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Amount and Utilization of Manure in Livestock and Poultry Breeding in China

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Abstract: The unreasonable discharge of manure from livestock and poultry breeding is the main source of agricultural non-point source pollution in China; however, manure is also a potential resource. Optimizing the resource utilization of livestock manure and reducing environmental pollution have become important issues that must be addressed for the sustainable development of China's breeding industry. In this paper, the pollutant discharge coefficient method is used to calculate the amount of manure produced by livestock and poultry breeding in China, and the current situation and problems of its utilization as a resource are analyzed. The results showed that with the expanding scale of livestock and poultry breeding farms and their continued intensification, livestock manure resources have increased significantly. In 2015, the amount of manure produced by large-scale livestock and poultry breeding was 3.834×10^9 t, comprising 6.36×10^8 t of fresh manure, 5.65×10^8 t of urine, and 2.633×10^9 t of sewage. The total amounts of nitrogen and phosphorus in livestock and poultry manure in China were 1.229×10^7 t and 2.046×10^6 t, respectively, with the highest production in Henan Province, followed by Shandong, Hebei, Sichuan, and Hunan provinces. The livestock manure was mainly utilized as fertilizer, fuel, and forage. We investigated and studied the current situation of livestock and poultry manure utilization and analyzed and proposed suggestions to the problems regarding the resource utilization of livestock manure.
Keywords: livestock and poultry breeding; manure; nitrogen; phosphorus; resource utilization

1 Introduction

As the average person's living standard is improving, the animal husbandry industry is developing rapidly. Meat, egg, and milk farming generates a large quantity of waste, which is becoming the main source of Chinese agricultural non-point source pollution [1]. This is occurring in both developed and developing countries. In the 1960s−1970s, pollution from livestock and poultry breeding began to appear in many countries and districts of the world with the development of animal husbandry [2−4]. Livestock and poultry waste have become the main sources of environmental pollution in areas with a high density of livestock and poultry breeding. For example, annually, there are 8×10^7 t of livestock and poultry manure requiring treatment in the UK, from which 0.119×10^6 t of P is recyclable. The density of animal husbandry in southern Holland is the highest, where problematically, the output of livestock and poultry manure greatly exceeds the load bearing capacity of farmland. It is reported that in Holland, the annual total output of manure was 9.5×10^7 t, with 1.5×10^7 t in excess of the demand. In Belgium, 4.1×10^7 t was produced, with an excess of 0.8×10^6 t. Brittany Province, France, accounts for 40% of the intensive animal

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husbandry in the country. In the early 1980s, there was only one district in this region where the nitrate content in drinking water exceeded the standard; however, in 2005, there were six districts with drinking water exceeding the standard, and 21 districts approximately exceeding the standard. In the US, the waste from husbandry farms is 130 times that from human living, which is a great threat to the local ecological environment. In China, there is a great deal of stockpiling of livestock and poultry manure, indicating a low utilization rate, and the effects on the environment are widespread. In parts of China, the pollution from livestock and poultry breeding has exceeded those from suburban resident living and crop planting. Thus, livestock and poultry manure pollution is one of the main causes of water pollution [5].

Although livestock and poultry manure are regarded as environmental pollutants when discharged unreasonably, they become a resource when used in fields as a fertilizer for crop production. It can displace chemical fertilizers to consistently supply nutrients to crops and increase the soil organic matter content. This paper analyzes and discusses the important issues of the resource usage and arable land bearing capacity of manure, on the basis of computing the output of livestock and poultry excrement and urine.

