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Research Paper

Air Quality and Aeromicrobiology of Market Environment in Port Harcourt Metropolis

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ABSTRACT: *In this study, the quality of the air of selected markets was analyzed and the extant microorganisms identified. Four selected markets located in Port Harcourt Metropolis consisting of 2 urban and 2 rural, were examined for particulate matter and airborne microbial load. An air quality meter was used in determining the level of particulate matter pollution, while using a sedimentation technique involving exposure of Petri-dishes containing Nutrient Agar (NA) and Sabouraud Dextrose Agar (SDA) above ground level for 10 minutes, different sections of the individually selected markets were sampled for microorganisms. Bacterial isolates were identified using standard microbiological techniques involving cultural, morphological, microscopic examination and different biochemical tests. Colony appearance, microscopic examination of spores and hyphal characteristics were used in the identification of the fungi species. The study showed the air quality index of urban markets to be within 60 – 168 and that of rural markets between 70 – 215, which shows that the air quality pollution raises moderate to very unhealthy concerns. The rural market proved to be the most polluted and PM10 the pollutant of concern. Bacterial isolates include Bacillus cereus, Bacillus substilis, Micrococcus lylae, Micrococcus luteus, Staphylococcus epidermis, Staphylococcus aureus, Pseudomonas sp., Proteus mirabilis, and Micrococcus roseus. The fungal isolates include Aspergillus fumigatus, Fusarium oxysporium, Aspergillus niger, Aspergillus flavus, Penicillium crysogenum, Cladosporium sp, Saccharomyces sp. and Geotrichum candidum. These microorganisms cause mild to severe allergies, lung and respiratory diseases/infection, skin disease and even cancers on prolonged exposures.*

KEYWORDS: *Aeromirobiology, AQI, Particulate matter, Air Pollution, Aerosols, Microorganisms, Market*

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I. INTRODUCTION

The emergence of transmissible air borne diseases/viruses like Covid19, and tuberculosis have shed light on the need for aeromicrobiology. In Nigeria and across the world these diseases have caused epidemiological issues, amongst such diseases is the whooping cough, diphteria, and Lassa Fever. Aeromicrobiology aims to study microbes suspended in air, demystifying the belief that microbes cannot survive in air since not enough nutrients exist for their proliferation [1]. Overtime, through study the air environment has recorded deviants in the ambient air levels due to anthropogenic disruption and natural interaction leading to the complication of air environment and consequently, air pollution. Breathing in air by humans has since been faced with hazards from aspiration of gases, smoke, dust, and other suspended substances like particulate matter and bioaerosols [2].

Due to uncontrolled and unplanned urbanization, motorization, and quest for energy in the developing countries, the air environments of their surroundings are largely dense and polluted resulting in poor air quality of environmental concern largely orchestrated by lack of effective control measures.The increasing rate of urbanization in the cities is a matter of great attention since it leads to a coherent rise in motorization and industrialization, which are one of the reasons for increased degradation of air quality. Situation of markets with urban settlement complicates air pollution and aggravates environmental deterioration due to increased traffic, uncontrolled waste generation and disposal and dense population convergence since there is little or no space for expansion. Activities within and around the market result in the release of bioaerosols, which are large

molecules of living airborne particles, and volatile compounds that were released from a living organism or the natural environment.

The increased level of air pollution is as a result of sources of emissions like industrial exhaust air from standard or convectional gas flaring and illegal/artisanal crude refining operations. Other sources of emissions are power plants, emission from automobiles and biogenic sources like burning of hydrocarbons and windblown dust. The rate at which pollutants are emitted is affected by other variables such as sunlight, moisture, geography, rain, cloud cover, and weather patterns which all have a role in the atmospheric concentration of any pollutant and variation in concentration [3].

The market is an open space that is exposed to bare unfiltered air. An average market merchant/seller and those who reside in its environment spend at least half their day and 5 days of a week in the marketplace carrying out their various activities of buying/selling, rendering and waste generation. These activities are carried out regardless of the prevailing weather conditions, the season of the year or time of the day which leaves them exposed to all forms of environmental hazards over which they have no control. These hazards could be naturally generated or contributed by them, other market merchants, residents of the area, passersby, industries, motorists, or even other anthropogenic activities carried out in the environment directly or simply just dispersed due to wind. These hazards affect them without their knowledge in the long run, causing several diseases/illnesses or even complicating already existing issues. These aerosols present in air also cause food spoilage, airborne infections as stated before, and deterioration. As a result, merchants encounter loss of goods, furthermore, consumers who purchase from those markets are at risk of illnesses/diseases from prolonged/immediate consumption of produce from the markets, as well as exposure to pollutants that could be an irritant or cause allergic responses.

Figure 1.1: A typical market in Nigeria

Air contaminants that are released into the atmosphere directly from sources are known as primary air pollutants. Most suspended particles, most hydrocarbons, nitrogen oxide from automobile exhaust, carbon monoxide, carbon dioxide, sulfur dioxide, and nitrogen oxide are a few examples of main pollutants. Primary pollutants that have chemically bonded together form secondary air pollutants. Acid rain, which is created when nitrogen oxides or sulfur dioxide react with water, is a common example of a secondary pollutant. Nitric acid, sulfuric acid, hydrogen peroxide, ozone, nitrates, sulfates, and various salts are additional examples of secondary air pollutants. Though emission levels are factors that contribute to concentration of pollutants in air, its control does not equal reduction in pollutant concentration. Other factors that are also involved are distribution of pollution sources, temperature and radiation, pressure, relative humidity, rainfall, seasons, altitude/elevation, wind speed and direction.

Figure 1.2: Typical point emission in Emuoha, Rivers state, Nigeria

These pollutants are also responsible for the greenhouse effect as well as global warming and climate change. Assessment of these pollutants and bio-aerosols exposure is necessary for putting in place measures to reduce or protect and at least educate the individuals who are at risk. Depending on the quantities of various constituents present in the atmosphere and the extent of the atmospheric reaction, pollutants are brought down in bulk as rain, dews or snow. Gases present in amounts larger than those needed to saturate the carrying medium (water) are left in the atmosphere [4]. The fate of pollutants in the troposphere involves several processes including transportation, dilution, transformation, removal (Washout, rainout, or fallout).

1.1 Particulate Matter

The criteria air pollutants are those commonly present in outdoor air, originating from multiple sources, with potential to pose harm to the environmental public health, and can also result in property damage. They include carbon monoxide (CO), ground level ozone (O3), lead (Pb), nitrogen dioxide (NO2), particulate matter (PM), and Sulphur dioxide (SO2), [5]. Particulate matter is defined as a complex mixture of compounds of contrasting source and chemical make-up that contributes to its toxicological potential [6]. It is grouped into coarse particles (PM10), fine particles (PM2.5), and ultrafine particles (PM0.1). The EPA defines PM10 as respirable tiny fragments, with diameters that are often 10 micrometers and less [aerodynamic diameter ≤10 μm (PM10)] or the thoracic fraction; and PM2.5 as fine inhalable tiny flecks, with diameters that are mostly 2.5 micrometers and tinier [aerodynamic diameter ≤ 2.5 μm (PM2.5)]. Larger particles than this are not readily inhaled and are removed relatively efficiently from the air by sedimentation.

