

Assessing the suitability of groundwater for human consumption: Yinbin City, China, gas station case study

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Abstract

People all over the world inhabit contaminated, areas without being aware of them or the grave health risks they pose. The first step in managing these areas is to identify and delineate the contamination using effective research and monitoring techniques. This paper is geared toward reviewing the chemical characters, and assessment of the quality of exploited groundwater of a gas station in Yinbin City, China. A comprehensive assessment method was used to determine suitability for drinking. The outcomes displayed that most samples of groundwater were contaminated, where the concentration of most physiochemical parameters was above permissible standard levels set by local and international standards for potable water. The Piper diagram showed a difference in the hydrogeochemical characteristics of groundwater in the studied region. Based on the results of the proposed evaluation methods, the F values for all analyzed samples ranged from 4.40 to 7.79, varying from poor quality to very poor quality. Based on a thorough evaluation process, this result shows that all groundwater samples are unfit for public drinking, and do not meet drinking water standards. It follows that it is clear that the gas station poses a risk to the environment at this time.

Key words-Groundwater, Yinbin City, Gas station, Piper diagram, Drinking water

I. INTRODUCTION

As an indispensable source of life, groundwater is essential for socio-economic development for most of the population of the world, but its accessibility depends on quality and quantity [1][2]. In latest years, the quality of groundwater has been suffering from many sources of pollutants, due to the rapid growth of population, agricultural land development, and urbanization and industrialization [3][4]. Among all pollution sources, gas stations are one of the major contamination sources of groundwater in many areas of the world recently [5]. According to data, China had a high incidence rate of gas station leak contamination; these incidents happened in Beijing, Guangzhou, Xi'an, Nanjing, Shenyang, Chengdu, and other cities [6]. As a result, concerns about groundwater quality and possible solutions for management need to receive more attention globally. The problem of contamination of groundwater from gas station leakage so far has not been attached to adequate importance in China. Due to the increasing number of large stations that are always located in the city center, it is inconvenient to ignore their risks, because the leakage related to gas stations is entirely feasible to be the biggest source for underground natural contamination [6]. When groundwater is contaminated, it can have a direct or indirect negative impact on ecosystem health and human health [3]. In order to make informed decisions about future water resource issues resulting from leakage contamination from gas stations, it is imperative that groundwater quality be evaluated in terms of its suitability for human consumption [3][7]. Groundwater quality is usually determined by its properties (physical, chemical and biological) and any alterations agents that may have occurred in soils due to anthropogenic and microbial activities [7]. World Health Organization (WHO) has

determined the basic guidelines of drinking water. Therefore, measuring groundwater quality parameters is very important for comparing water quality standards declared by each country to ensure public health [8]. Recently, several researchers crossways the world used methods for reflecting groundwater quality evaluation. The normally applied approaches are Water Quality Index, Fuzzy Evaluation Technique, Multivariate Statistical Method, Neural Network, The Gray Clustering Method and others [7]. These methods have their characteristics based on the objectives of the study. However, the comprehensive evaluation method (CEM) is adopted for evaluating groundwater quality for drinking use in this study. Because its mathematics with quick steps is easy and clean to calculate [3]. Likewise, it does not handiest classify water great but also offers the ranks and the results are extra objective and reasonable [9]. This paper at can be useful for home-grown decision-makers in local groundwater control and protection.

II. MATERIALS AND METHODS

A. Study area

The study area is located in Yibin City, China Figure (1) between latitude $28^{\circ}22'20'' \sim 28^{\circ}56'45''N$ and $104^{\circ}57'40'' \sim 105^{\circ}14'33''E$ with location covers Approximately 54.7 km. The climate of the area is characterized by a humid climate in the central and subtropical Sichuan Basin with an average annual precipitation of 1111 mm. About 68% of the precipitation falls in June and September. The annual temperature average is $18.1^{\circ}C$. The annual average relative humidity is 83%, and the annual average sunshine is 1199.3 h. The northerly wind is dominated in this area, with a maximum and an average wind speed of 1.2 and 15.7 m/s respectively. The study region is a