2 Current situation of livestock and poultry manure output in China

2.1 Method for calculating the output of livestock and poultry manure and sewage

Over the past decade, many studies have been conducted on the national or regional output of livestock and poultry manure and the evaluation of its effects on the environment. Most of these studies used the pollutant discharge coefficient method [6,7]. Among the studies, there was substantial variation in the results of the total amounts of excreta, N, and P from livestock and poultry. The main reasons leading to these deviations were as follows: some species of livestock and poultry were excluded (most studies only took swine, cattle, chicken, and ducks into account, but disregarded the others); differences among pollutant generation and discharge coefficients and feeding periods; slaughter and stock numbers were not distinguished or were miscalculated or omitted from the calculations; and in some studies, the slaughter and stock numbers for the same livestock or poultry variety were calculated concurrently, and double counting occurred. Over the past few years, traditional household breeding has changed to large-scale and intensified breeding, and this has led to a significant increase in livestock and poultry pollution. The daily amounts of animal feces and urine produced vary with the species, age, body weight, feedstuff, region, and season.

The national and provincial statistics data from the *China Rural Statistical Yearbook – 2015* were used. The selected livestock and poultry were swine, cattle, fowl, and sheep, which have a major influence on agricultural production and the environment. The items for computation were the amount of slaughtered swine, stock cows, slaughtered cattle, stock poultry, and stock sheep. The pollutant discharge coefficients of solid feces, urine, N, and P from livestock and poultry were mainly referred to in the results of *The First National General Survey of Pollutant Sources* from 2009 [8,9]. The calculation of annual pig discharge volume was calculated based on the ratios of piglets, fattening swine, and sows in a hoggery of 10 000 heads, as well as the corresponding pollutant discharge coefficients. The pollutant discharge coefficient for cows was calculated using the mean of that for breeding cows and dairy cows. The breeding days of cows, beef cattle, egg fowl, and sheep were 365 d. The calculation of annual poultry manure generation was based on rearing 3/4 of the total amount for 50 d and the remaining 1/4 for 365 d. According to the investigation by the Ministry of Agriculture and Rural Affairs, the annual sewage outputs of swine, cattle, and poultry were 5.26 t/head, 0.46 t/head, and 0.001 t/feather, respectively.

2.2 Solid feces and urine output of livestock and poultry

Based on the total data from 2015, the national manure and sewage output from swine, cows, beef cattle, and sheep were 5.687×10^9 t, of which fresh feces, urine, and waste water comprised 1.019×10^9, 8.9×10^8, and 3.778×10^9 t, respectively. According to the criterion used in the first general survey of pollutant sources from 2007, intensive-scale livestock farm sizes were at least 50 swine, 5 cows, 10 beef cattle, 500 stocked laying hens, and 2000 broiler chickens. Mutton sheep were not included in the survey. According to the above division criterion, the percentages of intensive-scale livestock and poultry breeding farms in China were 69.9%, 81%, 85.6%, 57% of the total for swine, layers, broiler chickens, and cows, respectively. The corresponding data on beef cattle and mutton sheep were not found and were assumed to be 50% and 80%, respectively. Based on these estimations, it was concluded that intensive-scale livestock and poultry breeding manure and sewage output in 2015 was 3.834×10^9 t, of which fresh feces, urine, and sewage comprised 6.36×10^8 t, 5.65×10^8 t, 2.633×10^9 t, respectively.

When considering these values without the sewage, the feces and urine produced by livestock and poultry in 2015

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was 1.91 × 10^9 t, of which swine, cattle, fowl, and sheep accounted for 6.5 × 10^8 t, 0.92 × 10^8 t, 9 × 10^7 t, and 2.5 × 10^8 t, being 33.9%, 48.3%, 4.7%, and 13.1%, respectively. If the sewage discharge was considered, the total livestock and poultry excreta and sewage output was 5.687 × 10^9 t, of which the total discharges of swine, cattle, poultry, and sheep were 4.37 × 10^9, 9.7 × 10^8, 9.639 × 10^7, and 2.5 × 10^8 t, accounting for 76.8% 17.1%, 1.7%, and 4.4%, respectively.

