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Review Article

AERO BACTERIOLOGY OF CONCENTRATED ANIMAL FEEDING OPERATIONS: A REVIEW

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ABSTRACT
With the advancement of the science and technologies, large-scale animal farming replaces the ancient practices of household livestock farming, to make the greater profit with lesser investment. Increasing number of animal holding in small areas resulted into the higher concentration of discharge of waste from these operational areas that drastically affected environment in the form of soil, water, and air pollutants. Concentrated animal feeding operations produce several types of air emissions, including gaseous, dust, and primary airborne biological particles, having both aesthetic and health significance. The aim of this work was to compile the studies on bioaerosols generated and disseminated from these concentrated animal feeding operations and their probable effect on their surrounding communities, which were carried out in recent past. Literature search was conducted mainly by using the Google scholar, Google search engine, MEDLINE, and PubMed databases, including articles published until December 2015. Plethora of scholarly articles available on knowledge domain giving exhaustive insight information about potential threats of airborne microbial contamination out of CAFOs operations worldwide. Diseased animals and contaminated food and fodders were reported as a primary potential source of pathogenic airborne microorganism for that environment. The difference in view among the scholars while recommending safer distance for community habitation, which may be due to absence of widely acceptable and rational tools and techniques for airborne microbial risk assessments while dealing with community health.

Keywords: *Aero-Bio-Pollutants, Bio-Aerosols, Biohazard, CAFOs, Community Environments*

INTRODUCTION
The relation between human and animals can be established much before the evolution of modern men the *Homo sapiens* var. *sapiens*. The first evident of taming of animals reported from the rock cave painting of India and other part of world, and from the scriptures like *Vedas* "*paśūntāṃścakre vāyavyānāraṇyān ghrāmyāśca ye* ||" (He formed the creatures of the air, and animals both wild and tame, *Rig Veda*: 10.90.16). The wolves (*Canis lupus*) or dogs (*Canis familiaris*) were probably the first animals of which utility in hunting were identified by the humankind, later on these animals were domesticated during the early Mesolithic age (Clutton-Brock, 1995; Leonard *et al.,* 2002). The more utilization of animals for the ease of business, secure food supply and probably for protection, by the human being leads to their conversion of natural habitats to agriculture based settlements, which further escorted to the origin of civilizations. However, the archaeological and ethnographic record throughout the world shows that the transition from hunting and gathering to farming eventually resulted in more work, lower adult stature, worse nutritional condition and heavier disease burdens (Cohen and Armelagos, 1984; Diamond, 2002).

The interactions between humankind and animals are multidimensional in nature, collectively studied in a new branch of science called anthrozoology. Anthrozoologist generally emphasizes on affirmative relation between human, and animals, as humans utilize animals for leisure, security, sociability, services, occult, metaphysics, religion, medicine, and foods. Since humans, animals and their pathogens have coexisted in nature, thus these two faceted relations must be viewed in multifaceted ways. Domesticated livestock and pet animals can spread both zoonotic and foodborne pathogens to their surrounding environment. Moreover, agriculture workers engaged in animal farming exposed to variety of allergenic substances derived from excreta, animal skin, waste water, food and fodders, able to sensitize the population eliciting both symptomatic and asymptomatic allergy (Osbern *et al.,* 1981; Terho *et al.,* 1985, 1987; van Hage-Hamsten *et al.*, 1987 a, b; Tee *et al.*, 1992; Rautalahti *et al.*, 1987). In modern era, where the domestication of animals were drastically changes from the family farming to the corporate farming; the threat of transmission of zoonotic pathogens are much higher than as previously thought.

