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Research Article

Investigation of Groundwater Quality for Drinking Usage in Kifri District (Iraq) by using NPI and WQI Indices

Abdulmutalib Raafat Sarhat[1], Muhammad Mohsin[2*], and Aram Hassan Mohammed[3]

[1]Department of Chemistry, College of Education, University of Garmian, Kurdistan, Iraq
[2]Department of Geography, Govt. Sadiq Egerton Graduate College, Bahawalpur, Pakistan
[3]Department of Social Sciences, College of Basic Education, University of Garmian, Kurdistan, Iraq

Abstract: The present study was mainly proposed to investigate the quality of groundwater for drinking in Kifri District. The main aim of this study was to identify some pollutants of groundwater using two types of indexes which are: Nemerow's pollution index (NPI) and Water quality index (WQI). The groundwater samples were collected from 36 stations (deep wells) and analyzed for seven physico-chemical parameters including EC, TDS, pH, TH, TA, Ca^{+2} and SO_4^{-2}; as well as, the results were compared to WHO standards. The results presented undesirable values for almost all physico-chemical parameters, according to WHO standard limits for drinking. Based on WQI, the results show that 33 stations out of 36 were classified under the 'Poor Quality' category. Also, most of the NPI values of EC, TDS, Ca^{+2}, TH, TA, and SO_4^{-2} concentrations were (>1) and exceeded the WHO standard. Thus, all the stations reported high values of WQI and NPI and all the groundwater samples belonged to polluted water.

Keywords: Groundwater Quality, Water Quality Index (WQI), Nemerow's Pollution Index (NPI), Kifri District, Iraq.

1. INTRODUCTION

Generally, drinking water plays a big role in human life, and humans have the right to access safe and affordable water in order to sustain good health because access to safe drinking water has benefits for human health [1]. However, poor quality of drinking water affects human health, especially children and infants who are highly exposed to contaminants [2]. Groundwater is considered a common resource of water for human consumption including drinking, industrial, irrigation and construction. Generally, groundwater is preferable to surface water due to a number of reasons. For instance, groundwater mostly has better quality; it is also well protected from contaminants sources and is less subjected to seasonal changes [3]. However, sometimes the groundwater is of poor quality because of the aquifers, which contain undesirable elements in large quantities, as is the case in the study area. The chemistry of groundwater highly depends on some factors including general geology, types of rock weathering as well as the quality of recharged water [4]. The sustainable supply of potable water is highly ambiguous in most developing countries therefore the assessment of groundwater quality is significant to ensure that the water is suitable and safe to be used [5,6]. Usually, the hydro-chemical assessment of groundwater is based on large amounts of information in terms of groundwater chemistry [7]. The excessive elements of groundwater are a global public health concern, as some elements and compounds are responsible to cause deleterious effects on human health. Kifri District is one of the cities of Iraq where groundwater has been the only water supply for all sectors for a long time. All the people in this district are utilizing groundwater for household usage. Based on a previous study, the quality of groundwater in Kifri District has high concentrations of some pollutants such as Ca^{+2}, Mg^{+2}, Fe^{+2}, and $SO4^{-2}$ which significantly exceeded the WHO and FAO drinking water quality standards [8]. The present paper aimed to investigate the possibility of using groundwater for drinking purposes by collecting samples from different stations in the city. For this purpose, Nemerow's Pollution Index (NPI)

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*Corresponding author: Muhammad Mohsin <mohsinshahzad10@yahoo.com>

and Water quality index (WQI) have been utilized considering the World Health Organization (WHO) standards [9]. The findings of this study are expected to pave the way to increase public consciousness on using groundwater for various usages, especially for drinking; then, this will promote the authorities to take some actions for finding new sources of safe water.

2. METHODOLOGY

2.1 Study Area

The study area of the present study was the Kifri District, about 100 Km southeast Kirkuk city, Iraq (Figure 1). It is geographically situated between 34^o 27′ 24″ – 35^o 10′ 17″N latitudes and 44^o 31′ 4″– 45^o 16’ 52”E longitudes.

2.2 Data Collection and Mapping

A (GPS) device was used to record the locations of the sampling stations. The collected data were properly arranged and manipulated according to the study’s needs. Also, cartography was conducted by utilizing cross-sectional maps prepared in ArcGIS 10.7 and ERDAS Imagine 14 software. The method of quantitative analysis was used to download the maps. The study area map was drawn on a scale of 1: 250000 for the year 2021.

