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AN APPLICATION OF WQI AND CORRELATION MATRIX TO EVALUATE GROUNDWATER QUALITY AROUND BRICK KILNS OF LORALAI DISTRICT BALOCHISTAN

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ABSTRACT

The present study aimed to assess the quality of groundwater close to functional brick kilns of the Loralai district of Balochistan using the water quality index (WQI) Model. 15 samples were collected from the bore wells and tube wells situated near brick kilns. To appraise the WQI groundwater samples were subjected to an extensive analysis of physicochemical such as color, odor, taste, pH, Electrical conductivity (EC), Total dissolved solids (TDS), Total hardness (TH), Sulfate (SO4), Chloride (Cl), Fluoride (F), Sodium (Na), Potassium (K), & Arsenic (As). GIS was used to map the sampling location. The descriptive statistical approach and correlation matrix were successfully applied to study the variation and determining the interdependence of various parameters in the Loralai district of Balochistan. Based on the Water Quality Index (WQI) results in the majority of the value of the samples ranged from 48-204 falling in poor water quality category. The assessment proclaims that groundwater sources surrounding brick kilns need a reliable degree of treatment before the consumption of end-users and should be protected from contamination in the future.

Contribution/ Originality: This research will serve as a pioneer study of groundwater quality of Loralai District Balochistan. It uses Mathematical models such as WQI, and descriptive Statistical analysis such as correlation Matrix to evaluate the water quality and level of contamination around brick kilns.

1. INTRODUCTION

Groundwater is one of the most valuable resources of water and around 50% population of the world relies on groundwater [1]; [2]. Groundwater is excessively used in various parts of the world as well as in Pakistan for drinking purposes, domestic use, and agriculture purpose and various industrial activities. Groundwater is considered as the purest form of water compared to the other water sources due to different filtration mechanisms taking place in underground soil [3]. Various trace metals are also entered into the water bodies through different activities done by humans. Brick kilns use oil, tires, wood, and coal. The use of coal, fuel gas and tires in brick kilns for combustion purposes releases air pollutants like COx, NOx, SOx, and particulate matter [4]; [5]. Consuming water contaminated with a high level of arsenic & Fluoride is one of the major public health problems in developing countries [6]. Drinking water contaminated with arsenic (As) has been noticed in many countries around the world and it has become a major concern of water purity in various areas of the planet, particularly in developing countries [7]. Pakistan also comes in those developing countries which are suffering from freshwater scarcity and severe groundwater contamination [8]. It's been reportable that millions of Pakistanis have been affected by the poisoning of As in groundwater [9]. The groundwater of Balochistan is in danger because of the contamination by various metals but contamination caused by As is one of the major concerns. Movement of As in the atmosphere has different factors like natural ways such as volcanic eruptions, degradation of biological activities and weathering of rocks [4]; [10]; [11]. Balochistan is the largest province of Pakistan and about 54% of the area of this province is under surface water irrigation and the rest of the area is under groundwater irrigation [2]. In many regions of Balochistan groundwater is considered as the only resource of water that is available [3]. In Balochistan, the groundwater table has now reached its peak level and in the coming years, its effects will be even worse. A limited amount coupled with increasing demand has impaired water quality. Examination of the important physicochemical parameters that govern the hydrochemistry of a specific area is widely used worldwide. These physicochemical parameters play a major role in groundwater management practices [12]. No significant studies related to contamination of groundwater have been conducted in Loralai, District, Balochistan [2]. The main objective of the current research paper is to evaluate the level of contamination in groundwater by WQI around functional brick kilns.

2. MATERIALS AND METHODS

2.1. Study Area

Loralai is a district of Balochistan and it has an area of 9,830 square kilometers, it lies between 67°41'18"-69°44'22" E and 29°54'50"–30°41'28" N Figure 1. The name 'Loralai' has originated from 'Lorala' that is a stream that flows in the south of this town. Loralai is found within the North-east of Balochistan. It has been known for its agriculture, livestock holding, and horticulture. The climate of Loralai is dry and the average annual temperature is 17.5°C and precipitation averages 234mm. Groundwater is the major drinking water source in the study area and the mainstream population relies on tube wells and bore wells for drinking water (NDMA) [13].

