

# Microbiological Assessment of Used Face Masks in Port Harcourt Secondary Schools in COVID-19 Era

### ABSTRACT

**Aim:** This study was aimed to identify bacterial and fungal contaminations in used face masks from different secondary schools in Port Harcourt during COVID-19 Era

**Study Design:** The study employs statistical analysis of the data and interpretation.

**Place and Duration of Study:** Five Secondary Schools – Three public schools: Federal Government College Rumuokoro; Rumueme and Rumuokuta Girls' Secondary Schools; Two Private Schools: Solid Steps and Istan Secondary Schools; all located in the city of Port-Harcourt, Nigeria. Sample collection lasted for a week and the analysis lasted for six months.

**Methodology:** The research study was facilitated through Laboratory analysis and the use of questionnaire to get the age and sex from the school children. A total of 25 used nose masks samples were collected from school children between ages of 12-18years and they were examined microbiologically. All the 25 (100%) were found contaminated with microorganisms.

**Result:** Bacteria isolated were *Staphylococcus aureus* (44.4%) > *Paenibacillus* spp (6.81%) > *Escherichia coli* (6.54%) > *Proteus* spp (6.25%). The fungal isolates were *Aspergillus* spp (42.1%) > *Mucor* spp (40.6%) > *Penicillium* spp (17.8%). The contaminated used face masks with microorganism were highest in school children of ages 16-18years (72%) and the lowest occurred in children of 12-14years of age (12%). Notably, Females had the highest rate of contamination (72%) than their male counterparts (28%), though *Aspergillus* spp was found more in males than females. The secondary school with the highest rate of *Staphylococcus aureus* contamination was Rumueme Girls' Secondary School (48.9%) and lowest in Solid Steps Secondary School at (0%), *Bacillus* spp was highest in Solid Step Secondary School (43.0%) and lowest in Rumueme Girls' Secondary School (5.0%), *Proteus* spp was highest in Solid Step Secondary School (57.0%) and lowest in Federal Government College (0%), Rumueme Girls' Secondary (0%), *Paenibacillus* spp was highest in Federal Government College (69.0%) and lowest in Rumuokuta Girls' Secondary School (0%), Istan Comprehensive Secondary School (0%) and Rumueme Girls' Secondary School (0%). *Escherichia coli* were highest in Rumueme Girls' Secondary School (100%) and lowest in Rumuokuta Girls' Secondary School (0%), Istan Comprehensive Secondary School (0%), Solid Step Secondary School (0%). The secondary school with the highest *Aspergillus* spp contamination was Rumuokuta Girls' Secondary School (29.6%), Istan Comprehensive Secondary School (22.2%), Solid Step Secondary School (18.5%), Federal Government College (14.8%) and Rumueme Girls' Secondary School (14.8%). *Mucor* spp was highest in Federal Government College (38.4%), Solid Steps Secondary School (23.0%), Rumueme Girls' Secondary School (19.2%) and Istan Comprehensive Secondary School (11.5%).

**Conclusion:** Female had the higher contamination level than their male counterpart, though *Aspergillus* sp were found more in males than in females. Highest contaminated face masks were found with School children of ages 16-18years while the lowest occurred in children of 12-14years of age. The presence of potential pathogen such as *Staphylococcus aureus*, *Bacillus* spp etc. are of public health significance. It is therefore recommended that crowd should be controlled in such environments with high bacterial and fungal load such as schools and COVID-19 protocols duly observed.

**Keywords:** Face mask, *Staphylococcus aureus*, *Bacillus* sp., *Aspergillus* sp., Secondary School students

### INTRODUCTION:

Presence of micro-organisms in the air is ubiquitous but then proportion varies according to the environmental condition and location. Bioaerosols are airborne particles that are living (bacteria, viruses and fungi) originated from living organisms [1]. Spore forming bacteria and fungi are able to survive in bioaerosols and stay viable for a long time in the air but the situation becomes worse when they are able to multiply in these aerosols. It is generally known that bacteria aerosols present in the air can affect human health, causing mainly respiratory and related disease transmitted via respiratory route, allergic and toxic reaction [2]. In addition, long-term contact of people with bacterial aerosols can be a source of serious illnesses can influence a person's mental power and learning ability. Some present study has also reported high level of potential hazardous bacterial aerosols in the similar environments [3]. Exposure to these aerosols can impose adverse effects on local inhabitants as well as tourists in crowded environments. For the above reasons, it is important to monitor the sanitary state of the air in environments where people spend time every day. Studies on atmospheric bacteria have been driven by the need to determine the concentration specimen source and/or their correlation factors of potential pathogen [4].

