

Simulation for non-point source pollution based on QUAL2E in the Jinghe River, Shaanxi Province, China

• Jucui Wang •

Chang'an University/Key Laboratory of Subsurface Hydrology and Ecological Effect in Arid Region of Ministry of Education, China

• Aidi Huo* • Anyan Hu • Xuezhen Zhang •

Chang'an University, China

*Corresponding author

• Yanqing Wu •

Shanghai Jiaotong University, China

Abstract

Wang, J., Huo, A., Hu, A., Zhang, X., & Wu, Y. (March-April, 2017). Simulation for non-point source pollution based on QUAL2E in the Jinghe River, Shaanxi Province, China. *Water Technology and Sciences* (in Spanish), 8(2), 117-126.

Water pollution in river basins is significantly influenced by point-source and non-point-source pollutants. Compared with point-source pollutants, the identification and quantification of non-point-source pollutants are critical but difficult issues in water environmental pollution studies. The Jinghe River is one of the main tributaries of the Weihe River. However, the non-point-source pollution of this river is not well understood. In order to analyze the sources of point- and non-point loads to river water, the river water quality model QUAL2E and Principal Component Analysis (PCA) & Factor Analysis (FA) were applied simultaneously to calculate the point- and non-point-source loads of ammonia nitrogen and nitrate nitrogen, respectively, in dry and wet seasons from 2002 to 2007. The results show that NO_3^- -N can be associated with point-source pollution, such as domestic sewage in dry seasons, but non-point-source pollution generated by precipitation in wet seasons. NH_4^+ -N can be associated with point-source pollution throughout the year. The methods applied in this research provide reliable results on non-point-source pollution caused by storm runoff.

Keywords: QUAL2E, degradation coefficient, source/sink term, non-point-source pollution.

Resumen

Wang, J., Huo, A., Hu, A., Zhang, X., & Wu, Y. (marzo-abril, 2017). Simulación de contaminación difusa mediante el modelo QUAL2E en el río Jinghe, provincia de Shaanxi, China. *Tecnología y Ciencias del Agua*, 8(2), 117-126.

La contaminación del agua en cuencas hidrológicas tiene una fuerte influencia de contaminantes puntuales y difusos. En comparación con los contaminantes puntuales, la identificación y cuantificación de los contaminantes difusos es un tema de gran importancia, pero difícil, en los estudios de contaminación ambiental del agua. El río Jinghe es uno de los principales tributarios del río Weihe; sin embargo, la contaminación difusa de este río no se ha dilucidado del todo. Con el fin de analizar las fuentes de cargas puntuales y difusas hacia el agua del río se aplicaron simultáneamente el modelo QUAL2E, el Análisis de Componente Principal (PCA) y el Análisis de Factores (FA) para calcular las cargas puntuales y difusas de nitrógeno amoniacal y de nitrógeno nítrico, respectivamente, en las temporadas seca y húmeda de 2002 a 2007. Los resultados muestran que el NO_3^- -N puede estar asociado con contaminación puntual, como la producida por aguas residuales domésticas, en la temporada seca, pero con la contaminación difusa generada por la precipitación en las temporadas húmedas. El NH_4^+ -N puede estar asociado con la contaminación puntual durante todo el año. Los métodos aplicados en este estudio proporcionan resultados confiables en la contaminación difusa ocasionada por escurrimientos pluviales.

Palabras clave: QUAL2E, coeficiente de degradación, término fuente/sumidero, contaminación difusa.