There is a correlating increase in PM during the dry season as compared to the rainy season in Nigeria [7]. Particulate matter (PM) is an issue of concern due to the correlation between its high concentrations and the health effects on humans. This has become a critical air pollution problem. It is introduced into the environment via burning of solids like wood due to heating during colder months grossly affects outdoor air quality in small villages [8], Kindergartens. Also, in areas that experience busy traffic the buildup is much due to the fumes from cars, particularly diesel vehicles. PM2.5 is also formed in the atmosphere when gases such as SO2, NOX, and VOCs are transformed in the air by chemical reactions [9].

Particulate matter on its own is harmful, but becomes even worse, causing cancer, with the discovery of those laced/bound with PAHs. These PAHs are released from the combustion of organic compounds like cooking oil, fossil fuels/crude or generally from thermal cooking processes. These PAHs-bound particulate matter, especially PM10, have been identified in not only markets [10] but in the indoor and outdoor environment of schools in Serbia [11]. In asthmatic patients, they impair regulatory T-cell function [12]. Suspended PMs are in the form of soot, dusty, fog/mist, smoke/fumes, and smog.

1.2 Bioaerosols

Due to the ubiquitous nature of microorganisms, they are also introduced via aerosolization into the atmosphere from exposed terrestrial and aquatic surfaces and are released in the terrestrial locations from plant, soil, and other surfaces when drying reduces bonding forces, and this loosely bonded material is disturbed by strong air movements [13]. Dry deposition (adherence to plants, water, and ground surfaces) and wet deposition

(precipitation) are the mechanisms of bacterial deposition in the atmosphere. Suspended microbes have been shown to be both metabolically active and capable of reproduction, performing multiple functions such as ice nucleation, cloud formation, the degradation of organic carbon-based compounds, nitrogen processing, sulfur oxidation and reduction, and photosynthesis. The dispersed organisms are of particle size ranging from 1 – 200μm, with those 1.0–5.0 μm floating freely and those larger settle on surfaces [14]. They survive indefinitely in the environment by spore-formation and cyst-formation based on the individual mechanism available to the microbe, which can render them viable but unculturable. The survival and diversity of air-borne microbes within aerosols is affected by the suspending medium, temperature, relative humidity, oxygen sensitivity, exposure to UV or electromagnetic radiation, presence of certain pollutants like particulate matter, carbon monoxide/ozone and air-associated factors (AOFs) [14].

1.3 The Role of Particulate Matter in Spread of Infections and disease development

Microbes get attached to particulate matter as a protective cover in the air, since vegetative cells cannot survive for lengthy period on their own. Studies has proven that there exist abundant pathogenic organisms in medium to heavily polluted air [14]. Particulate matter act as raft for bioaerosols there by transmitting infection via the dissemination of microorganisms by aerosolization. These organisms are contained in droplet nuclei (airborne particles of less than 5 μm resulting from the evaporation of larger droplets), or in dust particles that contain skin cells and other debris that remain suspended in the air for long periods of time. Dispersal of microorganisms are widely by air currents which are then inhaled by susceptible hosts [15].

The risks to hypersensitivity pneumonitis, allergic alveolitis or chronic rhinosinusitis is increased on exposure to mold and other dampness-related microbial agents [14]. Bacterial endotoxins carried by flour dust, soil, etc. can cause deleterious effects to those exposed to it [16]. Impairment of health and complication of other underlying disease conditions may also be obtained from the long-term exposure to high levels of particulate matter itself. This is due to the already disrupted immune system of the individual, making them susceptible to other illnesses [17]. This paper deals with the study of microorganisms and particulate matter prevalent/predominant in the air of select markets, the dynamics at different times of the day, how they are impacted by relative humidity and temperature and the correlation between the identified microorganisms and the particulate matter.

Figure 1.3: Impact of soot in homes in Port Harcourt, Rivers state Nigeria: Soot from a table hours after cleaning

II. MATERIALS AND METHODS

2.1 Research Design

For this analysis a qualitative research approach was adopted which proceeds by carrying out series of tests/sample isolation and environmental monitoring geared towards identifying the criteria pollutants (aerosols) and microorganisms (bioaerosols) that are present in the air environment of markets.

2.2 Study Area

Port Harcourt is the capital of Rivers State, Nigeria. It lies along the Bonny River (an eastern distributary of the Niger River, 41 miles (66km) upstream from the Gulf of Guinea. It is situated at 4.78 North Latitude and 7.01° East longitude and 468 meters elevation above the sea level. Its area is 360km. According to the 2020 Nigerian census, Port-Harcourt has a population of about 3,020,000. Port-Harcourt features a tropical monsoon climate with lengthy and heavy rainy seasons and very short dry seasons. Only the months of December and January truly qualify as dry season months in the city. The harmattan, which climatically influences many cities in West Africa, is less pronounced in Port-Harcourt. Port-Harcourt's highest precipitation occurs during September with an average of about 367mm of rain. December is the driest month of the year, with an average rainfall of 20mm. Temperature throughout the Port Harcourt city is relatively constant, showing little variation throughout the course of the year. Average temperatures are typically between 25ºC-28ºC in the city. The chosen sampling locations are purposive based on traffic density, closeness to rivers, level of urbanization.

Site 1: Town Market Creek Road (4.7583° N, 7.0209° E)
This market is at the heart of Port Harcourt township and borders around Nembe waterside on one side and is made up of merchants that mostly deal in fresh edibles especially fish. It is known as the biggest market for buying fish and the likes in Port Harcourt Metropolis. The Nembe waterside has a port. The design has stalls occupied by some merchants while the rest either hawk or use umbrellas. It has market days when other merchants from other markets come to trade. Since its structure is not well laid and lacks space, some merchants set up their stalls on the street, major road, and road median. It is largely polluted by the activities and amount of waste generated. It further gets polluted due to activities from the port/riverside.

Site 2: Mile 1 Market (4.7918° N, 6.9986° E)
The former Port Harcourt rail tracks run through its centre. It has more accentuated structures made up of full-blown stalls and shops of three storeys, although, some merchants occupy the rail tracks.

Site 3: Rumuji market, Emuoha (4.5631° N, 6.4656° E)
Its location is along the East-West Road, a high-way that is characterized by constant movement of motorist and consequent pollution. It is also close to where artisanal refining is carried out and so gets its own share of pollutants with wind movement.

Site 4: Omagwa Market (4.9845° N, 6.9182° E)
A remote market that is characterized by temporal structures for stalls made from wood. On both ends, it has road networks for motorists and is close to a dumpsite that serves its users.