Up to now, airborne bacteria and fungi have been predominantly approached in the context of their toxicity, allergic and general medical implication in specific environments such as hospital premises [5], markets, schools, homes and offices [6][7]. There is an emergent need for bacteria and fungi aerosols in the atmosphere to support many applications related to public health and international security. Such studies face significant challenges, including the broad diversity of bacteria that can be carried into the air from soil and plant sources and the tremendous variability (both locally regionally) in microbial load and composition owing to sea small effects, local climate, weather pattern, local human activities and local wind currents [8].

Crowd scene investigation and their monitoring is very evolving and an enliven field of learning. Crowd event is of immense concentration in a variety of realistic application [9]. Viral respiratory diseases, like influenza, occur in most countries in some years, and in some countries in most years, for many they are common annual events. In epidemic years, 10% or more of a population maybe infected with influenza, 50% of infected persons will develop symptom and an excess number of deaths will occur. Coronavirus disease 2019 (COVID-19) is an infection disease caused by severe acute respiratory syndrome Coronavirus 2 (SARS-Cor-2) which was first reported in China, December 2019. It has spread globally and resulted in an ongoing pandemic. As of August, 29<sup>th</sup>, 2020, there were more than 24,770,000 confirmed cases and are 837,000 deaths in about 180 countries/region according to data from the Coronavirus Research Centre of John Hopkins University.

Although some details about how COVID-19 is spread are still being determined, various measures have been taken to contain the pandemic. The measures advocated and implemented differ between countries but in general, social distancing is a measure that has been adopted in some form by virtually all countries now. This is based on the knowledge that the virus is primarily spread during close contact and by droplets or aerosols produced when people sneeze, cough or talk. Social distancing has contributed to successfully defeating severe acute respiratory syndrome (SARS). This could similarly apply to COVID-19. Social distancing measures, including closing schools, workplaces, restricting travels and canceling mass gatherings, however, are at the same time affecting almost every aspect of daily life, thereby raising concerns about their negative economic and public health implication. In this context, PPE includes gloves, medical/surgical facemasks hereafter referred as "medical masks", goggles, face shield and gowns as well as items for specific procedures – filtering face mask respirators (i.e. N95 or FFP2) or FFP3 standard or equivalent [10]. When you hear about facemask for COVID-19 prevention, it is generally three (3) types; (i) Homemade Cloth Facemasks (ii) Surgical Mask (iii) N95 Respirator

To prevent the transmission of the virus from people with symptom, the Centres of Disease Control and Prevention (CDC) is now recommending that everyone wears cloth face masks; such as homemade facemasks. The recommendation is for when you are in public places where it is difficult to maintain a 6-foot distance from others. Risks of Homemade Facemasks –(i) They may provide a false sense of security while homemade facemasks offer some degree of protection; they offer a lot less protection than surgical masks or respirators (ii) They don't replace or reduce the need for other protection measures. Proper hygiene practice and physical distancing are still the best methods of keeping yourself safe.

Several health effects have been associated with fungal and bacterial in the crowded environments. Their health effects include; rhinitis, upper respiratory symptom, asthma and other effects such as

allergic skin reaction, tiredness and headaches. Temperature and relative humidity appear to be major factors influencing the level of fungi and bacteria in the crowded environment [11].

As humans carry micro-organism on their epidemic, this might be one of the greatest sources of bacteria aerosol in crowded environment. Respiration and the shedding of millions of skins can daily contribute to dispersal of bacteria aerosols in crowded environments. In fact, human occupancy might be the most important factor affecting the total number and community structure of aerosols present in crowded environments [12]. With the development of quantitative polymerase chain reaction (PCR), researchers have been able to target and study specific bacteria in air. Mycobacterium tuberculosis, the bacterium responsible has also been shown to be aerosolized and remain viable when a patient cough. Human carry many other types of bacteria and viruses in the respiratory tract and saliva and discharge the micro-organism into the environment in aerosols during talking, sneezing, coughing and breathing [13].

