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EVALUATION OF SHALLOW GROUNDWATER QUALITY IN ZHENGZHOU AREA (CHINA) USING WATER QUALITY INDEX MODEL

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ABSTRACT: Water shortage and pollution are serious problems which are limiting sustainable development of the society and economy in Zhengzhou area. Due to its importance the Water Quality Index (WQI) model was used to classify groundwater in Zhengzhou according to its most beneficial use. Sixty-three groundwater samples from shallow wells were chemically analyzed to calculate WQI values. The results show that high quality groundwater for irrigation use (WQI>75%) exist in thirty three wells, fifty two wells in the area have high quality and are suitable for livestock drinking, and thirty eight wells can be used safely for domestic purposes. The spatial distribution maps for different groundwater classes show that better groundwater quality can be found in porous Quaternary aquifers in the alluvial plain, alluvial flat and flood plain of Yellow River. Results also show that the model can be conveniently used to evaluate the water quality and classify groundwater in Zhengzhou area.

KEYWORDS: Groundwater quality, Water Quality Index (WQI), Groundwater classification, Zhengzhou (China).

INTRODUCTION

Groundwater has become an essential resource over the past few decades due to its condensed usage for drinking, irrigation and industrial purposes [1]. More attention has not been given to the groundwater as compared to surface water in Zhengzhou area where the economy depends on the groundwater utilization. This study focuses on the quality of drawn water from the wells and introduces beneficial methods for determining groundwater use. The Water Quality Index (WQI) is developed to show the summation effect, concentration and importance of each variable related to the quality of groundwater for three main beneficial uses (irrigation, livestock drinking, and domestic use)[2] . The WQI values were calculated for sixty three water samples collected from shallow wells (unconfined aquifer less than 60 m deep) in Zhengzhou area. The groundwater was classified into different classes for the three main uses cited in this study.

STUDY AREA

Zhengzhou is the capital city of Henan province. It is located in the lower reaches of the Yellow River Basin (Figure 1). It covers all of Zhengzhou municipality, including Zhengzhou city and its six constituent counties. The total area of Zhengzhou is 7,446.2 Km^2, of which 13.6 % (1,010.3 Km^2) is an urban area.

As a whole, the elevation of the study area decreases from southwest to northeast (Figure 2). The surface water has been polluted badly by direct discharge of industrial and domestic wastewater. Therefore, groundwater is the most important source for urban and rural areas. The Archaeozoic to Neogene rocks are outcropped in the south and west mountain areas (approx. 50% of the study area) and Quaternary unconsolidated materials cover the north and eastern parts of the study area [3].

METHODOLOGY

Estimation of Water Quality Index

Bahargava (1983, 1984) introduced the WQI method. This method was adopted because of the simplicity involved in handling small to large data for various beneficial uses. The simplified model for WQI is given by:

$$WQI = [\prod_{i=1}^{N} Fi(Pi)]^{(1/N)} \times 100 \quad (1)$$

Where N is the number of variables considered more relevant to an individual use. Fi(pi) is the sensitivity function of the ith variable which includes the effect of weighting of the ith variable for an individual use. These values were taken from figures drawn according to limited values of the variables of the water intended for different uses[4,5] .

Various limits are used for the allowable concentrations chosen from different references, which are considered suitable for the nature of Zhengzhou area. For drinking water, WHO limits are used for the concentration of Ca^{2+}, $SO_4^{2-}$and H^+ [6]. TDS was taken from identical limits of American Health Organization [7]. Total Hardness from Al Ani (1988) [8]. Other sensitivity factors were taken from Al Bassam et al. 2007[9]. The sensitivity function values for the different concentrations of the quality variables are shown in figure 3.

The (1) value in the sensitivity function represents the best quality (low concentration which is less than or equal to the allowed limit), while (0.01) value represents the bad quality. Table (1) represents the variables, which have the largest effect in the determination of the quality related to each use.

Spatial and Attribute Database

Water samples were taken from sixty-three wells (figure 4). The depth of all the wells is less than 60 meters. The groundwater samples were analyzed for various hydro-chemical parameters adopting standard protocols [10] . Based on figure 3, water quality index for various beneficial uses of Zhengzhou was derived from equation (1). The obtained water quality data forms the attribute database for the present study.

