Groundwater Quality Index Evaluation: Case Study and Findings

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ABSTRACT

The present work aims to assess the water quality index (WQI) for the groundwater of nearby groundwater sources. This has been determined by collecting groundwater samples and subjecting the samples to a comprehensive physicochemical analysis. For calculating the WQI, the following 9 parameters have been considered: pH, TDS, Turbidity, Electrical Conductivity, Total Hardness, Sulphate, Potassium, Nitrate, and Magnesium. The WQI for these sample ranges has been calculated for February, March and April. The high value of WQI is mainly from the higher values of Turbidity, Electrical Conductivity, Total Hardness, and potassium in the groundwater. Models for forecasting the quality of water have been developed using the findings of analyses. The results of the analysis show that the area's groundwater requires some level of treatment before consumption and protection from contamination risks. We have also been able to observe monthly variations in the groundwater quality of the corresponding groundwater samples.

Keywords: *Groundwater; water quality index; monthly variation; physicochemical analysis; water quality*

INTRODUCTION

Around the world, groundwater is used for irrigation for home and industrial water supplies. The need for freshwater has increased intensely over the past decades due to both the accelerated rate of industrial development and the increasing growth of the population. Human health is susceptible by most of agricultural development activities, particularly concerning excessive application of fertilizers and unhealthy conditions. Due to inappropriate waste disposal, particularly in metropolitan areas, groundwater availability and quality have been impacted by rapid urbanization, particularly in emerging countries like India. The World Health Organization estimates that water is the primary cause of around 80% of human ailments. Once the groundwater is contaminated, its quality cannot be reinstated by preventing the pollutants from the source. It becomes imperious to monitor the quality of groundwater regularly and to strategize the methods and techniques to protect it. Water Quality Index (WQI) is one of the best techniques for informing concerned citizens and decision-makers about the quality of the water. As a result, it becomes a crucial factor in the evaluation and management of groundwater. A grade that reflects the combined influence of several water quality measures is known as WQI. WQI is calculated from the point of view of the suitability of groundwater for human consumption. The goal of this present study is to analyze groundwater's suitability for human consumption using calculated water quality index values [1-4].

Groundwater is chosen by common people due to its safe & pure characteristics compared to surface water, however many studies have revealed that groundwater can appear fresh but holds a wide variety of pathogenic organisms. The safety of groundwater depends on several factors, like the geology of the area, human activities, land use activities, and environmental and meteorological conditions of the area. [11-17]. The consumption of clean and safe drinking water has been linked to positive health outcomes and vice versa. The problem of consistent and sustainable supply of drinkable water is intensified in rural areas due to the lack of water supply infrastructure or the inadequate supply of potable water [19-20]. People are forced to look for alternate sources of water when they do not have sustainable

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access to drinkable water, which is typically accomplished by drilling shallow or deep wells, digging boreholes, or drawing water out of rivers and lakes [19-22]. Therefore, drinking untreated or insufficiently treated water continues to be a major cause of sickness. The majority of research on surface and groundwater quality does not provide policymakers and technical personnel with an easy-to-understand summary of the findings regarding the condition of their water resources [23-26]. Therefore, to determine if the water that is available from the different sources is suitable for drinking and other applications, a water quality assessment must be conducted. [27-29]. As a result, WQI is used to comprehend the general state of water resources water quality, including groundwater and surface water. WQI is still a vital tool for understanding the physicochemical characteristics that determine the drinking water quality status. Numerous techniques for estimating the water quality index have been published [30-32]. Even though WQI has several drawbacks due to the frequent omission of fundamental microbiological characteristics, it is nevertheless a vital tool for determining the physicochemical factors that determine the drinking water quality. Several techniques have been documented for estimating the water quality index [33-34].

STUDY AREA

The study is carried out in Sundernagar district Mandi in Himachal Pradesh. The Municipal Council came into existence in the year 1952. The area of this Municipal Council is 12.47 Sq. meter. and having 13 wards. The population of this as per census 2011 is 24329 and the floating population is about 20,000. The town has had a high growth rate of urban population for 20-25 years. For the assessment of groundwater, 6 different local water bodies were identified, and samples were collected month-wise for research work.