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Introduction

The extensive expansion of agriculture, rapid urbanization, and large-scale industrialization in China over the past three decades were accompanied with inevitable side effects, including water pollution, which is getting more severe each year. Moreover, anthropogenic activities associated with the revival and development of the Silk Road can further aggravate the water pollution crisis (Li, Qian, & Wu, 2014; Li, Qian, Howard, & Wu, 2015). Noteworthy is that surface water pollution has two main sources: (a) point source pollutants, such as industrial wastes and domestic sewage, and (b) non-point source pollutants, such as pesticides, herbicides, and fertilizers from agricultural activities. In addition, pollutants may originate from recharge of poor-quality groundwater and deposition of atmospheric pollutants. Once entering the aquatic environment, these pollutants may alter the composition and functions of ecosystems, thereby leading to a series of irreversible ecological changes (Huo *et al.*, 2014). While the point source pollution can be monitored by routine procedures and techniques, the non-point source one is difficult to control because it comes from the everyday activities of many different people, such as fertilizing a lawn, using a pesticide, or constructing a road or building. The fact that non-point source pollution is dynamic and complex process, which usually covers extensive areas, makes it quite problematic to provide an accurate quantification of its spatial location, extent, and discharge volume (Chowdary, Rao, & Sarma, 2005).

In order to face this challenge, numerous researchers developed various models of the agricultural non-point source pollution, most of which are based on different land use patterns (Whitehead, Johnes, & Butterfield, 2002; Polyakov, Fares, Kubo, Jacobi, & Smith, 2007; Munafo, Cecchi, Baiocco, & Mancini, 2005). Although these models are clearly mechanistic, they require a large number of input data, and it is difficult to directly monitor some of the

processes for which data are required. Pollutant mobilization processes and transport to the river network vary by region and river; studies that report model simulations at a range of spatial and temporal scales are also very scarce, so wide-spread application is constrained by both the variability in the landscape and lack of experience (Azzellino, Salvetti, Vismara, & Bonomo, 2006). We have made progress in non-point source pollution research in China by using software combined with remote sensing (RS) and Geographical Information Systems (GIS) (Feier, Huanchun, Yingxu, & Dong, 2003; Guihong & Jiangyong, 2007; Gao, Zhu, Zhou, Zhi, & Tang, 2008). However, these above methods are prone to large discrepancies when there are unique geographical features, complex landscape types, and diverse land use patterns in loess regions, which may, to a certain degree, bias the large-scale simulation results.

In this study, we used the River and Stream Water Quality Model (QUAL2E) developed by the United States Environmental Protection Agency (USEPA, 1992). We also used multivariate statistics principal component analysis (PCA) and factor analysis (FA) (Melching & Yoon, 1996; Wu, Li, Qian, Duan, & Zhang, 2014) to examine the sources of non-point pollution and to highlight the impacts of point and non-point source pollution on river water quality. The object of this study was the Shaanxi Reach of the Jinghe River in Shaanxi province of China. To provide a robust scientific basis for reducing water pollution in this area, the point source and non-point source loads of ammonia nitrogen and nitrate nitrogen between Jingcun and Zhangjiashan in dry and wet seasons are assessed.

Materials and methods

Study area

The Jinghe River originates in the eastern foothills of the Liupan Mountain, Jingyuan County, Ningxia Hui Autonomous Region. It enters

Shaanxi Province in Tangqu in Changwu County and merges with the Weihe River in Chenjiatan Village, Gaoling County. The Jinghe River is about 272.5 km long and it drains an area of 9 210 km² in Shaanxi Province (figure 1). In the Zhangjiashan section, the Jinghe Basin is mainly composed of a loess plateau and hilly gullies. The loess plateau region has a flat surface and is the agricultural center of the area, while the hilly-gully one is subjected to significant soil erosion promoted by high runoff rates and the relatively poor vegetation coverage. There are also small areas of stony soil and mountain forest in the Jinghe Basin. The area downstream from Zhangjiashan is dominated by river terraces. The average precipitation is 556 mm, but there is significant inter- and intra-annual variations in precipitation. Precipitation in the four months from July to October accounts for 56% of the annual precipitation. The industry is yet underdeveloped in this agricultural region, which is the main grain and cotton producer of Shaanxi province. However, in recent years, water quality has been steadily deteriorating in Shaanxi province because of the on-going industrial and agricultural developments.