In order to capture the spatial variation of groundwater quality in Zhengzhou area, spatial analyses with GIS were conducted employing ARCGIS software. The geographic coordinates of the wells were obtained from the hard copy maps and linked to the attribute database. The water quality data (attribute) is also linked to the sampling location (spatial) in ARCGIS and maps showing spatial distribution are constructed to easily identify the variation in water quality and in concentrations of each parameter in the groundwater at various locations of the study area using GIS software.

RESULTS AND DISCUSSION

pH of water samples in the study area ranges between (7.21-8.54). The highest concentration of Total Dissolved Solids is 822 mg/l at well D4. High TDS in this well is attributed to the intrusion of saltwater from Permian bed rock underlying the aquifer in Dengfeng County. Other high values in wells D3, D4, D7, and M06 are due to the presence of gypsum in coal layers in carboniferous and Permian rocks.

The Total Hardness of groundwater ranges between 17.31 to 522. High concentrations are found in the mountain areas in Xinmi County. These values are attributed to the presence of limestone rocks of Cambrian, Ordovician, and Carboniferous near the surface and also due to the common contamination caused by dense residence (wells M03, M04, M05, M06, D4, D01, G01).

High concentration of Nitrate-Nitrogen indicates sources of past or present activities [11] . These anomalies could be owed to the domestic and industrial waste discharge through the rivers flowing from the mountain area and to the agriculture practices (wells B02, B5, B8, B9, D4, D7, G5, X4).

WQI values range from (28.4%-94.8%) for irrigation use, (39.1%-99.8%) for livestock drinking, and (24.8%-99.3%) for domestic use.

Groundwater Classification

In order to classify the groundwater into different classes for the three main uses cited in this study, a new water quality index limits have been suggested (Table 2). Using these limits, 52.4% of WQI values (calculated for irrigation use) lie within classes II and III, 82.5% of WQI values (calculated for livestock drinking) lie within classes I, II, and III,. 60.3% of WQI values (calculated for domestic use) lie within classes I, II, and III, and.

Figure 5, 6 and 7 shows the spatial distribution of different groundwater classes calculated for irrigation, livestock drinking, and domestic use respectively.

CONCLUSIONS

Based on WQI values for each type of groundwater use in Zhengzhou area, high quality groundwater for irrigation use (WQI > 75%) exist in thirty three wells, fifty two wells in this area have high quality and are suitable for livestock drinking, and thirty eight wells can be used safely for domestic purposes. The spatial distribution maps of different groundwater classes show that better groundwater quality can be found in the porous Quaternary aquifers in the alluvial plain, alluvial flat and in the flood plain of Yellow River. WQI model can be conveniently used to evaluate the water quality and classify groundwater according to its nature and intended use.

REFERENCES

1. Asadi, S. S., Vuppala P., and Reddy, M. A. "Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V)", India. Int. J. Environ. Res. Public Health, Vol.4, No.1, 2007. pp: 45-52.
2. Lumb, A., Halliwell, D. & Sharma, T., "Application of CCME water quality index to monitor water quality: A case study of the Mackenzie River Basin", Canada. Journal of Environmental Monitoring and Assessment, Vol.113, 2006. pp: 411-429.
3. Sun R.L., Liu Y.F., Qian Y.P. & Villholth K.G. V., " Agricultural Groundwater Issues in North China: A Case Study of Zhengzhou Municipal Area". In Mukherji, A., Villholth, K.G., Sharma, B. R. & Wang, J. X. (eds)," Groundwater Governance in the Indo-Gangetic and Yellow River Basins": Realities and Challenges. Taylor and Francis, 2007.
4. Bhargava, D. S., Saxena, B. S., & Dewakar, " A study of geopollutants in the Godavary river basin in India". Asian Environment, 1998. pp: 36–59 (IOS press).
5. Dwivedi, S., Tiwari, I. C., & Bhargava, D. S. "Water quality of the river Ganga at Varanasi". Institute of Engineers, Kolkota, Vol. 78, 1997. pp: 1–4.
6. WHO, World Health Organization, "Guidelines for drinking-water quality". Vol 1, 4th ed., Recommendations. Geneva, Switzerland: World Health Organization. 2011. pp: 155–200.
7. United State Public Health Services, " Drinking water standards". Washington: U S Dept of health education, 1962.