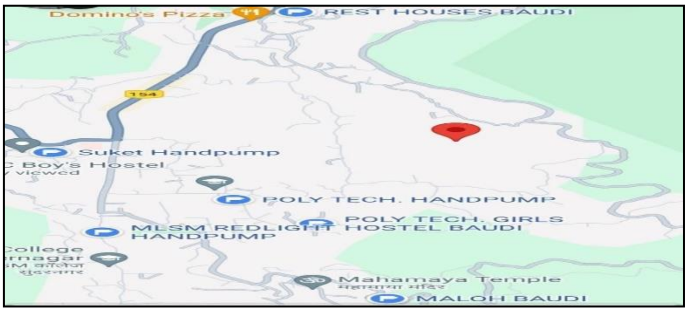

Figure 1 Location of different sample sources [5]

MATERIAL AND METHODOLOGY

SAMPLING

A total of 6 samples were collected in the months of February, March, April (2024) from nearby groundwater sources. Samples were collected using a pre-cleaned polyethylene bottle. Table 1 shows coding

Table 1 Coding of Sample Sources

Sample Source	Coding
Suket Handpump	H1
Polytechnical Ground Handpump	H2
MLSM Handpump	H3
Baudi Nagoun	B1
Maloh Baudi	B2
Baudi Near Polytechnical Girls Hostel	B3

TESTS CONDUCTED

The testing was done on the physical and chemical parameters. The physiochemical parameters selected were pH, TDS, Turbidity, Electrical Conductivity, Total Hardness, Sulphate, Potassium, Nitrate, Magnesium and different instruments used to perform tests on all parameters are shown in table 2

Table 2 Tests Conducted by Using Different Instruments

Parameters	Instruments
pH	Hanna pH meter
Electrical Conductivity	Hanna EC meter
T.D.S.	Hanna T.D.S. Tester
Turbidity	Eutech Turbidimeter
Total Hardness	U.V. Visible Spectrophotometer
Sulphate	U.V. Visible Spectrophotometer
Magnesium	U.V. Visible Spectrophotometer
Nitrate	U.V. Visible Spectrophotometer
Potassium	U.V. Visible Spectrophotometer

WATER QUALITY INDEX (WQI) DETERMINATION

Water quality index (WQI) was developed by Horton (1965). The Water Quality Index (WQI) is a metric used to assess the quality of groundwater by determining its physicochemical properties. Various methods can be used to find out WQI value these are National Sanitation Foundation water quality index (NSFWQ), Canadian Councils of ministers of the environment water quality index, Oregon water quality index (OWQI) and Weighted Arithmetic water quality index in which the Weighted Arithmetic water quality index method and Oregon water quality index are considered for the present work. [6]

The water quality was categorized using the most frequently measured water quality variables by the weighted arithmetic water quality index approach, based on the level of purity. For calculating water quality index three steps were followed. In the first step, each of the nine parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. In the second step, relative weight (Wi) was calculated from the following equation (1)

$$Wi = \frac{wi}{\sum_i^n wi} \qquad (1)$$

In which (Wi) is the relative weight, (wi) is the weight of each parameter and 'n' is the number of parameters. In the third step, a quality rating scale (qi) for each parameter was assigned by dividing its concentration in each water sample by its respective standard as per BIS (Bureau of Indian standards) and the result is multiplied by 100 as shown in equation (2)

$$Qi=(ci/si) \times 100 \qquad (2)$$

And qi is quality rating, Ci represents concentration of each chemical parameter in each water sample in mg/l, and Si is the BIS) water standard for each chemical parameter in mg/l according to the guidelines of the BIS, for computing the WQI, the SIi was first determined for each chemical parameter, which is then used to determine the WQI as per the following equation (3)

$$SIi = Wi \times qi \qquad (3)$$

SIi is the sub-index of the Ith parameter, qi is the rating based on the concentration of ith parameter and n is the number of parameters. The computed WQI values are classified into five types of excellent water, good water, poor water, very poor water and water unsuitable for drinking as shown in table 3 [6-8].

