Analysis of the Characteristics of Nitrogen and Phosphorus Emissions from Agricultural Non-Point Sources Pollution and Pollution Risk in Tianjin City, China

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Abstract. In order to understand the current status of agricultural non-point source pollution in Tianjin and figure out the main pollution source and areas, the evaluation and spatial distribution of agricultural non-point source pollution were analyzed. The pollution discharge coefficient method was used to estimate the agricultural non-point source pollution in Tianjin. The spatial distribution pattern of agricultural non-point source pollution load was analyzed by ArcGIS software, the pollution evaluation and sources analysis were carried out by equivalent pollution load method. The results show that the pollution load of TN and TP in Tianjin in 2017 was 11760.7 and 871.86 tonnes per year respectively, and the equivalent pollution loads were 11760.70 and 8718.68 m³ separately. Among the districts, the Baodi District, Wuqing District and Jinghai District have higher pollution loads, which are the key control areas. The spatial analysis showed the similar distribution characteristics of pollution load and intensity, which was higher in the middle and lower in the north and south in Tianjin. It is necessary to separately develop targeted pollution prevention measures to strengthen management and control.

1. Introduction

With the rapid development of the agricultural economy, it has brought various opportunities and challenges. However, agricultural non-point source pollution caused by agricultural activities has also brought serious environmental problems to Tianjin. Agricultural Non-point Sources Pollution (ANPSP) refers to nutrient substances such as nitrogen and phosphorus, pesticides and other organic or inorganic pollutants in agricultural activities, through surface runoff and farmland leakage [1] [2], which mainly includes rural human manure, Livestock manure, and Straw and aquaculture pollution. Compared with point source pollution, agricultural non-point source pollution has become an important cause of water environmental pollution due to its complex diversity, wide distribution, uncertainty of location and approach, and great hazard [3] [4] [5] [6]. Agricultural non-point source pollution is already a serious ecological environment problem facing the world today. It is also a difficult and hot area for domestic and foreign scholars to explore and study [1] [2].
Agricultural non-point source pollution has uncertainty and randomness, which was difficult to estimate and evaluate. At present, the main estimation methods for agricultural non-point source pollution load are output coefficient method [7], monitoring method [8], model method [9] and drainage coefficient method [10]. Zhao et al [11], Wu et al [12] and Rao et al [13] analyzed the status and development of agricultural non-point source pollution in China from a nationwide perspective, and many scholars have targeted China’s Fujian Province, Shandong Province, Hubei Province and Jiangxi Province. The research on agricultural non-point source pollution in other regions [5] [14] [15], but the research on agricultural non-point source pollution in Tianjin is rarely reported. Therefore, based on a large number of statistical data, this study uses the coefficient method to quantitatively calculate pollutants in farmland chemical fertilizers, livestock, aquaculture and rural life sources in all districts of Tianjin. The pollution load method and GIS technology comprehensively analyze and evaluate the pollution source load and regional spatial distribution characteristics, in order to formulate policies and control the agricultural non-point source pollution in Tianjin.

2. methods

2.1. Study area Overview
Tianjin is located in the northeastern part of the North China Plain, adjacent to the Bohai Sea. The geographical coordinates are between 38°34′N~40°15′N, 116°43′E~118°04′E, with a total area of 11966.5 km². According to the 2017 Tianjin Statistical Yearbook [16], at the end of 2017, the city's permanent resident population was 15.59 million, and the resident population was 12.96 million. There are 16 districts in Tianjin, including 10 agricultural areas, which was four districts around the city (Dongli District, Beichen District, Xiqing District and Jinnan District) and the six districts suburbs (Binhai New District, Yinzhou District, Jinghai District, Wuqing District, Baodi District and Ninghe District) [17]. In recent years, due to the increase of point and non-point pollution, the water quality of each river has decreased year by year, the self-purification capacity of water bodies has decreased, and the water pollution of each river is serious. In 2017, the city's water quality compliance rate was only 35%, and the inferior V water quality section was 40% [17], the water quality has deteriorated severely. According to the 2017 Tianjin Statistical Yearbook, the area of cultivated land in Tianjin is about 372,100 hm² in 2017, and the total agricultural population is about 3 million. The total amount of COD and ammonia nitrogen emitted by agricultural non-point source pollution accounts for more than 50%. The environment has a great impact.

2.2. Data collection and preparation
According to the administrative division of Tianjin, there are ten districts involved in agriculture. The basic data including crop farming, livestock and poultry breeding, aquaculture and rural life in various districts were collected. All data are derived from various statistical yearbooks, environmental quality bulletins and other relevant statistical data and reports of Tianjin in 2017. At the same time, collect other parameters needed for accounting.

The TN and TP loads of crop farming (fertilizer, organic fertilizer and crop straw), livestock and poultry breeding, aquaculture and rural life are estimated by the sewage coefficient method. The accounting methods and coefficients were derived from literature sources [18] [19] [20].

