REVIEW

BAT GUANO AS THE COMPONENT OF FERTILIZER OR THE HEALTH HAZARD?

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Abstract. Phosphorus is an important element for life since to it is the component of human and animal bodies and it is the composition of plant, the food of human and some animals. Fertilizer is compose of phosphorus, the limited element in the current situation that is also the vital mineral for agricultural sector. Although phosphorus can be extracted from phosphate rock, the quality and quantity may be not enough for using the global scale. The new sources of phosphorus are now from waste and wastewater recovery or guano extraction. Bat guano is rich in phosphate, but it is also the cause of the outbreak of zoonoses through inhalation of fungal spores *Histoplasma capsulatum*, the health hazard that can cause various losses for humans. Policies must be made to solve the health problem from bat guano harvesting to replace the use of phosphate rock with the integrated collaboration of all relevant parties. The objective of this review is to give information nowadays about the realization of phosphorus scarcity, to manifest the advantage of bat guano as phosphorus source and also as histoplasmosis outbreak for making the decision of whether to use bat guano or not in phosphorus inadequacy issue as well as to present the safety and security policies for bat guano collection in case of bat guano will be used as phosphorus source.

Keywords: bat guano, zoonotic diseases, histoplasmosis, phosphorus scarcity, fertilizer

INTRODUCTION

In general, phosphorus seems to be eliminated more than recovered due to it is the cause of eutrophication, the environmental pollution. Nowadays, there are full of reasons that phosphorus must be recovered. Firstly, from the continued world population growth, the need of food is also in high level that require more phosphorus consumption. Phosphorous is the essential element related to growth factor of plant, the food of human and some animals, by stimulating root growth, concerning the quality of fruit and being the disease resistance (Walan, 2013). Secondly, phosphorus is also the

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important element for human because it is the component of human bodies such as bones, teeth, DNA, RNA and ATP and also for stimulating nerves system and fixing tissues (Smil, 2000). Last but not least, phosphorus is the limited element that means it cannot be constructed, destroyed or replaced by other elements, it can only be recycled or recovered (Walan, 2013) that is why phosphorus is now shortage in the current situation.

The objective of this review is to give information nowadays about the realization of phosphorus scarcity, to manifest the advantage of bat guano as phosphorus source and also as histoplasmosis outbreak for making the decision of whether to use bat guano or not in phosphorus inadequacy issue as well as to present the safety and security policies for bat guano collection in case of bat guano will be used as phosphorus source.

We thoroughly searched journals in NCBI database using keywords *Histoplasma capsulatum,* zoonoses, fungal infections, bat guano and zoonoses, bat and bat guano and bat viruses; journals in NCBI-NIH database using keywords *Histoplasma capsulatum,* bat viruses, bat guano exposure and histoplasmosis; journal also in ICI database using keyword bat and bat guano as well as journals in SCImaco using keyword fungi isolate from cave without restricted date of the publication.

LACK OF ADEQUATE PHOSPHORUS RESOURCES FOR FOOD AGRICULTURE

Lack of phosphorus used for fertilizer is the bad situation that the world will surface in the near future, therefore, phosphorous scarcity situation for food agriculture should be defined at local, national and international scales. From the estimation of global phosphorus reserves in the future by using different types of model such as exponential production models system, dynamic models and bell-shaped curve models as well as from the prediction of maximum phosphorus production by using periodic analysis such as world phosphate rock exports as percent of production, ultimate recoverable resources (URR) and other methods, they showed that phosphorus reserves tend to be reduced in the future owing to less amount and high price of phosphate rock. The global phosphate rock reserves in the future were estimated to be last for 300-400 years or maybe reduced faster than the prediction due to the uncertain growth rate of world population that makes the peak phosphorus production might reach within 2020 (Walan, 2013). For this reason, phosphorus from other sources such as the recovery from waste and wastewater as well as the extraction from bat guano are the better ways to have new phosphorus sources used to be as fertilizer in agricultural sector, but the latter way maybe the cause of zoonoses.

ZOONOSES DEFINITION AND DRAWBACKS

Zoonoses or zoonotic diseases, are an important public health concern as fungal infection for the human population (Wood *et al*, 2012). Zoonoses are the cause of various losses for humans including: loss of working days, abandonment of farming or agricultural activities, cost for diagnosis of the disease and medical fees as well as disability and mortality (Battelli, 2008).