River water quality model

Three main processes occur when pollutants enter a river, namely, flow migration, random diffusion at pollutant points, and transformation of pollutants (Beck, 1987). It is very difficult to find a solution for a non-steady multidimensional model, and furthermore, the analytical formula is very complex. However, recent studies have shown that one-dimensional steady models can solve the actual problems in many rivers. We used QUAL2E, the updated and improved version of the QUAL-I and II developed by the USEPA in the 1970s, for the simulation. It is based on the stream dispersion mass transfer equation that describes spatial and temporal changes in any water quality variable. In this equation, the source and sink caused by chemical, physical, and biological effects (including the impacts of the branch and discharge outlet) are included along with terms to describe flow migration and dispersion (Reckhow, 1999), as follows:

$$\frac{\partial(Ac)}{\partial t} = \frac{\partial}{\partial x} \left(D_x A \frac{\partial c}{\partial x} \right) - \frac{\partial(Qc)}{\partial x} \pm S^a \quad (1)$$

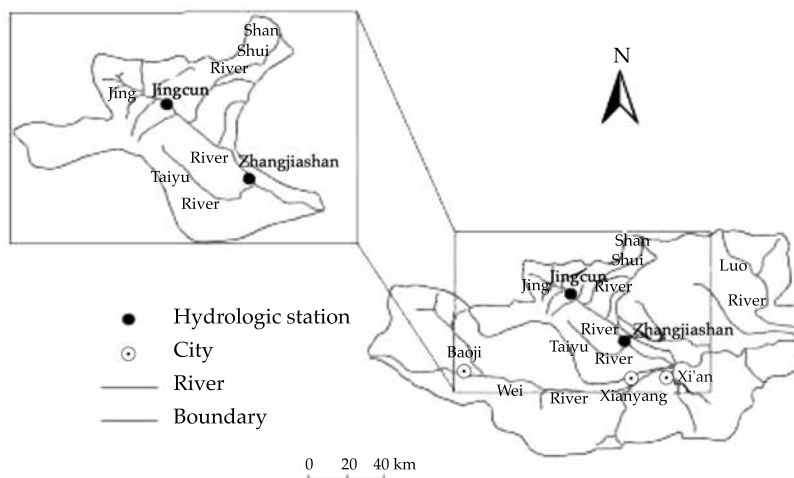


Figure 1. Jinghe River basin, Shaanxi province, China.

where c is the average concentration of pollutants in the section of river (mg/l); Q is the average flow of the section (m^3/s); D_x is the longitudinal dispersion coefficient (m^2/s); A is cross-sectional area (m^2); S^a is the source-sink term; x is the distance between the monitoring point and the pollution source (m), and t is the time at the monitoring point (s).

If the flow (flux) is steady, then $\frac{\partial Q}{\partial t} = 0$ and $\frac{\partial A}{\partial t} = 0$. Equation (1) then becomes:

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x} \left(D_x A \frac{\partial c}{\partial x} \right) - \frac{\partial(Qc)}{\partial x} + \frac{S_{int}}{A} + \frac{S_{ext}}{A} \quad (2)$$

where S_{int} is the internal source and sink of the water quality variable (i.e., chemical reaction, etc.) ($kg/(s.m)$), and S_{ext} is the external source and sink (i.e., branch impact, etc.) ($kg/(s.m)$).

To apply a steady model, the sections of the river must be even, the hydrological conditions should be stable, the current velocity and the dispersion coefficient should not change with time, and the source-sink term should be constant, namely $\frac{\partial c}{\partial t} = 0$. Equation (2) can be simplified into:

$$D_x \frac{\partial^2 c}{\partial x^2} - u \frac{\partial c}{\partial x} - kc + S = 0 \quad (3)$$

where u is the average current velocity through the river section (m/s); k is the degradation

coefficient of the pollutant (1/d), and S is the external source from the branch (mg/l.d).