Table 3 Water quality classification based on WQI value

WQI Value	Rating Of Water Quality
0-25	Excellent Quality
26-50	Good Water
51-75	Poor Quality
76-100	Very Poor Quality
Above 100	Unsafe for Drinking

OWQI combines eight water quality factors into a single number to assess the overall water quality of Oregon streams and the applicability of this method to other geographic regions. It expresses water quality status and trends for the legislatively instructed water quality status assessment. The index is free from arbitration in weighing the parameters and employs the concept of harmonic averaging. The mathematical expression of this WQI method is given by

$$WQI = \sqrt{\frac{n}{\sum_{i}^{n} \frac{1}{SIi^2}}} \quad (4)$$

In the above expression n is no. of subindices, SIi is Sub Index of ith parameter
Furthermore, the rating scale of this OWQI has also been categorized in various classes, which is mentioned in table 4 [7].

Table 4 Water Quality Rating as per Oregon WQI

WQI	Rating of Water Quality
90-100	Excellent Water Quality
85-89	Good Water Quality
80-84	Fair Water Quality
60-79	Poor Water Quality
0-59	Very Poor Water Quality

BIS STANDARD FOR DRINKING WATER QUALITY

The quality of groundwater has been assessed by comparing each parameter with the standard desirable limits of that parameter in drinking water as prescribed by BIS as stated in table 5[8].

Table 5 Standard Physical and Chemical parameters as per BIS

Characteristics	BIS Standards	WHO Standards
pH	6.5-8.5	7-8.5
Turbidity, mg/l	1-5	1-5
T.D.S., mg/l	500-2000	300
Electrical Conductivity, micro siemens/cm	300	400
Total Hardness, mg/l	200-600	300
Magnesium, mg/l	30-100	50
Potassium, mg/l	12	12

Nitrate, mg/l	45	45
Sulphate, mg/l	200-400	500

RESULTS AND DISCUSSION

In this section the results obtained after conducting various tests on several samples, have been discussed. The samples have been collected from nearby groundwater sources and samples were collected in clean bottles. All samples were tested in the laboratory within 24 hours from the time of collection. The physio-chemical parameters selected were pH, turbidity, T.D.S., Electrical Conductivity, total hardness, nitrates, magnesium, sulphate, potassium. The quality of groundwater has been assessed by comparing each parameter with the standard desirable limit of that parameter in drinking water as prescribed by BIS.

PHYSICOCHEMICAL PARAMETERS

Sample-wise representation of the water quality parameters of water samples collected from different locations during the month of February, March and April are collected and shown in tables along with their graphical representation below.

Water Quality Parameters of All Samples

Water quality parameters of all samples from 6 nos. of locations obtained from physicochemical analysis in the laboratory are shown in table 6.

Table 6 Water quality parameters of all samples

Property	**February**					
	H1	H2	H3	B1	B2	B3
pH	7.5	7.8	7.7	7.2	7.7	7.8
Turbidity	27.4	25.4	30.3	0.6	0	0
T.D.S.	380	172	192	296	169	193
Electrical Conductivity	883	421.9	485.7	682	396.9	454.2
Hardness	710	489	516	270	193	256
Sulphate	125	112	42.9	1.59	0.65	35.7
Nitrate	28.7	12.7	15.2	10	8.2	7
Magnesium	2.5	2.3	2.2	1.68	1.4	1.5
Potassium	12.6	12.7	12	11.9	3.9	4.5
Property	**March**					
	H1	H2	H3	B1	B2	B3
pH	7.1	8	7.7	7.3	7.6	7.7
Turbidity	214	12.3	47	0	0	0
T.D.S.	383	173	206	297	164	193
Electrical Conductivity	855.4	439	446.3	385.6	391	487.1
Hardness	760	385	503	253	177	234
Sulphate	133	13.7	37.4	0.58	0.32	0.44
Nitrate	30.9	3.6	15	8.3	5.1	6.6
Magnesium	3.6	1.8	2.4	1.6	0.9	1.1
Potassium	16.3	11.9	6.9	12.4	10.4	16
Property	**April**					
	H1	H2	H3	B1	B2	B3
pH	6.9	7.7	7.5	7	7.6	7.4
Turbidity	429	17.21	41.4	0	0	0
T.D.S.	386	188	225	308	157	202
Electrical Conductivity	916.1	451	535.9	734.1	390	469
Hardness	853	405	567	303	189	247
Sulphate	138	14.2	40.1	0.73	0.67	2.41
Nitrate	30.4	7.7	9.4	8.4	2	5.3

