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Assessment of Ground Water Quality and Suitability for Irrigation Purposes in Parts of Gv-41 Watershed of Aurangabad, Maharashtra, India

S. M. Deshpande
Department of Geology,
Government Institute of Science,
Aurangabad, Maharashtra, India

Saleh Saeed Ali Albani
Department of Geology,
Government Institute of Science,
Aurangabad, Maharashtra, India

***Abstract*— With the increase in population, industrial development, and agriculture, pollution, increasing food production and improving crops in the world need to irrigate the largest area of agricultural land and groundwater suitable for irrigation. According to this idea, a study was conducted to evaluate the groundwater quality in the Indian state of Maharashtra's GV-41 Gangapur area. Thirty samples were taken, examined, and evaluated in this investigation to determine whether the water was suitable for irrigation. Acidity, electrical conductivity, total lupus solids, cations represented by sodium, potassium, calcium, and magnesium, as well as anions represented by bicarbonates, and chlorides, were known as the key parameters for the analysis of the samples. and auxiliary variables such as the Sodium Absorption percentage, Residual sodium carbonate (RSC), Kelly's ratio (KR), Sodium percentage Na%, permeability index (PI), Magnesium absorption ratio (MAR), and Residual Sodium Bicarbonate (RSBC) were calculated to know the quality of irrigation water. Values suggested that the majority of groundwater samples were suitable for irrigation purposes. The USSL and Wilcox diagrams were also used to evaluate the groundwater in the study area.**

***Keywords*— Groundwater; GV-41 watershed; Groundwater chemistry; Irrigational water quality; Aurangabad**

1. INTRODUCTION

Groundwater is considered one of the major sources of irrigation uses in India, especially in the arid rural areas, where agriculture is the main source of income for the population. The increase in population needs for increasing food, drought and climate change have a direct impact on agricultural land; crops and irrigation at the same time Around 275 million or about 20% of arable land in the world is irrigated, with irrigated agriculture accounting for 40% of all crop production (1). Groundwater quality has been deteriorating day by day because of the shrinking water table, improper sanitation, the introduction of chemical compounds, and inefficient or less efficient irrigation practices (2). Accessibility to groundwater is influenced by geography, surface drainage, geology, slope, and land cover. The topographic level and slope are the elements that control the tenacity of the water table's elevation. The drainage pattern also has a strong impact since it affects how quickly rain falls and how much of it may seep into the ground. The amount and distribution of groundwater as well as the permeability of the ground surface are significantly influenced by rainfall (3). The main reason why the quality of soils and the crops cultivated on them has declined is due to the use of irrigation water of poor quality. Due to the presence of these ions in irrigation fluids at high concentrations, the buildup of different ions in the soil mass has been primarily blamed for this degradation. (4, 5, 6, 7). The quality of groundwater is the end product of all the actions and reactions that have been performed on the liquid since it first began to condense in the atmosphere until it is released by a well. As a result, the quantity and makeup of dissolved particles in groundwater determine its quality, which changes from location to location, with water table depth, and from season to season (8). Analysis of the water quality is one of the most crucial components of groundwater investigations. Water quality that is good for, agriculture is revealed by the hydro-chemical research. Additionally, it is feasible to comprehend how the quality of (1, 2) changed as a result of rock-water contact or any other anthropogenic influence (9). The quality of groundwater and soils are primarily influenced by its geogenic sources, such as the weathering and erosion of bedrock, the interaction between rocks and water, and the length of time it remains in the aquifer system. (10). The top soil polluted due to heavy traffic and industrial waste in urban areas (11) but in rural area due to the pesticides. The chemical composition of groundwater must be determined to assess the water quality for irrigation purposes, and identifying potential sources of groundwater pollution is essential to take corrective action should the water quality deteriorate (12). The quality of groundwater has a determining effect on its use for agricultural reasons. In fact, irrigation is by far the largest consumer of water resources, particularly in semiarid and arid regions where the rapid expansion of irrigated agriculture is intimately tied to the availability of appropriate quantity and quality groundwater resources. (13, 14, 15, 16, 17). Aside from their abundance on the planet, groundwater resources are less sensitive to pollution than surface water resources due to the first purification in the soil column via filtration, anaerobic decomposition, and ion exchange. None the less, its pollution resistance is greater in deeper or confined aquifers than in shallow or unconfined aquifers. This is one of the reasons for the global misuse of groundwater. (15, 18,19,20).

