

Concentration of nutrients in the soil in water-level-fluctuating zone of Three Gorges Reservoir

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Abstract

Contents of nutrients in the surface soil in the water-level-fluctuating zone of Three Gorges Reservoir was investigated. Soil samples were collected at 57 sampling stations from Wushan County to Chongqing City in April 2010. The average organic matter concentration was 10.636 ± 4.401 mg g⁻¹ with a range of 1.097-19.947 mg g⁻¹, total nitrogen was 0.865 ± 0.423 mg g⁻¹ with a range of 0.127-1.903 mg g⁻¹, and total phosphorus was 0.595 ± 0.222 with a range of 0.205-1.365. Variability of organic matter and total nitrogen concentrations between sampling sites was high, whereas total phosphorus concentration was little diversified. Results of TOC/TN analysis showed that organic matter in surface soils was mainly derived from sedimentation of biomass. Nitrogen and phosphorus in soils of the water-level-fluctuating zone could become potential pollution sources. Therefore, more attention should be paid to the potential impact of nitrogen and phosphorus in soils of this zone on reservoir eutrophication. Single standard index of total nitrogen ranged from 0.72 to 2.12 and was generally above 1, indicating relatively serious nitrogen pollution. However, total phosphorus concentration was relatively low, with standard index values ranging from 0.83 to 1.40, indicating that the phosphorus pollution is not very serious.

Key words: Three Gorges Reservoir, water-level-fluctuating zone, organic matter, nitrogen, phosphorus.

1. Introduction

A water-level-fluctuating zone is the water-land cohesion zone with alternating wet and dry cycles caused by the periodical inundation and drying of soils. It is often formed due to seasonal fluctuations

of water level in rivers, lakes, reservoirs, etc. (Diao, Huang 1998; Wantzen *et al.* 2008). In order to satisfy its multi-purpose objectives of power generation, desilting, and flood control, Three Gorges Reservoir is being operated between a high water level of

175 m from October to mid-April and a low water level of 145 m from April to September. As a result, the reservoir's water-level-fluctuating zone with annual fluctuation up to 30 m is formed. When the reservoir is operated under the high water level, the water-level-fluctuating zone is inundated, while when the reservoir is operated under the low water level, the water-level-fluctuating zone is exposed, opposite to the natural water level fluctuation patterns of most of natural rivers and lakes in China. As the cohesion zone between the water area and land area, complicated material and energy exchange and transformation processes would occur in water-level-fluctuating zone of Three Gorges Reservoir.

Before the construction of Three Gorges Dam, the main stream and tributaries of Yangtze River in the reservoir area had never experienced the problem of algae bloom. However, the first major incidence of algae bloom occurred in June 2003 in segments of Xiangxi River, Daning River, and other tributaries to Three Gorges Reservoir when a 135 m deep impoundment was formed. Since then, the problem of algae bloom has happened frequently in the reservoir (Cai, Hu 2006). Carbon, nitrogen and phosphorus are generally considered as the main factors for the growth of algae (Fong *et al.* 1993; Johnson *et al.* 2006). As a special zone of periodical impoundment and flooding in the Three Gorges Reservoir area, the carbon, nitrogen and phosphorus in the submerged soil in the water-level-fluctuating zone can have physical, chemical and biological exchanges through soil interstitial water and overlying water. Therefore, the study of carbon, nitrogen and phosphorus contents and their soil-water exchanges may have great significance in the reservoir ecosystems. Until now, numerous researches on the water-level-fluctuating zone have been conducted mainly in terms of nitrogen and phosphorus contents in soils and overlying water (Tang *et al.* 2005; Guo *et al.* 2010), the background value of heavy metals (Chen, Peng 2003; Yu *et al.* 2006; Pei *et al.* 2008), the absorption and desorption of nitrogen and phosphorus (Wang *et al.* 2006; Yuan *et al.* 2008; Wang *et al.* 2009; Zhang *et al.* 2012). However, there is little study done on the evaluation of nitrogen and phosphorus pollution in the soil of water-level-fluctuating zone by signal factor method (Li *et al.* 2001) through comprehensive consideration and coupling of carbon, nitrogen and phosphorus. In this study, contents of organic matter, nitrogen and phosphorus of the water-level-fluctuating zone of Three Gorges Reservoir, from Wushan County to Chongqing City were studied. Also, the ratios of TOC/TN, TOC/TP and TN/TP, as well as their coupling relationships were studied by integrating the distribution of organic matter,

