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Journal of Hazardous Materials A73 (2000) 107–113

Journal of Hazardous Materials

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Nitrogen contamination in the Yangtze River system, China

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Received 29 July 1998; received in revised form 25 April 1999; accepted 2 October 1999

Abstract

The data at 570 monitoring stations during 1990 were studied. The results indicate as follows: (i) the contents of nitrogen in the Yangtze mainstream has a raising trend from the upper reaches to the lower reaches; (ii) total nitrogen content at a lot of stations during the middle 1980s is 5–10 times more than that during the 1960s; (iii) seasonal variances of nitrogen content vary with watersheds; and (iv) the difference of nitrogen contamination level is related to the regional population and economic development.

Keywords: China; The Yangtze River; Nitrogen contamination

1. Introduction

The Yangtze River is the largest river in China, and its mainstream is 6300-km long and drainage area is about 1.8×10^6 km^2. The natural and economic conditions vary largely with regions. The degree of nitrogen contamination differs from one area to another.

Since 1956, the Water Conservancy Ministry of China had set up more than 900 chemical monitoring stations in succession on 500 rivers all over the country. Within 1958–1990, a quantity of water-quality data, including nitrogen, was accumulated but nobody has studied them systematically. In this paper, the data of three nitrogen (NH_4^+-N, NO_2^--N, NO_3^--N) within 1958–1990 collected from the Water Yearbooks

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0304-3894/00/$ - see front matter
PII: S0304-3894(99)00165-X

edited by the Water Conservancy Ministry [1] were analyzed statistically. Although organic nitrogen is an important parameter reflecting the behavior of nitrogen in waters, unfortunately, this was not included in the routine monitoring in China. The content of the paper includes: (i) the nitrogen contamination status of the Yangtze River mainstream during 1990; (ii) the nitrogen contamination status of the major tributaries of the Yangtze River during 1990; (iii) the seasonal variance of nitrogen contamination during 1990; (iv) the trends of nitrogen contamination from 1960s to 1980s; and (v) the relationship between river nitrogen contamination and the watershed's social and economical development.

2. Materials and methods (source of data)

Water samples were collected at more than 600 sections on streams in the Yangtze River catchment by about 500 monitoring stations. The sampling stations are shown in Fig. 1. In general, water samples were collected and tested once per month or once per 2 months for each year. Sample analysis was conducted in five provincial laboratories belonging to the National Monitoring Network. The laboratories have passed the ''qualified analysis quality examination.'' The analytic methods were used according to the ''Guidebook on Chemical Analysis of Inland Surface Waters'' edited by the Water Conservancy Ministry of China. The methods for NH_4^+-N, NO_2^--N and NO_3^--N were Nash reagent colorimetric method, *N*-(I-naphthalin group) diaminoethane photometric method and ultraviolet spectrophotometry, respectively. Their detection limits were 0.02 mg/l, 0.003 mg/l and 0.08 mg/l, respectively. Of the total samples, 20% samples were conducted parallel to assure the analytical quality.

3. Statistical analysis

The Microsoft Excel 97 and the Seasonal Kendall procedure were used to analyze the data collected from the Water Yearbook within 1958–1990. Analysis of variance and social–economical activities' correlation were computed between the NH_4^+-N, TN concentration and the population, and the quantity of applied nitrogen-fertilizer.

4. Results and discussion

4.1. The nitrogen contamination status of the Yangtze River mainstream during 1990

The nitrate-nitrogen and ammonia-nitrogen's statistical averages of 25 representative stations along with the Yangtze River mainstream during 1990 indicate that nitrogen contamination level has a raising trend from upper reaches to lower reaches. As to ammonia-nitrogen, from Shigu station to Zhutuo station in Sichuan Province, the

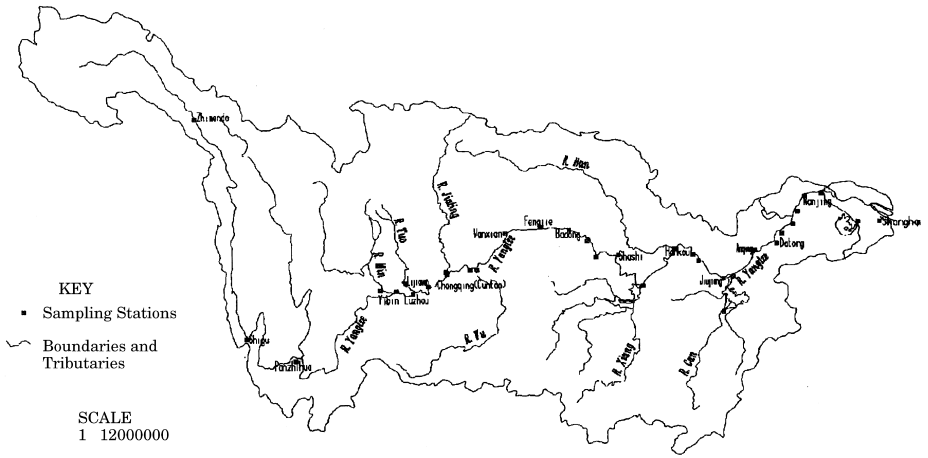

Fig. 1. The main sampling stations in the Yangtze River catchment.

