Pollution from animal husbandry in China: a case study of the Han River Basin
Chen Sun and Hongjuan Wu

ABSTRACT

Animal husbandry is one of the major agricultural pollution sources in China. The Xiangyang Reach of the Han River Basin was used as a case study to identify pollutants from animal rearing. The gross amount of pollutants from livestock and poultry rearing in the Xiangyang Reach was estimated using two empirical models with different data sets. The pig, cattle, sheep, and poultry population in 2009 amounted to 2.6, 0.6, 0.5, and 39.2 million head, respectively. The total annual pollutant loads generated from the feces and urine of livestock and poultry were 270,400 t of chemical oxygen demand; 228,900 t of biochemical oxygen demand; 26,500 t of ammonia nitrogen; 16,500 t of total phosphorus; and 63,900 t of total nitrogen. Approximately 12% of these pollutant loads were estimated to enter the Han River through the watershed outlet. Animal breeding has been one of the main pollution sources in this area, followed by domestic sewage and industrial wastewater. Cattle produced the most pollution, with the heaviest pollution load in downtown Xiangyang City. Several recommendations are presented to control the pollution caused by livestock and poultry breeding.

Key words | agricultural pollution, animal breeding, China, Han River, non-point source pollution, water quality

INTRODUCTION

Agricultural activities have been increasingly recognized as a main contributor to water quality impairment in many countries (Van der Molen et al. 1998; Harding et al. 1999; Chen & Chen 2008; USEPA 2009). According to the China Pollution Source Census Bulletin (MEP 2010b), the gross chemical oxygen demand (COD) and total phosphorus (TP) loads from animal farming account for nearly 96 and 56% of agricultural pollution, respectively. Livestock and poultry rearing has become the leading source of agricultural pollution in China. China is one of the largest producers and consumers of meat in the world, but most of its intensive animal feedlots had not been evaluated using environmental impact assessments (EIA) before 2001. Moreover, corresponding treatment measures for excreta have not been well established in many large-scale intensive farms (Nature Eco-protection Department of the State Environmental Protection Administration of China 2002; Gao et al. 2006; Su 2006). Contaminants from free-range and small-scale breeding are difficult to control and regulate because they are generated over wide areas, and they enter the receiving water bodies through a variety of dispersed paths. Since 1978, surface waters in eastern and central China have been overwhelmed by accelerated deterioration and eutrophication, which has been recently extended even to western China (Chen et al. 2002; Liu 2008; Pu & Feng 2008). In 2009, the percentages of water in 203 main rivers and 26 main lakes and reservoirs, with water quality worse than Class III (based on the Chinese Surface Water Quality Standard), were 42.7 and 76.9%, respectively (MEP 2010a). Pollution from agriculture and the rural regions, especially excessive pollutant loading from animal farming, is considered a significant contributor to water quality degradation (Kong & Han 2002; Jiao et al. 2010).

To protect the water environment, the Chinese government has consistently implemented various measures, including the regulation of animal feedlots. Although political awareness of animal breeding pollution issues has increased substantially in China during the last decade, the evaluation of this problem remains limited. Learning more about contributions from specific pollution sources is a prerequisite to effective pollution control efforts. Estimation of...
pollutant loads from livestock and poultry rearing is crucial for accurate assessment of water pollution. Nevertheless, the exact contribution from animal excreta pollution in China is very difficult to estimate because it is produced over wide regions. Moreover, the contribution from different pollution sources is still subject to debate. The current study aims to estimate the amount of pollutants produced by animal husbandry through a case study of the Han River Basin in Central China. The feasibility of improvement based on the current status of policy makers and researchers is proposed.

**Background of the case study area**

The Han River is the longest tributary of the Yangtze River in Central China. It is traditionally divided into two parts: the 925 km upper reach upstream of the Danjiangkou Reservoir and the 676 km middle and lower reaches from the reservoir to Wuhan City, where it descends into the Yangtze River. The total drainage area in the middle and lower reaches is 64,000 km². This area is under the jurisdiction of Hubei Province, covering the cities of Shiyan, Xiangyang, Zhongxiang, Shiyang, Xiantao, Hanchuan, and Wuhan. The Han River is one of the main sources of drinking water and agricultural water in the middle and lower reaches. The Han River runs through Xiangyang City from north to south. The Xiangyang Reach of the Han River covers the four cities and districts of Laohoukou, Gucheng, downtown Xiangyang, and Yicheng, with a length of 195 km and an approximate watershed area of 16,893 km² (Figure 1). The Xiangyang Reach has an annual mean water discharge of 1,490 m³/s and an annual mean velocity of 0.61 m/s. The five tributaries in the Xiangyang Reach are the South, North, Xiaqing, Tangbai, and Man Rivers.