nitrogen, and phosphorus. The pollutions of nitrogen and phosphorus in the study area were evaluated by using the single index method (Li *et al.* 2001). These studies, lead to better understanding of the spatial variability of organic matter, nitrogen and phosphorus in the soils of the water-level-fluctuating zones of Three Gorges Reservoir. This study also provides management guidance for the prevention and control of algae bloom in the reservoir area and in the water-level-fluctuating zone.

2. Materials and methods

2.1. Study area

Fifty-seven soil samples from the water-level-fluctuating zones were collected in the mid-section of Three Gorges Reservoir area from Wushan County to Chongqing County. These sampling sites are located in the main stream of Yangtze River, Daning river basin in Wushan, Pengxi river basin in Yunyang and Kaixian, Ganjing river basin in Zhongxian, Wujiang river basin in Baitao of Fuling, Longxi river basin in Dandu of Changshou, and Guangyang Dam Ancient River in the area of south bank. Detailed locations of sampling sites and sampling time are listed in Fig. 1 and Table I.

2.2. Sampling and analyzing methods of soil samples

All soil samples were collected from the water-level-fluctuating zone in April 2010 after it was flooded by the impoundment. Luoyang spade was used to collect the surface soil (0-20 cm), and 4 different soil samples were collected within the scope of 1m. After mixing and splitting into about 1kg by quartering technique, they were put in polyethylene bag and sealed. After the samples were taken back to the laboratory, they were stored in refrigerators with the temperature of -20°C. The latitude and longitude, temperature, pH, oxidation-reduction potential, conductivity and water content of all samples were measured during the collecting process.

The samples were frozen and dried by using FD-1C-50 freeze-dryer. Dried samples were grinded by a porcelain mill and then passed through a 100-mesh sieve. The indoor analysis indexes are total nitrogen, total phosphorus and organic matter in soils. Total nitrogen, total phosphorus and organic matter were measured by Kjeldahl method, acid dissolution-molybdenum antimony resistance to colorimetric method, and potassium bichromate-external heating method, separately. TOC is calculated by the following formula (Lu 2000):

$$\text{TOC} = \text{The content of organic matter} / 1.724$$

Table I. Locations of sample sites in various river basins.

| River basin | Location | Type of soil | Sampling time |
|-----------------------------|--|------------------|----------------|
| Yangtze River | Gonghe Village in Shibao Stockaded Village longitude 108°08.473' E, latitude 30°24.191' N | Purple soil | April 1, 2010 |
| | Xinzheng Village in Shibao Stockaded Village longitude 108°10.473' E, latitude 30°25.225' N | Purple soil | April 1, 2010 |
| | Wenxi Village in Fengdu longitude 107°49.735' E, latitude 29°58.681' N | Yellow soil | April 7, 2010 |
| | Main stream of Guangyang Dam longitude 106°43.190' E, latitude 29°34.903' N | Fluvo-aquic soil | April 14, 2010 |
| Daning River | Zhoujiawan in Wushan longitude 109°45.797' E, latitude 31°17.752' N | Purple soil | April 3, 2010 |
| | Qiliqiao in Wushan longitude 109°46.555' E, latitude 31°17.378'v N | Fluvo-aquic soil | April 3, 2010 |
| | Xujiawan in Wushan longitude 109°46.148' E, latitude 31°17.766' N | Fluvo-aquic soil | April 3, 2010 |
| | Dachang ancient town in Wushan longitude 109°47.445' E, latitude 31°16.212' N | Yellow soil | April 3, 2010 |
| | Yangxi River estuary in Wushan longitude 109°49.809' E, latitude 31°17.214' N | Purple soil | April 3, 2010 |
| Pengxi River | Hanfeng Lake 1 in Kaixian longitude 108°26.393' E, latitude 31°11.139' N | Fluvo-aquic soil | April 17, 2010 |
| | Hanfeng Lake 2 in Kaixian longitude 108°26.167' E, latitude 31°11.243' N | Fluvo-aquic soil | April 17, 2010 |
| | Baijia brook in Kaixian longitude 108°33.604' E, latitude 31°08.507' N | Fluvo-aquic soil | April 20, 2010 |
| | Yanglu Lake in Yunyang longitude 108°33.901' E, latitude 31°04.998' N | Purple soil | April 20, 2010 |
| Ganqing River | Xinqiao Village in Zhongxian longitude 108°01.964' E, latitude 30°19.110' N | Purple soil | April 2, 2010 |
| Wujiang Rive | Baitao in Fuling longitude 107°28.979' E, latitude 29°32.115' N | Luvio-aquic soil | April 8, 2010 |
| Longxi River | Dandu in Changshou longitude 107°07.408' E, latitude 29°48.573' N | Purple soil | April 9, 2010 |
| Guangyang Dam Ancient River | tributary of Guangyang Dam longitude 106°41.495' E, latitude 29°33.329' N | Fluvo-aquic soil | April 14, 2010 |