As commonly occurs in non-tidal rivers, more pollutants are removed by flow migration than by the dispersion effect. Under steady state conditions, the dispersion effect can be ignored, and we obtain:

$$u \frac{\partial c}{\partial x} = -kc + S \quad (4)$$

If the initial condition is: $x = 0, c(x = 0) = c_0$, equation (4) is solved within the interval from $x = 0$ to $x = x$, and the analytical solution to the one-dimensional water quality model is:

$$c = c_0 \exp\left(-\frac{k}{u}x\right) + \frac{S}{k} \quad (5)$$

The diffuse source pollution between the Jingcun and Zhangjiashan sections is ascribed to the confluent pollutants introduced by the tributaries in the wet season (including the discharge from point sources in the dry season) and can be obtained by subtracting the confluent pollutants from the tributaries in the dry season from those in the wet season.

When the water quality model is applied, the confluent pollutants from the branches between the two sections are the source-sink term distributed evenly between the two sections. The space between the two sections is subdivided into several uniformly-spaced small cells to improve the accuracy, as is shown in figure 2.

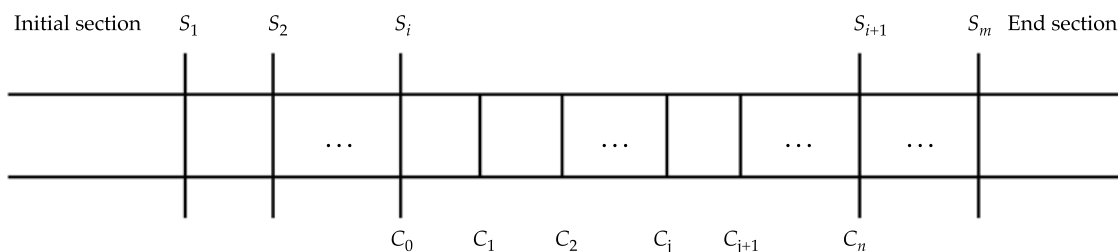


Figure 2. One-dimensional diagram of the river sections.

Where $S_1, S_2, \dots, S_i, \dots, S_m$ are sections in the basin; c_0 is the concentration of section S_i ; c_n is the concentration of section S_{i+1} ; the basin is divided into n parts uniformly spaced between S_i and S_{i+1} ; $c_1, c_2, \dots, c_j, \dots, c_n$ are the concentrations of all the sections. The precision is higher for higher values of n . The concentration of the j^{th} section is taken as the initial concentration of the $j + 1^{\text{st}}$ section. When calculated with equation (5), then:

$$c_1 = c_0 \exp\left(-\frac{k}{u}x\right) + \frac{S}{k} \quad (6)$$

$$c_2 = c_0 \exp\left(-\frac{2k}{u}x\right) + \frac{S}{k} \left[1 + \exp\left(-\frac{k}{u}x\right)\right] \quad (7)$$

$$c_3 = c_0 \exp\left(-\frac{3k}{u}x\right) + \frac{S}{k} \left[1 + \exp\left(-\frac{k}{u}x\right) + \exp\left(-\frac{2k}{u}x\right)\right] \quad (8)$$

$$c_{j+1} = c_0 \exp\left(-\frac{(j+1)k}{u}x\right) + \frac{S}{k} \sum_{\lambda=0}^j \exp\left(-\frac{\lambda k}{u}x\right) \quad (9)$$

Similarly,

$$c_n = c_0 \exp\left(-\frac{nk}{u}x\right) + \frac{S}{k} \sum_{j=0}^{n-1} \exp\left(-\frac{jk}{u}x\right) \quad (10)$$

Then

$$S = \frac{c_n - c_0 \exp\left(-\frac{nk}{u}x\right)}{1 - \exp\left(-\frac{nk}{u}x\right)} \left[1 - \exp\left(-\frac{k}{u}x\right)\right] \cdot k \quad (11)$$

where the water quality and hydrological values of the conventional sections can be acquired by monitoring, and only the degradation coefficient (k) is unknown. Usually, the degradation coefficient is temperature-dependent, and is calculated using equation (12):

$$k = k_{(20^\circ\text{C})} 1.008^{(T-20)} \quad (12)$$

where $k_{(20^\circ\text{C})}$ is the degradation coefficient of the water quality parameter at a temperature of 20 °C (1/d), and T is the water temperature (°C).