8. Al Ani, M. Y. "Water quality index for Tigris river classification". Journal of Biological Science Research, Vol.19, 1988. pp: 715-733.
9. Al Bassam, Jin Menggui1 & Lu Xiaohui, " Groundwater Classification in The Southern Region of NW Iraq Plain Using WQI Model". Proceedings of the 12th International Symposium on Water-Rock Interaction WRI-12, Kunming, China, 31 July-5 August 2007. pp: 1001-1004.
10. APHA, AWWA, WPCF, "Standard Methods for the Examination of Water and Wastewater". 20th edition, American Public Health Association, Washington, DC, New York, USA.1998.
11. Todd, D. K. " Ground Water Hydrology". John Wiley and Sons: New York, 1980.

Table 1. Variables used to determine the quality of groundwater for each beneficial use

Variables	Use
HCO_3^-, Cl^-, SAR, pH, TDS	Irrigation
Mg^{2+}, NO_3^-N, Cl^-, TDS, pH	Livestock drinking
Total Hardness, Na^+, Mg^{2+}, SO_4^{2-}, NO_3^-, Cl^-, pH	Domestic

* SAR= Sodium Adsorption Ratio

Table 2. Suggested limits for WQI values used in the classification of groundwater in Zhengzhou area

Class	WQI	Irrigation Use		Livestock Use		Domestic Use	
		N	P%	N	P%	N	P%
I (Excellent)	95-100	0	0	28	44.4	12	19.0
II (V. Good)	85-94.9	6	9.5	15	23.8	15	23.8
III (Good)	75-84.9	27	42.9	9	14.3	11	17.5
IV (Fair)	60-74.9	18	28.6	3	4.8	14	22.2
V (Marginal)	35-59.9	7	11.1	8	12.7	9	14.3
VI (Poor)	<35	5	7.9	0	0	2	3.2