Fig. 1. Location sketch of the sampling sites: 1. Main stream of Guangyang Dam, 2. Tributary of Guangyang Dam, 3. Dandu, 4. Baitao, 5. Wenxi Village, 6. Xinqiao Village, 7. Gonghe Village, 8. Xinzheng Village, 9. Hanfeng Lake 1, 10. Hanfeng Lake 2, 11. Baijia brook, 12. Yanglu Lake, 13. Zhoujiawan, 14. Xujiawan, 15. Qiliqiao, 16. Dachang ancient town, 17. Yangxi River.

3. Results and analysis

3.1. Contents of soil organic matter in flooded water-level-fluctuating zone

Soil organic matter refers to carbon organic matter in the soil, including all animal and plant residues, micro-organisms, and all kinds of organic substances decomposed and synthesized by them in the soil. They are extremely important natural colloids in soils, as they are active substance for the absorption, distribution and complexation of heavy metals, organic matter, and other contaminants. They are also the important source of various nutrients in the soil, and the important indicator which reflects the organic nutrition degree (Wang *et al.* 2004). They can not only increase the soil's abilities of fertilizer reservation and supply, but also can promote the formation of granular structure, improve the water permeability, water storage capacity and air permeability of soil, and increase the buffering capacity of soil. The contents of organic matter in the studied river basins in the study area are listed in Table II.

Table II indicates that the average value of organic matter in the study area is $10.636 \pm 4.401 \text{ mg g}^{-1}$, and the distribution scope is 1.097-19.947 mg g^{-1} . The contents of organic matter in most river basins in the study area show no significant difference ($p > 0.05$), except that in Daning River and Pengxi river basin ($p < 0.05$). The maximum content

Table II. Contents of soil organic matter in water-level-fluctuating zone in the flooded areas of different river basins (mg g^{-1}).

| Drainage basin (number of samples) | Content of OM | Range of OM |
|---|--------------------|----------------|
| Study area (n = 44) | 10.636 ± 4.401 | 1.097-19.947 |
| The main stream of Yangtze River (n = 11) | 10.011 ± 4.494 | 3.89-18.038 |
| Danang river (n = 11) | 14.328 ± 3.494 | 8.397-19.947 |
| Pengxi river (n = 10) | 7.926 ± 3.508 | 1.097-12.928 |
| Ganjing river (n = 3) | 8.184 ± 1.297 | 7.411-9.681 |
| Wujiang river (n = 3) | 13.288 ± 3.826 | 9.642-17.271 |
| Longxi river (n = 3) | 10.072 ± 6.426 | 5.064-17.318 |
| Guangyang Dam Ancient River (n = 3) | 8.789 ± 1.561 | 7.130-10.228 |

of organic matter is $14.328 \pm 3.494 \text{ mg g}^{-1}$ from Daning river basin, and the minimum value is $7.926 \pm 3.508 \text{ mg g}^{-1}$ from Pengxi river basin. The low content of organic matter in Pengxi river basin may be related with the soil quality in some sampling points in this river basin. The sampling point in Hanfeng Lake of Kaixian is an abandoned city, and its soils are mainly sandy soil with little ground vegetation. Therefore, the content of organic matter in this river basin is lower than others. Within the entire study area, sampling points in Hanfeng Lake of Pengxi river basin showed the minimum value of organic matter of 4.77 mg g^{-1} .

