Investigation and Analysis of the Main Pollution Sources in Fuxian Lake

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Abstract. Fuxian Lake is a plateau-based freshwater lake. In recent ten years, with the rapid development of the economy around the lake, the water quality of Fuxian Lake has declined and the nutritional status in lake has increased obviously. To identify the main sources of pollution in Fuxian lake and provide a reference for the protection and management direction and theoretical guidance, the pollution status of Fuxian Lake basin was analyzed and evaluated from the aspects of rural domestic pollution, farmland runoff pollution, urban domestic pollution, phosphorous chemical pollution and tourism pollution, respectively, based on years of field investigation and the indexes detection and analysis such as chemical oxygen demand (COD), total nitrogen, total phosphorus. The results showed that the pollution in Fuxian Lake basin mainly came from the rural non-point source pollution, urban domestic pollution, waste phosphate rock area pollution, tourism pollution and other aspects, among which the most important source of pollution was the rural non-point source pollution, including watershed village pollution, human and animal excrement pollution, rural waste pollution, and farmland runoff pollution in the basin. The COD, total nitrogen and total phosphorus from rural non-point source pollution accounted for 94.81%, 94.85% and 87.79% of the total pollution into the lake, respectively. Among them, the farmland runoff pollution was the most important component of rural non-point source pollution.

1. Introduction
In recent years, with the development of economy of China, the wantonly discharge of industrial and agricultural waste water and sanitary sewage, thus it’s imperative to protect the environment of lakes water resource. Sun Hao [1] comes up with the idea of taking all the rivers which flow and gather in Fuxian lake as the basic control area of water pollution’s prevention and treatment. At the same time, Zhang Weili [2] gets the reason of sharp increase of nitrogen and phosphorus in the water is that the over recharge of the waste water of rural life, the recharge of rising the beasts and birds, and also the pollution recharge of the pesticide though the long term research on several large lakes in our country. Zheng Fenli [3] propose the theory of the agricultural surface source is non-point pollution through the long term survey and research on the foreign lakes.

2. General environment of Fuxian lake basin
2.1. Overview of natural environment
Fuxian Lake is located in the northeast part of Yuxi City, Yunnan Province, and it’s at the junction of Chengjiang, Jiangchuan and Huaining counties. Fuxian Lake is located in the Middle West water system of Nanpan river basin, with the basin area excluding Xingyun Lake reaching 674.69 km². When the lake level is 1722.5m, the water area is about 216.6km², the lake length is about 314km, and the width of the lake is about 11.8 km, with a total shoal length of about 100.8 km. The maximum water depth is 158.9 m, with an average of 95.2 m, and the corresponding water storage is about 20.62 billion m³, which is the largest water storage in Yunnan province [4]. Fuxian Lake has the comprehensive functions of irrigation, flood control, aquaculture, tourism and domestic water.

Fuxian Lake basin has 103 channels rivers into the lake, 20 of which are larger rivers. Among them, there were 3 with a catchment-area greater than 30km², 6 with an area between 10km² and 30km², and 18 with an area less than 10km². The river out of the lake has the Haikou River and the river change the diversion.

2.2. Overview of Socio-economic
Fuxian Lake basin is located in Chengjiang, Jiangchuan and Huaining counties, among which Chengjiang County involves 5 towns, about 117869 people (the 6th population census, the same below); Jiangchuan County involves 2 towns, about 29,229 people; there is only one town of Qing long in Huaining County, with about 8,031 people. There are about 238 natural vilages in Town, with a total population of about 155,129 people.

Phosphorite is the main mineral resources in Fuxian Lake basin. There are several phosphate ore mining points and phosphorous chemical factories around the lake. The area around the valley is rich in tourist attractions, tourism developed, Luchong scenic area, the Moon Bay Wetland and the Sakura Valley scenic area.

The land use in Fuxian Lake basin is as follows. The forestry land is about 22.67 km² which accounting for 36.71%. The land used for agriculture, animal husbandry and transportation is about 198.7 km², accounting for 26.16%; the rest of the land is about 5.07%.

3. Research and analysis of environmental situation
The main pollution sources in the basin include domestic sewage of rural residents, runoff pollution from farm fertilizers and pesticides, pollution from livestock and poultry breeding, industrial point source pollution (including phosphate mining enterprises and phosphorous chemical enterprises) and tourism pollution, etc.

3.1. Research and analysis of rural non-point source pollution
Rural non-point source pollution mainly includes rural domestic pollution and farmland runoff pollution in the river basin.

3.1.1. Survey and analysis of rural domestic pollution. There are about 134,700 rural people in the basin, among which sewage, livestock and poultry breeding and household garbage are the main sources of rural life pollution. Accordind to the report, the daily sewage volume of the rural population in this basin is about 37L. The pollutant discharge of domestic sewage and the total amount of sewage entering the lake are calculated in Table 1.

