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Form Distribution Characteristics of Nitrogen in a Reservoir as Drinking Water Source

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Abstract

Based on field detected water quality data, the distribution characteristics of different forms of nitrogen in a reservoir as drinking water source in Dongguan, which locates at the Pearl River Delta of China, have been analyzed in order to provide theoretical bases for prevention and reduction of eutrophication. The analyzed results show that nitrogen forms in the influent area of the reservoir are given priority to ammonia nitrogen and nitrate nitrogen, whose proportion is more than 45% respectively, and this is probably caused by the pollution of inflow water quality; but in the effluent area, the forms are given priority to nitrate nitrogen, whose proportion is as high as 96% and above; also the proportion of ammonia nitrogen drops by more than 80% during the process from the influent area to the effluent area, and this shows that the natural process of nitrification and denitrification can be well accomplished in the reservoir. We recommend here that to reduce the input amount of ammonia nitrogen and organic nitrogen into the reservoir is the most efficient way to prevent or mitigate eutrophication of water body.

Keywords

Nitrogen Form, Reservoir for Drinking Water Source, Eutrophication, Dissolved Organic Nitrogen

1. Introduction

Nitrogen pollution in a reservoir not only can promote the degree of water body eutrophication, but also will generate disinfection by-products of nitrogen (N-DBPs) during the process of chlorine disinfection when the water is pumped to prepare for dinking. The N-DBPs are carcinogenic and most harmful to human health. In order to control this risk, it is necessary to make clear distribution regulation of nitrogen forms and their variation in a reservoir.

But up-to-date, researches on nitrogen form characteristics in a reservoir are still few. Xiaoli Ge *et al.* investigated geochemical characteristics of water body in Reservoir Miyun in Beijing during 2001, and found out that TN/TP ratio was as high as 38.4:1 and pointed out that phosphorus is the major nutrient element limiting biological productivity [1]. Yeqing Feng *et al.* investigated the mean concentrations of TN, TP, chlorophyll-a and SD in Reservoir Hongfeng located on the Guizhou plateau in southwest China in 2010 as 1.83 mg/L, 0.034 mg/L, 0.0127 mg/L and 2.3 m respectively, which shows that the water body in the reservoir was in meso-eutrophic state [2]. Yuejuan Lin analyzed and assessed the characteristics of sediment cores and their overlaying water quality. The results show that concentration of total nitrogen is relatively low in both summer and winter but much high in both spring and autumn [3]. Yunxian Dong *et al.* established 9 sampling plots on 3 sections in Lake Chenghai located in Yunnan of China by global positioning system to study the speciation and distribution of nitrogen and phosphorus, and their relationships with chlorophyll-a, and the results indicated that the total nitrogen, total phosphorus and total chlorophyll-a in the lake water were 0.773 mg/L, 0.046 mg/L and 0.024 mg/L respectively, and the majority of the total nitrogen was dissolved nitrogen in which dissolved organic nitrogen was predominant, while dissolved inorganic phosphorus consisted of majority of the total phosphorus [4]. Fengjiao Wang analyzed the geochemical behavior of nitrogen, phosphorus and other biogenic elements in the overlaying water and sediment of the Hulun Lake in arid areas within the Mongolian Plateau, and found out that the main existing form of nitrogen is the organic nitrogen in the lake [5]. Honelei Yu (2013) analyzed the distribution and transformation of DON in both landscape water and effluent water from different treatment processes in municipal sewage treatment plants, and concluded that there was seasonal variation in the concentrations of DON in the landscape water, and there was significant difference between the north and south part in different months. And DON in landscape water is the potential nutrition of algae, and it is remarkable in the process of eutrophication control [6]. So far, the distribution and its variation of nitrogen forms in a reservoir as drinking water source are still not clear and need to be further deeply studied. Thus, we have taken Reservoir TS, which locates at Dongguan of Guangdong Province in China, as an example to analyze the distribution characteristics and its spatial and temporal variation of nitrogen forms in reservoir.

2. Survey of the Reservoir

2.1. Basic Condition

Reservoir TS is located in southeast of Dongguan city. It has catchment area of 100 km^2 and total capacity of 65.2 million m^3, as shown in **Figure 1**. It was classified as one of the backup drinking water sources for the city in 2006. Huanyan Huang *et al.* indicated after analyzed the detected water quality data that the reservoir is in a state of slight pollution [7], and Jiao Han discussed the environmental capacity of the reservoir [8].

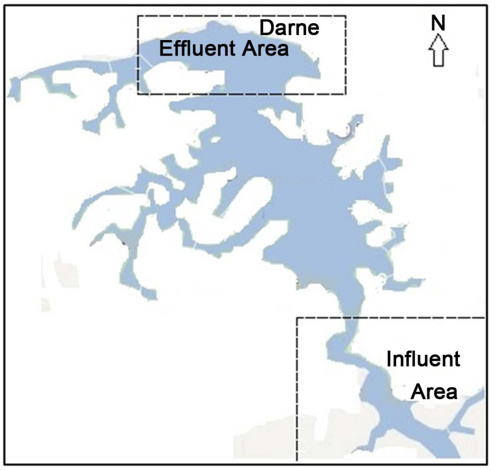

Figure 1. Plan of reservoir TS.