3.2. Contents of Total Nitrogen and Total Phosphorous in the soil of flooded water-level-fluctuating zone

To some extent, the contents of nitrogen and phosphorous in the soil of water-level-fluctuating zone would correspond to reservoir biological productivity. The study of contents of nitrogen and phosphorous in the soil of water-level-fluctuating zone has great significance in finding out the distribution laws of nitrogen and phosphorous in the reservoir, and its eutrophication potential. The contents of total nitrogen and total phosphorous in the soil of water-level-fluctuating zone within the study area are listed in Table III.

Table III indicates that the average value of total nitrogen in the study area is $0.865 \pm 0.423 \text{ mg g}^{-1}$, which distribution scope of 0.127-1.903 mg g^{-1} . There are no significant differences in the contents of total nitrogen in different river basins ($p > 0.05$). The maximum value is $1.167 \pm 0.298 \text{ mg g}^{-1}$ from Daning River basin, and the minimum value is $0.403 \pm 0.120 \text{ mg g}^{-1}$ from the Ancient River of Guangyang Dam. The distribution trends are similar to that of organic matter (as shown in Fig. 2). It is speculated that the organic matter and total nitrogen may have the same source or most of the total nitrogen are organic in nature. The increase in content may be mainly caused by organic nitrogen. The analysis of nitrogen species by the authors supports the above hypothesis (data to be published). As one of the convertible nitrogen, organic nitrogen has the potential of release to the overlying water. Therefore, the soil in the flooded water-level-fluctuating zone has the risk of releasing nitrogen.

The average value of total phosphorous in the study area is $0.595 \pm 0.222 \text{ mg g}^{-1}$, with a distribution scope of 0.205-1.365 mg g^{-1} . There are also no significant differences in total phosphorous content in different river basins ($p > 0.05$). The maximum phosphorous value is $0.84 \pm 0.095 \text{ mg g}^{-1}$ measured at the Ancient River, a tributary of Guangyang Dam. The minimum phosphorous value is measured is

0.499±0.183 mg g⁻¹ measured at Longxi river basin. Fig. 2 indicates that the distribution pattern of total phosphorous is different from that of total nitrogen and organic matter. The total content of phosphorous in Daning river basin is not the highest within the study area, but its contents of total nitrogen and organic matter are the highest. Possibly, the source of total phosphorous is different from that of total nitrogen and organic matter. Generally, agricultural non-point source pollution is the principal source of total phosphorous.

3.3. Variation of nitrogen and phosphorous contents in soils in non-inundated areas and in water-level-fluctuating zone

To study the influences of impoundment of Three Gorges Reservoir to the contents of nitrogen and phosphorous in soils in water-level-fluctuating zones, the contents of nitrogen and phosphorous in the non-flooded soil and soil from flooded water-level-fluctuating zone were compared. The results are shown in Fig. 3. It can be seen that the contents

Table III. Contents of nitrogen and phosphorous in the soil of water-level-fluctuating zone from different river basins (mg g⁻¹).

| Drainage basin (number of samples) | Content of TN | Range of TN | Content of TP | Range of TP |
|--|---------------|-------------|---------------|-------------|
| Study area (n = 44) | 0.865±0.423 | 0.127-1.903 | 0.595±0.222 | 0.205-1.365 |
| The main stream of Yangtze River (n = 11) | 0.766±0.337 | 0.271-1.302 | 0.619±0.345 | 0.205-1.365 |
| Danang river (n = 11) | 1.167±0.298 | 0.564-1.438 | 0.529±0.127 | 0.375-0.78 |
| Pengxi river (n = 10) | 0.742±0.349 | 0.127-1.186 | 0.57±0.2 | 0.277-0.908 |
| Ganjing river (n = 3) | 0.762±0.099 | 0.66-0.858 | 0.633±0.11 | 0.549-0.758 |
| Wujiang river (n = 3) | 1.108±0.695 | 0.612-1.903 | 0.643±0.066 | 0.58-0.711 |
| Longxi river (n = 3) | 0.849±0.854 | 0.319-1.834 | 0.499±0.183 | 0.333-0.469 |
| Guangyang Dam Ancient River (n = 3) | 0.403±0.12 | 0.264-0.476 | 0.84±0.095 | 0.732-0.912 |

