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Simulation of Groundwater Quality in Xi 'an,Shaanxi Province Based on Visual Modflow

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ABSTRACT

The so-called groundwater quality simulation is to study the spatial and temporal variation law of the concentration of a certain soluble substance (element or other component) when it is dispersed and transported by simulation method, to predict the instantaneous dynamics and expansion range of polluted groundwater, and to provide scientific basis for formulating reasonable and effective prevention measures. In recent years, the environmental hydrogeology survey results of some provinces, cities and regions in China show that the groundwater in most cities in China has been polluted to varying degrees. This situation directly affects industrial and agricultural production and people's health. However, in the past, environmental hydrogeology work was mostly limited to surface investigation, lacking quantitative and predictive evaluation research. Monitoring groundwater quality dynamics and forecasting the development trend of groundwater pollution is one of the main tasks of groundwater pollution investigation and research. Relevant information shows that some countries in the world have already carried out this research and established a predictive groundwater quality model. Among them, the United States has established 22 material transport models and 5 heat transport models; France has established 5 models of material transport and 4 models of heat transport. The following countries have only established material transport models: 7 in Israel; 2 in the UK; 2 in Canada; 1 in West Germany and 1 in Japan. Therefore, we believe that the study of groundwater quality simulation experiment, which is still blank in China's scientific field, has become an important subject that needs to be carried out urgently to ensure the four modernizations and people's health. The hydrogeological conditions and dynamic characteristics of groundwater resources have been comprehensively analyzed and studied. It points out that the continuous exploitation of groundwater resources in 2018 has led to the deterioration of groundwater quality, land degradation, underground, cracks and depletion of groundwater resources, and puts forward some preventive measures.

KEYWORDS

Visual MODFLOW; Groundwater simulation; Xi'an.

1. PREFACE

For nearly half a century, hydrogeology has roughly gone through two stages of development: from the 1950s to the mid-1970s, it is the foundation stage, which mainly receives the influence of Soviet thought; from the mid-1970s to the 1990s, it is the development stage, with the input of new ideas, new theories and new technologies such as system science, environmental science, modern applied mathematics and computer technology, the basic concepts and research categories of hydrogeology have undergone tremendous changes, from qualitative research to quantitative research. In the stage, the track of systems engineering is incorporated. With the development of industrial and agricultural production and the improvement of people's living standards, the contradiction between the supply and demand of groundwater resources has become increasingly prominent, which puts forward higher requirements for the evaluation and management of groundwater resources, that is, prediction and evaluation of groundwater resources from a quantitative perspective. Establish a reasonable development and utilization plan. However, the inherent complexity of hydrogeological conditions restricts the extensiveness of using analytical methods established in groundwater dynamics to solve problems. After the mid-1970s, the application of numerical simulation technology made it possible to solve this problem. The establishment of a mathematical model of the groundwater system is the key to the quantitative study of the laws of groundwater movement. After nearly 30 years of development, groundwater simulation in China has experienced a difficult development process from scratch, from simple water flow models to more complex material and heat transport models, from imitation to independent development, and finally to the world[1]. Now, China has established P. ven der Heijd, which almost encompasses the International Groundwater Modeling Center (IGWMC). All models in the category. The research scope involves saturated zone, unsaturated zone and saturated-unsaturated zone. However, so far, China has not had a universal, authoritative computing software with intellectual property rights. This cannot but be said to be a great pity In recent years, the research on groundwater flow simulation in saturated zone has mainly focused on the development of three-dimensional flow model, the calculation method of velocity field and streamline, the regional generalization of heterogeneous parameters, and the optimization of complex data. At present, the main software for regional three-dimensional groundwater flow analysis is HST3D (Iipp, 1987), SWIFT (Gran well and Reeves, 1981) and the world's most popular Visual MODFLOW (M cDonald and Harbangh, 1994). This article first gives a brief introduction to the Visual MODFLOW software and the basic theory of MODFLOW. On this basis, the Visual MODFLOW software is used to simulate the groundwater flow in Xi'an, Shaanxi Province. Through the correction and identification of the model, a relatively satisfactory result was obtained[2]. The mathematical model built can better reflect the actual local hydrogeological conditions, and can be used for prediction and management of groundwater resources[3].

