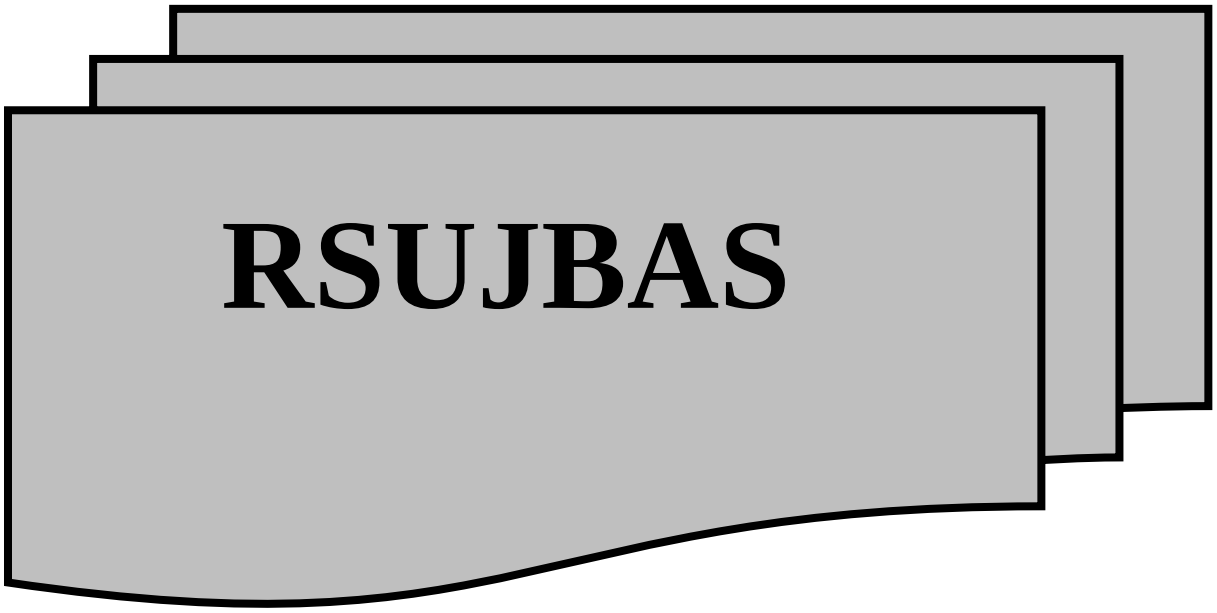
RSU JOURNAL OF BIOLOGY

AND

APPLIED SCIENCES

ISSN: 2811 – 1451



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PROFILES OF MICROORGANISMS AND DISEASES ASSOCIATED WITH BIOAEROSOLS AND WAYS OF IDENTIFYING THEM.

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ABSTRACT
A review of published works related to the profiles of microorganisms in bioarosols was done. It also gives a description of some specific diseases caused by these organisms. Identification methods used for these organisms was also considered. Some key groups of associated microorganisms are bacteria, fungi, viruses, and protozoa. Examples of bacterial organisms and diseases caused by them (in parenthesis) are Mycobacterium tuberculosis (tuberculosis), Streptococcus pneumoniae (Pneumonia); Haemophilus influenzae (meningitis); and Bordetella pertussis (whooping cough). Some fungi related diseases are Microsporum racemosus (Dermatosis - superficial mycosis); Aspergillus fumigatus (Aspergillosis); and Cryptococcus neoformans (Cryptococcosis). Some Viruses associated with bioaerosols and their related diseases are Corona virus (Corona virus infection (COVID-19); Orthomyxoviruses (Influenza); Paramyxovirus (Influenza, measles, mumps, and pneumoniae in neonates); Rhinoviruses and Corona virus (Cold, Rhinitis) and Pox virus (Cowpox). Pneumocystis carrinii, a protozoa is also associated with bioaerosols. Methods of identification of microorgnisms in bioaerosols are both conventional/classical, and advanced. Some methods are manually operated using miniaturized devices while others are automated, and depends on phenotypically expressed traits for their identification. PCR-based methods are now in vogue. The cost implications, using advanced methods is high and poses a challenge to individuals who may be interested to research in related fields. It is therefore recommended that government agencies should make grants available to researchers in need. Most importantly, some microorganisms associated with bioaerosols are pathogenic and poses a serious health challenge, and are epidemic prone. Thus, affordable and rapid means of detection, identification and prevention of diseases implicating these microorganisms is paramount.