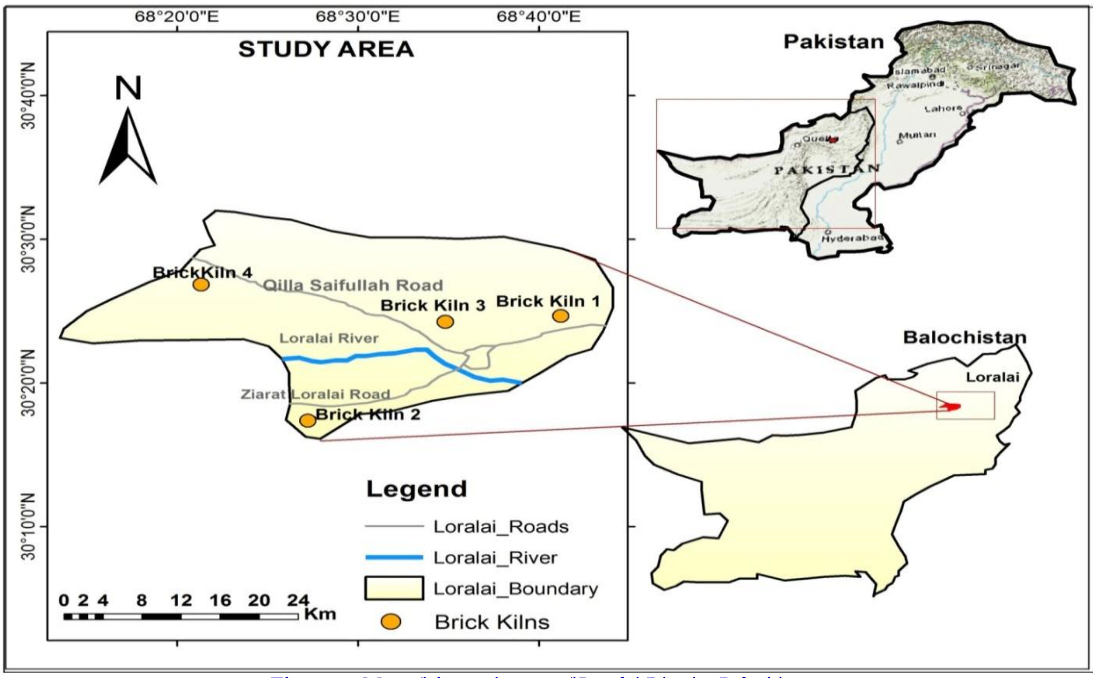

Figure-1. Map of the study area of Loralai District Balochistan.

2.2. Collection of Water Samples

A total of 15 groundwater samples were collected from the tube wells and bore wells near brick kilns Figure 1 in pre-cleaned polyethylene bottles of 500ml capacity treated with 5% Conc. HNO_3 before sampling, the bottles were carefully cleaned and rinsed with the sampling water and collected in two different bottles for analyzing the anions and the second one was used for heavy metal analysis and those bottles were acidified with few drops of Conc. HNO_3 following the standard procedure of APHA [14]. The bottles were assigned with codes and sampling sites.

2.3. Analysis of Physicochemical Parameters

The water samples were analyzed for physicochemical parameters. The APHA standard protocols were followed for EC, pH, and TDS were determined through EC meter, TDS meter, and pH meter respectively, Sulfate was determined by UV-Spectrophotometer, Chloride was measured by Argentometric Titration K^+ and Na^+ were measured by flame photometer. The assessment of Fluoride and Arsenic was done using Ion-selective electrode& Atomic absorption spectroscopy respectively [14].

2.4. Water Quality Index (WQI)

The water quality index is a numeric expression and it provides a single number (like a grade) that represents overall water quality at a definite location [15]. The main purpose of the Water Quality Index (WQI) is to reduce a set of water quality data in an informative way [12]; [15]; [16].

Water quality index was calculated by using the following steps:

1. The very first step involved the assignment of weight to the most important parameters which have a vital role it changing the overall quality of water for consumption.

The relative weight (Wi) was determined by the following equation.

$$\boldsymbol{Wi} = \frac{\boldsymbol{wi}}{\sum \boldsymbol{wini}} \qquad (1)$$

Whereas: **"Wi"** is the relative weight, **"wi"** is the weight of each parameter, **"n"** is the number of parameters Equation 1.