2.3 Sampling Analysis

The samples were taken and collected in (1 L) polypropylene bottles, and all the samples were labelled. Then, 0.4 % HNO_3 was added in each collected sample and stored in a refrigerator.

Some of the parameters such as pH, TDS and EC were immediately measured after sampling in the site by using digital pH and conductivity TDS meters. The samples were analyzed to determine Ca^{+2} and total hardness (TH) by Titration with EDTA (Ethylenediaminetetraacetic Acid). Also, SO_4^{-2} were determined by an ion-selective electrode with specific parameters comprising a sulphate

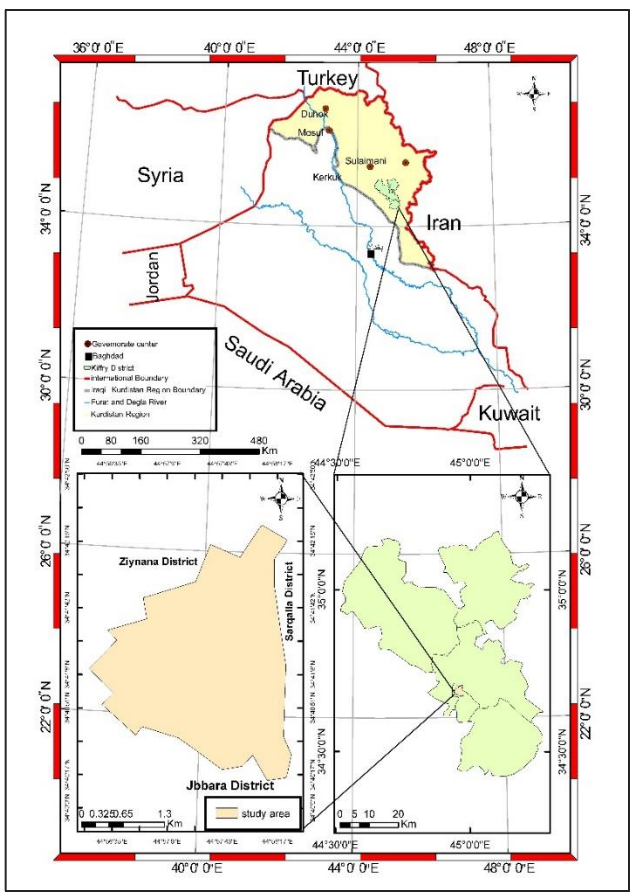

Fig. 1. Location of the studied area
Source: Directorate of Survey, Ministry of Water Resources, Iraq

electrode [10]. Total alkalinity (TA) has been determined by titrating the groundwater samples with sulfuric acid.

2.4 Water Quality Index (WQI)

Water Quality Index (WQI) is one of the most effective methods to investigate water quality. WQI was calculated by using the values of seven parameters, and it was determined based on the WHO [9]. The samples for WQI were collected from deep wells of 36 stations in the Kifri district and each of the seven parameters of these samples was given a special weight (wi) based on their influence on the water quality, ranging from 1 to 3 as shown in Table 1. A minimum weight which is a value of 1 was given to pH and TA which have less significant roles in human health [11]. However, the maximum weight of 3 was given to the both SO_4^{-2} and TH parameters for their significance in the assessment of the water quality. To find the relative weight, the following equation was utilized [12]:

$$\mathbf{Wi = w_i \,/\, \sum_{i=1}^{n} W_i}$$

Where:

Wi represents the relative weight of each parameter and n, is the number of tested or studied parameters Then, the following equation was used to calculate the quality rating (Qi):

$$Qi = \left(\frac{Ci}{Si}\right) * 100$$

Where:

Ci is each parameter's value

Si is each parameter's standard value.

Finally, the following equation was used to compute WQI [11]:

$$\mathrm{WQI} = \sum_{i=1}^{n} (W_{i*} q_i)$$

Where:

WQI is the water quality index, and it is classified into five categories as shown in Table 2; qi is the rating value of each parameter which is given from 1 to 3 based on the parameter's concentration and importance.

Table 1. Relative and assigned weight value to calculate WQI based on WHO standards

Parameters	WHO standard	Assigned weight	Relative weight
pH	8.5	1	0.0714
EC	1,000	2	0.1429
Ca^{+2}	100	2	0.1429
SO_4^{-2}	250	3	0.2143
TDS	500	2	0.1429
TH	500	3	0.2143
TA	250	1	0.0714

Table 2. Classification of WQI categories

Ranges statue	WQI categories
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unsuitable

Wi= is the relative weight of each parameter i^{th}.