* N= Number of wells; P%= Percentage of wells

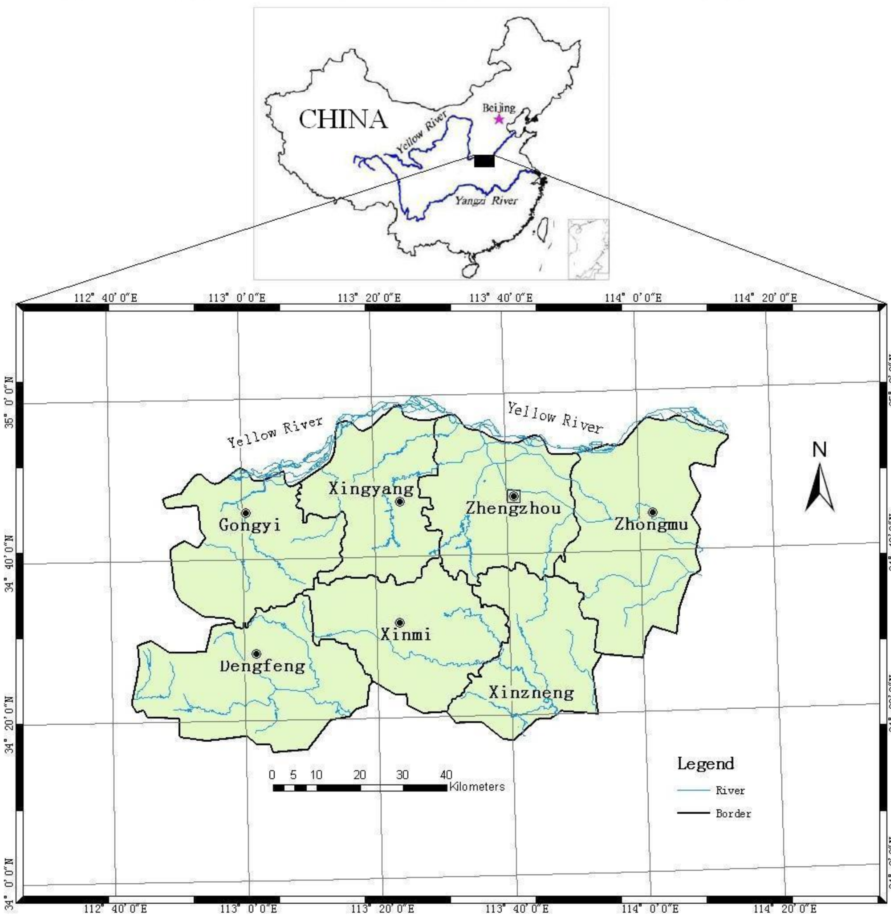

Figure 1. Location map of Zhengzhou city area

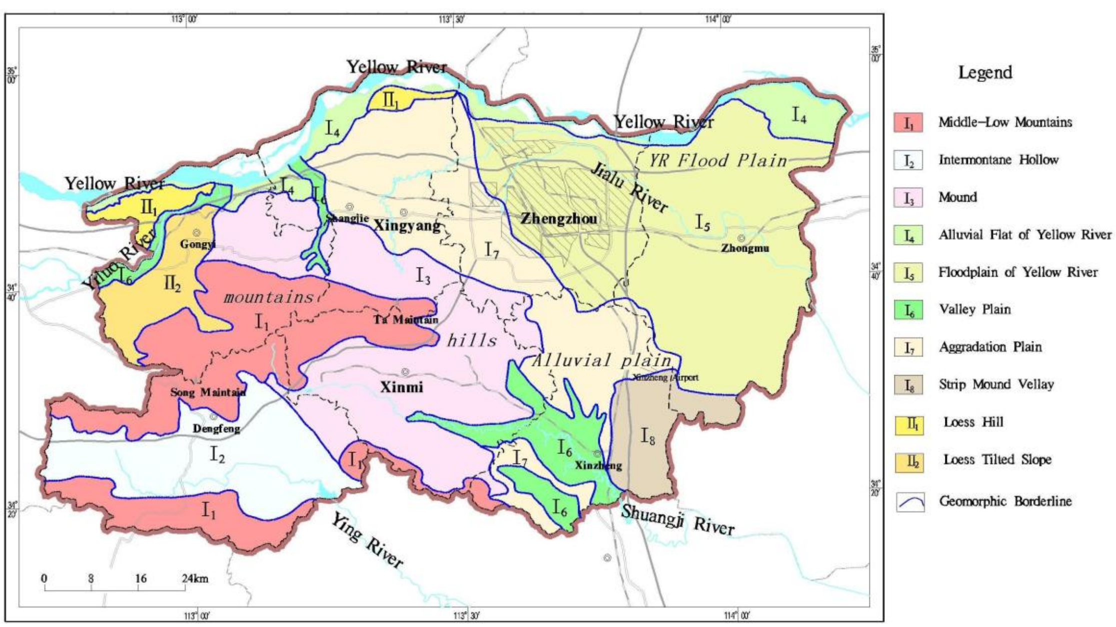

Figure 2. Geomorphologic map of Zhengzhou