Key words*:* Profile, bioaerosol, diseases, bacteria, fungi, identification.

INTRODUCTION
Biological aerosols also known as Bioaerosols or organic dust, consists of microorganisms (bacterial cells, fungal spores, detritus, cellular fragments, pollen, viruses, protozoa, microalgae and cyanobacter***ia***), microbial products (such as Lipopolysaccharides) and toxins in the air and other volatile organic compounds. In brief, a bioaerosol is an airborne collection of biological materials which may be solid or liquid. Exposure to these agents may cause

different health conditions such as infection, respiratory diseases, allergies, acute toxic effects, nervous system disorders, and possibly cancer (Lighthart, 1997; Crook and Swan, 2001; Douwes and Thorne, 2008). Some sources of bioaerosols are water, soil, waste dump sites, and sewage. These collections of biological materials form a profile of microorganisms responsible for several debilitating and life-threatening human infections and diseases (Obire *et al*., 2002; Londahl, 2014; National Academies Press, 2017). The distribution of bioaerosols vary in different geopositions due changing environmental and anthropogenic activities with respect to the procedures of operation, ranging from residential, industrial or agricultural activities (Ekaterina & Agranovski, 2018). There is also the concept of sampling efficiency namely physical efficiency, which is the comparison of the amount of the collected particles to the amount of particles in the sampling location or environment, and biological efficiency, which is an estimation of the fraction of microorganisms that remain viable after collection, since some bioaerosol organisms are non-viable (Hogan *et al*., 2005; Kulkarni *et al.*, 2011).

Microbial Groups of Bioaerosols

Microorganisms associated with bioaerosols are bacteria, fungi, viruses, protozoa and microalgae, and with their microbial products and volatile organic compounds (Srikanth *et al*., 2008; Londahl, 2014).

In these groups, bacterial species and their diseases caused by them are *Mycobacterium tuberculosis* (Tuberculosis); *Legionella sp.* (Legionnaires disease, Pontiac fever)*; Streptococcus pneumonia* (Pneumonia); *Streptococcus sp.* (Scarlet fever, Angina, laryngitis); *Haemophilus influenzae* (Inflammation of upper and lower respiratory system, Menigitis); *Bordetella pertussis* (Whooping cough); *Legionnella pneumophillia* (Pulmonary infections > Legionnaire disease); Norcardia sp. (Norcardiosis); and Corynebacterium diphtheria (Diphtheria) (Burge1990; Nrior, 2020).

Fungal profiles found in bioaerosols with their respective diseases are *Alternaria sp*. (Asthma, rhinitis); *Cladosporium* (Asthma, rhinitis); *Microsporum racemosus* (Superficial mycosis); *Aspergillus fumigatus* (Aspergillosis); *Cryptococcus neoformans* (Criptococcosis) (Nrior & Chioma, 2017).

In the profile of viruses, the following types are prominent in bioaerosols with their diseases in parenthesis: Influenza A and B (Influenza); Rubella virus (Measles); Corona virus (Corona virus infection – COVID 19); Orthomyxoviruses (Influenza); Paramyxovirus (Influenza, measles, mumps and, pneumoniae among new borns); Rhinoviruses and Corona virus (Colds); Pox virus (Cowpox); Adenoviruses (Sorethroat, Pneumonia); Enteroviruses (Meningitis, Pleurdynia); Rhinoviruses, Hantavirus from rodent faeces, and Coronaviruses (chicken pox) (Diglisic *et al*., 1999; Nrior, 2020). Prozoal organisms found in bioaerosols is *Pneumocystis carrinii* which causes Pneumoniae in humans. Protozoa and algae are also found in bioaerosols and they are implicated in Hypersensitivity pneumonitis (Burges, 1990; Londahl, 2014).