Then, it is necessary to collect detailed information about airborne bacteria all around the world, both indoor and outdoor environments with typical characteristics to enrich the database. Many studies were carried out about the bacteria community in outdoor environment [5][14], however little are known about the composition concentration and distribution of bacterial and fungal aerosols in Used Face Mask in Port Harcourt. It is indispensable to survey both concentration variation pattern and composition of airborne bacteria and fungi systematically and extensively in crowded environment especially secondary schools.

The main goal of this research work is to determine the prevalence of bacteria and fungi associated with nose masks from different secondary schools in Port Harcourt.

## 2.0 MATERIAL AND METHODS

### 2.1 Study area/Sampling sites

Port Harcourt is situated within the Niger Delta region at the southernmost part of Nigeria and it is bound by longitude  $6^{\circ}56'$  to  $7^{\circ}07'E$  and latitude  $4^{\circ}44'$  to  $4^{\circ}52'N$  of the equator. It has a plane topography and about 5m above sea level.

The sampling sites include five (5) different secondary schools within Port Harcourt metropolis, (One Federal Government School, Two State Government School and Two Private School) namely; Federal Government College Rumuokoro, Rumuokuta Girls' Secondary School, Rumueme Girls' Secondary School, Istan Comprehensive School and Solid Step School.

### 2.3 Sampling Technique

A total of Twenty-Five (25) used facemasks which comprises of homemade face masks and surgical masks were collected aseptically from the school children (exchanged with new ones), the used facemasks was taken and carefully put in a sterile container and transported to the laboratory.



Fig. 1 Home made Reusable face mask (inner surface)



Fig. 2 Home made Reusable face mask (Outer surface)



Fig. 3 Factory made Reusable face mask (inner surface)



Fig. 4 Factory made Reusable face mask (Outer surface)



Fig. 5 Factory made Disposable face mask (inner surface)



Fig. 6 Factory made Disposable face mask (Outer surface)

