



Pollution status of nitrogen and phosphorus in sediments of Danjiangkou Reservoir and its treatment countermeasures

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Abstract. Danjiangkou Reservoir, as the water source of China's South-to-North Water Diversion Project, should be emphasized for its water quality, and the sediment, as an important source and sink of nitrogen and phosphorus in the reservoir, is of great significance in the biogeochemical cycle. In this paper, we studied the current status of nitrogen and phosphorus fugacity in sediments of Danjiangkou Reservoir, and found that the overall condition of nitrogen and phosphorus pollution in Danjiangkou Reservoir is good, but the degree of TN pollution is more serious than that of TP, and it is more important to strengthen the management of TN in sediments. The results of the study can provide basic support for the eutrophication control of Danjiangkou Reservoir.

Keywords: Danjiangkou reservoir; nitrogen and phosphorus; Pollution status; Governance responses

1 Introduction

Nitrogen and phosphorus are the basic nutrients necessary for life activities, and they are also the main factors causing eutrophication of water bodies, and their contents are often used as the core indicators for evaluating the eutrophication level of water bodies in reservoirs^[1,2]. Sediment is an important source and sink of nitrogen and phosphorus in reservoirs, and is very important in the biogeochemical cycle of nitrogen and phosphorus^[3].

Danjiangkou Reservoir is the water source of China's South-to-North Water Diversion Middle Line Project, and its water quality condition is directly related to the water safety of the residents in the downstream of the reservoir and the cities along the South-to-North Water Diversion^[4,5]. Under the influence of environmental protection policies of all levels of government, the exogenous pollution of Danjiangkou Reservoir has

basically been effectively controlled, and the overall water quality is good, but the nutrient salts in the surface sediments of the reservoir are still relatively rich [6,7]. After the commencement of the construction of the South-to-North Water Diversion Central Line Project in 2005, the Danjiangkou Dam was elevated to 176.6 m, and the storage level of the reservoir was elevated, which resulted in a smaller flow rate of the water body, and a decrease in the self-purification ability of the water body. Therefore, the influence of sediment nutrient diffusion and transport on the water quality of Danjiangkou should be emphasized [8].

This paper analyzes the current situation of sediment nitrogen and phosphorus pollution in Danjiangkou and the characteristics of the pollution, reasonably assesses the risk of sediment nitrogen and phosphorus pollution in Danjiangkou Reservoir, and provides scientific support for further improvement of Danjiangkou Reservoir water quality.

2 Materials and methods

2.1 Sampling areas

According to the hydrological and water environment characteristics of Danjiangkou Reservoir and its inlet tributaries, relying on the Danjiangkou Reservoir Area Water Quality Monitoring Station Network Platform, 30 sampling points are set up, including 6 reservoir sampling points and 12 tributary sampling points in Han Reservoir; 8 reservoir sampling points and 4 tributary sampling points in Dan Reservoir, with the specific setups as shown in Fig. 1.

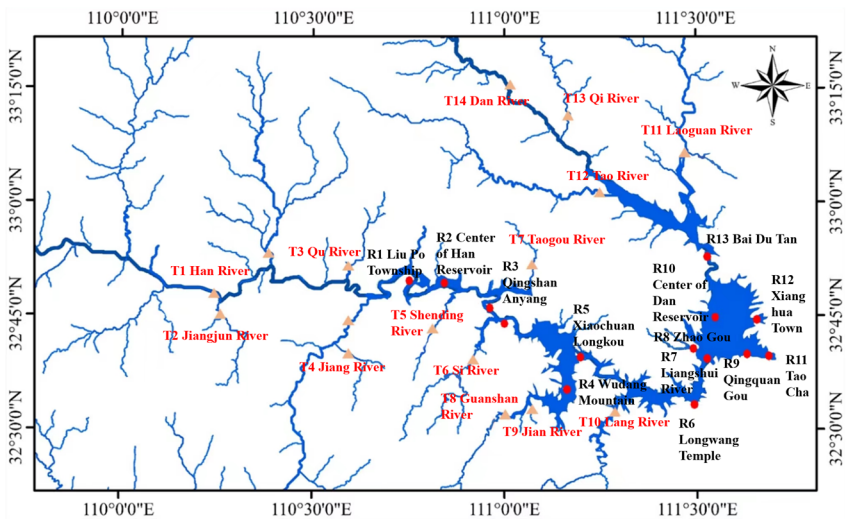


Fig. 1. Distribution of sampling points in Danjiangkou Reservoir

2.2 Pollution risk evaluation

The evaluation of the risk of nitrogen and phosphorus contamination of Danjiangkou reservoir sediments is unified with reference to the standard values of 0.55 g/kg and 0.60 g/kg for the evaluation of the combined TN and TP contamination indices, i.e., they are consistent with the content of TN and TP in the sediments that can cause the lowest level of ecological risk effects given by the Ministry of the Environment and Energy of the Province of Ontario, Canada (see Table 1). The individual pollution indices were calculated using the formula:

