



## **Air Quality Assessment of Port Harcourt Urban Slums and Health Implications**

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### **Authors' contributions**

*This work was carried out in collaboration between both authors. Author HOS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HOS and MEA managed the analyses of the study. Author MEA managed the literature searches. Both authors read and approved the final manuscript.*

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### **ABSTRACT**

This study was conducted to assess the outdoor air quality of some urban slums in Port Harcourt. Six sampling sites were selected, from the Port Harcourt urban slums; two sites from each slum represented with a suffix 1 or 2. The slums are designated Marine base (#1 and #2), RSU BG, Obudu 2, Bundu (#1 and #2). The air quality was analyzed using portable handheld air quality analyzer and the microbiological parameters were determined by standard cultural method. The study revealed that the sampled sites were laden with bacterial and fungal species, namely; *Klebsiella* sp., *Micrococcus* sp., *Escherichia* sp., *Pseudomonas* sp., *Bacillus* sp., *Aeromonas* sp., *Streptococcus* sp., *Serratia* sp., *Aerococcus* sp., *Proteus* sp. *Penicillium* sp., *Fusarium* sp., *Candida* sp., *Aspergillus* sp., *Mucor* sp., *Rhizopus* sp. and *Tricorderma* sp. Highest obtained noise level was at Marine base 1 which was 66 db, highest relative humidity of 54.8% at RSU BG, CO<sub>2</sub> (ppm) values of 4.8, 80, 796, 850, 638, 698 for Marine base 2, Marine base 1, Obudu 2, RSU BG, Bundu

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1 and Bundu 2 respectively. The values for NO<sub>2</sub> (ppm) was (0.05, 0.053, 0.071, 0.022, 0.035, 0.023), suspended particulate matter (ppm) was (7.1, 8.7, 9.5, 9.5, 6.2, 6.2), SO<sub>2</sub> (ppm) was (0.42, 0.15, 0.50, 0.34, 1.26, 0.41) CO (ppm) was (4.8, 1.7, 2.2, 3.0, 3.9, 3.6) and volatile organic compound (ppm) was (1.0, 1.1, 0.9, 75 and 1.2). This study has shown that Port Harcourt urban slums are experiencing some degree of contamination not acceptable for healthy living that requires attention to curb. These areas require all-round improvement in sanitation. M Give one sentence on methodology.

*Keywords: Air pollution; urban slums; Port Harcourt; microorganisms.*

## 1. INTRODUCTION

### 1.1 Background of the Study

Air is a bearer of suspended matter, which remains generally laden with microorganism but not a natural medium for microorganisms [1]. Air transports the microorganisms and the ultimate fate of such microorganisms depends on factors such as sunlight, temperature, humidity, size of microorganism, particulate carriers, degree of susceptibility of the microorganism and their ability to form spores or cyst [1].

Human activities are contributing to the alteration of atmospheric condition by the introduction of gaseous pollutants [2]. Chief among the anthropogenic sources contributing to atmospheric pollution are vehicular transport, power generation, burning of waste and bio-matter [3]. These processes emit sulphur dioxide, NO<sub>x</sub> gases, carbon monoxide (CO), Volatile Organic Compounds (VOCs), benzene (C<sub>6</sub>H<sub>6</sub>), Persistent Organic Pollutants (POPs) and Suspended Particulate Matter (SPM) which could exceed permissible limits.

Bioaerosol containing microorganisms are produced anywhere human activities take place [3]. Under normal environmental conditions, low bioaerosol concentrations are produced which does not pose any health risk. Unfortunately, some of microorganisms may be pathogenic, allergenic, or toxic. Their presence in the environment can lead to adverse health effects in people, from simple irritation, through allergic reactions, to the occurrence of infections or toxic reactions [3].

Objectionable air quality is a threat to human health in that we are compelled to breathe the air around us [4]. In so doing, toxic chemicals gain entrance into the body and compromise respiratory health. Air pollution triggers acid rain and eutrophication, both conditions that adversely impact on flora and fauna [4].

Urban areas of the world are often confronted with the challenge of population due to unceasing migration of people from rural areas to urban areas to enhance their living standards through job seeking, businesses and trading [5]. The population increase results in skyrocketing demands for housing that culminate in the development slums. In most developing countries, the environmental impacts of urbanization are enormous; the most common of these being air pollution.

