Study on non-point sources pollution loading of nitrogen and phosphorus in Ashi river basin

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Abstract: The formation process of the non-point source pollution (NSP) was understood, through research and survey of Ashi River Basin of China. Different sources of NSP loads were obtained, by different sources of NSP monitoring techniques and estimation methods. The amount of NSP into the river was obtained, by monitoring techniques and estimation methods of NSP into the river in the Basin. The monitoring technology and loading estimation method system of NSP in the Ashi River Basin was established. It were calculated that different sources of NSP loading of total nitrogen (TN) was 8975.42t and total phosphorus (TP) was 606.27 t in 2010. NSP coefficient into the river the amount of TN was 4140.75 t and TP was 343.98 t, therefore, TN was 0.46, TP was 0.57 of the NSP into the river coefficient in the Ashi River Basin in 2010.

1. Introduction
Non-point source pollution (NSP) has gradually become an important source of water environment pollution. NSP is a type of pollution relative to point source pollution (PSP), which refers to water pollution caused by dissolved or solid pollutants inflow from large-area precipitation and run off erosion [1]. With randomness, intermittency, complexity, concealment and dispersion characteristics of NSP, therefore, it presents an obvious challenge of monitoring and load estimating based on monitoring. Sung Wan Yoon et al. monitored the runoff of 12 storms in 2008-2009, monitoring factors biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved organic carbon (DOC), suspended solids (SS), Total nitrogen (TN), total phosphorus (TP), NH4+-N, NO3–-N, PO43–-P, most were positively correlated with precipitation, rainfall intensity and total runoff [2]. NSP is usually influenced by the soil type characteristics, land use, management and terrain of the location [3, 4]. Uncontrollable meteorological factors such as rainfall intensity, rainfall duration, and the number of drought days after the previous rainfall are also important influencing factors [5, 6]. Based on the investigation and study of NSP monitoring technology and loading estimation method, the Ashi River Basin as a research area, NSP estimation method system was established in the Ashi River Basin, the amount of its production and discharge into the river were estimated, so as to establish the applicable technical methods for pollution load estimation based on non-point source (NPS) monitoring in the northeastern river of China.
2. Materials and Methods

2.1 Study area
The Ashi River is a tributary of the Songhua River in northeast of China (Figure.1), located in the southeastern part of Harbin City, Heilongjiang Province, the Ashi River Basin (45°05’-45°49’N, 126°40’-127°42’E) covers area of 3545km$^2$, and is the typical northeastern river\textsuperscript{[7]}. The whole territory of the Ashi River Basin is located within the Harbin city, it originates in the southern Daqing Mountain and then flows through the Shangzhi, Wuchang, Acheng, and Xiangfang districts of Harbin city from southeast to northwest.

![Figure 1: Topography and watersystem of Ashi River Basin](image)

2.2 Establishment of NSP monitoring and estimation system
Based on the monitoring of NPS output coefficients of different sources in the Ashi River Basin, it was estimated that different sources of NPS intensity loading. Based on water quality and water quantity monitoring, it was estimated that NSP loading into the river. Studied to determine the NSP type, systematically monitored the NSP of planting, breeding, rural life, urban runoff, forest, grassland and other land use; the amount of NSP coefficient into the river was studied, monitored the typical watershed water quality and water quantity, and calculated accordingly by use of output coefficient method and the average concentration method. The establishment of estimation method system for NSP emission source intensity which based on monitoring was for purpose of obtaining the total amount of NSP source intensity in the watershed, the total amount of NSP source intensity and the risk of pollution were characterized.

