Analysis on the relationship between economic development and water environment pollution in Shandong province

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Abstract: With the continuous development of the economy of the Shandong Province watershed, a large number of pollutant emission, resulting in water quality of the basin has undergone significant changes. To study the Shandong Province watershed economic development and the relationship between the discharge of pollutants, in this paper, the relationship between economic growth and pollutant emissions in the Shandong Province watershed was established by Shandong Province watershed in 2002-2015 per capita GDP and wastewater, COD, ammonia nitrogen(AN) pollutant emissions. The data were analyzed by software such as SPSS, and the cubic equation model between various pollutants and economic indexes was fitted. To further make the relationship between pollutants and economic development map to study the conventional pollutant emissions and economic development trends. It is found that only the relationship between industrial wastewater discharge and per capita GDP is most coordinated, that is, industrial wastewater emissions with the continuous development of the basin economy, showing a tendency to rise first and then fall. Finally, ultimately based on the results of the study of the water environment and economic development proposals were proposed.

1. Introduction
With the development of the economy more and more lakes and rivers have been severely polluted, people began to realize the importance of protecting the lake basin. How to do both economic development and protection of the lake basin is a matter of great concern to scholars. More and more domestic and foreign scholars began to study the relationship between economic development and river basin pollutant emissions. Zhaokui Ni et al [1] studied the economic development of China's lake basin brought many pollutant emissions, resulting in water eutrophication and extreme deterioration. Marianna Pastuszak et al [2] studied the effects of nitrogen and phosphorus pollutants from agriculture and animal husbandry on the economic development of the basin in the Vistula and Oder Rivers basins in Poland. Lei Ding et al [3] realized that with the socioeconomic development, water resources are scarce, and the water environment begins to deteriorate, in order to make the environment and the economy develop healthily, through quantitative evaluation model to obtain watershed water environmental carrying capacity, to control pollution and to protect the water body provides the direction.

In this paper, the regression analysis model of Shandong Province's watershed was made by using
SPSS and Microsoft Excel software, which was used to analyze the pollution of pollutants in Shandong Province, using the life and industrial pollutants such as wastewater, COD, and ammonia nitrogen in Shandong Province. Moreover, economic development model to provide reference recommendations.

2. Data source
The selection of standard environmental indicators is the key to the economic growth and water quality measurement model of the Shandong Province watershed. According to the statistical yearbook of the Shandong Province watershed, the industrial wastewater discharge, the domestic sewage discharge, the industrial COD discharge, the living COD discharge, the industrial ammonia nitrogen emission and the ammonia emission of the living were selected as the environmental indicators from 2001 to 2015. Select the per capita GDP of the basin as an economic indicator; the following data are from the Shandong Province River Valley City Statistical Yearbook. See Table 1.

| years | Per capita GDP | Industrial wastewater discharge | Domestic wastewater discharge | Industrial COD emissions | Life COD emissions | Industrial Ammonia Nitrogen Emissions | Living Ammonia Nitrogen Emissions |
|-------|----------------|-------------------------------|-----------------------------|------------------------|------------------|------------------------------------|-------------------------------|
| 2002  | 11645          | 106668                        | 124041                      | 41590                  | 442781           | 30628.2                            | 53040                         |
| 2003  | 13661          | 115933                        | 129849                      | 406348                 | 421556           | 25912                              | 51544                         |
| 2004  | 16925          | 128706                        | 135308                      | 349476                 | 429349           | 27953                              | 52931                         |
| 2005  | 20030          | 139071                        | 141306                      | 356650                 | 413611           | 31781                              | 52478                         |
| 2006  | 23794          | 144365                        | 158272                      | 336291                 | 421810           | 25010                              | 58225                         |
| 2007  | 27807          | 144365                        | 158272                      | 336291                 | 421810           | 25010                              | 58225                         |
| 2008  | 33083          | 176977                        | 181934                      | 257316                 | 421282           | 15933                              | 54441                         |
| 2009  | 35894          | 182673                        | 204058                      | 260521                 | 386479           | 13898                              | 53407                         |
| 2010  | 40891          | 208257                        | 228115                      | 295128                 | 325405           | 15441                              | 51042                         |
| 2011  | 47071          | 208257                        | 228115                      | 295128                 | 325405           | 15441                              | 51042                         |
| 2012  | 51631          | 183634                        | 295135                      | 139404                 | 344093           | 10982                              | 74135                         |
| 2013  | 56184          | 181179                        | 313124                      | 132727                 | 413286           | 10224                              | 79757                         |
| 2014  | 60707          | 180022                        | 334100                      | 130511                 | 385112           | 9625                               | 76335                         |
| 2015  | 63981          | 185493                        | 364399                      | 125425                 | 420274           | 9028                               | 77865                         |