2. STUDY AREA INFORMATION

Groundwater is an important source of water supply in Xi'an. Annual average water supply of groundwater in Xi'an is 9.65×108m3, which is an important water source to support the sustainable, development of urban economy. It is accounting for 65.52% of the total water supply. In recent years, with the development of "Long-term Development Initiative" and "Great Xi 'an Plan", the population and economy of Xi 'an have increased rapidly, and human activities in regional groundwater environment have deepened day by day. The situation of prevention and control the groundwater, pollution is also more severe[4]. These areas are facing environmental geological problems, such as the decline of regional groundwater, development and cracks around land. Define the significance of groundwater pollution, ensure the safety of urban water supply, and establish sustainable development, ecological environment and economic coordination. Many scholars have done a lot of research on water pollution. Uncertainty, it is generally, believed that with the development and possibility of groundwater pollution, groundwater pollution will be reduced. In this assessment method, according to the hydrogeological conditions of aquifer, the vulnerability of circulating water is expressed by the essential vulnerability, of circulating water and the vulnerability, assessment model of circulating water.

On the basis of combination, considering all kinds of characteristics and land using, and considering the load and using of pollutants in circulating water, the pollution risk assessment method was established, and the pollutant discharge of circulating water was evaluated[5].

The influence of pollution caused by groundwater is considered, and the pollution sources are re-analyzed and evaluated. A coupling evaluation model of groundwater inherent vulnerability and pollution source ,load was established, and the pollution risk of large ,groundwater resources in northern China was evaluated.

3. DATA SOURCE

The plain area of Xi'an is located at 107°98E-109°54'E, 33°98'N-34°74'N, located in the hinter land of Guan Zhong Plain, crossing Weihe River in the north, Qinling Mountains in the south and west , It starts from the eastern foot of Taibai Mountain, reaches the Bayuan Mountain in the east, is about 145km long from east to west, and North-South width is about 88km, and the total area is about 4658km2, accounting for about the total of Xi'an The area is 46.1%. Xi 'an Plain was influenced by Tertiary geological tectonic movement, and accumulated a large number of Tertiary and Quaternary river sediments, which extended from southeast to north to piedmont alluvial fan, Loess Plateau, alluvial fan, Weihe River terrace, southeast, northwest and southwest.Water-bearing strata include alluvium, alluvium, gravel layer and gravel layer, which are mixed with loess and clay[6].

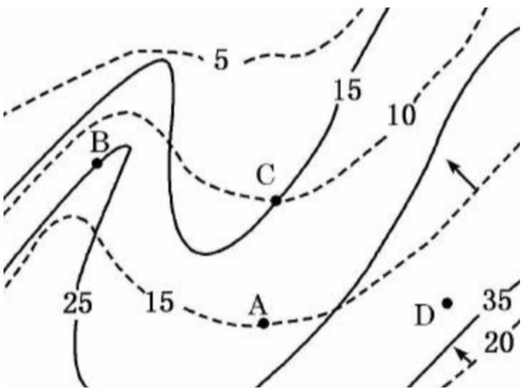

Figure 1. Example map of groundwater level in Xi 'an

4. BASIC THEORY OF WATER POLLUTION AND WATER QUALITY SIMULATION EXPERIMENT RESEARCH

At present, the research on groundwater pollution has made great progress in both theory and technology, and a new discipline of pollution hydrogeology and environmental hydrogeology has been preliminarily established. Some people define polluted hydrogeology as "a discipline that studies and applies theories and practices of hydrogeology and geochemistry to protect aquifers from pollution, protect surface water environment from pollution conducted by underground water flow system, and carry out measures for underground treatment of wastes". It can be seen that the study of groundwater pollution belongs to the category of hydrogeochemistry research, which basically adopts hydrogeochemistry theory and research methods, and also reflects the general development trend of modern hydrogeology, in which groundwater persuasiveness and hydrogeochemistry research cooperate and penetrate each other, and groundwater quantity and groundwater quality simulation are unified[7].

The principle of groundwater pollution research is based on the theory of pollutant mixing and transportation. In most cases, pollutants are miscible with groundwater, or at least have the property of tracer, and the dispersion in some transitional zones can not be ignored. The miscible flow of pollutants is dominated by dispersion theory, but sometimes it can be treated as an immiscible migration phenomenon of pollutants, ignoring the dispersion effect. For example, it is not expected that a certain one-dimensional flow will flow at a constant speed, and the inflow of pollutants will remain unchanged.