The World Health Organization (WHO) defines zoonoses as "Those diseases and infection which are naturally transmitted between vertebrate animals

and man" and the other definitions are firstly, an occupational disease which subject to animal husbandry and related activities such as collection, transportation and extraction of manure or guano (Battelli, 2008); secondly, zoonoses means communicable diseases between human and vertebrate animals such as pets and wild animals that communicate from animals to human or human to animals (Laima, 1988). These are reasons why people should be aware of the disease related to contact with animals.

BAT AND BAT GUANO

Bats are Mammalia in the species *Chiroptera* that have mostly nocturnal activity (Vandžurova *et al*, 2012). There are two main types: megabats (*Megachiroptera*) and microbats (*Microchiroptera*) (Suwannarong and Schuler, 2016). Megabats are found in the subtropics and tropics of Asia and Africa feeding on fruit, leaves, and water. Microbats feed on insects as their primary food and they are geographically more widespread than the megabats (Suwannarong and Schuler, 2016), therefore, their guano were used as fertilizer (Kamins *et al*, 2015). Guano is the excrement produced by cave-dwelling bats (FAO, 2011) and can be used as an organic fertilizer.

Guano deposit is important to agricultural enterprise as a source of phosphorus, either as guano or rock phosphate (high percentage of phosphorus rock result from leaching guano deposits) (Richards *et al*, 2014). Composition of guano may vary depending on the diet of bats (Vandžurova *et al*, 2012).

Natural bat guano development process

Bat guano deposits located in coastal and caves. Plants are eaten by insects, which are then eaten by bats. After the digestion has taken place, the bats excrete droppings onto the cave floor which are consumed by guano beetles and decomposing microbes. This process helps to eliminate most viruses that might have passed from a bat to its fecal (Buliga, 2010).

Bat guano is a very rich fertilizer, due to its high content of carbon and the three vital primary macronutrients: nitrogen, phosphorus and potassium (N-P-K) as well as important secondary minerals such as calcium and magnesium that help control soil pH (Buliga, 2010; Shetty *et al*, 2013). Bat guano is superior to bird guano in higher nitrogen and potassium, moreover, live micro bacterial flora is another essential content in bat guano for plants which helps absorb the nutrients in bat guano and helps in resistance to plant diseases and fungi, so it is widely used in agriculture for fertilization of plants. (Buliga, 2010; Shetty *et al*, 2013).

HISTOPLASMOSIS: INFECTION AND OUTBREAK

Histoplasmosis

Histoplasmosis is an infectious disease originates from spores of *Histoplasma capsulatum* through the inhalation that can cause respiratory problems and are costly to treat (Heymann, 2004; Buliga, 2010). *H. capsulatum* grows in soils and also has been found in habitats of bats (Ajello and Weeks, 1983; Walsh *et al*, 2003). The mold form of *H. capsulatum* can affect person's lung and the fungus form can spread to other organs outside the lungs that will be the cause combination of symptoms, including headache, fever, chest pain, dry cough and loss of appetite (Steven *et al*, 2004; Mitchell, 1992). Symptom depends

on the number of spores inhaled, age of person and resistance to the disease (Steven *et al*, 2004). In some cases of receiving medical treatment, death still can occur (Wheat *et al*, 1990). Histoplasmosis can be diagnosed by identifying *H. capsulatum* in a symptomatic person's tissues or secretions, testing the patient's blood serum, urine and other body fluids for *H. capsulatum* antigen (Deepe, 2000).

Outbreak investigation

Histoplasmosis outbreaks can occur among infected people even they had no part in the activities related to contaminated aerosolized material (Chamany *et al*, 2004). Investigations of community outbreaks of fungal infection resulted in a better understanding of fungal diseases, their sources/routes and modes of transmission as well as the risk factors for the endemic fungal infections, such as histoplasmosis, blastomycosis and coccidioidomycosis that leads to more effective prevention and control strategies for further cases (Ellis *et al*, 2000).

BAT GUANO EXPOSURE AND DANGER

Harmful from bat guano

Unfortunately, bat guano is one of the energy sources for fungi development, it means that bat guano may serves as a reservoir or vector of several zoonoses (Poulson and Lavoie, 2000; Nováková, 2009).