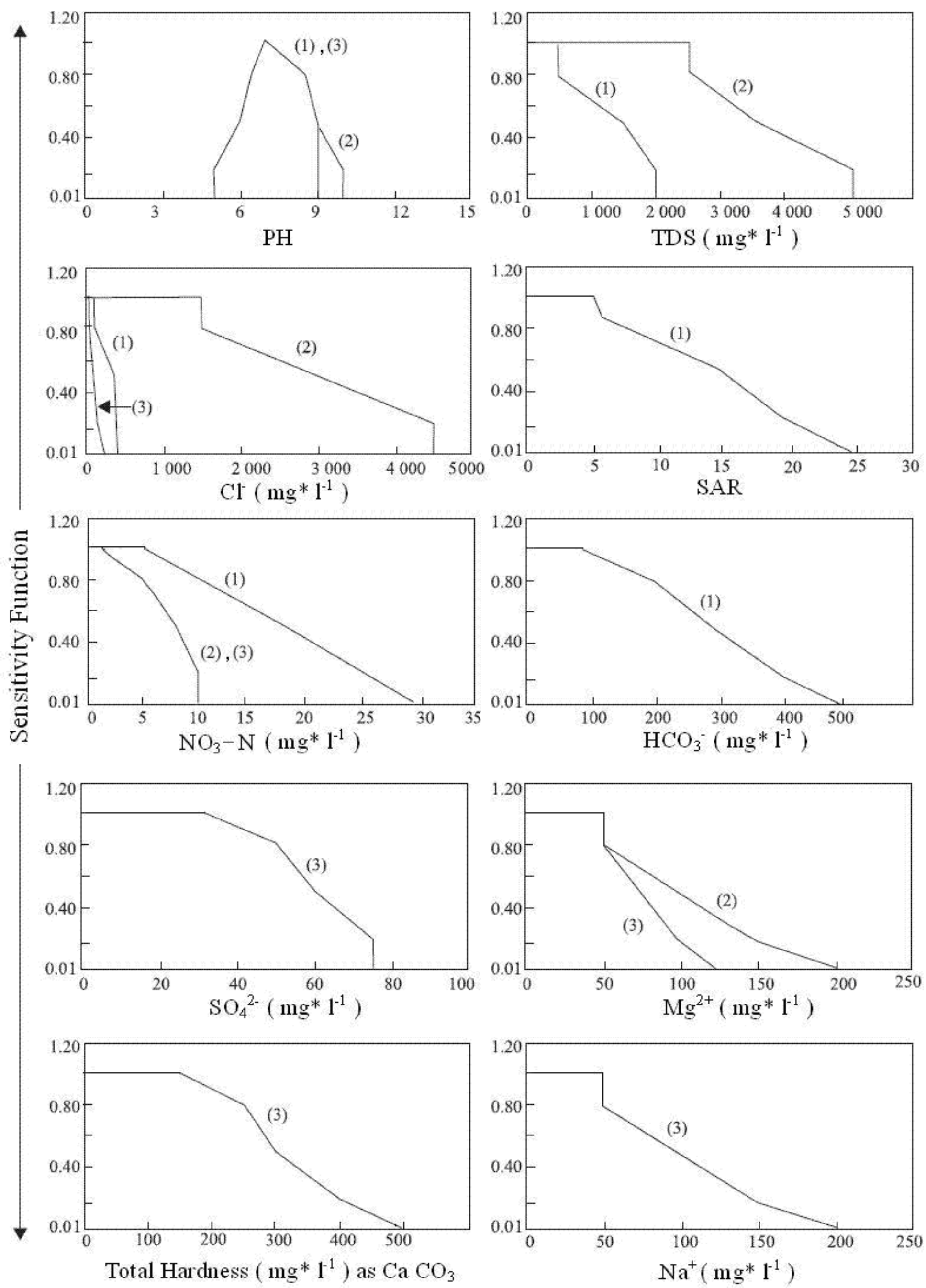

Figure 3. Relation between values of different variables and sensitivity function. (1) Irrigation water; (2) Livestock drinking water; (3) Domestic use water