UNDER REVIEW

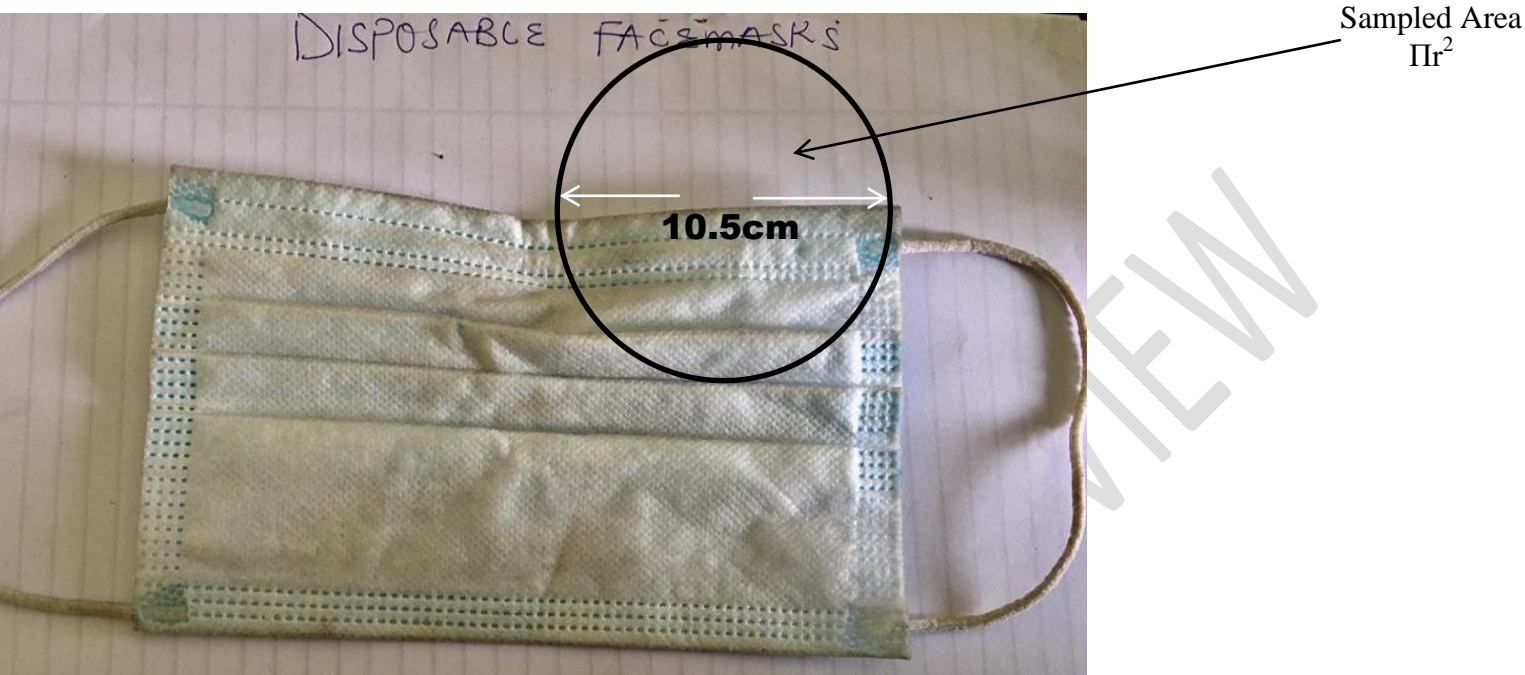


Fig. 7 Picture of Disposable face mask (inner surface) showing diameter of sampled area

B = Sampled Area =  $(\pi r^2)$   
 Diameter = 10.5cm  
 Radius = 5.25cm  
 $\pi = 3.142$

#### 2.4 Enumeration of microbial population

Sterile swab was soaked into nutrient broth prepared and sterilized through autoclaving and used to rub consistently with the used face mask and dipped into normal saline for serial dilution. This mixture was then diluted through a ten-fold serial dilution process. An aliquot of 0.1ml of the last two dilutions were then plated separately on a Nutrient Ager (NA) and Sabouraud Dextrose Agar (SDA) plates in duplicates.

The insulated Nutrient Agar (NA) plates were incubated at 37°C for 24hours while the insulated SDA plates were incubated at ambient temperature for 3-5days. After incubation, counts of the ensuring colonies on the plates were used to calculate the bacterial and fungal population with the formula.

Microbial load of the swabbed Surface Area:

$$CFU/cm^2 = Ax \frac{B}{C} \quad \dots \text{equation 1}$$

Where,

A = \*CFU/ml of the Suspension

$$*CFU/ml = \frac{\text{No. of Colonies}}{\text{Dilution} \times \text{Volume Plated}} \quad \dots \text{equation 2}$$

B = Sampled Surface Area (SSA)

$$SSA = \pi r^2 \quad \dots \text{equation 3}$$

C = Volume of Diluent used in Sample Collection

### 3.0 RESULT AND DISCUSSION

To reveal the adverse effects of airborne bacteria and fungi on human beings, firstly acknowledging the microbial profile of the atmosphere in crowded environments such as schools is essential [4]. Recently, many studies about bacterial and fungal investigation in the air have been carried out in such indoor environments as crowded [3] such as crowded classrooms [4][8][15].

A total of twenty-two (22) bacterial isolates belonging to five (5) genera were identified, these organisms occurred with varied frequencies in all location with *Staphylococcus aureus* with highest percentage (48.9%) in Rumueme Girls' Secondary School, *Bacillus* spp was highest in Solid Step Secondary School with (43.0%), *Proteus* spp was highest in Solid Step Secondary School with (57.0%), *Penibacillus* spp was highest in Federal Government College, Rumuokoro with (69.0%) and *Escherichia coli* occurred highest in Rumueme Girls' Secondary School (100%) due to poor sanitary conditions of the environment (Table 1-2).

**Table 1: Level of significance of bacterial and fungal population (Log10 CFU/cm<sup>2</sup>) at the various secondary schools in Port Harcourt**

