Analysis of chlorinated hydrocarbon source of groundwater in the eastern part of a city

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Abstract. In order to control the pollution of chlorinated hydrocarbons in groundwater, it is necessary to analyze the source of chlorinated hydrocarbons in groundwater. Therefore, this paper uses the method of factor analysis and multiple linear regression equation to analyze the source of the study area. The results show that the pollution sources in the study area can be summarized as chemical enterprise pollution sources, electromechanical manufacturing pollution sources, chemical fiber pollution sources and pesticide pollution sources.

1. Introduction
Groundwater is a very important resource in industry, agriculture and life[1]. But with unreasonable development and utilization of groundwater rising of groundwater water quality decline, the prevention of groundwater pollution are badly needed[2]. In order to effective governance of groundwater pollution, pollution source identification is also essential. As an effective method to extract useful information from complex data, multivariate statistical method has been widely used in practice. At present, multivariate statistical method is mostly used in the research of groundwater quality and hydrochemical evolution in the field of groundwater, and its application in the analysis of pollution sources is still rare[3]. For the groundwater level and water quality in the regions heavily dependent on groundwater are in the process of long-term dynamic change, the identification of pollution sources is helpful to ensure safe water use[4]. And the research has obvious scientific significance and application value, which has certain guiding value for the work of groundwater pollution control.

2. Overview of the study area

2.1. Overview of the study area
The study area is located in the eastern part of a city. In the south, it relies on the taishan mountain range and is close to the Yellow River on its back. It is about 12km from east to west and 10km from north to south, with an area of about 120 square kilometers. Xiaoqing river flows through this area from southwest to northeast. The study area has a warm temperate continental climate with four distinct seasons, with an average annual temperature of about 14℃ and annual average precipitation of...
The terrain in the study area is high in the south and low in the north, high in the east and low in the west.

2.2. Factor analysis
In this study, 43 sampling sites were set up in the study area to study the pollution status of chlorinated hydrocarbons in groundwater in the study area, and the results showed that there were 13 major chlorinated hydrocarbon pollutants in the study area.

![Figure 1. Sample point figure](image1)

![Figure 2. Hydrogeological map](image2)

The detection of chlorinated hydrocarbons in groundwater in the study area is shown in Table.

| Chlorohydrocarbon                   | Minimum (μg/L) | Maximum (μg/L) | Average (μg/L) |
|-------------------------------------|----------------|----------------|----------------|
| Chloroethylene                      | 0.47           | 8.53           | 3.87           |
| Dichloromethane                     | 5.21           | 16.85          | 10.04          |
| 1, 2-dichloroethane                 | 2.03           | 12.56          | 6.60           |
| 1, 1-dichloroethylene               | 1.11           | 10.46          | 5.34           |
| Cis-1, 2-dichloroethylene           | 1.12           | 2.42           | 1.95           |
| Trans 1, 2-dichloroethylene         | 0.44           | 1.31           | 1.03           |
| Trichloromethane                    | 0.20           | 2.40           | 1.50           |
| 1, 1, 1-trichloroethane             | 1.00           | 2.05           | 1.59           |
| Trichloroethylene                   | 2.10           | 73.64          | 48.87          |
| Perchloroethylene                   | 3.01           | 32.25          | 10.07          |
| Carbon tetrachloride                | 1.50           | 23.31          | 10.28          |
| Benzene hexachloride                | 0.10           | 0.52           | 0.37           |
| Dichlorodiphenyl trichloroethane    | 0.10           | 0.12           | 0.11           |

3. Methods
Factor analysis is a widely used multivariate statistical method for qualitative identification of potential sources of pollutants in the environment. The basic principle is that on the premise of not losing the main information, the correlation between a large number of monitoring data is used to reduce these correlation variables to a few unrelated, abstract common factors, and each original variable can be represented by a linear combination of common factors. The method is simple to use, does not need to monitor the pollution sources in the study area, and the calculation process is simple, which can be completed by using the general statistical data processing software[5][6]. The disadvantage is that factor analysis requires a large amount of sample monitoring data.

\[ x_{ij} = \sum_{k=1}^{p} a_{ik} f_{kj} + \varepsilon_{ij} \]
\((i=1, 2, 3, \ldots, m, m\) is the number of pollutants detected in each sample; \(j=1, 2, \ldots, n, n\) is the number of samples collected in the study area). \(x\) is the measured concentration of pollutant \(i\) in sample \(j(\mu g/L)\); \(a\) refers to the concentration of pollutant \(i\) discharged by pollutant source \(k(\mu g/L)\), which is called factor load, reflecting the contribution of pollutant source \(k\) to pollutant \(i\) in the collected samples, \(f\) is the mass concentration \((\mu g/L)\) contributed by pollutant \(k\) to sample \(j\). It contributes to all chemical components of sample \(j\), which is called the common factor. \(p\) is the number of common factors extracted.