The degradation coefficient of different water quality parameters is determined by different methods. For the water quality parameter BOD₅, the methods include the laboratory method, slope method, two-point method, multi-point method, and others. Nitrogen is involved a very complex circulation process in the water environment, comprising nitrifying and denitrifying processes. Since, in general the inorganic nitrogen concentrations in rivers are quite low, the basic reactions are reduced to nitrification and denitrification. In this study, we used the two-point method to calculate the degradation coefficient between S_i and S_{i+1} at 20 °C using the following equation:

$$k = \frac{86400u}{l} \ln\left(\frac{c_{\text{up}}}{c_{\text{down}}}\right) \quad (13)$$

where k is the degradation coefficient (1/d); u is the average current velocity between sections (m/s); l is the distance between sections (m); c_{up} is the upstream concentration of the water quality parameter (mg/l), and c_{down} is the concentration of the water quality parameter downstream (mg/l).

Equation (11) is applied to calculate the source-sink term of the water quality parameter in wet and dry seasons of a hydrological year, respectively; the difference between the source-sink term in wet season and that in dry season is the diffuse source pollution for the water quality parameters between S_i and S_{i+1} in the current hydrological year. The diffuse source pollution from all the adjacent sections in the basin during the hydrological year is calculated, and the total sum being the diffuse pollution load of the basin for the hydrological year.

There are two monitoring sections on the Jinghe River in Shaanxi province, namely the Jingcun and Zhangjiashan sections, with no point source discharges in-between, except for such tributaries as the Taiyu River and Sanshui River. The area between these two sections is the

study area, and two water quality parameters, ammonia nitrogen ($\text{NH}_4^+\text{-N}$) and nitrate nitrogen ($\text{NO}_3^-\text{-N}$), were chosen as nitrogen nutrient indices to calculate the diffuse source pollution load in this study by combining the results of PCA for the water quality variables.

The water quality data from the Water Environment Monitoring Center of Shaanxi Provincial Hydrologic Bureau indicated that the average water temperature of the two monitoring stations in June each year was approximately 20 °C (lower than 20 °C for Jingcun and higher than 20 °C for Zhangjiashan, with the temperature difference between them not exceeding 1 °C). Concentrations of nitrite nitrogen were very low in both sections, therefore nitrifying reactions of nitrite nitrogen were disregarded, but only the denitrifying effect of $\text{NO}_3^-\text{-N}$ was taken into account. Equation (13) was used to calculate the degradation coefficients of $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$, based on the values for the year when the precipitation in June was low and on the average values for many years at 20 °C. To account for the impact of temperature on water quality parameters, the degradation coefficients for each month of each year were calculated using equation (12).

Principal component analysis (PCA) and factor analysis (FA)

River pollution is a complex process comprised of several water quality parameters that may interact with each other. This implies that it may not be possible to obtain accurate results because of colinearity between the parameters. PCA groups the original parameters into a few mutually-independent comprehensive indices by a linear transformation to simplify the data and improve the reliability of the analysis results (Wu *et al.*, 2014; Xiaohua, Ruiming, & Yong, 2008). PCA has been applied in recent years to assess surface water quality in combination with other multivariate statistical analysis, such as cluster analysis (CA), factor analysis (FA), and discriminant analysis (DA) (Li, Wu, & Qian, 2013a; Li, Qian, Wu, Zhang, & Zhang, 2013b;