In as recent as November 2016, plumes of soot hovered menacing over the city of Port Harcourt and its environs. Periodically in Port Harcourt, thick haze of rising visible black soot settles on materials and is inhaled by humans as evidenced by black particles in nostrils and throat soreness. All over the slums of Port Harcourt, evidence of noxious smoke emissions from generators, kerosene stove, burning of firewood, burning of coal for cooking and vehicles coupled with lack of ventilation continue to raise the imminent human health challenges in these suburbs.

The aim of this study was to assess the air quality of Port Harcourt urban, in terms of its microbiological and physicochemical parameters.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Six sampling sites were selected from three Port Harcourt urban slums; two sites from each slum represented with a suffix 1 or 2. The slums are Marine base, Diobu and Bundu waterside which are designated Marine base 1, Marine base 2, Rivers State University Back gate (RSU BG), Obudu 2, Bundu 1 and Bundu 2. They were selected because they are within the capital city and are unplanned settlements, generally harbouring large number of inhabitants, typical of any urban slum.

## 2.2 Sample Collection

The settling plate technique also known as sedimentation method was used as sample collection method for microbiological analysis [1]. This technique of sample collection is known as scheme 1/1/1, as described by Pasquarella et al. [5]. The Aeroqual 500 Series gas monitor was used to monitor the air pollutants. The samples were collected once at noon on each day of sampling.

## 2.3 Identification of Microorganisms

Identification of isolates was based on Gram reaction, biochemical, cultural and colonial morphologies with reference to Bergey and Holt [6] and Cheesbrough [7].

## 2.4 Statistical Analysis

Data obtained were analysed using descriptive statistics and subjected to One Way Analysis of Variance.

## 3. RESULTS AND DISCUSSION

Tables 1 and 2 present the results for the characterization and identification of bacterial isolates sampled from the study sites. The bacterial isolates were identified as *Klebsiella* sp., *Micrococcus* sp., *Escherichia* sp., *Pseudomonas* sp., *Bacillus* sp., *Aeromonas* sp., *Streptococcus* sp., *Serratia* sp., *Aerococcus* sp. and *Proteus* sp. The fungal isolates were identified as *Penicillium* sp., *Fusarium* sp., *Candida* sp., *Aspergillus* sp., *Mucor* sp., *Rhizopus* sp. and *Tricorderma* sp. (Table 3) According to Stetzenbach et al. [8] bioaerosols in suspended, aerosolized droplets typically contain microbes and cell fragments combined with byproducts of cellular metabolism. In addition, they may carry viruses, bacteria, and fungi that float on dust particles along with cells and parts of cells. Most of the isolated organisms such as *Bacillus* sp., *Candida* sp., *Klebsiella* sp and *Streptococcus* sp. are potential pathogens and could cause infection in susceptible individuals based on immune status and dose response [9].

The lowest bacterial count was recorded at RSU BG with a bacterial count of  $12 \times 10^3$  CFU/m<sup>3</sup> and the highest bacterial count was recorded at Obudu 2 with a count of  $722 \times 10^3$  CFU/m<sup>3</sup> which is about three times higher than the second highest which is  $260 \times 10^3$  CFU/m<sup>3</sup> recorded at Bundu 1. Marine base 1 had the highest fungal

count of  $35 \times 10^3$  SFU/m<sup>3</sup> and the lowest fungal count of  $2 \times 10^3$  SFU/m<sup>3</sup> was recorded at Marine base 2 (Fig. 1) The area had the highest human activity and vehicular movement during the sampling periods, and there was statistical significant difference ( $p < 0.05$ ) in bacteria population between this site and others. Ambrose et al. [10], reported lower bacterial count ( $1.386 \times 10^3 - 2.470 \times 10^3$  CFU/m<sup>3</sup>) and fungal count ( $7.23 \times 10^2 - 1.536 \times 10^3$  SFU/m<sup>3</sup>) in the suburb of Uyo, the capital of Akwa Ibom State, Nigeria. Both Uyo and Port Harcourt are highly populated cities in the Niger Delta, attracting immigrants because of the concentration of the oil and gas industries in both states. However, the city of Uyo is known to be better in keeping with sanitation standards [11].

Human and related activities coupled with atmospheric condition normally influence the bacterial and fungal count, as reported by other researchers who reported that high microbial concentrations was a reflection of economic growth and human population [12-14].

