The isolates were observed for morphological features, Gram stained and characterized using standard biochemical procedures. Identification of filamentous fungi was carried out by a combined microscopic examination of each isolate mounted in lactophenol blue and through macroscopic morphological characteristics. The identity of each isolates was further authenticated using standard DNA Sequencing protocols. DNA was extracted from the isolates at molecular biology laboratory of Niger Delta University, Bayelsa state Nigeria and the DNA extracts sequenced for their nucleotide sequences for use in identification.

3. RESULTS AND DISCUSSION

Total airborne heterotrophic bacterial concen-trations in the Ahiaeke sawmill during the dry season for 10, 20 and 30 minutes exposure at different distances were between 7.4 to 2; 8.6 to 1.8 and 9.9 to 1.9cfu/plate/minute, respectively, and total airborne fungi concentration at each distance and for 10, 20 and 30minutes were 5.8 to 0.9; 6.7 to 1.1 and 7.8 to 1.4cfu/per plate/minute, respectively whilst for the Okigwe sawmill site, total heterotrophic bacterial loads of 5.9 to 0.9; 6.8 to 1 and 7.6 to 1.6cfu/plate/minute were recorded for 10, 20 and 30 minutes respectively during the dry season. The results (Tables 1 and 2) show that the total airborne bacterial and fungal concentrations at the various distances of study from both sites were significantly different from each other (P=0.05). The total heterotrophic bacteria loads were found to be higher during dry season at all sampling sites. Lower counts were obtained from all sampling sites during rainy.

Seasonal trends were observed in the levels of air quality from both sites. PM_{10} and $PM_{2.5}$ were at the peaks during the dry season at both sites 275ppm and 98ppm (PM_{10}) and 134ppm and 124 ppm ($PM_{2.5}$) for Ahiaeke and Okigwe respectively, as for the sulphur oxide (SO_x), nitrogen oxide (NOx), hydrogen sulphide (H_2S) and methane (CH_4). SO_x and NO_x levels had much less variation. However, all of these air quality parameters except SO_x and NO_x exceeded the limit set by FEPA by a large margin (Figs. 1 and 2).

For the overall H_2S and CH_4 concentration at the different sites in dry season, Ahiaeke sawmill had highest concentration of 15.3ppm and 16ppm respectively at the 0m (Edge) followed by the 50m distance with 13.5ppm and 13ppm respectively (Figs. 3 and 4). There was a continual decline in the values observed for H_2S and CH_4 as the distances decreased at sites during both the rainy and dry seasons. At the okigwe sawmill, highest concentration of 12.5ppm and 12 ppm (H_2S and CH_4) were also recorded during the dry season as compared with the 6.7ppm and 8 ppm for the rainy season respectively. Total Particulate matter (PM_{10}) at the Okigwe site for the various distance of study ranged from 28ppm to 98ppm and 20ppm to 32ppm for the dry and rainy seasons respectively. At the Ahiaeke site, PM_{10} ranged from 31 ppm to 275ppm and 19ppm to 258ppm for the dry and rainy seasons respectively.

Table 1. Microbial counts of sawmill and control air samples at different distance during dry season

	Section A					Section B				
Parameter	**0m (15min)**	**50m (30mins)**	**100m (45min)**	**500m (60min)**	**LSD**	**0m (15min)**	**50m (30min)**	**100m (45min)**	**500m (60min)**	**LSD**
THBC	16^a	8.2^b	5.4^c	3.9^d	1.50	11^a	6.3^b	4.0^c	3.1^d	0.90
TCC	5^a	2.5^b	1.6^c	1.4^c	0.90	3^a	1.5^b	0.8^c	0.7^c	0.70
TFC	10^a	4.7^b	3.2^c	2.3^d	0.90	7^a	3.4^b	2.4^c	1.9^d	0.50

Values with different superscript across a row are significantly different from each other.
Key:THBC Total Heterotrophic Bacteria Count; TCC Total Coliform Count; TFC Total Fungal Count; Section A: Ahieke Ndume Ibeku; Section B: Okigwe

Table 2. Microbial counts of sawmill and control air samples of different distance during rainy season