Ouyang, 2005; Ouyang, Nkedi-Kizza, Wu, Shinde, & Huang, 2006; Shrestha & Kazama, 2007); it has also been used in non-point source load forecasting along with multiple regression analysis (Geladi & Kowalski, 1986). In particular, FA has been integrated with a water quality model to study the distribution of point and non-point sources of nutrients in surface water (Azzellino *et al.*, 2006). To highlight spatial and temporal changes in water quality in different periods of a year, the SPSS software (version 16.0) was used for PCA and FA of water quality parameters in dry and wet seasons. The analysis involved the following five main steps, as follows (Li *et al.*, 2013a; Li *et al.*, 2013b; Wu *et al.*, 2014):

1. An original data matrix was set up (M_{ij} ($i = 1, 2, \dots, n; j = 1, 2, \dots, p$)) with n samples and p indices, which were standardized to ensure that they all had equal weights in the analysis.
2. The covariance matrix R_{jk} was calculated.
3. The eigenvalues (λ_k ($k = 1, 2, \dots, p$)) and corresponding eigenvectors (L_k ($k = 1, 2, \dots, p$)) were derived.
4. The variance contribution rate $T_k = \lambda_k / \sum_{i=1}^p \lambda_k$ and the cumulative variance contribution rate $D_k = \sum_{i=1}^k T_i$ were calculated, and the principal components that corresponded to the eigenvalues $\lambda_1, \lambda_2, \dots, \lambda_m$ ($m < p$) were selected for $D_k \geq 85\%$.
5. The factor loading matrix was developed and a vari_{\max} rotation was performed on the factor loading matrix to infer the principal parameters. In this study, only those factors that had an eigenvalue greater than one were retained.

Data sources

In this study, 16 sets of monitoring data from the Jingcun and Zhangjiashan sections in the Shaanxi Reach of the Jinghe River were selected for the analysis. We used data from Nov 2001

to Oct 2007; the period from Nov to Feb of the following year represented dry seasons while the period from July to Oct represented wet seasons. The average values of the current velocity and the flow rate from 2002 and 2007 for the two sections were selected. The river reaches from the Jingcun section to Zhangjiashan section is 120 km long.

Results and analysis

PCA was conducted for the 16 sets of water quality data for dry seasons in the Jingcun section and for dry and wet seasons in the Zhangjiashan section from Nov 2004 to Oct 2007. The rotated factor loadings matrixes obtained for the different periods are give elsewhere (Wang *et al.*, 2012). Six factors with eigenvalues greater than 1 extracted from the Jingcun section contributed to 87.737% (> 85%) of the variance in dry seasons, and three and four factors extracted from the Zhangjiashan section corresponded to 87.253 and 92.865% (> 85%) of the variance in dry and wet seasons, respectively. The most meaningful parameters within each component can be identified by investigating the factor loadings matrix. It can be reasonably assumed that parameters of the same component share the same origin.

The main pollutants in the Jingcun section during dry season were salt indices (VF1, including chloride, conductivity, NO_x , and salinity) and organic pollution indices (VF2, including volatile phenol and ammonia nitrogen), whereas those of the Zhangjiashan section in dry seasons were organism indices (VF1, including sulfate, COD_{Mn} , $\text{NH}_4^+\text{-N}$, NO_x , and BOD_5) and salt indices (VF2, including salinity, electrical conductivity, and chloride). In dry seasons, the river water was recharged by the groundwater, and NO_x and chloride in the Jingcun section were closely associated on VF1, which suggests an exchange of water from the groundwater to surface water system. In the Zhangjiashan section, NO_x was loaded on VF1 and was thus associated with point source discharges of domestic sewage, and similar other

discharges. In dry seasons, ammonia nitrogen and volatile phenol in the Jingcun section were loaded on VF2, the source of which was waste water discharged from papermaking enterprises in the upper reaches of the Jinghe River; in the Zhangjiashan section, ammonia nitrogen and NO_x , which came from point source discharges of domestic sewage and similar, were on VF1. In wet seasons, the main pollutants in the Zhangjiashan section were non-point source pollution indices (VF1, including nitrogen nutrient indices (NO_x and total nitrogen) and sulfate) and organic pollution indices (VF2, including volatile phenol, ammonia nitrogen, and salinity).