2.5 Nemerow's Pollution Index (NPI)

In order to understand the contamination levels in the water, Nemerow's Pollution Index (NPI) has been utilized. It is represented by the following equation [13]:

$$NPI = \sqrt{[(maxPi)2} + (Pi)2/2]$$

Where:

NPI= refers to Nemerow's pollution index

max Pi= is the maximum value of each pollutant or parameter P̄I, which is the standard value of the specific pollutant.

Therefore, each value of (NPI) with less than one (PN < 1) indicates the suitability of water; however, the value of NPI with more than one (PN > 1) indicates the unsuitability of water to be used in terms of a specific parameter [14].

3. RESULTS AND DISCUSSION

The obtained results of the studied parameters are illustrated in Table 3 below:

Table 3. Results of the studied physio-chemical parameters in the study area

S. No.	Locations E	Locations N	pH	EC µS/cm	Ca^{+2} (mg/l)	SO_4^{-2} (mg/l)	TDS (mg/l)	TH (mg/l)	TA (mg/l)
1	44.96181	34.68425	7	1,470	211	369	971	718	228
2	44.96854	34.69875	7.1	1,256	200	472	789.1	690	201
3	44.96987	34.68071	7.3	1,000	121	278	601	461	212
4	44.97005	34.69084	6.95	1,950	35	382	799.4	538	261
5	44.96973	34.68842	7.2	1,002	151	340	645	518	198
6	44.96205	34.68703	7.3	1,110	156	313	720.3	528	248
7	44.96326	34.6823	6.99	1,338	167	333	791	617	251
8	44.95958	34.68342	6.75	1,350	178	309	855.8	673	282
9	44.94542	34.69012	6.85	1,121	51	281	718.4	542	253
10	44.95513	34.6883	6.7	1,594	167	432	1,028	818	310
11	44.94377	34.68702	7.2	1,595	198	310	1,016.3	722	319
12	44.96282	34.69113	7	1,455	115	432	925.2	695	257
13	44.96142	34.69272	6.7	359	123	448	198.3	754	296
14	44.95837	34.69439	6.9	1,267	146	309	781.2	598	281
15	44.94942	34.68392	6.88	301	149	369	175.3	618	261
16	44.95173	34.68058	6.9	1,246	110	287	753.5	576	282
17	44.96644	34.6848	8.5	1,003	44	267	651.7	374	303
18	44.96784	34.68211	7.87	1,401	149	317	920	483	173
19	44.95754	34.68019	6.45	304	98	349	195	431	283
20	44.95472	34.69469	6.57	264	129	451	159	592	232
21	44.97005	34.69084	6.6	269	130	338	174	567	271
22	44.96278	34.68988	7.1	1,111	97	362	670.5	428	205
23	44.96205	34.68782	7.18	1,498	200	440	900.6	493	319
24	44.9625	34.69903	7.95	1,012	198	318	640.3	487	245
25	44.95296	34.68775	7.99	1,404	231	301	912.7	691	307
26	44.9575	34.68576	7.95	1,278	193	293	813.8	570	291
27	44.95795	34.68741	8.25	1,167	189	425	729.1	576	301
28	44.96573	34.6889	8.01	1,321	173	298	835.6	429	248
29	44.95124	34.68914	7.95	1,169	152	291	720	625	257
30	44.96658	34.69384	7.98	814	91	300	471	575	303
31	44.96194	34.67824	7.22	1,621	200	348	983	701	298
32	44.95425	34.678	7.31	1,198	121	287	698	489	284
33	44.94679	34.68043	7.21	1,188	145	411	770	517	254
34	44.96641	34.67627	7.05	1,200	157	513	702	654	318
35	44.96002	34.68669	7.96	878	178.5	201	502	502	159
36	44.96239	34.69772	7.71	298	62	119	164	195	171
Min.			6.45	264	35	119	159	195	159
Max.			8.5	1,950	231	513	1,028	818	319
Ave.			7.29	1,105.9	144.88	341.5	677.25	567.9	260
WHO			6.5-8.5	600	150	75	500	500	250

3.1 pH

Generally, the value of pH shows the concentration of hydrogen ions in the solution [15]. It is considered an important parameter of water quality due to its effect on the process of disinfection. According to the obtained data, the pH of the samples was ranging between 6.45 and 8.5 with an average of 7.29. Out of 36 stations, only one location has a pH value equal to the maximum permissible limit for drinking purposes viz. 6.5-8.5 [9]. The water pH has no direct influence on human health; while it has an indirect influence on health as it affects other parameters. Figure 2 illustrates the pH spatial distribution in the Kifri District.