2.3 Sampling and Sampling Technique

2. 3.1 Criteria Pollutants (Aerosols)

Using a portable gas analyser air environment of selected markets are sampled and the criteria pollutant levels are analysed instantly at stipulated times of the day. In this case at morning, afternoon and evening. The four markets selected were measured using standard method in compliance with USEPA method (Code for Federal Regulations completeness goal) [18]. Sampling was done once for each market at stipulated times of the day. SainSmart P5 Pure Morning Air Quality Monitor combined thermometer and anemometer was used in determining the temperature and relative humidity, at the same time and intervals as stated above.

2.3.2 Bioaerosols

Air samples were collected once a month in triplicates at stipulated times of the day (morning, afternoon, and evening) in December 2021 using the Sedimentation Methods which is based on particles and micro-organisms settling onto surfaces of agar plates via gravity. The plates containing sterile prepared solid nutrient agar (NA) and Sabouraud dextrose agar (SDA)) were used for the isolation of bacterial and fungal isolates respectively. An antifungal agent (Griseofulvin) was incorporated into the nutrient agar medium to inhibit the growth of fungi while antibiotic (chloramphenicol) was incorporated into the potato dextrose agar to inhibit the growth of bacteria. Each plate was exposed at a height of 1m to 1.5m from the floor for a period of 5 to 15minutes [19, 20, 21]. The bacterial culture plates were incubated at 37ºC for 24 - 48hrs while the fungal culture plates were incubated at room temperature (20ºC – 28ºC) for 3 - 4 days. After incubation, the total number of Colony Forming Units (CFU) for the bacterial and fungal air-flora were enumerated and converted to organism's colony forming unit per cubic meter.

$CFU/m^3 = CFU/t \times k$ (Equation 3.1)

Where CFU=mean of colony forming units,
t = total sampling time in minutes,
k = a conversion factor from cubic feet to cubic meters [22].

2.4 Method of Data Collection/Instrumentation

2.4.1 Aerosols

Data were obtained in the morning, afternoon, and evening hours for one day for each of the selected markets. Criteria pollutants (particulate matter) were measured using standard method in compliance with USEPA method (Code for Federal Regulations completeness goal) with the aid of a portable gas analyzer as directed by the manufacturer. SainSmart P5 Pure Morning Air Quality Monitor combined thermometer and anemometer was used in determining the temperature and relative humidity, at the same time and intervals as stated above.

2.4.2 Bioaerosols

Following the instructions for collection of aerosols the bioaerosols were collected using a petri-dish containing solidified agar. After incubation of the exposed plates the microorganisms were sub-cultured to obtain pure colonies.

2.4.2.1 Bacteria Identification

Bacterial colonies were initially characterized by cultural, morphological, and microscopic examinations using Gram Staining Technique and further identified by biochemical characterization of the isolates.

a. Stock Culture

Stock culture slants were prepared with nutrient agar in Bijou bottles, and each was aseptically inoculated with different isolated obtained from the sub-cultured plates. The stock culture slants were labelled and incubated at 35 °C for 24 hours. Fungal colonies were sub-cultured in sterile Subouraud agar plates by using a cork bore to cut a piece from the cultured plates and placed on sterile Subouraud agar. At 26°C for 3 days the colonies were incubated.

b. Microscopy

Fungal colonies were stained using lactophenol cotton blue stain on a clean grease slide and covered with a cover slip, then viewed under 10 x 20 objective lens.

c. Gram Staining

Gram staining was carried out to differentiate between Gram positive and Gram-negative organisms. A smear was made on the glass slide using a sterile wire loop to pick a drop of potable water and placed on the slide. The wire loop was sterilized again by flaming and an inoculum was picked and placed on the slide and heat fixed by passing the slide over the Bunsen burner flame. The slide was flooded with crystal violet (primary stain) for 60 seconds rinsed with to wash unbound dye. Gram's iodine (mordant) was added for another 60 seconds and rinsed with. Decolourizing solvent (95% alcohol) was added for 30 seconds to remove unbound dye and immediately rinsed with water followed by the addition of safranin for counterstaining (secondary stain) for another 30 seconds and rinsed with water. Excess stain was wiped off from the slide using cotton wool. The slide was air dried and ready for microscopic examination (oil immerse on, x100).

2.4.2.2 Biochemical Tests

The identities of the bacterial isolates were confirmed using biochemical tests (Cheesebrough, 2005). Tests carried out include indole, catalase, methyl red production, Voges Proskauer reaction, oxidase, citrate, triple sugar iron agar test (TSIA) and urease for all isolates.

a. Indole Production

The test was used to determine the ability of certain microorganisms to break down the amino acid tryptophan in the medium into indole in the presence of the enzyme tryptophanase.

The test organism was inoculated into test tubes containing 10 ml of sterile tryptone broth and incubated for at least 48 hours at 35-37ºC. After which 0.5 ml of Kovac's reagent was added to the media and shook gently and examined for a red colour in the surface layer.

b. Catalase Test

This test was done to differentiate between bacteria that produce the enzyme from non-catalase producing bacteria. A drop of potable water was placed on a clean glass slide with water and a drop of hydrogen peroxide after which a colony of the isolate was picked using a sterile wooden applicator stick and emulsified on the glass slide. The production of bubbles is an indication that oxygen was given off which indicates a positive result.

c. Citrate Utilization

This test was used to determine if an organism can utilize citrate as its sole source of carbon and energy. The citrate test uses a medium in which sodium citrate is the source of carbon and energy. In the Simmon citrate agar, the pH indicator is bromothymol blue, which is green neutral pH and becomes blue when the medium become alkaline. Slopes slant of Simmon's citrate agar was prepared in Bijou bottles and the test organisms was inoculated by streaking the surface and stabbing the butt with a sterilized inoculating needle and incubated at 35^{o}C for 48 hours and was observed for a bright blue colour in the medium which indicates a positive result.

d. Methyl Red (MR), Voges Proskauer (VP) Tests

This test is made up to two tests: methyl red and Voges Proskauer test. The methyl red indicates the production of sufficient acidic products from the fermentation of glucose while the Voges Proskauer test indicates the production of acetoin from the fermentation of glucose. The MR-VP broth (10 ml) was inoculated with the test organisms and incubated for 48 h. After incubation, 5ml of the test culture was transferred aseptically to a clean test tube for the VP test. 3-4 drops of methyl red were added to the first test tube. A positive reaction is indicated by a distinct red colour showing the presence of acid. A yellow colour indicates a negative result.

For the Voges Proskauer test, 0.6 ml of alpha-naphthol and 0.2 ml of 40% potassium hydroxide was added to the second test tube. The broth was left to stand for few minutes for colour change after shaking. If acetoin was produced, there will be a red colour change. A yellow to brown colour indicates a negative result.

e. Oxidase Test

The test was used to determine the presence of cytochrome oxidase. Kovac's oxidase reagent is turned purple by organisms containing cytochrome C as part of their respiratory chain. Few drops of Kovac's oxidase reagent were put on strips of filter paper and allowed to dry, sterile wire loop will be used to pick a loopful of the isolates from the culture media and streaked across the filter paper and will be observed for a purple colour change.

f. Triple Sugar Iron Agar Test

Triple sugar iron agar as prepared and dispensed into test tubes, autoclaved, slanted and allowed to cool. The isolates were inoculated into sterile test tubes using inoculating needle and streaked across the top of the slant and incubated for 24 hours at 35^{o}C. After which Hydrogen Sulphide production was indicated by a black precipitate which showed the reduction of sodium thiosulphate to hydrogen sulphide. Colour change was observed indicating a positive result and gas production was observed by the cracking of the media.