	Section A					Section B				
Parameter	**0m (15min)**	**50m (30mins)**	**100m (45min)**	**500 (60min)**	**LSD**	**0m (15min)**	**50m (30min)**	**100m (45min)**	**500m (60min)**	**LSD**
THBC	9^a	4.3^b	2.8^c	2.2^d	0.60	7^a	3.3^b	2.4^c	1.7^d	0.70
TCC	2^a	1.2^b	0.6^c	0.4^c	0.60	1^a	0.6^b	0.2^c	0.3^c	0.30
TFC	6^a	2.9^b	2.2^c	1.6^d	0.60	4^a	2.1^b	1.2^c	1.1^c	0.90

Values with different superscript across a row are significantly different from each other.
Key: THBC Total Heterotrophic Bacteria Count; TCC Total Coliform Count; TFC Total Fungal Count. Section A: Ahieke Ndume Ibeku; Section B: Okigwe

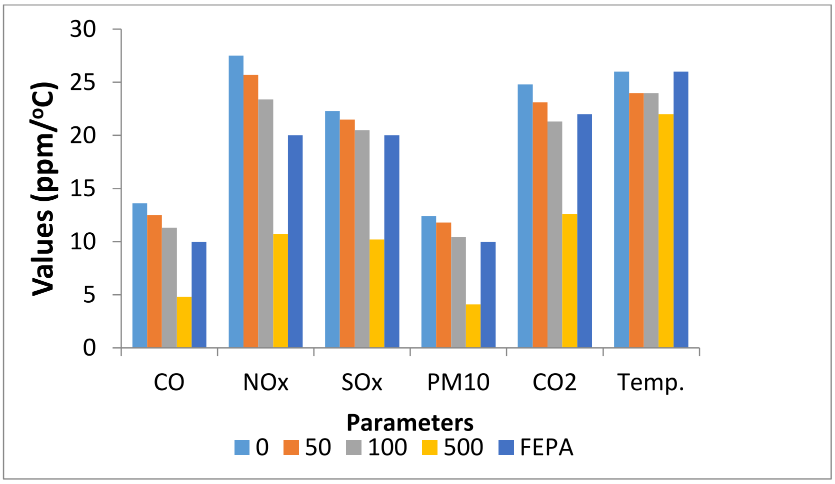

Fig. 1. Air Pollutants levels during the dry season at Ahiaeke sawmill

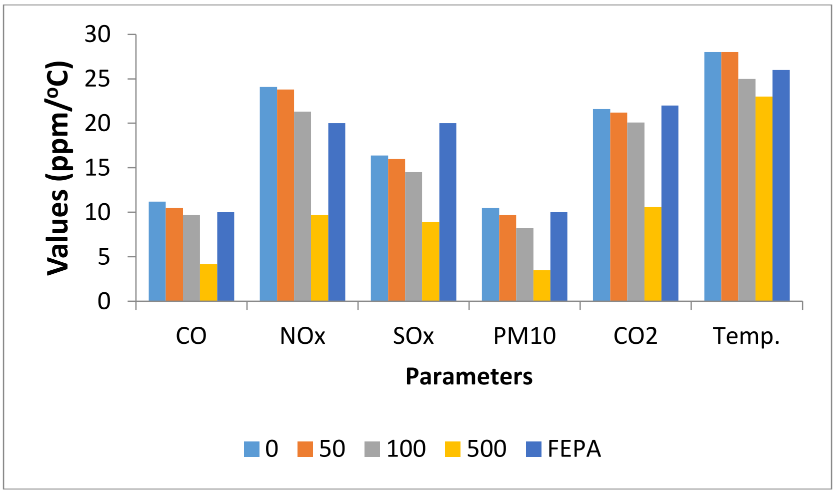

Fig. 2. Air pollutants levels during the dry season at Okigwe Sawmill

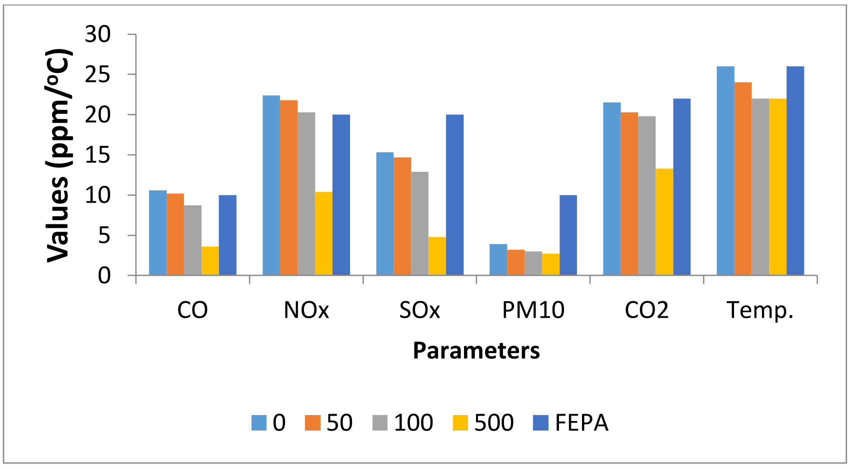

Fig. 3. Air pollutants levels during the rainy season at Ahiaeke Sawmill

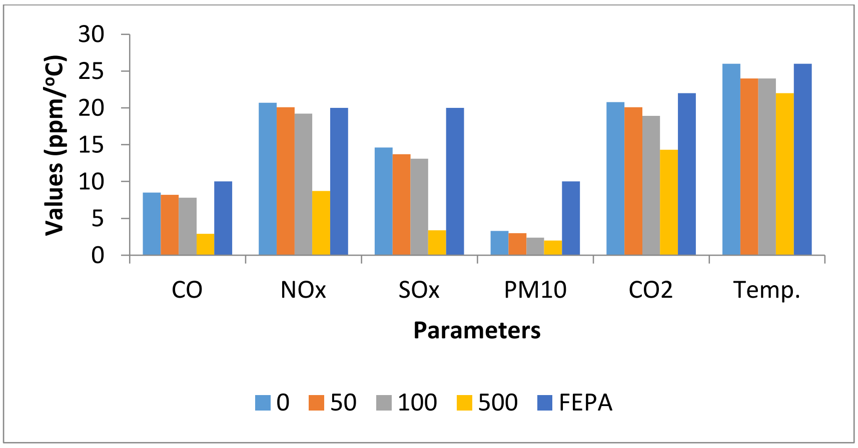

Fig. 4. Air pollutants levels during the rainy season at Okigwe Sawmill

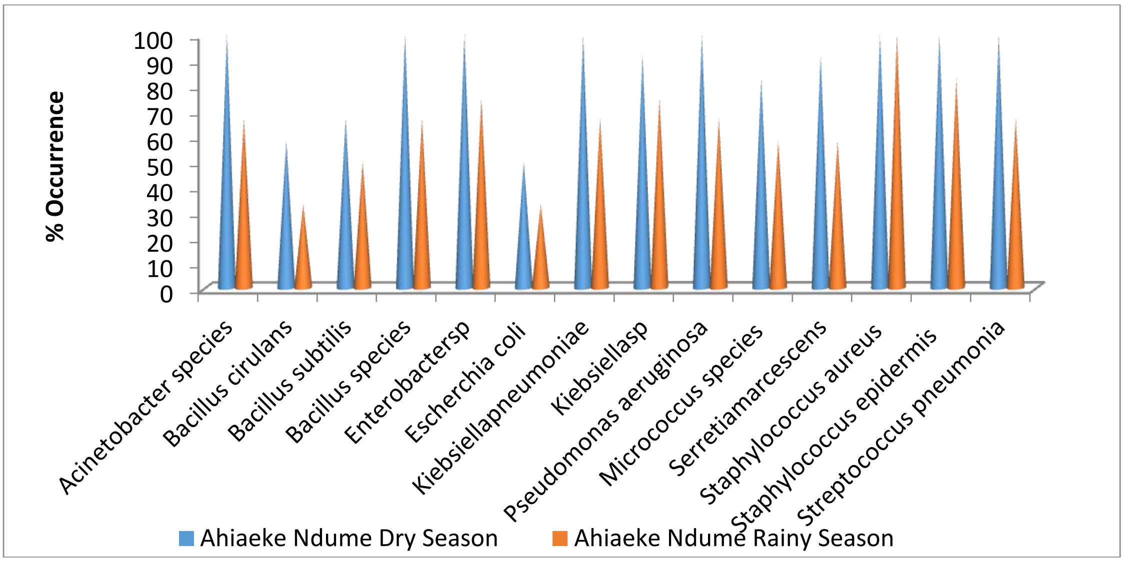

Fig. 5. Prevalence of bacteria isolates in sawmill air samples from Ahiaeke