4. Results and discussion

4.1. Source identification

Before the factor analysis, the data were normalized with a mean of 0 and a variance of 1. The kaiser-meyer-olkin (KMO) test and Bartlett sphericity test were used to verify whether the data were suitable for factor analysis.

| KMO sampling moderation value | 0.826 |
|-----------------------------|-------|
| Bartlett sphericity test    |       |
| Test value                  | 1146.832 |
| Degrees of freedom          | 78    |
| Significance level          | 0.000 |

The KMO detection value is 0.826, indicating that the partial correlation between variables in the data used is very strong, and the effect of factor analysis will be very good. The test value of Bartlett sphericity test is 1146.832, common factors can be extracted from the original variables, and the data to be tested is suitable for factor analysis.

| Common factor | Eigenvalue | Initial eigenvalue | Cumulative variance interpretation rate (%) |
|---------------|------------|--------------------|---------------------------------------------|
|               | Interpretation rate of variance (%) |                     |
| 1             | 5.510      | 42.384             | 42.384                                      |
| 2             | 3.594      | 27.646             | 70.030                                      |
| 3             | 1.671      | 12.852             | 82.882                                      |
| 4             | 1.291      | 9.928              | 92.810                                      |
| 5             | 0.394      | 3.029              | 95.840                                      |

According to the principle that the eigenvalue is greater than 1, four common factors were extracted in this study. These four common factors explain 92.810% of the total variance, indicating that they can well represent the characteristics of the original groundwater chlorinated hydrocarbon data. The first common factor explained 42.384% of the total variance, the second common factor explained 27.646% of the total variance, the third common factor explained 12.852% of the total variance, and the fourth common factor explained 9.928% of the total variance. And then you do the orthogonal rotation to get the factor loading matrix.

| Variable                  | Common degree of variables | F1    | F2    | F3    | F4    |
|---------------------------|----------------------------|-------|-------|-------|-------|
| Chloroethylene            | 0.963                      | 0.956 | -0.054| -0.210| -0.046|
| Dichloromethane           | 0.948                      | 0.924 | 0.243 | -0.133| -0.133|
| 1, 2-dichloroethane       | 0.972                      | -0.270| 0.255 | 0.911 | -0.067|
1, 1-dichloroethylene 0.966 -0.199 0.182 0.943 -0.070  
Cis-1, 2-dichloroethylene 0.917 0.835 -0.034 -0.401 -0.240  
Trans 1, 2-dichloroethylene 0.910 0.811 -0.437 -0.075 0.236  
Trichloromethane 0.834 0.787 0.383 -0.342 -0.182  
1, 1, 1-trichloroethane 0.920 0.043 0.896 0.338 -0.025  
Trichloroethylene 0.925 -0.255 0.833 0.408 -0.025  
Perchloroethylene 0.794 -0.003 0.880 0.016 -0.139  
Carbon tetrachloride 0.948 0.954 -0.071 -0.051 -0.172  
benezene hexachloride 0.980 -0.133 -0.105 -0.031 0.975  
DDT 0.989 -0.112 -0.093 -0.070 0.981  

The first common factor is composed of 6 indexes: vinyl chloride, dichloromethane, cis 1, 2-dichloroethylene, inverse1, 2-dichloroethylene, trichloromethane and carbon tetrachloride. These six chlorinated hydrocarbons are mainly used as organic solvents in chemical production in the research area, so the first common factor can be called as a chemical pollution source.

The second common factor is mainly composed of 1, 1, 1-trichloroethane, trichloroethylene and tetrachloroethylene. These three kinds of chlorinated hydrocarbons are mainly used in the cleaning of mechanical components in the research area and in the production of machinery manufacturing industry. Therefore, we call the second common factor as the source of pollution of electromechanical manufacturing.

The common factor three is composed of 1, 2-dichloroethane and 1, 1-dichloroethylene. They in the study area are mainly used in the production of chemical fiber, so the third common factor can be defined as the source of chemical fiber.

The fourth common factor is mainly composed of two indexes, namely, HCH and DDT. These two chlorinated hydrocarbons are the most typical representatives of organochlorine pesticides and have been widely produced and used in China. In the northwest part of the study area, there are historical pesticide manufacturers, so the fourth common factor can be defined as a pesticide pollution source.

4.2. Spatial distribution of pollution

Factor analysis was carried out with SPSS software, and the results of each factor score were given. The weighted comprehensive factor score could be calculated by using the number of seats of variance contribution rate after variance rotation. Four factors were plotted by drawing software.
Figure 5. Common factor 3 score chart

For the first common factor chemical pollution sources, the high value is mainly distributed in the northeast of the study area and decreases to the southeast. In the northeast of the study area, the main factories are a large steel plant, a number of chemical plants, chemical fertilizer plants, plastic plants and other chemical enterprises, which contribute greatly to the pollution of chlorinated hydrocarbons in groundwater.

The high score of the second common factor is mainly concentrated in the middle of the research area, and the general trend is decreasing from the northeast to the southwest. In the middle of the research area, there are a large number of mechanical and electrical manufacturing enterprises, such as machinery manufacturing, automobile manufacturing, motorcycle manufacturing, water tank manufacturing, etc., which have a great impact on the groundwater chlorinated hydrocarbons in the research area.

The third common factor score was mainly concentrated in the southwest of the study area, and decreases from the high value center to the surrounding areas, which has a great impact on the chlorinated hydrocarbon pollution in the area. The major enterprises in this area are chemical fiber enterprises.

The fourth common factor is that the pollution space of pesticide pollution sources is mainly distributed in the northwest part of the research area. The groundwater chlorinated hydrocarbons in this area are mainly affected by pesticide pollution sources. In this area, a large number of pesticide manufacturing enterprises have existed on both sides of the river in history.

5. Conclusion

(1) Based on the principle that the characteristic value is greater than 1, four common factors are extracted in this study, which are chemical pollution sources, mechanical and electrical manufacturing pollution sources, chemical fiber pollution sources and pesticide pollution sources.

(2) Factor analysis can preliminarily identify pollution sources.

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