$$S_i = C_i / C_s \quad (1)$$

$$FF = \sqrt{\frac{F^2 + F_{\max}^2}{2}} \quad (2)$$

S_i is individual evaluation indices or standardized indices, $S_i > 1$ indicates that the content exceeds the evaluation standard value; C_i is the measured value of evaluation factor i (g/kg); C_s is the evaluation standard value of evaluation factor i (g/kg), C_s of TN is 0.55 g/kg, C_s of TP is 0.60 g/kg; FF is the composite pollution index; F is the average of n pollutant pollution indices (the average of the standard indices S_{TN} for TN and S_{TP} for TP); F_{\max} is the maximum single pollution index (the maximum value of S_{TN} and S_{TP}). Danjiangkou reservoir sediment nitrogen and phosphorus pollution evaluation and pollution level grading based on Table 2.

Table 1. Nutrient Quality Benchmarks for Sediments in Ontario, Canada

Pollutant indicators	security level	lowest level	serious level
TN	<550 mg/kg	550~4800 mg/kg	>4800 mg/kg
TP	<600 mg/kg	600~2000 mg/kg	>2000 mg/kg

Table 2. Classification of integrated sediment contamination levels

classification	S_{TN}	S_{TP}	FF	degree of contamination
1	$S_{TN} < 1.0$	$S_{TP} < 0.5$	$FF < 1.0$	cleanliness
2	$1.0 \leq S_{TN} \leq 1.5$	$0.5 \leq S_{TP} \leq 1.0$	$1.0 \leq FF \leq 1.5$	mildly
3	$1.5 < S_{TN} \leq 2.0$	$1.0 < S_{TP} \leq 1.5$	$1.5 < FF \leq 2.0$	moderately
4	$S_{TN} > 2.0$	$S_{TP} > 1.5$	$FF > 2.0$	severe degree

3 Results and discussion

3.1 Characteristics of Nitrogen and Phosphorus in Danjiangkou Reservoir Sediments

The TN and TP distribution of each sampling point is shown in Fig. 2. The TN content of Danjiangkou Reservoir sediment ranges from 134-4500 mg/kg, with a mean value of 1166 mg/kg, of which the highest is 4500 mg/kg at the Jian River sampling point of

the Han Reservoir tributary, and the smallest is 134 mg/kg at the Tao River sampling point of the Danjiangkou tributary. TP content ranged from 96 to 1060 mg/kg, with an average value of 569 mg/kg, of which the highest was 1060 mg/kg at the sampling point of Langhe in the tributary of Han Reservoir, and the smallest was 96 mg/kg at the sampling point of Qi River in the tributary of Danku.

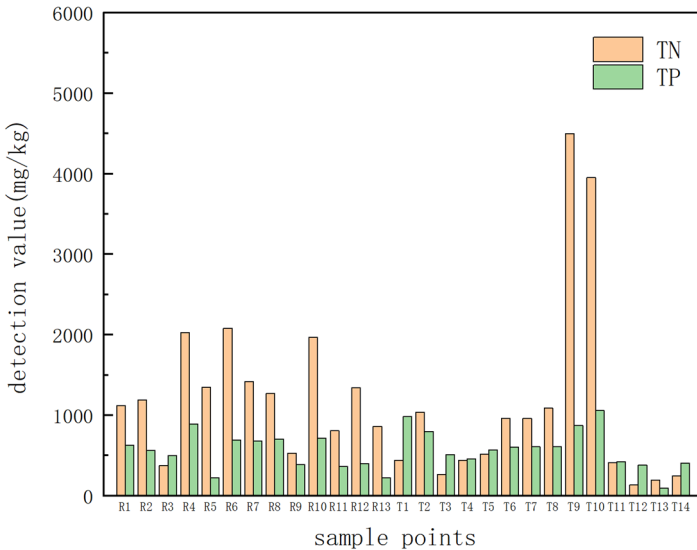


Fig. 2. TN and TP detection values at sampling points

It was slightly increased compared with the results of the surface sediment study of Danjiangkou Reservoir from 2011 to 2016 [6]. Compared with lake reservoirs in other regions of China, the sediment TN content was lower than that of surface sediments from Taihu Lake and Dongting Lake Basin^[9,10], and slightly lower than that of Poyang Lake^[11]; the TP content was lower than that of Xinfengjiang Reservoir sediments, and similar to that of the TP concentration measured by Li Bing et al. in Danjiangkou Reservoir in 2018, and higher than that of TP content in Gaozhou Reservoir, Guangzhou [6,12,13].