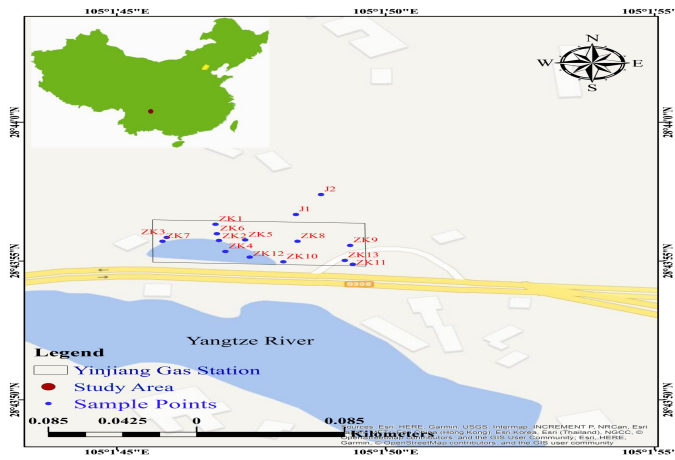


Fig. 1: Location map of the study area

part of Yangtze River on the south bank and the Minjiang River on the west bank. There are various rivers belonging to the Yangtze River system which are mainly includes Changning River, Mianxi River Hongqiao River, Paradise River, and Nanjing River. The main compensating groundwater sources are vertical infiltration of rainwater, runoff from dams, side runoff during floods during the rainy season and return of irrigation water. In the study area, the aquifer is described from the part of the top to the bottom are mainly as:

- 1) Quaternary Holocene alluvial. This layer is brown, slightly wet, plastically shaped with clay and it contains mainly of clay powder and some stones and slag.
- 2) Quaternary Holocene residual slope, mainly yellowish-brown clay, which is hard plastic and relatively wet.
- 3) The Jurassic Upper Shaximiao Formation which represents as the underlying bedrock in the study area and it basically consists of brown red mudstone, brown yellow calcareous sandstone and common feldspar quartz sandstone at the bottom. Consider this layer to be impermeable. The groundwater table around the gas station is approximately 1.5–6.59 meters deep, with the direction of groundwater flow being from north-western to south-eastern, according to data collection and field surveys combined with the environmental and hydrogeological characteristics of the study region.

B. Overview of gas stations

A secondary gas station is the one in Yi Jiang. With a total area of $3,900 \text{ m}^2$, the main features include a gas station, a tank area, and a shed. On the north side of the national highway is where you can find the shed. It is an 800 m^2 rectangular awning with three rows and six columns. When the gas station was built on the property in 1979, only gasoline was marketed. The old gasoline tanks were removed from the site during the expansion, which gave rise to concerns about leaks. Furthermore, interviews with former employees revealed that on another occasion some diesel tanks were removed, the input and output were noted after a deficit of about 2,000 L of diesel in the fuel records According to investigations and management reports, the fuel leak was confirmed.

C. Sampling and analysis

In order to accurately identify the groundwater contamination and its spread at the gas station, a thorough survey, well drilling, sampling, and testing were used in this paper's study and analysis. The groundwater samples were taken from 15 wells, which are represented by 13 observation/monitoring wells for groundwater pollution and 2 water supply wells for background value Figure (1). In situ instantly, pH and TDS parameters were measured. The groundwater samples were kept in plastic bottles at a temperature under 4°C and was kept in ice coolant after filtered by a $0.45 \mu\text{m}$ membrane. Groundwater samples were transported to the laboratory of Environmental Engineering Center of Sichuan Geological Engineering Investigation, and analyzed for several parameters, including PH, total dissolved solid (TDS), total hardness (TH), major ions (K^+ , Na^+ , Ca^{2+} , Mg^{2+} , Cl^- , SO_4^{2-} and HCO_3^-), nitrogen (NH_4^+ , COD_{Mn} , NO_2^- and NO_3^-), manganese (Mn), aromatics compounds such as (benzene, Toluene, Ethylbenzene and Xylene, which are known together as the BTEX compounds and organic matters like naphthalene, dichloromethane and total petroleum hydrocarbon (TPH). The organic matters of ethylbenzene, naphthalene, dichloromethane and O-xylene were not detected (ND) in any groundwater samples. Detection methods for each parameter are summarized in Table (I). All the water quality parameters were expressed in (mg/L), except pH is dimensionless. Water samples were analyzed according to the methods outlined by the American Public Health Association Publication [10]. It should be renowned that all these samples were randomly selected within and outside the vicinity of the depot, but at different distances from each other for the purpose of this study. The description of the locations of the groundwater samples and water level are illustrated in Table (II).