Table 4 presents the parameters monitored using the Aeroqual 500 Series gas monitor. The noise level ranged from 11.23-66 db; wind speed from 1-2.2 M/s; relative humidity from 40.1-54.8%; temperature from 34.4-39°C; CO<sub>2</sub> from 4.8-698 ppm; NO<sub>2</sub> from 0.022-0.071 ppm; CO from 1.7-4.8 ppm and VOC from 0.9-75 ppm. Noise level, VOCs, SO<sub>x</sub> and temperature at some locations exceeded the Federal Ministry of Environment (FMEV) limits. The values of SO<sub>x</sub> in this study (0.15-1.26 ppm) are more than values (0.02-0.1 ppm) reported by Nwokocha et al. [15], in a study of air quality in urban areas of Port Harcourt, but within the range (0.03-1.4 ppm) reported by Gobo et al. [16] in a study of air quality in Okrika, another urban slum in Port Harcourt. However the CO values (1.7-4.8 ppm) and SPM (6.2-9.5 ppm) values reported in this study are lesser than the values (CO 34-53 ppm and SPM 8.2-14 ppm) reported by Nwokocha et al. [15]. The NO<sub>x</sub> values in this study (0.022-0.071 ppm) are lesser in range compared to values (0.025-1.7 ppm) reported by Gobo et al. [16] but the CO values (1.7-4.8 ppm) are within the range (CO 0.5-12.7 ppm) reported in the same study. However, the VOCs values (0.9-75 ppm) in this study are far lesser than values (10-520 ppm) reported by Gobo et al. [16]. The difference in values could be from the location of sampling and the type of activity taking place there. VOCs have been muted as possible carcinogens and mutagens in humans [17], noise impact on hearing [18], SO<sub>x</sub>

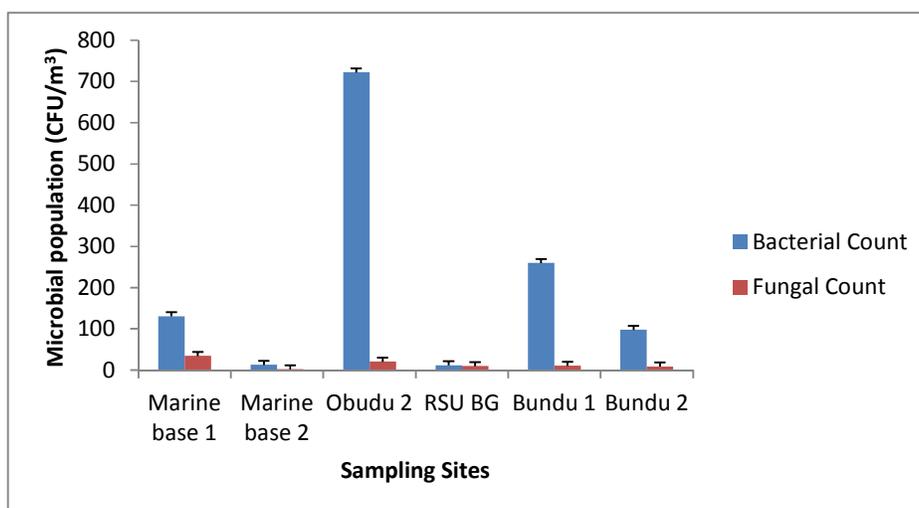
and temperature can alter the ecological balance of pH and temperature which could be injurious to health [4].

Owing to the epileptic power situation in the city of Port Harcourt, majority of households rely on power generating sets to meet their energy need [17]. Thus, power generating sets used as the common source of electric power in these slums might have contributed to the elevated levels of noise, VOCs, SOx and temperature. The use of kerosene fuelled cooking stove and firewood for

cooking could be another reason for the observed high levels of pollutants. Fagbeja et al. [19] reported that substantial emissions of CO, CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>x</sub>, SO<sub>x</sub>; VOC and particulate matter in cities in the Niger Delta, like Port Harcourt are from household generators, cooking stove using kerosene and firewood. According to Ede and Edokpa [20], cities within the Niger Delta including Port Harcourt are observing a “double air pollution burden”, as the air quality has been by particle matter, SO<sub>x</sub> and NO<sub>x</sub> pollution.

