Open access Journal International journal of Emerging Trends in Science and Technology

Suitability of Groundwater Quality for Irrigation

Authors

Latha S[1], G.P. Shivashankara[2], Thanushree M.S [3]

[1]Research Scholar, Perceiving MTech in Health Science and Water Engineering, SJCE, Mysore, Karnataka, India,

E-mail: *lathalucky6@gmail.com*

[2]Professor, Department of Civil/Environmental Engineering, P.E.S College of Engineering, Mandya, Karnataka, India

E-mail: *gpshivashankara@yahoo.com*

[3] Assistant Professor, Department of Environmental Engineering, SJCE, Mysore, Karnataka, India

E-mail: *thanushree.shree@gmail.com*

Abstract

Reconnaissance on the suitability of groundwater quality for irrigation in Tubinakere industrial area, Mandya district, Karnataka was done by determining ion exchange, potential salinity, Cl^-/HCO_3^- ratio, magnesium hazard, percentage sodium, Kelley's ratio and Residual Sodium Bi-Carbonate (RSBC). 94% of the samples are positive in case of both cation exchange indices leading to reverse ion exchange, potential salinity is slightly high making groundwater samples unfit for irrigation purpose. 75% of samples are slightly to moderately affected on the basis of Cl^-/HCO_3^- ratio. Two of samples falls in unsuitable category with Magnesium Hazard >50%. Based on the classification of percentage sodium, maximum of samples falls under excellent, good waters and 87% of samples were suitable for irrigation as per Kelley's ratio. RSBC values were <5meq/L safe for irrigation purposes. The study stated that water quality hazards of potential salinity and ratio of Cl^-/HCO_3^- values indicates that groundwater samples are not suitable for irrigation.

***Keywords**: Industrial effluent, irrigation, sodium, impact.*

1. INTRODUCTION

Groundwater begins with precipitation that seeps into the ground. Nevertheless, the aggregate volume of those tiny water droplets is greater than the volume of all the lakes and rivers of the world combined. In fact, the volume of groundwater is estimated to be more than 30 times the combined volume of all fresh-water lakes in the world and more than 3,000 times the combined volume of all the world's streams [4]. Large scale, concentrated sources of pollution such as industrial discharges, landfills & subsurface injection of chemicals & hazardous wastes, are an obvious source of groundwater pollution. The more difficult problem is associated with diffuse sources of pollution like leaching of agrochemicals & animal wastes subsurface discharges from latrines & septic tanks & infiltration of polluted urban run-off & sewage where sewerage does not exists or defunct. Hence it is important to know the acceptable limit of hazardous loads to crops so as to minimize the deviation from the normal growth [16]. Study of chemical composition of groundwater can give understanding of characteristics of irrigation water and also their pollution status [18].

2. MATERIALS AND METHODOLOGIES

2.1 Study Area

Tubinakere industrial area is located in Mandya taluk, Mandya district, which is 10 Km apart from Mandya, which is surrounded with the agricultural lands. The main objective is to study the impact of industrial wastewater on groundwater quality and specific objectives was to collect and characterize the groundwater samples for various parameters for both domestic and agricultural bore wells to assess the groundwater quality status for irrigation.

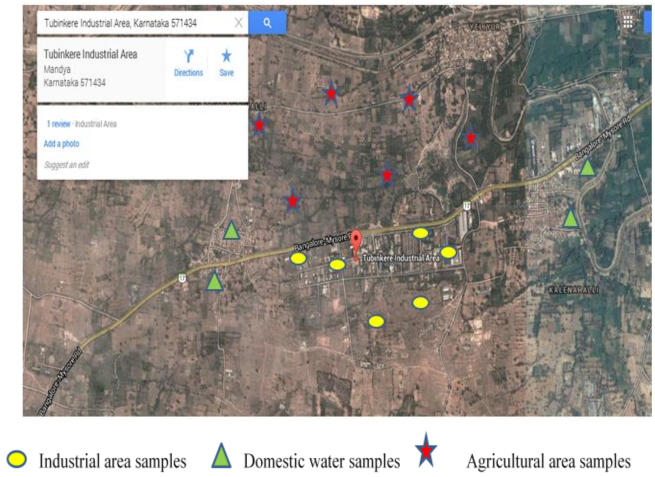

Figure 1: Sampling points indication in Google map.

2.2 Sample Collection and Analysis

The site selection was divided into 4 zones namely at the industrial area (6 samples), 0.5Km and 1Km away from industrial area (6 samples from agricultural lands) and 2 Km away from industrial area (4 samples from Tubinakere and Kalenalli villages domestic bore wells). The water samples were collected in 15 days intervals of 6 trails totally 96 samples and were analyzed as per the guidelines of APHA (1998). The results are shown in Table 1 below.

3. RESULTS AND DISCUSSIONS

The groundwater samples were collected to analyze its chemical properties to check its suitability for irrigation as per the studies and classifications. The study reveals the study on drinking quality reconnaissance by means of water quality index and irrigation water quality reconnaissance through ion exchange, potential salinity, Cl^-/HCO_3^- ratio, sodium percentage, Kelley's ratio, Residual Sodium Bi-Carbonate and magnesium hazard. The results are discussed and tabulated in the Table 1.