2.4.2.3 Identification of Fungi

The airborne fungal spores grown on the Sabouraud dextrose agar plates were grouped based on their colonial morphology. Identifying the genera of dominant fungal colonies was carried out using slides wetted with lactophenol blue which is then observed and identified under a microscope (400x). Spores were checked for and Gram Stain was used to classify yeast.

2.5 Method of Data Analysis

All numerical data was analysed using Statistical Package for Social Sciences (SPSS) and Microsoft Excel. SPSS was used to carryout Spearman correlation, to analyse the relationship between the individual parameters obtained (physicochemical parameters, microbial CFU and particulate matter.

2.5.1 Aerosols

The quantitative and qualitative data analysis in this study was inputted to the Microsoft Excel Spreadsheet computer program and mean values for concentration of each of the parameters were calculated. Bar graphs were used to analyze and compare side by side, the concentrations of the different parameters for the sampling locations on the various sampling days. The Air Quality Index (AQI) was calculated for all sampling locations using the daily average concentration of the measured parameters. The AQI was computed automatically by the air quality meter.

Table 2.1: Air quality index for particulate matter [24]

VALUES OF INDEX	LEVELS OF CONCERN	DAILY AQI COLOUR CODE	DESCRIPTION OF AIR QUALITY
0 - 50	Good	**Green**	Air quality is satisfactory, and air pollution poses little or no risk
51 - 100	Moderate	**Yellow**	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution
101 - 150	Unhealthy for Sensitive Groups	**Orange**	Members of sensitive groups may experience health effects. The public is less likely to be affected.
151 - 200	Unhealthy	**Red**	Some members of the public may experience health effects; members of sensitive groups may experience more serious health effects.
201 - 300	Very Unhealthy	**Purple**	Health alert: The risk of health effects is increased for everyone
301 AND ABOVE	Hazardous	**Maroon**	Health warning of emergency conditions: everyone is more likely to be affected.

2.5.2 Bioaerosols

Data obtained from the biochemical characterization of the bacterial isolates were used in accordance with Bergey's Manual of Determinative Bacteriology [25] while the fungal colonies were identified based on their colonial morphology and microscopic examination of the spore and hyphae [26].

III. RESULTS AND DISCUSSIONS

3.1.1 Particulate Matter, Air Quality and Physicochemical Parameters

Figure 3.1 - 3.6 shows the representation of data for particulate matter gotten, given the average of field data obtained from the air quality meter used for the measurement of particulate matter, AQI, relative humidity and temperature using bar charts. Fig 3.7- 3.8 shows the trend for AQI including colour coded representation for its interpretation.

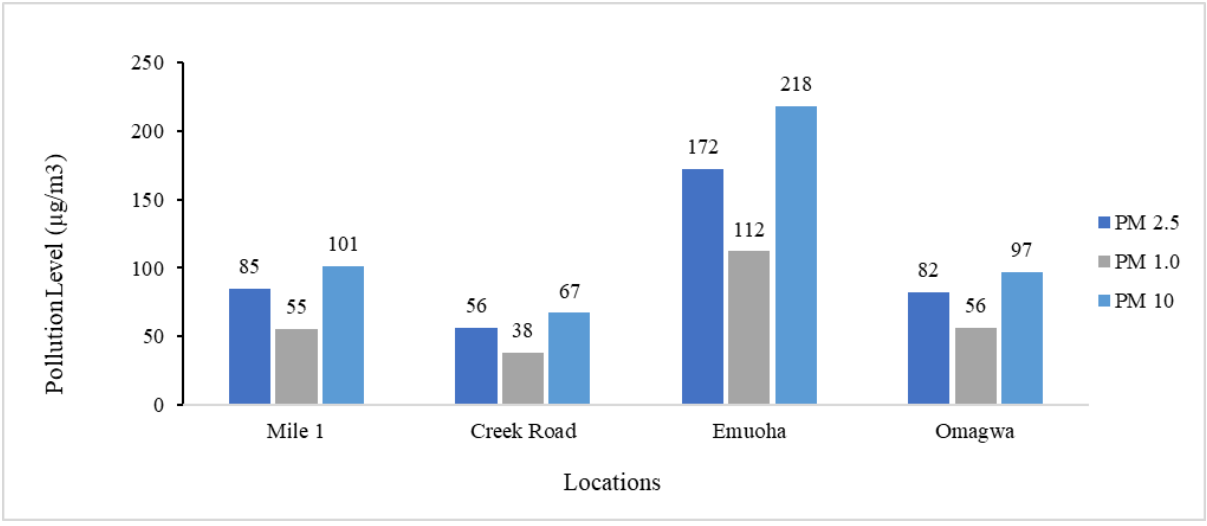

Figure 3.1: Average concentrations of pollutants obtained from selected markets in the morning.

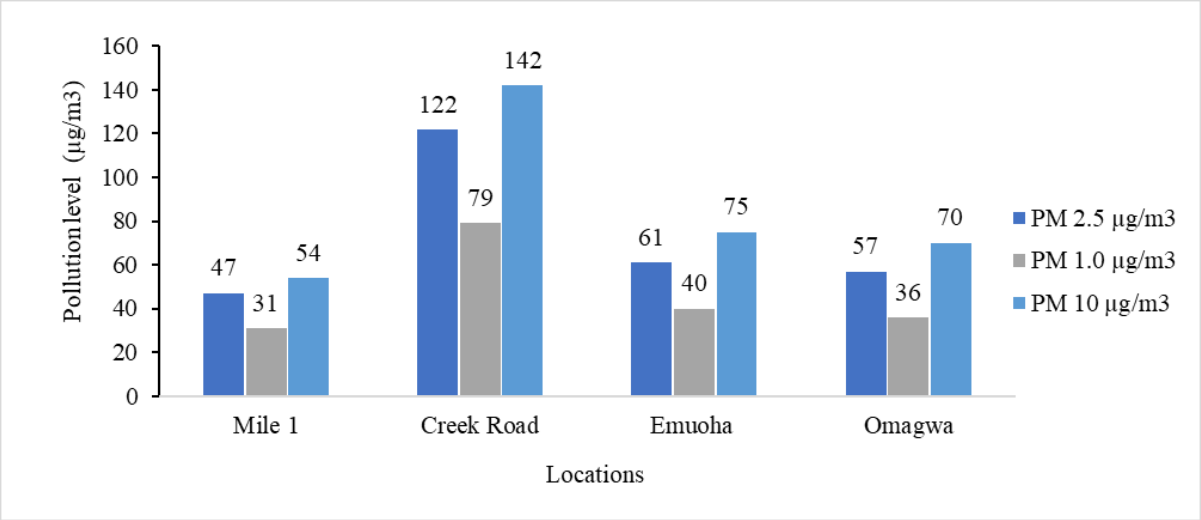

Figure 3.2: Average concentrations of pollutants obtained from selected markets in the afternoon.

