Estimation of Production Amount of Livestock and Poultry Manure and Environmental Impact Assessment in Guangxi

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Abstract This study was intended to estimate production of major livestock and poultry manure and contaminant content, and find out current situation of manure pollution, so as to provide reference for pollution control of livestock and poultry breeding industry in Guangxi. Based on the related statistic data in 2010 and the excretion coefficient of different livestock and poultry, the manure and its contaminant production amount of main livestock and poultry in Guangxi were estimated. Then the annual livestock and poultry manure load of farmland and the loss of contaminant were also calculated to analyze the ecological pressure resulted from livestock and poultry breeding in Guangxi. Following results were obtained: in 2010, the production amount of the livestock and poultry manure in Guangxi was 9141.30×10^4 tons, including nutrient TN 42.07×10^4 tons and TP 13.62×10^4 tons; the annual livestock and poultry manure and N, P pure nutrient load of farmland was 21t/hm^2, 98 kg/hm^2, and 32 kg/hm^2 respectively; the production amount of manure contaminants was BOD_5 383.43×10^4 tons, COD_{Cr} 435.42×10^4 tons, and NH_3-N 42.08×10^4 tons; according to 30% loss rate, the loss amount of COD_{Cr} and NH_3-N was higher than the sum of industrial and life waste water. It was concluded that the livestock and poultry breeding industry had little impact on soil environment, but posed a grave threat to water environment.

Key words Livestock and poultry manure, Pollution, Environmental impact, Assessment, Guangxi

1 Introduction

Vigorous development of livestock and poultry breeding industry in China brings enormous economic benefits, but also causes serious environmental pollution. Reports show that the production amount of livestock and poultry manure in China has reached 3.264 billion tons in 2009, which is 1.6 times the total emission of industrial solid waste (Zhang Tian, *et al.*, 2012). Livestock and poultry contamination has become major source of rural diffused pollution in China. The Diffused Pollution (DP) is also called Non-Point Source (NPS) pollution. As a pillar industry of Guangxi agricultural economy, the livestock and poultry breeding industry is gradually developing towards large scale and intensification. Nevertheless, huge amount of livestock and poultry manure and contaminants restricts further development of this industry. Therefore, it is absolutely necessary to study production amount of livestock and poultry manure and investigate environmental risk situation, so as to provide basis for pollution control of livestock and poultry breeding industry in Guangxi. In the 1980s, livestock and poultry breeding scale in China increased, leading to huge increase in production amount of livestock and poultry manure; in addition, with development of chemical fertilizer industry, the use of organic fertilizer significantly decreased, resulting in piling of huge amount of livestock and poultry manure, and consequently leading to environmental pollution. At the early of the 1990s, the water pollution in Hangzhou Bay resulted from animal manure firstly sounded the alarm of environmental pollution, and relevant researches started to estimate the production amount of livestock and poultry manure. Qian Yongqing *et al.* (1992) firstly introduced the excretion coefficient to estimate the production amount of livestock and poultry manure in Shanghai suburbs. Wang Fanghao *et al.* (2006) estimated the production amount of livestock and poultry in China using the excretion coefficient, and proposed using the livestock and poultry manure load of farmland to assess ability of farmland to digest livestock and poultry manure, and using N and P nutrient load of soil in unit area farmland to assess pollution risk of livestock and poultry manure to farmland soil. Zhou Zuguang (2006) made actual measurement and estimation of pollution of livestock and poultry breeding in Hainan Province, analyzed systematic control of major problems in livestock and poultry breeding, and reached the conclusion that the COD, inorganic nitrogen, and phosphate produced by livestock and poultry manure will lose, enter the water and lead to eutrophication, and using aerobic and anaerobic marsh gas to digest contaminants has brought about marked effect. Zhou Kai *et al.* (2010) estimated the production amount of livestock and poultry manure in Henan Province in 2008, and got following result: the production amount of livestock and poultry manure reached 280 million tons, and the

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livestock and poultry manure load of farmland reached 40.79 t/hm^2, far higher than national average level, revealing rural ecological environment of Henan Province faced with huge ecological pressure of pollution of livestock and poultry breeding. Besides, many provinces and cities, including Chongqing (Peng Li and Wang Dingyong, 2004), Beijing (Wang Xiaoyan and Wang Qingping, 2005), Jiangsu (Zhang Xumei *et al.*, 2007), Jilin (Wang Xiuchuan, 2007) and Hainan (Wang Ling and Yue Ping, 2008), have launched survey on pollution of livestock and poultry breeding industry. At present, the pollution of livestock and poultry breeding is the major point in the control of non-point source pollution, so this study takes this as the starting point. The animal husbandry develops vigorously in Guangxi, while there is still no report about researches relevant to pollution of its livestock and poultry breeding industry. Through estimating the production amount of livestock and poultry manure in Guangxi and making assessment of its environmental impact, it is expected to provide reference to control pollution in the livestock and poultry breeding industry.