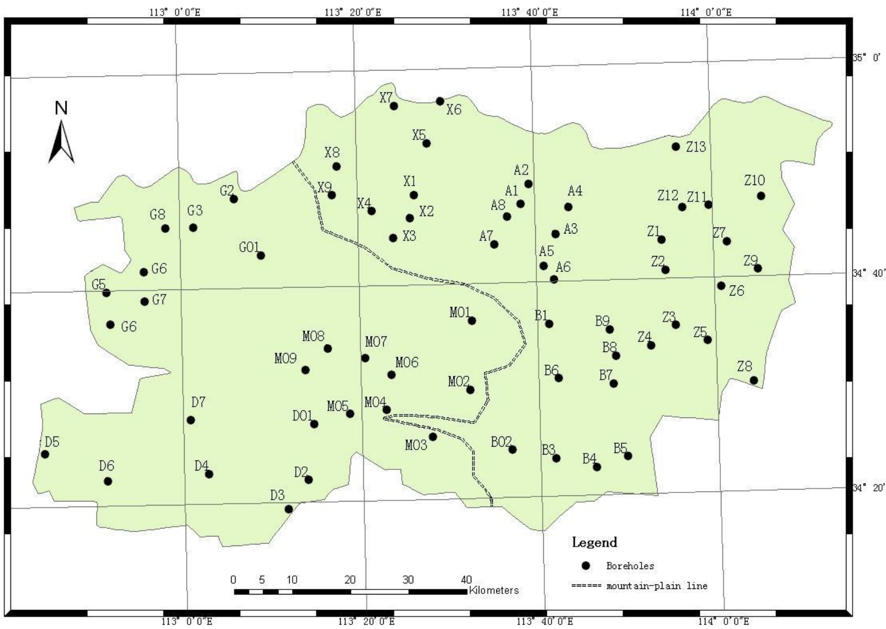

Figure 4. Location map of shallow wells in the study area

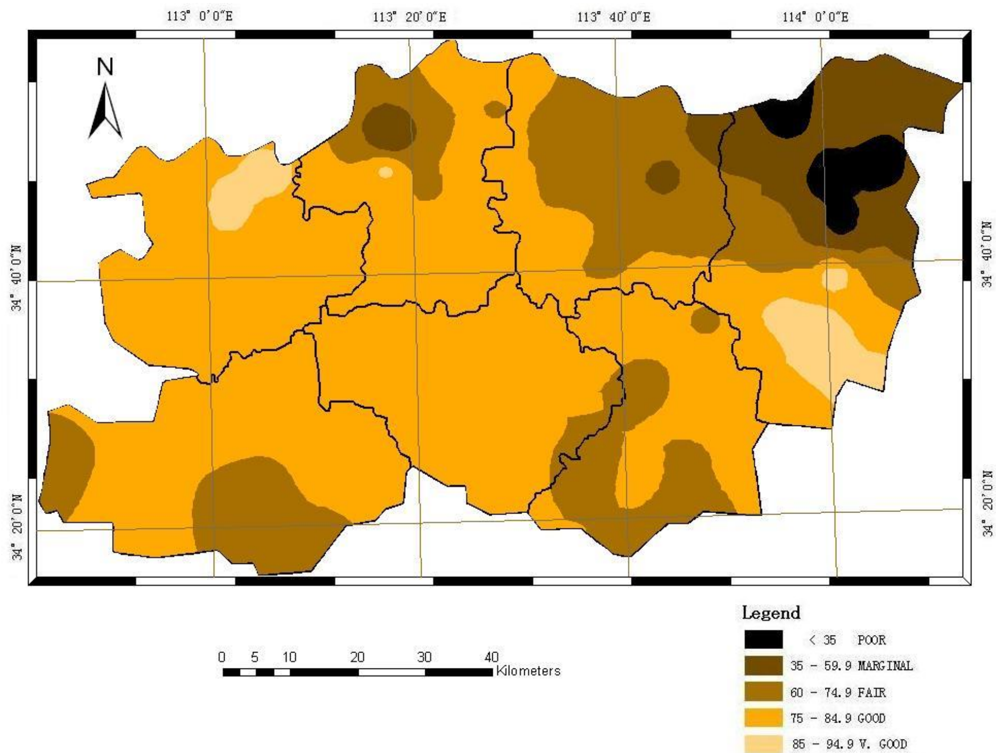

Figure 5. Spatial distribution map showing different groundwater quality zones (classified for irrigation use) in Zhengzhou area

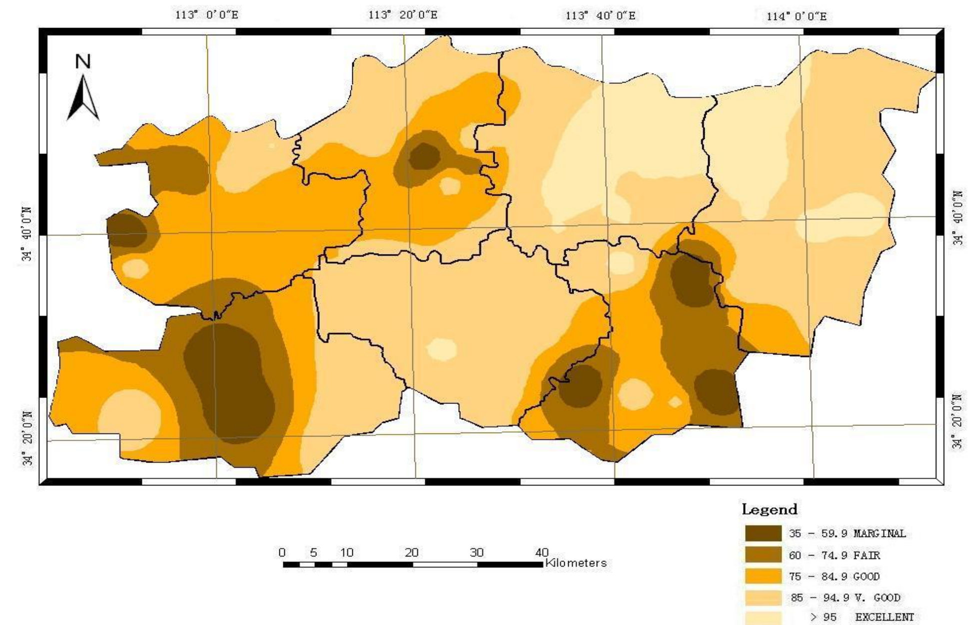

Figure 6. Spatial distribution map showing different groundwater quality zones (classified for livestock drinking use) in Zhengzhou area