3. Establishment of Basin Economic Development and Pollutant Emission Model in Shandong Province
The water quality data and RGDP data of the Shandong Province watershed from 2001 to 2015 were used to analyze the relationship between economic growth and pollutant emissions. The equations of economic development-pollutant emissions were analyzed by SPSS software. The model correlation coefficients were shown in Table 2 and 3.
Table 2. Regression Analysis of Industrial Pollutant Discharge and Per Capita GDP in the watershed of Shandong Province.

|                  | Industrial waste | Industrial COD | Industrial Ammonia Nitrogen |
|------------------|------------------|----------------|-----------------------------|
| **R²**           | FPM               | QM            | CM                          |
| constant term    | 0.675            | 0.907         | 0.914                       | 0.893               | 0.895            | 0.897           | 0.88            | 0.896            | 0.905             |
| F value          | 24.923            | 53.53         | 35.58                       | 99.835              | 46.707           | 29.156          | 87.604          | 47.208           | 31.931             |

a FPM represents the primary equation model; b QM represents the quadratic equation model; c CM represents the cubic equation model.

Table 3. Regression Analysis of Domestic Pollutant Discharge and Per Capita GDP in the watershed of Shandong Province.

|                  | Living wastewater | Life COD | Living Ammonia Nitrogen |
|------------------|-------------------|----------|-------------------------|
| **R²**           | FPM               | QM       | CM                      |
| constant term    | 0.987             | 0.987    | 0.987                   | 0.239               | 0.493            | 0.691           | 0.618            | 0.762            | 0.767             |
| F value          | 272.114           | 427.912  | 259.411                 | 3.764              | 5.351            | 7.448           | 19.423           | 17.586           | 10.993             |

a FPM represents the primary equation model; b QM represents the quadratic equation model; c CM represents the cubic equation model.

According to the estimated parameters, for industrial wastewater, COD, ammonia and other pollutant emissions and GDP per capita regression results, it is clear that the R² value of the cubic model is more excellent than the linear and the secondary model R² values. This result shows that the three models can be used to better describe the relationship between pollutants and economic development in the Shandong Province watershed. The life of pollutants is also the third model of the fitting effect is better, but the life of COD emission fit coefficient R² is less than 0.7, its equation is less fitting than the other. Other water environment indicators of the fitting coefficient R² are higher than 0.7. This figure shows that the model is well fitted, which can better explain the relationship between water pollution and GDP per capita.

Three types of models were used to study the relationship between pollutants and economic development in the Shandong Province watershed, the cubic equations of industrial pollutants, living pollutants and RGDP are obtained as follows:

Industrial wastewater: \(6.773 \times 10^4 + 3.125 \text{RGDP}_t + 3.172 \times 10^{-5} \text{RGDP}_t^2 - 8.489 \times 10^{-10} \text{RGDP}_t^3\)  

Industrial COD: \(5.078 \times 10^5 - 10.169 \text{RGDP}_t + 0 \text{RGDP}_t^2 - 1.622 \times 10^8 \text{RGDP}_t^3\)  