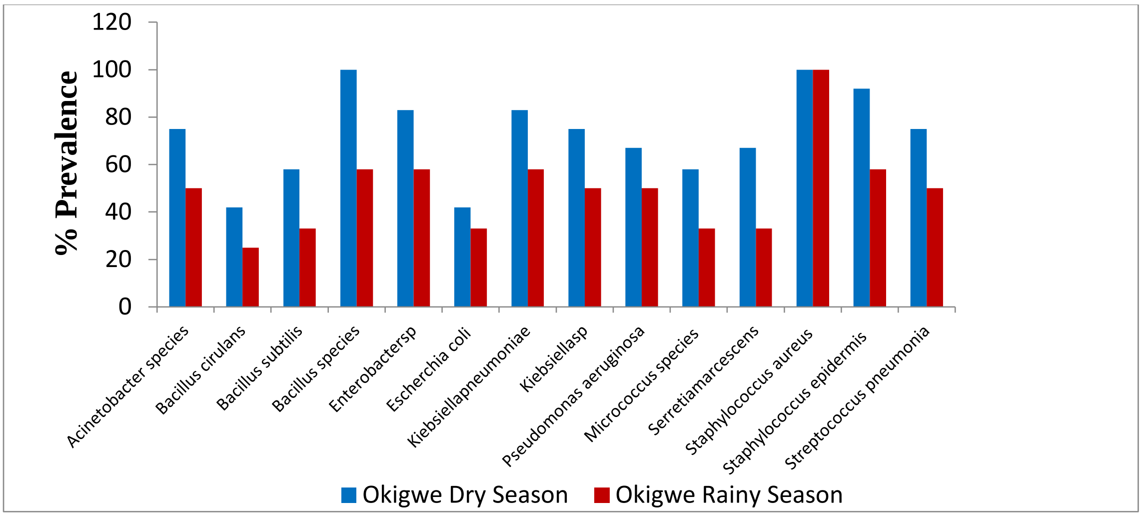

Fig. 6. Prevalence of bacteria isolates in sawmill air samples from Okigwe

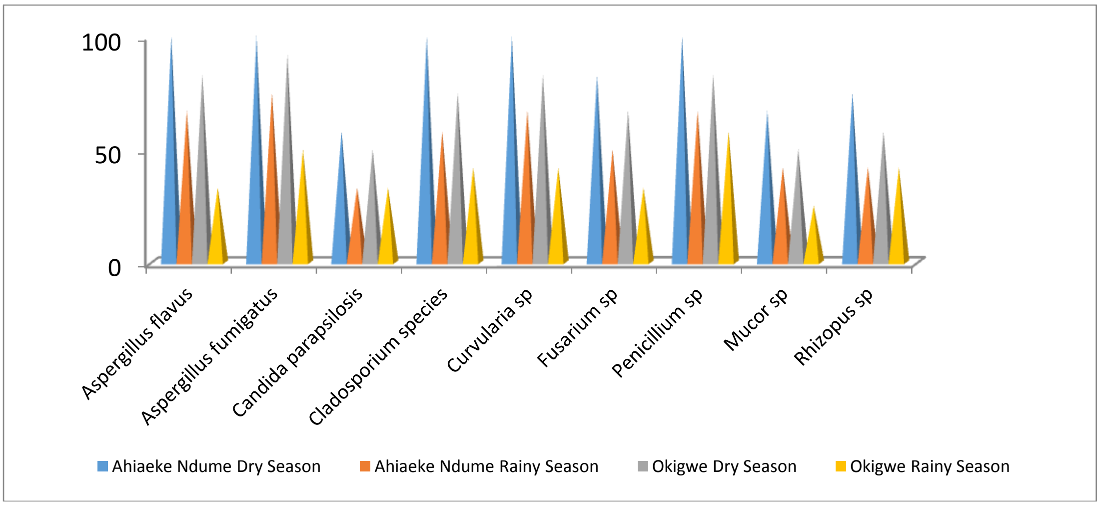

Fig. 7. Prevalence of fungi isolates in sawmill air samples

4. DISCUSSION

The activities of wood processing and furniture making at sawmills involve the use of various chemicals (adhesives, thinners, paints, preservatives). These activities release volatile chemicals into the ambient air and immediate surroundings, thus increasing the concentration levels of photochemical oxidants into the environment that may be hazardous to humans.

