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Phosphorus distribution and loss in the livestock sector – The case of Thailand

Nuchnapa Prathumchai[a], Chongchin Polprasert[b,d,*], Andrew J. Englande Jr.[c]

[a] Faculty of Public Health, Mahasarakham University, Thailand
[b] Department of Sanitary Engineering, Faculty of Public Health, Mahidol University, Thailand
[c] Department of Global Environmental Health Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, LA, 70112, USA
[d] Center of Excellence on Environmental Health and Toxicology, Rajvithi Road, Bangkok, 10400, Thailand

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ABSTRACT

Mass balance analysis of phosphorus (P) flows in livestock activities in Thailand was conducted with the aim to determine quantitatively its current status coupled with recovery and recycling potentials. From the total average P input to the Thai livestock sector of 126,343 t P y^{-1}, over 90% of these quantities come from animal feed, while the remaining is from the import of animal products. After animal feed P is contained mostly in (a) manures (103,114 t P y^{-1}) of which 96% are recycled to cultivation fields, (b) animal products (meat, milk, and eggs) (8120 t P y^{-1}), (c) solid waste and wastewater released from processing plants (1201 t P y^{-1}) and (d) unidentified loss during animal husbandry activities (13,908 t P y^{-1}). Products produced from the livestock sector are delivered to the domestic market (89%) and exported (11%). The manures recycled, however, contribute to only 41% of the country's P fertilizers applied on crop lands. The overall mass balance for Thailand's livestock ecosystem indicates a P utilization efficiency of 88%. Concurrently, the livestock ecosystem exhibits an annual loss of 15,311 t P y^{-1}. The greatest loss of about 39% occurs in layer hen husbandry activities; while, the highest loss per ton product is due to layer duck farming. Based on the findings of this work it is recommended that minimization of P loss, especially from husbandry farms, via maximization of P recycling be the focus of future research. Results should be aimed at reducing P imports needed for food cultivation and curtailing pollution causing eutrophic environments.

1. Introduction

Thailand is an agricultural-based country in which cultivation and livestock play a major role in the livelihood of Thai people occupying about 47% of the country's territory (OAE, 2013). Its agricultural activities have developed from small-scale production for family consumption in the past to large-scale production at present with their products being used for both export and domestic consumption. After plant cultivation livestock production in Thailand is growing very rapidly so as to provide proteins for human consumption, employment, income and foreign exchange (ODI, 2011). Its practice has shifted from backyard animals and integrated crop-livestock farming systems to industrial livestock farming enterprises, although the extent of this development differs among livestock species (DLD, 2013a). For instance, swine, as well as broilers and layer hens, are now produced mainly by large agribusiness companies for the export markets. Despite the fact that agricultural products bring in large sums of revenue, Thailand must import over five million tons of chemical fertilizers (N, P, and K) from abroad as to enable its production activities (OAR, 2014).

Meanwhile P is known to be an essential nutrient for agricultural production of food and feed (Cooper and Carliell-Marquet, 2013; Linderholm et al., 2012; Seyhan, 2009). However, it is a non-renewable and finite resource derived from mined phosphate rock (PR) (Chowdhury et al., 2017; Cooper et al., 2011; Egle et al., 2014). Currently, 85% of PR reserves are controlled by only four countries, i.e. China, Morocco and West Sahara, United States, and Russia (Manschadi et al., 2014). It has been claimed that global commercial phosphate reserves will be depleted in the near future (Wu et al., 2015). Nevertheless, actual estimates of PR reserves depletion are uncertain, from the critical point occurring in 50–100 years to 300-400 years (Cordell et al., 2009; Kauwenbergh, 2010; Seyhan et al., 2012). This may lead to severe issues on phosphorus shortage, ranging from higher price and eventual concern regarding global food production and food security, especially in the countries with limited RP deposits which include Thailand (Thitanuwat et al., 2016).

Studies on P input-output and material flow analysis (MFA) have

* Corresponding author at: Department of Sanitary Engineering, Faculty of Public Health, Mahidol University, Bangkok 10400, Thailand.
E-mail addresses: nuchnapa.p@msu.ac.th (N. Prathumchai), chongchin.pol@mahidol.ac.th (C. Polprasert), aenglan@tulane.edu (A.J. Englande).

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extensively been carried out in a number of countries; i.e., Australia (Chowdhury et al., 2018; Cordell et al., 2013), European Community (EU15) (Ott and Rechberger, 2012), China (Wu et al., 2014), France (Senthilkumar et al., 2014), and Sweden (Schmid Neset et al., 2008). Depending on geographical locations, different countries exhibit different mass flows and transformation pathways of phosphorus movement (Chowdhury et al., 2014). In France, P flows were monitored in the food processing industries and urban communities to evaluate P recycling efficiency (Senthilkumar et al., 2014). P transforming processes (animal and plant productive, household and industrial processing, consumption and waste handling) were examined in Linkoping, Sweden to determine the per-capita amounts of P consumed, lost, and recycled (Schmid Neset et al., 2008). Contrastingly, a material flow analysis for P in food consumption in two megacities in northern China indicated that P was accumulated in cities at about 64% of the total inflow (Qiao et al., 2011).

Because animal manures contain significant amounts of the primary nutrients (N, P, and K) as well as other essential plant nutrients, they are an excellent nutrient source for crop growth. The studies of Smil (2000); Liu et al. (2008), and Bateman et al. (2011) report that animal wastes have been identified as being a significant global reservoir of reusable P with animal manures having the potential to supply up to 50% of all phosphorus required for agricultural use in Western Europe and 25% of that required for the United States.