The Han River Basin performs a significant role in the nation’s development strategy for the central region. Over the last 20 years, the Han River Basin has experienced rapid growth in economic development and has become a major urban and industrial area in Central China. The basin is also one of the most important centers of animal husbandry. Livestock and poultry farming is concentrated in the middle and lower reaches of the basin, especially in Xiangyang City, which ranks first in livestock production across Hubei Province (Xiangyang Environmental

![Figure 1](image_url)
However, the water quality of the Han River, specifically that of the middle and lower reaches, has gradually declined. The annual average concentrations of organic substances, nitrogen (N), and phosphorus (P) increased by more than 10% in 1998–2005 (Luo et al. 2006). From 1992 to 2005, large-scale algal blooms occurred five times in the middle and lower reaches, jeopardizing the safety of drinking water and agricultural water (Luo et al. 2006). Loading of N and P often causes eutrophication, and livestock farming is a major source in this area (Shi et al. 2011).

The present study focused on the Xiangyang Reach in the middle reach of the Han River because animal breeding is concentrated in this area.

### METHODS

Estimation was spatially conducted at the county level. The study area was divided into four parts, namely, Laohekou, Gucheng, downtown Xiangyang, and Yicheng. Data from the 2005–2009 period on the pig, cattle, sheep, and poultry population in each part were collected from the Xiangyang Statistical Yearbook (Xiangyang Statistics Bureau 2006–2010). The annual pollutant loads from livestock and poultry, expressed in quantities of COD, biochemical oxygen demand (BOD), ammonia nitrogen (NH3-N), TP, and total nitrogen (TN) were estimated using two empirical models based on export coefficient modeling (Liu et al. 2002; Zhu et al. 2010).

Pollution from livestock and poultry can be calculated as follows. This equation is based on the pollutant loads produced per day per animal:

\[
Q = N \times T \times P \times C, \tag{1}
\]

where \(Q\) is the total pollutant load from livestock per year, \(N\) denotes the annual number of animals raised per year, \(T\) is the feeding period of livestock and poultry (365 days), \(P\) represents the amount of feces and urine produced per animal per day, and \(C\) is the production of pollutant per kg of feces and urine.

The equation for annual pollution generated by livestock and poultry is given below. This equation is based on the loads of pollutants produced per year per head:

\[
Q = N \times q, \tag{2}
\]

where \(q\) is the load of pollutant produced per head per year.

Equations (1) and (2) were used for five different pollutants (i.e. COD, BOD, NH3-N, TP, and TN) and for four categories of livestock (i.e. pigs, cattle, sheep, and poultry). The calculated pollutant load indicates the ‘potential load’ produced by livestock and poultry. Part of the potential load that enters the watercourse indicates the ‘delivered load’, which will be estimated in the discussion section.

Normally, feces produced by domestic and overseas pigs, cattle, sheep, and poultry ranges from 2.5 to 12.0, 15.0 to 60.0, 1.5 to 5.0, and 0.07 to 0.16 kg/d per head, respectively. Correspondingly, the urine produced by pigs, cattle, and sheep was approximately 2.0–4.0, 6.0–25.0, and 0.5–1.5 kg/d per head (American Society of Agricultural Engineers 1997; Wang 1998). As most livestock and poultry were locally bred, the coefficients of feces and urine were taken from the Xiangyang Environmental Monitoring Station. The amount of feces and urine excreted from pigs, cattle, sheep, and poultry per day per head (\(P\) in Equation (1) was estimated based on data from the Hubei Academy of Environment Sciences (2007), as shown in Table 1. Parameters for annual amounts of pollutants from feces and urine from livestock and poultry in Equation (2) were based on data from the Nature Eco-protection Department of the State Environmental Protection Administration of China (2002), as shown in Table 3.

### Table 1

| Average amount of pollutants in livestock and poultry excreta (C) in Equation (1) was estimated based on data from the Hubei Academy of Environment Sciences (2007), as shown in Table 2. Parameters for annual amounts of pollutants from feces and urine from livestock and poultry in Equation (2) were based on data from the Nature Eco-protection Department of the State Environmental Protection Administration of China (2002), as shown in Table 3.

<table>
<thead>
<tr>
<th>Amount of feces and urine excreted from livestock and poultry per day per head in the Xiangyang Reach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Feces (kg/d)</td>
</tr>
<tr>
<td>Urine (kg/d)</td>
</tr>
</tbody>
</table>

### Table 2

| Average amount of pollutants in livestock and poultry excreta in the Xiangyang Reach |
|---|---|---|---|---|---|
| Pigs | Feces | 52.0 | 57.0 | 3.1 | 3.4 | 5.9 |
| Urine | 9.0 | 5.0 | 1.4 | 0.5 | 3.3 |
| Cattle | Feces | 31.0 | 24.5 | 1.7 | 1.2 | 4.4 |
| Urine | 6.0 | 4.0 | 3.5 | 0.4 | 8.0 |
| Sheep | Feces | 4.63 | 4.1 | 0.8 | 2.6 | 7.5 |
| Poultry | Feces | 45.0 | 47.87 | 4.8 | 5.4 | 9.8 |
RESULTS

Livestock and poultry population

The livestock and poultry population in the Xiangyang Reach of the Han River remained stable from 2005 to 2007. However, from 2008, pig, cattle, sheep, and poultry populations markedly increased because of the large-scale expansion of animal husbandry. As the 2010 data have not been released, the 2009 population size of each animal was selected to represent the latest status of livestock and poultry farming. The livestock and poultry population in the Xiangyang Reach is presented in Table 4.