S/N	School	Reusable	Disposabl	Colour	Bacterial Isolates (Log10 CFU/cm <sup>2</sup> )					Fungal Isolates (Log10 CFU/cm <sup>2</sup> )		
					Staphylococcus aureus	Bacillus spp	Proteus spp	Penibacillus spp	Escherichia coli	Aspergillus spp.	Mucor spp	Penicillium spp
1	RMG	-		Blue	9.188	9.551	9.344	0	0	3.283	0	0
2	RMG	-		White	9.938	0	0	0	0	0	2.983	2.983
3	RMG	-		Blue	0	9.225	0	0	0	3.592	0	0
4	RMG	-		Yellow	0	9.626	0	0	0	3.283	0	2.983
5	RMG	-		Blue	9.928	9.840	0	0	0	3.590	2.983	2.983
6	ISC	-		Blue	9.886	0	0	0	0	0	3.283	0
7	ISC	-		Blue	0	9.682	9.461	0	0	3.591	3.591	3.283
8	ISC	-		White	0	0	9.461	0	0	3.761	0	0
9	ISC	-		Blue	9.897	0	0	0	0	3.283	0	3.283
10	ISC	-		Blue	0	9.489	0	0	0	0	0	3.283
11	FGC	-		Red	0	9.584	0	9.776	0	3.283	3.591	0
12	FGC	-		Blue	0	9.334	0	9.886	0	0	3.283	0
13	FGC	-		Blue	0	9.430	0	0	0	0	3.886	3.283
14	FGC	-		Blue	9.992	0	0	0	0	3.591	3.591	0
15	FGC	-		Blue	0	9.897	0	9.400	0	3.283	3.283	0
16	RMM	-		Red	0	0	0	0	9.104	3.283	3.283	0
17	RMM	-		Black	9.983	9.460	0	0	0	0	0	3.591
18	RMM	-		Brown	9.090	0	0	0	0	0	3.283	0
19	RMM	-		Blue	9.841	9.130	0	0	0	3.761	3.591	0
20	RMM	-		Blue	9.130	0	0	0	0	0	3.279	3.283
21	SSS	-		Blue	0	0	9.430	0	0	3.591	3.591	0
22	SSS	-		Blue	0	9.595	9.364	0	0	3.283	3.591	0

23	SSS	-	Blue	0	9.064	0	0	0	3.283	0	0
24	SSS	-	Blue	0	9.897	9.283	0	0	0	3.591	0
25	SSS	-	Blue	0	9.875	0	9.626	0	3.283	0	3.283

**KEY:** RMG – Rumuokuta Girls’ Secondary School, ISC – Istan Comprehensive School, FGC – Federal Government College, Rumuokoro, RMM – Rumueme Girls’ Secondary School, SSS – Solid Step Secondary School.

Table 2: Bacterial and fungal percentage occurrences for used nose masks in secondary schools in Port Harcourt

School	Bacterial Isolates (%)						Fungal Isolates (%)		
	<i>Staphylococcus aureus</i>	<i>Bacillus</i> spp	<i>Proteus</i> spp	<i>Penibacillus</i> spp	<i>Escherichia coli</i>	<i>Aspergillus</i> spp.	<i>Mucor</i> spp	<i>Penicillium</i> spp	
RMG	21.6%	23.0%	18.0%	0	0	29.6%	7.69%	27.27%	
ISC	16.0%	5.91%	25.0%	0	0	22.2%	11.53%	27.27%	
FGC	14.4%	23.1%	0	69.0%	0	14.8%	38.4%	9.09%	
RMM	48.9%	5.0%	0	0	100%	14.8%	19.23%	27.27%	
SSS	0	43.0%	57.0%	31.0%	0	18.5%	23.07%	9.09%	

**KEY:** RMG – Rumuokuta Girls’ Secondary School, ISC – Istan Comprehensive School, FGC – Federal Government College, Rumuokoro, RMM – Rumueme Girls’ Secondary School, SSS – Solid Step Secondary School.

Fungal evaluation shows that *Asperigillus* spp occurred the highest are Rumuokuta Girls’ Secondary Schools and lowest in Federal Government College and Rumueme Girls’ Secondary School. *Mucor* spp occurred the highest in Federal Government College and lowest in Rumuokuta Girls’ Secondary School. *Penicillium* spp occurs highest in Rumuokuata Girls’ Secondary School, Rumueme Girls’ Secondary School and Istan Comprehensive School (Table 1-2).

Table 3: Occurrences of microorganisms amongst secondary school children in different age groups

Age Group	No. of Examined Face Masks	No. of Infected Face Masks
12-14	3	3
14-16	4	4
16-18	18	18
Total	25	25

Table 4 Contamination rates of used face masks among different gender in secondary school children in port Harcourt

Organism	No. of Infected School Children	Male	Female
<i>Staphylococcus aureus</i>	13	1	12
<i>Penibacillus</i>	3	0	3
<i>Proteus</i> spp	3	1	1
<i>Escherichia coli</i>	1	1	1
<i>Penicillium</i> spp	1	1	0
<i>Aspergillum</i> spp	3	3	1
<i>Mucor</i> spp	1	1	0
<b>Total</b>	<b>25</b>	<b>7</b>	<b>18</b>

Table 3 shows the number of face masks examined, the age bracket of 16-18years had the highest number of infections, while 12-14years had the lowest infection rate. Table 4 shows that infection rates were highest among the female school children than the males.