Bats serve as a reservoir of many harmful diseases (Richards *et al*, 2014) including, Ebola and Marburg viruses (Leroy *et al*, 2005; Towner *et al*, 2007; Leroy *et al*, 2009; Towner *et al*, 2009; Hayman *et al*, 2010), severe acute respiratory syndrome (SARS)-like coronaviruses (Ksiazek *et al*, 2003; Wang *et al*, 2006; Field, 2009), Hendra virus (Murray *et al*, 1995), Nipah virus (Luby *et al*, 2009), rabies and rabies-related viruses (Wood *et al*, 2012), moreover, guano harvesting in a cave increases exposure to zoonotic diseases such as white-nose, so these are resulted in unsustainable guano harvesting practices (Richards *et al*, 2014).

Bat guano exposure

Health hazards from excreta reuse are hazard to those who expose to bats, bat guano, and bat excreta result from direct contact with bat-borne viruses (Feachem *et al*, 1983; Richard and Jenkins, 2008). Guano is hazardous to workers working in a guano cave owing to three main dangers: diseases that have transmitted from the bats to their droppings, imbedded viruses in the guano and histoplasmosis (Buliga, 2010). A person can be reinfected after re-exposure to *Histoplasma capsulatum* and a person who works or lives where airborne material contaminated with *H. capsulatum* exists can develop histoplasmosis by longer durations of exposure or exposure to higher concentrations in a short time (Wheat, 2000; Steven *et al*, 2004). The severity of infections ranges from mild to life-threatening (Carreto-Binaghi *et al*, 2015). From the study of Suwannarong and Schuler (2016) focused on which groups of people who exposed to bats and bat excreta are the risk group in the context of guano sale as fertilizer. The results showed that three groups of people were the most at risk: the guano mine operator, guano-mixing worker and the person who dry, package, and/or purchase the guano at the mine site groups.

SAFETY AND SECURITY POLICIES FOR BAT GUANO COLLECTION

Since safety and security are the important driving force for the prevention

of zoonosis from bat guano collection, the development of appropriate policies such as cave zone management, guano collection training, veterinary services establishment as well as exposure reduction must be carried on immediately. The policies are as follows.

1. Cave zone management policy

For safety and security policies, cave zone management should be a priority over other policies because the protection from any diseases should start from prevention to correction. A safety zoning means the disease free, is an important control measure of animal diseases in a form of safe trade (Fujita, 2004). There are several types of zones as follows:

A. Free zone is a zone where disease does not exist following the requirements prescribed in the international standards (Organisation for Animal Health; OIE) (Fujita, 2004). The focus of this zone is on early detection of surveillance (Edwards and Abila, 2004).

B. Control zone or surveillance zone is created to inspect the main activities and to get rid of outbreaks (Edwards and Abila, 2004). This zone is a 7 km radius from the buffer zone (Kamarudin *et al*, 2004).

C. Buffer zones focus on transportation control, surveillance to guard against new infectious diseases (Edwards and Abila, 2004). This zone is 2 km radius from the infected zone (Kamarudin *et al*, 2004).

D. Infected zone is a zone within 1 km radius from infected area (cave or farm) (Kamarudin *et al*, 2004).

We can apply a zoning to develop the policy of cave zone management by establishing four zones from inside the cave where the guano was deposited (as the infected zone) to the cave entrance (as the buffer zone) to area around the cave (as control zone or surveillance zone) and to area outside the cave (as free zone) depends on the measurement of zoonotic disease dispersion.

2. Bat guano collection training

Bat guano collection training must be performed to promote human resource development by raising health and safety issues in discussion in with workers and the persons related to bat guano collection and promoting the awareness of disease from guano harvesting (Suwannarong and Schuler, 2016). Moreover, lesson learning manual about the practice of gathering bat guano, common pastures (Battelli, 2008) and disease spread protection (Meslin and Formenty, 2004) should also be produced and distributed to this group of people. Community knowledge and perceptions of the risks associated with bats should be provided to people who live or present near the caves (Suwannarong and Schuler, 2016) to realize the importance of zoonotic disease reduction and to make decisions about management techniques that could prevent this disease in guano-mining communities (Woods, 2004).

3. Establishment of veterinary services

Veterinary services establishment should be included in the policies to develop appropriate procedures and standards for safe and suitable guano collection by performing the risk analysis, disease outbreaks prevention and control as well as epidemiological surveillance (Fujita, 2004).

