Fate of Bio-aerosols

Airborne microorganisms and microbial by-products from intensive livestock and manure management systems are a potential health risk to workers and individuals in nearby communities. This report presents information on zoonotic pathogens in animal wastes and the generation, fate, and transport of bioaerosols associated with animal feeding operations and land applied manures. Though many bioaerosol studies have been conducted at animal production facilities, few have investigated the transport of bioaerosols during the land application of animal manures. As communities in rural areas converge with land application sites, concerns over bioaerosol exposure will certainly increase. Although most studies at animal operations and wastewater spray irrigation sites suggest a decreased risk of bioaerosol exposure with increasing distance from the source, many challenges remain in evaluating the health effects of aerosolized pathogens and allergens in outdoor environments. To improve our ability to understand the off-site transport and diffusion of human and livestock diseases, various dispersion models have been utilized. Most studies investigating the transport of bioaerosols during land application events have used a modified Gaussian plume model. Because of the disparity among collection and analytical techniques utilized in outdoor studies, it is often difficult to evaluate health effects associated with aerosolized pathogens and allergens. Invaluable improvements in assessing the health effects from intensive livestock practices could be made if standardized bioaerosol collection and analytical techniques, as well as the use of specific target microorganisms, were adopted. Bioaerosol monitoring is a rapidly emerging area of industrial hygiene. Microbial roles in atmospheric processes are thought to be species specific and potentially depend on cell viability. Accumulating evidence suggests that exposure to bioaerosols may cause adverse health effects, including disease. Bioaerosol monitoring is a rapidly emerging area of industrial hygiene. Microbial roles in atmospheric processes are thought to be species specific and potentially depend on cell viability. Accumulating evidence suggests that exposure to bioaerosols may cause adverse health effects, including disease. Studies of bioaerosols have primarily focused on chemical composition and biological composition, and the negative effects thereof on ecosystems and human health have largely gone unnoticed. This gap can be attributed to international standards on acceptable maximum bioaerosol loads not being uniform and the lack of uniform standardized methods for collection and analysis of bacterial and fungal bioaerosols. In this chapter, bioaerosol composition, relevance of bioaerosols to the food processing facility, sampling and detection approaches, and complications were discussed. Studies of bioaerosols have primarily focused on chemical composition and biological composition, and the negative effects thereof on ecosystems and human health have largely gone unnoticed. This gap can be attributed to international standards on acceptable maximum bioaerosol loads not being uniform and the lack of uniform standardized methods for collection and analysis of bacterial and fungal bioaerosols. In this chapter, bioaerosol composition, relevance of bioaerosols to the food processing facility, sampling and detection approaches, and complications were discussed.

Transport mechanisms

Ejection of bioaerosols into the atmosphere

Bioaerosols are typically introduced into the air via wind turbulence over a surface. Once airborne they typically remain in the PBL, but in some cases reach the upper troposphere and stratosphere.[18] Once in the atmosphere, they can be transported locally or globally: common wind patterns/strengths are responsible for local dispersal, while tropical storms and dust plumes can move bioaerosols between continents.[2] Over ocean surfaces, bioaerosols are generated via sea spray and bubbles.[5]

Small scale transport via clouds

Knowledge of bioaerosols has shaped our understanding of microorganisms and the differentiation between microbes, including airborne pathogens. In the 1970s, a breakthrough occurred in atmospheric physics and microbiology when ice nucleating bacteria were identified.[19]

The highest concentration of bioaerosols is near the Earth's surface in the PBL. Here wind turbulence causes vertical mixing, bringing particles from the ground into the atmosphere. Bioaerosols introduced to the atmosphere can form clouds, which are then blown to other geographic locations and precipitate out as rain, hail, or snow.[2] Increased levels of bioaerosols have been observed in rain forests during and after rain events. Bacteria and phytoplankton from marine environments have been linked to cloud formation.[1] However, for this same reason, bioaerosols cannot be transported long distances in the PBL since the clouds will eventually precipitate them out. Furthermore, it would take additional turbulence or convection at the upper limits of the PBL to inject bioaerosols into the troposphere where they may transported larger distances as part of tropospheric flow. This limits the concentration of bioaerosols at these altitudes.[1]

Cloud droplets, ice crystals, and precipitation use bioaerosols as a nucleus where water or crystals can form or hold onto their surface. These interactions show that air particles can change the hydrological cycle, weather conditions, and weathering around the world. Those changes can lead to effects such as desertification which is magnified by climate shifts. Bioaerosols also intermix when pristine air and smog meet, changing visibility and/or air quality.