Disease Categories Associated with Bioaerosols.

Diseases associated with bioaerosols are due to exposure to bioaerosols. The incidences are due to a combination of allergens, toxins and microorganisms. Three distinguishing diseases associated with bioaerosols are infectious diseases, respiratory diseases and cancer (Turjanmaa, 1987; Charous *et al.*, 1994).

Infectious diseases

Infectious diseases arise from viruses, bacteria, fungi, protozoa and helminthes, and involve the transmission of an infectious agent from a reservoir to a susceptible host through direct contact, a common vehicle, airborne transmission or vector-borne transmission. Diseases caused by microorganisms associated with bioaerosols may be attributable to occupation-specific exposures, such as in health workers (tuberculosis, winter stomach flu, measles). For farmers, abattoir workers, veterinarians diseases of common occurrence are Q-fever, swine influenza and anthrax) and forestry workers (tularaemia). Gathering or clustering of people in the workplace such as in the case of market places, office, military or schools may experience influenza, winter stomach flu, Tuberculosis and Corona infection) (Driver *et al.*, 1994; Van den Ende *et al.*, 1998; Srikanth *et al*., 2008; NCDC, 2020). Other bioaerosol transmitted infections are (particularly *Legionella pneumophila*) caused by exposure to Legionellae. They become airborne often as a result of active aerosolizing processes (Pastoris *et al.*, 1997; Brown *et al.*, 1999). Aloso, inhalation of fungal spores in the course of handling decaying matters, faeces, composts or soils can result in several mycoses. They include adiaspiromycosis, aspergillosis, blastomycosis, coccidioidomycosis and histoplasmosis. (MMWR, 1993 ; NIOSH, 1997). Thus, high-risk occupations for occupational infectious diseases due to bioaerosol exposure include farmers, veterinarians, health care workers and biomedical workers studying infectious agents.

Respiratory diseases

Bernstein *et al.* (1999) explains that respiratory, dust-aerosol associated diseases range from acute mild conditions to severe chronic respiratory diseases that require specialist medical attention. Respiratory diseases due to bioaerosls result specifically from exposures to toxins, pro-inflammatory agents or allergens.

Cancer

Cancer can be caused by a variety of factors including oncogenic viruses and other biological agents. Notably the only clearly established non-viral biological occupational carcinogens are the mycotoxins. Hayes *et al.,* (1984) reported that aflatoxin from *Aspergillus flavus* was capable of causing liver cancer. These occur in industries in which mould-contaminated materials are handled (Anonymous, 1998).

Viruses are considered as the most common cause of infectious diseases acquired within indoor environments (Brankston *et al*., 2007), and many nosocomial infections are due to respiratory and enteric infections of viruses (Belliot *et al.*, 2014; Bruijning *et al*., 2012, Kambhampati *et al*., 2015, Rhinehart *et al*., 2012). Recent examples of particular concern are emerging infectious diseases such as Severe Acute Respiratory Syndrome (*SARS*) coronavirus (*SARS*-

CoV)– *virus* identified with outbreak in 2003, the outbreak of Ebola Virus Dissease (EVD) in West Africa in 2014-15, and the on-going Middle East Respiratory Syndrome Coronavirus (MERS CoV) outbreaks in the Middle East since 2012, where many health care workers (HCWs) were infected and acted as the amplifiers for the spread of the disease to the community, and the Corona Virus infection (COVID 19) which became a pandemic and affected virtually all countries in the world from March, 2019 to June, 2020, with implied extension towards the second half of 2020. (Ansumana *et al*., 2017; Ho e*t al*., 2003; Ki, 2015; Shears and O'Dempsey, 2015; Nrior & Dumbor, 2019; WHO, 2020).