**Table 1. Morphological characteristics of bacteria isolates from sampling sites**

S/NO	Sampling site	Isolate code	Morphological description
1	Marine Base 1	JJ1	Serrated, pinpointed, Cream, dull and dry surface
2		JJ2	Yellow, Flat, shinny, smooth, entire margin
3		JJ3	Yellow, entire, raised, moist, shinny, smooth and entire
4	Marine Base 2	JJ5	Orange, raised, small, entire, smooth and shinny
5		JJ6	Serrated, rough, dry flat, dull surface
6		JJ7	Straw coloured, raised smooth, shinny and entire
7		JJ8	Rough surface, dry flat and irregular (swarming)
8	RSU Back gate	JJ9	Pinpointed, dull, rough, entire straw colour
9	Bundu 2	JJ10	Segmented, White, dry rough surface,
10		JJ11	Rhizoid, transparent, dry, rough surface
11	Obudu Street	JJ12	Rough, flat, dry surface, serrated margin
12	Bundu 1	JJ13	Orange, raised, entire, shinny and smooth
13		JJ14	Small, entire, shinny, flat
14		JJ15	Small, white and raised
15		JJ16	Yellow, shinny, raised, entire, smooth surface.
16		JJ17	Rough, dry, flat surface
17		JJ18	Entire, raised, dry smooth white
18		JJ19	Bright, yellow, entire, shinny, smooth surface
19		JJ20	White, flat, dry, entire, smooth surface



**Fig. 1. Bacterial and Fungal counts from sample sites**

Table 2. Characterization and identification of bacteria isolates from sampling sites

Isolate Code	Citrate	Oxidase	Catalase	Glucose	Lactose	Indole	MR	VP	Motility	Butt	Slant	Gas	H <sub>2</sub> S	Gram Reaction	Probable isolate
JJ1	-	-	-	+	+	-	+	+	-	B	B	-	-	-Rods	<i>Klebsiella</i> sp.
JJ2	+	-	-	-	+	-	+	+	-	A	B	-	-	+Cocci	<i>Micrococcus</i> sp.
JJ3	-	-	-	+	+	-	+	-	-	A	A	-	-	-Rod	<i>Escherichia coli</i>
JJ5	+	+	-	+	+	-	+	-	+	B	B	-	-	-Rod	<i>Pseudomonas</i> sp.
JJ6	-	-	+	+	+	-	+	-	-	A	B	-	-	+Rod	<i>Bacillus</i> sp.
JJ7	-	-	-	+	+	-	+	+	+	A	B	-	-	-Rod	<i>Aeromonas</i> sp.
JJ8	-	-	-	+	-	-	+	+	+	B	B	-	-	-Rod	<i>Proteus</i> sp.
JJ9	+	-	+	+	+	-	+	+	+	A	B	-	-	-Rod	<i>Aeromonas</i> sp.
JJ10	-	-	+	+	+	-	+	-	-	A	B	-	-	-Rod	<i>Aeromonas</i> sp.
JJ11	-	+	+	+	-	-	+	+	+	A	B	-	-	-Rod	<i>Aeromonas</i> sp.
JJ12	+	-	+	+	-	-	+	-	+	A	B	-	-	+ Cocci	<i>Staphylococcus</i> sp.
JJ13	-	-	-	+	-	-	+	-	-	B	B	-	-	+Cocci	<i>Aerococcus</i> sp.
JJ14	+	-	+	+	-	-	+	-	-	B	B	-	-	+Cocci	<i>Aerococcus</i> sp.
JJ15	-	-	-	+	-	-	+	-	-	A	B	-	-	- Rod	<i>Serratia</i> sp.
JJ16	-	-	-	+	-	-	+	-	-	B	B	-	-	+ Cocci	<i>Streptococcus</i> sp.
JJ17	-	-	+	+	+	-	+	+	+	A	B	-	-	- Rod	<i>Aeromonas</i> sp.
JJ18	+	-	+	+	+	-	+	+	+	A	B	-	-	-Rod	<i>Klebsiella</i> sp.
JJ19	-	-	+	+	+	-	+	+	+	B	B	-	-	- Rod	<i>Aeromonas</i> sp.
JJ20	+	-	+	+	-	-	+	-	-	A	B	-	-	+ Rod	<i>Bacillus</i> sp.