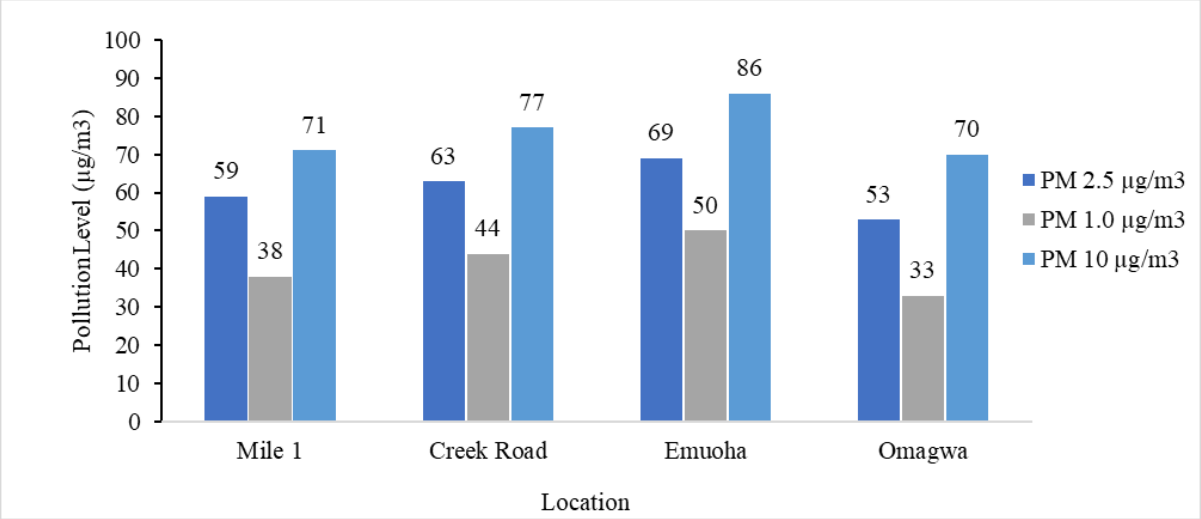

Figure 3.3: Average concentrations of pollutants obtained from selected markets in the evening.

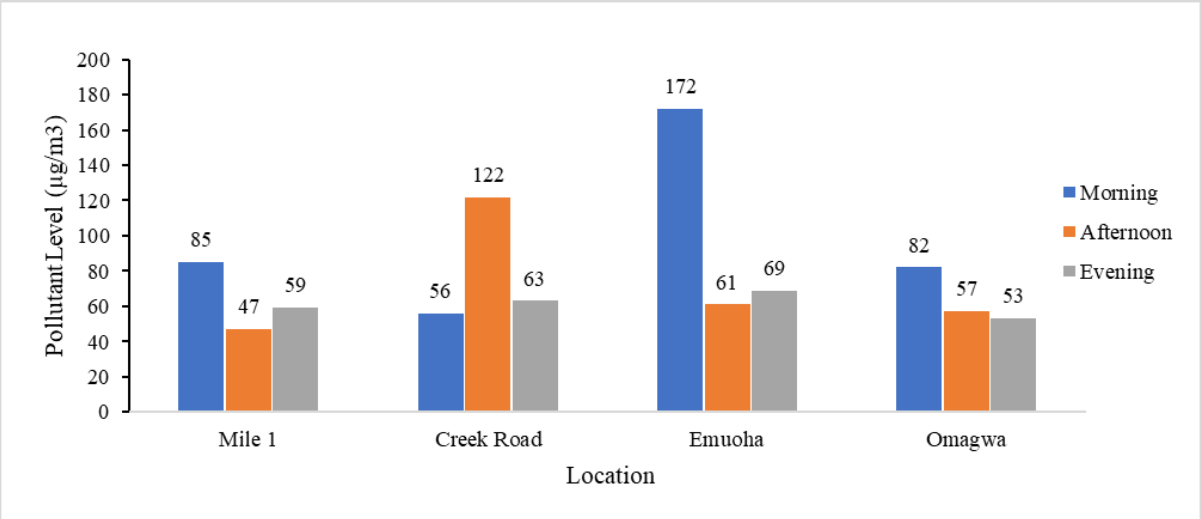

Figure 3.4: Diurnal PM2.5 levels in ambient air of selected markets in Port Harcourt

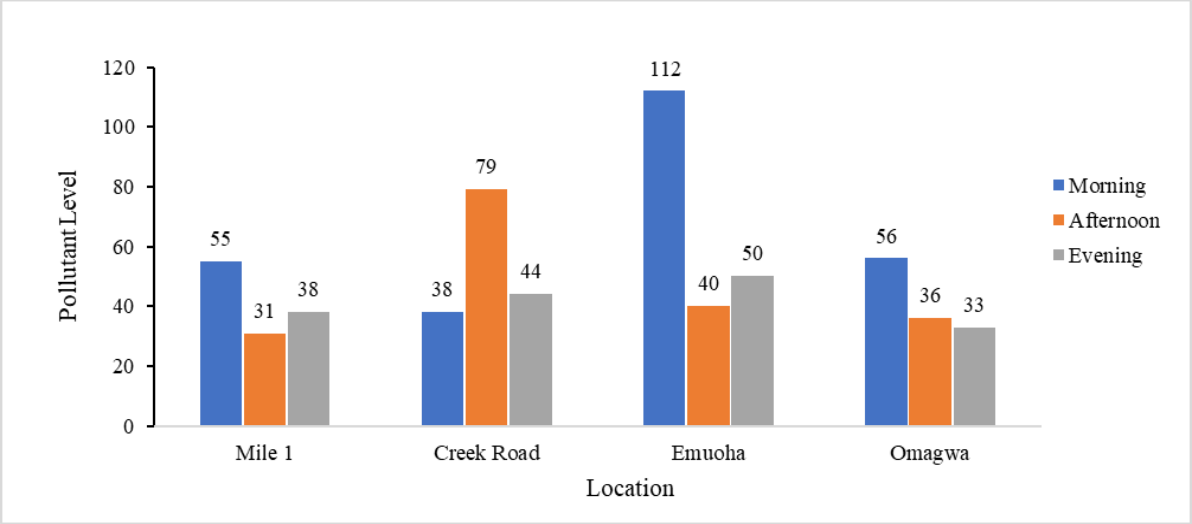

Figure 3.5: Diurnal PM1.0 levels in ambient air of selected markets in Port Harcourt