The corporate animals farming were confined to small area without rearing facilities, increases the concentration of animals per square area, thus these called as concentrated animal feeding operations. Feed brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland. Concentrated Animal Feeding Operations (CAFOs) are facilities where large numbers of chickens, cattle, sheep, ducks pigs, or other animal types confined within a much smaller area than traditional pasture operations. The concentrations of the wastes laden with potentially pathogenic microorganism were recorded higher in some operational areas thus the mishandling of these wastes impacted negatively on their surrounding environment (Wing and Wolf, 2000). Many studies so far been conducted to assess the generation and transmission of microbes aerosolized from these CAFOs and their impact on surroundings, were evaluated in present review. The main object of the review has been to analyze the volume of airborne bacteria generation and to consider whether, these CAFOs generating bio-aerosols poses some real threat to their surrounding are not.

Literature

The literature reviewed in MEDLINE and PubMed databases, Google scholar, Google search engine and others, including articles published until December 2015. The keywords used for the search included: Aerobiology and/or bioaerosols and/or airborne microorganism and/or airborne bacteria with biohazards, aero-bio-pollutants, air sampling, Concentrated Animal Feeding operation, animal herds. Animal houses, pathways, and cultivation. The meta-analysis was conducted to collect the recent advancements in bio-aerosol research and aerobiology in particular, which yielded 235 references, out of which 69 references were included for analysis, without publication bias. In addition, the citations in each study found during the main search were reviewed for potential relevance. Finally, standard textbooks on aerobiology, medical and veterinary microbiology, and aerosol science were examined for information.

Concentrated Animal-Feeding Operations

In order to analyzed the menace of aerosolization of pathogenic bacteria associated with mass scale animal feeding operations, here author have taken three common form of practices that were widely investigated by the scholars i.e. poultry, swine, and cattle.

Poultry Farms

Domestication of galliformes can be traced back to 5,400 years ago in Southeast Asia (Underhill, 1997) or 7,000 years ago in India (Hehn, 1888; Brown, 1929; Fuller, 2006), but the modern commercial scale breeding for meat and egg production achieved only after 19^{th} century. Presently, worldwide more than 50 billion chickens from widely heterogeneous and polymorphic breed representing over 100 varieties are raised annually not only as a source of food but also been used in winemaking, in medicine, as binding agents for pigments, as hair products and in ritual (Kovacs-Nolan *et al.*, 2005, Groeneveld *et al.,* 2010; Storey *et al.,* 2012). Presently, both commercial free range and intensive form of poultry farming that includes breeding of chickens, ducks, turkeys, and geese for the purpose of meat and eggs, practices in almost all part of the world. Intensive indoor breeding or concentrated animal feeding operation often leads to air pollution both gaseous and microbial in nature, became a threat to the surrounding inhabitants.

Martin *et al.,* (2010) reported Actinobacteria, Firmicutes, Bacteroidetes, and Proteobacteria from the air of a duck house, some of these classified in the risk group 2 of biological agents and may cause negative pulmonary health effects. In another study conducted by Plewa and Lonc (2011) in hatcheries, among the airborne bacterial isolates, the species of the genera *Staphylococcus*, *Enterococcus*, *Acinetobacter*, *Enterobacter*, *Escherichia*, *Pantoea*, and *Klebsiella* were reported predominant. In two isolated studies, Bakutis *et al.,* (2004) and Lawniczek-Walczyk *et al.,* (2013) noted a strong correlation between dust concentrations with endotoxin, gram-negative rods and total bacteria, indicative of the prevalence of bacterial carrying dust particles for the atmosphere of poultry farms.

Swine Confinement

Pig farming is common in many parts of the world. Pigs by their self not responsible for dirtiness, the types of feeds, garbage, water, and poor handling of excretes are responsible for creation of unhygienic environment in swine confinement area. Da Silva *et al.,* (2015) while analyzing effluents originated from swine confinements identified vast variety of microorganism associated with phylum Firmicutes, Bacteroidetes, Proteobacteria and Actinobacteria by using pyrosequencing. Apart from soil and water contamination, foul-odours, fly-breeding, rodents, and recently airborne contaminants especially airborne microorganism originated from these confinements are some of the major concerned of hygienist, as same varieties of organisms were isolated by Arfken *et al.*, (2015) from the air of swine confinements with spatial and temporal variability (Kumari and Choi, 2014).