3.2 Risk assessment of nitrogen and phosphorus contamination of Danjiangkou Reservoir sediments

Referring to the nutrient quality benchmark of sediments in Ontario, Canada, it was found that the TN content in sediments of Danjiangkou Reservoir were all in the range of 134-4500 mg/kg, with an average value of 1166 mg/kg, of which 62.96% of the sampling points had TN content higher than 550 mg/kg, indicating that the overall pollution exceeded the safety level, the degree was the lowest level, and the ecological risk was low. The TN concentrations in Jian River and Langhe were relatively high at 4500

mg/kg and 3950 mg/kg, respectively. The TP concentration in the sediments of Danjiangkou Reservoir was analyzed with reference to the nutrient quality benchmarks of Ontario, Canada, and the mean value of TP was 569 mg/kg, and the sampling points with the content of 600 mg/kg or more accounted for 48.15%, which indicated that most of the contamination was within the safe level, and only the Langhe had a higher content. This indicates that most of the pollution is within the safe level, and only the content of Langhe is high, and the ecological risk is very low. It can be seen that Danjiangkou Reservoir as a whole is more seriously contaminated with nitrogen in the sediment, but the threat to the ecological risk is small.

From Table 3, it can be seen that the Danjiangkou Reservoir Danku reservoir area and tributaries TN pollution is very light, especially Danku tributary sampling points are clean level, but there is also a certain risk of contamination, especially Han Reservoir tributary part. Combined with the specific conditions of the sampling sites, it may be related to local industrial development and human activities. For TP, the overall concentration is relatively low and most of them are clean or mildly polluted. Overall the management of TN pollution in Danjiangkou sediments should be strengthened.

Table 3. Danjiangkou Reservoir Sediment Contamination Classification

Sample points	S_{TN}	S_{TP}
R1	2.036364	1.05
R2	2.163636	0.936667
R3	0.685455	0.831667
R4	3.690909	1.486667
R5	2.454545	0.375
R6	3.781818	1.156667
R7	2.581818	1.131667
R8	2.309091	1.176667
R9	0.965455	0.645
R10	3.581818	1.195
R11	1.472727	0.605
R12	2.436364	0.67
R13	1.563636	0.375
T1	0.801818	1.638333
T2	1.890909	1.333333
T3	0.48	0.855
T4	0.798182	0.766667
T5	0.94	0.953333
T6	1.743636	1.003333
T7	1.745455	1.018333
T8	1.981818	1.011667
T9	8.181818	1.456667
T10	7.181818	1.766667
T11	0.749091	0.708333
T12	0.243636	0.635

T13	0.350909	0.16
T14	0.450909	0.676667
<i>FF</i>	5.976632	1.417989

3.3 Danjiangkou Reservoir Endogenous Pollution Control Countermeasures

Control of exogenous pollution.

Mainly for the existing sewage treatment plant to carry out reasonable transformation, strengthen the nitrogen removal process, and combined with the actual local production and living conditions of the nitrogen fertilizer industrial wastewater total nitrogen pollution removal key technologies developed to improve the TN emission standards. In addition, from the point of view of agricultural surface pollution, the use of nitrogen fertilizer should be appropriately controlled to radically and effectively reduce the agricultural surface pollution of TN, and at the same time, the emission of TP should also be appropriately controlled.

Rehabilitation of vegetated buffer zones in the riparian zone of the reservoir.

Vegetated buffer strips in riparian zones to stop or absorb surface runoff. Total nitrogen in surface runoff. Along the shoreline of the reservoir and shallow water channels, plant submerged plants, water-supporting plants and wetland plants from low to high, create a variety of biological communities, enhance the ecological function of the reservoir and self-purification ability, form a multi-level barrier system with ecological isolation zones as the backbone, and construct a barrier zone with intertwined forests and grasslands around the reservoir at the landscape level.

4 Conclusion

Danjiangkou Reservoir, as the water source area of the South-to-North Water Diversion Central Line, has generally good water quality, especially the TP pollution is light, and most of the area is clean or mildly polluted. However, attention needs to be paid to the control of TN pollution to avoid eutrophication of water bodies.

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