2 Materials and methods

2.1 Basic data Basic data of this study was selected from *Guangxi Statistical Yearbook* 2011 (Editorial Board of Guangxi Yearbook, 2011), with the end of 2010 as deadline of incorporation.

2.2 Quantity and period of livestock and poultry breeding

2.2.1 Quantity and period of livestock and poultry breeding. The livestock and poultry breeding in Guangxi are mainly pig, cow, sheep and poultry. As a characteristic industry of Guangxi, milk buffalo industry takes up certain proportion in overall breeding quantity of cows. Thus, when making statistic of breeding quantity of cows, it is required to include quantity of milk buffalo; since duck and goose breeding data were not included in the statistical yearbook, we estimated the meat and egg poultry breeding quantity with reference to breeding quantity of meat poultry and egg poultry.

Generally, the breeding quantity of livestock and poultry depends on life cycle of various livestock and poultry. If the life cycle is less than one year, the number of slaughtered of that year will be used as breeding quantity; if the life cycle is longer than one year, the number of livestock on hand will be taken as breeding quantity, and breeding period is 365 days. The breeding period of various livestock and poultry is as follows:

Hogs: average breeding period is 199 days (Zhang Keqiang and Gao Huaiyou, 2004); cows and sheep: the breeding period is relatively long, there is few amount of slaughtered in the same year, so the breeding period is calculated at 365 days; poultry: since there is great difference in life cycle and daily excretion between meat poultry and egg poultry, when calculating excretion of poultry, they should be separately calculated, the breeding period of meat poultry is generally 55 days, while the breeding period of egg poultry is generally 365 days (Gong Junyong *et al.*, 2011). In 2010, the breeding amount of various livestock and poultry in Guangxi: 3230 ($\times 10^4$) hogs, 450 ($\times 10^4$) beef cattle, 12.07 ($\times 10^4$) milk buffalos, 193.4 ($\times 10^4$) sheep, 6.33 ($\times 10^8$) meat chickens, and 2.85 ($\times 10^8$) egg chickens, as listed in Table 1.

Table 2 Breeding situation of livestock and poultry in Guangxi in 2010

Item	Hogs	Beef cattle	Cows	Milk buffalos	Sheep	Poultry
Amount of slaughtered// $\times 10^4$	3230.00	146.30	–	–	212.30	77 100
Amount of livestock on hand// $\times 10^4$	2344.00	450.00	6.89	5.18	193.40	28 500

2.2.2 Calculation parameters. The excretion coefficient of livestock and poultry manure is influenced by many factors, including animal variety, weight, life cycle, feed composition, and region and weather condition. Since there is no uniform standard in all regions, we adopted the excretion coefficient obtained from referring to similar domestic research results in recent years (Ding Jianghua, 2000; Liu Peifang *et al.*, 2002; Wang Fanghao *et al.*, 2006; Zhang Xumen *et al.*, 2007), as listed in Table 2.

2.3 Estimation items and methods Annual production amount of livestock and poultry manure = Breeding quantity × Breeding period × Excretion coefficient of manure

Annual production amount of contaminants (BOD_5, COD_{Cr}, and NH_3-N) = Breeding quantity × Breeding period × Excretion coefficient of contaminants

Nutrient content of livestock and poultry manure (TN and TP) = Annual production amount of livestock and poultry manure × Nutrient content of livestock and poultry manure in unit weight

Annual livestock and poultry manure load of farmland = Annual total amount of livestock and poultry manure / Annual farmland area

Table 2 The excretion coefficient of livestock and poultry manure and its nutrient content

Animal variety	Manure excretion kg/d	TN %	TP %	BOD_5 g/d	COD_{Cr} g/d	NH_3-N g/d
Hogs	5.30	0.238	0.074	203.00	266.00	37.50
Beef cattle	21.10	0.351	0.082	805.00	1 100.00	12.00
Cows & milk buffalos	53.15	0.351	0.082	639.00	1 100.00	55.00
Sheep	2.38	1.014	0.216	9.76	11.02	1.90
Meat chickens	0.10	1.032	0.413	13.50	9.00	1.80
Egg chickens	0.15	1.032	0.413	6.75	4.50	0.90

Annual TN and TP pure nutrient load of farmland = Annual TN and TP pure nutrient amount / Annual farmland area

2.4 Statistical analysis In this study, we made statistical analysis on experimental data with the aid of Excel 2003 software.

