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Evaluation of groundwater quality and pollution in Daqing Oilfield

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Abstract: Daqing Oilfield is located in the northeast of Songnen Plain in Daqing City, Heilongjiang Province, which is a petrochemical industry gathering place based on petroleum refining, chemical industry, chemical fiber and fertilizer. In recent years, the quantity demand of petroleum and petrochemical production for groundwater in Daqing Oilfield is growing, and it's of great significance to analyze and study the quality and pollution degree of groundwater for groundwater exploitation, utilization and protection. In this paper, groundwater quality of Daqing Oilfield evaluated by Nemerow Index is poor, and most points are Class IV groundwater; When evaluating groundwater pollution by hierarchical ladder method, the results show that the severe and extremely severe pollution points account for 34.48% in shallow phreatic water and 20% in deep confined water, showing that shallow groundwater is more seriously polluted than the deep. The main components influencing the quality of groundwater in the study area are total hardness, total dissolved solids, Cl^-, SO_4^{2-} and so on, which are affected by both the native environment and human activities; The main pollution components in groundwater are nitrite and nitrate nitrogen which are affected by human activities. Daqing Oilfield groundwater pollution is characterized by inorganic pollution, while organic components related to human activities contribute less to the groundwater pollution currently.

Keywords: Daqing Oilfield; Groundwater quality; Groundwater pollution; Evaluation

Introduction

Daqing's petroleum and petrochemical industries play an important part in the national economic and social development. Due to the lack of surface water resources in the hinterland of Daqing, groundwater resources play a very important role in the production and living water supply in Daqing (MU Shan *et al*. 1998). With the rapid development of petrochemical enterprises in Daqing, the environmental load in the process of petroleum exploration and development is getting heavier. Especially the promotion of ASP oil-displacing technology, oil-bearing dirt and waste water have potential threats to different groundwater layers, and the aeration zone and phreatic water have suffered from oil pollution (HOU Jie, 1999). Based on the research results (1212011220978) of the Investigation and Assessment of Groundwater Pollution in Songnen Plain (Heilongjiang) (KONG Qing-xuan *et al*. 2015), the paper evaluates the groundwater qualityand pollution in Daqing oilfield, thus providing a scientific basis for appropriate exploitation, utilization and protection of Daqing groundwater and serving the sustainable development of the economy and society.

Water quality assessment refers to the assessment of water quality, utilization and water treatment using relevant water quality parameters, water quality standards and evaluation methods, based on assessment goals (XIAO Chang-lai *et al*. 2008). Water quality assessment is to ensure water quality and rational use of water resources (WANG Wei *et al*. 2014). Groundwater quality assessment

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methods include single factor evaluation, comprehensive index method, analytic hierarchy process (WANG Xiao-ming *et al*. 2005), fuzzy mathematics (WANG Shu-wen and LIU Chen, 2001), gray evaluation method (SU Yang-ping *et al*. 1991), Nemerow comprehensive index method (Nemerow, 1974; GUAN Yun-peng, 2012; GU Chao-jun *et al*. 2002). Nemerow comprehensive index method was proposed by the American scholar Nemerow, which has the advantages including simple mathematics, convenient operation and clear physics concept. It is a method commonly used for groundwater quality evaluation. There are also many groundwater pollution assessment methods, like quality evaluation methods. This article uses hierarchical ladder method recommended by “Regional Groundwater Pollution Investigation and Evaluation Criteria (DZ/T0288-2015)”. This method focuses on reflecting the contribution in groundwater pollution of indicators that are highly affected by human activities including the “three nitrogen”, heavy metals and organic matter, *etc*, which is instructive for carrying out groundwater pollution prevention and control work in a targeted manner.

1 Overview of the researched area

1.1 Topography

The terrain of the research area is high in the northeast and low in the southwest, showing gentle slopes (ZHU Wei *et al*. 2013). According to the genetic type and morphological characteristics, it is a lowland plain with a gentle topography and undulating waves, with undulating sand dunes, lakes, marshlands, and saline-low-lying lands. Aeolian dunes are distributed northwest to southwest, most of which are fixed or semi-fixed.