TABLE I: Detection methods for each parameter

Monitoring factors	Detection method
pH	Portable pH meter
TDS	Portable TDS meter.
TH	EDTA-2Na titration
HCO_3^-	titration
SO_4^{2-}	Ion chromatography (IC)
Cl^-	
Na^+	
K^+	Absorption spectrophotometry
Ca^{2+}	
Mg^{2+}	
COD_{Mn}	Spectrophotometry
NH_4^+	Nashi reagent spectrophotometry
NO_3^-	ion chromatography (IC)
Mn	
BTEX	Gas-chromatography (Agilent 6890N)
Naphthalene	gas chromatographs (GCs)
Dichloromethane	Mass spectrometry (detection limit $0.3 \mu\text{g/liter}$)
Total petroleum hydrocarbon	Gas chromatography with mass spectrometric detection (EPA Methods 8270 and 625)

TABLE II: Description of the location of the selected groundwater samples and water level from the study area.

Sampling point	GPS coordinate		Drilling depth (m)	Ground level (m)	Groundwater level (m)	Water level (m)	Monitoring point type
	latitude	longitude					
ZK1	28°43'56.35"	105°1'46.87"	15	301.90	303	1.10	Pollution monitoring point
ZK2	28°43'55.74"	105°1'46.90"	15	298.47	303	4.53	
ZK3	28°43'55.85"	105°1'45.93"	15	300.13	302	1.87	
ZK4	28°43'55.34"	105°1'47.02"	15	297.49	302	4.51	
ZK5	28°43'55.76"	105°1'47.39"	15	298.22	303	4.78	
ZK6	28°43'55.98"	105°1'46.86"	15	299.16	303	3.84	
ZK7	28°43'55.71"	105°1'45.85"	15	300.05	302	1.95	
ZK8	28°43'55.71"	105°1'48.36"	15	297.45	303	5.55	
ZK9	28°43'55.56"	105°1'49.34"	15	297.41	304	6.59	
ZK10	28°43'54.97"	105°1'48.10"	15	297.08	301	3.92	
ZK11	28°43'54.88"	105°1'49.39"	15	296.52	302	5.48	
ZK12	28°43'55.14"	105°1'47.47"	10	297.33	302	4.67	
ZK13	28°43'55.02"	105°1'49.24"	11	296.88	303	6.12	
J1	28°43'56.67"	105°1'48.33"	30	299.76	304	4.24	Background value monitoring point
J2	28°43'57.39"	105°1'48.80"	40	296.76	306	9.24	

D. Approach to groundwater quality monitoring

1) : Single components of assessment the groundwater quality

This appraisal was chiefly based on the data collected and survey results of the water systems at 2018. Based on the standard (GB/T 14848-2017) of the groundwater quality listed in the classification indicators, Groundwater quality on this area may be classified into a few single parts. In this paper, the evaluation method was adopted in single components evaluation and comprehensive evaluation methods to evaluate groundwater quality. Eleven physicochemical parameters were selected as the basic criterion to assess groundwater quality in fifteen selected wells.

2) : Assessing groundwater quality according to comprehensive index method

According to China (GB/T 14848-2017) standard of groundwater quality, the comprehensive index method of groundwater quality by annotated scoring methods should be performed as follows:

- 1) Firstly, assess the individual component for determining the quality category.
- 2) Secondly, consistent with the Table (III) decide the individual component assessment rating F_i , and then according to equation (1) calculate the comprehensive evaluation score F [11]
- 3) Finally, it can classify groundwater quality level according to F value and Table (IV) [12]. As per standard, the comprehensive index method can be computed as follows [9]:

$$F = \sqrt{\frac{\overline{F^2} + F_{max}^2}{2}} \quad (1)$$

$$\overline{F^2} = \frac{1}{n} \sum_{i=1}^n F_i^2 \quad (2)$$

Where is the average in each single component rating value of F_i , F_{max} is the maximum value of the individual component evaluation score F_i and n is the index number. Based on the quality of groundwater in China and anthropoid health requirement in addition to the aim of water protection, the (GB/T 14848-2017) standard clasifies quality of groundwater

into 5 scores/grades I, II, III, IV, and V using a comprehensive water-quality index appiasal: grade I - excellent, grade II - good, grade III - moderate, grade IV - poor, and grade V - very poor. (Grades I and II) is excellent and good great of groundwater and is match for all purposes. (Grade III) is moderate-satisfactory water water, which is generally fitting for drinking, industrial production and irrigation. (Grade IV) is poor-quality water, which is appropriate only for irrigation and industrial production and can be employed for drinking after suitable treatment. (Grade V) is very poor-quality water that can't be ulized for any purpose [13].