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2. STUDY AREA

The study area is situated at 19°47' 03" to 20° 34' 42"N latitudes and 74° 35' 23" to 76° 02' 88"E longitudes in Gangapur tehsil of Aurangabad District (Fig. 1) and located in the district of Aurangabad between encompassing 30 villages which cover an area of about 367.78 km2. It is a watershed called GV-41. The study area is a part of a survey of India, Toposheet no. 47M/1 and 47P/4 drainage systems contributing to the river the Godavari in monsoon from June to October, have a good deal of rainfall, with an annual average rainfall of 650 mm. The study area belonging to the Deccan volcanic province is underlain and surrounded mainly by basaltic lava flows. Weathered fractured basalt acts as good aquifers in this study area (GSDA, 2020). The majority of GV-41 is agricultural land. Moreover, Agriculture is the primary occupation of the vast majority of the inhabitants. Farmers rely on groundwater irrigation during dry seasons. Cotton, cereals, pulses, sugarcane, oil seeds, citrus fruits, mango, banana, and diverse horticulture crops are the main crops.

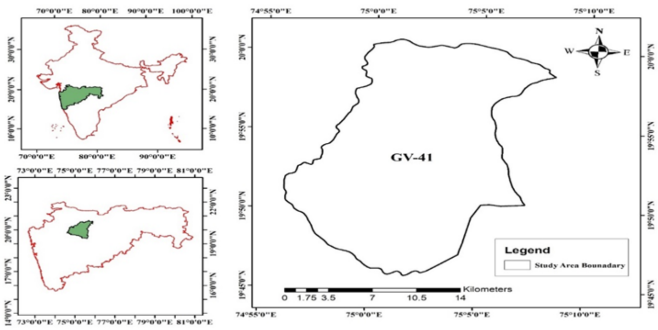

Fig.1 Location Map of the study area.

3. MATERIALS AND METHODS

A total of 30 groundwater samples were collected from dug wells and hand pumps from various locations of the study area during the pre-monsoon season in April (2019), were major ions analyzed such pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), bicarbonate (HCO3), chloride (Cl) and sulphate (SO4) as per the standard protocol prescribed by APHA (1995). Measured for electrical conductivity (EC), PH and total dissolved solids (TDS) by digital meters, and used volumetric titration method for determine Calcium (Ca), magnesium (Mg), bicarbonate (HCO3), chloride (Cl). The flame photometer method is applied to measure the concentration of sodium (Na), potassium (K), and sulphate (SO4) ions, which were measured by the spectrophotometer. Using physicochemical analyses calculated water quality secondary parameters for irrigation such as total hardness (TH), sodium adsorption ratio (SAR), percent sodium (%Na), residual sodium carbonate (RSC), residual sodium bicarbonate (RSBC), Kelley's Ratio (KR), permeability index (PI), Magnesium Adsorption Ratio (MAR).

4. RESULT AND DISCUSSION

In India, agriculture accounts for about 40% of total groundwater extraction. The size of irrigation varies from region to region depending on the diversity of climate, crops and how to grow. Irrigation is essential for agricultural production in the country. The significant increase in the number of crops depends mainly on the quality of groundwater used for irrigation, and water quality plays an important role in maintaining soil structure, accessibility and productivity and in protecting the environment through the type of interchangeable ions in irrigation water. In the study area, groundwater is one of the main sources for irrigation purposes identifying a set of physical and chemical parameters for 30 samples collected from miscellaneous places of the study area such as electrical conductivity EC, dissolved salt ratio TDS, sodium absorption ratio SAR, Sodium Percentage %Na, permeability index PI, Kelly's Ratio KR, Magnesium absorption ratio MAR, Residual sodium bicarbonate (RSBC) and Sodium Carbonate RSC.

These parameters (21,22) methods were used to understand the Na%. In this study, it is seen from Wilcox diagram (1955) when the values of EC are plotted against Na% that 12 groundwater samples fall in the good to the permissible category for irrigation proposes, 9 samples fall in the permissible to a doubtful category, 5 samples fall in doubtful to unsuitable and 4 samples fall in unsuitable category for irrigation purposes (Fig 2).