2.3. Model description
The equivalent pollution load method is used to evaluate the potential pollution potential of different pollutants or pollution sources, and different pollutants are compared on the same scale [20] to identify the main pollution sources and major pollutants. Calculated as follows:

$$P_{ij} = \frac{M_{ij}}{C_{oi}} \times 10^{-6}$$  

(1)
Where $P_{ij}$ is the amount of the $i$ pollutant of the $j$ pollution source (m$^3\cdot$a$^{-1}$), $M_{ij}$ is the amount of the $i$ pollutant of the $j$ pollution source (t$\cdot$a$^{-1}$), $C_{oi}$ is standard value of water quality control category based on functional partition of water environment for pollutant $I$ (mg$\cdot$L$^{-1}$), $K_{ij}$ is the equivalent pollution load ratio of pollutant $i$.

According to the water function zoning in Tianjin, the current water quality in Tianjin is mostly Class III in the Surface Water Environmental Quality Standard (GB3838-2002), and the water quality management target is also Class III, so the lower limit of the threshold concentration of the Class III standard series is adopted. For accounting, TN and TP were calculated by taking 1, and 0.1 mg$\cdot$L$^{-1}$, respectively.

3. Results and discussion

3.1. Estimation of agricultural non-point source pollution load and spatial distribution of contribution intensity in Tianjin.

The TN and TP pollution load and load contribution rate of 10 districts in Tianjin in 2017 were estimated by the discharge coefficient method, including four major types of pollution sources such as crop farming, livestock and poultry breeding, aquaculture and rural life livestock. The calculation results are shown in Table 1.

In 2017, the TN and TP pollution loads of agricultural non-point source emissions in Tianjin were 11760.7 and 871.86 t, respectively, which were significantly lower than the results of the first national pollution source survey in 2010 [21], with a drop of 47%-68%. This is similar to the pollution of non-point source pollution in Tianjin, which was simulated by Feng et al [22] using remote sensing analysis.

Table 1. TN and TP emissions and pollutant discharge rates of different pollution sources in Tianjin

| Source of pollution            | Amount of pollutant /t$\cdot$a$^{-1}$ | Contribution rate /% |
|-------------------------------|-------------------------------------|----------------------|
|                               | TN                                  | TP                   | TN            | TP            |
| crop farming                  | 5525.56                             | 292.3                | 46.98%        | 33.53%        |
| livestock and poultry breeding| 3077                                | 331.32               | 26.16%        | 38.00%        |
| aquaculture                   | 1086.53                             | 123.06               | 9.24%         | 14.12%        |
| rural life                    | 2071.61                             | 125.18               | 17.61%        | 14.36%        |
| total                         | 11760.7                             | 871.86               | 100.00%       | 100.00%       |

The TN emitted by crop sources accounted for the largest proportion of agricultural sources, accounting for 46.98%, and the TP emissions from livestock and poultry sources accounted for the largest proportion of agricultural sources, accounting for 38%. The amount of TN and TP emitted by the aquaculture industry is the lowest among all sources. The results are similar to the results of agricultural non-point source research in the Hanfeng Lake Basin conducted by Xiong et al and the results of agricultural non-point source research in Jiangxi Province conducted by Xie et al.

This study uses ArcGIS10.6 software to add the pollution contribution and contribution intensity results to the table attributes of the administrative division map, and draws the spatial distribution map of the contribution of TN and TP in each district of Tianjin in 2017, as shown in Figure 1(a) and (b). The areas with large TN pollutant load are Wuqing District, Baodi District, Jinghai District and Ninghe District, accounting for 70.21% of the city. The areas with large TP pollutant load are Baodi District, Wuqing District, Ninghe District and Jinghai District, accounting for 73.94% of the city.
The spatial distribution of TN and TP pollution intensity in various districts of Tianjin is shown in Figures 1 (c) and (d). The variation range of TN pollution intensity in each area was 4.44~17.16 kg.hm⁻², the average pollution intensity was 9.97 kg.hm⁻², the variation intensity of TP pollution intensity was 0.30~1.64 kg.hm⁻², and the average pollution intensity was 0.74 kg.hm⁻². The areas with the higher TN and TP pollution intensity are Wuqing District and Baodi District, respectively. This is mainly because the two areas have larger crop farming area and livestock and poultry breeding than other areas, with more rural population and more agriculture. So when conducting water environment management, these two areas should be considered as key management targets. Feng et al [22] used remote sensing analytical method to simulate the TN and TP pollution intensity of non-point source pollution in Tianjin was 6.90 and 0.30 kg.hm⁻², respectively, which is similar to the results of this study.