It is considered that a certain one-dimensional flow flows at a constant speed, and the inflow of pollutants remains unchanged. The dispersion in the transition zone is proportional to the square root of time. According to the formula L=ut, the distance l of migration is proportional to the time T .. Therefore, the width c of the transition zone is proportional to L1/2, while the relative width e/L is proportional to Li/2/L .. When L increases, L/2/L decreases, which means that the dispersion effect becomes smaller when the flow distance is long, which is less important than the continuity effect. Experimental data show that longitudinal dispersion, transverse dispersion and vertical dispersion can be distinguished. In some cases, the lateral dispersion effect is dominant, while the longitudinal dispersion effect is concealed by convection. In other cases, the opposite is true. -Some examples also show that the actual dispersion effect of aquifer is dominated by the permeability and fracture form of rock stratum. Bifurcation of groundwater can constitute a large number of dispersion phenomena on a large scale.

When studying groundwater pollution, we must solve the following two problems: 1) What is the pollution quality? (Whether it is miscible with natural groundwater, what are its physical and chemical properties, and what harm is caused by its existence); What is the scale of pollution? (total amount of pollutants, concentration, size and geometry of pollution sources, fallout of pollutants invading aquifers, pollution period). Therefore, it is necessary to select appropriate models and research methods. -under normal circumstances, firstly, choose the most dangerous and frequent pollution type in the aquifer which is miscible with the natural water in the aquifer; However, the immiscible compounds can be treated as miscible substances as tracers.

The basic theory of groundwater pollution and groundwater quality simulation is dispersion theory. This theory is a qualitative description and quantitative calculation of the mutual mobility of miscible fluids in porous media. The dispersion of liquid flow in porous media occurs and evolves in the transition zone with different components of liquid phase. There are two kinds of actions involved in the process: pure mechanical action and physical and chemical action. Among them, physicochemical dispersion is a kind of molecular diffusion, which is caused by chemical potential gradient, and chemical potential is related to concentration. Molecular diffusion often exists, and it can happen even in a still liquid[8].

(1) Dispersion equation

$$\left[div\left[Dq.\left(grda\frac{c}{p}\right)\right]-Djv(cv)=\frac{c}{t}$$

(2) continuity equation

$$dvi(pv)=-\frac{p}{t}$$

(3) equation of motion

$$v=-\frac{k}{n}(gradp+pggradz)$$

(4) state equation

$$p = f(c)u = g(c)D = D(c)$$

In the formula, c is the pollutant concentration; D is diffusion tensor; V is the average flow velocity and 3K is the permeability coefficient; P is the pressure head; T is time and n is porosity; μ is viscosity; G is the acceleration of gravity; Z is the bit head; ρ is the density of the miscible substance. In general, the dispersion system equation is not linear, and the hydrodynamic equation and dispersion equation are interdependent. Because the change of concentration c may cause the change of density p and viscosity u of fluid, and the change of p and μ in turn will cause the change of flow field. The coefficient of dispersion equation is a function of mixing speed. At this time, it is very complicated to solve the seepage equation and convection-open equation by coupling. Generally, it is very difficult to obtain the simultaneous solution of the equation of dispersion system. At present, numerical method, such as iterative method, is used for calculation.

There are two basic ways to apply the dispersion system in practice: first, the density and viscosity of miscible substances are unchanged (that is, tracing slip condition); Second, the density and viscosity of miscible substances change with the concentration (that is, the general situation). In the case of tracing, the hydrodynamic equation has nothing to do with the dispersion equation, because density and viscosity are constant, and the velocity of the mixture does not depend on the concentration of pollutants. The research methods and steps can be summarized as follows: 1) calculate the liquid flow according to the existing data, and determine the possible pollution edge types (local, whole area, horizontal, vertical, etc.); 2) select the appropriate mathematical model according to the regional hydrogeological conditions, pollution punishment and pollution range: either hydraulic convection model (immiscible liquid flow, no dispersion effect) or hydrodynamic dispersion model (with dispersion effect) If the former is chosen, the problem of groundwater pollution will become a typical groundwater dynamics problem, and only the elements of groundwater flow movement can be measured; If the latter is selected, the dispersion equation should be applied to determine the dispersion coefficient. This paper mainly discusses the latter.

5. THEORETICAL BASIS AND RELEVANT ANALYSIS OF XI'AN

5.1. Theoretical basis

MODFLOW is a three-dimensional finite difference groundwater flow model based on the following basic equations:

$$\frac{\partial}{\partial x}\left\{K_{xx}\frac{\partial h}{\partial x}\right\}+\frac{\partial}{\partial y}\left\{K_{yy}\frac{\partial h}{\partial y}\right\}+\frac{\partial}{\partial z}\left\{K_{zz}\frac{\partial h}{\partial x}\right\}-W=S_s\frac{\partial h}{\partial t}$$