Table 1. Estimation of the village sewage discharge and the amount into the lake in the basin.

| Indicator             | Per capita emissions | Total emissions | Into lake |
|-----------------------|----------------------|-----------------|-----------|
| Water yield(m³/a)     | 13.51                | 181.98×10⁶      | 90.99×10⁴ |
| COD (t/a)             | 0.23×10⁻¹            | 3098.22         | 1549.11   |
| Total nitrogen(t/a)   | 0.99×10⁻³            | 133.40          | 66.70     |
| Total phosphorus(t/a) | 0.20×10⁻³            | 26.90           | 13.45     |
It can be seen from Table 1 that, without effective water treatment equipment, the domestic sewage of rural residents is directly discharged into the river without effective treatment. About 50% of the COD, total nitrogen and total phosphorus in the domestic sewage are discharged into the Lake River of Fuxian Lake, which has caused a certain impact on the water quality of it.

The breeding industry in the basin is mainly scattered by farmers, with the total of 70,313 pigs and 9,931 cattle and sheep and other large animal excrement production and lake inflow are shown in Table 3. It can be seen from the table that the remaining 10% of pollutants in human and animal feces are discharged into the lake channel after being simply treated in the biogas digester, thus it can be seen that COD, total nitrogen and phosphorus in human and animal feces can be easily remove in small rural methane devices.

**Table 2. Estimation of human and animal manure production and inflow into the lake.**

| Indicator         | output (t/a) | Into lake (t/a) |
|-------------------|--------------|-----------------|
|                   | excrements of livestocks | human waste | Total |
| COD               | 5221.62      | 3704.31         | 8925.83 | 892.62 |
| Total nitrogen    | 1150.43      | 592.70          | 1743.13 | 174.33 |
| Total phosphorus  | 307.20       | 94.32           | 401.52  | 40.14  |

According to the research results, rural residents produce about 0.50kg of household waste per person per day. According to the estimated population of 134,700, the annual output of garbage in this basin is about 24,600 tons. According to the investigation and estimation, the COD of the receiving water body is about 2.46×10^3 t/a, the total nitrogen is about 1.23×10^2 t/a, and the total phosphorus is about 49.20t/a, respectively accounting for 1096 and 0.596 of the total waste. 2096, among them, the garbage is not effective transportation amount 4.92×10^3 t/a, accounting for 20% of the total waste, the receiving water body because of its produce COD is about 492t/a, about 24.6 t/a total nitrogen, total phosphorus is about 9.84t/a, accounted for 20% of their total: the last research calculated without effective transportation amount 20% into the Fuxian lake (table 3), the analysis from the table all residents living garbage was not effective treatment, namely into rivers into the lake, caused certain pollution to Fuxian lake, adding to the lake water eutrophication process.

**Table 3. Estimation table of the rural garbage pollution.**

| Indicator         | total amount(t/a) | Non-transportation amount(t/a) | Into lake(t/a) |
|-------------------|--------------------|--------------------------------|----------------|
| Total waste       | 2.46×10^4          | 4.92×10^3                      | 9.84×10^2      |
| COD (10%)         | 2.46×10^3          | 4.92×10^2                      | 98.40          |
| Total nitrogen(0.5%) | 1.23×10^2      | 24.60                           | 4.92           |
| Total phosphorus(0.2%) | 49.20             | 9.84                            | 1.97           |

3.1.2. Survey and analysis of farmland runoff pollution in the basin. Runoff pollution of farmland in watershed mainly refers to runoff pollution caused by fertilization and spraying. According to the survey, there are about 68.76 km² of cultivated land in Fuxian Lake Basin, and the amount of chemical fertilizer applied reaches 20,735.40 t/a. In the basin, the cultivated area of the industrial crop like garlic and peas covers a large area, and it consumes a large number of chemical fertilizer, about 50% of the total fertilizing amount. Additionally, the average amount fertilizing amount which apply to farmland in the basin is about 133.4t/ (m²• a), the converted total nitrogen and total phosphorus application amount reaches 33.35 t/ (m²• a) and 13.34 t/ (m²• a). ( in Table 4)
Table 4. Pollution table of farmland runoff in Fuxian Lake basin.

| counties   | agricultural acreage (km²) | emission amount (t/a) | Into lake (t/a) |
|------------|---------------------------|-----------------------|-----------------|
|            |                           | COD                   | Total nitrogen  | Total phosphorus |
| Chengjiang | 42.93                     | 1609.84               | 386.36          | 32.20            |
| Jiangchuan | 21.53                     | 807.41                | 193.78          | 16.15            |
| Huaning    | 4.30                      | 161.11                | 38.67           | 3.22             |
| Total      | 68.76                     | 2578.36               | 618.81          | 51.57            |
| COD        |                           | 1126.89               | 270.45          | 22.54            |
| Total      |                           | 565.19                | 135.64          | 11.30            |
| Total      |                           | 112.78                | 27.07           | 2.26             |
| Total      |                           | 1804.85               | 433.16          | 36.10            |

From analysis through table 4, counties COD emissions of pollutants total is about 2578.36 t/a, total nitrogen missions about 618.81 t/a, total phosphorus emissions about 51.57 t/a, pollutant amount of COD, total nitrogen, total phosphorus into the lake were 1804.85 t/a, 433.16 t/a, 36.10 t/a. Because the pollutants have not been effectively treated, farmland fertilizer applied in the basin is too serious, COD pollutants in chemical fertilizer, 70% of the total nitrogen, total phosphorus go into the lake, make the lake been polluted.