3.2 Total Dissolved Solids (TDS)

The value of Total Dissolved Solids (TDS) in groundwater is a significant parameter to investigate the suitability of water for different purposes [16]. The concentration of TDS of the groundwater samples in the studied area were ranging between 159 and 1,028 mg/l with a mean of 677.25 mg/l. Approximately 80.55 % of the groundwater samples had TDS values of more than 500 mg/l; while only

7 samples 19.45 % had TDS values of less than the permissible value [17]. Figure 3 illustrates the spatial distribution of TDS in the studied area.

3.3 Electric Conductivity (EC)

Electric Conductivity (EC) is representing the measurement of salinity in water indirectly [18]. The EC values of the Kifri groundwater samples were ranging between 264 to 1,950 µS/cm with an average of 1,105.9 µS/cm. About 83.33 % of the groundwater samples in the study area had EC values above the critical limit value for drinking. Only 6 samples have values of EC less than 600 µS/cm. Figure 4 below shows the EC spatial distribution in the present area.

3.4 Calcium (Ca^{+2})

The concentrations of calcium in all groundwater samples were ranging between 35 to 231 mg/l with an average of 144.9 mg/l. The standard limit of calcium is 150 mg/l. The obtained results showed that most of the samples had Ca^{+2} concentrations more than the permissible limit. Figure 5 below illustrates the Ca^{+2} spatial distributions within Kifri City.

3.5 Total Alkalinity (TA)

The presence of both carbonate and bicarbonate ions is the main cause of alkalinity levels in water [19]. The results show that the total alkalinity (TA) values ranged between 159 and 319 mg/l, with a mean of 260 mg/l. Therefore, the total alkalinity values in most of the samples were above the desirable limit [9]. While 12 samples (33.34 %) have (TA) values less than the permissible limit. Figure 6 shows the representation of total alkalinity in groundwater samples within the study area.

3.6 Sulfate (SO_4^{-2})

The concentrations of sulfate in the samples were ranging between 119 to 513 mg/l, with a mean value of 341.5 mg/l. Only 2 samples (5.56 %) had values of sulfate less than the permissible limit of 250 mg/l. Figure 7 demonstrates the sulphate spatial distribution within the study area. Recently, health issues that are linked to sulfate in water have increased [20]. Presence of high concentrations of sulfate in water cause an undesirable taste. It contributes to the corrosion of the water distribution pipe system [9].