Magnesium	3.5	2.2	1.9	1.8	1.1	1.4
Potassium	15.6	10.7	11.7	8.5	4.5	8

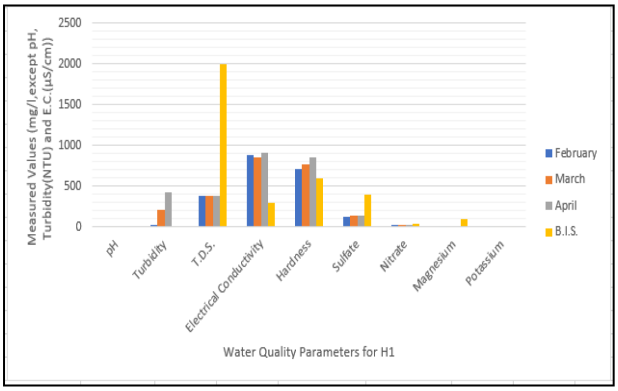

Figure 2 Water quality parameters of sample H1

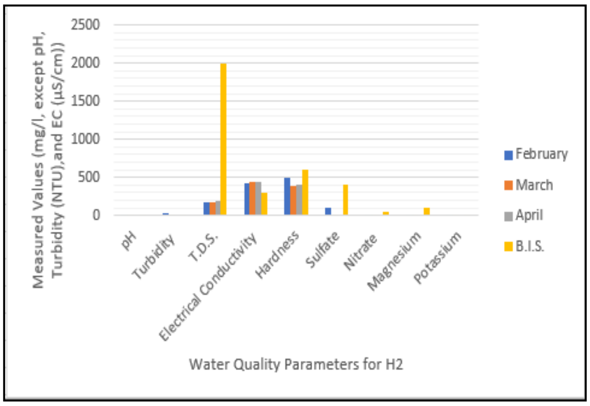

Figure 3 Water quality parameters of sample H2

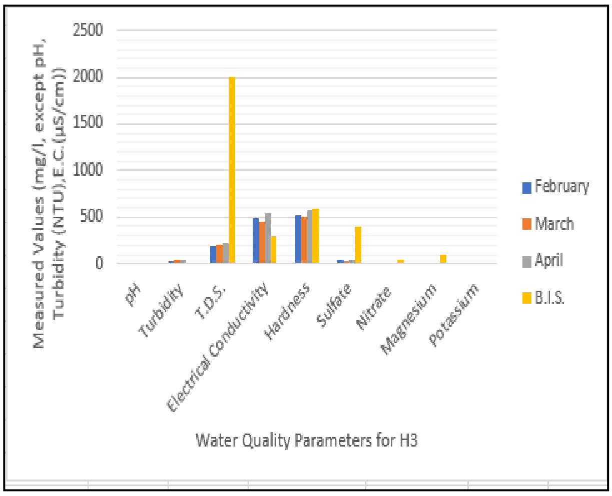

Figure 4 Water quality parameters of sample H3

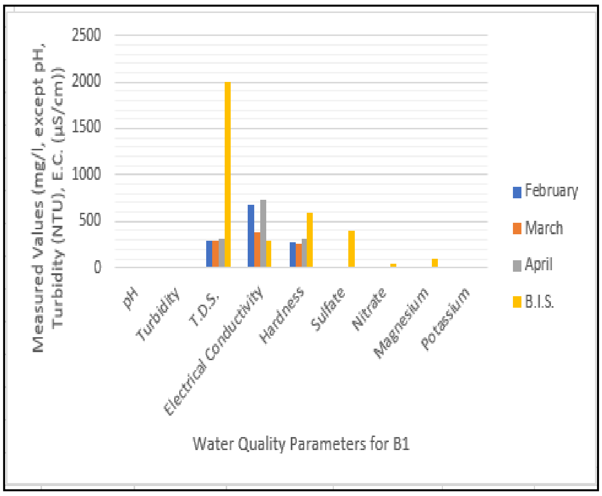

Figure 5 Water quality parameters of sample B1

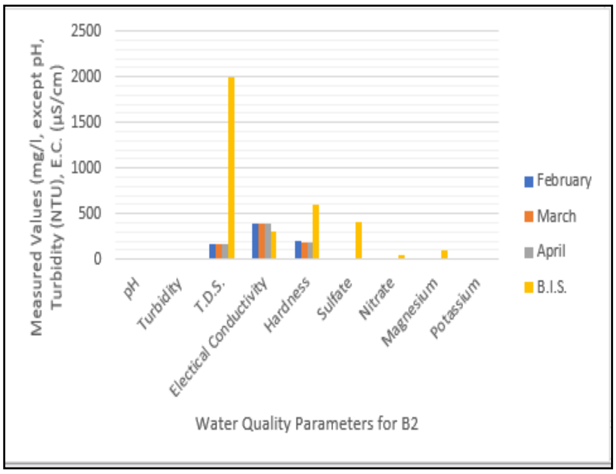

Figure 6 Water quality parameters of sample B2

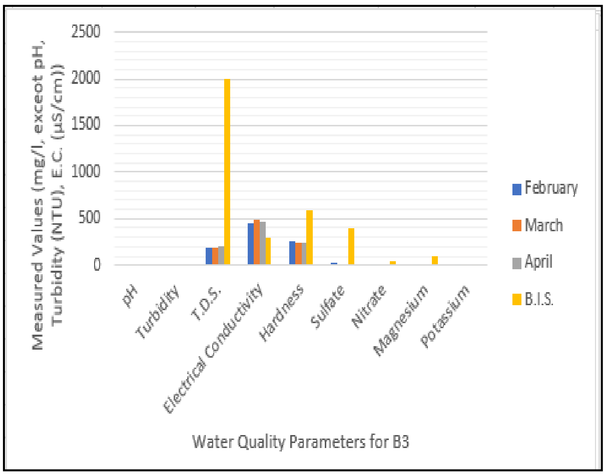

Figure 7 Water quality parameters of sample B3

Figure 2 depicts that water quality parameters Turbidity, Electrical Conductivity, Total Hardness, Potassium is above the drinking water standards as prescribed by B.I.S. Figure 3 describes that water quality parameters Turbidity, Electrical Conductivity, Potassium is above the drinking water standards as prescribed by B.I.S. but for March and April the Potassium concentration is within drinking water standards. Figure 4 depicts that water quality parameters Turbidity, Electrical Conductivity, is above the drinking water standards as prescribed by B.I.S. Figure 5 illustrates that water quality parameters Electrical Conductivity, Potassium is above the drinking water standards as prescribed by B.I.S. but Potassium concentration for the month February and March are within drinking water standards. Figure 6 depicts that water quality parameter Electrical Conductivity is above the drinking water standards as prescribed by B.I.S. Figure 7 shows that water quality parameters Electrical Conductivity, Potassium is above the drinking water standards as prescribed by B.I.S. but Potassium concentration for the month of February and April are within drinking water standards.

WATER QUALITY INDEX OBTAINED BY WEIGHTED ARITHMETIC INDEX METHOD

Water quality indices for all the groundwater samples obtained from Weighted Arithmetic Index Method are shown in Table 7 below.

Water quality index (WQI) was developed by Horton (1965). The assessment of water quality through the determination of groundwater's physicochemical properties is represented by the Water Quality Index (WQI). Various methods can be used to find out WQI value these are National Sanitation Foundation water quality index, Canadian Councils of ministers of the environment water quality index, Oregon water quality index and Weighted Arithmetic water quality index in which we use the Weighted Arithmetic water quality index method. [6]

Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables. For computing water quality index three steps were followed. In the first step, each of the nine parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. In which weight age 5 was given to parameter chloride and sulphate, 4 was given to parameter pH and fluoride and 3 is given to Total Hardness, Total Alkalinity, and Calcium. The maximum weight has been assigned to the parameter nitrate due to its major importance in water quality assessment. So, the water quality indices obtained by Weighted Arithmetic Index Method are shown in Table 7 below