Where: K_{ZZ} is the hydraulic conductivity (LT) along the x, y,coordinate axis, h is the head (L)， W is the unit volume of the homogeneous and isotropic soil medium under non-equilibrium conditions, Ss is the flow rate, indicates the source and sink of groundwater, indicates the specific water storage coefficient of the porous medium (L^{-1}),t is time (T). For three-dimensional steady flow, the mass balance equation of MODFLOW can be expressed by effective porosity and seepage flow velocity, as：

$$\frac{\partial(nVx)}{\partial x}+\frac{\partial(nVy)}{\partial y}+\frac{\partial(nVxz)}{\partial z}=W$$

Where: V_x, V_y, V_z, Represents the component of linear flow velocity vector in the direction of each coordinate axis， $(LT)^{-1}, n$ is the effective porosity of the aquifer (%), W represents the amount of water produced by the source and sink per unit volume inside the aquifer.

5.2. Natural and socio-economic overview

Xi'an City is located in the Guanzhong Basin in the middle of the Weihe River Basin, between 107.40 degrees to 109.49 degrees east longitude and 33.42 degrees to 34.45 degrees north latitude, bordering the Weihe River and the Loess Plateau in the north, and the Qinling Mountains in the south. It is bounded by Linghe and Bayuan Mountain in the east, and is connected with Huazhou District, Weinan City, Shangzhou, and Luonan County of Weinan City; in the west, it is bounded by Taibai Mountain and Qinghua Loess Plateau, and it is bordered by Meixian and Taibai County, South to the main ridge of the North Qinling Mountains, bordering Foping County, Ningshan County, and Zhashui County; north to Weihe, northeast across Weihe, and Xianyang City, Yangling District and Sanyuan, Jingyang, Xingping, Wugong, Fufeng, Fu The equal counties (cities) are adjacent. The jurisdiction is about 204 km from east to west, and about 116 km from north to south. In 1965, 17 key flood control dikes were built upstream and downstream. More than 2,000 tons of limestone were built by the masses, 88,000 cubic meters of foundations were dug, 57,000 cubic meters of stone masonry, 310,000 cubic meters of sand piled, and an investment of 316,000 yuan (of which the state invested 264,000 yuan, 52,000 yuan raised by the people), invested more than 700,000 man-days, built 14.5 kilometers of sundeck dams, lead wire cage dams, and dry stone dams, picked up 2,730 acres of river beach land, and protected more than 6,700 acres of arable land. During the "Cultural Revolution", no one was interested in treating the river, and the masses spontaneously made repairs. In late October 1977, the County Party Committee and the County Revolutionary Committee established the Bahe Control Command Headquarters, with three theaters of Dongchuan, Chengguan, and Xichuan, organized along the river Yushan, Jiujifang, Malou, Puhua, Lihou, and Dalian. Members of 12 communes, including Zhai, Chengguan, Sanli Town, Xiehu, Ancun, Mengcun, and Huaxu, launched a general battle to manage the "Baili Bahe River".

5.3. Hydrogeology overview

Main characteristics of aquifers Xi'an is part of the hydrogeological unit of the sloped plain of Qinling Mountain. Groundwater mainly occurs in the pores of the Quaternary loose rock formations. The Quaternary System can be divided into 4 water-bearing rock groups according to the characteristics of lithology and sedimentary age, the distribution of aquifers and aquifers, and hydrodynamic conditions. The first water-bearing rock group corresponds to the Holocene (Q4) stratigraphically, the second water-bearing rock group corresponds to the Upper Pleistocene (Q3) stratigraphically, and the third water-bearing rock group corresponds to the Middle Pleistocene (Qa) stratigraphically, The fourth water-bearing rock group corresponds to the Lower Pleistocene (Q). In the horizontal direction, the single layer thickness of the aquifer gradually thickens from the west to the east, the grain size changes from fine to thick, the layers increase from less, and the water richness from weak to strong.

In the vertical direction, the upper and lower sand layers have finer grain size and smaller thickness, while the middle sand layer has a coarser grain size and a larger aquifer thickness. The first and second aquifers are well developed. There is no continuous aquifer and impermeable aquifer between the two groups. Atmospheric precipitation infiltration replenishment is the most important recharge method for groundwater in Xi'an Because the lithology of the unsaturated zone is dominated by sand and loam, the infiltration coefficient is large, mostly around 0.25, and the terrain slope is small, which provides good conditions for precipitation infiltration. It is flood irrigation, and the infiltration amount accounts for about 8% of the irrigation water used in farmland. The groundwater discharge in Xi'an is dominated by artificial exploitation. Agricultural irrigation water accounts for about 88% of the total water consumption, and it is mainly concentrated in March and June when winter wheat consumes a lot of water. Due to continuous over-extraction, the groundwater depth has reached 20m. Groundwater evapotranspiration is almost zero. Groundwater dynamic characteristics Xi'an groundwater dynamics belong to the type of precipitation, irrigation infiltration replenishment—agricultural exploitation. The change of groundwater level is mainly controlled by the amount of agricultural exploitation and rainfall. Groundwater extraction was suspended from January to February at the beginning of the year. ,