TABLE III: Classification of single component

categories of water quality	I	II	III	IV	V
Fi value	0	1	3	6	10

TABLE IV: rating criteria of groundwater quality

Grade	Classification/applicable uses	F
I	Excellent suitable for drinking water	< 0.80
II	Good suitable for drinking water	0.80~< 2.50
III	Moderate suitable for drinking water	2.50~<4.25
IV	Poor suitable for drinking water	4.25~<7.20
V	Unsuitable for drinking water	> 7.20

III. RESULTS AND DISCUSSION

A. Statistical Analysis

In order to find out whether the groundwater samples are appropriate for drinking, they were statistically analyzed of some parameters was performed to describe the overall physio-chemical traits with appreciate to prescribed limits of standards for groundwater first-rate of China (GB/T 14848-2017). The Table (V) reveals the details of descriptive statistics of the quality of groundwater parameters measured in the region area. For the parameters of Na^+ , Mg^{2+} , Ca^{2+} , HCO_3^- and TPH are not included in (GB/T 14848-2017) standard for groundwater quality, therefore, Guidelines for Drinking-water Quality by (WHO 2011) and Chinese national standard (GB 5749 - 2006) are used instead. As per (GB/T 14848-2017) standard, the permissible limit of pH concentration varies from 6.5 to 8.5. The measured pH values in the present study between 6.86 to 7.68, with the mean of 7.37. For all groundwater samples

the values of pH fall under the permissible limit of the above standard. The TH and TDS values ranged from 90 to 465 mg/L and from 255 to 615 mg/L with an average 370.80 and 492.45 respectively. The allowable limit of TH and TDS are 450 and 1000 mg/L (GB/T 14848-2017). In this study the TH and TDS values of the all-groundwater samples are found lower the permissible limit of (GB/T 14848-2017) standard except sample ZK6 of TH exceeded the limit of (GB/T 14848-2017) standard. This increase is probably due to contamination from oil depot leakage and fertilizer application in the study area. In the study area, groundwater is slightly acidic to mildly alkaline based on pH value, and classified as very hard and freshwater type of (TH and TDS) concentrations respectively according to [14][15]. The mean concentrations of Na^+ , K^+ , Ca^{2+} , Mg^{2+} and HCO_3^- are 2.925, 106.21, 16.525, 24.71 and 303.56 mg/L respectively. All locations measured Na^+ , K^+ and Mg^{2+} , and HCO_3^- levels are found within the limit of 200, 12, 75 and 500 mg/L recommended by (WHO 2011) for drinking water, except sample ZK7 of HCO_3^- exceed the acceptable limit of the standard. Regarding the Ca^{2+} concentration is found that all groundwater samples above the permissible limit of WHO 2011 (75 mg/L), except sample ZK13 fall under the permissible limit. The higher value of HCO_3^- in the study area have an almost similar trend with the Ca^{2+} concentration, therefore, the HCO_3^- in the ZK7 could have resulted from the oxidation of organic matter and the dissolution of carbonate matrix minerals. The SO_4^{2-} and Cl^- concentrations ranged from 1.24 to 42.00 mg/L and from 1.16 to 25.67 mg/L, respectively. whereas, COD_{Mn} and NH_4^+ values ranged from 0.89 to 27.6 mg/L and from 0.441 to 1.64 mg/L respectively. The concentrations of (SO_4^{2-} , Cl^- and COD_{Mn}) are found below the permissible limit of most groundwater samples, except sample ZK6 for both SO_4^{2-} and COD_{Mn} exceeded the permissible limit of (GB/T 14848-2017) standard. Meanwhile, only four samples (26.7%) showed that the NH_4^+ value within the allowable limit of 0.5 mg/L of the (GB/T 14848-2017) standard, represented in the sampling sites (ZK8, ZK9, ZK10 and ZK11), and the others remaining above the permissible limit. The higher SO_4^{2-} concentration in groundwater resulted due to of industrial waste contamination and dissolution of sulfate-bearing minerals. While the high concentration of COD_{Mn} and NH_4^+ in the groundwater come from chemical fertilizer and natural decomposition of organic matter from oil depot leakage of the gas station in the study area. The mean values of NO_3^- and NO_2^- in groundwater samples during the study are 2.221 and 0.037 mg/L respectively, and it less than the standard value (20 and 1 mg/L) of the (GB/T 14848-2017) for all samples. The Mn content in the present study ranged from 0.0474 to 2.06 mg/L with the mean 0.627 mg/L. Permissible levels are exceeded for Mn in all wells according to (GB/T 14848-2017) standard and higher Mn values in the groundwater aquifer were found due to natural processes. According to (GB/T 14848-2017) standard, the acceptable limit of benzene and toluene are 0.01 and 0.7 mg/L respectively. The mean concentrations of benzene and toluene in the groundwater of the study location is 0.004 mg/L of both. All groundwater samples of toluene are fall under the permissible limit, However, some groundwater samples had

