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Livestock housing and manure storage need to be improved in China

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Improving livestock housing and manure storage is essential for reducing environmental and human health impacts of animal production in China

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Feeding a burgeoning human population with limited land and water is always a challenge, but especially for China, where *per capita* arable land and fresh water reserves are much lower than world averages. China has strongly increased the production and *per capita* consumption of animal-source food, but improper management of animal manure has resulted in excessive losses of nutrients to the environment. These losses cause severe pollution of: i) air, via ammonia (NH_3) emissions that contribute to smog and eutrophication, and via methane and nitrous oxide emission that contribute to climate change; and ii) water, via direct discharge of manure to watercourses and leaching of nitrate (NO_3^-), causing nitrate accumulation in drinking water[1-4].

Current polices related to nutrient management

China has learned that poor nutrient management has an environmental cost. The government recently introduced several legislations to control air and water pollution and the use of chemical fertilizers. These legislations include "Ten-Point Air Plan" (http://www.gov.cn/jrzg/2013-09/12/content_2486918.htm), "Ten-Point Water Plan" (http://www.gov.cn/zhengce/content/2015-04/16/content_9613.htm), and "Zero Increase Action Plan"[3]. Most of these regulations have the point of fertilizer application at fields, greenhouses and orchards, but so far miss livestock housing and manure storage systems.

According to data for 2010[3], animals excrete 19 Tg nitrogen (N) and 4.1 Tg phosphorus (P) in housing annually. Livestock production in China is rapidly expanding, however, little has been done to improve manure management. Direct discharge of manure to surface watercourses continues to be seen on farms, and housing and manure stores continue to be left unattended to emit N. We believe that environmentally sustainable animal food production must include proper manure management. Improvements must be made in livestock housing and manure storage in order to reduce losses of manure N and P to air and waterbodies.

Nitrogen losses from livestock housing and storage

High atmospheric PM2.5 concentrations are of major concerns for China[2]. Ammonia plays an important role in the formation of secondary inorganic aerosols, a main component of $PM_{2.5}$[2]. Reducing NH_3 emissions is therefore an effective approach to decrease $PM_{2.5}$ concentrations. Estimates suggest that livestock production in China emitted 6.7 Tg NH_3-N in 2010, equivalent to 49% of the total NH_3 emissions from agriculture[3]. Housing systems and manure storage are the major sources of NH_3 emission, representing up to 73% of the total NH_3 emissions from livestock production. Inadequate manure collection and storage are the main sources for the release[3] (see also Fig 1). In addition, manure treatment and application accounted for 0.8 and 1.0 Tg NH_3-N, respectively (Fig 1a). The externality costs of NH_3 emissions from housing and manure storage to human health in China is estimated at $26-106 billion annually, based on the approach of the European Nitrogen Assessment[5], and ought to be considered against the costs of implementing mitigation strategies.

A large proportion of the rivers, lakes and coastal waters in China are suffering from severe eutrophication. Approximately 46% of the rivers in China were classified as harmful for direct human contact[1]. The nutrients causing eutrophication are mainly emitted from industrialized animal production systems, which are becoming increasingly disconnected with crop production. Direct manure discharge into surface waters accounts for over two-thirds of the N and P in the northern rivers and for 20–95% of the N and P in the central and southern rivers[2]. In 2010, 5.5 Tg of manure N entered the surface water system, with 97% from livestock manure seepage and direct discharge from housing and manure storage. The other 3% was came from manure application through runoff, erosion etc. (Fig 1a, c). Direct discharge of manure results mainly from the lack of i) enforcement of regulations for manure storage capacity, ii) obligation to recycle manures back to crop production, iii) appropriate monitoring and control, and iv) appreciation of the fertilizer value of manures[3-4].

In a recent study[1], 62% of the drinking water wells monitored in China exceeded the 50 mg L^{-1} standard set by the World Health Organization[1]. The main sources of nitrate in drinking water wells identified by isotopes are agricultural fertilizers, untreated wastewater, and livestock manure[1]. N losses from livestock housing and manure storage are larger than losses occurring during manure treatment and land application (Fig 1a). In an analysis of soil cores from the edge of a 20-year old layer hen manure store, NO_3^--N was 50 to 130 mg kg^{-1} in the top 100 cm soil, greater than in the soil of a nearby 30-year old fertilized wheat-maize rotation system. Similarly high soil NO_3-N concentrations were found near a 12-year old dairy manure store (Fig 1b). There also might be higher soil organic N concentrations nearby the manure storage places. The soil nitrate concentration would be even higher at the center of these manure stores. Clearly, current livestock housing and manure storage in China pose a great threat to groundwater quality. The estimated externality cost associated with surface water eutrophication and groundwater pollution is $40-159 billion annually[5].