1.2 Hydrogeological conditions

The shallow water exploited in the research area is quaternary pore phreatic water. There are newly-developed Cretaceous pore-fissure water in the Taikang formation and Cretaceous Mingshui formation fissure-sand pore fissure water in the deep confined water.

Quaternary pore phreatic water aquifers: It is yellowish brown fine sand, fine sand, with groundwater depth of 1-4 m. The sand layer usually has 2-3 layers, with vertical joint development of interlayer silty clay and close hydraulic contact, forming thicker pore aquifers, but with weak water bearing capabilities. It is also easily polluted due to its shallow burial, and is directly supplied by atmospheric precipitation and surface water infiltration. This layer of water is also the main source of supply for the lower aquifer.

Tertiary Taikang formation glutenite aquifer: Daqing Oilfield is the main mining aquifer. It is generally greyish gravel, coarse sandstone and sandstone, with loose cementation. The roof of aquifer is around 60-150 m in depth, confined water head is 10-36 m in depth and single well water inflow is 3 000-8 000 m^3/d. Underlying quaternary gravel layer, there is a layer of unstably distributed mudstone or sandy mudstone, with thickness of around 5-20 m.

Cretaceous Mingshui formation sandstone aquifer: This is the main target aquifer in the Longfeng-Wolitun area. The original water level is generally 8-30 m beneath the ground and the roof top depth of the aquifer is 17-210 m. The aquifer is mainly medium-coarse sandstone and pebble sandstone with thickness of 30-50 m. The aquifer has good permeability, strong water yield property, with single well water inflow of 1 800-3 300 m^3/d (ZHAO Haiqing *et al*. 2009; MU Shan *et al*. 1998).

1.3 Groundwater replenishment and drainage conditions

The research area is located in the central part of the Songnen Plain, where the groundwater pooling occurs and the runoff of groundwater is slow. Phreatic water is mainly replenished by precipitation. Evaporation and artificial mining are the main means of discharge. Groundwater flows generally from north to south, from northeast to southwest, and runs from northwest to southeast to the marsh area near Babai Shang. The main source of replenishment of deep confined water is mainly the leakage recharge of the upper layer water or direct supply by “skylight”. Discharge is mainly by exploitation and runoff downstream. The groundwater mainly flows from the north, northeast to the south and southwest.

1.4 Groundwater exploitation and utilization

According to the 2011 census of groundwater resources in Daqing City, the groundwater consumption in 2011 was 3.20×10^4 m^3, among which domestic water consumption is 1.70×10^4 m^3, industrial water consumption is 0.65×10^4 m^{3}and water for agricultural irrigation is 0.85×10^4 m^3. Study shows that domestic water is of large proportion, and the quality of groundwater has great impact on people's health.

2 Sample collection and testing

The sample collection was carried out at the normal season in 2013. The sampling points were mainly distributed in the shallow quaternary pore-based phreatic water and deep confined water as the main water-supplying layer. The sampling range was in the Saertu Area, the Ranghulu area, Honggang District, Datong District, Gaotai Town of the oilfield as well as the western part of Anda City, and the Longfeng and the Wolitun District where petrochemical enterprises are concentrated. The total area is about 3 000 km^2. There are altogether 29 shallow groundwater points, 15 deep groundwater points, and the sampling density is about 1.5 points per 100 km^2 (Fig. 1).

The sampling work should be carried out in strict accordance with the technical requirements of "Regional Groundwater Pollution Investigation and Evaluation Specification (DZ/T0288-2015)", under strict quality control. The organic sampling points should be blank samples, parallel samples and labelled samples at a ratio of 5%, with re-sampling for exceptional data points.

Sample testing is completed by the Institute of Geological Mineral Testing and Application of Heilongjiang Province certified by China Bureau of Geological Survey. Inorganic analysis projects include HCO_3^-, COD, CO_3^{2-}, Cl^-, CN^-, NO_3^-, total P, H_2SiO_3, SO_4^-, DBS, Ca, Fe, K, Mg, Mn, Na, volatile phenol, Cr, Zn, Cu, As, Br, Se, Cd, I, Hg, Pb, Al^{3+}, Cr^{6+}, NO^{2-}, NH_4^+, F^-, total dissolved solids and total hardness.