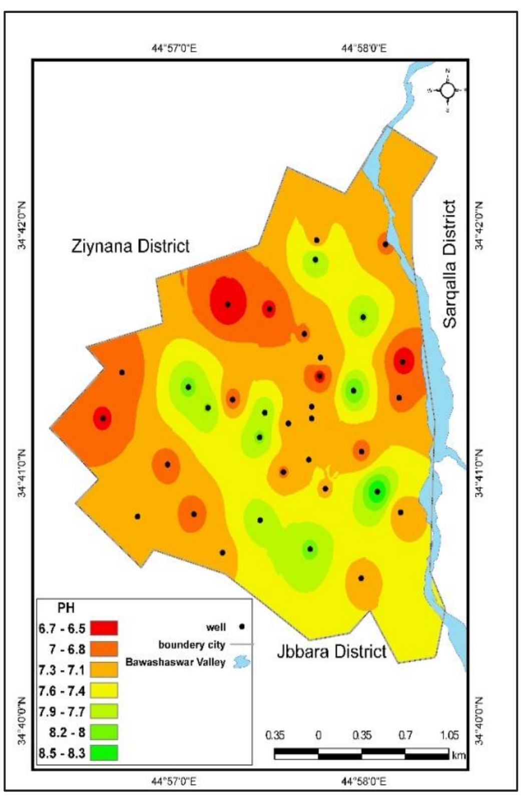

Fig. 2. Distribution of pH values in the study area

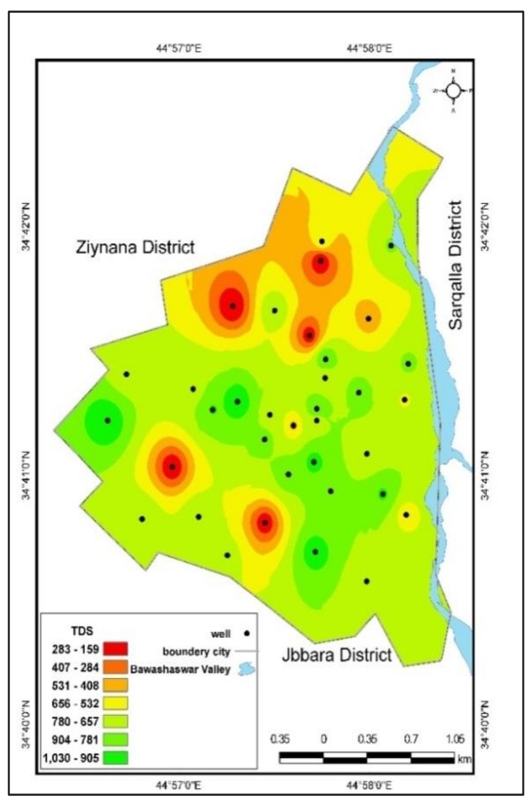

Fig. 3. Distribution of TDS values in the study area

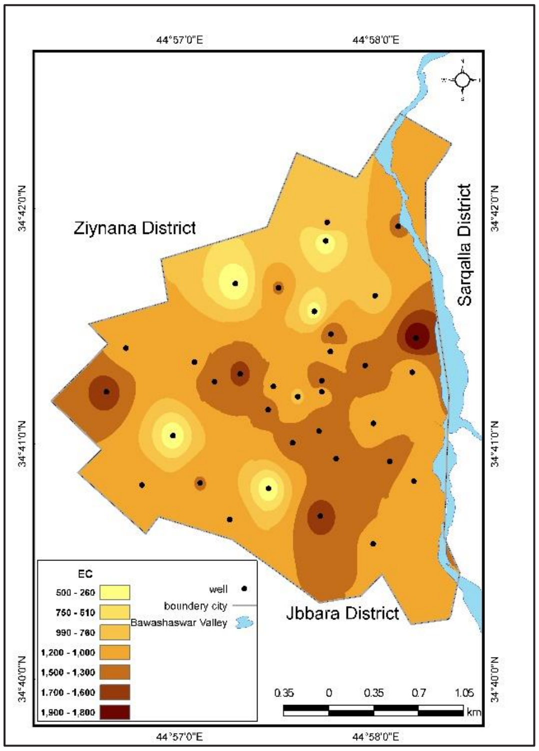

Fig. 4. Distribution of EC values in the study area

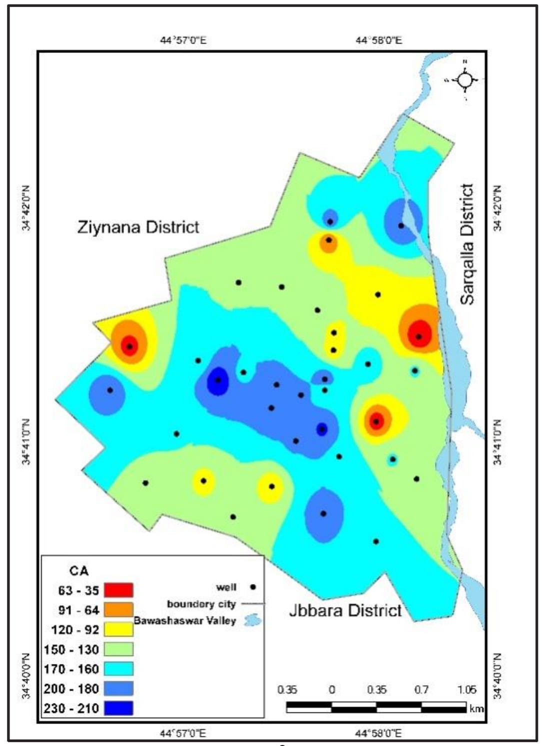

Fig. 5. Distribution of Ca^{+2} values in the study area

3.7 Total Hardness (TH)

Water hardness relies on some anions and cations including sulfate, bicarbonate, calcium, chloride and magnesium [21]. High values of total hardness of more than 300 mg/l can cause problems for daily human uses [22]. The concentrations of total hardness of the groundwater samples were ranging between 195 to 818 mg/l with a mean value of 567.9 mg/l. The permissible value of TH is 500 mg/l according to WHO [9]. In the study area, 36 samples (72.23 %) had TH values greater than 500 mg/l; while only 10 samples (27.78 %) had values less than the permissible value. Generally, water containing $CaCO_3$ concentration less than 75