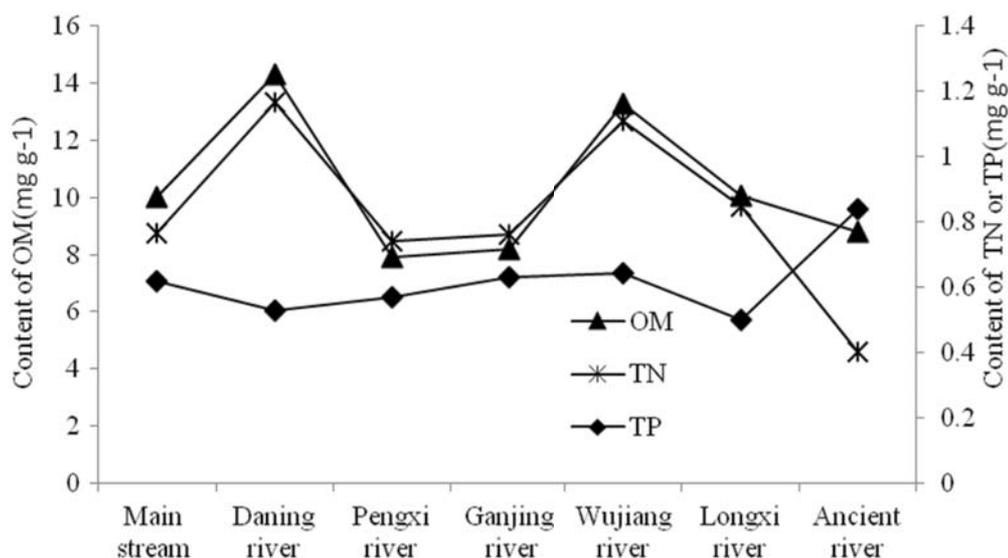


Fig. 2. Variation trends of OM, TN and TP in the study area.

of nitrogen in inundated soils and non-inundated soils vary in different river basins. The contents of nitrogen in non-flooded soils in the main stream of Yangtze River, Wujiang River and Ancient River in Guangyang Dam are higher than that in inundated soils in the water-level-fluctuating zone. It can be speculated that the soil in the water-level-fluctuating zones may release nitrogen to the overlying water during the flooded period. On the contrary, the contents of soil nitrogen in flooded water-level-fluctuating zone in Daning River basin, Pengxi (Xiaojiang) river basin, Ganjing river basin and Longxi river basin are higher than that in non-flooded soil. It can be speculated that the soil in the water-level-fluctuating zones may absorb nitrogen during the flooded period.

Relation between phosphorous content in non-inundated soil and in the soils in the water-level-fluctuating zones are different with that of nitrogen. Except of the water-level-fluctuating zone in Longxi river basin, the contents of phosphorous in the non-inundated soils are higher than that in the inundated soils. It indicates that the soils in the water-level-fluctuating zones release phosphorus to the overlying water during the flooded period. Past research indicates that nitrogen and phosphorous could be released from soils to the overlying water (Jia *et al.* 2007; Hu *et al.* 2008; Yuan *et al.* 2008; Wang *et al.* 2009). The existence of this natural interface transfer process is supported by the results derived from this study.

3.4. Ratio of nutritive salt in the study area

TOC/TN

TOC/TN ratio is different with different species. Therefore, TOC/TN in sediments reflects the source of organic matter, the TOC/TN of advanced plants, aquatic life, zooplankton and phytoplankton, and algae are 14-23, 2.8-3.4, 6-13, and 5-14, respectively (Cai *et al.* 2007). The value of TOC/TN in different parts of the study area is quite similar with an average value of 7.13. The range of variation is 6.20-12.65 which is small, and the maximum value is 2.0 times of the minimum value (Table IV). This indicates that the or-

ganic matter in the soil of the water-level-fluctuating zones come mainly from the biological settlement in the overlying water.