Among the different regions (Fig. 1), the largest amount of livestock and poultry feces and urine output (no sewage included) was in the Henan Province, followed by Sichuan, Hunan, and Shandong provinces, all exceeding 1 × 10^8 t; there were 11 provinces with an output of between 5 × 10^7 −1 × 10^8 t, with the sequence in decreasing order being Yunnan, Hubei, Hebei, Guangxi, Heilongjiang, Inner Mongolia, Liaoning, Guangdong, Jilin, Jiangxi, and Guizhou. There were 16 provinces with an output of less than 5 × 10^7 t. Locations with less than 1 × 10^7 t were Shanghai, Beijing, and Ningxia. The other provinces were in the range of 1 × 10^7–5 × 10^7 t.

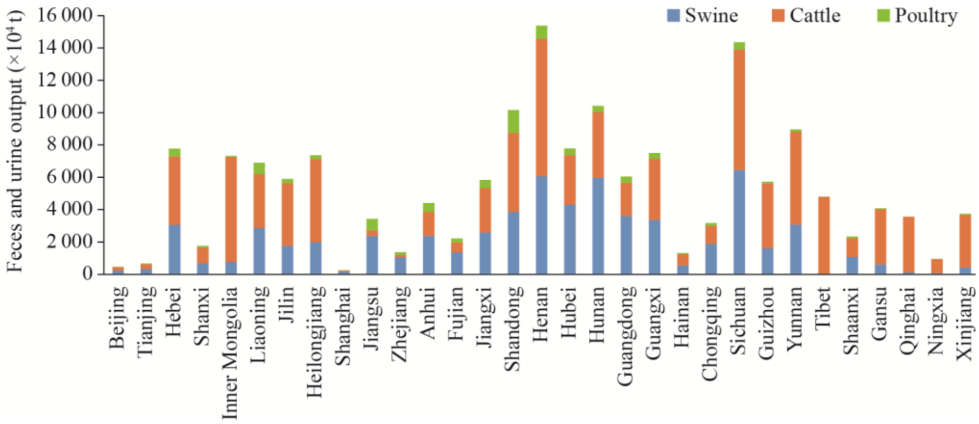

Fig. 1. Livestock and poultry feces and urine output in different provinces in 2015.

Considering the proportion of feces and urine output of different livestock and poultry (Fig. 2), the proportions of swine feces and urine output exceeded 60% in Zhejiang, Jiangsu, Shanghai, Fujian, Guangdong, and Chongqing, and was approximately 50%−60% in Hunan, Hubei, Anhui, and Beijing, where swine excreta handling and usage must be improved. The higher proportions of cattle feces and urine occurred mainly in northwest China, with 10 provinces exceeding 60%: Tibet, Qinghai, Ningxia, Inner Mongolia, Xinjiang, Gansu, Heilongjiang, Guizhou, Jilin, and Yunnan; six provinces were between 50%−60%: Henan, Shanxi, Hebei, Hainan, Guangxi, and Sichuan. For other provinces, the value was less than 50%, and the lowest proportions appeared in Jiangsu and Zhejiang, being only 10%−11%. The provinces with the highest proportion of fowl droppings in the livestock and poultry excreta output were Jiangsu, Shandong, Zhejiang, Anhui, Fujian, and Liaoning, all having more than 10%; other provinces had less than 10%.