Table 3 The production amount of livestock and poultry manure and its nutrient content in Guangxi in 2000

Animal variety	Index//10^4 t/year					
	Production amount of manure	TN	TP	BOD_5	COD_{Cr}	NH_3-N
Hogs	3406.68	8.11	2.52	130.48	170.98	24.10
Beef cattle	3465.00	12.16	2.84	132.22	180.68	1.97
Cows & milk buffalos	234.16	0.82	0.19	2.82	4.85	0.24
Sheep	168.26	1.71	0.36	0.69	0.78	0.13
Meat chickens	348.15	3.59	1.44	47.00	31.33	6.27
Egg chickens	1519.05	15.68	6.27	70.22	46.81	9.36
Total	9141.30	42.07	13.62	383.43	435.42	42.08

3 Results and analyses

3.1 Estimation of the production amount of livestock and poultry manure in Guangxi From Table 3, it can be known that the production amount of livestock and poultry manure in Guangxi reached 91.413 million tons in 2010, accounting for 2.9% of the total amount of livestock and poultry manure in the whole country, 1.6 times the total emission of industrial solid waste. Among the manure, the portion produced by beef cattle is the largest, accounting for 37.9% of the total livestock and poultry manure in Guangxi, followed by hogs, egg chickens, meat chickens, cows and milk buffalos, respectively accounting for 37.3%, 16.6%, 3.8%, 2.6% and 1.8% of the total livestock and poultry manure in Guangxi. The manure amount produced by beef cattle and hogs takes up 3/4 of the total livestock and poultry manure in Guangxi and constitutes the major part of livestock and poultry manure in Guangxi. Feces of hogs and cattle contain little nutrient but much water, so breeding farms often discard those feces, easily leading to environmental pollution. Thus, pollution from hog and beef cattle breeding should not be neglected, and should be taken as the essential point for control of agricultural non-point source pollution in Guangxi.

3.2 Estimation of N and P nutrients in livestock and poultry manure The livestock and poultry manure contain N and P nutrients which are necessary for plant growth. After harmless treatment, livestock and poultry manure can be used as organic fertilizer, to effectively reduce use of chemical fertilizer and improve soil quality. In 2010, the conversion value of application of chemical fertilizer was 2.371 6 million tons in Guangxi, including 0.699 4 million tons nitrogen fertilizer and 0.2885 million tons phosphorus fertilizer (counted by Statistical Bureau of Guangxi Zhuang Autonomous Region, 2011). However, the major livestock and poultry manure in Guangxi in 2010 was 0.420 7 million tons of TN and 0.136 2 million tons of TP, respectively equivalent to 60.2% and 47.2% of application of chemical fertilizer in the same period, manifesting that the livestock and poultry manure is an important resource in agricultural production of Guangxi.

3.3 Environmental impact of contaminants of livestock and poultry manure

3.3.1 Impact on soil environment. The livestock and poultry manure load of farmland is an indicator for assessing ability of farmland to digest livestock and poultry manure, and the N and P nutrient load of soil in unit area farmland is an indicator reflecting pollution risk of livestock and poultry manure to farmland soil (Wang Fanghao, *et al.*, 2006). By the end of 2010, the total farmland area of Guangxi was 4.287 5 million hm^2. According to estimated production amount of livestock and poultry manure and farmland area of Guangxi in the same year, if all livestock and poultry manure is used as organic fertilizer, the annual livestock and poultry manure load of farmland was 21 t/hm^2; from Table 3, it can be known that TN and TP in livestock and poultry manure in Guangxi in 2010 were 42.07×10^4 tons and 13.62×10^4 tons separately, and pure N and P nutrient load of farmland was 98 kg/hm^2 and 32 kg/hm^2 respectively. Relevant reports indicate that one hectare farmland can bear 30 to 45 tons of livestock and poultry manure (Department of Natural Conservation of State Environmental Protection Administration, 2002), with limit for annual N fertilizer application of 170 kg/hm^2, and limit for annual P fertilizer application of 80 kg/hm^2 (Oenema O *et al.*, 2004). Thus, both annual livestock and poultry manure load of farmland, and pure N and P nutrient load of farmland in Guangxi have not exceeded the limit; although there is certain pollution, its threat to soil environment is relatively small.