Bioaerosol organism detected by qPCR analysis of aerosol samples.

Quantitative Polymerace Chain Reaction (qPCR) approach has discovered various kinds of fungal and bacterial species. These include both culturable and unculturable species of bacteria, fungi and viruses. According to (Kaarakainen *et al.,* 2011), fungal organisms associated with bioaerosols include *Aspergillus fumigatus/ Neosartorya fischeri, Aspergillus niger/awamori/foetidus/phoenicis, Aureobasidium pullulans, Cladosporium cladosporioides, Cladosporium herbarum, Cladosporium sphaerospermum, Eurotium amstelodami/ chevalieri/herbariorum /rubrum/repens, Epicoccum nigrum Penicillium brevicompactum/stoloniferum, Penicillium chrysogenum*, *Penicillium variabile*, *Wallemia sebi, Cladosporium spp*. *Streptomyces spp*., and Gram-positive and –,Gram-negative. Several of which are implicated in diverse infectious diseases, posing serious health hazards to humans (Kaarakainen *et al.,* 2011). Some of the microbial bioaerosols are culturable while others were unculturable, so could only be detected using metagenomic approache. Some bacterial and fungal species detected through metagenomic studies include *Micrococcus*. *Nocardiopsis, Paracoccus, Streptomyces*, *Scopulariopsis*, *Pseudonocardia*, *Staphylococcus, Enhydrobacter, Methylobacterium, Corynebacterium, Sphingomonas, Acinetobacter, Bacillus, Kocuria, Massila* and *Nocardioides*. Some fungi in indoor and outdoor air identified at the phylum and class levels discovered through metagenomic insight are given on Table 1 (Shin *et al*., 2015).

Table 1: Fungi in indoor and outdoor air identified at non-specific levels

Dothideomycetes	Eurotiomycetes	Sordariomycetes
Leotiomycetes	Pezizomycetes	Saccharomycetes
Orbiliomycetes	Lecanoromycetes	Arthoniomycetes
LIchinomycetes	Unclassified Ascomycota	Agaricomycetes
Tremellomycetes	Exobasidiomycetes	Waalemiomycetes
Ustilaginomycetes	Agaricomycotina	Agaricostilbomycetes
Dacrymycetes	Atractiellomycetes	Tritirachiomycetes
	Chytridiomycetes	Unclassified Glomeromycota.
	Unclassified Eukarya	

Source: Shin *et al*, (2015).

Bioaerosols are generated due to anthropogenic activities. Such activities include residential, industrial, agricultural and laboratory experimentation, Bioaerosols can be generated in the laboratory by a number of different methods utilizing either dry or wet procedures. Dry dispersion methods are predominantly utilized for fungal aerosol generation. Fungal spores can be detached and dispersed directly from their culture medium by vibration (Scheermeyer and Agranovski, 2009), brushing or establishment of airflow across the surface of the agar plate (Jung *et al.*, 2009; Zhen *et al*., 2014).

Bioaerosols are also generated in anthropogenic environments by bursting bubbles: When bubbles from sea waves burst whitecaps becomes efficient producers of marine bioaerosol particles. In residential and industrial environment transfer of microorganism from water to air by bursting bubbles occur frequently during aeration or agitation of liquids (Aziz *et al*., 2008; Chen *et al*., 2013; Mannina *et al*., 2016). Other methods of bioaerosol generation are liquid dispensing and splashing with high probability of bacteria surviving more than one hour after generation process (Joung *et al*., 2017); High pressure cleaning using high pressure mechanical spray guns and machines applied in various industrial and residential areas for cleaning contaminated surfaces (Seidl *et al*., 2016).