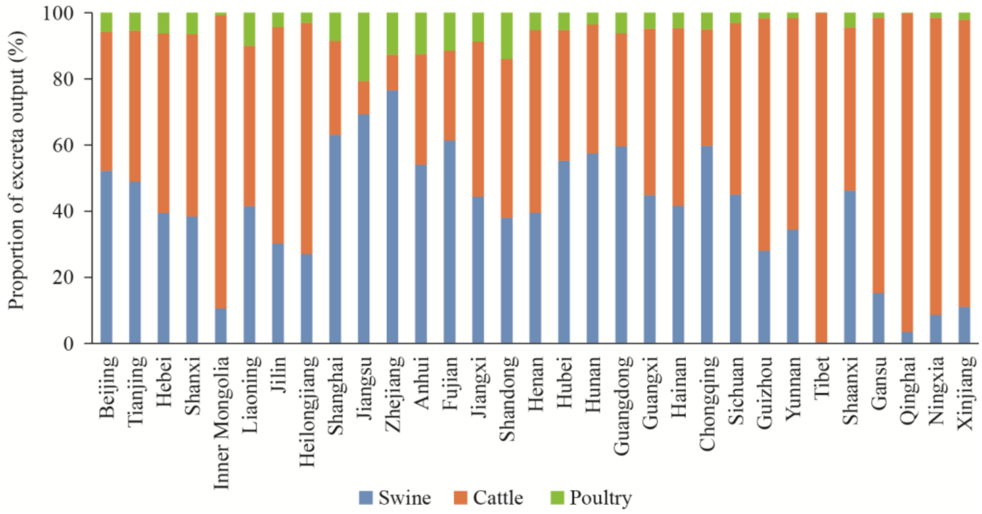

Fig. 2. Proportion of excreta output of different species of livestock and poultry in different provinces in 2015.

3 Analysis of nutrient resources in livestock and poultry feces and urine

3.1 Current situation of resources in livestock and poultry excreta

Livestock and poultry breeding in China are developing rapidly. Over the past 65 years, the number of cattle, swine, sheep, and fowl increased by 1.98, 7.53, 7.11, and 27.96 times, respectively. The amounts of both stock and slaughter pigs are the highest of any country, accounting for half of the global total.

The N and P contents in livestock and poultry feces and urine in China were calculated using the pollutant discharge coefficient method [8]. The total amounts of N and P outputs were 1.229×10^7 and 2.046×10^6 t, respectively, generated by feces and urine resources from swine, cattle, sheep, and fowl in China. The data for each province are shown in Fig. 3, in which the highest output was in Henan Province, followed by Shandong, Hebei, Sichuan, and Hunan provinces.

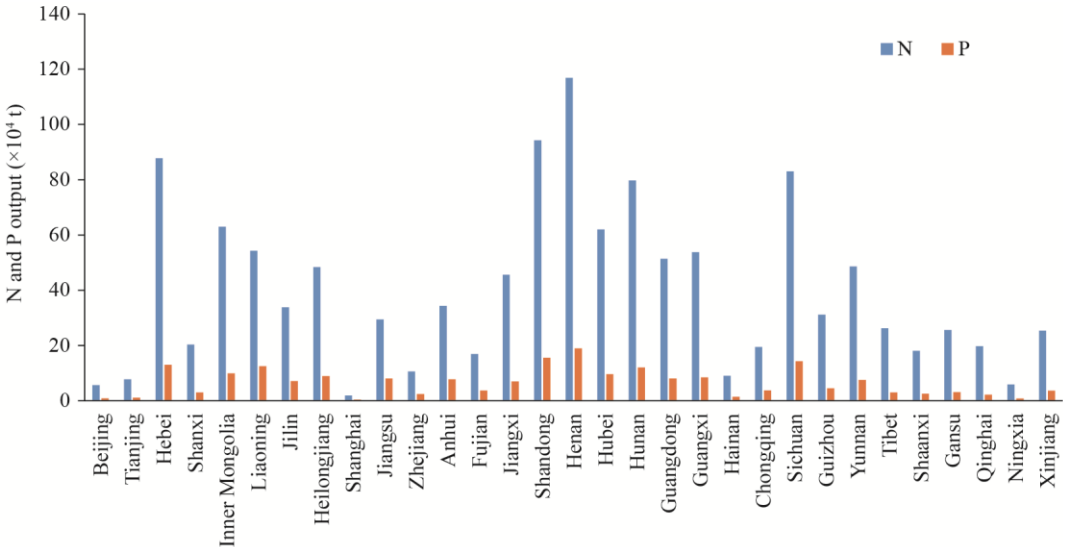

Fig. 3. N and P outputs from livestock and poultry breeding in different provinces.