Figure 1. Pollution load distribution of TN (a) and TP (b), pollution intensity distribution of TN (c) and TP (d) in Tianjin in 2017
Based on the spatial distribution map of pollution load and pollution intensity, it can be seen that the pollution load and pollution intensity of different pollutants have a certain correlation in space, which is the area with high pollution load has high pollution intensity. The overall appearance is lower in the central part, higher in the north and south, and highest in the north and south. The main reason is that the agricultural land use area in the north and south of Tianjin is large, the planting industry has a high multiple cropping index, the large-scale farming has relatively rapid development, the pollution discharge is large, and the pollution load and pollution intensity are at a relatively high level.

3.2. Analysis of agricultural non-point source pollution characteristics

The equivalent pollution load of TN and TP of various agricultural non-point sources in Tianjin in 2017 is shown in Table 2. In 2017, the total equivalent pollution load of agricultural non-point source pollution in Tianjin was 20479.38 m³. Among the various pollution sources, the total load of crop farming, livestock and poultry breeding, aquaculture and rural life were 8448.59, 6390.18, 2317.18 and 3323.43 m³ respectively, the proportions are 41.25%, 31.20%, 11.31% and 16.22% respectively.

The equivalent pollution load and ratio of each district in Tianjin are shown in Table 3. There is a big difference in the amount of pollutant load in each district, ranging from 387.79 to 4494.13 m³. The areas with a large proportion of equal standard load are Baoyu District, Wuqing District, Jinghai District and Ninghe District. The equivalent pollution load of these four districts accounted for 71.78% of the city's total. This result is similar to the results of the pollution contribution analysis in this article. It can be seen that the seriousness of the agricultural non-point source pollution status and the necessity of governance in these four areas.

| Administrative district | equivalent pollution load /m³ | equivalent pollution ratio /% |
|-------------------------|-------------------------------|-------------------------------|
|                         | TN   | TP   | TN   | TP   |
| Baodi District          | 2011.48 | 2482.65 | 44.76% | 55.24% |
| Beichen District        | 364.15 | 220.62 | 62.27% | 37.73% |
| Binhai District         | 1010.11 | 694.68 | 59.25% | 40.75% |
| Dongli District         | 251.37 | 159.83 | 61.13% | 38.87% |
| Jizhou District         | 1273.77 | 755.27 | 62.78% | 37.22% |
| Jinan District          | 222.04 | 165.75 | 57.26% | 42.74% |
| Jinghai District        | 1871.49 | 1136.66 | 62.21% | 37.79% |
| Ninghe District         | 1680.35 | 1164.05 | 59.08% | 40.92% |
| Wuqing District         | 2693.79 | 1661.22 | 61.85% | 38.15% |
| Xiqing District         | 382.13 | 277.92 | 57.89% | 42.11% |

The equivalent pollution load of TN and TP in the city is 11760.70 and 8718.68 m³ respectively, among which TN has the higher equivalent pollution load, accounting for 57.43%, and TP is lower, accounting for 42.57%, indicating that TN is the main pollutant. This result is similar to the water
quality monitoring results of surface water sections in Tianjin in 2017. The high application rate of
nitrogen fertilizer and phosphate fertilizer in agricultural planting is a main reason of high pollution
load such as TN and TP in agricultural pollution sources [23]. It is necessary to increase the utilization
ratio of pesticides and fertilizers, promote the use of green organic fertilizers, and manage the
fertilization of agricultural crops.

The emission of pollutants TN and TP from livestock and poultry breeding industry is also very
large. It is necessary to strengthen the recycling of manure from large-scale farms, promote the
composting of livestock and poultry manure, and reduce the load on the corresponding manure
treatment facilities. In addition, in rural life, we should also strengthen the management and treatment
of waste discharge, classify domestic garbage and domestic sewage, such as the establishment of
garbage disposal stations and sewage drainage systems, and reduce the pollution of rural living
sources from the source.

4. Conclusion
In this study, the discharge coefficient method, the equivalent pollution load method and ArcGIS
software were used to estimate the pollution load, the pollution intensity, the spatial distribution and
the equivalent pollution load of agricultural non-point source pollution TN and TP emission in 10
districts of Tianjin in 2017. The results showed that the TN and TP pollution loads of agricultural non-
point source pollution in Tianjin are 11760.7 and 871.86 tonnes, respectively. The pollution load and
pollution intensity of various pollutants are similar in space, which was lower in the middle and higher
in the north and south, and the highest was the north. The four districts of Wuqing District, Baodi
District, Ninghe District and Jinghai District contributed the most pollution load.

The equivalent pollution load of TN and TP is 11760.70 and 8718.68 m³ respectively, the order of
cortribution of equivalent pollution load of various agricultural sources is crop farming > livestock
and poultry breeding > rural life > aquaculture. The contribution ratio of the equivalent pollution load
of agricultural source pollutants is TN>TP, and TN is the main pollution indicator.

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