2.2. Survey Result

During the period from April 2014 to January 2016, we sampled water quality and nutritional level of the reservoir. According to the water quality requirement of *China National Environmental Quality Standards for Surface Water* (GB3838-2002), the single factor standard indexes of the water quality have been calculated out as shown in Table 1 based on the detected data. It can be seen from the table that there exist five indexes exceeded the national standard, *i.e.*, COD_{Mn}, COD_{cr}, ammonia nitrogen, BOD_5 and total phosphorus. Thus, it has been shown from this phenomenon that the reservoir has been obviously contaminated by organic and nutrient pollutants.

Based on the monitored data of water body nutritional level, the comprehensive nutritional status index of the reservoir has been calculated out as shown in Figure 2 according to the improved comprehensive nutrition state index calculation method provided by Rui Zhang *et al.* [9]. It has been shown from Figure 2 that the reservoir is at meso-eutrophic status, but its nutritional level has a decrease trend. But the degree of comprehensive nutrition in the effluent area is lower than that in the influent area of the reservoir. This shows that the reservoir has good self-purification ability because nutrient pollutants can be degraded obviously from influent area to effluent area.

3. Nitrogen Form Distribution Characteristics

Nitrogen in water can be mainly divided into inorganic nitrogen and organic nitrogen. Usually, inorganic nitrogen includes ammonia nitrogen and nitric nitrogen, in which the ammonia nitrogen includes free ammonia nitrogen $\left(NH_3-N\right)$ and ammonium nitrogen $\left(NH_4^+-N\right)$, and the nitric nitrogen includes nitrate nitrogen $\left(NO_3-N\right)$ and nitrite nitrogen $\left(NO_2-N\right)$. But organic nitrogen in water contains a lot of organic compounds, such as urea, amino acid, protein, nucleic acid, uric acid, fatty amine, organic base, amino sugar and so on. The concentration and proportion of different forms of nitrogen in water are often determined by specific circumstances of the water body.

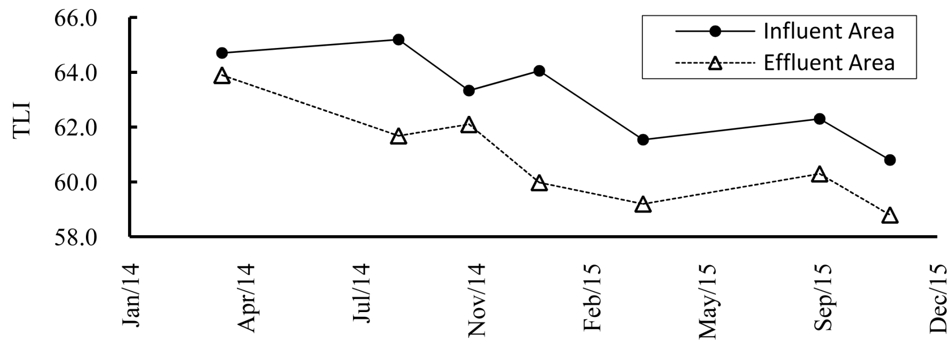

Figure 2. Variation of the comprehensive nutritional status index TLI of the reservoir.

Table 1. Present status of water quality standard indexes of the reservoir.

Item	Standard Index			Status
	Influent area	Effluent area	Average	
pH	0.085	0.098	0.091	Qualified
DO	0.273	0.204	0.239	Qualified
COD_{Mn}	1.080	0.963	1.022	Exceed standard
COD_{cr}	1.020	1.370	1.195	Exceed standard
Ammonia nitrogen	2.768	1.498	2.133	Exceed standard
BOD_5	1.265	1.690	1.478	Exceed standard
TP	2.960	2.240	2.600	Exceed standard
Petroleum class	0.800	0.800	0.800	Qualified
Anionic surface-active agent	0.150	0.150	0.150	Qualified
Volatile phenol	0.100	0.100	0.100	Qualified
Sulfide	0.015	0.015	0.015	Qualified
Cyanide	0.003	0.003	0.003	Qualified
Zinc	0.010	0.008	0.009	Qualified
Copper	0.004	0.003	0.004	Qualified
Lead	0.001	0.001	0.001	Qualified
Cadmium	0.006	0.006	0.006	Qualified
Selenium	0.010	0.010	0.010	Qualified
Mercury	0.050	0.050	0.050	Qualified
Arsenic	0.023	0.024	0.024	Qualified
Chromium of six valence	0.040	0.040	0.040	Qualified
Fluoride	0.672	0.538	0.605	Qualified

3.1. Proportion of Different Forms of Nitrogen

The proportion of different forms of nitrogen in the reservoir has been analyzed base on the detected data of water quality, and the result shows that inorganic nitrogen occupies most proportion of total nitrogen, and its proportion is as high as over 92% in the influent area or over 84% in the effluent area at any time, but the organic nitrogen only occupies below 8% in the influent area or below16% in the effluent area at any time, as shown in Figure 3.