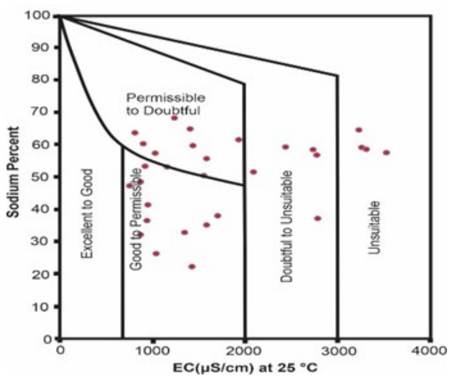

Fig 2. Wilcox Diagram

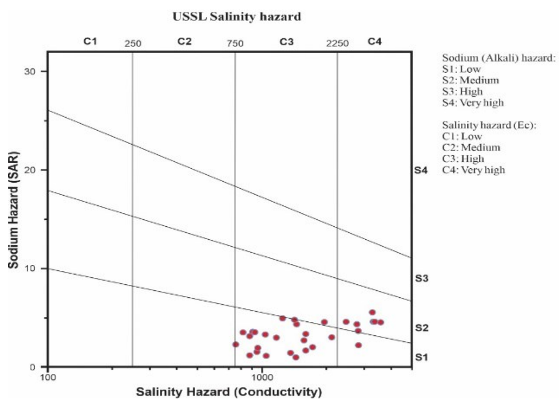

Fig.3 USSL diagram

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By using the method of the United States Salinity Laboratory diagram (USSL 1954) It was observed that 1 groundwater sample fall in the C4S1 category (very high salinity and low sodium hazard), 7 samples fall in the C4S2 category (Very high salinity and medium sodium hazard), 1 sample fall in C3S2 category (high salinity and medium sodium hazard) and 21 samples fall in C3S1 category (high Salinity and low sodium hazard) Fig. 3.

4.1 Kelly's Ratio (KR)

Kelly's Ratio is important for irrigation water quality, it determines the suitability of water for irrigation, when Kelly's ratio is less than one (KR < 1), it signifies a deficit of Sodium in water, so it is suitable for irrigation purposes, and when it is more than one (KR > 1) it indicates an excess quantity of sodium (23). Kelly's Ratio is computed by the formula:

KR = Na ⁄ (Ca + Mg) (All values in meq/l) (24,25). In the study area, Kelly's Ratio ranges from 0.27 to 2.16 with a mean value of 1.12, in this study, 12 water samples showed KR values less than one (KR > 1) are suitable for irrigation, 17 samples fall in the marginal category, and one water samples with KR values more than one (KR > 1) are unsuitable for irrigation purposes in Table 1.

KR =Na/ Ca2+ + Mg2+ (All values in meq/l).

4.2 Sodium Adsorption Ratio (SAR)

The values of Sodium adsorption ratio in groundwater are important for assessing the suitability of water for irrigation purposes (16,26,21,22,27,28,29).

SAR is calculated from the formula given by (22)

SAR =Na+ / [(Ca+2+Mg+2] ½

(All values in meq/l).

The Na+ ions in the water can instantly replace the Mg+2 and Ca+2 ions existing in the soil when groundwater with a high SAR value is introduced to it (30). The proportional mobility of the Na+ ions inside the exchange reactions of soil is additionally determined by SAR. The relative concentration of sodium ions to magnesium and calcium ions is further developed by this ratio (28). Water is classified into four categories based on the SAR values. SAR=10 is deemed excellent (sodium hazard class S-I), SAR=10–18 is good (class SII), SAR = 19–26 is doubtful/fairly poor (class S-III), and SAR > 26 of water is deemed undesirable (class S-IV) (21,22). As shown in (Table 1). The SAR values of the groundwater samples varied from 0.96 to 5.53 with a mean value of 3.19. The SAR values in 30 samples of the study area were found within the excellent to good category for irrigation purposes.

4.3 Residual Sodium Carbonate (RSC)

Water rarely contains carbonate and bicarbonate ions, which are measured relatively and symbolized by the symbol RSC. In contrast, water contains calcium and magnesium ions. When the amount of carbonate and bicarbonate is greater than the amount of calcium and magnesium, the carbonate ions combine with the calcium and magnesium ions to form a solid that settles out of the water, which increases the risk of alkalinity in the soil structure. It also increases the abundance of sodium, which leads to the deterioration of irrigation water and crops. Treatment of such problems is added acid or gypsum.