Pollution from livestock and poultry farming

Table 4 shows the total fecal and urine weight estimated for livestock and poultry in the four cities and districts of the Xiangyang Reach for 2009. These were calculated using Equation (1), which is based on the amount of excreta produced per day per head in this area. The total pollutant loads generated by the feces and urine of livestock and poultry were calculated using Equations (1) and (2) (Table 5).

DISCUSSION

The calculated pollutant loads generated by the feces and urine of livestock and poultry varied considerably, reflecting two different calculation approaches (Table 5). These differences are predominantly caused by the variances in the coefficients. First, the average growth period of pigs in Equation (1) is the average value for the Han River Basin. The parameter used in Equation (2) was based on the national average. Thus, the result of Equation (1) for pigs was more precise. Second, the growth period of poultry in Equation (1) is the mean value for chickens, whereas that in Equation (2) is the mean value for both chickens and ducks. Third, data on sheep urine were missing and so the larger value of Equation (1) was selected as the final calculation result. Consequently, different methods were selected according to different situations: the pollutants generated by pigs and sheep were based on Equation (1), and those generated by poultry were based on Equation (2). Conversely, both methods produced the same results for cattle. The most applicable calculation result for each animal is shown in Table 5. Table 6 provides information on the pollutants produced by livestock and poultry, with cattle being the greatest contributor.

According to an investigation by the Chinese Academy for Environmental Planning (2003), the ratio of animal raising-generated pollutants that enter the watercourse reached 12% on national average. Using 12% as the coefficient of livestock and poultry-produced pollution that enters the watercourse, the following results for the pollutant loads entering the Xiangyang Reach in 2009 were obtained: 32,448 t COD; 27,468 t BOD; 3,180 t NH3-N; 1,980 t TP; and 7,668 t TN. In contrast, in 2009, the amount of COD derived from the industrial wastewater of Laohekou, Gucheng, downtown Xiangyang, and Yicheng was 13,254.5 t, and that from domestic sewage was 23,163.59 t. Therefore, livestock and poultry rearing is one
of the main pollution sources in the Xiangyang Reach of the Han River. The distribution of the COD load to the Han River from livestock and poultry raising was approximated as follows: 51% from downtown Xiangyang City, 20% from Gucheng County in the southwest, 16% from Yicheng City, and 13% from Laohekou City.

Nutrient mobilization from animal husbandry depends on the concurrence of source (soil and management) and transport (runoff, erosion, and channel processes) (Heathwaite et al. 2000). In this study, empirical evidence suggests that excessive loading of nutrients and farm effluents (principally silage and slurry) via surface runoff and leachate from livestock farming sites were significant factors contributing to the degradation of water quality in the Xiangyang Reach of the Han River. In China, several laws and regulations directed at intensive animal feedlots have been issued by the Ministry of Environmental Protection of China, for example: the Regulation of Contamination Control and Management of Livestock and Poultry Rearing, the Discharge Standard for Livestock and Poultry Breeding, and the Technical Policy for Contamination Prevention and Control of Livestock Breeding Industry. Since 2010, all intensive animal feedlots in the study area have been approved by the Environment Protection Department through the use of EIA. Moreover, disposal facilities for animal excreta have been established in accordance with these regulations. However, many intensive animal feedlots, especially those established prior to 2001, have not been able to meet contamination control and management requirements. These account for more than 50% of the total intensive animal feedlots in the study area. In addition, these laws do not cover free-range and small-scale breeding operations. As a result, random emissions and improper disposal of excreta from these sites may result in diffuse source pollutant loading to adjacent waterways. This situation is not unique to China; large-scale animal production has been identified as a significant source of pollution in other developed countries (Hooda et al. 2000; Sharpley et al. 2004). Best management practices (BMPs), presenting