Transmission of Bioaerosol associated microorganisms/diseases

In nosocomial instances, airborne transmission usually occurs only when an infected subject is coughing, sneezing, or otherwise actively shedding fresh organisms into air close to susceptible individuals. Bio-aerosols can be transmitted either at long distances beyond the patient room environment, or within short distances. Small particle are transmitted to persons in the immediate area near the patient. Viruses like Corona virus (COVID 19), Severe Acute Respiratory Syndrome (SARS), influenza and norovirus are transmitted from patients usually by contact and/or droplet routes, while airborne transmission occurs over a limited distance (Bollin *et al.*, 1985). Centre for Diseace Control (2020) recommends at least 6 feet (2 arms) length physical/social distance from person to person (Legionella may be derived from the environment (Bollin *et al*., 1985) and others include contaminated food, water, medications (e.g., intravenous fluids) or through vectors (Anaissie *et al*.,2003).

Transmission routes of infections is not always easily determined in an environment with undefined parameters. Infection by direct contact can occur when infected hosts are in close proximity with a susceptible population. On the other hand, infected hosts can transmit the disease without direct contact. Moreover, many microorganisms, including viruses (Dinsdale *et al.*, 2008), can remain infectious outside their hosts for prolonged periods of time, and this can lead to infections by indirect contact. For example, a surface can become contaminated by deposited infectious droplets and eventually cause the infection of susceptible hosts coming into contact with it. The probability of airborne transmission of an infectious disease can be determined by conducting epidemiological studies (Pirtle and Beran, 1991) and/or by analyzing the microbiological content of air samples.

Methods of Identification of Microorganisms in Bioaerosols

Sampling and Cultivation of airborne bacteria and fungi follows mostly a passive approach. The passive sampling based on settle plate (sedimentation sampling) method which is preferred mostly in the collection of air borne particles containing microorganisms (Sivagnanasundaram *et al*., 2019)

Bacteria: Identification of microorganisms from bioaerosols according to conventional methods. In this proposal bioaerosol samples are collected in a specified environment and their cultivation on agar nutrient media. Representative colonies are picked and inoculated unto nutrient agar to obtain pure cultures. The bacterial isolates are identified either gram positive or gram negative based on their reaction with gram stain. The pure cultures are stored as frozen 10%(v/v) glycerol suspensions at -35^{o}C in a refrigerator. This glycerol stock serves as a means for fresh working cultures. Further inoculation of pure cultures unto appropriate media is done to check for consistency. Identification of the isolates are carried out using appropriate identification schemes, which supposes that traditional schemes for identifying a pure culture phenotype characteristics chosen for an identification scheme should be easily determinable by most microbiology laboratories (Krieg, 2001; Duquenn, (2018; Sivagnanasundaram *et al*., 2019).

Fungi: Isolation and identification of fungi is based on their macroscopic morphology, such as best growth temperature *(e.g.* Growth at 37^{O}C, 40^{O}C, 45^{O}C), growth rate (e.g. colony diameter 5 cm in 15 days), colour or pigmentation on SDA (e.g. white, cream, yellow, brown, pink, grey, black *etc*.), colour/pigmentation on reverse side of plate (e.g. none, yellow, brown, red, black, *etc*.) , texture and special features (e.g. glabrous, suede-like, powdery, granular, fluffy, downy, cottony), Surface topography (*e.g.* flat, raised, heaped, folded, domed, radial grooved), septation of hyphae (septate, non-septate), while the microscopic morphologies and identities of the different species of fungal isolates are based on characteristic features of conidiophore, phialides, vesicle, sclerotia, hulle cells, sporangiophore, apophysis, columella, sporangium and rhizoids according to scheme of Cheesbrough, 2002; Kidd *et al*., 2016; Lindsley, *et al*., 2017; Nrior, 2020).

Some Settled Dust Collection Devices used for Bioaerosol sampling.

Instead of passive sedimentation method, bioaerosol is also sampled using settled dust collection devices. These include Vacuums, Swabs, wipes, adhesive tapes and contact plates. Their respective methodologies are giving by HUD (2008); Bolanos-Rosero *et al.* (2013); Morey, (2007) and Poletti *et al.,* (1999).