average annual NH_4^+-N concentration ranged from 0.04 to 0.07 mg/l; From Chongqing station in Sichuan Province to Ezhou station in Hubei Province the average annual NH_4^+-N concentration generally is 0.20 mg/l; more or less, the contents at some stations are higher. From the Ezhou station to the Zhenjiang Station in Jiangsu Province and Shanghai Station it is generally higher than 0.20 mg/l and reaches 0.35 mg/l. As to total nitrogen (TN equal to the sum of NH_4^+-N, NO_2^--N and NO_3^--N) there exists the similar trend (Fig. 2).

In general, in local smaller rivers, the NH_4^+-N concentration decreased from pollution source to downstream and the NO_3^--N concentration increased simultaneously. The Yangtze River is too big, the length of which is more than 6×10^3 km and the discharge

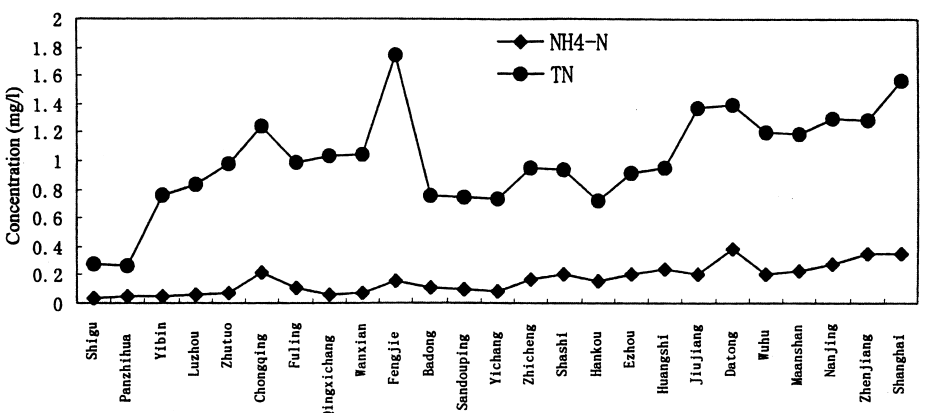

Fig. 2. The nitrate-nitrogen and ammonia-nitrogen contents of major hydrologic stations of the Yangtze River mainstream in 1990.

is very huge (3×10^4 m^3/s, the Datong Station upstream from Nanjing). We could not study the transformation of nitrogen species in waters.

4.2. The nitrogen contamination status of the major tributaries of the Yangtze River during 1990

The contents of NH_4^+-N in water of major tributaries is presented in Fig. 2. The Han River, Ganjiang River, and Lake Poyang were polluted lightly, the annual average NH_4^+-N concentrations are all below 0.1 mg/l; The upper tributaries, Tuo River and down tributaries, the Great Canal (the south part of Jiangsu Province) and the Huangpu River were polluted heavily, their annual average NH_4^+-N concentration were 1.76, 1.50, and 0.77 mg/l, respectively. The annual average NH_4^+-N concentrations in the Min River, Jialing River, Zishui River, Yuanshui River, Xiang River, and Lake Chaohu were about 0.3 mg/l. The regional distributions of TN content in the Yangtze River tributaries were similar to that of ammonia-nitrogen (Fig. 3).

4.3. The seasonal variance of nitrogen contamination during 1990s

The statistical analysis indicates that there exists three categories of seasonal variance of nitrogen contamination in the Yangtze River mainstream and tributaries: (i) Nitrogen content in flood season (months 7 and 8) is remarkably higher than that in dry season (months 11, 12, 1, and 2); (ii) Nitrogen content in flood season is remarkably less than that in dry season; (iii) There is no remarkable rule on seasonal variance. The first category is distributed in areas with lower ammonia-nitrogen and higher nitrate-nitrogen content. This category is exemplified in Fig. 4, which shows the seasonal variance of NH_4^+-N and TN content at the Xinfeng Station of the Taojiang River in Jiangxi Province. This phenomenon can be explained as the influence of the non-point source