The groundwater level began to gradually rise to the highest water level. After the beginning of spring irrigation, the groundwater level gradually decreased until the beginning of the rainy season, agriculture stopped mining, the groundwater level began to gradually rise, if the autumn and winter irrigation water consumption is large, the groundwater level will also temporarily drop, but the total The trend is to rebound until it reaches the highest value in March of the second year. At present, the overall flow of groundwater in Xi'an is from northwest to southeast, and the hydraulic gradient of groundwater is basically the same as that of the ground. The current situation of water resources and development and utilization of Xi'an surface water resources is lacking, and currently only The city's general drainage canal and the Jiaohe section have clear currents all the year round. However, due to the city's insufficient treatment of waste water, biological oxygen consumption, chemical oxygen demand, suspended solids, sulfide, ammonia nitrogen, cyanide, volatile phenol and other pollution The waste water is used to irrigate part of the arable land along the banks of the river.The groundwater resources are very rich and the water quality is good. They are suitable for industrial, agricultural and domestic use. The average amount of groundwater resources for many years is about 10g m3, and the total recharge is about10g m3. In recent years, due to the continuous drought and the improvement of agricultural water conservancy, the amount of agricultural water consumption has increased year by year. The rapid development of the country and the improvement of people's living standards have caused a heavy burden on groundwater resources[9].

6. MODFLOW GROUNDWATER NUMERICAL MODEL

6.1. Model building

VisualModflow is a visual professional software system of 3D groundwater flow and solute transport simulation evaluation standard issued by Waterloo Hydrogeology Company of Canada in 1994. On the basis of seamless integration of Modflow, Modpath, Pest, MT3D, ZoneBudget and other software, the system has developed a powerful graphical visual interface function. Modflow is a three-dimensional finite difference groundwater flow model, and finite difference is a commonly used numerical solution[10-11]. It uses difference quotient instead of partial derivative in differential equation to obtain the corresponding difference equation, and obtains the approximate value of the solution of differential equation by solving the difference equation. The buried depth of phreatic aquifer in the study area is 5 ~ 20 m, which is covered with three layers of confined water aquifer: the first layer is buried 30 ~ 50 m, and its lithology is fine sand and fine sand; The second aquifer has a buried depth of 70 ~ 80m and its lithology is fine sand. The third aquifer has a buried depth of 90 ~ 120 m, and its lithology is fine sand mixed with a small amount of gravel[12].

Groundwater exploitation depth is generally less than 150m, agricultural exploitation depth is 50 ~ 60m, and residential drinking well depth is 90 ~ 150m. The first and second confined aquifer water is mainly exploited. Because there is a thick clay layer between the second and third confined aquifer, this simulation study takes phreatic aquifer, the first and second confined aquifer as the research object. The groundwater model generalizes the above hydrogeological structure into five layers from top to bottom: phreatic aquifer, weak permeable layer, first confined aquifer, weak permeable layer and second confined aquifer. The modeling range is centered, and the model area is 349km2. According to the lithologic conditions revealed by drilling holes, the simulation depth of the model is 90m[13]. The main recharge sources of groundwater in the study area include atmospheric precipitation infiltration, lateral inflow, wetland river and lake infiltration and agricultural irrigation reinjection The main drainage methods include artificial exploitation and lateral outflow.

Combined with groundwater flow field, it is determined that the north, west and northeast sides of the model are inflow boundaries, the southeast is outflow boundary, and the south and east sides are basically parallel to the groundwater flow direction, which is defined as zero flux boundary. The free water surface of phreatic aquifer is the upper boundary of the system, through which vertical water exchange occurs between phreatic water and the outside of the system, such as receiving river channel recharge, field infiltration recharge, atmospheric precipitation infiltration recharge, discharge, etc.

6.2. Model parameter setting

After sorting out and analyzing 55 drilling holes for pumping test, the permeability of aquifer in the study area is divided into four areas through model adjustment, combined with the zoning map of permeability coefficient and specific yield map.