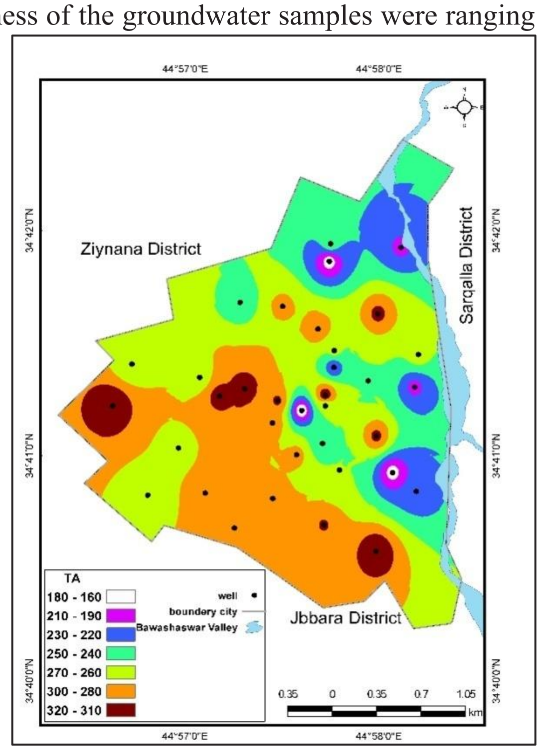

Fig. 6. Distribution of TA values in study area

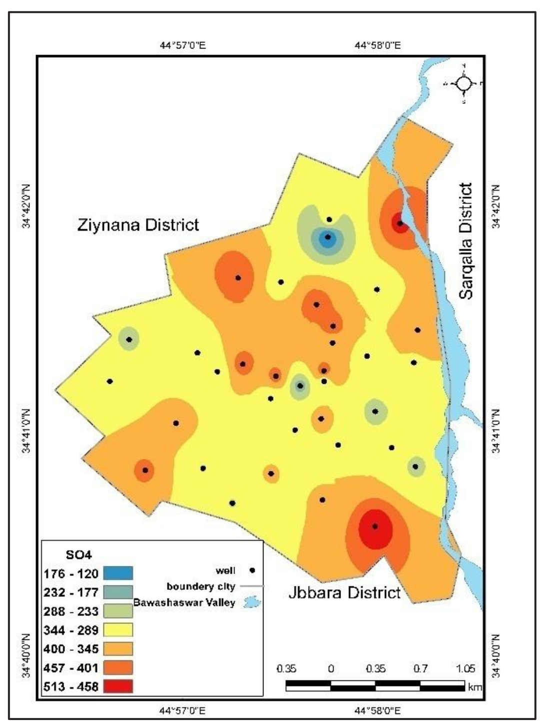

Fig. 7. Distribution of SO_4^{-2} values in the study area

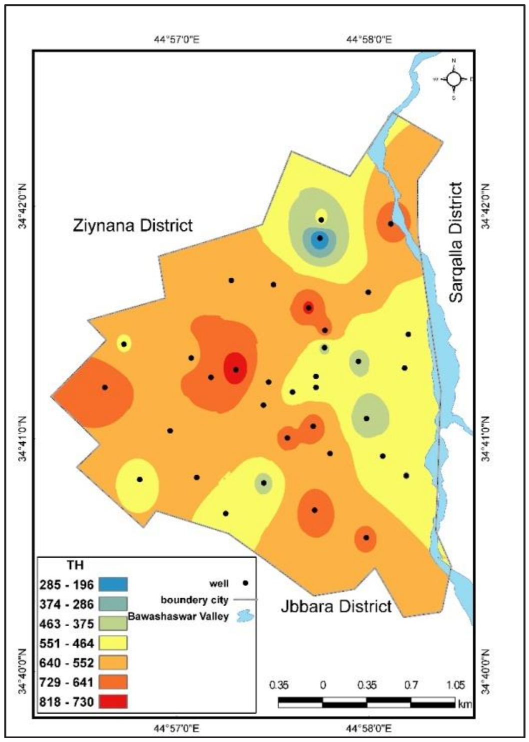

Fig. 8. Distribution of Total Hardness values in the study area

mg/l is soft; 75-150 mg/l of $CaCO_3$ concentration is moderately hard; while 150-300 mg/l of $CaCO_3$ concentration is regarded as hard; however, greater than 300 mg/l of $CaCO_3$ concentration is regarded as very hard [23]. A study conducted in Shorkot City (Jhang) concluded that certain parameters exceeded WHO standards like TDS (62 %), Calcium (62 %), Hardness (44 %) and Chloride (28 %) respectively, whereas Electrical Conductivity exceeded 100 % than the prescribed limit of WHO. These exceeding concentrations of these parameters created various fatal waterborne diseases in the study area i.e. Gastroenteritis, Cholera, Dysentery, Diarrhea, Hepatitis, Kidney stone, Cancer, Asthma and Heart diseases [24].

3.8 Correlation Matrices

The correlation matrices for the parameters including pH, EC, Ca^{+2}, SO_4^{-2}, TDS, TH and TA has been prepared and explained as shown in Table 4. The results illustrate that EC has a high positive correlation with Ca^{+2}, TDS and TH. In addition, a high positive correlation of Ca^{+2} with each of TDS and TH has been demonstrated. Furthermore, the same is true for SO_4^{-2} with TH and TA.

3.9 Water Quality Index (WQI)

The categories of WQI are included excellent, good, poor, very poor, and unsuitable for drinking [25]. The results of the WQI of the study area showed that 33 stations out of 36 were classified under the 'Poor Quality' category. However, only 3 stations were classified as 'Good Quality' category. Table 5 indicates that the groundwater in Kifri is not suitable for drinking.

A study conducted in Karnataka (India) found that various samples of groundwater samples were

Table 4. Correlation matrix of the studied parameters

Parameters	pH	EC	Ca^{+2}	SO_4^{-2}	TDS	TH	TA