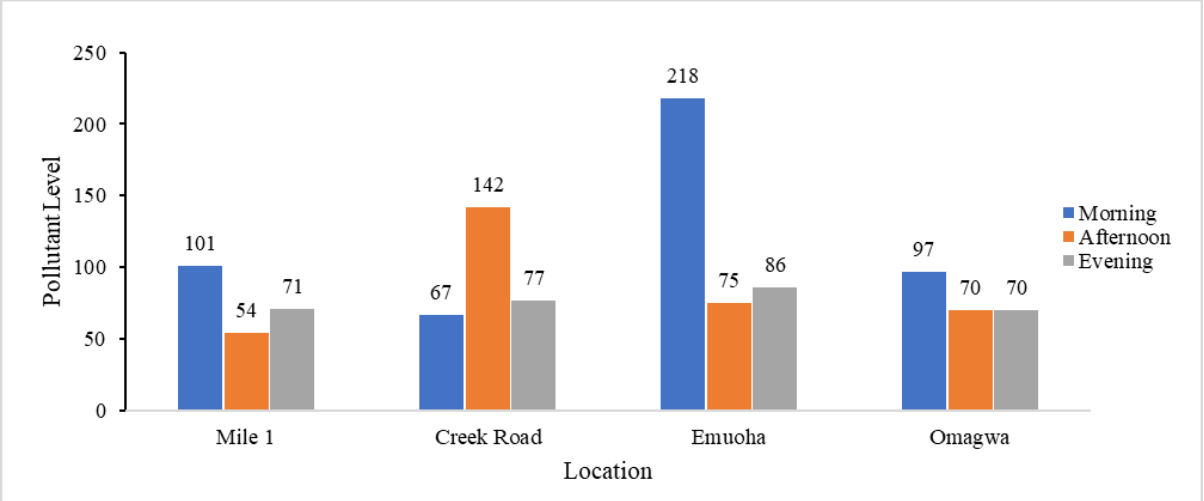

Figure 3.6: Diurnal PM10 levels in ambient air of selected markets in Port Harcourt

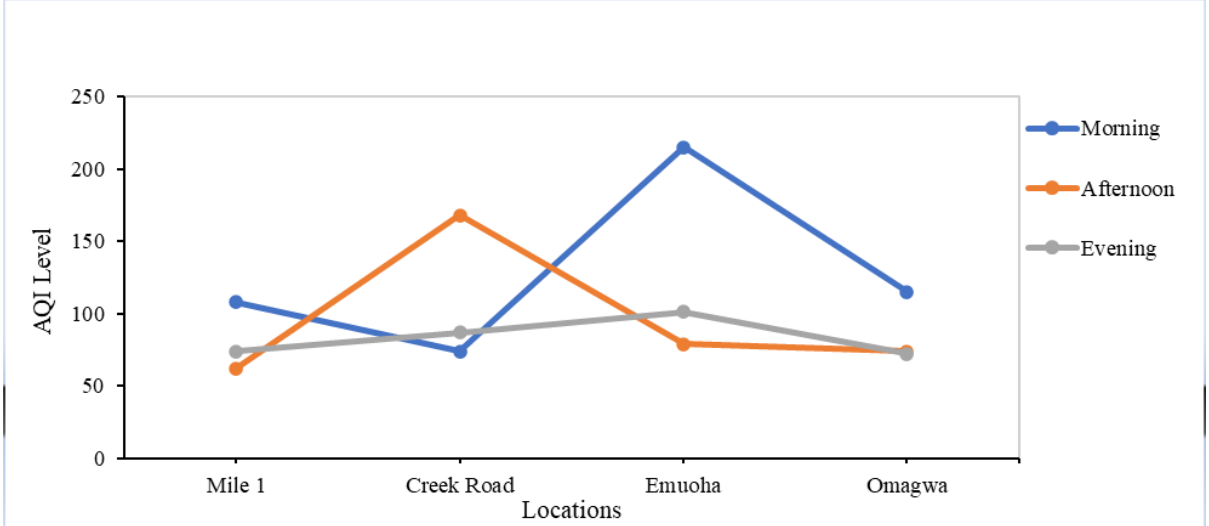

Figure 3.7: Trends of AQI obtained based on diurnal PM levels of selected markets in Port Harcourt

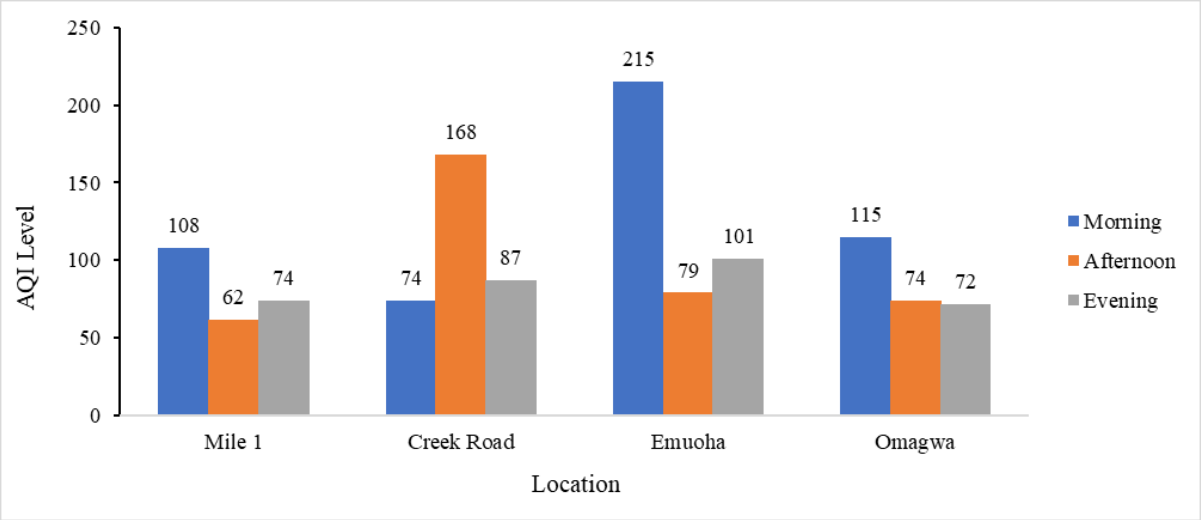

Figure 3.8: Coded representation of AQI gotten from selected market at the different stipulated time.

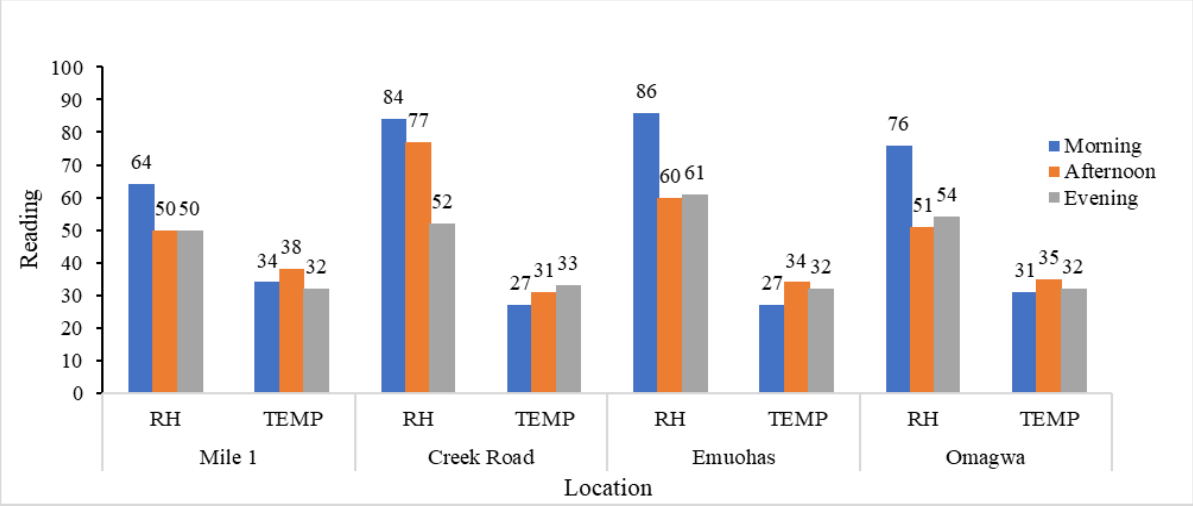

Figure 3.9: Diurnal temperature and relative humidity of various markets analyzed in the study.