TN/TP

Average value of TN/TP in the study area is 1.45 (Table IV). Different from the uniform distribution of TOC/TN, the spatial distribution of TN/TP varies greatly, and the range of variation is 0.48-2.21. The

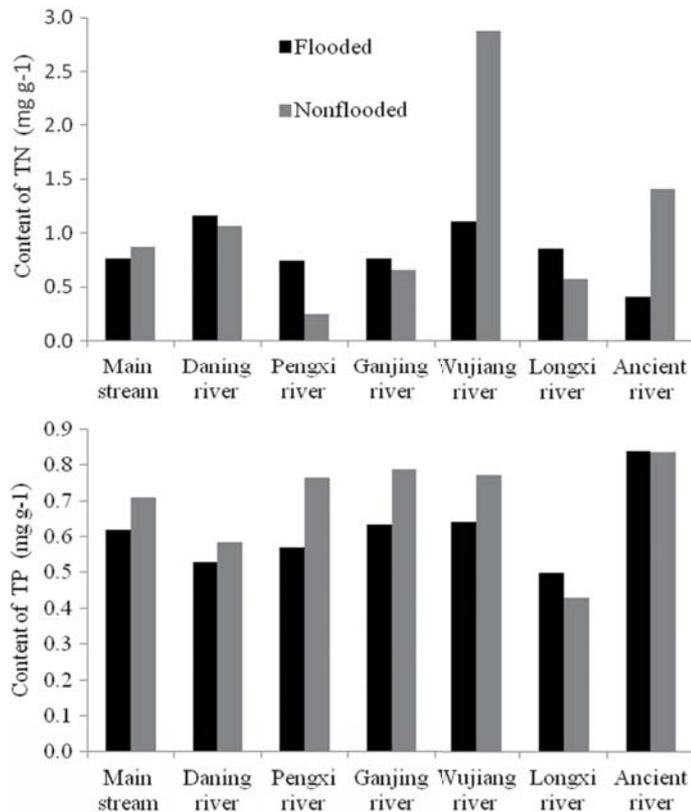


Fig. 3. Contents of nitrogen and phosphorous in non-flooded soil and in soil in flooded water-level-fluctuating zone

Table IV. Ratio of nutritive salts in the soil of the water-level-fluctuating zones in the study area.

| Drainage basin | TOC/TN | TN/TP | TOC/TP |
|----------------------------------|--------|-------|--------|
| Study area | 7.13 | 1.45 | 10.37 |
| The main stream of Yangtze River | 7.58 | 1.24 | 9.38 |
| Danling river | 7.12 | 2.21 | 15.71 |
| Pengxi river | 6.2 | 1.3 | 8.07 |
| Ganjing river | 6.23 | 1.2 | 7.5 |
| Wujiang river | 6.96 | 1.72 | 11.99 |
| Longxi river | 6.88 | 1.7 | 11.71 |
| Guangyang Dam Ancient River | 12.65 | 0.48 | 6.07 |

maximum value is 2.21 in Daning River basin, and the minimum value is 0.48 in Ancient River in the tributary of Guangyang Dam. The maximum value is 4.6 times of the minimum value. Due to the small variation of phosphorous spatial distribution in the flooded soil, TN/TP may be directly affected by the content of nitrogen. Therefore, the spatial distribution of TN/TP is basically the same with the distribution trend of total nitrogen.

TOC/TP

The average value of TOC/TP in the study area is 10.37. The distribution trend of TOC/TP is basically the same as that of TN/TP. The maximum value and minimum value of TOC/TP are 15.71 in Daning River basin and 6.07 in Ancient River. The maximum value is 2.6 times of the minimum value. Due to the small variation of phosphorous' spatial distribution, TOC/TP may be directly affected by the content of TOC.