The above analysis shows that, regardless of dry or wet seasons, the water environment between the Jingcun and Zhangjiashan sections was mainly polluted by nitrogen nutrient and organic pollution indices.

The source-sink terms of $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ in wet and dry seasons from 2002 to 2007, respectively, were calculated using equation (11) and tabulated in table 1.

There was a slight variation in the source-sink terms of $\text{NO}_3^-\text{-N}$ in dry seasons of the years (Table 1), showing that the point source discharges of domestic sewage and similar were stable; the terms varied considerably in wet seasons, and the values in 2003 and 2007 were much higher than in those the other years. The precipitation and runoff values were large in the wet seasons of 2003 and 2007, so the non-point source pollution loads were also quite large. Examination of the annual precipitation and corresponding non-point source load of $\text{NO}_3^-\text{-N}$ (figure 3) shows that, when the precipitation was between 400 and 500 mm, the non-point source load did not change significantly, but as the precipitation increased, the load also increased rapidly, because the increased amount of runoff carried more pollutants. However, with further increases in precipitation, the non-point source load gradually dropped down, which may be attributed to the smaller amount of fertilizers in the soil. Even though 2006 was a normal year, the non-point source load of $\text{NO}_3^-\text{-N}$ was less

Table 1. NPS loads of NO_3^- -N and NH_4^+ -N from 2002 to 2007.

Year	Source-sink terms of NO_3^- -N (t)		Non-point load (t)	Source-sink terms of NH_4^+ -N (t)		Non-point load (t)
	Wet season	Dry season		Wet season	Dry season	
2002	558.433	303.387	255.047	75.642	69.739	6.390
2003	1 012.816	175.820	836.996	152.163	80.829	71.333
2004	–	–	–	37.489	18.973	18.555
2005	506.638	297.984	208.653	56.418	51.117	5.302
2006	286.242	209.878	76.364	37.466	29.140	8.327
2007	1 297.502	147.330	1 150.958	26.037	6.231	19.806
Annual average	732.301	226.880	505.604	64.203	42.672	21.619

Note: There is no monitoring value of NO_3^- -N in 2004.

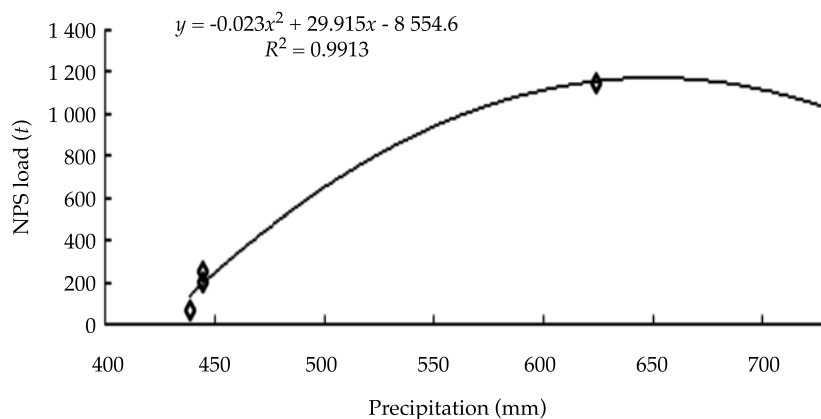


Figure 3. Fitted curve chart of annual precipitation and NPS loads of NO_3^- -N from 2002 to 2007.

than in the other normal years, due to lower monthly precipitation from July to October in 2006, as compared to those of other normal years. In 2006, the maximum monthly precipitation occurred in June.