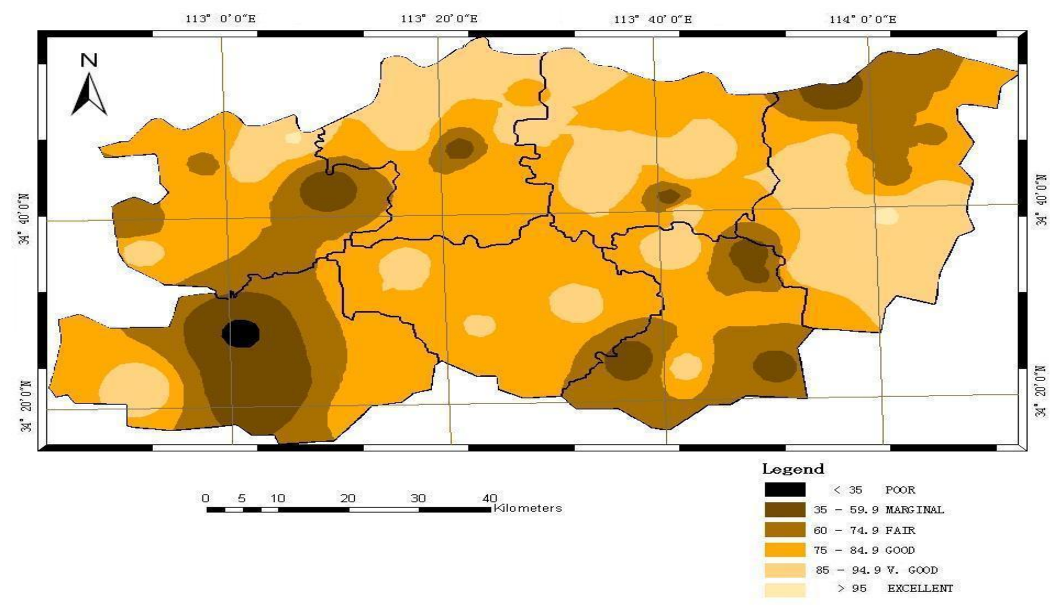

Figure 7. Spatial distribution map showing different groundwater quality zones (classified for domestic use) in Zhenzhou area

تقييم نوعية المياه الجوفية الضحلة في منطقة جينغ جو (الصين) باستخدام موديل معامل نوعية المياه (WQI)

الخلاصة

النقص والتلوث في المياه هي من المشاكل الجدية التي تحدد استمرارية التطورالاجتماعي والاقتصادي في منطقة جينغ جو في الصين. في هذه الدراسة تم استعمال معامل نوعية المياه (Water Quality Index (WQI في تصنيف المياه الجوفية في منطقة جينغ جو وفقا لاستخداماتها الرئيسية النافعة. اخذت النماذج من ثلاثة وستون بئرا ضحلا في منطقة الدراسة وتم تحليلها كيميائيا لغرض حساب قيم WQI لكل استخدام من الاستخدامات الرئيسية. اظهرت النتائج ان النوعية العالية للمياه الجوفية الصالحة لاستخدام الري تتواجد في ثلاثة وثلاثون بئر, اثنان وخمسون بئرا تحتوي على نوعية عالية للمياه الجوفية الصالحة لشرب الحيوانات وثمانية وثلاثون بئرا ممكن ان تستخدم بامان في الاغراض المنزلية. اظهرت خرائط التوزيع المكاني للاصناف المختلفة للمياه الجوفية ان المياه الجوفية ذات النوعية الجيده ممكن ان تتواجد في خزانات المياه الجوفية التي تتكون من رسوبيات العصرالرباعي العائده للسهل الرسوبي للنهر الاصفر (Yellow River). اظهرت النتائج ايضا ان هذا الموديل ممكن استخدامه بشكل مناسب في تقييم نوعية المياه الجوفية وتصنيفها في منطقة جينغ جو.

الكلمات الدالة: نوعية المياه الجوفية, دليل نوعية المياه, تصنيف المياه الجوفية, جينغ جو (الصين).