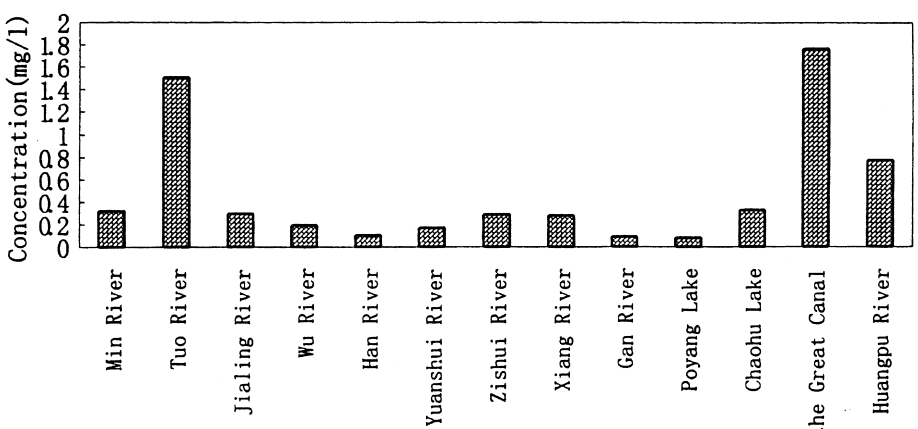

Fig. 3. The ammonia-nitrogen contents of the major tributaries of the Yangtze River.

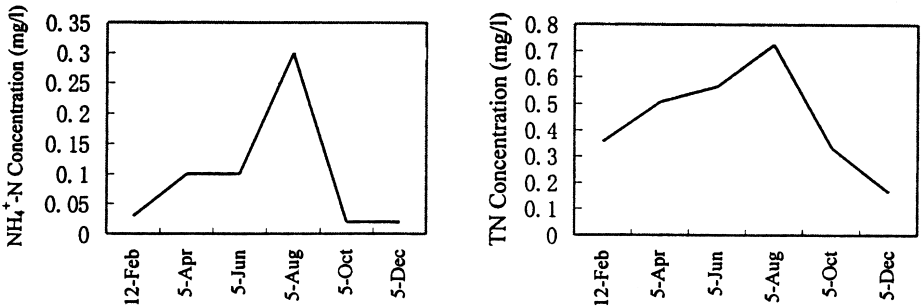

Fig. 4. The seasonal variance curve of NH_4^+-N and TN content of Taojiang River's Xinfeng station.

contamination. In flood season, soil loss contributes to the increase of nitrogen content in river water. The second category is distributed in areas with relatively higher ammonia-nitrogen percentage. This category is exemplified in Fig. 5, which shows the seasonal variance of NH_4^+-N and TN content at the Henglin Station, the Great Canal in Jiangsu Province. This phenomenon can be explained as the influence of the discharge of sewage and industrial liquid waste. In the dry season, the nitrogen concentrations of river water were higher because of lower flow and in flood season, the nitrogen concentration were lower because of dilution of higher flow. The third category, perhaps, can be explained as the mixed and irregular influence such as the stream-flow, the point source and the non-point source contamination and so on. This phenomenon should be studied continuously.

4.4. The trends of nitrogen contamination from 1960s to 1980s

TN concentration of representative hydrologic stations from 1960 to 1985 was analyzed with a Seasonal Kendall method. The result indicates that TN concentration of river water at most stations (such as Cuntan station, Yichang station, Hankou station, Datong station of mainstream and some stations of tributaries) has a notable raising trend during 1960s–1980s (see Fig. 6).

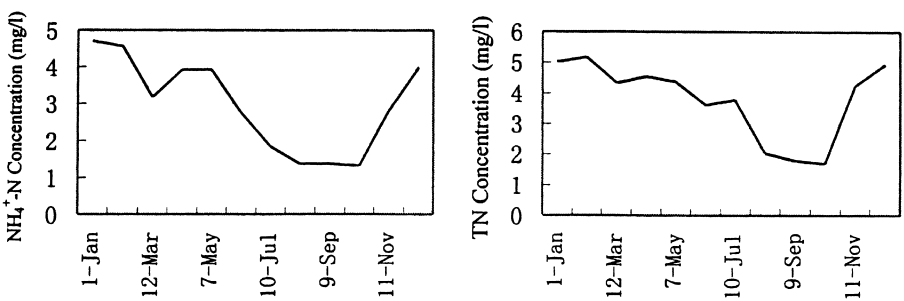

Fig. 5. The seasonal variance curve of NH_4^+-N and TN content of the Great Canal Henglin station.

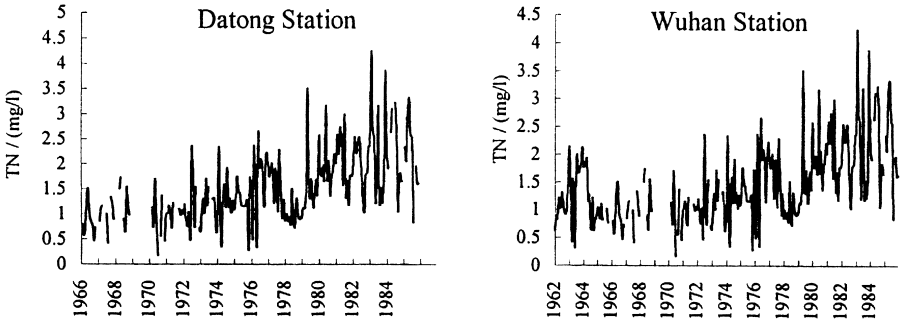

Fig. 6. The annual variance curve of TN content of Datong station and Wuhanguan station.