2. In the second step, the observed concentration of each parameter was divided by its respective [17] standard then multiply the result by 100 and it will result in developing a quality rating scale.

$$\mathbf{qi} = (\mathbf{Ci}/\mathbf{Si}) \times 100 \qquad (2)$$

Whereas: "Ci" is the observed concentration of each parameter, "Si" is WHO standards Equation 2.

3. In the third step, the SI was determined for each water quality parameter Equation 3 by multiplying relative weight and quality rating scale (q) hence the sum of SI will be equal to the water quality index.

$$\mathrm{SI} = \mathrm{Wiqi} \qquad (3)$$

$$\mathbf{WQI} = \sum SIi \qquad (4)$$

Table-1. Assignment of relative weight to the studied groundwater quality parameters.

Chemical Parameter	WHO standards	Weight (wi)	Relative weight(Wi)
pH	6.5 – 8.5	4	0.12
EC	1500	4	0.12
TDS	1000	4	0.12
TH	500	2	0.06
K^+	12	2	0.06
Cl^-	250	4	0.12
$SO4^-$	250	5	0.16
Na^+	200	3	0.09
F^-	1.5	5	0.16
Σ		31	0.95

Source: Khanoranga and Khalid [12], Zandagba, et al. [15], Howladar, et al. [16].

3. RESULTS AND DISCUSSION

3.1. Application of Water Quality Index

The target of water quality index is to show advanced water quality knowledge into data that is useable, understandable by the general public. It is very useful in the provision of water quality data in an informative as well as a simple way to the general public and also to various management and policymaking authorities [16]. The value of WQI and water type of the individual samples are presented in Tables 1, & 2. The value of WQI ranges from 48 to 204.

Table-2. Computation of water quality index (WQI) for individual samples of groundwater.

Sample No.	Water Quality Index	Water Type
BS 01	139	Poor Water
BS 02	128	Poor Water
BS 03	62	Good Water
BS 04	108	Poor Water
BS 05	225	Very Poor Water
BS 06	103	Poor Water
BS 07	124	Poor Water
BS 08	79	Good Water
BS 09	163	Poor Water
BS 10	136	Poor Water
BS 11	48	Excellent Water
BS 12	204	Very Poor Water
BS 13	113	Poor Water
BS 14	123	Poor Water
BS 15	76	Good Water

Table-3. Range and percentage of WQI for different water types.

WQI range	Water Type	Percentage of samples
< 50	Excellent Water	6.6%
50-100	Good water	20%
100-200	Poor water	60%
200-300	Very poor water	13.3%
>300	Water unsuitable for drinking	0%

Source: Khanoranga and Khalid [12], Zandagba, et al. [15].

In Present research study 60% of the groundwater samples were "poor", 13.3% were "very poor", 20% "good" and 6.6% were "Excellent" Table 3. A high concentration of physicochemical parameters such as TDS, EC, and TH, the ions such as Cl^- and Na^+ contributed to higher values of water quality index.

3.2. Descriptive Statistical Analysis

The results revealed that the color of the groundwater was Objectionable; the samples contained dust particles and were odorless and tasteless. A descriptive statistical analysis of groundwater is presented in Table 4. The pH was within permissible limits (6.5-8.5) of WHO [17] & the highest pH was 7 with the least variation. EC ranged between (704 – 5480mg/L) the values of the study area were crossing the permissible limits of WHO Table 4. The higher concentrations of EC in groundwater of the study area might be due to excess of different minerals in the groundwater through the interaction between rock and water [12]; [18]; [19]; [20]. Total dissolved solids extended from (1580-6758mg/L) and a majority of the water samples were above the maximum acceptable limits of WHO [17] the high TDS values indicated a variety of minerals in the region [2]. The values of TH were exceeding the limits of WHO [17]. TH ranged from 310-1590mg/L, whereas WHO and EPA permit any values less than 500mg/L. The hardness in groundwater is due to alkaline earth metals [21]. Total hardness is an important water quality parameter whether the water is to be used for agricultural, domestic or industrial purposes [22].

Table-4. Descriptive statistical analysis for the physicochemical parameters of Groundwater samples.