6.3. Model Identification and Verification

It is a very important step in the whole simulation to identify and test the model by repeatedly modifying the parameters and adjusting the source and sink terms to achieve ideal fitting results. The identification and verification of the model mainly follow the following principles: ① The simulated groundwater flow field should be basically consistent with the actual groundwater flow field, that is, the simulated groundwater isoline should be similar in shape to the measured groundwater level isoline; ② From the perspective of equilibrium, the simulated equilibrium change of groundwater is basically consistent with the actual situation; ③ The identified hydrogeological parameters should conform to the actual hydrogeological conditions. The verification period is selected from June 2012 to June 2015, and the simulated flow field of aquifer at the end of simulation (June 2015) is compared with the actual flow field as shown in Figure 3. After the simulation model has been running for three years, the contour line of groundwater level calculated by the numerical model is basically consistent with the actual trend of groundwater flow field in the study area, The results show that the simulation model accords with the actual hydrogeological conditions and can be used for the prediction and evaluation of groundwater environmental impact.5.4 MT3DMS solute transport model

The model building MT3DMS is an enhanced version of MT3D, which was developed by professor Zheng chunmiao when he was employed by S.S.Pa-podopulos&Associates in the United States. MT3DMS can not only simulate the physical migration process (including convection, dispersion, adsorption, etc.) of various pollutants in groundwater at the same time, but also simulate the simple biochemical reaction of pollutants in the migration process with other software. Because it does not include groundwater flow simulation program, MT3DMS connects with Modflow through interface, reads groundwater flow field established and identified by Modflow, and simulates solute transport. In the three-dimensional unsteady groundwater flow system in the study area, the migration of ammonia nitrogen and chloride ion accords with the convection-dispersion principle, and the dispersion action accords with Fick's law. The concentration of ammonia nitrogen and chloride ion in groundwater is low, which accords with equilibrium isotherm adsorption, and the chemical transformation of nitrate nitrogen accords with first-order reaction kinetics.

7. ANALYSIS RESULTS

7.1. Groundwater Vulnerability

According to the administrative divisions and geomorphic units, the plain area of Xi 'an is divided into 32 sub-intervals, which are the basic units of groundwater vulnerability assessment. By collecting and sorting out the relevant data required by DＲASTIC groundwater vulnerability assessment model, the groundwater vulnerability index is obtained by assigning values according to the corresponding grades and substituting them into formula (1) for superposition calculation. According to the calculation results, the groundwater vulnerability in the study area is divided into five grades according to each unit, and the results are shown in Figure 2.

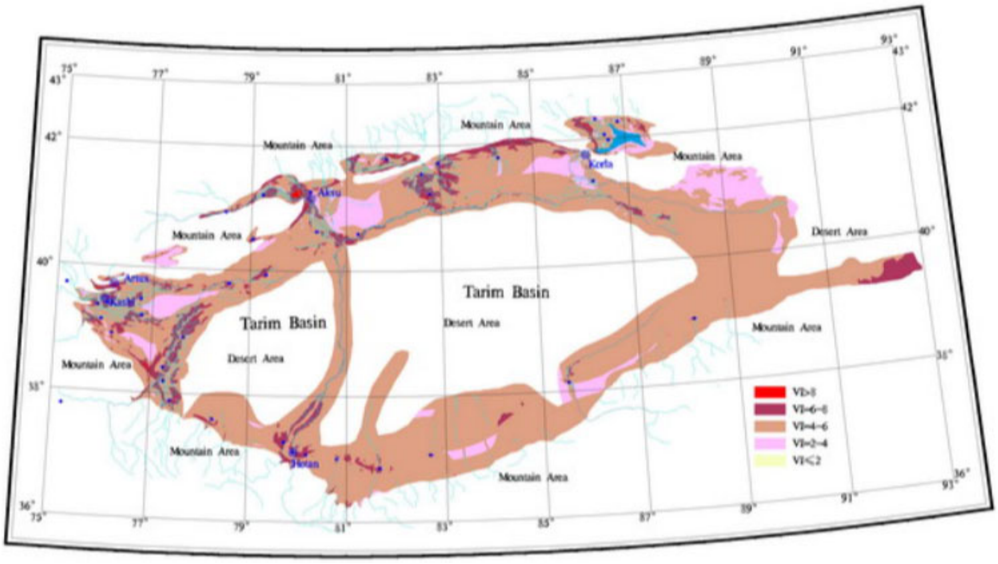

Figure 2. Distribution map of groundwater vulnerability in Xi 'an

The area of high groundwater vulnerability in Xi 'an plain area is 421.10km2, accounting for 9.0% of the total area of plain area. The area with high groundwater vulnerability is 1785.11km2, accounting for 38.3% of the total area of plain area. The area of moderately vulnerable groundwater is 963.26km2, accounting for 20.7% of the total area of plain area. The area with low groundwater vulnerability is 791.97km2, accounting for 17.0% of the total area of plain area. The low vulnerability area of groundwater is 696.12km2, accounting for 14.9% of the total area of plain area.