We have a sudden-change analysis with the TN concentration of some stations by M–K method. The results indicate that the sudden-change points of TN concentration of almost all stations emerged in 1973. That is to say, before 1973, the TN concentrations change slightly and just after that, it rises sharply.

4.5. Relationships between river nitrogen contamination and regional social–economical development

The Yangtze River is the largest river in China and the third largest one in the world. Within the river basin, it resides 25% of the national population and more than 20 major Chinese cities are located along the river basin. The Yangtze River valley, together with the coastal economic zone, formed the most important T-shaped economic zone in China. In general, the density of population of the provinces or cities in eastern China is higher than that in western China. The density of population of Jiangsu province and Shanghai city, which locates in eastern China, are 2212 persons/km^2 and 676 persons/km^2, respectively, while that of Yunnan province and Guizhou province only are 98 persons/km^2 and 192 persons/km^2, respectively. Also, the industrial economics development of provinces or cities in eastern China were more advance than those in western China. The total industrial out value of Shanghai in 1990 is about four times as that of the Yunnan province [2].

We analyzed two groups of data to find out the relationship between river nitrogen contamination and the watershed's social and economical development. In the first group, because of limited data, only two stations — Cuntan station (in flood season and in dry season) and Lijiawan station (in dry season), could be selected for analysis. The correlation analysis between the TN concentration of these two stations and the quantity of fertilizer N use of last year [3,4] was carried on. Their correlation coefficients are 0.70, 0.86, and 0.97, respectively, which indicates that TN concentration is effected remarkably by the quantity of fertilizer used.

In the second group, we hunt down the density of population, and quantity of nitrogen-fertilizer applied of every province distributed in Yangtze River basin [3]. Then we calculate the annual average NH_4^+-N and TN concentration of relevant hydrologic stations of tributaries which can stand for defined area. Between the two sets of data,

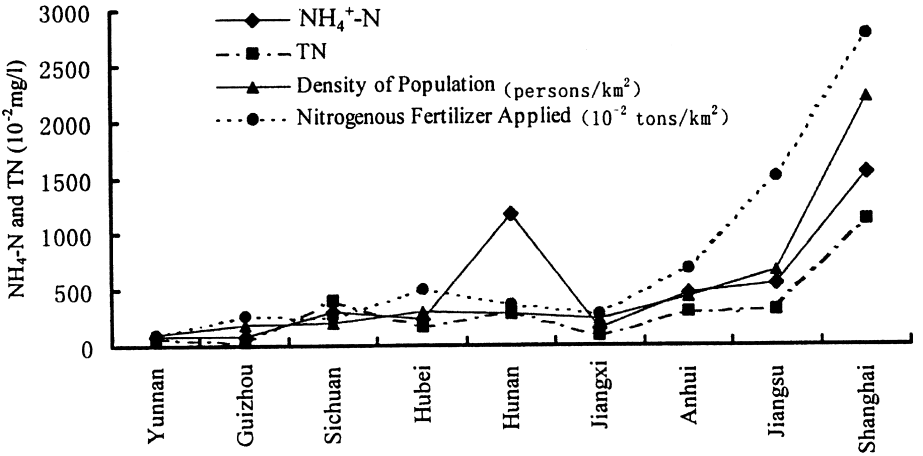

Fig. 7. The relationship between NH_4^+-N and TN content of major tributaries of Yangtze River basin and area economical indexes.

there exists good correlation (Fig. 7). The correlation coefficients between the NH_4^+-N, TN and the density of population, and the quantity of nitrogen-fertilizer applied are 0.80, 0.76, 0.94, 0.89, respectively.

5. Conclusions

The following conclusions can be made from this study:

1. Nitrogen contamination level has a raising trend from upper reaches to lower reaches along the Yangtze River.
2. Of the major tributaries of the Yangtze River, the Tuo River, the Great Canal (the south part of Jiangsu Province) and the Huangpu River were polluted most heavily.
3. There exists three categories of seasonal variance of nitrogen contamination in the Yangtze River mainstream and tributaries.
4. Total nitrogen concentration of river water at most stations has a notable raising trend during 1960s–1980s.
5. Between the density of population, the quantity of nitrogen-fertilizer applied and the NH_4^+-N, NO_3^--N concentrations, there exists good correlation.

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