Enumeration of viruses

Prior to molecular PCR-based detection methodologies, cell cultures and serological methods were used as detection methods of viral pathogens. By the use of commercially available immortal cell lines, researchers can screen collected bioaerosols by inoculating cells and observing for modal cytopathic effects (CPEs) such as fusion and lysis of cells (Leland and Ginocchio, 2007).

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Sampling and Characterization of Viruses in Bioaerosols

Several methods are available, but only few are mentioned below.

Viral Plaque assay (VPA)

A common method for detecting and quantifying viral pathogens and titres respectively is the viral plaque assay (VPA) (Condit, 2007).

Tissue Culture infectious dose Assay (TCID)

Tissue Culture Infectious Dose assay (TCID) also known as endpoint dilution assay, is also a culture based method of assaying viruses in bioaerosols (Condit, 2007). The procedure selecting cells which are plated at a predetermined concentration in a 96-well format and inoculated with serial dilutions of the collected sample. Predetermined incubation period is set, and then cytopatic effects (CPEs) are closely observed. The TCID50 is defined as the dilution of virus required to infect 50% of the cell culture wells (Reed & Muench, 1938). Based on the number of cells that are infected at the designated virus dilution, viral titers are mathematically calculated. However, this method has its limitation (Reed & Muench, 1938).

Immuofluorescence Antibody (IFA) Assay

Detection and quantification of viral loads is also achieved via direct or indirect immunofluorescence antibody (IFA) assays and are frequently used in combination with cell culture-based methods (Flint *et al*., 2009; Tortora *et al*., 2013). Infected cells are by this method combined with a fluorescently-labeled, antigen-specific antibody. Optimization is possible by varying the parameters (Flint *et al*., 2009; Tortora *et al*., 2013).

Molecular Genetic Methods

Molecular identification of bioaerosol samples follows a predetermined procedure. Samples are collected in a specified environment and subsequently, cultivation on agar nutrient media (except for viruses). The morphologically different colonies are then selected, and individually transferred into a DNA-free reaction tubes. *PCR Amplification of Purified Bacterial DNA using* 16S rRNA gene region of bacterial genomic DNA is amplified using universal bacterial primers. An amplicon-mixture of each bioaerosol sample is prepared by mixing equimolar DNA amounts of PCR product from each selected colony. Then, the amplicon-mixture is used to generate clone libraries that are sequenced; the gene sequences are finally aligned against the NCBI database for bacterial identification (Schäfer *et al.*, 2017; Disegha & Akani, 2919; Sivagnanasundaram *et al*., 2019).

PCR-based method of identifying Viruses from Bioaerosol.

Generally, viruses consist of more genetic material, DNA or RNA than other microorganisms. More general studies have also been conducted (Sigari *et al*., 2006) based on PCR detection of a number of viruses, especially enteroviruses and reoviruses, from aerosols around a sewage treatment facility. The most generalized detection of viruses, however, lies in the metagenomics studies mentioned above, particularly the study of Dinsdale *et al*. (2008). In this study, viral DNA only, not RNA, was isolated from the smallest-size fraction of a serially filtered environmental sample, and included a wide variety of viruses, phages and prophages.

More effective and rapid detection of viruses in collection media, preferably in real-time, is well-preferred in aerovirology. Some good technologies include loop-mediated isothermal amplification, which has the potential to detect and offer a presumptive identification of a virus under one hour, as demonstrated for influenza virus (Mori and Notomi, 2009), and real-time PCR.

Analytical Formula for Direct Sedimentation Methods

Culturable Microbial Sample Analysis.

In culturable microorganisms, the number of both bacterial and fungal colonies is enumerated on each agar plate after incubation and the counts are obtained as colony forming units per m^2 area (cfu/m2) (Sivagnanasundaram *et al*., 2019. A good background information on enumeration of bioaerosol microorganisms can be found in Nrior & Chioma (2017). Analytic method is used to calculate the estimated number of colony forming units from a bioaerosol sample. The standard time for bioaerosol sampling is ten minutes (10 mins) (Nrior, 2020).