The livestock breeding scale is changing from household breeding, which dominated in the past, gradually to large-scale or intensive farms. In the early 21st century, more than 50 000 large-scale breeding farms appeared. Over the past decade, these developed have more quickly, especially swine farms. Large-scale livestock and poultry breeding farms are favorable for the treatment of manure with advanced equipment, and the promotion of resource utilization of livestock and poultry manure.

3.2 The manner of resource utilization of livestock and poultry manure

China is the country with the highest amount of stock pigs and slaughtered swine in the world, and concurrently has a large number of crop plantings. The balance between crop-planting and livestock-raising can not only enhance soil quality and decrease chemical fertilizer input, but also alleviate environment pollution. The integrated utilization of waste from livestock and poultry breeding is one of the most important issues in China. It is conducive to alleviating prominent environmental problems, promoting the realization of circular agriculture, saving resources, and protecting the environment. Treating and converting livestock and poultry waste into fertilizer, feedstuff, or energy resources can generate large economic value and social benefits, and decrease environmental pollution.

3.2.1 Manure fertilizer produced from livestock and poultry feces

Livestock and poultry feces contain large amounts of organic matter, N, P, K, and micronutrients, which can enhance crop growth and improve soil fertility. Early research showed that livestock and poultry feces were already composed at the edge field and then applied to the field as fertilizer [10]. Manure fertilization is the main method of resource utilization from livestock and poultry feces and urine.

Before the reform and opening-up policy was implement in 1978, livestock and poultry breeding in China were mainly operated at the household level, and manure was applied to the nearby fields. With the increasing demand for meat, eggs, and milk, an increasing number of large-scale breeding farms have appeared in the suburbs, and treatment methods of livestock and poultry manure began to change.

The traditional compost technique occupied a large area for a long period, and the odor produced from the

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compost could not be confined. This disadvantage limited its application to large-scale breeding. The industrialized composting process under high temperature and aerobic conditions has a fast decomposition rate, shorter fermentation period, and best pathogen mortality. All of these advantages make it the first choice for the composting of manure. High temperature and aerobic composting are a technology in which the organic matter is converted into fertilizer and humus can be synthesized as an important active substance for improving soil fertility. This is a relatively mature technology for the utilization of livestock manure resources. According to incomplete statistics by the Ministry of Agriculture and Rural Affairs [11], at the end of 2015, there were 2961 organic fertilizer production enterprises. Currently, more than 65%−75% of the feces from large-scale livestock and poultry farms are mainly stored or manufactured into organic fertilizer for crop production [12].

3.2.2 Energy produced from livestock and poultry waste

Livestock and poultry manure can be used as a biomass energy source. After development and utilization, it can partly replace the original resources, reduce the dependence on non-renewable resources, and realize the sustainable use of resources. Manure of livestock and poultry used as energy is mainly adopted in large-scale breeding farms by methane engineering. Most of the organic matter can be decomposed by anaerobic fermentation. The methane gas produced can be used as energy to burn and generate electricity. The biogas residue and biogas slurry byproducts can be applied as fertilizer and returned to crop fields. Finally, all of the components are used effectively.

With the increased energy demand in rural areas, rapid development of the large-scale breeding industry, and increasing pressure on environment management, methane engineering with manure as a raw material is developing rapidly and supported by national policies and funds. In short, the use of methane technology in the comprehensive handling of sewage not only solves the pollution problem caused by large-scale breeding, but also uses sewage as a resource. Both ecological and economic benefits can be achieved. Compared with that being used as a fertilizer, the proportion being used to produce methane is still very small, accounting for only 1% of the manure from large-scale breeding farms in China [12].