<table>
<thead>
<tr>
<th>COD (%)</th>
<th>BOD (%)</th>
<th>NH3-N (%)</th>
<th>TP (%)</th>
<th>TN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>56.7</td>
<td>52.2</td>
<td>58.9</td>
<td>38.2</td>
</tr>
<tr>
<td>Pigs</td>
<td>25.6</td>
<td>29.5</td>
<td>21.1</td>
<td>26.6</td>
</tr>
<tr>
<td>Poultry</td>
<td>16.9</td>
<td>17.4</td>
<td>18.5</td>
<td>27.3</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.8</td>
<td>0.9</td>
<td>1.5</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Table 6 | Proportion of pollutant loads contributed by each category of livestock and poultry excreta in the Xiangyang Reach in 2009

| Total amount of livestock and poultry excreta and potential pollutant loads from animal excreta in the four cities and districts of the Xiangyang Reach in 2009
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Weight (1,000 t)</td>
<td>COD</td>
<td>BOD</td>
<td>NH3-N</td>
<td>TP</td>
<td>TN</td>
<td>COD</td>
<td>BOD</td>
<td>NH3-N</td>
<td>TP</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Pigs</td>
<td>1,034.8</td>
<td>53.8</td>
<td>59.0</td>
<td>3.2</td>
<td>3.5</td>
<td>6.1</td>
<td>52.9</td>
<td>58.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Feces</td>
<td>1,707.4</td>
<td>15.4</td>
<td>8.5</td>
<td>2.4</td>
<td>0.9</td>
<td>5.6</td>
<td>15.1</td>
<td>8.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Urine</td>
<td>4,505.0</td>
<td>139.7</td>
<td>110.5</td>
<td>7.7</td>
<td>5.4</td>
<td>19.8</td>
<td>139.7</td>
<td>110.5</td>
<td>7.7</td>
</tr>
<tr>
<td>Cattle</td>
<td>4,205.2</td>
<td>135.5</td>
<td>115.0</td>
<td>7.9</td>
<td>5.4</td>
<td>18.0</td>
<td>135.5</td>
<td>115.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Feces</td>
<td>2,252.5</td>
<td>13.5</td>
<td>9.0</td>
<td>7.9</td>
<td>0.9</td>
<td>18.0</td>
<td>13.5</td>
<td>9.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Urine</td>
<td>2,252.5</td>
<td>13.5</td>
<td>9.0</td>
<td>7.9</td>
<td>0.9</td>
<td>18.0</td>
<td>13.5</td>
<td>9.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Poultry</td>
<td>8,253.2</td>
<td>37.0</td>
<td>35.4</td>
<td>4.0</td>
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<td>58.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>1,034.8</td>
<td>53.8</td>
<td>59.0</td>
<td>3.2</td>
<td>3.5</td>
<td>6.1</td>
<td>52.9</td>
<td>58.0</td>
<td>3.1</td>
</tr>
</tbody>
</table>
clearly defined benefits, are frequently adopted with beneficial results (Ice 2004; Ha & Lee 2008).

CONCLUSIONS

The case study of the Han River Basin shows that livestock and poultry rearing is one of the major pollution sources, which contributes more to COD load than do the domestic and industrial wastewater in the Xiangyang Reach. The annual pollution generated by livestock and poultry in the Xiangyang Reach was analyzed. Downtown Xiangyang City exhibited the heaviest load, followed by Gucheng County, Yicheng City, and Laohekou City. Cattle produced the greatest pollutant load, followed by pigs, poultry, and sheep. Therefore, prevention and control of pollution from livestock production should be concentrated in downtown Xiangyang City. Pollution from cattle is also a critical concern in this region. Generally, the proportion of animal waste transported to watercourses depends on many factors, such as treatment methods, climate, soils, distance to watercourses, etc. In China, there are some regional variations in the current situation of animal breeding so the proportion may be different for different districts. The value (12%) recommended by the Chinese Academy for Environmental Planning (2003) was based on the national average. To the authors’ knowledge, no research has been performed to examine the proportion of animal waste that enters watercourses in the Han River Basin; hence, future investigations are recommended. The recent results can be relevant and adaptable to similar parts of China and other developing countries.

RECOMMENDATIONS

Livestock and poultry pollution has drawn great attention in China within the last decade. Although the government has issued a number of laws and regulations, several problems remain evident. For example, the existing laws are mainly directed towards large-scale intensive animal feedlots. They are not enforced at free-range and small-scale operations. The following recommendations for pollution management should be considered by policy makers and researchers in China. First, the government needs to improve the supervision of intensive animal feedlots, especially those constructed before 2001. As point source pollution, the pollution control in large-scale intensive animal feedlots is not a technical challenge. Pollution mitigation in livestock and poultry raising should remain focused on point sources with the development of large-scale animal husbandry. Second, a strong program of instruction and economic incentives for farmers may improve small-scale animal farming BMPs. These units should be encouraged to utilize the animal excreta as resources, such as biogas. These operations should be supported by a direct subsidy from the government.

Finally, environmental and agricultural ministries should strengthen cooperation in contamination prevention and control of animal breeding. By communicating with each other, the two departments can work together to deal with these challenges.

ACKNOWLEDGEMENTS

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