There is a wide variation of the source-sink terms of NH_4^+ -N in dry and wet seasons, indicating the instability of point and non-point source discharges, due to different sources of NH_4^+ -N in dry and wet seasons. PCA analysis shows that NH_4^+ -N, COD_{Mn} , and BOD_5 were loaded on factor VF1 in dry seasons, which indicates that they were from domestic sewage and organic waste water discharged by juice factories. NH_4^+ -N, volatile phenol and salinity

were loaded on factor VF2 in wet seasons, showing that the main sources were industrial waste water discharged by papermaking enterprises in the upper reaches of the Jinghe River and NH_4^+ -N adsorbed to eroded non-point source soil particles that were transported in runoff. Because the waste water discharges were different in these years, the source-sink terms of NH_4^+ -N were different in dry and wet seasons. The non-point source load of NH_4^+ -N was 71.3328 tons in 2003, which was higher than those observed in other years. Since 2003 was an unusually wet year, runoff transported large amounts of NH_4^+ -N associated with eroded soil particles to the river channel, whereas in other

years, $\text{NH}_4^+\text{-N}$ in the river mainly came from point source discharges such as domestic sewage and organic waste water.

The above method yielded quite expected results for such non-point source pollutants, as $\text{NO}_3^-\text{-N}$, and somewhat contradictory ones on such point source pollutants, as $\text{NH}_4^+\text{-N}$.

Conclusion

In this study, we proposed the combined application of QUAL2E, a river water quality model, and PCA and FA to study the source apportionment of point and non-point pollutant loads to surface water. PCA and FA were used to evaluate pollutant sources in different river sections in dry and wet seasons, and then the amount of point source and non-point source pollution was calculated by using QUAL2E.

The results of PCA and FA show that the water pollution in the lower reaches of the Jinghe River mainly involved nitrogen and organisms. $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$, as the nitrogen nutrient indices, were taken as the objects, and the QUAL2E model equation was adopted to calculate their source-sink terms in dry and wet seasons, respectively; the difference between the terms in wet and dry seasons were the non-point source loads. The calculation results for $\text{NO}_3^-\text{-N}$ were reasonable, while those of $\text{NH}_4^+\text{-N}$ were somewhat unexpected, but consistent with the results of PCA and FA. $\text{NO}_3^-\text{-N}$ comes from point source discharges of domestic sewage and similar in dry seasons and from non-point source pollution generated by precipitation in wet seasons, whereas $\text{NH}_4^+\text{-N}$ was mainly discharged from point sources throughout the year. The instability of the point source discharges caused the above deviation of the calculation results. It is shown that application of the QUAL2E river water quality model provides reliable results for non-point source pollution caused by storm runoff, but unreliable results for point source pollution. Therefore, further model refinement or application of newer version QUAL2K (<https://www.epa.gov>, <http://www.QUAL2k.com/>) may be expedient. In contrast to QUAL2E, which segments the system into river reaches comprised of equally spaced elements. QUAL2K uses unequally-spaced reaches. In addition, multiple loadings and abstractions can be input to any reach, which may be quite instrumental for more accurate account of the local specific features.

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Author's institutional address

Ph.D. Jucui Wang

Chang'an University
College of Environmental Science and Engineering
Xi'an 710054, CHINA

Xi'an University of Technology
College of Water Conservancy and Hydropower
Xi'an 710048, CHINA
Yanta south road No. 126, Xi'an City,
Shaanxi Province, CHINA
Telephone: +86 (029) 8233 9952
wjvcuisw@sina.com

Ph.D. Aidi Huo
Ph.D. Anyan Hu
Ph.D. Xuezhen Zhang

Chang'an University
College of Environmental Science and Engineering
Xi'an 710054, CHINA
Yanta south road No. 126, Xi'an City,
Shaanxi Province, CHINA
Telephone: +86 (029) 8233 9952
huoaidi@163.com
huanyan97@163.com
346628478@qq.com

Ph.D. Yanqing Wu

Shanghai Jiaotong University
College of Environmental Science and Engineering
Shanghai 200240, CHINA
Dongchuan Road No.800, Shanghai City, CHINA
Telephone: +86 (021) 3420 3731
wuyanqing@sjtu.edu.cn