For Direct Sedimentation Method:

$$CFU(min - m^2 = \frac{Number\ of Colonies}{Time\ of\ Exposure\ (Min)\ \text{x}\ \pi r^2}$$

Where r= radius of media plate (Petri dish) used (in meters).

The above method uses settled plates using prepared Petri dishes with preferred medium for microbial growth.

For Indirect Sedimentation Method:

$$CFU(min - m^2 = \frac{Number\ of Colonies\ x\ VD}{Time\ of\ Exposure\ (Min)\ \text{x}\ \pi r^2 \text{x}\ VP}$$

Where: r = radius of beaker used in (in meters); VD = Volume of diluent (normal saline 100 ml in 250ml beaker) and VP = Volume plated (usually 0.1 ml aliquot /inoculum) (Nrior and Dumbor, 2019).The indirect method uses beaker with diluents placed for at least 24 hours.

Other Devices used for bioaerosol sampling

This review considers only settle plate (gravitational sedimentation) method for bioaerosol sampling. Settle plates are culture plates containing culture media exposed at sampling locations of interest for passive inoculation of microorganisms. Airborne particles are allowed to settle onto the plates for a specified time. Usually 10 minutes (Nrior, 2020), and the plates are then closed, incubated and inspected for growth (Dyer *et al.* 2004). For purposes of simplicity and efficiency in cost, settle (gravitational sedimentation) plates are more frequently used by researchers in conducting bioaerosol sampling. However, there are other devices or techniques used for bioaerosol sampling. Some of them are given below:

(i)**Filters:** These are useful for personal bioaerosol sampling because filter-based collectors are small and lightweight and work well with personal sampling pumps (Raynor *et al*., 2011).

(ii) **Impactors**: These are described by Hering (2001) and Marple and Olson (2011) as instruments consisting of a series of nozzles (circular- or slot-shaped) and a surface for

impaction (Marple and Willeke, 1976). Air is drawn into the impactor using a vacuum pump, and the air stream flows through the nozzles and toward the impaction surface, where particles are separated from the air stream by their inertia. Larger particles collect on the impaction surface, while small particles that do not impact follow the air stream. The impaction surface typically consists of a greased plate or tape, filter material, or growth media (agar) contained in Petri dishes. In some applications, impactors are not used as collection devices themselves, but rather to remove particles above a certain size before collection or characterization of the downstream aerosol (Figure 1). The most commonly used impactor for sampling airborne culturable bacteria and fungi is the Andersen impactor illustrated below (Andersen ,1958).

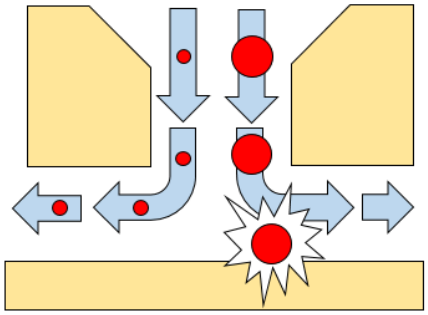

Figure 1: Example of impaction mechanism. Existing air stream in the impactor nozzle, quickly changes direction following the arrows. On the left, smaller/ligher particles flow with the air stream and are not collected. Larger particles cannot change direction as quickly due to their higher inertia and collide with the collection surface and are accumulated. (Source: Lindsley *et al*., 2017)

(iii) Cyclones: A cyclone sampler consists of a circular chamber with the aerosol stream entering through one or more tangential nozzles (Hering, 2001). Clone is similar to an impactor; a cyclone sampler depends upon the inertia of the particle to cause it to deposit on the sampler wall as the air stream curves around inside. See Figure 2

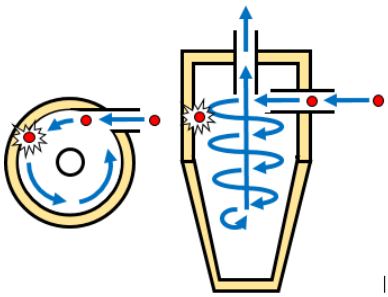

Figure 2: Cyclone aerosol collection. From the inlet, aerosol stream enters the body of the cyclone, the air flow is according to curved interior wall and moves in a spiral pattern. Collision of larger aerosol particles with the inner wall occur due to the inertia of the particles and accumulate. After spiraling downward, the air flow exits through the vortex finder via the center of the cyclone. Source: Lindsley *et al*. (2017).