The prevention of disease outbreaks should concentrate on notification of diseases, health education and information, diagnosis and therapy of human pathologies, eradication and pasteurization that can lead to the gradual decrease in the number of diseases (Battelli, 2008). Mini-

mizing the transmission of microorganisms from wild animals to humans must be realized for human wellbeing and environmental sustainability Public health and environmental science perspectives should be needed to elucidate how people interact with bats couple with agricultural view (Wood *et al*, 2012).

Epidemiological surveillance and suspected disease outbreaks investigation. The epidemiological surveillance is a continuous recording method of population which used to follow up the health situation or the risk factors in time and space to provide the appropriate actions (Romain, 2004). Population-based surveillance such as fungal diseases surveillance, although it is expensive and may be difficult to conduct, it can provide accurate incidence rates and better descriptive epidemiology due to it can be used to define burden and trends, to evaluate interference as well as to detect new pathogens (Ellis *et al*, 2000).

Suspected disease outbreaks should be investigated from hypotheses about the cause and source of the outbreak (Ellis *et al*, 2000) along with using laboratory diagnostic capabilities (Hussein, 2004) and should create risk management framework to deal with future outbreaks.

4. Exposure reduction policy

There are three solutions to solve the problem of "How can we do to reduce *H. capsulatum* exposure?"

A. Controlling airborne material when removing bat guano from a cave. Excavation process can result in aerosolized dusts containing *H. capsulatum* spores and can cause infections not only in persons on work site, but also in other areas around. The best way to prevent *H. capsulatum* spores is to keep a distance from situations where contaminated material can become aerosolized and then be inhaled. The other solution is water sprays or other dust suppression techniques. Moreover, work practices also help deplete the risks of infection, for examples, wetting contaminated material with water spray and collect it in a plastic bag. For large accumulations of bat manure, industrial vacuum bag and truck-mounted or trailer-mounted vacuum systems are recommended. During windy periods, respiratory protection such as air filters should be inspected for the work site persons (Steven *et al*, 2004).

B. Wearing personal protective equipment. Using personal protective equipment is still necessary in case of work practices and dust control have not been fully evaluated. Wearing a NIOSH-approved respirator (NIOSH = National Institute for Occupational Safety and Health) and other items during collection of bat manure from an enclosed area such as cave is to protect *H. capsulatum* exposure. In addition, the types of respirator are available with half-facepiece, full facepiece, loose-fitting facepiece, hood and helmet. The other personal protective equipment that workers should wear are clothing and shoe coverings that can reduce the possibility of transferring *H. capsulatum* spore dust from work site to other places, wearing chemical-resistant gloves is recommended when working in a spore-contaminated area (Steven *et al*, 2004).

C. Using other method than the disinfectants. Formaldehyde solution was the only disinfectant that was used to disinfect *H. capsulatum* contaminated soil and material (Tosh *et al*, 1966; Tosh *et al*, 1967; Bartlett *et al*, 1982). However, exposures to formaldehyde can cause a variety of adverse health effects. Thus, a number of EPA-registered fungicidal products contain formaldehyde is not registered for use as disinfectant. Fur-

thermore, there is no chemical that claimed by EPA (Environmental Protection Agencies) of being effective against *H. capsulatum*. In this case, any material that tends to be contaminated with *H. capsulatum* should be properly and safely disposed or decontaminated as well as not be moved to other areas (Steven *et al*, 2004).

CONCLUSION

Bat guano deposit is another choice of seeking phosphorus for use as fertilizer in agricultural sector to produce food in global scale, owing to its natural availability and has high phosphorus content. Management of health safety and security of zoonotic diseases from bat guano collection by developing the policies such as cave zone management, guano collection training, veterinary services establishment as well as exposure reduction can help this choice to be the most sustainable way suits for the situation that phosphorus from apatite rock reserve is now lacking all over the world and will finally deplete. Furthermore, the integrated collaboration from all parties such as research teams, government and agencies should be made to manifest the safety act, to avoid added time and cost of treating disease and to promote safe guano collection that give tremendous benefits of using guano as fertilizer along with answer the question of traceability and credibility of guano harvest, otherwise inadequate phosphorus source or ineffective using guano as fertilizer will be occurred.

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