The inorganic nitrogen in the reservoir is found to be composed of ammonia nitrogen and nitric nitrogen, and their average proportions during the detecting period are 49.9% and 50.1% in the influent area, and 48.5% and 51.5% in the effluent area respectively, as shown in Table 2.

The nitric nitrogen in the reservoir is also found to be composed of about 96% - 99% of nitrate nitrogen and 1% - 4% of nitrite nitrogen, as shown in Table 3.

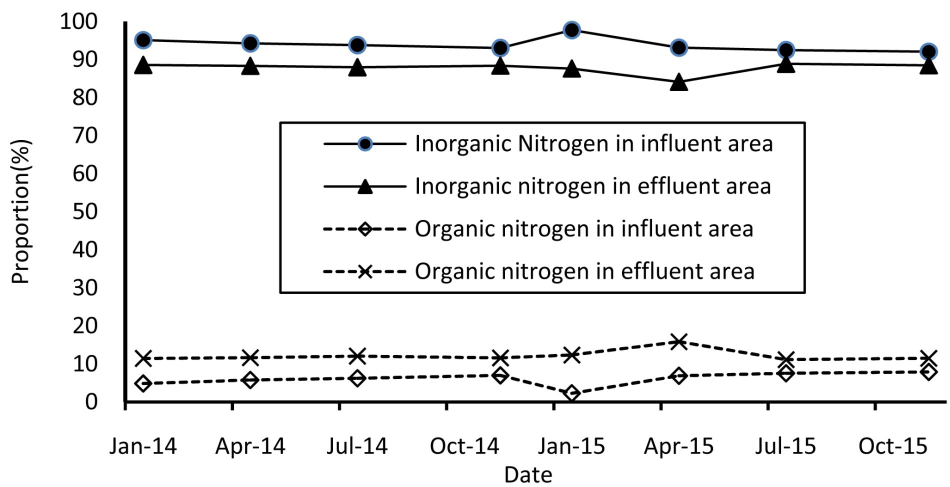

Figure 3. Variation of proportion of inorganic and organic nitrogen in the reservoir.

Table 2. Composition proportion of inorganic nitrogen in the reservoir.

Nitrogen form		Proportion (%)								
		Jan-14	Apr-14	July-14	Nov-14	Jan-15	Apr-15	July-15	Nov-15	Average
Ammonia Nitrogen	Influent	52	51	51	51	49	48	48	49	49.9
	Effluent	51	50	49	49	48	47	47	47	48.5
Nitric Nitrogen	Influent	48	49	49	49	51	52	52	51	50.1
	Effluent	49	50	51	51	52	53	53	53	51.5

Table 3. Composition proportion of nitric nitrogen in the reservoir.

Nitrogen form		Proportion (%)								
		Jan-14	Apr-14	July-14	Nov-14	Jan-15	Apr-15	July-15	Nov-15	Average
Nitrate Nitrogen	Influent	98	98	98	98	97	96	96	96	97.1
	Effluent	99	99	99	98	97	96	96	96	97.5
Nitrite Nitrogen	Influent	2	2	2	2	3	4	4	4	2.9
	Effluent	1	1	1	2	3	4	4	4	2.5

It can be concluded from the above analyses that the proportion of different forms of nitrogen in the reservoir are 45.0% of nitrate nitrogen, 44.7% of ammonia nitrogen, 9.1% of organic nitrogen and 1.2% of nitrite nitrogen.

3.2. Spatial Distribution of Different Forms of Nitrogen

The spatial distribution of inorganic nitrogen and organic nitrogen has obvious differences in the reservoir, *i.e.*, during the process from the influent area to the effluent area, the inorganic nitrogen will degrade about 6.1%, but the organic nitrogen will increase about 6.1%, as shown in **Figure 3**.

The degradation of inorganic nitrogen may be caused by the reaction of its nitrification and denitrification. This phenomenon demonstrates that the water quality is getting improved and the self-purification ability of water is strong in the reservoir.

4. Conclusions

Nitrogen forms in a reservoir as drinking water source behave as over 84% of inorganic nitrogen and below 16% of organic nitrogen. The inorganic nitrogen is composed of ammonia nitrogen and nitric nitrogen, in which the nitric nitrogen is mostly composed by nitrate nitrogen.

The proportion of inorganic nitrogen in the influent area is some higher than those in the effluent area, but the proportion of organic nitrogen is little lower in the influent area than those in the effluent area.

Reservoirs as drinking water source may have essential capability of self-purification to degrade nutrient pollution.

Acknowledgements

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