Parameters	Minimum	Maximum	Mean	Median	SD	Variance
pH	6.8	7	6.9	7	0	0
EC	704	5480	2126.2	2074	1217	148208
TDS	1580	6758	3585	3570	1774	314811
TH	310	1590	750	800	347	120457
Chloride	69	747	283	276	170	29175
Sodium	57	349	156	159	60.86	3704
Sulfate	37	472	161	71	147	2319
Potassium	1	6	3.4	3	1.35	1.82
Fluoride	0.96	1.73	1.2	1.14	0.21	0.04
Arsenic	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL, below detection level.

The Chloride exceeded the permissible limit 250mg/L ranging between (69–747mg/). It's high conc. can contribute to the presence of several minerals in the water, it might be due to the invasion of domestic disposal and waste by human activities and chloride rocks [12]; [23].

Sulfate concentration in water samples ranged between (37-472mg/L), K^+ and F- were also within prescribed range whereas the Level of Na^+ in some of the water samples exceeded the allowable limit of WHO with a maximum value of 349mg/L. Arsenic was below the detection level in all the samples of Groundwater around Brick kilns.

3.3. Correlation Coefficient

The correlation coefficient helps in measuring the degree of association or mutual relationship between two different variables The range of correlation coefficient values is from -1 to +1 [21]; [24]; [25].

Table-5. Pearson correlation coefficient matrix among different physicochemical parameters.

Variables	pH	EC	TDS	TH	Cl-	K^+	Na^+	$SO4^{-2}$	F^-
pH	1								
EC	0.469	1							
TDS	.574	.876	1						
TH	0.33	.931	.810	1					
Cl^-	0.427	.973	.860	.895	1				
K^+	-0.159	.530	0.439	0.467	.563	1			
Na^+	0.421	.988	.828	.951	.954	.525	1		
$SO4^{-2}$	.543	.812	.720	.619	.807	0.403	.757	1	
F^-	.839	.514	.548	0.376	0.506	-0.098	0.463	.579	1

Note: Significant values are highlighted in bold; $p < .05$.

The results showed that most of the parameters have a strong positive correlation and they are dependent on each other. pH is one of the parameters that are responsible for controlling metals mobility in soil medium and water [12]; [24]; [25]; [26].

In this study pH has shown positive correlation with most of the parameters and a significant positive correlation with F^- describes that high pH values are responsible for ions mobility, this significant correlation also indicates that the leaching and weathering of rocks and alkalization might be the reason of high concentration of such ions in groundwater [12]; [27]. EC, TDS, and TH have shown a very strong correlation with each other and also with different variables such as Na^+, Cl^-, and SO_4^-, there was a negative correlation between TH and Fluoride Table 5.

TDS and EC are directly proportional to TH resulting a strong significant correlation with each other indicating the management of EC, TH, and TDS by the concentration of Na^+, Cl^- and SO_4^- ions and it also showed that these ions are most influential in groundwater of the study area [21]. The positive correlation between Na and Cl states that they are capable of triggering the water chemistry indicating processes that are involved in the various hydrochemistry of the area. The Loralai District is characterized in the category of arid to a semiarid region, so the possible source of high sodium and chloride concentrations might be due to the dissolution of halite rocks, excess amount of evaporation taking place and various anthropogenic activities [12]. Previous studies identified a significant correlation of F^- with $SO4^-$, this study also revealed the same Table 5.

4. CONCLUSION

In the current study, through the water quality index Model and statistical approaches, the groundwater around functional brick kilns of the Loralai district of Balochistan was evaluated successfully. The groundwater samples are influenced by TH, Cl, Na, TDS, and EC these parameters are exceeding the limits of WHO. pH shows all the samples are slightly basic.

The calculated values from WQI ranges from 48-204 which shows that 73% of water samples fall in 'poor' to 'very poor' category which shows its unsuitability for drinking. It can be concluded that the geological composition and different anthropogenic activities such as brick kilns and agricultural practices are greatly influencing the groundwater of the region.

The study also indicates that WQI and correlation coefficient were useful tools in giving a comprehensive picture of groundwater quality to concerned authorities and also to the public. Some degree of treatment on groundwater resources before distribution and minimizing the stress of human activities can be good solutions to upgrade the quality of groundwater.

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