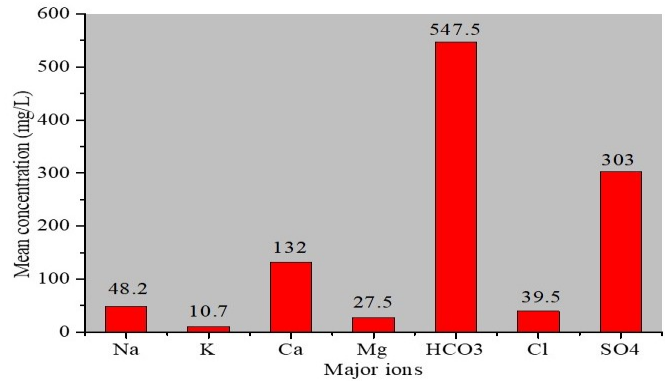


Fig. 2: Sequence of the major ions in groundwater samples

high values of benzene as shown by well points ZK1, ZK6 and ZK12, probably owing to contamination from oil depot leakage of the gas station. Finally, the concentration of TPH in the groundwater ranged from 0.12 to 17.39 mg/L with an average 3.233 mg/L. The acceptable limit of TPH for drinking water is 0.3 mg/L as per the Chinese national standard (GB 5749-2006). In this study, eight groundwater samples higher than allowable limit of 0.3 mg/L represented in sites (ZK1 to ZK8) and others fall within the permissible limits. According to the results of the analysis obtained for the major groups, the sequence of the cations was $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ and the anions $HCO_3^- > SO_4^{2-} > Cl^-$ according to their mean values. Figure (2). illustrates the dominance of cations and anions in groundwater of the study area.

TABLE V: Statistics of groundwater quality parameters

Parameter	Unit	Min	Max	Mean	SD	(GB/T 14848-2017) (Class III)
pH	-	6.86	7.68	7.370	0.24	6.5~8.5
TH	(mg/L)	90	465	370.80	92.59	≤450
TDS	(mg/L)	255	615	492.45	113.70	≤1000
Na^+	(mg/L)	25	48.2	34.76	5.61	≤200
K^+	(mg/L)	0.59	10.7	2.925	2.47	-
Ca^{2+}	(mg/L)	29.4	132	106.21	24.43	-
Mg^{2+}	(mg/L)	3.17	27.5	16.525	5.96	-
Cl^-	(mg/L)	12.6	39.5	24.71	8.86	≤250
SO_4^{2-}	(mg/L)	20.1	303	113.75	76.09	≤250
HCO_3^-	(mg/L)	31.72	547.5	330.56	153.22	-
COD_{Mn}	(mg/L)	0.89	27.6	3.217	6.77	≤3
NH_4^+	(mg/L)	0.441	1.64	1.012	0.44	≤0.5
NO_3^-	(mg/L)	ND	11.4	2.221	3.51	≤20
NO_2^-	(mg/L)	ND	0.123	0.037	0.04	≤1
Mn	(mg/L)	0.0474	2.06	0.627	0.61	≤0.1
benzene	(mg/L)	ND	0.013	0.004	0.005	≤0.01
Toluene	(mg/L)	ND	0.0534	0.004	0.014	≤0.7
TPH	(mg/L)	0.12	17.39	3.233	6.08	-

B. Hydrochemical facies

Based on major ions (Ca^{2+} , Mg^{2+} , Na^+ , and K^+ , HCO_3^- , SO_4^{2-} and Cl^-), hydrogeochemical facies analysis is useful method to determine groundwater type because it reflects the process of chemical reaction when the water passes through the pores and rock fractures [4][16]. The analytical values received from the groundwater samples