Carbonates in water + soil calcium ⇒ calcium carbonate (lime deposit in soil).

Residual sodium carbonate (RSC) can be calculated by the following:

RSC = (CO3 + HCO3) – (Ca + Mg). (All values in meq/l).

Groundwater is classified into three categories depending on the RSC values (RSC <1.25 meq/L) is suitable for irrigation, RSC values (1.25-2.5 meq/L) marginally suitable for irrigation purposes and (RSC>2.5 meq/L) unsuitable for irrigation purposes. In the study area, RSC values range from -0.27 to 11.13 with an average of 3.98. I was observed that 20 samples were unsuitable for irrigation 4 samples are less than 1.25 that are suitable for irrigation purposes and 6 samples are between 1.25- 2.25 meq/L which is marginally suitable for irrigation purposes Table 1.

4.4 Residual sodium bicarbonate (RSBC)

Residual sodium bicarbonate (RSBC) is calculated by the following equations (31):

RSBC = HCO3− Ca+2 (meq⁄l).

In the present study, RSBC varied between 1.5 and 13.5 with an average of 6.3 meq/l, 10 water samples was less than (<5 mg/L), this indicates that these samples are safe for agriculture, 17 samples with values from 5-10 which fall in the marginal category and 3 was more than 10 which unsatisfactory for irrigation Table 1.

4.5 Total hardness (TH)

Magnesium is harmful when its concentration in water exceeds the allowable limit of 200 mg/l. Metal ions with bivalent valence and pH also play a key role in increasing sedimentation when heated, which leads to corrosion of water pipes (3,26,32). Total hardness is the sum of calcium and magnesium concentrations. (32,33,34). The degree of hardness is classed as (1) soft: 0-75 mg/L, (2) moderate: 75-150 mg/L, (3) hard: 150-300 mg/L, and very hard > 300 mg/L. In the present study, the results showed that the total hardness (TH) concentrations varied between 268– 580 mg/L with an average of 413.9 mg/L, where all water samples fall in the hard and very hard category (150-300) and (>300 mg/l) respectively. this indicates that it is unsuitable for agriculture.

4.6 Magnesium Adsorption Ratio (MAR)

Magnesium adsorption ratio is important for plant growth, but in the appropriate quantity. When magnesium adsorption ratio values increase more than (50 meq/L) the permissible limit, it is risky for irrigation affects the soil, which reduces agricultural yields (35). In the present study, the results showed that the Magnesium adsorption ratio (MAR) less than 50 meq/L varied between 22.22 to 78.86 meq/L with an average of 54.42 mg/L Table 1. 20 samples are unsuitable for irrigation with MAR more than 50 and 10 samples are suitable for irrigation purposes.

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4.7 Sodium percentage (Na %)

The concentration of sodium is important in the water, it determines the water suitable for irrigation purposes or unsuitable. Referred to as the Sodium Percentage (Na%), the sodium values less than 50 or equal to 50 indicates good quality water and if it is more than 50 indicates unsuitable water quality for irrigation because it causes flocculation and clogging of the inter-granular matrix in soil which leads to reduction of soil permeability, thereby causing degradation of soil. Sodium percentage (Na %) is calculated by the following equation:

$$Na\% = (Na + K) / (Ca + Mg + Na) \times 100 \text{ (All values in meq/l)}$$

In the study area the Sodium percentage %Na was less than 50 (%Na < 50) in 11 samples and exceeded 50 in 19 samples. The maximum value is 68.52 and the minimum value is 22.39 Table 1.