Seasonal trends were observed in the levels of air pollutants from both sites in this study. $PM_{2.5}$ and PM_{10} were at the peaks during the dry season at both sites (Ahiaeke and Okigwe) reaching 134ppm and 275ppm respectively for Ahiaeke whilst it was 39ppm and 65ppm respectively for Okigwe at ground level (0m). There was continual decline in PM values as the distances under investigation increased. The level of dust emitted from the sawmill industry is a concern for persons residing and working within. These findings substantiated earlier assertions by [17,18], that the farther the distance from the sawmill industry, the lower the environmental problems associated with sawmilling activities. The air quality parameters evaluated in the present investigation except for SO_x and NO_x exceeded the limit set by FEPA by a large margin. For the overall H_2S and CH_4 concentration at the different sites in dry season, Ahiaeke sawmill had highest concentration at the 0m distance (15.3ppm and 16.0ppm respectively) followed by the 50m distance (13.5ppm and 13.0ppm respectively). There was a continual decline in the values observed for H_2S and CH_4 as the distances decreased at both sites during dry seasons at 100m while at 500m (control) nothing was detected. At the Okigwe sawmill, highest concentration of H_2S and CH_4 were also recorded during the dry season at 0m (8.5ppm and 11.0ppm respectively) as compared with the rainy season. The reduction in the concentration of gases noticed at both sites during the dry seasons could be attributed to the absence of rain during the dry season which might have contributed to the dispersion of the gases. This agrees with earlier reports of Brorson and Larsson [19]. The presence of these gases could be attributed to the burning of woods and using of heavy equipment which releases smoke to the atmosphere. Boateng and Amefodu [18], had earlier reported that when wood burns, gases and fine particles are produced which are microscopic. Clinical syndromes such as skin rashes, burns, asthma, frequent headache, fatigue, eye irritation, chronic cough, hypersensitivity, chronic obstruction of lungs, liver and kidney as a result of inhalation and contact with wood dust and other chemicals used in the industry have been reported elsewhere [20]. The noise levels were very high at 0m (edge) for both sites during both seasons. The workers are at risk to daily exposure of noise pollution without any means of protection.

Aerosolized organisms were collected on TSA, MacConkey and PDA filled Petri plates at both sites for 10 minutes, 20minutes, and 30minutes (Table 1). It was determined that sampling times of 10minutes yielded countable bacterial growth of 7.4cfu/m^3 and 6.2cfu/m^3 at the 0m and 50m distances respectively at the Ahiaeke site. A sampling time of 30minutes yielded increased bacterial load of 9.9cfu/m^3 and 8.4cfu/m^3 at the 0m and 50m distances respectively at same site. A similar trend was observed for total bacterial, coliform and fungal counts at the Okigwe site. The results further indicated that concentrations of fungi were more pronounced during the dry season. Both sites presented the highest fungal contamination in dry season.

Nucleotide sequences extracted from the respective bacterial and fungal isolates and blasted on the NCBI website revealed that most of the isolates belonged to the genera *Acinetobacter*, *Bacillus* and *Enterobacter* for the bacteria and *Aspergillus Aspergillus*, *Curvularia* and *Cladosporium* for the fungi. The isolates were furthered deposited in the GenBank nucleotide sequence database under their respective accession numbers (www.ncbi.nlm.nih.gov). Fungi isolated were of the genera *Aspergillus*, *Curvularia*, *Cladosporium*, *Fusarium*, *Mucor*, *Penicillium* and *Rhizopus. Acinetobacter species, Bacillus* species, *Enterobacter* species were amongst the most predominant bacterial isolates during season. Lower prevalence were observed in the rainy seasons across both sites (Figs. 5 and 6). The implication of findings of this study is that the presence of airborne fungal contaminants of outdoor workplace environment may pose serious occupational health consequences.

Fungal and bacterial concentrations in sawmill air were significantly more than control air. Exposure to a concentration of airborne microorganisms revealed in the present study is higher than the degree of exposure found in sawmills in some of the studies [21,22] whereas similar high concentration has been reported from sawmills where there is more mold infection of wood [21]. The predominant fungi found at both sawmills were *Penicillium* spp, *Aspergillus fumigatus, Cladosporium* species.

4. CONCLUSION

Activities at both sawmilling sites were being carried out in an open area and as such there is no control of the wood dust. This dust is also emitted to air and as such causes environmental impacts and health problem. The implication is that continual discharge of this wood dust without proper waste management strategy is place could result in elevated concentrations and pose serious threat to inhabitants within the vicinity. This study has established that there is increased emissions of potentially hazardous airborne particles in the sawmill sites studied. Further studies could be channeled towards evaluating the effects of these particulates on inhabitants within such vicinity. Hence continuous monitoring and evaluations as well as changing trends are advocated.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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