2.3 NSP Monitoring Technology

2.3.1 Monitoring Factors and Analytical Methods. NSP monitoring factor selected TP, TN, and runoff flow. TP followed in accordance with GB11893-1989 "molybdenum antimony anti-spectrophotometry", TN followed in accordance with GB11894-1989 "alkaline potassium persulfate oxidation- ultraviolet spectrophotometry"\textsuperscript{[8]}, runoff flow monitored of the Ashi River with a flow meter.
2.3.2 NSP Monitoring Type. The monitoring of the NSP source intensity of the basin mainly includes five parts that were planting, livestock and poultry breeding, rural life, urban runoff, forest, grassland and other land use. The five NSP monitoring factors were determine by the study of the major pollution indicator from variety sources of NSP. The monitoring methods and frequency of variety of NSP were determined by studying the characteristics of five pollutants production. The setting methods of monitoring site for five kinds of NSP were determined by studying the main influencing factors of various pollutants production. NSP production coefficients were obtained by rain intensity monitoring, runoff monitoring, features monitoring of living garbage pollution production.

2.4 Estimation Methods of NSP Loading
The output coefficient of pollutants per unit area or quantity were obtained by the monitoring the NSP of planting, breeding, rural life, urban runoff and forest, grassland and other land use in the river basin. The different NSP source intensity were estimated by use of the improved output coefficient method. The typical watershed export section was selected to monitor the water quality and water quantity simultaneously. Base flow segmentation and average concentration method were used to estimate the amount of NSP into the river which within the basin above the monitoring section.

2.4.1 Estimation Methods of NSP Output. Using the improved output coefficient model (ECM) by Johnes et al\(^{[9]}\), to estimation the output of NSP, which can be applied to calculate the source intensity of NSP in any one of the surface watersheds. The source elements are land use type, the number and spatial distribution of population and livestock and the NSP load input to the basin and through atmospheric deposition, the expression:

\[
L = \sum_{i=1}^{n} E_{i} [A_{i} \left( I_{i} \right)] + P
\]

In formula (1), L is the output of pollutants (t/a); \(E_{i}\) is the output coefficient of the i pollutant that the output coefficient of different land use (t/ km\(^2\)-a), or the output coefficient of population, livestock and so on (t/a), with a total of \(n\) species; \(A_{i}\) is the i-type land use area (km\(^2\)), or the i quantities of livestock or the number of population (ca); \(I_{i}\) is the i input of nutrient resource (t); \(P\) is the amount of nutrients input for rainfall (t). The output coefficient \(E_{i}\) represents the unit area or unit number of livestock and poultry population, the different nutrient output rate, and the output coefficient \(E_{i}\) comes from the monitoring results.

2.4.2 Estimation Methods of NSP into River. According to the principle of hydrology the total runoff is divided into two parts that surface runoff and base flow. The base flow is the part of perennial streams in the river. Base flow separation is the process of separating the base stream from total runoff. According to the principle of base flow separation, the pollution loading in the water flow in the base flow is regarded as the natural background value of the PSP and the dry season, and the pollutants in the water under the surface runoff are regarded as NPS rain and normal season natural background value. Therefore, the NSP load is estimated by the total pollution loading minus the PSP loading. The NSP load estimation formula can be expressed as:

\[
\bar{W}_{n} = \sum_{i=1}^{n} C_{i} \cdot Q_{i} \cdot \Delta t - \sum_{j=1}^{m} C_{P,j} \cdot Q_{P,j} \cdot \Delta t
\]

In the formula (2), \(W_{n}\) is the NSP loading, \(C_{i}\) is the concentration of pollutant quality in the i monitoring, \(Q_{i}\) is the monitoring flow in i, \(C_{P,j}\) is the PSP concentration at time t, \(Q_{P,j}\) is the river base flow, and \(\Delta t\) represents the time period by the i monitoring. Among them, the PSP loading is calculated by measuring the pollutant mass concentration in the dry season, and the water quality and water quantity data of the monitoring section are directly calculated, and the river base flow is divided by the runoff of the river\(^{[10]}\).
2.4.3 Coefficient of NSP into river. The coefficient of NSP into the river is the pollution loading accumulated by the rainfall on the slope of the river basin, according to the source intensity loading and the amount of the NPS in the Ashi River Basin, calculated coefficient of NSP into the Ashi River Basin in formula (3):

\[ \lambda_i = \frac{L_i}{S_i} \]  

(3)

In formula (3), \( \lambda_i \) is the coefficient of NSP i into the river (\( \leq 1 \)) of the basin, and is non-dimensional. \( L_i \) is the amount of the NSP i into the river (t); and \( S_i \) is the NSP i source intensity loading (t).