pH	1						
EC	0.152	1					
Ca^{+2}	0.131	0.305	1				
SO_4^{-2}	-0.439	0.143	0.237	1			
TDS	0.192	0.960	0.432	0.128	1		
TH	-0.373	0.341	0.497	0.570	0.378	1	
TA	-0.089	0.219	0.127	0.344	0.218	0.445	1

Table 5. Classification of WQI in the study area

Station	Statue	WQI Type
1	171.85	Poor
2	166.8	Poor
3	115.1	Poor
4	138.95	Poor
5	129	Poor
6	134.7	Poor
7	148.4	Poor
8	152.7	Poor
9	110.75	Poor
10	178.65	Poor
11	172.3	Poor
12	157.1	Poor
13	115.4	Poor
14	139.96	Poor
15	105.55	Poor
16	129	Poor
17	105.6	Poor
18	144.98	Poor
19	85.33	Good
20	104	Poor
21	95.2	Good
22	119.8	Poor
23	168.3	Poor
24	139.8	Poor
25	172.4	Poor
26	152.8	Poor
27	160.3	Poor
28	144.1	Poor
29	140.95	Poor
30	113.85	Poor
31	174.2	Poor
32	126.66	Poor
33	143.55	Poor
34	159.86	Poor
35	117.1	Poor
36	50.4	Good

had 'Very Poor Water Quality', showing that, the area is prevailed by remnants of weathered rock and dissolution of salts from the bedrock into the water resources, creating a serious threat to the natural environment [26].

3.10 Nemerow's Pollution Index (NPI)

The parameters of pollution as NPI at all the stations have been determined and demonstrated in Table 6. The NPI results of pH were in the permissible range for drinking purposes based on WHO standards. Also, the NPI values for EC varied from 0.44 to 3.25 with an average of 1.84 at all monitoring stations. Thus, the NPI values of EC illustrated that 83.34 % of the samples were not fit for drinking purposes based on WHO standards. Roughly the same scenario has been found in terms of TDS values as per WHO standards. Approximately 94.45 % and 80.56 % of the samples in the monitoring stations had NPI values for SO_4^{-2} and Ca^{+2} concentrations respectively, exceeding one, this indicates the high level of pollution for these parameters. It was noticed also that 72.23 % and 66.67 % of groundwater samples had NPI values of more than one in terms of TH and TA concentrations respectively. This indicates that most of the samples in Kifri City were unsuitable for drinking.