3.5. Analyzing the coupling relations among organic matter and total nitrogen in the study area

The coupling relations of organic matter and total nitrogen in the study area are shown in Fig. 4. The results show that organic matter and total nitrogen are significantly and positively correlated ($R = 0.721$, $p < 0.01$); Significant and positive correlation between organic matter and total nitrogen further indicates that the organic matter in the soil in water-level-fluctuating zone is the main source of total nitrogen in water and a large part of total nitrogen in soils is in the form of organic nitrogen. The significant and positive correlation between organic matter and total nitrogen, and the main existing form of organic nitrogen have been proved by the researches of Datta *et al.* (1999) for sediments

in Ganges-Brahmaputra-Meghna River, Li and Xu (1990) for sediments in the central and northern parts of Taiwan Strait, Ashby and Schindler (1995) for sediments in reservoir, Yang *et al.* (2004) for sediments in Donghu Lake in Wuhan, and Yu *et al.* (2010) for surface sediments in Hongze Lake (Li, Xu 1990; Ashby, Schindler 1995; Datta *et al.* 1999; Yang *et al.* 2004; Yu *et al.* 2010).

3.6. Evaluation of pollution caused by nitrogen and phosphorous in soils in water-level-fluctuating zone

At present, there is no reported methods and standards for evaluating soil environment in a water-level-fluctuating zone. In this study, the evaluation of pollution caused by nitrogen and phosphorous was conducted using sediment standard (Li *et al.* 2001) and single factor standard index which were originally developed for evaluating sediments. The general standard index of single pollution factor i has the following relational expression:

$$S_i = C_i / C_s$$

Where, S_i is the single evaluation index or standard index, and the content exceeds the evaluation standard value if it is larger than 1; C_i is the measured value of evaluation factor i ; C_s is the evaluation standard value of evaluation factor i . The concentration of total nitrogen and total phosphorous (0.55 mg g^{-1} and 0.6 mg g^{-1}) of the minimum level ecological risk effect caused by sediments in the Guidelines (Leivuori, Niemist 1995) published by the Ministry of Environment and Energy of Ontario in Canada (1992) is adopted by this study as the evaluation standard of total nitrogen and total phosphorous C_s . The detailed evaluation results are listed in Table V.

Table V indicates that standard indexes of total nitrogen range between 0.73 and 2.12. Except the evaluation index of 0.73 in soil samples collected in the Ancient River in Guangyang Dam, all other calculated values of indexes of nitrogen are more than 1. It indicates a serious problem of pollution of nitrogen of soils in the flooded water-level-fluctuating zone. The scope of evaluation index of total phosphorous is 0.83-1.4, which is densely distributed and fluctuated around 1. It indicates a modest problem of phosphorous pollution of soils in the flooded water-level-fluctuating zone.

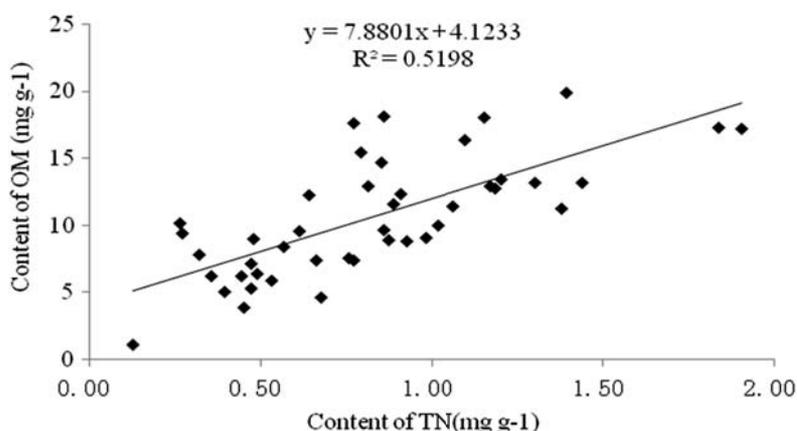


Fig. 4. Correlations between total nitrogen and organic matter in the study area.

The content of total nitrogen in the soil samples collected in the flooded water-level-fluctuating zone is 0.403-1.167 mg g⁻¹. According to the guidelines published by the Ministry of Environment and Energy of Ontario in Canada (1992), the concentration of total nitrogen in the substrate which may cause serious ecological risk is 4.8 mg g⁻¹. Therefore, the content of total nitrogen in the soil from the flooded water-level-fluctuating zone is between the minimum level and maximum level of ecological risk effects. The variation scope of the concentration of total phosphorous is 0.499-0.84 mg g⁻¹, and mostly fluctuating at 0.6 mg g⁻¹. This indicates that the concentration of total phosphorous in the soil from the flooded water-level-fluctuating zone has modest ecological risk effect and is less harmful to the reservoir's environment than nitrogen.