3.2.3 Feed produced from livestock and poultry manure

Because of the crude protein, coarse fiber, pure protein, crude fat, and mineral elements (Ca and P) in the manure of livestock and poultry, it can be used to produce regenerated feed, which is one of the methods for resource utilization. Chicken droppings have the highest value in feed processing. Because chicken feed contains relatively complete nutrition, and the chicken’s body structure leads to a shorter feed stagnation time in the digestive tract, chickens have low food digestion and absorption rates. Thus, the nutrient content of chicken droppings is high. Regenerative feed from chicken droppings can feed chicken, swine, cattle, and sheep. The regenerative feed from pig manure is mostly used to feed ruminants because of their special digestion ability to use this kind of forage effectively. The proportion of regenerative feed from pig manure should be less than 15%. In addition, regenerative feed can be used in aquaculture. Some fish, such as tropical fishes, silver fish, catfish, and *Tilapia* have a high ability to use animal dung. By controlling the nutrition flow from animal dung, it creates optimal conditions for rapidly increasing fish reproduction.

The regenerative feed from livestock and poultry breeding manure declines substantially with the cost of meat, milk, and other livestock products. The processing methods of regenerative feed include desiccation, fermentation (including anaerobic, oxygenation, and silage), thermal spray treatment, and physical and chemical methods [13]. Sometimes it can be combined with other materials to feed ruminants, fish, and maggots directly to provide animal protein feed resources.

4 Survey on the current situation of livestock and poultry manure applied to fields

4.1 Survey on the proportion of organic fertilizers in agricultural production

Although the application of livestock and poultry manure has a long history, it is still difficult to use in large-scale operations compared to chemical fertilizers, because the large volume of manure makes it difficult to transport, and it requires greater time and labor to apply. However, in China, small households are the main form of agricultural production, especially where older people and women are the main subjects.

According to the latest investigation on 23 706 typical fields by the Ministry of Agriculture and Rural Affairs, the percentage of grain fields to which manure was applied averaged 19.1%, among which rice, wheat, corn, sweet potato, and potato accounted for 11.9%, 34.5%, 20.5%, 31.7%, and 48.2% of the total, respectively. The percentage of cash crop fields to which manure was applied averaged 36.9%, among which flower and fruit fields had manure applied more than 50% of the time; the percentages of sugarcane, sugar beet, tobacco, tea, and mulberry crops fields to which manure was applied were 30%−40%; and cotton, rape, and other oil-crop fields had a very low percentage of manure application. The percentages of melon, fruit, and vegetable fields to which manure was applied were relatively high, among which tubers and leaf vegetables, gourds and fruit vegetables, and aquatic vegetables had applications of 56.1%, 56.4%, and 24.6%, respectively.

The survey results showed that in current agricultural production, there still a large number of fields planting grain crops and some cash crops without manure; thus, work toward the substitution of chemical fertilizer with organic fertilizer should be increased. In the past, the government has issued related policies and measures to promote and guide farmers to use organic manure, and some local governments, such as those of Beijing, Shanghai, and Jiangsu, also issued subsidy policies for manure application. These measures promoted manure application in agricultural production to a certain extent.

4.2 The current situation of livestock and poultry manure bearing capacity of arable land

There have been numerous papers published on the evaluation of the livestock and poultry manure bearing capacity of arable land. Some Chinese researchers [6] suggested that the arable land bearing capacity is approximately 30 t/hm^2, whereas some European countries limit manure application to 35 t/hm^2 and the N content in manure to 170 kg N/hm^2. Nitrate leaching will occur when this limit is exceeded. They also limit the annual P application in manure to 35 kg P/hm^2 [14]. Chinese scientists regard the maximal application rates for N and P on arable land to be 150 kg N/hm^2 and 30 kg P/hm^2, respectively [15]. Based on the results of Shen Genxiang [16], the annual average demands of N and P for grain crops were 219 kg N/hm^2 and 63 kg P_2O_5/hm^2, respectively. In addition, the effects of chemical fertilizers should be considered when calculating the bearing capacity of livestock and poultry manure on arable land.

Integrating the factors mentioned above, this study took 30 t/hm^2 of manure application rate on arable land as the upper limit bearing capacity, and the N and P maximal application rates were 150 kg N/hm^2 and 30 kg P/hm^2, respectively.