Organic analysis projects include hexachlorobenzene, P.P'-DDD, O.P'-DDT, P.P'-DDT, α-BHC, β–BHC, γ -BHC, δ–BHC, P.P'-DDE, total BHC, total DDT, vinyl chloride, vinylidene chloride, methylene chloride, 1,2-dichloroethylene, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, benzene, 1,2-dichloroethane, trichlorethylene, 1,2-dichloropropane, bromodichloromethane, toluene, 1,1,2-trichloroethane, tetrachlorethylene, dibromochloromethane, chlorobenzene, ethylbenzene, m-p-xylene, o-xylene, styrene, bromoform, m-dichlorobenzene, p-dichlorobenzene, 1,2,4-trichlorobenzene, benzo (a) pyrene, altogether 37 items.

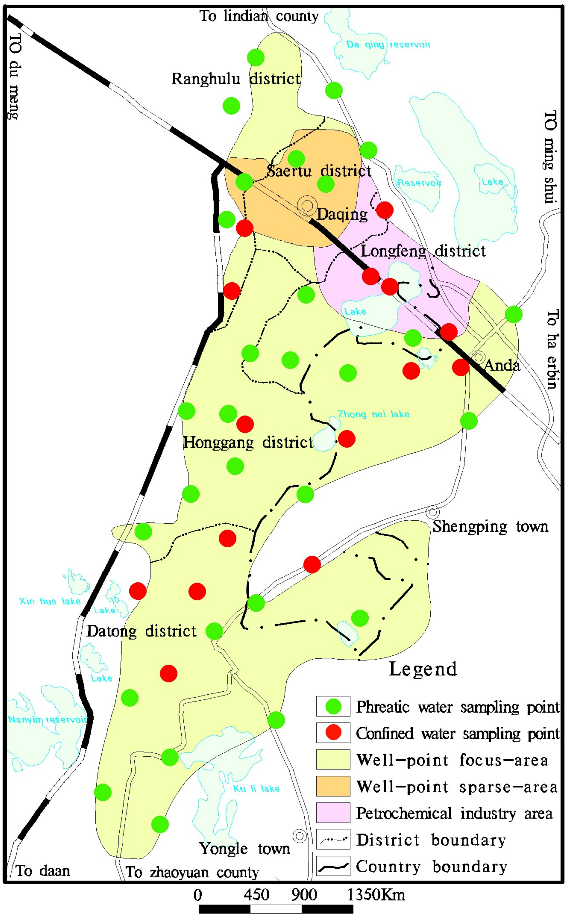

Fig. 1 Distribution of sampling points in Daqing Oilfield

Analysis and testing use ICP-MS, GC-MS, gas phase, high performance liquid chromatography, UV-visible spectrophotometry as the main set of analysis methods, and the detection limits of the analysis method are met or better than a variety of standards. According to the requirement of Geology and Mineral Resources Laboratory Quality Management Standard DZ/T0130-2006 and "Geological Survey of Groundwater Pollution Investigation and Evaluation Standard", the quality of analysis is controlled using spike recovery and extraction of duplicate samples, analysing at the same time, thus monitor the result deviation between the batches, and the pass rate is 100%, which ensures the accuracy of the groundwater quality evaluation based on experimental test data.

3 Evaluation methods

3.1 Groundwater quality assessment

In this paper, Nemero comprehensive index method is used to evaluate the quality of groundwater in the study area. This method can quantitatively describe the water quality in the study area, and make comparisons about the water quality and changes throughout different time and space. This method also takes into account the impact of indicators that exceed limits on water quality, enabling people to better understand the results of water quality evaluation. This method is the most commonly used method for water quality evaluation at home and abroad. According to the "Groundwater Quality Standard" (GB/T14848-1993), the recommended scoring method is usually adopted in single-factor evaluation.