Implications for research and practice

Manure management must be improved in China. A systems approach is needed to reduce losses of manure N and P[3]. Improved manure management focused on livestock housing and manure storage would greatly reduce N losses in NH_3 emissions, discharge of manure and NO_3^- leaching. It would also contribute to the implementation of the 'Zero Increase Action Plan' as a result of increased manure N and P recycling and reduced use and manufacture of synthetic N and P fertilizers. Proper manure management requires the understanding of N and P loss pathways, mitigation mechanisms and options in animal housing and manure storage, and of the loss vulnerability of different production systems, including traditional, mixed and industrialized landless systems. Policy makers, scientists and farm managers need to work together to develop standards and regulations for livestock housing and manure storage systems. Adoptions of cost-effective technologies are necessary. The use of manures as fertilizer and soil conditioners should be promoted in crop production systems. We also recommend that governmental subsidies currently used for synthetic fertilizer N and P production be redirected to renovation of livestock housing and manure storage facilities, and to infrastructure development for manure treatment, transportation and application to cropland. Improvements in manure management would contribute to significant reductions in manure N and P losses, greenhouse gas emissions, and losses of other nutrients (such as potassium), and at the same time would contribute to soil carbon sequestration and a decrease in the use of synthetic fertilizer. The investments required for improved manure management ought to be considered relative to the externality costs of the current mismanagement of manures.

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Notes

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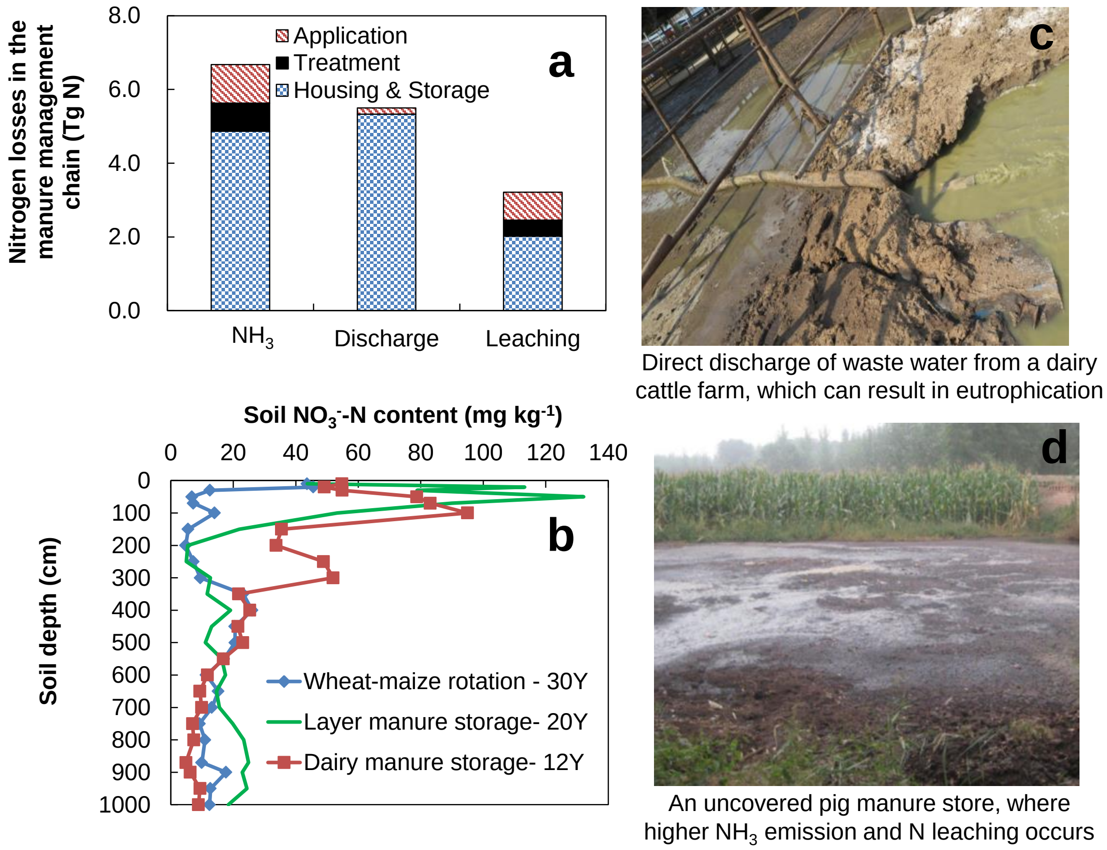

Fig 1. Total nitrogen losses from the manure management chain in China in 2010 (a), NO_3^-N contents of different soil depth from different management systems in North China Plain (b), direct discharge of manure from a dairy farm (c) and an uncovered cattle manure store (d) in the North China Plain (in 2016).

Note: a, derived from Bai et al., 2016; b, derived from on farm sampling and laboratory analysis in 2016.