Industrial Ammonia Nitrogen: \(3.094 \times 10^4 + 0.158 \text{RGDP}_t - 2.322 \times 10^{-5} \text{RGDP}_t^2 + 2.44 \times 10^{-10} \text{RGDP}_t^3\)  

Domestic wastewater: \(1.60 \times 10^5 + 0.09 \text{RGDP}_t + 6.195 \times 10^{-5} \text{RGDP}_t^2 - 4.504 \times 10^{-11} \text{RGDP}_t^3\)  

Life COD: \(3.45 \times 10^5 + 12.327 \text{RGDP}_t - 0.001 \text{RGDP}_t^2 + 5.198 \times 10^9 \text{RGDP}_t^3\)  

Life ammonia Nitrogen: \(5.278 \times 10^4 + 0.143 \text{RGDP}_t - 1.095 \times 10^5 \text{RGDP}_t^2 + 2.498 \times 10^{-10} \text{RGDP}_t^3\)

4. Analysis on Basin Economic Development and Pollutant Discharge in Watershed of Shandong Province

It can be seen from Figure 1, the economy of the Shandong Province watershed is on the rise from 2002 to 2015, regional GDP growth is rapid. In 2015, the gross national product (GDP) reached 63002.3 billion yuan, compared to 10552.06 billion yuan in 2002, an increase of 6.0 times; GDP per
capita growth from 11645 yuan in 2002 to 639812 yuan in 2015. GDP and GDP per capita are primarily in the trend of simultaneous growth.

It can be seen from Figure 2, the Shandong Province watershed after 2011, the domestic wastewater discharge exceeds industrial wastewater emissions, the domestic wastewater becomes the primary source of water pollution in the Shandong Province watershed. Increasing domestic sewage discharge is mainly due to the growing population of the Shandong Province watershed; urbanization is accelerating, people’s living standards are also increasing, resulting in a gradual increase in domestic sewage discharge. The life of the COD emissions in the Shandong Province watershed is significantly higher than those of industrial COD emissions, while the overall discharge of industrial COD shows a downward trend, indicating that the implementation of the watershed regulation of industrial COD emissions control effect is noticeable. At the same time, Ammonia nitrogen emissions in life exceeded industrial ammonia emissions in 2003 and maintained an increase. In the year 2015, the emissions of industrial ammonia nitrogen are only 9028 tons, while the emission of living ammonia nitrogen is 77865 tons, and the emission of ammonia nitrogen is nearly 9 times of the emissions of industrial ammonia.

Since 2003, the Shandong Province watershed through the implementation of strict national standards of local environmental standards, and gradually realize the transition from the industrial emission standards to the watershed emission standards, the abolition of paper pollution and other high-polluting industries. For more than ten years, the Shandong Province watershed accumulated investment of billions of dollars, the construction of a large number of pollution control projects, prevention, and control of water quality. TO 2012, all 119 projects in the watershed plan were completed on schedule, and provincial assessment of cross-section of water quality all meet the requirements. In recent years, the surrounding areas of the basin also spent 730 million yuan to build, expand and transform the urban sewage treatment plant 11 and supporting the construction of sewage pipe network 615 km, and ultimately make the urban sewage treatment rate of 93.5%. Sewage treatment standards to force the sewage enterprises to improve standards, and ultimately make the city's 150 industrial point source implementation of the sewage treatment project. It is precisely because of these high environmental pollution control policies and control measures, which makes the industrial COD and industrial ammonia emissions with the economic development has gradually reduced.
5. Conclusions and suggestions

5.1. Conclusions
Combined with the above analysis, we can understand that pollutant emissions and economic development is still in a discordant situation in the Shandong Province watershed. In general, the emission of pollutants in the industry is on a slowing trend. On the one hand, the continuous development of the economy has brought significant progress in technology, making the industrial sector to use more sophisticated machinery and equipment, resource utilization more fully discharge less pollution and a large number of the high-tech high-performance machine makes the use of resources recycling. Moreover, at the same time, while the input of some pollutant treatment equipment to promote the concentration of pollutants lower emissions. On the other hand, the economic development is bound to bring pollution products, the Shandong Province watershed has long suffered from pollution from industrial production, in the past, the Shandong Province watershed was dominated by heavy industry. The Shandong Province watershed was severely damaged by papermaking pulp, electroplating, tanning, dyes, bleaching and dyeing industries [4].