The number and types of airborne pollutant in swine confinements are not based on one or two factors; these are multifactorial by nature like herd size, breeding system, feeding method and the type of ventilation system (Sowiak *et al.,* 2011). Banhazi *et al.*, (2005 and 2008) reported an inverse correlation between pen hygiene and airborne bacteria, similarly Chien *et al.*, (2011) reported that pig's faeces are the major contributor of airborne bacteria in a controlled environment. Once these microorganisms get into the air, it transported from one area to another in the form of plumes. It would be better to live close to the working place; most of the agriculture workers prefer to reside as close as to their working environment. However, these are not recommended from the both security and health point of view, because of the risk of zoonosis (Chapin, 1916), fire and other hazards associated with large animal confinement areas. Many studies so far been conducted to recognize the maximum distance covered by these bio-aerosols originated from swine confinements. The most agreed distance or the safer distance to reside where these air plumes containing airborne microorganism generated from CAFOs cannot be reached are 200 m (Green *et al.,* 2006). However, Hartung and Schulz, (2011) reported 4000 CFU/m³ of *Staphylococci* at 477 m downwind while studying a broiler houses.

Cattle Farms

In the contrary to the swine and poultry farms, many scholars (Lange *et al.*, 1997; Kullman *et al.,* 1998) reported the lesser concentrations of airborne microorganism in dairy cattle farms previously. The study revealed that Cow dung (*Gomaya*) extract possess fungicidal, bactericidal, and nematicidal properties, may be responsible for lower concentration of human pathogens in cow barns. There also considered that the dung from the hump backed Indian cow is the best, which purify the environment even it checks the radiation effects. The microorganisms present in Cow dung are helpful for decreasing the value of total petroleum hydrocarbons and also helps in improving the soil properties like pH and electrical conductivity (Shrivastava *et al.,* 2014; Abdel-Mohsein *et al.,* 2010; Waziri and Suleiman, 2012; Lu *et al.*, 2014; Girija *et al.*, 2013). In Indian tradition and culture, the cow is a theophany. Cow dung (*Gomaya*) is considered purer than any other things. Daily cleansing of floors with *Gomaya* prevents against many diseases to the inhabitants of the houses (Brown, 1957; Harper, 1964; Lodrick, 1979; Korom, 2000). That were proven by metagenomic investigation performed by Girija *et al.,* (2013), according to them Cow dung containing many species belonging to the genera of *Pseudomonas* and *Bacillus* known to their antagonistic nature to the many pathogenic microorganisms.

Generation and Disseminations of Bio-Aerosols

Airborne disseminations of pathogenic gram negative bacteria were investigated by Sanz *et al.,* (2015), reported that *Escherichia coli* originated from dairy cattle farm could able to transport at least 150 m. However, Dungan, (2012) not reported the presence of bacteria known to be pathogenic to human while investigating similar environment. Dungan, (2010 and 2012) by using culture free methods reported Proteobacteria (α-, β-, and γ-subdivisions) were as most abundant class in airborne bacteria of open-free stall dairy environment. He also reiterated the findings of Bakutis *et al.*, (2004) that the airborne concentration of microorganism were higher in insulated than the free stall cowsheds, and the exposure to bioaerosols in the downwind environment decreases with increasing distance from the open-lot dairy. The airborne dust and endotoxin concentration also reported low in dairy barns (Lange *et al.,* 1997; Kullman *et al.,* 1998) as compare to other animal houses.