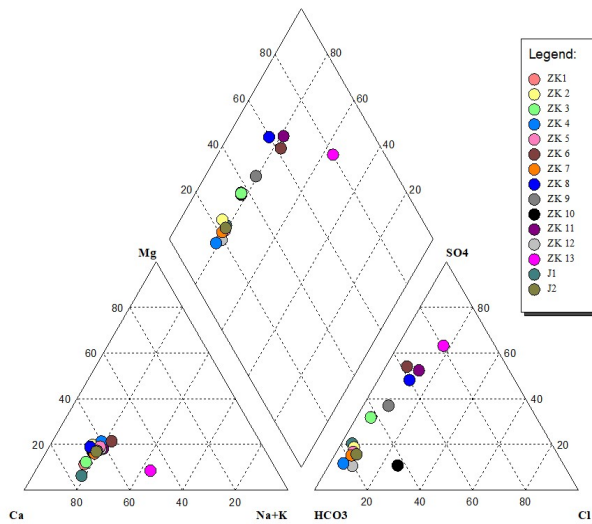


Fig. 3: Piper trilinear diagram of the study area

are plotted on Piper trilinear diagram to recognize the hydrochemical system and categorization of groundwater samples by representing of similar hydrochemistry sample points to assembly together in the diagram [17]. This diagram of groundwater samples was designed by Hill and improved by Piper. The study area emerged significant differences in composition of cationic and anionic concentration. Ca^{2+} and HCO_3^- were dominant in the cationic and anionic groups of most groundwater samples (14 samples) respectively. From the Piper trilinear diagram Figure (3), three water types revealed in the study area. These types are HCO_3-Ca , HCO_3-SO_4-Ca , and $SO_4-Na-Ca$, which are represented in the sites (ZK2, ZK4, ZK5, ZK7, ZK9, ZK10, ZK12 and J2); (ZK1, ZK3, ZK6, ZK8, ZK11 and J1) and (ZK13) respectively. The percentage of these three hydrogeochemical facies were 58.3%, 40% and 6.7% respectively. This result of Piper diagram reveals that the major hydrogeochemical types of groundwater in the region area are mostly HCO_3-Ca and HCO_3-SO_4-Ca , indicating fresh water and mix-water types, respectively. From the plot, it is observed that alkalis (Ca^{2+} and Mg^{2+}) significantly exceeded the alkaline (Na^+ and K^+) and HCO_3^- exceeded other anions. The major cations in water were $Ca^{2+} > Na^+ > Mg^{2+} > K^+$, and the major anions were $HCO_3^- > SO_4^{2-} > Cl^-$. The anions and cations in groundwater could have come basically from the dissolution of carbonate rock, and could also be associated with anthropogenic activities [18][19].

C. Assessing the quality of groundwater based on CEM method

In this method, the groundwater high-quality was assessed for 15 locations (ZK1, ZK2, ZK3, ZK4, ZK5, ZK6, ZK7, ZK8, ZK9, ZK10, ZK11, ZK12, ZK13, J1 and J2) as decided in the region. Of the 18 groundwater parameters analyzed, eleven parameters (pH, TH, TDS, Ca^{2+} , Cl^- , COD_{Mn} , NH_4^+ , NO_3^- , NO_2^- , Mn and benzene) had been selected due to it's miles periodically monitored through the Local Environmental Protection Department for their vital importance to the

groundwater quality and potential impact on human health [3]. Based on the conventional single components assessment technique and F value appraisal, the results are shown in Table (VI), F standards of entirely examined samples reached from (4.40 to 7.79), ranging from poor quality to very poor quality. Eleven groundwater samples (ZK1, ZK2, ZK3, ZK5, ZK9, ZK10, ZK11, ZK12, ZK14, J1 and J2) representing (73.33% of all samples) are classified as poor-quality water (grade IV) and four samples (ZK4, ZK6, ZK7 and ZK12) are belonging to very poor-quality water (grade V), which representing that completely groundwater samples are not fit for various purposes. The common pollutants that led the index of all samples exceeds the allowable limits of (GB/T 14848-2017) standards are NH_4^+ , Mn and benzene which mainly caused by man-made activities, natural environment and oil depot waste of gas station. Therefore, all sampled groundwater must be treated first before consumption local community. In general, the total groundwater quality is poor, and does not accord with drinking water standard according to a comprehensive evaluation method.