TABLE 1. IRRIGATION GROUNDWATER QUALITY PARAMETERS

Sr. No	SAR	Na%	RSC	RSBC	KR	MAR	PI
1	0.96	22.39	4.26	8.09	0.27	61.50	62.24
2	1.12	26.42	2.49	6.24	0.34	70.75	64.78
3	1.42	32.99	5.28	7.78	0.49	60.24	82.57
4	1.66	35.33	4.15	6.07	0.55	41.52	76.81
5	2.00	38.18	1.53	4.87	0.61	61.35	68.03
6	2.68	50.65	2.94	5.11	1.00	59.91	85.39
7	2.20	37.35	-0.27	2.98	0.56	42.48	58.73
8	4.59	59.38	5.59	8.01	1.44	47.70	85.43
9	4.32	59.95	6.13	8.63	1.49	59.52	90.57
10	4.78	65.12	7.70	10.28	1.87	78.68	100.33
11	3.01	51.77	2.62	4.29	1.06	41.49	82.60
12	3.28	57.57	3.10	4.77	1.35	56.18	92.77
13	2.96	53.33	5.29	8.38	1.03	74.60	87.34
14	5.53	64.80	3.60	5.60	1.82	43.48	86.63
15	4.33	58.71	4.27	6.43	1.42	46.43	85.12
16	2.27	47.48	1.12	3.71	0.87	76.35	80.12
17	1.52	36.68	3.10	5.02	0.57	53.00	81.91
18	1.17	32.32	3.45	5.20	0.43	48.61	81.71
19	3.34	55.92	4.19	5.85	1.26	47.39	90.68
20	4.92	68.52	2.48	3.98	2.16	57.69	95.79
21	4.55	61.76	10.75	13.50	1.61	68.75	98.48
22	4.57	59.52	4.48	7.89	1.47	70.21	84.91
23	4.52	57.78	1.89	3.23	1.36	24.32	78.65
24	4.58	58.79	3.82	6.07	1.42	43.27	82.55
25	3.56	60.53	11.13	12.88	1.51	62.50	113.29
26	3.52	53.54	2.43	4.93	1.15	53.19	79.89
27	3.65	57.00	8.61	9.61	1.22	22.22	91.20
28	3.12	48.72	1.96	5.21	0.94	59.09	74.06
29	3.49	63.90	0.67	1.50	1.73	40.98	93.00
30	1.92	41.57	0.71	2.96	0.70	59.21	74.01
Max	0.96	22.39	-0.27	1.50	0.27	22.22	58.73
Min	5.53	68.52	11.13	13.50	2.16	78.68	113.29
Avg	3.19	50.60	3.98	6.30	1.12	54.42	83.65

4.8 Permeability Index (PI)

Permeability index is important to determine the suitability of water for irrigation purposes. The calculation of the PI depends on the amount of sodium, calcium, magnesium and bicarbonate ions present in the soil and water. Groundwater for irrigation is investigated depending on the Permeability Index (PI). PI can be computed by the formula given below:

$$PI = [(Na + \sqrt{HCO3}) / (Ca + Mg + Na)] \times 100 \text{ (All values in meq /l)}$$

Irrigation water is classified into three Categorization of irrigation water quality based on PI. As shown in Table 1.
In the study area 5 samples are in class II (PI 25-75%), these samples fall in intermediate category for irrigation purposes, and 25 samples in class III (PI >75) which are classified as a good water for irrigation Table 2

TABLE 2. CATEGORIZATION OF IRRIGATION WATER QUALITY BASED ON PI

Sr. No	Limiting value	Category	No. of samples
1	<25%	Class I	-
2	25-75%	Class II	5
3	>75 %	Class III	25

5. CONCLUSIONS

This study shed the light on a set of physical and chemical parameters from thirty GV-41 watershed samples. These parameters include determining groundwater suitability for irrigation purposes, The groundwater in this study has been assessed for irrigation purposes using the following metrics: Sodium Adsorption Ratio (SAR), Percent Sodium (N%), Kelly's Ratio (KR), Residual Sodium Carbonate (RSC), Permeability Index (PI), Magnesium Adsorption Ratio (MAR), and Residual Sodium Bicarbonate (RSBC) which show that the analyzed samples were good for irrigation.
Depend on USSL Diagram classification, 1 groundwater sample fall in the C4S1 category (very high salinity and low sodium hazard), 7 samples fall in the C4S2 category (Very high salinity and medium sodium hazard), 1 sample fall in C3S2 category (high salinity and medium sodium hazard) and 21 samples fall in C3S1 category (high Salinity and low sodium hazard). As per Wilcox Diagram, 12 groundwater samples fall in the good to the permissible category for irrigation proposes, 9 samples fall in the permissible to a doubtful category, 5 samples fall in doubtful to unsuitable and 4 samples fall in unsuitable category.

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