Table 7 Water Quality Index obtained by Weighted Arithmetic Index Method

Sample Source	**WQI (February)**	**Water Quality Rating (February)**	**WQI (March)**	**Water Quality Rating (March)**	**WQI (April)**	**Water Quality Rating (April)**	**Observation**
Suket Handpump	147.11	Unsafe for Drinking	526.17	Unsafe	960.02	Unsafe	No Improvement
Polytechnincal Ground Handpump	117.78	Unsafe for Drinking	76.07	Unsafe	87.25	Very poor	Slight improvement
M.L.S.M. Handpump	124.47	Unsafe for Drinking	152.41	Unsafe	147.03	Unsafe	No Improvement
Baudi Nagoun	53.65	Poor	47.69	Good	50.90	Good	Slight Improvement
Maloh Baudi	36.41	Good	39.55	Good	34.14	Good	No Improvement
Baudi Near Polytechnical Girl Hostel	43.26	Good	49.15	Good	42.2	Good	No Improvement

For sample H2, there is slight improvement in groundwater quality from unsafe to very poor from the month March to April. Also, for sample B1 there is slight improvement in groundwater quality from poor to good from the month February to March.

WATER QUALITY INDEX OBTAINED BY USING OREGON WATER QUALITY INDEX METHOD

Water quality indices for all samples obtained from Oregon Water Quality Index Method are shown in Table 8 below

Sample Source	WQI (February)	Water Quality Rating (February)	WQI (March)	Water Quality Rating (March)	WQI (April)	Water Quality Rating (April)	Observation
Suket Handpump	5.99	Very Poor	12.05	Very Poor	3.17	Very Poor	No Improvement
Poly. Ground Handpump	1.88	Very Poor	2.06	Very Poor	1.76	Very Poor	No Improvement
M.L.S.M. Handpump	2.26	Very Poor	4.91	Very Poor	1.79	Very Poor	No Improvement
Baudi Nagoun	0.14	Very Poor	0.019	Very Poor	0.17	Very Poor	No Improvement
Maloh Baudi	0.001	Very Poor	0.007	Very Poor	0.15	Very Poor	No Improvement
Baudi Near Polytechnical Girl Hostel	1.79	Very Poor	0.01	Very Poor	0.52	Very Poor	No improvement

Table 8 Water Quality Index obtained by Oregon Water Quality Index Method

From above table, it is observed that there is no improvement in groundwater quality from the month of February to April.

COMPARISON OF MONTHLY VARIATION IN GROUNDWATER QUALITY OBTAINED FROM WEIGHTED ARITHMETIC INDEX METHOD AND OREGON WATER QUALITY INDEX METHOD

Comparison of monthly variation in groundwater quality is shown in Table 9 below

Table 9 Comparison of Monthly Variation in Groundwater Quality obtained from Weighted Arithmetic Index Method and Oregon Water Quality Index Method

Sample Source	Variation By Weighted Arithmetic WQI Method	Variation by Oregon WQI Method
Suket Handpump	No improvement	No improvement
Poly. Ground Handpump	Slight improvement	No improvement
M.L.S.M. Handpump	No improvement	No improvement
Baudi Nagoun	Slight improvement	No improvement
Maloh Baudi	No improvement	No improvement

Baudi Near Polytechnical Girl Hostel	No improvement	No improvement

CONCLUSION

Evaluation of the overall groundwater quality through a comprehensive analysis of key water quality parameters pH, turbidity, T.D.S., Electrical Conductivity, total hardness, nitrates, magnesium, sulphate, potassium has been done. It is found that Turbidity, E.C., Total Hardness and Potassium concentration are above drinking water standards in case of Suket Handpump H1 whereas Turbidity, E.C., Potassium concentration are above drinking water standards in case of Polytechnical Ground Handpump H2 and Turbidity and EC of MLSM Handpump H3 are above drinking water standards. In case of Baudis (B1, B2, B3) water quality parameters EC and Potassium concentration are above drinking water standards. The comparison of the water quality parameters with established water quality standard is done. The assessment of the variability in groundwater quality in order to understand monthly variation has been done and it has been found that the groundwater quality of Polytechnical Ground Handpump (H2), Baudi Nagoun (B1) is slightly improved from Unsafe to Very Poor, Poor to Good water quality respectively and there is no change in groundwater quality of Suket Handpump (H1), MLSM Handpump (H3), Maloh Baudi (B2), Baudi near Polytechnical Girl Hostel (B3) from Weighted Arithmetic WQI method. The results obtained from Oregon WQI method shows that there is no improvement in groundwater quality for all six samples and all of them have Very Poor water quality.

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