The bioaerosols emitted from animal herds is an established fact (Donham *et al.*, 1977; Donham, 1987, 1995). In order to recommends the safer distance for inhabitation, several models so far been were proposed by the scholars to forecast the generation of these bioaerosols and the distance these aerosols containing microorganism travels in the atmosphere (Carruthers *et al.*, 1994; Jarosz *et al.*, 2004, Helbig *et al.*, 2004; Sofiev *et al.*, 2006; Burrows *et al.*, 2009; Verma and Pathak, 2009, Wilkinson *et al.*, 2012; Pathak, 2015). Van Leuken *et al.*, (2015) thoroughly reviewed various scholarly articles on microbial risk assessments, according to them, five major determinants which may be responsible for the epidemics caused by airborne pathogens in community these are, rate of emission of pathogenic microorganism from sources, meteorological parameters, rate of inactivation of pathogens en route, the inhalation fraction and the immunity status of sinks.

To test for differences in rates of decline in CFU/m^3 (colony-forming unit (*CFU*)/ per cubic meter of air sampled) per meter distance from the CAFOs between respirable and non-respirable bacteria, Green *et al.*, (2006) proposed a simple non-automated model based on linear regression by including three independent variables only, i.e. (1) Natural log transform of distance, (2) An indicator variable for respirable, and (3) The interaction term of distance by group. Given the following model: $y = CFU/m^3 = b0 + b1\ (meters) + b2\ (respirable) + b3\ (meters * respirable) + e$; where meters is measured in m (meters), respirable indicates respirable bacterial organisms. According to Green *et al.*, (2006), one can use the estimates of b3 and the standard error of b3 to test the hypothesis that slopes (i.e. rates of change in CFU/m^3 per meter) for respirable and non respirable bacteria are similar. Specifically, the statistical significance of the interaction coefficient, b3, as measured by the p-value can be used to conduct the test (Green *et al.*, 2006).

Most of these models though includes a lot of variables to forecast the risk associated with generation and transportation of airborne microorganism, however these are failed to notice two major properties of bio-aerosols i.e. tenacity (under specific environmental condition) and aggregation of microorganism, which is essential to evaluate dose‒response relationships for any epidemiological studies (Pathak, 2015). To avoid the uncertainty and delusion in aerobiological investigation, Millner (2009) proposes that the future bioaerosol studies of animal operations need to emphasize uses of widely acceptable and rational tools and techniques along with the evaluation of effects of new improved analytical technologies during and after their development on the concentrations of airborne biological and particulate material and their impact on community health (Millner, 2009).

Summary of the literature review

1. A review has been made of literature on the generation and transportation of airborne pathogenic microorganisms from the concentrated animal feeding operations to their vicinity. The main objective of the review has been to consider whether is there any evidence to support the view that CAFOs generates critical amount of bacterial bioaerosols, which can able to pose any risk to their surrounding inhabitants are not?

2. There is either ample evidence that both pathogenic and saprophytic microorganisms generated from CAFOs but there is insufficient evidence on the generation and the disseminations of human pathogens from the CAFOs are out of operational practices (Otte *et al.,* 2007) or malpractices (Wing and Wolf, 2000).

3. Animal excreta are the common source of pathogenic bacteria in animal herds, if not properly handled these were multiply and disseminated to their surrounding environment (USEPA, 2005; Murayama *et al.,* 2010).

4. Diseased animals and contaminated food and fodders also become the potential source of pathogenic microorganism posing risk not only to the other healthy animals of the herds but also to the human associated with that environment (Jahne *et al.,* 2015), presence of multidrug resistance in these organisms make the thing worse.

5. Many scholars have suggested the safer distance, where no chances of airborne infection out of CAFOs operations can occur, but long distance transport by other means even the long distance transport of

airborne microorganism cannot be ruled out (Gloster *et al.*, 2005; Chen *et al.*, 2010; Smith *et al.*, 2010 and 2011).

CONCLUSION

From reviewing the literature, it is apparent that high concentrations airborne dusts and bioaerosols generated during the CAFOs operations and that presence of pathogenic microorganism and endotoxin in dust may be hazardous and impacted negatively not only on their surrounding communities but also the on the animals of the herds. In absence of any acceptable standardization/validation of analytical tools and techniques, it is hard to analyses the real effect of airborne pathogens generated out of these CAFOs operation on community health.

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