3.3.2 Impact on water environment. Some livestock and poultry manure will enter farmland and some will enter water. Generally, there are two approaches for livestock and poultry entering water: direct discharge during breeding; accompanied with rainwater or others during stacking and storage. Livestock and poultry manure contains much organic contaminants. In 2010, the amount of contaminants produced by livestock and poultry manure in Guangxi was as follows: BOD_5 383.43×10^4 tons, COD_{Cr} 435.42×10^4 tons, and NH_3-N 42.08×10^4 tons respectively. According to survey results of State Environmental Protection Administration about pollution of large-scale livestock and poultry breeding industry in the whole country, the loss rate of livestock and poultry manure contaminants was 30% – 40%. If calculated at 30%, the annual loss of livestock and poultry manure in Guangxi was 115.03 ($\times 10^4$) tons of BOD_5, 130.63 ($\times 10^4$) tons of COD_{Cr}, and 12.62 ($\times 10^4$) NH_3-N. This indicates that the COD_{Cr} and NH_3-N pollution of livestock and poultry manure in Guangxi was very serious, the loss of COD_{Cr} was far higher than the sum of COD_{Cr} discharge of industrial and life waste water (93.69×10^4 tons), while the loss of NH_3-N was equivalent to 1.5 times the sum of NH_3-N discharge of industrial and life waste water, counted by Department of Environmental Protection of Guangxi Zhuang Autonomous Region in 2011. Contaminants of livestock and poultry manure have big threat to water environment, without proper supervision and control, it will lead to more severe consequence than industrial pollution, and exert harmful influence on ecological environment.

4 Discussion

Influenced by various factors, there will be certain difference in

estimated amount and actual production amount of livestock and poultry manure. In this study, the estimation of production amount of livestock and poultry manure only considered breeding quantity of major livestock and poultry, such as hogs, cows and sheep and poultry, while others, such as horse, donkey, rabbit, dog, duck and goose were not included, so the actual discharge amount of livestock and poultry manure should be larger than this result. In addition, different scholars adopted different excretion coefficient when estimating the excretion amount of livestock and poultry manure, thus they obtained different excretion amount of livestock and poultry manure. For example, estimation of Wang Fanghao *et al.* (2006) and Su Qiuhong (2007) had a difference of 500 million tons. In order to get close to actual value, this study selected some representative data when determining the excretion coefficient of livestock and poultry manure. Nevertheless, the excretion coefficient may change due to factors including animal variety, type, weight, life cycle, feed composition, region and weather conditions. Therefore, it is required to make definite excretion coefficient to obtain more accurate estimation of livestock and poultry manure.

Since livestock and poultry manure contains a large amount of plant nutrients, it is still mainly used as fertilizer for farmland, and farmland naturally becomes the major consumption place of livestock and poultry manure. Suppose all livestock and poultry manure is returned to farmland, in other words, the annual livestock and poultry manure of farmland in Guangxi in 2010 was 21.21 ton/hm^2. Compared with other provinces, such as 40.79 ton/hm^2 (Zhou Kai *et al.*, 2010) of Henan, 29.68 ton/hm^2 (Bai Minggang and Ma Changhai, 2010) of Hebei, 29.6 ton/hm^2 of Fujian (Wu Feilong *et al.*, 2009), 33.12 ton/hm^2 of Hainan (Wang Ling and Yue Ping, 2008), Guangxi has less pressure in livestock and poultry manure load of farmland. In 2010, the pure N and P nutrient load of farmland was 98 kg/hm^2 and 32 kg/hm^2 respectively in Guangxi, lower than the national limit standard. On the whole, the N and P in livestock and poultry manure have slight impact on soil environment, but the threat is small. This result is basically consistent with recent report about pollution of livestock and poultry manure in Guangxi (Wang Fanghao *et al.*, 2006; Zhang Tian *et al.*, 2012). However, the farmland load of Guangxi fails to objectively reflect actual condition of a certain region. Breeding characteristics of Guangxi Zhuang Autonomous Region show that southeast of Guangxi mainly develops hog and poultry breeding, northwest region mainly develops beef cattle breeding, suburbs of middle cities develop milk cow and buffalo breeding, thus the livestock and poultry breeding in different regions may have different degree of impact of local environment. Due to lack of breeding data of regions in Guangxi, it is impossible to make further analysis on actual farmland load of all regions. Livestock and poultry manure of Guangxi can be digested by farmland, but dissolution of manure will result in pollution to water through soil penetration. Besides, the loss of COD_{Cr} and NH_3-N in livestock and poultry manure in Guangxi exceeds the sum of industrial and life waste water. This has great impact on water environment. Some rivers have excess COD_{Cr} and NH_3-N, which seriously reduces their water quality. Without proper supervision and control, it will lead to more severe consequence than industrial pollution, and exert harmful influence on ecological environment.

