2023 International Conference on Engineering Practice and Medical Sciences (ICEPMS 2023)

Study on the Impact of Urbanization on Health Risk Pollutants in Rivers

Chao Wang[1,2,*] and Jing Qin[3]

[1]Changjiang Water Resources Protection Institute, Wuhan 430051, China

[2]Key Laboratory of Ecological Regulation of Non-point Source Pollution in Lake and Reservoir Water Sources, Changjiang Water Resources Commission, Wuhan 430051, China

[3] Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China

*corresponding author

Keywords: Urbanization, river, health risks, lead, mercury

Abstract: It is important to determine the impact of urbanization on health risk substances in rivers for healthy city management and watershed pollution control. With lead and mercury as the typical health risk substances, Haihe River Basin, which was characterized by rapid urban development, was selected as the study area. Factor analysis and multiple regression analysis were used to establish the response relationship between the pollution load of the monitoring section and the intensity of human activities within the control basin. The results showed that human activities in the basin could be divided into urban, rural, natural and other factors. Lead and mercury loads in the river were significantly correlated with urban factors, but not with rural, natural and other factors. In the process of urban development, it is necessary to pay more attention to health risk substances such as lead and mercury, strengthen relevant control measures, and effectively support the management of healthy cities.

1. Introduction

With the rapid development of urbanization, the influence of human activities on water environment is more and more intense. River water quality is influenced not only by natural environment, but also by urban activities. It is important to determine the impact of urbanization on health risk substances in rivers for healthy city management and watershed pollution control.

A large number of studies have shown that urban land and agricultural land have a great impact on river water quality [1-5]. Establishing the corresponding relationship between the spatial-temporal variation of water quality indicators and the degree of urban development is a common means to study the effects of human activities on river water quality [6]. Many explorations have been made in Japan [7], the United States [8], China [9] and other places. Land type index cannot include the content used in urban activities. By directly linking various quantified social and economic activities with water quality index, the influencing factors of river water quality can be comprehensively reflected [10,11].

In this study, the heavy metals lead and mercury are taken as typical representatives of health risk substances, and the response relationship between urbanization development indicators and the concentrations of lead and mercury in river water bodies is established to provide reference for the management of healthy cities.

2. Data and Methods

The monitoring data of river water quality and quantity were collected to establish the response relationship between the pollution load of the monitoring section and the intensity of human activities in the control basin. Pollution load is the product of pollutant concentration and discharge; The intensity of human activities is based on social and economic statistics of population, industry and other data as well as land use data. Through factor analysis, four comprehensive indicators including urban, rural, natural and other indicators are obtained. The relationship between the two was analyzed by multiple linear regression, with pollution load as the dependent variable and human activity index (factor score) as the independent variable.

2.1. Study Area

Haihe River Basin is taken as the study area. Haihe River Basin is located between 112° ~ 120° east longitude and 35° ~ 43° north latitude. The total area of Haihe River Basin is about 300,000 km^2. There are 113 rivers with a catchment area of more than 500 km^2, with a total length of 16,100 km. Haihe River Basin has a dense population, large in many cities, it has now become one of most developed areas in our country. There are 25 large and medium-sized cities in the basin, including Beijing, Tianjin, Shijiazhuang, Qinhuangdao, Chengde, Baoding, Handan, Xingtai and Cangzhou. Haihe River Basin is an important industrial base and a high-tech industrial base, which plays an important strategic role in national economic development. Haihe River Basin is one of the regions with the most scarce water resources among the seven river basins in China. Since the reform and development, the Haihe River Basin has witnessed rapid economic and social development, urbanization and industrial development, and a large amount of industrial wastewater and domestic sewage have entered the river system, seriously deteriorating the ecological environment.

2.2. Data and Sources

Collect social and economic statistical data and land type data of Haihe River Basin in 2005. In order to facilitate data collection and analysis, Haihe District, county and municipal district are set as data units, in which district and county are the administrative units under the jurisdiction of the municipality directly under the Central Government, county and city are the administrative units under the jurisdiction of the prefecture-level city, and municipal district is the scope of the municipality directly under the Central Government and prefecture-level urban area. There are 322 data units in Haihe River Basin, and the socio-economic data comes from the socio-economic data of all 322 data units in the basin in 2005, including 20 indicators such as population and non-agricultural population. In order to match social and economic data, land type data is also listed in data units, including the area of 7 land types such as woodland and grassland. Water quality and flow data are given according to the monitoring points, including 6 water quality indicators such as COD_{Mn} and flow. Since there are monitoring data for several times a year, the average value is taken. The data and main sources are shown in Table 1.