Currently, a few studies on P flow analysis in Thailand have been conducted. They include P flow in its urban and fisheries sectors but not for livestock and cultivation, although the majority of P import is consumed for this purpose (Prathumchai et al., 2016; Thitanuwat et al., 2016, 2017). Moreover, excessive concentrations of P can be harmful to the environment because it is a stimulating nutrient which can result in eutrophic conditions in natural water courses (Reijnders, 2014; Scholz and Wellmer, 2015; Theobald et al., 2016). Thus, questions arise as to whether or not P released from this sector is the major cause of many environmental problems; and if so, where and what measures should be implemented to address these issues.

Many studies of P flow analyses exist for agricultural activities conducted

at different geographical scales (Chowdhury et al., 2014). Most researchers evaluate the total P flow through the livestock system. However, individual species are typically not considered and quite often the livestock sector is treated as a small subsystem "black box" within the agricultural sector. Sometimes its evaluation is combined with larger and more important industrial and urban sectors. As a result, the detailed P flows of many animal species are seldom elucidated to indicate what species, where and how much P loss occurs during the process of P-production transformation. This consequently makes it difficult for management to determine the practical actions needed for sustainable farming. In addition, most of the studies mentioned above employ only a single-year data set in their investigation. These might preclude long-term oscillatory effects on P flows for several species, thereby potentially leading to mistaken information used for planning sustainable P management programs of livestock breeding. Such effects depend on socioeconomic and/or environmental factors, e.g., politics, trade sanctions and, in certain circumstances, epidemics like bird flu or foot-and-mouth disease. These may result in cessation of P flow of the infected species for at least a harvest year or more. Thus, this work was carried out as to fulfill the aforementioned gap by which the livestock system of each species was investigated thoroughly from animal feeds until the consumer's end products (meat, egg and dairy products). Field surveys were conducted to evaluate not only regarding animal husbandry but also material processing in the relevant agro-industrial factories. This baseline information may be very useful to identify key points (e.g., P loss, P recycle, and P stock) of P flow which is a requisite for making better P management decisions. A mass balance analysis of P flows in the livestock activities of Thailand, therefore, was conducted with the objective to determine its current status in Thailand`s livestock ecosystem and to quantify the potential recovery, recycling and losses of P output. As this is a pioneering study of the country's phosphorus balance in livestock breeding, results of this work may assist decision makers in setting policies and developing strategic frameworks towards sustainable P management for its livestock sector.

2. Methodology

2.1. Livestock background

The Thai livestock system includes various types of agricultural farms either as specialized animal farms or as mixed with cropping activities. Previously, indigenous livestock had an important role in small-holder farms in local communities. Animal products and by-products were only produced to meet household needs. But at present, livestock production has switched from backyard systems to industrial husbandry. In parallel, new technology is imported to improve the production performance for economically important trades. Indigenous livestock is therefore gradually used for crossbreeding and are becoming completely replaced with commercial breeds. Seven major livestock species were selected in this study and include cattle, dairy cow, swine, broiler, layer hen, meat duck and layer duck. Based on annual productivity, the quantity of their products amounts to over 90% of meat and dairy products totally produced in Thailand (DLD, 2013b).

Poultry is estimated to represent about 55% of the total meat production in Thailand (OAE, 2015). The industry has been transformed from backyard farming for household consumption into a leading exporter. Chickens (broiler and layer hens) and ducks (meat duck and layer duck) are the major species of poultry in Thailand. The principal area for poultry production is the central plains region where more than 62% of poultry are raised. Generally, chicken broilers are reared on the farms for about 140 days to attain a weight of approximate 2.7 kg per head prior to being transported to slaughter houses (DLD, 2013a). Commercial swine production in Thailand has been greatly improved to meet the requirements of market standards. It has increased 0.4 percent per year between 2004 and 2013, reaching a quantity of approximately nine million pigs per year. Normally, pigs spend about 170 days to grow on the farm (DLD, 2013a). After a weight of 100 kg is reached, they are transported to slaughter houses. Also, the average numbers of cattle and dairy-cows in the country are found to be 4,531,000 and 532,800 head, respectively. Most cattle farms are densely located in the Central and Northeastern region of Thailand. Confined feedlots under controlled grazing and extensive grazing systems are currently widely used for animal husbandry (DLD, 2004, 2013b). However, meat and milk produced from cows in Thailand are not sufficient for domestic consumption and must be imported from abroad. Mass quantities of import and export of meat and dairy products are summarized in Table 1.

2.2. Analytical framework

P inputs studied come from three sources: animal feeds, imports of minerals and vitamins and imports of meat and livestock products. Animal feed, which is a key source of P input into the livestock sector, contains protein, minerals, vitamins, and other nutrients. These are useful for meat and milk production as well as survival and growth of the animals. The basic raw materials required for the production of animal feed include maize, soybean meal, broken rice, rice bran, and others. Although Thailand has ample raw materials needed to produce animal feed, some are imported from abroad. P outputs of animal farms range from animal products, manures and other losses. Animal products include such items as meat, blood, milk and eggs. About 80% of P is found in bone and teeth. The remainder is widely distributed throughout the body in combination with proteins, fats and inorganic salts. Animals satisfy their P needs from plant products and feed supplements. P is then lost directly through animal products and manures.