5 Conclusion

Both annual livestock and poultry manure load of farmland, and pure N and P nutrient load of farmland in Guangxi have not exceeded the limit, so its impact on soil environment is small. However, the loss of livestock and poultry manure contaminants is huge, and seriously threatens water environment.

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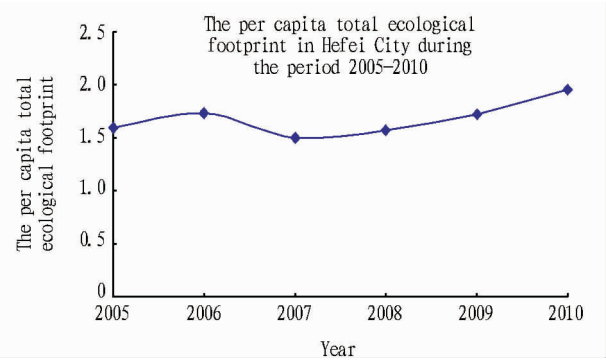

Fig. 9 The per capita total ecological footprint in Hefei City during the period 2005 – 2010

2.2.2 Analysis of ecological footprint per 10^4 yuan GDP. As can be seen from Table 2, the ecological footprint per 10^4 yuan GDP showed a gradually decreasing trend from 2005 to 2010, and the rate of reduction was obvious, from 0.774 268 019 $hm^2/10^4$ yuan in 2005 to 0.355 574 433 $hm^2/10^4$ yuan in 2010, indicating that the efficiency of resource utilization in Hefei City was increased year by year.

Due to the promotion of recycling economy and saving economy in recent years, the rate of resource utilization in Hefei City has been improved to some extent, and the city's economic development has already begun to be resource-intensive.

Table 2 The per capita ecological footprint and footprint per 10^4 yuan GDP in Hefei City during the period 2005 – 2010

Year	Per capita ecological footprint hm^2/person	Per capita GDP 10^4 yuan/person	Footprint per 10^4 yuan GDP $hm^2/10^4$ yuan
2005	1.591 895 048	2.056	0.774 268 019
2006	1.732 506 179	2.423	0.715 025 249
2007	1.498 739 06	2.9545	0.507 273 332
2008	1.564 395	3.6802	0.425 084 235
2009	1.715 614	4.2981	0.399 156 371
2010	1.947 765 628	5.4778	0.355 574 433

3 Conclusions

(i) Based on the analysis of six types of ecological footprint during the period 2005 – 2010, the per capita ecological footprint of arable land basically shows a steady rising trend; the per capita ecological footprint of water area is basically unchanged; the per capita ecological footprint of grassland shows an overall upward trend; the per capita ecological footprint of woodland is basically unchanged; the per capita ecological footprint of construction land is increased substantially; the per capita ecological footprint of fossil energy land shows an overall upward trend. It indicates that in recent years, the industrial economic development in Hefei City is accelerated, people's living standards are improved, and the momentum of urbanization is gathered.

(ii) Based on the analysis of the ecological footprint per 10^4 yuan GDP during the period 2005 – 2010, the ecological footprint per 10^4 yuan GDP decreased from 0.774268019 $hm^2/10^4$ yuan in 2005 to 0.355574433 $hm^2/10^4$ yuan in 2010, reducing by more than two times, indicating that the rate of resource utilization in Hefei City is increased year by year, and the city's economic development has already begun to be resource-intensive.

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