This study indicated that airborne Gram-positive bacteria were dominated in most places like schools, home and church. There are many important factors that influence biological pollution in indoor environments. According to several studies, the moisture content of building material, relative humidity

and temperature, [8][16][17], human activities [14][18] significantly affect the levels of indoor bioaerosols. In addition, housing condition, the activities and life style of occupants can contribute to the varying concentration. The survival and quantity of microorganism in air depends on microbiological condition such as relative humidity, temperature, uv-radiation and wind velocity. The degree to which these factors influence the survival of microorganism in aerosols depends strongly on the type of microorganism and the time it has to spend on the atmosphere.

**Table 5 Percentage of occurrence of bacterial and fungal genera**

GENERA	PERCENTAGE (%)	GENERA	PERCENTAGE (%)
1. <i>Staphylococcus</i> spp	44.4	<i>Aspergillus</i> spp	42.18
2. <i>Bacillus</i> spp	36.4	<i>Mucor</i> spp	40.62
3. <i>Proteus</i> spp	6.25	<i>Penicillium</i>	17.18
4. <i>Penibacillus</i> spp	6.81		
5. <i>Escherichia coli</i>	6.54		

Table 5 shows that *Staphylococcus* spp (44.4%) was the highest occurring bacterial genera, followed by *Bacillus* spp (36.4%), *Penibacillus* spp (6.81%), *Escherichia coli* (6.54%) and the lowest being *Proteus* spp (6.25%). In respect to fungal isolates; *Aspergillus* spp (42.18%) occurred highest, followed by *Mucor* spp (40.62%) and the least occurring as *penicillium* spp (17.18%). Nrior and Adiele [8] reported percentage frequency occurrence of bacterial isolates from aerosol from school environment; university cafeteria, *Enterobacter* spp. (46.20%) > *Bacillus* spp. (26.72%) > *Micrococcus* spp.(16.10%) > *Escherichia coli* (5.78%) ; Student toilet , *Staphylococcus aureus* (33.10%) > *Micrococcus* spp. (31.78%) > *Bacillus* spp. (16.44%) > *Escherichia coli* (12.00%) > *Enterobacter* spp. ( 6.66%); Main laboratory , *Micrococcus* spp. (23.74%) > *Enterobacter* spp. (23.50%) > *Bacillus* spp. (22.34%) > *Escherichia coli* (11.80%) > *Staphylococcus aureus* (1.00%); Laboratory preparatory room , *Micrococcus* spp. (40.72%) > *Escherichia coli* (25.00%) > *Bacillus* spp. (17.84%) > *Staphylococcus aureus* (5.22%). *Staphylococcus aureus* are major pathogenic microorganisms which can create a lot of health problem to humans associated with air, this *Staphylococcus aureus* are frequently found in human respiratory tract and minor skin infection, it is a common cause of leg, boil, respiratory disease, food poisoning and Scaled skin syndrome.

Colonies of bacteria isolated from the different secondary schools in Port Harcourt were very high because of overcrowding, old buildings and lack of space which makes the environment to be crowded. Three groups of viable bacteria were identified, gram positive cocci, gram positive rods, gram negative rods. Gram positive rods were most abundant. In secondary schools, *Staphylococcus aureus* were dominant and are wide spread in nature and can be isolated either from the environment. It is also a commensal inhabitant of the skin, mucous membrane and other body sites in humans and animals. Children's activity is normally high and thus, *Staphylococcus aureus* can be transmitted to the air from their bodies and respiratory tracts. *Staphylococcus aureus* are indicators of the severity of air pollution and their presence may indicate the further presence of pathogenic bacteria. Similar results were also obtained by Kim *et al.*, [19] in South Korea, they found that 84% of identified bacteria were gram positive and *Staphylococcus aureus* were the most abundant.

## CONCLUSION AND RECOMMENDATIONS

In conclusion, this study was carried out in a number of Secondary Schools in Port Harcourt, the study revealed the high bacterial and fungal contamination on used nose masks collected from different Secondary Schools. Staphylococcal species and heterotrophic bacteria are ubiquitous and quite dominant in the outdoor environment, as a result, to reduce the load of bacterial and fungal contamination on the used masks, the school environments, especially microbial air quality should be improved by preventing overcrowding and reduce the risk of exposure to these organisms.