Table 1 Basic data overview

Data type	**data overview**	
	index	***source***
Social economy	Population; Non-agricultural population; The output value of the primary industry; The output value of the secondary industry; Output value of tertiary industry; Gross output value of agriculture, forestry, husbandry and fishery; Total agricultural output value; Gross forestry output value; Total output value of animal husbandry; Gross fishery output value; Fertilizer use; Gross industrial output value	Hebei Statistical Yearbook; Henan Statistical Yearbook; Shanxi Statistical Yearbook; Shandong Statistical Yearbook; Beijing Statistical Yearbook; Tianjin Statistical Yearbook; China Urban Statistical Yearbook
Land type	Forest land area; Meadow area; Farmland area; Urban construction land area; Rural settlement area; Inland water body area; River and lake flats area	Institute of Remote Sensing, Chinese Academy of Sciences
Water quality and discharge	Mercury (mean 0.067μg/L, standard deviation 0.084μg/L), lead (mean 0.016μg/L, standard deviation 0.051μg/L), flow (mean 11.2 m^3/s, standard deviation 17.8 m^3/s)	Haihe Water Conservancy Commission (105 monitoring site)

2.3. Calculation of Corresponding Indexes of Water Quality Monitoring Points

The pollution load of each water quality monitoring site is the cumulative effect of all data units within the control range of the monitoring site. If the distance between each data unit and the monitoring point is different, the effect of each index in the data unit on the water quality of the monitoring point is also different. King et al. [12] introduced the distance weighting function IDW (taking the reciprocal of distance as the weight) to represent the effect of different distances when studying the relationship between the land use type in the basin and the river water quality index. In this study, the distance weighting function was appropriately modified:

$$x_i = \sum_{1}^{N_i} X_{ji} \frac{1}{D + d_{ji}} \tag{1}$$

Where, x_i was the corresponding index *x* of the *i*th monitoring point; N_i was The number of data units in the basin controlled by the *i*-th monitoring point; X_{ji} was the index *x* value of the *j*-th data unit within the basin controlled by the *i*-th monitoring point, d_{ji} was the distance between the *j*-th data unit and the monitoring point within the basin controlled by the *i*-th monitoring point.

2.4. Factor Analysis

After calculating the corresponding index data of each monitoring point, factor analysis was used to process the data. Factor analysis is a multivariate statistical method that uses the idea of dimensionality reduction to transform multiple indicators into several comprehensive indicators on the premise of losing little information [13] There are many indicators of social economy and land type as independent variables, and there may be strong collinearity among some indicators. Factor analysis can simplify the number of variables, replace the complex relationship of original variables with several main variables, and reduce the influence of collinearity at the same time [14]. The comprehensive index (factor) generated by factor analysis is the linear combination of original variables, and the principal components are not interrelated. Factor analysis was completed by statistical analysis software SPSS 13.0, which provided a variety of rotation methods. After comparison, equamax method with the best effect was finally adopted.

2.5. Multiple Linear Regression Analysis

The form of multiple linear regression model is

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_p x_p + \varepsilon \tag{2}$$

Where, *y* is the pollution load of lead and mercury; *x* is the factor score; β is regression coefficient, *ε* is random error.

In the regression model, residuals must satisfy the normality [14], while variables should preferably conform to the normal distribution [15]. Logarithmic conversion is generally adopted for data that do not conform to the normal distribution. In this study, Kolmogorov-Smirnov method and p-p graph test were used for data normality [16], and natural logarithm conversion was used for data conversion. All regression and test processes were completed by statistical analysis software SPSS 13.0.

3. Results and Discussion

The result of factor analysis is shown in Table 2. Factor 1 is mainly composed of agriculture-related indicators, factor 2 is mainly composed of city-related indicators, and factor 4 is mainly composed of natural landscape related indicators. Therefore, the original variable can be simplified into four new variables after principal component extraction, which are named agriculture, city, nature and other. The information proportion of the four variables to extract the original variable reached 83%, so it can be considered that the new variable can well replace the original variable.

Table 2 Factor analysis result

Index		factor 1	factor 2	factor 3	factor 4
Factor load	Population	0.726	0.587		
	Non-agricultural population		0.943		
	The output value of the primary industry	0.757			
	The output value of the secondary industry		0.858		
	Output value of tertiary industry		0.889		
	Gross output value of agriculture, forestry, husbandry and fishery	0.787		0.526	
	Total agricultural output value	0.846			
	Gross forestry output value			0.509	
	Total output value of animal husbandry	0.681		0.606	
	Gross fishery output value			0.831	
	Fertilizer use	0.904			
	Gross industrial output value			0.805	
	Forest land area				0.913
	Meadow area				0.933
	Farmland area	0.667			0.534
	Urban construction land area		0.889		
	Rural settlement area	0.753			
	Inland water body area				0.561
	River and lake flats area				0.736
Extract the original variable ratio		26.7%	22.6%	17.6%	17.0%