Table 1 Groundwater quality score

Category	I	II	III	IV	V
F_i	0	1	3	6	10

Based on the data of water quality test, the Nemerow comprehensive index method was used to separate the categories of individual components according to "Groundwater Quality Standard" (DZ/T0290-2015), and to score each category according to Table 1.

The composite score F is calculated using the Nemeroc index formula.

$$F = \sqrt{\frac{F_{\max}^2 + F_{\text{ave}}^2}{2}}$$

$$F_{ave} = \frac{\sum_{i=0}^{n} F_i}{\text{n}}$$

In the above equation: F-composite score; $F_{\max}$-maximum single component F_i; F_{ave}-the average score of each component F; n-terms, n=48

Reference to "Regional Groundwater Pollution Investigation and Evaluation (DZ/T0288-2015)" and "Groundwater Quality Standards (DZ/T0290-2015)", a total of 48 indicators were selected, including 21 inorganic indicators and 27 organic indicators. Due to the natural conditions in the study area, the Fe-Mn content far exceeds the third-class water standard of "Groundwater Quality Standard (DZ/T0290-2015)" (ZHAO Chun-mei *et al*. 2002) and the iron-manganese index is a general chemical indicator with low toxicity. Field survey found that all industries have treatments of high Fe-Mn water, and the treatment is simple, convenient and effective, low processing costs. There was no case of human damage or economic loss caused by the use of high-iron-manganese water in the study area, indicating that the adverse impact of high-iron-manganese groundwater on water use is small. Therefore, this comprehensive evaluation of water quality indicators does not contain iron and manganese.

Table 2 Groundwater quality grading

Grading	Excellent	Good	Fair	Poor	Bad
F	＜8.0	0.80-2.50	2.50-4.25	4.25-7.20	＞7.20

Ground water quality grade is divided according to Table 2 according to F value.

3.2 Groundwater pollution assessment

The groundwater quality and pollution level ladder evaluation method recommended by "Regional Groundwater Pollution Investigation and Evaluation Standard (DZ/T0288-2015)" is adopted. According to the chemical characteristics of groundwater in the study area (ZHOU Wei-guo *et al*. 2016; LIU Wen-zhong *et al*. 2009), the total dissolved solids, total hardness, iron, manganese, fluorine, iodine and arsenic in groundwater have far exceeded those of natural water or approached the third category of water standards in "Groundwater Quality Standards (DZ/T0290-2015)", this paper makes appropriate adjustments to the parameters of the indicators specified in the standards, and selects those inorganic toxicological indicators and trace organic indicators that affect human health and can direct the disorderly discharge of toxic and harmful pollutants from human activities for level and integrated evaluation.

Inorganic toxicological evaluation indicators include cadmium, hexavalent chromium, lead, mercury, selenium, nitrite nitrogen, nitrate nitrogen, altogether 7 indicators; trace organic evaluation indicators include volatile components chloroform, carbon tetrachloride, 1,1,1-trichloroethane, tetrachlorethylene, methylene chloride, 1,2-dichloroethane, tribromomethane (bromoform), vinyl chloride, vinylidene chloride, 1, 1-dichloroethylene, 1,2-dichloroethylene, chlorobenzene, o-dichlorobenzene, p-dichlorobenzene, benzene, toluene, ethylbenzene, xylene, styrene, trichlorobenzene, 1,2-dichloropropane, 1,1,2-trichloroethane, a total of 22; semi-volatile components of total 666, total DDT, hexachlorobenzene, benzo (a) pyrene, γ-BHC (lindane), 5 items.

First of all, groundwater is divided into five levels according to inorganic toxicological indicators and trace organic indicators (“Regional Groundwater Pollution Investigation and Evaluation Standard (DZ/ T0288-2015) ”):

Level 1: Mainly reflects the natural background content of groundwater chemical components or no clearly identifiable sources of pollution exist and the changes in water quality is not obvious, that is, inorganic toxicological indicators and trace organic indicators are less than or equal to water quality standards Class Ⅲ, classified as uncontaminated water.