The areas with high groundwater vulnerability are mainly distributed in the floodplain and first-class terrace of Weihe River and its tributaries in the north of plain area. The groundwater in these areas is shallow, and the aquifer is mostly composed of gravel and sub-clay, with coarse particles and close hydraulic connection, which makes the aquifer highly permeable and vulnerable to pollution. Therefore, the vulnerability of groundwater is relatively high, while the areas with low vulnerability are mainly distributed in Bailu tableland, Shaoling tableland and Shenhe tableland in the southeast. The groundwater in these areas is deeply buried, the vadose zone is thick and the aquifer is mainly composed of loess, which has good natural protection performance and is not easy to be polluted, so the groundwater vulnerability is relatively low.

The overall trend of groundwater vulnerability decreases from floodplain, first terrace, second terrace, third terrace, alluvial fan and loess tableland in turn, and groundwater is less and less affected. The research results of groundwater vulnerability in Xi 'an show that groundwater vulnerability near Weihe River and its tributaries in Xi 'an is high, while that in loess tableland is low, which is similar to the evaluation results in this paper.

7.2. Load of Groundwater Pollution Source

In this study, gas stations, cultivated land, industrial parks, landfills, hazardous waste disposal sites and golf courses are selected as the investigation objects of pollution sources. By sorting out and analyzing relevant data, the comprehensive index of groundwater pollution load is obtained. The load zoning map of groundwater pollution source is obtained under GIS environment, as shown in Figure 3.

Figure 3. Example map of groundwater pollution in Xi 'an

The load situation of groundwater pollution sources in Xi 'an is generally good, and the load degree of pollution sources is mainly concentrated in the low and low range. The area with low load influence accounts for 43.73% of the total area of plain area, and the low one accounts for 54.90%, among which industrial and agricultural pollution are the main sources of groundwater pollution risk. The lower load of pollution sources in most areas in the central plain area is mainly due to the fact that this area belongs to the main urban area of Xi 'an, with high urbanization rate, less cultivated land and less affected by agricultural pollution. In recent years, Xi 'an municipal government has strengthened environmental supervision and moved key polluting enterprises in the main urban area to remote suburbs, so this area is also less affected by industrial pollution. Agricultural land is widely distributed in the southeast, northeast and west of the plain area, which is mainly affected by agricultural non-point source pollution. The load of pollution source is higher than that in the middle of the plain area, but the overall level is still in the low and low range.

7.3. Functional Value of Groundwater

The areas with strong groundwater abundance in the plain area of Xi 'an are mainly distributed in the floodplain and first-class terrace of Weihe River in the north of the plain area, which are obviously replenished by rivers and rich in groundwater resources; However, groundwater resources are scarce in the northeast of plain area. The overall trend of groundwater abundance decreases from floodplain, first terrace, second terrace, third terrace, alluvial fan and loess tableland. Geomorphic units and the distribution of river systems are the main reasons that affect the distribution difference of groundwater abundance in Xi 'an plain area. According to the analysis results of the investigation data of groundwater quality, the overall situation of shallow groundwater quality in plain area is general, and the poor areas are mainly distributed in the floodplain and the first-class terrace of the main rivers such as Weihe River, Fenghe River and Bahe River. The groundwater in these areas is highly vulnerable and prone to pollution. Under GIS environment, the analysis results of water abundance and groundwater quality are superimposed, and the comprehensive index of groundwater function value is obtained and graded according to Figure 4.

Among them, most areas in the eastern part of the Sixth Dstrict (weiyang district, Baqiao District, Yanta District, beilin district, Lianhu District, Xincheng District), zhouzhi county and Yiyi District have relatively good groundwater quality and water abundance, so their groundwater function value is the highest. The functional value of groundwater in the south of Chang 'an District, the south of Lantian County, the north of Lintong District, yanliang district and Gaoling District is the lowest. Generally speaking, the functional value of groundwater in the plain area of Xi 'an is high on the whole, and most areas are medium or above. The water abundance is an important factor affecting the functional value zoning of groundwater in the plain area of Xi 'an.

7.4. Groundwater pollution risk

Under GIS environment, the groundwater vulnerability, groundwater pollution source load and groundwater function value are calculated by superposition, and the results are shown in Figure 5.