3.1.2 Correlation of Particulate Matter Against Temperature and Relative Humidity.

Table 3.1 shows result from the correlation of the different particulate matter ($PM_{2.5}$, $PM_{1.0}$ and PM_{10}), gotten at stipulated time of the day, against physicochemical parameters (Relative humidity and temperature).

Table 3.1: Correlation between particulate matter, temperature, and relative humidity in ambient air of selected markets in Port Harcourt

	MILE 1 MARKET		CREEK ROAD		RUMUJI, EMUOHA		OMAGWA MARKET	
SPM	**R.H**	**Temp.**	**R.H**	**Temp.**	**R.H**	**Temp.**	**R.H**	**Temp.**
$PM_{2.5}$	0.919	-0.483	0.216	0.283	1.000	-0.977	0.972	-0.596
$PM_{1.0}$	0.975	-0.460	0.177	0.320	0.997	-0.947	0.974	-0.602
PM_{10}	0.955	-0.527	0.190	0.380	0.999	-0.978	0.994	-0.693

4.1.3 Aeromicrobial Results

Tables 3.2 and 3.3 presents the average counts of the microorganisms (bacteria and fungi respectively) obtained after exposure of agar plates to air. Table 3.4 and 3.5 presents the list of isolated microorganism identified after exposure of agar plates to air in the selected markets grouped into urban and rural.

Table 3.2: Diurnal bacteria counts of ambient air in selected markets situtated in Port Harcourt

BACTERIAL CFU/M^3

	Morning	Afternoon	Evening
MILE 1 MARKET	734.24	854.26	995.46
CREEK ROAD MARKET	886.03	942.51	1302.57
RUMUJI, EMUOHA MARKET	974.28	444.78	607.16
OMAGWA MARKET	511.85	589.51	741.3

Table 3.3 Diurnal fungi counts of ambient air in selected markets situtated in Port Harcourt

FUNGI CFU/M^3

LOCATIONS	Morning	Afternoon	Evening
MILE1 MARKET	98.84	81.19	120.02
CREEK ROAD MARKET	154.1433	98.84	122.3733
EMUOHA MARKET	54.12667	121.1967	97.66333
OMAGWA MARKET	65.89333	80.01333	81.19

Table 3.4: Fungal genera isolated from ambient air of selected markets in Port Harcourt

	MORNING	AFTERNOON	EVENING
URBAN MARKETS	*Penicillium chyrsogenum, Cladosporium* sp., *Aspergillus flavus, Saccharomyces* sp.	*Penicillium chyrsogenum, Aspergillus niger*	*Aspergillus flavus* *Aspergillus niger* *Saccharomyces* sp.
RURAL MARKETS	*Aspergillus fumigatus, Fusarium oxysporium, Aspergillus niger*	*Geotrichum candidum, Aspergillus niger*	*Geotrichum candidum, Aspergillus flavus, Fusarium oxysporium, Cladosporium* sp

Table 3.5: Bacterial genera isolated from ambient air of selected markets in Port Harcourt

	MORNING	AFTERNOON	EVENING
URBAN MARKETS	*Bacillus cereus, Bacillus substilis, Micrococcus lylae, Micrococcus luteus*	*Bacillus cereus, Staphylococcus epidermis, Staphylococcus aureus, Micrococcus lylae*	*Bacillus substilis, Pseudomonas* sp., *Staphylococcus epidermis, Micrococcus lylae, Micrococcus luteus*
RURAL MARKETS	*Staphylococcus aureus, Micrococcus luteus, Bacillus cereus, Bacillus substilis*	*Staphylococcus epidermis, Bacillus cereus, Proteus mirabilis, Bacillus substilis, Micrococcus luteus, Micrococcus roseus,*	*Pseudomonas* sp., *Staphylococcus epidermis, Bacillus cereus, Proteus mirabilis, Bacillus substilis*

3.1.4: Correlation Between Microbial Growth and Particulate Matter

Table 3.6 gives the result of the correlation test of microbial growth colonies and particulate matter present in the air environment of selected markets.

Table 3.6: Extent of correlation between microbial populations in air and particulate matter

	MILE 1		CREEK ROAD		EMUOHA		OMAGWA	
	Bacteria	**Fungi**	**Bacteria**	**Fungi**	**Bacteria**	**Fungi**	**Bacteria**	**Fungi**
PM 2.5	-0.634	0.259	-0.297	-0.871	0.972	-0.959	-0.836	-0.998
PM 1.0	-0.643	0.246	-0.259	-0.890	0.985	-0.975	-0.832	-0.999
PM 10	-0.593	0.308	-0.272	-0.884	0.973	-0.960	-0.760	-0.998

From Emuoha we recorded a high concentration of particulate matter in air in general unlike all the other markets (Fig 3.1). Creek road market had the lowest value which may be due to factors such as closeness to rivers, altitude, and elevation. Fig. 3.2 showed a drastic reduction in PM values for Emuoha with Creek Road taking the lead. The spike in PM values in Creek Road could be due to the traffic congestion occurring on the road with consequent emission from vehicles, boats, and other activities like burning, cooking, roasting, etc. occurring in the market. In Fig. 3.3, all the selected markets showed similar ranges in the pollution level of their varying pollutants. Based on AQI level reading, they all had a range of 51 – 100. Omagwa and Mile market maintained a moderate pollution. From Fig. 3.1-3.3 the major criteria pollutant proved to be PM_{10}.

Fig. 3.4 - 3.6 showed a spike in $PM_{2.5}$, $PM_{1.0}$, and PM_{10} for Emuoha in the morning, while in the afternoon Creek Road market read the highest. Omagwa and Emuoha maintained similar range of pollution. The spike in Emuoha is due to the release of emissions due to the artisanal refineries in the area that operate at night through the morning. Creek Road market recorded the least amount (38) for $PM_{1.0}$ in the morning, which is within the healthy range for AQI: the other markets had a moderate pollution rating of 50 – 100 range. Creek Road market further showed a high pollution level (142) in the afternoon, second to that obtained in Emuoha (215) in the morning.