Level 2: If a single inorganic toxicological indicator or organic indicator is over water quality standards of Class III, but not exceed water quality standards of Class IV, and a number of indicators exceed Class Ⅲ and the value exceeds less than 50% of the standards of Class Ⅲ, there are sources of pollution; set as lightly polluted water that needs treatment before it can be supplied.

Level 3: If a single inorganic toxicological indicator or trace organic indicator exceeds Class IV, or a number of indicators exceed Class Ⅲ and the value exceeds more than 50% of the standard, there are sources of pollution set as moderately polluted water and cannot be directly supplied in principle.

Level 4: If a number of inorganic toxicological indicators or trace organic indicators exceed Class Ⅳ and the value exceeds the standard more than 50% and less than or equal to 200%, there are important sources of pollution and set as seriously polluted water; in principle, direct water supply is forbidden.

Level 5: If a number of inorganic toxicological indicators or trace organic indicators are evaluated as Class Ⅴ, and the indicators exceed the standards more than 200%, there are dangerous sources of pollution, and set as extremely polluted water; direct water supply is strictly forbidden.

According to the groundwater pollution level of each indicator obtained by the progressively evaluation, the pollution level of groundwater is finally determined according to the principle of inferiority and poor quality, so that the pollution control can be effectively targeted at the indicators causing groundwater to become “inferior” (ZHANG Zhao-ji *et al*. 2012).

4 Results and discussions

4.1 Exceedance of groundwater component detection

The inorganic excessive components of deep and shallow groundwater in Daqing Oilfield were calculated and the excessive rates of total dissolved solids, total hardness, NO_3^-, NO_2^-, NH_4^+, Na^+, Cl^- and SO_4^{2-} were measured (Groundwater Quality Standard DZ/T0290-2015) which are higher than the statistical value of Songnen (Heilongjiang) Plain area (Table 3).

The detection rates of organic volatile components and semi-volatile components are higher than the regional statistics (Table 4).

In the shallow groundwater, the only organic component detected exceeded the standard point is located in a pasture of Ranghulu District of Daqing City in the study area, and the exceeding component is 1,2-dichloropropane, exceeding the standard 1.59 times.

There were three exceeding points of organic components detected in deep groundwater. One of them was located in Qianhujia village of Gaotaizi town in the study area, and the excessive component was 1,2-dichloropropane, which exceeded the standard by 1.3 times. The other two were located out of the study area However, one of the excessive points is located at the edge of Daqing petrochemical enterprises’ pollutant- containing lake (Maiken Lake). The excessive component is benzene, exceeding the standard by 7.78 times.

Table 3 Statistics on excessive inorganic chemical components in groundwater

Sampling layer	Sampling numbers	Inorganic indicators	Excessive points	Excessive ratio (%)	Regional excessive ratio (%)
Shallow groundwater	29	TDS	21	72.41	23.50
		Total hardness	14	48.28	24.65
		Na^{+}	8	27.59	4.38
		Cl^{-}	7	24.14	5.30
		SO_4^{2}	3	10.34	3.00
		NO_3^{-}	8	27.59	24.19
		NO_2^{-}	11	37.93	13.59
		NH_4^{+}	10	34.48	24.42
Deep groundwater	15	TDS	7	46.67	16.03
		Total hardness	3	20.00	18.37
		Na^{+}	7	46.67	4.66
		Cl^{-}	3	20.00	3.21
		SO_4^{2}	2	13.33	3.50
		NO_2^{-}	3	20.00	17.78
		NH_4^{+}	3	20.00	15.45

Table 4 Statistics on organic chemical components detected in groundwater

Sampling layer	Sampling numbers	Organic indicators	Detected points	Detected rate (%)	Regional detected rate (%)
Shallow groundwater	29	Volatility	4	13.79	8.10
		Semi-volatility	5	17.24	5.95
Deep groundwater	15	Volatility	4	26.67	9.79
		Semi-volatility	3	20.00	8.01

4.2 Groundwater quality

Evaluation results by Nemerow index method in Table 5.