Fig. 4 shows that in China, there was 16.1% of provinces, municipalities, and autonomous areas where the bearing capacity of manure on arable land exceeded the threshold value of 30 t/hm^2. These included Tibet, Beijing, Guangdong, Fujian, and Hunan. When evaluated by the N or P content of manure (Fig. 5), 10 provinces exceeded 150 kg N/hm^2: Beijing, Tibet, Guangdong, Tianjin, Shandong, Hunan, Fujian, Henan, Jiangxi, and Hainan. With the exception of Hainan, Henan, Hunan, and Jiangxi, the arable land bearing capacity of the remaining six provinces exceeded 30 kg P/hm^2. To guarantee national food security and increase the level of nutrition for human beings, livestock and poultry production in China continue to grow. Under the condition of a lack of resources, how to use livestock and poultry manure as resources to reduce environment pollution and maintain sustainable development of husbandry has become an important problem to be faced and solved.

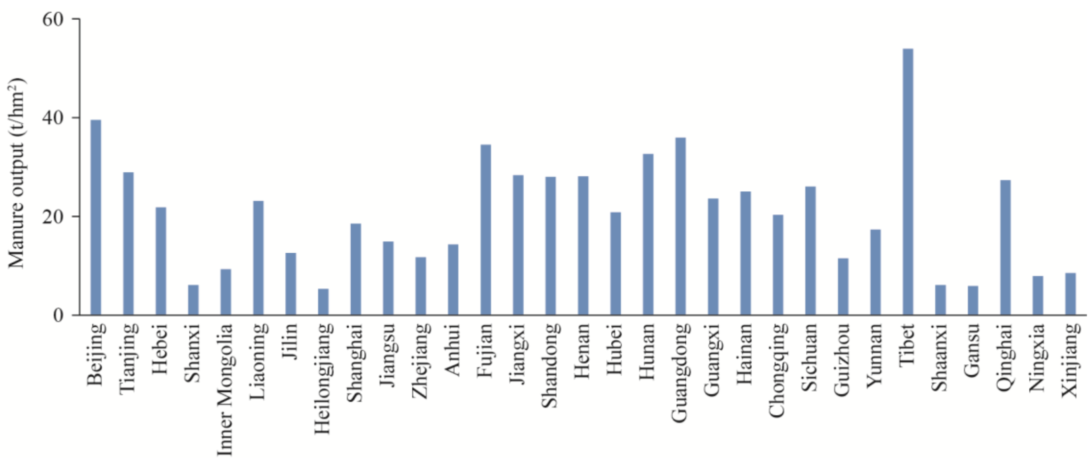

Fig. 4. The manure output per hectare of arable land in different provinces.

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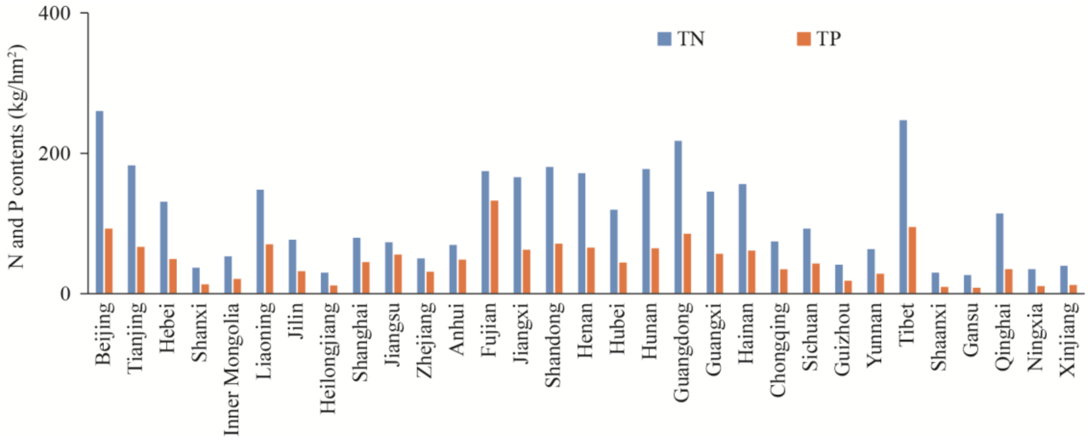

Fig. 5. The total N and P contents in livestock and poultry manure per hectare of arable land in different provinces.