The discharge of domestic wastewater in the Shandong Province watershed is lower than that of industrial wastewater from 2002 to 2011, and the discharge of industrial wastewater after 2011 is the primary source of water pollution in the Shandong Province watershed. Domestic wastewater, living ammonia emissions showed a growing trend, and the increase is growing [5].

5.2. Suggestions
To strengthen the regulation of industrial pollutant emissions, on the one hand, taking into account the industrial sector itself can introduce high-quality equipment, which is conducive to the full use of resources and reduce pollution emissions. On the other hand, government departments in industrial pollution control occupy an essential guiding position, so the department to implement the responsibility and different departments of the division of labor [6]. Environmental protection departments to implement the Shandong Province watershed industrial water pollutants total control
and discharge permit issuance work. The management department is required to rectify or suspend industrial enterprises that can’t meet the emission standards; the supervisory department shall conduct a weekly inspection of the daily sewage treatment.

On the one hand, people want to strengthen environmental awareness and the daily life of emissions to be ordered in an orderly place in the designated place [7]. Less use of nitrogen, phosphorus, and other water pollutants products and develop a good habit of saving water and recycling water. On the other hand, government departments to introduce policies to limit the emissions of living pollutants and in the life of residents to establish an individual pollution control institutions. Each city develops a governance system that is consistent with local water pollution and vigorously advocate multi-party cooperation to monitor water pollution and encourage residents to participate in supervision. The relevant laws and regulations need to be perfected to curb the behavior of polluted water environment [8].

References
[1] NI Z, WANG S. Economic development influences on sediment-bound nitrogen and phosphorus accumulation of lakes in China [J]. Environmental Science and Pollution Research, 2015, 22(23): 18561-73.
[2] PASTUSZAK M, KOWALKOWSKI T, KOPIŃSKI J, et al. Impact of forecasted changes in Polish economy (2015 and 2020) on nutrient emission into the river basins [J]. Science of the Total Environment, 2014, 493(3): 32-43.
[3] DING L, CHEN K L, CHENG S G, et al. Water ecological carrying capacity of urban lakes in the context of rapid urbanization: A case study of East Lake in Wuhan [J]. Physics & Chemistry of the Earth Parts A/b/c, 2015, s 89–90:104-13.
[4] WU Yuping ,DONG Suocheng ,SONG Jianfeng .Modeling economic growth and environmental degradation of Beijing[J]. Geographical Research, 2002,21( 2) : 239-246.
[5] Yu Guangjin,Shang Bo,Wang Guixun,Liu Jing.Research on Eutrophic Evaluation and Control Measures for Nansi Lake[J]. Journal of Environmental Management College of China, 2013(6):54-56. (in chinese)
[6] MAO Cuicui, ZUO Qiting, The Research Progress and the Key Problem of Human-water Relationship[J]. South-to-North Water Transfers and Water Science & Technology,2011, 09(5):74-79. (in chinese)
[7] HUANG Sheng. Research on Legal Problems of Soil Pollution Prevention in Rural Areas[J]. Journal of Tianshui College of Administration,2015(2):85-89. (in chinese)
[8] Ying Huang,Liangjian,Wang Guifeng,Li Di Jiang. An Empirical Analysis for the Environmental Kuznets Curve in China Based on Spatial Panel Models[J]. SOUTH CHINA JOURNAL OF ECONOMICS, 2009,(10) : 59-68. (in chinese)