Note: If the factor load factor is less than 0.5, it will not be displayed

Human activities and natural environment are two major factors affecting river water quality. The influence of human activities on water quality mainly includes two aspects: urban and agricultural. Cities are the concentrated areas of the world's population. The impervious surface of cities changes the hydrological characteristics of rivers, and the discharge of storm runoff, municipal sewage and industrial wastewater brings loads of pollutants such as large amounts of nutrients and metals [17,18] . Agricultural activities also bring a large pollution load to rivers. Pesticides have an impact on the water environment and the whole ecosystem [19]. Chemical fertilizers are the main source of nutrients in water [20]. Livestock manure is an important source of nutrients and organic pollution load in water [20,21]. The influence of natural environment on river water quality is mainly through rock weathering, plant absorption, and microbial transformation [22]. These factors show different characteristics in different natural landscapes. Therefore, the land type of natural landscape can roughly represent the influence of natural factors on river water quality. The main factors affecting water environment can be properly reflected by dividing socio-economic activities and land types into agricultural, urban, natural and other variables through principal component analysis.

After logarithmic transformation of variables, multiple linear regression analysis results are shown in the Table 3. Since the regression coefficient is affected by variable units, in order to compare the influence of the corresponding variables of each variable, standardized regression coefficient is adopted to measure the role of the corresponding variables of each variable. It can be seen that the concentrations of mercury and lead are mainly affected by urban variables and are positively correlated. The standardized regression coefficients of both agricultural and urban variables are positive. The natural variable is almost always negative, but it's almost not significant. In terms of the overall fitting effect, the fitting of all pollutants reached a very significant level.

Table 3 Multiple regression analysis results

Factor	**Regression coefficient**	
	Mercury	***Lead***
Urban factor	0.350*	0.432**
Rural factor	0.281	0.184
Natural factor	-0.039	0.103
Other factor	0.171	0.041
Multiple correlation coefficient R^2	0.321**	0.342**

Note: * p<0.05 was significant; ** p<0.01 is extremely significant

Lead in water mainly comes from cities. In addition to industrial wastewater discharge, all kinds of non-point sources, such as transportation and lead-containing buildings in building materials, are important sources of lead pollution [23,24]. The largest source of mercury in the environment is coal-fired power plants, where mercury from coal diffuses into the atmosphere and later transfers to ground and water bodies [25], and sewage treatment plants and sludge are also significant sources of mercury [26]. These studies all show that lead and mercury are mainly affected by urban activities.

In this study, river Pb and Hg loads in Haihe River Basin were only significantly affected by urban variables, and the results were consistent with the above analysis. The quantitative comparison of pollution sources of heavy metals such as lead and mercury has been done by predecessors. Studies have shown that 77% of mercury and 90% of lead in Lochnagar, an alpine lake in Scotland, is caused by human factors [27]. In the non-point source pollution in Hanyang area of Hubei province, heavy metals produced in urban surface are much more than those in farmland [28]. A study by Zhang et al. [29] on trace metals in granular form in estuaries in China showed that the concentration of trace metals in agriculture-dominated watercourses was significantly lower than that in industrial-dominated watercourses.

4. Conclusion

Using principal component analysis, socio-economic activity and land type variables can be reduced to four factors. These factors can not only well reflect the information of the original variable, but also distinguish the three different influencing factors of agriculture, city and nature. Through multiple regression analysis, it is found that urban development has a significant impact on lead and mercury in Haihe river basin. In the process of urban development, it is necessary to pay more attention to health risk substances such as lead and mercury, strengthen relevant control measures, and effectively support the management of healthy cities. In this paper, the effects of urbanization on lead and mercury are presented statistically. In the next step, we can sort out specific potential emission sources and establish emission inventories to provide a basis for the prevention and control of lead and mercury pollution.

References

[1] Wang, X.H., Yin, Z.Y., 1997. Using GIS to assess the relationship between land use and water quality at a watershed level. Environment International 23, 103-114.

[2] Ha, S.-R., Bae, M.-S., 2001. Effects of Land Use and Municipal Wastewater Treatment Changes on Stream Water Quality. Environmental Monitoring and Assessment 70, 135-151.

[3] Tong, S.T.Y., Chen, W., 2002. Modeling the relationship between land use and surface water quality. Journal of Environmental Management 66, 377-393.

[4] Allan, J.D., 2004. Landscapes and riverscapes: The influence of land use on stream ecosystems. Annual Review of Ecology Evolution and Systematics 35, 257-284.

[5] Gergel, S.E., Turner, M.G., Miller, J.R., Melack, J.M., Stanley, E.H., 2002. Landscape indicators of human impacts to riverine systems. Aquatic Sciences - Research Across Boundaries 64, 118-128.