4. Discussion

This study indicates that agricultural non-point source pollution is probably the primary source of total phosphorous in the water-level-fluctuating zones. In order to further verify this finding, the composition of phosphorous is to be investigated in order to confirm that the phosphorous occurs mainly in the inorganic form.

The environmental impact factors that influence the sorption-release of nitrogen and phosphorus include pH, temperature, DO, recurrent submergence (Søndergaard *et al.* 2003; Borch *et al.* 2010). Contents of nutrient salts are different in the different sampling sites of the studied area, and this variation may be because the sorption-release mechanisms of nutrient salts are different in different locations. In some areas, the sorption-release process may be influenced by pH and DO. In the others, that may be caused by temperature, recurrent submergence and so on. In order to better understand the spatial variability characteristics of nitrogen and phospho-

rous and sorption-release mechanisms of nutrient salts in the water-level-fluctuating zone, field and laboratory experiments are to be designed and conducted to investigate sorption-release mechanisms of nitrogen and phosphorous at the interface of soil and overlying water.

Conclusions

(1) Except the Ancient River in Guangyang Dam, the contents of total nitrogen in all soils in the flooded water-level-fluctuating zone exceed the established standards. The calculated values of standard index of nitrogen range between 0.73 and 2.12, indicating a serious potential problem of nitrogen pollution in soils in the inundated water-level-fluctuating zone. The calculated values of standard index of phosphorous are between 0.83 and 1.40, indicating a modest potential problem of phosphorous pollution in soils in the inundated water-level-fluctuating zone.

(2) The average concentrations of organic matter, total nitrogen and total phosphorous in soil samples collected in the flooded water-level-fluctuating zone are 10.636±4.401 mg g⁻¹, 0.865±0.423 mg g⁻¹ and 0.595±0.222 mg g⁻¹, respectively. Spatial variation of organic matter and total nitrogen are rather similar and they both vary greatly in the study area.

(3) Concentration of soil nitrogen in the flooded water-level-fluctuating zone in Daning River basin, Pengxi river basin, Ganjing river basin and Longxi river basin (1.17 mg g⁻¹, 0.74 mg g⁻¹, 0.76 mg g⁻¹, 0.85 mg g⁻¹, respectively) are much higher than that in non-flooded soil. It indicates that adsorption or the interface transfer of nitrogen from overlying water to soils may be an important environmental pathway of nitrogen in the flooded water-level-fluctuating zone. On the other hand, it was found that contents of phosphorous in the non-flooded soils are higher than that in the flooded soils in the main stream of Yangtze River, Daning River basin, Pengxi river basin, Ganjing river basin and Wujiang river basin (0.62 mg g⁻¹, 0.53 mg g⁻¹, 0.57 mg g⁻¹, 0.63 mg g⁻¹, 0.64 mg g⁻¹, respectively). It indicates that desorption or the interface transfer of phosphorous from soils to overlying water may be an important environmental pathway of phosphorous in the flooded water-level-fluctuating zone.

(4) The measured TOC/TN values of soil samples collected in the flooded water-level-fluctuating zone indicate that biological settlement in the water is probably the main source of organic matter in soils. According to the coupling relations of organic matter and total nitrogen, the total nitrogen in soils in the flooded area is mainly from organic matter, and much of total nitrogen is in the form of organic nitrogen.

Table V. Evaluation indexes of nitrogen and phosphorous in the soil from the flooded water-level-fluctuating zone

| Drainage basin | Evaluation indexes of TN | Evaluation indexes of TP |
|----------------------------------|--------------------------|--------------------------|
| Study area | 1.57 | 0.99 |
| The main stream of Yangtze River | 1.39 | 1.03 |
| Danang River | 2.12 | 0.88 |
| Pengxi River | 1.35 | 0.95 |
| Ganjing River | 1.39 | 1.06 |
| Wujiang River | 2.01 | 1.07 |
| Longxi River | 1.54 | 0.83 |
| Ancient River in Guangyang Dam | 0.73 | 1.41 |

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