In the study area, the shallow phreatic water quality is Class IV; there is only one Class II point in the deep confined water, and the other investigation points are also Class IV. The quality of deep groundwater points is mostly poor. At the same time, fuzzy comprehensive evaluation method was used to evaluate. The vast majority of groundwater points in the study area are Class V water. It can be seen that when there are many evaluation factors and the number of over-standard factors is less than 1/2, the highlight of the component with the largest concentration using Nemerow index method is weakened, and the influence of the extreme value is smoothed.

Table 5 Statistics on results of groundwater quality evaluation

Sampling layer	Sampling numbers	Class I		Class II		Class III		Class IV		Class V	
		Points	Ratio (%)	Points	Ratio (%)	Points	Ratio (%)	Points	Ratio (%)	Points	Ratio (%)
Shallow groundwater	29	0	0.00	0	0.00	0	0.00	29	100.00	0	0.00
Deep groundwater	15	0	0.00	1	6.67	0	0.00	14	93.33	0	0.00

According to the contribution of chemical components to the groundwater quality, the indexes that have a great influence on the quality of groundwater in the study area are the total hardness, total dissolved solids, Cl^- and SO_4^{2-}, which are affected by the native environment and human activities. The study area is located in the center of the Songnen Plain. The runoff of groundwater is sluggish. Hydrochemical effects are mainly evaporation and ion-exchange adsorption, and the chemical environment of water is a weakly alkaline reducing environment. The salinity of groundwater in the natural state is relatively high. At the same time, human's over-exploitation of groundwater has made changes to the hydrodynamic field and hydro-geochemistry environment and a series of hydrogeochemical processes occur between the polluted carrier and the aeration zone and the water-bearing rocks, thus, the indicators such as total dissolved solids in groundwater, Cl^-, SO_4^{2-} increased; when the acid and salt in sewage from factories and domestic get under the ground, the rock can release calcium and magnesium from insoluble calcium carbonate and magnesium carbonate, in the form of soluble state of Ca^{2+}, Mg^{2+}. These actions promote the calcium and magnesium soluble salts, insoluble salts and exchangeable calcium and magnesium in soil and sediments below transfer from the solid phase to water, making groundwater hardness increased. The combined effect of nature and human makes the groundwater total hardness, total dissolved solids, Cl^-, SO_4^{2-} and other indicators of the study area higher, which are also the main indicators making the groundwater quality poor (Class IV).

The "three nitrogen" indicator, which is obviously affected by human activities, is also the main influence index of Class IV water. The contribution of organic pollutants to poor water quality is negligible.

According to the results of "Songnen Plain (Heilongjiang) Groundwater Resources and Environmental Problems Survey" project in 2005, there were no Class I, III water points in shallow groundwater in the study area, while Class II water points accounted for 18.2%, Class IV water points accounted for 36.4% and Class V water points accounted for 45.4%. In deep confined groundwater, there were 41.7% of Class II water points, 50.0% of Class IV and 5.3% of Class V ; By 2013, there were basically no Class I-III water points in groundwater of the study area, indicating that the overall quality of groundwater in the study area showed a decreasing trend, and the water quality in some extremely polluted areas improved somewhat.

4.3 Groundwater pollution

The results of pollution evaluation showed that the shallow phreatic water pollution in the study area was more serious than that in deep confined water, with 34.48% of severe and extremely severe sites; deep water points accounts for 20% and most of them are uncontaminated (Table 6).

The main pollution factors of shallow and deep groundwater are nitrite nitrogen and nitrate nitrogen, and the contribution of heavy metals and organic components to groundwater pollution is small. The contribution of nitrate nitrogen in shallow water III, IV, V water is the highest, reaching 72%-96%; and in the deep water, it reaches 100%.