It is recommended that crowd should be controlled in environments with high level of bacterial and fungal load such as school. This can be achieved by reducing the number of students admitted each session, consciously spacing the students in the classrooms.

Having enough windows in rooms to reduce poor ventilation will help to reduce bacterial and fungal load especially in schools, homes and church. Dust control can be a preventive measure in reducing pathogens sources.

General sanitation should be carried out at least twice every month to reduce bacterial and fungal load in crowded environments.

Lastly, regular cleaning, inspection, good personal hygiene should be practiced. It is recommended that hand sanitizer should be provided at the entrance of places like schools, church etc. to reduce the transmission of airborne diseases in the environment.

## REFERENCES

1. Kuffer L, Hofma K. Bulletin of the World Health Organization: *The Internal Journal of Public Health*. 2004;82(8): 616-619
2. Colosia AD, Masaquel A, Hall CB, Barrett AM, Mahadevia PJ, Yogev R. "Residential crowding and severe respiratory syncytial virus disease among infants and young children: a systematic literature review". *Biomedical central of Infectious Diseases*. 2012;12: 95-340
3. Yang W, Kim J. Indoor air quality investigation according to age of the school buildings in Korea. *Journal of Environmental Management*, 2009;90; 348-354
4. Nrior RR, Thompson ET (2018) Black Soot: Percentage Source and Aeromicrobiology. *International Journal of Science and Research (IJSR)* 2018;7(6):991-996 DOI: 10.21275/ART20183354
5. Nrior RR, Dumbor KP. Incidence of Alarming Microbial Pathogens over Refuse Dump Sites and Its 'Harmful Distance' in Port Harcourt, Southern Nigeria *Journal of Scientific Research & Reports* 2019;23(3): 1-11.
6. Stetzenbach LD, Hurst CJ, Crawford RL, Garland JL, Lipson DA, Mills AL. Introduction to aerobiology. Manual of environmental microbiology. American society for microbiology press Washington D. C. area, 2007;925-938
7. Nrior RR, Lucky GL. Assessment of Sedimentation Rate of Aero-Pathogens in Health Centres in Port Harcourt. *Journal of Biology and Genetic Research* 2018;4(1):17-27
8. Nrior RR, Adiele P. Microbial-Aerosol contamination in a University Campus in Port Harcourt, Nigeria. *Journal of International Society of Comparative Education, Science and Technology (ICEST)* 2015;2(1):105-122
9. Soaita AM. "Overcrowding and 'under-occupancy' in Romania: a case study of housing inequality". *Environment and Planning A*. 2014;46(1): 203-221
10. Evans GW. "The built environment and mental health". *Journal of Urban Health*. 2003;80(4): 536-55
11. Okafor EC, Opuene K. Preliminary assessment of trace metals and polycyclic aromatic hydrocarbons in the sediments. *International Journal of Environmental Science and Technology*. 2007;4(2): 509-516
12. Jamriska M. Effect of ventilation and filtration on submicrometer particles in an indoor environment. *Indoor Air*, 2000;10(1); 19-26
13. Pastuszka JS, KyawThaPaw U, Lis DO, Wlazlo A, Ulfig K. Bacterial and fungal aerosol in indoor environment in upper Silesia, Poland. *Atmospheric Environment*. 2000;34: 3833-3842
14. Baker M, McNicholas A, Garrett N, Jones N, Stewart J, Koberstein V, Lennon D. Household crowding a major risk factor for epidemic meningococcal disease in Auckland children. *Pediatric Infectious Disease Journal*. 2000;19(10), 983-990
15. Banerjee D. Study of precipitation chemistry over an industrial city. *International Journal of Environmental Science and Technology*. 2008;5(3):331-338
16. Passenen AL, Lappalainen S, Passenen P. Volatile organic metabolites associated with some toxic fungi and their mycotoxins. *Analyst*, 1996;121:1949-1953
17. Krieger J, Higgins DL. "Housing and health: time again for public health action". *American Journal of Public Health*. 2010;92(5): 758-68
18. Nrior RR, Chioma CI. Black Soot in Port Harcourt: Incidence of Pathogenic Microbes Associated With Black Soot in Indoor Aerosols of Classrooms In Port Harcourt Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)* 2017;11(12):43-49.
19. Kim NY, Kim YR, Kim J. Isolation and characterization of airborne bacteria and fungi in indoor environment of elementary schools. *Korean Journal Microbial*. 2007;43; 193-200