(iv) Liquid Impingers: Many microorganisms can lose their viability if they are collected onto dry solid surfaces. Impingers often have curved inlets to remove larger particles from the air

stream before collection. Because impingers are essentially another type of inertial collection device, they have a collection efficiency curve and a cut-off diameter like impactors and cyclones. Additives to the collection medium such as proteins, antifoam, or antifreeze aid in resuscitation of bacterial cells, prevent foaming and loss of the collection fluid, and minimize injury to the cells (Chang and Chou, 2011; Cown *et al*. 1957; Dungan and Leytem, 2015).

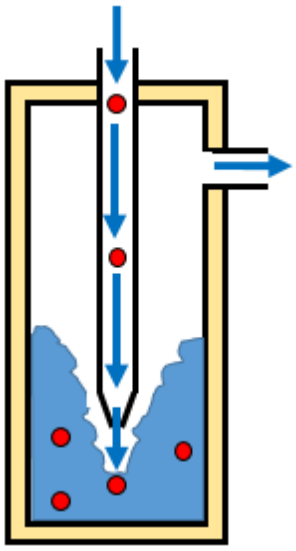

Figure 3: Impingement. Bioaerosol particles exit the nozzle of the impinger at high velocity and impact the liquid or the bottom surface of the collection vessel. Some types of impingers produce air bubbles in the collection media, which can enhance particle collection, but can damage some types of microorganisms. Source: Lindsley *et al*. (2017).

(v). Wetted-surface bioaerosol samplers (WSBS)

Wetted-surface bioaerosol sampler generates streams of air, which impacts onto a wetted surface with collection media (Kesavan and Sagripanti, 2015; Kesavan *et al.,* 2011). WSBS produce bubbling and agitation, which may not be favourable to some microorganisms (Lin *et al.,* 2000).

CONCLUSION:

This study has made some exposition on the profile of microorganisms associated with bioaerosols. It was noted that the predominant microbial groups of bioaerosol are fungi, bacteria and viruses, while protozoa and microalgae were present in low numbers. Some disease categories caused by specific organisms or combination of them are infectious diseases, and respiratory diseases expressed on humans in varying degrees, depending on the measure of exposure. Sources of micro-bioaerosols and transmission routes are critical for contact of microorganisms and their consequent infection on susceptible hosts. Some sampling devices are also mentioned which are used in bioaerosol researches. Detection and identification of bioaerosol microorganisms used to be carried out using cultural and biochemical methods. But recently, the trend has changed to molecular approaches using different advanced method, including the real time PCR and other analytical techniques. The use of advanced techniques enhances the detection of microoganisms including non-culturable species via metagenomic

approaches, is a great achievement. However, cost of advanced techniques is high and not easily affordable by research students, and even some Research Institutes.

It is therefore recommended that government agencies such as TETFUND, World Bank and non-governmental establishments should make grants available to researchers in need of such equipment and devices. Most importantly, some microorganisms associated with bioaerosols are pathogenic and are of significant health challenge, and are epidemic prone. Thus, affordable and rapid means of detection, identification and prevention of diseases and epidemics from bioaerosols associated microorganisms is paramount.

ACKNOWLEDGEMENT

We acknowledge with gratitude the various authors whose works are used and cited in this review. Their detailed reports actually widened the horizon of this article. Thanks also due to Dr. R.R. Nrior for his encouragement in partnership and provision of materials which served as guideline. We also wish to appreciate Professor O. Obire who initially introduced the corresponding author to the culture of learning how to write academically. Thanks are also due to other members of the academic community in the Rivers State University, Port Harcourt, Nigeria, who have assisted us in diverse ways.

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