Fig. 3.7 shows the spike in AQI at Emuoha in the morning. Standards for AQI suggest 0-50, 51-100, 101-150, 151-200, 201-300 and 301-500 as good, moderate, unhealthy for sensitive groups, very unhealthy, and hazardous respectively. Sensitive groups include children, the elderly, pregnant women, those with cardiac and pulmonary diseases. From Fig 3.8 orange bars were gotten for Omagwa and Mile 1 in the morning and Emuoha in the evening. The orange shows the AQI obtained for the locations at those times fall between 101-150 and consequently unhealthy for sensitive groups, making them at risk of eye, skin and throat irritation, including respiratory issues. They are advised to avoid outdoor activities, and if it is necessary then a nose mask should be employed, but ventilation is discouraged. For stalls or shops in the market environment they can employ air-purifiers.

Still based on the AQI standards, yellow bars for Fig. 3.8 were attained in Mile 1 (afternoon and evening), Creek Road (morning and evening), Emuoha (afternoon) and Omagwa (afternoon and evening. This shows that pollution in those areas in said period was of moderate range (51-100), consequently sensitive groups should reduce outdoor exercise and avoid ventilation of indoor spaces with outdoor air. A worrisome red bar was gotten for Creek Road in the afternoon, which suggests increased likelihood of general health impacts including heart and lung aggravation, particularly in the sensitive group. The purple bar from Emuoha in the morning shows AQI falls between 201 and 300, and so very unhealthy. Pollution/nose mask should be enforced, air purifiers on for those in the environment, ventilation and outdoor exercise entirely avoided.

The temperature reaches its maximum at noonday and its minimum at midnight. Fig 3.9 showed a decrease in relative humidity with an increase in temperature, and an increase in relative humidity with consequent decrease in temperature.

A negative correlation exists between PM and temperature for all selected markets except Creek Road market that showed a positive correlation (Table 3.1). During the day temperature reaches its maximum whilst the PM reach their lowest. Temperature reaches its maximum overnight while the PM reaches their highest into the wee hours of the morning. Mile 1 and Omagwa markets had a moderate negative correlation of 0.46 – 0.69 in range, but Rumuji had a strong negative correlation for PM with at least a -0.978 value. Creek road market had a weak positive correlation of 0.216 – 0.380 in range. This positive correlation may be due as a result of its closeness to water (Nembe Waterside) and the weather changes that occurred during the period of sample collection and air quality reading. The weather change directly affects Relative Humidity and Temperature, and Rivers State largely experiences weather changes often, with rain falls recorded during various seasons of the year. The phenomenal effect of increased daytime temperature on particulate matter concentration may be explained by the process of thermally induced convection. The diffusion of PM is witnessed with increased ground heat during the day leading to dust and wind increase.

A very strong correlation was observed between PM (2.5, 1.0 and 10) and relative humidity. Higher values were obtained during the morning and evening, with moderate or lower values in the afternoon, implying that as relative humidity increases or decreases, there is a corresponding increase or decrease in the concentration of PM.

Tables 3.2 and 3.3 indicate that the highest microbial counts were obtained in the Creek Road market, meaning more microbes were present in the air as compared to those of other markets, like Omagwa market that had the least microbial counts. Although in the morning and afternoon Emuoha market had higher bacterial and fungal populations in air compared to Creek Road market. The highest microbial populations were obtained in the evening for each of the markets. Both Urban markets both had more microbial counts in the air when compared to the rural markets, and this is due to the nature of the market, location, population, waste produced, and kind of products sold. The urban markets run all the days of the week unlike the rural markets that are run on specific market days, which may be once or twice in a week; so, the accumulation of waste is reduced, including population.

Table 3.4 and 3.5 provide lists of microorganisms belonging to different genera that were isolated from the ambient air of markets. Bacteria isolated from air samples of selected urban markets includes *Bacillus cereus, Bacillus substilis, Micrococcus lylae, Micrococcus luteus, Staphylococcus epidermis, Staphylococcus aureus,* and *Pseudomonas* sp., while those from rural markets include *Staphylococcus aureus, Micrococcus luteus, Bacillus cereus, Bacillus substilis, Staphylococcus epidermis, Proteus mirabilis, Micrococcus roseus, Pseudomonas* sp.. Fungi isolated from the selected rural markets includes keratitis and asthma causing *Penicillium chyrsogenum*, asthma eliciting and central nervous system invading *Cladosporium* sp., *Aspergillus flavus* (causing sinusitis, lung infection, keratitis, and cutaneous aspergillosis), *Saccharomyces* sp. that cause invasive infections of respiratory tracts and *Aspergillus niger* that can cause aspergillosis and lung diseases. *Aspergillus fumigatus, Fusarium oxysporium, Aspergillus niger,* and *Geotrichum candidum* can lead to bronchial geotrichosis whereas, *Cladosporium* sp. may lead to allergic reaction and asthma on extended exposure. *Fusarium oxysporium* is considered as an opportunistic microorganism that causes keratitis, onychomycosis, dermatitis, and allergies.

Bacillus substilis and *Micrococcus* sp. are known to cause bacteremia, endocarditis, pneumonia, and septicemia in immunocompromised patients, although Micrococcus luteus which can also cause meningitis and septic arthritis is a normal flora in the eyes and skin of humans. *Bacillus cereus* a spore forming microbe produce toxins that may settle on food surfaces causing food poisoning affecting gastrointestinal tracts, and this is of concern since it was isolated in food markets. *Micrococcus* species are generally opportunistic in nature. *Staphylococcus* sp. are normal flora of skin and mucosal membrane but can lead to skin infections, sinus infections, inflammations and sometimes pneumonia, endocarditis, and osteomyelitis. *Proteus mirabilis* which can be transmitted via contaminated food are of fecal origin, cause upper respiratory and urinary tract infections, its presence in a market environment confirms its contamination due to indiscriminate deposition of fecal matter including urine.

The Pearson's R resulted in a strong negative correlation between the microbial growth and particulate matter analyzed in the selected markets (Table 3.6). The negative correlation is due to the fact the level of pollution by particulates is not structured since its production and presence is affected by other factors like source of pollutants. The pollutants are largely produced by vehicular emissions since the markets are situated along major roads where the vehicles produce large amount of smoke. Also, a market in Emuoha is largely plagued with soot emission due to the illegal/artisanal refinery situated in its locality. The microbial load is affected by the rate of its production, source and temperature which is not metered and controlled. So, microbes can increase or decrease based on the factors that affects them. In rural markets where the population is minimal, microbial source from both animals and humans is reduced, plus there is little accumulation since the markets are run on a market-day basis. The only positive correlation was obtained from fungi of Mile market and bacteria of Creek Road market.

IV. CONCLUSION

Increased humidity support the anchoring of microorganisms in air. In areas where they have artisanal refineries or chimneys the air pollution may be increased in the mornings when the there is increased humidity. Also, for areas with increased activities like traffic congestion the air may stay dense through out the day. The market merchants are at risk to disease caused by continuous exposure to particulate matter and bioaerosols in air

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