Table 6 Statistics on results of groundwater pollution evaluation

Sampling layer	Sampling numbers	Class I		Class II		Class III		Class IV		Class V	
		Points	Ratio (%)	Points	Ratio (%)	Points	Ratio (%)	Points	Ratio (%)	Points	Ratio (%)
Shallow groundwater	29	5	17.24	2	6.90	12	41.38	3	10.34	7	24.14
Deep groundwater	15	11	73.33	1	6.67	0	0.00	0	0.00	3	20.00

According to the study, the larger the particle size of aeration zone is, the greater risk of groundwater contamination will be. And the vertical migration of pollutants in clay is the weakest (ZHAO Yong-sheng, 2015). The aeration zonelithology in the study area is fine-grained loam, silty loam and silt, which play a protective role in the groundwater. During the process of heavy metal passing through the aeration zone, the adsorption and alternation will occur and the content attenuates. The microorganisms in the aeration zone also play a very important role in the degradation of organic pollutants. Therefore, although the study area is located in the important petroleum and petrochemical industry base, the groundwater pollution of heavy metals and organic matter is minor.

Although the organic pollution in the study area was slight, the detection rate and exceed standard rate were far greater than those of the Songnen Plain (Heilongjiang). There were 4 points where organic components exceeding the standard in the region, 2 in the study area, of which the excessive component is 2-dichloropropane, and there are chemical companies and large storage tanks near the points. In the study area, the oil wells are distributed intensively, and oil refining, chemical industry, chemical fiber, chemical fertilizer and other petrochemical industries are gathering here. There is a certain degree of leakage or the volatilization of organic pollutants in the process of petroleum production, processing, storage and transportation, *etc*. There will also be some organic toxic substances getting into the aeration zone and into the groundwater with the infiltration, making the detection rate and exceeding rate of groundwater in Daqing and its surrounding areas higher than the standard.

With every ton of crude oil produced in Daqing Oilfield, 2-3 tons of water were needed to be re-injected and there were 36 879 m^3 of oil polluted wastewater in 2003 (WANG Shi-jun *et al*. 2010). The oil content of oil polluted wastewater separated from the crude oil is very high, with 6.8-2 024 mg/L (WANG Yu-mei and DANG Jun-fang, 2000). In the process of re-injection into abandoned deep wells, once the injection well is ruptured, the polluted water can easily be forced into the upper aquifer under the pressure of huge reinjection pressure, resulting in the contamination of groundwater. Therefore, the oil polluted wastewater should be given sufficient attention since there may be contamination when treated in the process.

The result of factor analysis shows that the organic pollution areas are mainly distributed in Longfeng District and Wolitun District, where the eastern petrochemical enterprises gather (GU Tian-xue *et al*. 2016). Organic contaminants in groundwater often have the characteristics of diverse types, low content, great harm and are difficult to control. Many organic pollutants are difficult to be removed by natural degradation process in groundwater environment and are likely to accumulate for a long time (SHI Jian-sheng *et al*. 2011). Therefore, the research area should strengthen the investigation, monitoring and protection of groundwater and prevent further development of groundwater organic pollution.

Nitrite nitrogen, nitrate nitrogen pollution is mainly in the city center and the distribution area of fertilizer companies in the east. The main pollutants come from urban sewage, the waste-water and solid waste produced by enterprises. Nitrogen in urban sewage and chemical fertilizers exist in the form of ammonia nitrogen (NH_4^+ -N) in the aeration zone. Under the oxidizing environment, nitrification takes place and produces NO_2 - N and NO_3 - N.

5 Conclusions

(1) The quality of groundwater in Daqing Oilfield is mainly Class IV, with the main affecting factors such as total hardness, total dissolved solids, Cl^-, SO_4^{2-}, and "three-nitrogen". In terms of groundwater contamination, shallow phreatic water is more serious than that of deep confined water and the major pollutants are nitrite nitrogen and nitrate nitrogen, characterized by inorganic pollution.

(2) Organic pollution has occurred in ground-water in Daqing Oilfield. Although organic components contribute little to the pollution of groundwater, we should pay sufficient attention, and conduct investigation and monitor of groundwater organic components in large scale as soon as possible, and demonstration work on restoration and treatment should be carried out in key polluted areas.

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