4. CONCLUSION

The quality of the groundwater samples that were collected from 36 various stations in the Kifri district were all analyzed and studied to meet the main objectives of the present research. Based on the results, the pH of 97.23 % of the samples was within the permissible limits. However, the EC, TDS, TH, TA, Ca^{+2} and SO_4^{-2} values of most of the samples were above the standard limits set by the WHO. Also, total alkalinity (TA) values for all the samples were higher than the permissible limit. Based on WQI, the results show that 33 stations out of 36 were classified under the 'Poor Quality' category; while only 3 stations were classified as the 'Good Quality' category. Nemerow's pollution index (NPI) method was applied to evaluate the groundwater quality for drinking. In terms of pH, most of the NPI values were acceptable and were within the permissible limits for drinking usage. However, most of the NPI values of EC, TDS, TH, TA, Ca^{+2} and SO_4^{-2} concentration were (>1) and exceeded the WHO standard. Ultimately, those parameters generated many problems for human health. Thus, suitable treatment is required for the consumption of groundwater for drinking. Also, there is a need of finding another source of drinking water in Kifri City for securing the health of the inhabitants from various waterborne diseases.

Table 6. NPI values of studied parameters

Site	pH	EC	Ca^{+2}	SO_4^{-2}	TDS	TH	TA
1	0.82	2.45	2.11	1.48	1.94	1.44	0.91
2	0.84	2.09	2.00	1.89	1.58	1.38	0.80
3	0.86	1.67	1.21	1.11	1.20	0.92	0.85
4	0.82	3.25	0.35	1.53	1.60	1.08	1.04
5	0.85	1.67	1.51	1.36	1.29	1.04	0.79
6	0.86	1.85	1.56	1.25	1.44	1.06	0.99
7	0.82	2.23	1.67	1.33	1.58	1.23	1.00
8	0.79	2.25	1.78	1.24	1.71	1.35	1.13
9	0.81	1.87	0.51	1.12	1.44	1.08	1.01
10	0.79	2.66	1.67	1.73	2.06	1.64	1.24
11	0.85	2.66	1.98	1.24	2.03	1.44	1.28
12	0.82	2.43	1.15	1.73	1.85	1.39	1.03
13	0.79	0.60	1.23	1.79	0.40	1.51	1.18
14	0.81	2.11	1.46	1.24	1.56	1.20	1.12
15	0.81	0.50	1.49	1.48	0.35	1.24	1.04
16	0.81	2.08	1.10	1.15	1.51	1.15	1.13
17	1.00	1.67	0.44	1.07	1.30	0.75	1.21
18	0.93	2.34	1.49	1.27	1.84	0.97	0.69
19	0.76	0.51	0.98	1.40	0.39	0.86	1.13
20	0.77	0.44	1.29	1.80	0.32	1.18	0.93
21	0.78	0.45	1.30	1.35	0.35	1.13	1.08
22	0.84	1.85	0.97	1.45	1.34	0.86	0.82
23	0.84	2.50	2.00	1.76	1.80	0.99	1.28
24	0.94	1.69	1.98	1.27	1.28	0.97	0.98
25	0.94	2.34	2.31	1.20	1.83	1.38	1.23
26	0.94	2.13	1.93	1.17	1.63	1.14	1.16
27	0.97	1.95	1.89	1.70	1.46	1.15	1.20
28	0.94	2.20	1.73	1.19	1.67	0.86	0.99
29	0.94	1.95	1.52	1.16	1.44	1.25	1.03
30	0.94	1.36	0.91	1.20	0.94	1.15	1.21
31	0.85	2.70	2.00	1.39	1.97	1.40	1.19
32	0.86	2.00	1.21	1.15	1.40	0.98	1.14
33	0.85	1.98	1.45	1.64	1.54	1.03	1.02
34	0.83	2.00	1.57	2.05	1.40	1.31	1.27
35	0.94	1.46	1.79	0.80	1.00	1.00	0.64
36	0.91	0.50	0.62	0.48	0.33	0.39	0.68
Min.	0.76	0.44	0.35	0.48	0.32	0.39	0.64
Max.	1.00	3.25	2.31	2.05	2.06	1.64	1.28
Ave.	0.86	1.84	1.45	1.37	1.35	1.14	1.04

5. CONFLICT OF INTEREST

The authors declare no conflict of interest.

6. REFERENCES

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