D. Groundwater contamination

Groundwater samples had been gathered and analyzed as a way to evaluate the leakage pollution because of the gas station on the quality of groundwater in the study region. The results suggest:

- 1) The most of groundwater samples are contaminated, where concentration of most physiochemical parameters were above permissible standard levels set by local and international standards for potable water.
- 2) Some contaminants had leaked out and caused contamination of the aquifer in the study area.
- 3) Some contaminants contained inorganic contaminants (e.g., ammonia nitrogen, total hardness, and arsenic), organic contaminations (e.g., aniline, 4-chloroaniline and Phenol), coli bacillus, and total bacterial count.
- 4) There is a potential risk of groundwater contamination in the research area from gas leakage resulting from the station
- 5) Old gasoline tanks in the area need to be re-planned for more conservative use.
- 6) The migration of most elements in the soil is very large due to the high rate of precipitation over the city, and also due to the high permeability of the surface soil.
- 7) In the same vein, it was found that ammonia and benzene were the most important contaminant which has exceeded the standard and therefore, they can be selected in a future study as a contaminant for simulation the model.
- 8) Based on the results of the analysis of the selected groundwater samples, all wells were verified to be contaminated by the gas station. Therefore, the results provide a reliable and reasonable basis for the ecological protection department law enforcement and supervision.

IV. CONCLUSIONS

The following details were made clear by the findings of the groundwater sample collection and analysis conducted

TABLE VI: Groundwater quality classification and evaluation

Sample point	pH	TH	TDS	SO_4^{2-}	Cl^-	COD_{Mn}	NH_4^+	NO_3^-	NO_2^-	Mn	benzene	F value	Grade	Result
ZK1	III	III	III	III	I	I	IV	I	II	IV	IV	4.69	IV	poor
ZK2	III	III	II	II	I	III	IV	I	II	IV	II	4.54	IV	poor
ZK3	III	III	III	III	I	II	IV	I	II	IV	I	4.63	IV	poor
ZK4	III	III	III	II	I	III	IV	I	II	V	I	7.30	V	very poor
ZK5	III	III	II	II	I	II	IV	I	II	IV	I	4.54	IV	poor
ZK6	III	IV	III	IV	I	V	IV	I	II	V	IV	7.79	V	very poor
ZK7	II	III	III	II	I	II	III	V	I	IV	I	7.55	V	very poor
ZK8	II	III	III	III	I	II	III	III	II	IV	I	4.58	IV	poor
ZK9	III	III	III	II	I	II	III	II	III	IV	I	4.51	IV	poor
ZK10	III	III	III	I	I	II	III	II	III	IV	I	4.49	IV	poor
ZK11	III	II	III	III	I	I	III	II	III	IV	I	4.56	IV	poor
ZK12	III	III	III	I	I	III	V	I	II	V	IV	7.50	V	very poor
ZK13	III	I	I	II	I	I	IV	III	II	III	I	4.38	IV	poor
J1	III	III	I	II	I	I	IV	I	II	IV	I	4.43	IV	poor
J2	III	III	II	II	I	III	IV	I	II	I	I	4.40	IV	poor

at the field site to apply the level III of (GB/T14848-2017) groundwater quality standard as a guide:

- 1) The concentration of most physiochemical parameters were above permissible standard levels set by local and global standards for potable water.
- 2) The groundwater is slightly acidic to mildly alkaline based on pH value, and classified as very hard and fresh-water type of (TH and TDS) concentrations respectively
- 3) The order of the cations was ($Ca^{2+} > Na^+ > Mg^{2+} > K^+$) and the anions ($HCO_3^- > SO_4^{2-} > Cl^-$) according to their mean values
- 4) The results of the traditional single components evaluation method and F value analysis showed that eleven groundwater samples (73.% of total samples) were classified as poor-quality water (rank IV) and four samples with very poor water quality (rank V), indicating that not all groundwater samples were suitable for different purposes.
- 5) We confirm that the leaks that occurred at the test site can have a significant impact on the groundwater. Therefore, the gas station in the study area should be monitored periodically to ensure that gasoline tanks does not leak into the subsurface soil.
- 6) The majority of groundwater parameters that surpass the standard's allowable limits (GB/T 14848-2017) are primarily brought on by human activity, the environment, and gas station waste from oil depots. Therefore, in order to safeguard the environment and the health of impacted residents, local city authorities must devise better plans for swiftly responding to fuel spills. In the near future, competent risk assessment studies will require the establishment of a robust interface for inter-institutional collaboration by health and environmental authorities.

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