2.5 Data Sources and Processing

2.5.1 Data sources. Spatial data include Digital Elevation Model (DEM), county administrative map, soil type data, and land use data of the Ashi River Basin, data sources (Table 1).

| Data Type                  | Dimension   | Data Sources         | Data Description                                    |
|----------------------------|-------------|----------------------|-----------------------------------------------------|
| DEM                        | 1: 250,000  | NGCC                 | Watershed elevation raster data, .raster file        |
| County administrative map  | 1: 1000,000 | NGCC                 | Spatial data, .shape file                           |
| soil type                  | 1: 1000,000 | CAS; IGSNRR          | Spatial data, .shape file                           |
| land use data              | 1: 100,000  | CAS; IGSNRR          | land use type of 2010, .shape file                   |
| Yearbook of Harbin city    | Harbin city | Harbin Statistics Bureau | 2010, Excel file                                   |
| meteorology                | Harbin city | Heilongjiang province meteorological bureau | Daily precipitation, 2010, Access file |

2.5.2 Processing of Monitoring Data

The rural life, aquaculture and livestock NPS nitrogen (N) and phosphorus (P) loading were calculated, using the county statistics data of Harbin and the output coefficients. Based on the output coefficient method, the NPS N and P spatial simulation and loading estimation were used to add the NPS N and P load in rural life, breeding, planting, forest, grassland and other land use together, and get the non-P load then concluded that the N and P loading of NPS of in different regions. The improved Aitkin interpolation method was used to data interpolation \([11, 12]\), due to various uncontrollable causes monitoring data are deficient, which affect the integrity of the monitoring sequence, in the monitoring of discharge into the river in a typical basin, and the monitoring data are processed, including the modification of the data error, adjustment, repair and the correction of the missing.

3 Results and Discussion

3.1 Source Intensity Loading of NSP

NSP loading was summarized caused by different NSP sources in the Ashi River Basin that breeding, rural life, urban runoff, planting, forest, grassland and other land use (Table 2), it shows that TN loading was 8975.42 t, TP loading was 606.27 t of the Ashi River Basin in 2010. NSP loading changes of urban runoff, planting, forest, grassland and other land use can be characterized by land use characterization.
3.2 Coefficient of NSP into the river

Through calculating the coefficient of NSP into the river TN was 0.46 and TP was 0.57 in the Ashi River Basin in 2010. The base stream is the part of the streams perennial in the river, and its size is mainly affected by the soil, vegetation, topography, geology and climate of the basin. Therefore, the base flow separation has some deviation with the actual situation inevitably. The discharge from the PSP to the receiving water body is constant usually and has a major impact on the water quality at low flow rates. NSP was driven runoff by such as rainfall, snowmelt and so on usually, and it significant effect on the water quality at high flow rates.

Normally surface runoff mainly defined by the wet and dry season, the Ashi River water comes from the precipitation, rainfall and snowfall all over the years which has a certain amount of change, therefore, the NSP coefficient into the river is not a constant number, and there are changes in the years in the Ashi River Basin.

4 Conclusion

The pollution degree of NSP into the river was obtained by monitoring and estimation of the discharge into the river. It were calculated that the TN was 8975.42 t, TP was 606.27 t in different sources of NSP load of the Ashi River Basin, TN was 4140.75 t TP was 343.98 t in the discharge of NSP into river, then the coefficient of NSP into the river were calculated which TN was 0.46 and TP was 0.57 in 2010. On the basis of the monitoring the NSP monitoring techniques and estimation method system of the Ashi River Basin was established, it can provide technical support for NSP input river coefficient of the smaller watershed, and it can provide the reference for the NSP overall estimation of the larger river basin.

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