3.2. Investigation and analysis of urban domestic pollution status quo

Close to the north of Fuxian Lake is Chengjiang County, with an urban population of about 20,400. According to the survey, the per capita sewage capacity of the county residents is about 200L/(person • day), with COD of about 70g/(person • day), total nitrogen of about 10g/day (person • day), and total phosphorus of about 1.5g/(person • day). Some urban domestic sewage is discharged after being treated by the sewage plant, but this sewage plant is small in scale with the current treatment capacity of about 3000 TD, which is far from the design scale of 10000 TD.

Table 5. Analysis of urban domestic pollution.

| Indicator    | total(t/a) | Discharge into lake from sewage plant (t/a) | Discharge into lake undisposed(t/a) | Into lake total(t/a) |
|--------------|------------|--------------------------------------------|------------------------------------|---------------------|
| COD          | 521.22     | 12.90                                      | 206.95                             | 219.85              |
| Total nitrogen | 74.46      | 7.01                                       | 27.03                              | 34.04               |
| Total phosphorus | 11.17       | 0.48                                       | 4.62                               | 5.10                |

3.3. Investigation and analysis of water pollution in abandoned phosphate ore area

The research reveals that, Approximately 28.56 t of total phosphorus is lost per year from exposed waste phosphate ore layers and feedstock and slag dumps in the drainage basin. Based on the average runoff volumes of the main surface runoffs (Dongda River and Daicun River) from the phosphate mine waste site at the Yuxi Environmental Monitoring Station. An analysis of the amount of pollutants carried by landmark runoff resulted in a total phosphorus input to the lake from phosphate mine waste sites in the drainage basin of approximately 7.50 t/a.

3.4. Research and analysis of the current situation of pollution in tourism

There are more than 300 hotels in the Fuxian Lake drainage basin, with about 7,300 beds available, and the annual volume of sewage from tourism is about 182,700 t. Of which sewage plants treat about 131,000 t, or 71.7 per cent, Self-built waste water treatment of about 23,000 t, or 12.6 per cent, with the remaining 15.7 per cent of waste water discharged directly or after simple treatment, and the results are shown as follows: COD 17.77 t/a, Total nitrogen 2.82 t/a, Total phosphorus 0.38 t/a.

Analyzing the above results, we can see that the pollution sources in the Fuxian Lake drainage basin are mainly four aspects, including rural non-point source pollution, urban domestic pollution, pollution from abandoned phosphate mines and tourism pollution. Of these, rural surface pollution (including pollution from watershed villages, human and animal manure, rural garbage and agricultural runoff) is
the largest source of pollution, COD, total nitrogen, and total phosphorus account for 94.81%, 94.85%, and 87.79%, respectively, of their respective combined pollution loads into the lake. Pollution from agricultural runoff is the most significant component of rural non-point source pollution (Table 6).

Table 6. Statistics of pollution sources in Fuxian Lake basin.

| Source of pollution                  | COD (t/a) | Total nitrogen (t/a) | Total phosphorus (t/a) |
|-------------------------------------|-----------|----------------------|------------------------|
| Agricultural non-point source pollution | 1549.11   | 66.70                | 13.45                  |
| human and animal excreta pollution | 892.62    | 174.33               | 40.14                  |
| rural garbage pollution             | 98.40     | 4.92                 | 1.97                   |
| farmland runoff pollution           | 1804.85   | 433.16               | 36.10                  |
| Total                               | 4344.98   | 679.11               | 91.66                  |
| Urban domestic pollution             | 219.85    | 34.04                | 5.10                   |
| Phosphorite pollution               | -         | -                    | 7.50                   |
| Tourism pollution                    | 17.77     | 2.82                 | 0.38                   |
| Total                               | 4582.60   | 715.97               | 104.64                 |

4. Conclusion

1) The research on pollution in the Fuxian Lake drainage basin in recent years and its data analysis led to the following conclusions. The main sources of pollution in the Fuxian Lake drainage basin are rural non-point source pollution, urban domestic pollution, pollution from abandoned phosphate mines, and tourism pollution.

2) The rural non-point source pollution includes pollution from drainage basin villages, human and animal manure, rural waste and runoff from agricultural lands. It is the largest pollution source in the drainage basin. It’s COD, contents of total nitrogen and total phosphorus occupied 94.81%, 94.85%, and 87.79% of amount of pollution into the lake, respectively. Among them, the pollution from runoff from agricultural fields was the most significant component of rural non-point source pollution.

It can be seen, if we want to protect the water quality of Fuxian Lake, we should mainly proceed to the control of rural non-point source pollution, and supplemented by control of pollution from urban life, phosphorus chemical industry, tourism and other aspects of governance, with a multi-pronged approach.

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