Separate Genus from species eg *Bacillus* sp

**Table 3. Morphological and microscopic characterization of fungal isolates**

Sampling site	Colony morphology	Microscopy	Probable organism
Marine-base 2	Green surface with a guiding white round ring, light reverse	Conidia are borne on phialides, showing brushlike conidiophore	<i>Penicillium</i> sp.
Marine base 2	Whitish gray colouration, cotton wool like	Canoe shaped macro conidia, multicelled.	<i>Fusarium</i> sp.
	Cream butyrous surface, light reverse	Yeast cells, Production of germ tube and chlamydoconidia( Positive term tube)	<i>Candida</i> sp.
	Thick dark surface, dark on reverse	Large spherical vesicle that give rise to metulae, phialide and conidia	<i>Aspergillus</i> sp.
Marine base 1	Thick dark surface, dark on reverse	Large spherical vesicle that give rise to metulae, phialide and conidia	<i>Aspergillus</i> sp.
			<i>Mucor</i> sp.
Obudu	Thick dark surface, dark on reverse	Large spherical vesicle that give rise to metulae, phialide and conidia	<i>Aspergillus</i> sp.
	Thick dark surface, dark on reverse	Large spherical vesicle that give rise to metulae, phialide and conidia	<i>Aspergillus</i> sp.
	Green surface with a guiding white round ring, light reverse	Conidia are borne on phialides, showing brushlike conidiophore	<i>Penicillium</i> sp.
	Cream butyrous surface, light reverse	Yeast cells, Production of germ tube and chlamydoconidia( Positive term tube)	<i>Candida</i> sp.
Rsu BG	Green surface with a guiding white round ring, light reverse	Conidia are borne on phialides, showing brushlike conidiophore	<i>Penicillium</i> sp.
	Light green surface, fine green circles light reverse	Septate hyaline hyphae, conidiospores, and conidia observed	<i>Tricorderma</i> sp.
Bundu 1	Brownish dark surface(spotted dark), dark reverse	Showing sporangiophore arising from pauciseptate hyphae	<i>Rhizopus</i> sp.
	Thick dark surface, dark on reverse	Large spherical vesicle that give rise to metulae, phialide and conidia	<i>Aspergillus</i> sp.
	Green surface with a guiding white round ring, light reverse	Conidia are borne on phialides, showing brushlike conidiophore	<i>Penicillium</i> sp.
Bundu 2	Green surface with a guiding white round ring, light reverse	Conidia are borne on phialides, showing brush like conidiophore	<i>Penicillium</i> sp.

Some Genus and species not separated

**Table 4. Values of physicochemical parameters from sample sites**

S/N	Parameters	Marine base 1	Marine base 2	Obudu 2	RSU BG	Bundu1	Bundu2	FMEV Limits
1	Noise (db)	66	42.5	65	11.23	57.1	51	65
2	Wind speed (Ms <sup>-2</sup> )	0.5	2.2	1.1	0.9	1.6	1.0	-
3	RelativeHumidity (%)	46.5	48.6	40.1	54.8	50	53.6	4.90-75.9
4	Temperature °C	37.5	35.9	39	35.2	34.5	34.4	29.5-36.9
5	CO <sub>2</sub> ppm	4.8	80	796	850	638	698	-
6	NO <sub>2</sub> ppm	0.05	0.053	0.071	0.022	0.035	0.023	0.04-0.06
7	SPM ppm	7.1	8.7	9.5	9.5	6.2	6.2	115-150
8	SO <sub>2</sub> ppm	0.42	0.15	0.50	0.34	1.26	0.41	0.01-0.1
9	CO ppm	4.8	1.7	2.2	3.0	3.9	3.6	50
10	VOC ppm	1.0	1.1	0.9	75	1.2	4.1	0.50

Air pollution represents the nastiest of all of the environmental risks; causing about 3 million deaths per annum for outdoor air pollution exposure alone, with greater percentage of the deaths in low and middle-income countries [21].

Port Harcourt urban slum residents are encouraged to drink adequate quantity of water to be hydrated and help flush out some contaminants from their system, eat healthy food and more of fruit which can serve as anti-oxidant, plant more trees in our environments, stop activities that pollute the air such as burning of refuse and staying close to generator fumes and encourage the practice of hand washing whenever they come in from an outdoor environment.

#### 4. CONCLUSION

This study has shown that Port Harcourt urban slums are experiencing some degree of contamination not acceptable for healthy living that requires attention to curb. The levels of contamination by bacteria, fungi, SO<sub>x</sub> and VOCs suggest the air quality of the slums is generally bad. This calls for improved sanitation; improvement of public transport and others means to cut down air pollution.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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