It can be seen that the shallow groundwater pollution risk in Xi 'an plain area has the following characteristics: the high-risk areas of groundwater pollution are mainly distributed along the Weihe River in the north of zhouzhi county and the Bahe River in the north of Lantian County, with a distribution area of about 8.2km2, accounting for 0.2% of the total area of the study area. These areas are located along rivers, which are obviously replenished by rivers, have high water abundance, and are buried in shallow groundwater. The aquifer is thick and mostly composed of gravel and clayey silt, and has strong water permeability. Therefore, the groundwater vulnerability and groundwater function value are at a high level, which is prone to pollution, and the expected damage after pollution is relatively large. Meanwhile, according to the investigation of pollution sources, these areas are affected by industrial activities, and the load of groundwater pollution sources is relatively high. The medium risk areas of groundwater pollution are mainly distributed along Weihe River in zhouzhi county, Chanhe River in Chang 'an District, Laohe River in Renyi District and Chanhe River in Lantian County, with a distribution area of about 1336.78km2, accounting for 28.8% of the total area of the study area.

These areas belong to floodplains or low-level terraces, and the groundwater is buried deeplyShallow, the aquifer is thick and mostly composed of gravel and sub-clay, with coarse particles, strong water-rich and easy to be polluted, so the groundwater vulnerability and groundwater function value are relatively high, but the land use types in these areas are mostly cultivated land and grassland, with few pollution sources and low load of groundwater pollution sources. The low-risk areas of groundwater pollution are mainly distributed in the south of zhouzhi county, the south of Renyi District, and most of the six districts (weiyang district, Baqiao District, Yanta District, beilin district, Lianhu District, Xincheng District), yanliang district and Chang 'an District, with an area of 3313.02km2, accounting for 71.1% of the study area. Most of these areas belong to the second and third terraces or loess tableland. The groundwater is buried deeply, the vadose zone is thick, the natural protection performance is good, there are few pollution sources, the groundwater is less likely to be polluted, or the aquifer is poor in water quality, the groundwater function value is low, and the expected damage caused by pollution is relatively small.

8. PREVENTIVE MEASURES

8.1. Strictly control the decline of confined water level

To control the continuous development of land subsidence and ground fissures, the key is to control the decline of confined water level, so that the land subsidence tends to be stable, the sharp deformation of ground fissures can be alleviated, and the harm of land subsidence and ground fissures to urban construction will also be reduced.

8.2. Vigorously promote water conservation

There is no urban water supply network in some areas, and self-prepared wells are still used for water supply. Only by vigorously advocating water conservation, minimizing the exploitation of confined water, and keeping the land subsidence to a minimum, the momentum of strong active deformation of ground fissures will be further weakened until it tends to be stable.

8.3. Scientific planning and rational utilization of water resources

With the economic development of Xi 'an, various development zones are being built in the surrounding areas, but the urban water supply network in these areas has not yet arrived, so sinking wells and taking water has become an inevitable way. Therefore, feasible countermeasures should be worked out in the planning of water supply in the newly developed areas. If urban centralized water supply is needed, the pipe network will be laid in place during capital construction. If groundwater is taken, the water source should be uniformly arranged according to the whole area. Artificial recharge of groundwater is one of the most effective methods to control the continuous decline of water level, and there are many successful experiences in this field at home and abroad. Therefore, it should be considered to use Black River water for artificial recharge in winter and spring when water consumption is low.

9. CONCLUSION

1) The groundwater vulnerability in Xi 'an plain area is mainly affected by topography, and the overall trend decreases from floodplain, first terrace, second terrace, third terrace, alluvial fan and loess tableland in turn. The overall level of pollution source load is weak, and the central plain area is weaker than other areas; The areas with high water function value are mainly distributed in the west and east of plain area. 2) The groundwater pollution risk in Xi 'an plain area was evaluated by establishing the groundwater pollution risk evaluation model and evaluation index system, and the areas of high, medium and low risk areas of groundwater pollution in plain area were 8.2, 1336.78 and 3313.02km2 respectively. 3) The groundwater pollution risk in Xi 'an plain area is generally at a low level, while the pollution risk is relatively high along the Weihe River in the west and northeast of the plain area, and along the Bahe River and Chanhe River in the southeast. The groundwater is buried in shallow depth and the grain structure of the stratum is relatively simple and coarse, which makes the groundwater vulnerable to pollution. Moreover, the strong load of pollution sources affected by industrial and agricultural activities in some areas is the main reason for the high groundwater pollution risk.

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