5 The problems and suggestions on livestock and poultry manure as a resource

5.1 Developing clean production and increase manure use efficiency

Livestock and poultry manure may be used as a resource, but to the contrary, if it is unreasonably discharged into water bodies, it becomes a pollutant. Large-scale breeding farms often use one of three feces cleaning processes: water flushing, water soaking, and dry cleaning. They are all used in pig farms universally, while chicken farms and cattle farms usually use the dry-cleaning method. Regarding water flushing feces, because the water content in sewage discharged is up to 95%−98%, manufacturing fertilizer from sewage is very difficult, and transportation and storage are troublesome. The process of separating water from sewage is very complicated, and the solid dregs contain few nutrients and are of low value as manure.

Clean production starts at the source control, which means eliminating the pollutant before its production as far as possible. If labor, material, and finance resources are adequate, optimized feed formulae, better breeding technology, and dry-cleaning processes, which reduce sewage output, should be adopted to decrease the cost of handling and increase manure recovery and use efficiency.

5.2 Optimizing layout of livestock and poultry farms and strengthening the combination of crop-planting and livestock-breeding

Chinese livestock and poultry breeding are undergoing a transfer from traditional to modernized, and from household breeding to large-scale farm development. Nevertheless, household breeding and small-size breeding farms still account for a high percentage of the total. Traditional breeding is mainly located in cropping or grazing regions, with enough fields to apply the manure from breeding. With the large-scale breeding farms settled in the suburban belts, breeding has become disjointed from planting, with longer distances between farm and field; thus, it is difficult to transport the waste from breeding to fields for reutilization.

In long-term development, the layout of breeding farm construction should consider the balance between crop-planting and livestock-breeding. The local environment bearing capacity should be considered at first, and market demand, efficiency, and pollutant discharge management should also be considered. At present, the Chinese government and some local provinces have issued technical guidance for the delineation of livestock and poultry forbidden and restrictive zones. On the basis of these guidance, reasonable construction area layout, animal species, total volume, and scale of livestock and poultry farms are to be confirmed.

5.3 Strengthening treatments for the safe use of livestock and poultry manure

There are still many problems that should be emphasized in the resource utilization process for livestock and poultry manure.

With an unreasonable application of manure, the soil may be secondarily polluted, leading to a decline in crop growth and product quality. This is because the feed used in large-scale breeding farms contains a lot of additives, leading to high concentrations of antibiotics and heavy metals in manure. In addition, there is a number of pathogens in manure that need to be treated for it to be safe to use. In May of 2018, the Ministry of Agriculture and Rural Affairs issued the technical specification for sanitation treatment of livestock and poultry manure (GB/T 36195—

2018), which indicates the basic requirements for the treatment of livestock and poultry manure, and regulates the selection and layout of manure disposal sites, feces collection, storage and transportation, manure disposal, and post-disposal usage. In the resource utilization process for livestock and poultry manure, this technical specification should be followed. When applying as an organic fertilizer, manure should be combined reasonably with chemical fertilizer to avoid overuse and the accompanying soil pollution and agricultural product pollution.

Feed processing using livestock and poultry manure is a topic of great debate because the components of manure are very complex and contain pathogenic microbes and parasites that may cause infective outbreaking diseases, as well as exceeding the standard for harmful materials, such as antibiotics and heavy metals. Up to now, some developed countries have claimed to stop using manure as feed. It must be processed properly before adding into the feed. Different livestock and poultry species, regions, and feeding management practices produce different manure, which should be considered in the process of feed utilization.

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