Large scale transport via dust plumes

Satellite images show that storms over Australian, African, and Asian deserts create dust plumes which can carry dust to altitudes of over 5 kilometers above the Earth's surface. This mechanism transports the material thousands of kilometers away, even moving it between continents. Multiple studies have supported the theory that bioaerosols can be carried along with dust.[20][21] One study concluded that a type of airborne bacteria present in a particular desert dust was found at a site 1,000 kilometers downwind.[2]

Possible global scale highways for bioaerosols in dust include:

- Storms over Northern Africa picking up dust, which can then be blown across the Atlantic to the Americas, or north to Europe. For transatlantic transport, there is a seasonal shift in the destination of the dust: North America during the summer, and South America during the winter.
- Dust from the Gobi and Taklamakan deserts is transported to North America, mainly during the Northern Hemisphere spring.
- Dust from Australia is carried out into the Pacific Ocean, with the possibility of being deposited in New Zealand.[21]

Community dispersal

Bioaerosol transport and distribution is not consistent around the globe. While bioaerosols may travel thousands of kilometers before deposition, their ultimate distance of travel and direction is dependent on meteorological, physical, and chemical factors. One study generated an airborne bacteria/fungi map of the United States from observational measurements, resulting community profiles of these bioaerosols were connected to soil pH, mean annual precipitation, net primary productivity, and mean annual temperature, among other factors.[22]

Biogeochemical impacts

Bioaerosols impact a variety of biogeochemical systems on earth including, but not limited to atmospheric, terrestrial, and marine ecosystems. As long-standing as these relationships are, the topic of bioaerosols is not very well-known Bioaerosols can affect organisms in a multitude of ways including influencing the health of living organisms through allergies, disorders, and disease. Additionally, the distribution of pollen and spore bioaerosols contribute to the genetic diversity of organisms across multiple habitats.[1]

Cloud formation

A variety of bioaerosols may contribute to cloud condensation nuclei or cloud ice nuclei, possible bioaerosol components are living or dead cells, cell fragments, hyphae, pollen, or spores.[1] Cloud formation and precipitation are key features of many hydrologic cycles to which ecosystems are tied. In addition, global cloud cover is a significant factor in the overall radiation budget and therefore, temperature of the Earth. Bioaerosols make up a small fraction of the total cloud condensation nuclei in the atmosphere (between 0.001% and 0.01%) so their global impact (i.e. radiation budget) is questionable. However, there are specific cases where bioaerosols may form a significant fraction of the clouds in an area. These include:

- Areas where there is cloud formation at temperatures over -15 °C since some bacteria have developed proteins which allow them to nucleate ice at higher temperatures.
- Areas over vegetated regions or under remote conditions where the air is less impacted by anthropogenic activity.
- Near surface air in remote marine regions like the Southern Ocean where sea spray may be more prevalent than dust transported from continents.[1]

The collection of bioaerosol particles on a surface is called deposition. The removal of these particles from the atmosphere affects human health in regards to air quality and respiratory systems.[1]

Alpine lakes in Spain

Alpine lakes located in the Central Pyrenees region of northeast Spain are unaffected by anthropogenic factors making these oligotrophic lakes ideal indicators for sediment input and environmental change. Dissolved organic matter and nutrients from dust transport can aid bacteria with growth and production in low nutrient waters. Within the collected samples of one study, a high diversity of airborne microorganisms were detected and had strong similarities to Mauritian soils despite Saharan dust storms occurring at the time of detection.[25]

Affected ocean species

The types and sizes of bioaerosols vary in marine environments and occur largely because of wet-discharges caused by changes in osmotic pressure or surface tension. Some types of marine originated bioaerosols excrete dry-discharges of fungal spores that are transported by the wind.[1]

One instance of impact on marine species was the 1983 die off of Caribbean sea fans and sea urchins that correlated with dust storms originating in Africa. This correlation was determined by the work of microbiologists and a Total Ozone Mapping Spectrometer, which identified bacteria, viral, and fungal bioaerosols in the dust clouds that were tracked over the Atlantic Ocean.[26] Another instance in of this occurred in 1997 when El Niño possibly impacted seasonal tradewind patterns from Africa to Barbados, resulting in similar die offs. Modeling instances like these can contribute to more accurate predictions future events.[27]

Spread of diseases

The aerosolization of bacteria in dust contributes heavily to the transport of bacterial pathogens. A well-known case of disease outbreak by bioaerosol was the meningococcal meningitis outbreak in sub-Saharan Africa, which was linked to dust storms during dry seasons. Other outbreaks have been reportedly linked to dust events including *Mycoplasma* pneumonia and tuberculosis.[2] Another instance of bioaerosol-spread health issues was an increase in human respiratory problems for Caribbean-region residents that may have been caused by traces of heavy metals, microorganism bioaerosols, and pesticides transported via dust clouds passing over the Atlantic Ocean.[26][28]

Common sources of bioaerosols include soil, water, and sewage. Bioaerosols can transmit microbial pathogens, endotoxins, and allergens[29] and can excrete both endotoxins and exotoxins. Exotoxins can be particularly dangerous when transported through the air and distribute pathogens to which humans are sensitive. Cyanobacteria are particularly prolific in their pathogen distribution and are abundant in both terrestrial and aquatic environments.[1]

Future research

The potential role of bioaerosols in climate change offers an abundance of research opportunities. Specific areas of study include monitoring bioaerosol impacts on different ecosystems and using meteorological data to forecast ecosystem changes.[5] Determining global interactions is possible through methods like collecting air samples, DNA extraction from bioaerosols, and PCR amplification.[20]

Developing more efficient modelling systems will reduce the spread of human disease and benefit economic and ecologic factors.[2] An atmospheric modeling tool called the Atmospheric Dispersion Modelling System (ADMS 3) is currently in use for this purpose. The ADMS 3 uses computational fluid dynamics (CFD) to locate potential problem areas, minimizing the spread of harmful bioaerosol pathogens include tracking occurrences.[2]

Agroecosystems have an array of potential future research avenues within bioaerosols. Identification.

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