[6] Markich, S.J., Brown, P.L., 1998. Relative importance of natural and anthropogenic influences on the fresh surface water chemistry of the Hawkesbury-Nepean River, south-eastern Australia. The Science of The Total Environment 217, 201-230.

[7] Tabayashi, Y., Yamamuro, M., 2009. Changes in the impact of anthropogenic effects on river water quality during the last 50 years in Japan. Wetlands Ecology and Management 17, 409-415.

[8] Han, H.J., Allan, J.D., Scavia, D., 2009. Influence of Climate and Human Activities on the Relationship between Watershed Nitrogen Input and River Export. Environmental Science & Technology 43, 1916-1922.

[9] Xing, G.X., Zhu, Z.L., 2002. Regional nitrogen budgets for China and its major watersheds. Biogeochemistry 57, 405-427.

[10] Xu, H., Zheng, H., Chen, X., Ren, Y.F., Ouyang, Z. Y., 2016. Relationships between river water quality and landscape factors in Haihe River Basin, China: Implications for environmental management. Chinese Geographical Science, 26, 197-207.

[11] Morrice, J.A., Danz, N.P., Regal, R.R., Kelly, J.R., Niemi, G.J., Reavie, E.D., Hollenhorst, T., Axler, R.P., Trebitz, A.S., Cotter, A.M., Peterson, G.S., 2008. Human influences on water quality in Great Lakes coastal wetlands. Environmental Management 41, 347-357.

[12] King, R.S., Baker, M.E., Whigham, D.F., Weller, D.E., Jordan, T.E., Kazyak, P.F., Hurd, M.K., 2005. Spatial considerations for linking watershed land cover to ecological indicators in streams. Ecological Applications 15, 137-153.

[13] He Xiaoqun (Ed), 2008. Multivariate Statistical Analysis (2nd Ed). China Renmin University Press, Beijing.(in Chinese)

[14] Tabachnick, B.G., Fidell, L.S. (Eds.), 2006. Using Multivariate Statistics (5th Edition). Allyn & Bacon, Boston.

[15] Osborne, J.W., Waters, E., 2002. Four Assumptions Of Multiple Regression That Researchers Should Always Test. Practical Assessment, Research & Evaluation 8.

[16] Park, H.M., 2006. Univariate Analysis and Normality Test Using SAS, STATA, and SPSS.

[17] Paul, M.J., Meyer, J.L., 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32, 333-365.

[18] Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., Morgan, R.P., 2005. The urban stream syndrome: current knowledge and the search for a cure. Journal of the North American Benthological Society 24, 706-723.

[19] vanderWerf, H.M.G., 1996. Assessing the impact of pesticides on the environment. Agriculture Ecosystems & Environment 60, 81-96.

[20] Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., Smith, V.H., 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8, 559-568.

[21] Chen, D.W., 2001. Environmental challenges of animal agriculture and the role and task of animal nutrition in environmental protection - Review. Asian Australas. J. Anim. Sci. 14, 423-431.

[22] Hem, J., 1959. Study and interpretation of the chemical characteristics of natural water. United States Government Printing Office Washington, DC.

[23] Legret, M., Pagotto, C., 1999. Evaluation of pollutant loadings in the runoff waters from a major rural highway. Science of the Total Environment 235, 143-150.

[24] Davis, A.P., Shokouhian, M., Ni, S., 2001. Loading estimates of lead, copper, cadmium, and zinc in urban runoff from specific sources. Chemosphere 44, 997-1009.

[25] Raj, D., Maiti, S.K., 2019. Sources, toxicity, and remediation of mercury: an essence review. Environmental monitoring and assessment, 191, 1-22.

[26] Glass, G.E., Sorensen, J.A., Schmidt, K.W., Rapp, G.R., 1990. NEW SOURCE IDENTIFICATION OF MERCURY CONTAMINATION IN THE GREAT-LAKES. Environmental Science & Technology 24, 1059-1069.

[27] Yang, H.D., Rose, N.L., Battarbee, R.W., Boyle, J.F., 2002. Mercury and lead budgets for Lochnagar, a Scottish mountain lake and its catchment. Environmental Science & Technology 36, 1383-1388.

[28] Yang, L., Ma, K.M., Zhao, J.Z., Bai, X., Guo, Q.H., 2007. The relationships of urbanization to surface water quality in four lakes of Hanyang, China. International Journal of Sustainable Development and World Ecology 14, 317-327.

[29] Zhang, J., Liu, C.L., 2002. Riverine Composition and Estuarine Geochemistry of Particulate Metals in China--Weathering Features, Anthropogenic Impact and Chemical Fluxes. Estuarine, Coastal and Shelf Science 54, 1051-1070.