3.1 Ion Exchange

Chloro-alkaline indices I and II (CAI-1 and CAI-2) help in determining the ion exchange process in groundwater [11]. It is calculated using the formulae:

$$CAI\ 1 = Cl^- - \frac{(Na^+ + K^+)}{Cl^-} \quad (1)$$

$$CAI\ 2 = Cl^- - \frac{(Na^+ + K^+)}{(SO_4^{2-} + HCO_3^- + CO_3^{2-} + NO_3^-)} \quad (2)$$

All values are measured in meq/l. When there is an exchange between sodium or potassium in groundwater with calcium or magnesium in the aquifer material, CAI I and II are positive and it indicates reverse ion exchange. During ion exchange process, there is exchange between calcium or magnesium in groundwater with sodium or potassium in the formation. In this case both the indices are positive except the sample 9 which undergo ion exchange. This observation indicates that the reverse ion exchange is the leading process in the groundwater.

3.2 Potential Salinity

The suitability of water for irrigation is not dependent on soluble salts. Because, the low solubility salts precipitate in the soil and accumulate with successive irrigation, the concentration of highly soluble salts increases the soil salinity [3]. Potential salinity is defined as the chloride concentration plus half of the sulfate concentration as showed below:

$$P{:}S = Cl^- + \frac{1}{2} SO_4^{2-} \quad (3)$$

All ionic concentration is in meq/L. The potential salinity of the water samples range from 0.83 to 21.34 meq/L (Table 1). The potential salinity in the groundwater of the studied area nearly is high, thus, making the water unsuitable for irrigation usage. High values of potential salinity in the area can be ascribed to high chloride content since the industrial area which might contribute the effluents which potentially increases the salinity value.

3.3 Cl^-/HCO_3^- Ratio

The salinization amount in the groundwater can be classified using the Cl^-/HCO_3^- ratio ratios [9]. The Cl^-/HCO_3^- ratio was computed for the groundwater samples of the study area and given in Table 2 below. The four groundwater samples in the study area having less than 0.5 Cl^-/HCO_3^- ratio ratios are not affected by salinization. All the other groundwater samples in the study area are in slight to moderate salinity affected range. However, the values of Cl^-/HCO_3^- ratio high in some stations do not indicate the seawater intrusion [14].

Table 1: Average concentration of cations, anions and other groundwater quality illustrations for status of irrigation

NO	Ca	Mg	Na	K	HCO_3^-	Cl	SO_4	NO_3	PS	Cl^-/HCO_3^-	%Na	KR	MH, %	RSBC	CAI-1	CAI-2
S_1	0.44	0.18	0.46	0.04	3.57	0.5	1.51	0.44	0.83	0.14	44.6	0.74	29.03	3.13	0.0	0.0
S_2	0.48	0.81	0.47	0.04	2.93	0.64	1.41	0.51	0.99	0.21	28.33	0.36	62.79	2.45	0.20	0.02
S_3	0.80	0.86	1.03	0.19	3.20	4.78	2.37	0.54	4.99	1.49	42.36	0.62	51.8	2.4	0.74	0.58
S_4	1.77	1.76	1.35	0.16	4.58	10.33	2.63	0.53	10.52	2.25	29.96	0.38	49.85	2.81	0.85	1.14
S_5	0.86	0.18	1.26	0.08	3.94	5.73	1.50	0.46	6.06	1.45	56.3	1.21	17.3	3.08	0.76	0.74
S_6	2.19	1.81	1.75	0.25	4.12	13.75	2.53	0.44	13.94	3.34	33.33	0.43	45.25	1.93	0.85	1.65
S_7	1.32	0.76	0.36	0.06	5.83	3.96	1.57	0.35	4.27	0.68	16.8	0.17	36.53	4.51	0.89	0.45
S_8	0.81	0.54	0.33	0.05	4.13	4.28	2.16	0.42	4.51	1.03	21.97	0.24	40.0	3.32	0.91	0.58
S_9	0.65	0.53	6.45	0.06	3.43	5.87	3.31	0.37	6.02	1.71	84.65	5.46	44.91	2.78	-0.11	-0.09
S_{10}	4.90	0.86	0.42	0.05	4.23	21.17	2.83	0.57	21.34	5.0	7.54	0.07	14.93	-0.67	0.97	2.71
S_{11}	5.74	1.53	0.95	0.05	4.15	11.50	2.55	0.51	11.69	2.77	12.09	0.13	21.04	-1.59	0.91	1.45
S_{12}	4.79	1.76	0.35	0.04	3.42	17.65	3.90	0.62	17.78	5.16	5.62	0.05	26.87	-1.37	0.97	2.17
S_{13}	1.11	0.46	0.36	0.06	4.60	1.49	2.46	0.41	1.69	0.32	21.11	0.23	29.29	3.49	0.71	0.14
S_{14}	0.60	0.56	0.36	0.06	4.37	2.20	2.32	0.43	2.41	0.5	26.58	0.31	48.27	3.77	0.81	0.25
S_{15}	134	0.52	0.32	0.06	4.38	1.7	2.96	0.48	1.86	0.38	16.96	0.17	27.95	3.04	0.77	0.16
S_{16}	1.47	0.53	0.34	0.06	4.18	2.53	2.95	0.41	2.69	0.6	16.66	0.17	26.5	2.71	0.84	0.28

* PS-potential salinity, %Na- percentage sodium, KR- Kelley's ratio, MH-Magnesium Hazard (in %), RSBC-Residual Sodium Bicarbonate, CAI-1&2- Chloro-Alkaline Indices 1&2.

S_1 to S_6 = Industrial bore wells; S_7 to S_{12}= Agricultural bore wells; S_{13} to $_{S16}$= Domestic bore wells.

Table 2: Classification of irrigation water on the basis of Cl^-/HCO_3^- ratio

Classification	Cl^-/HCO_3^- ratio ratio	Sample points of bore wells
Not affected waters	<0.5	1,2,13,15
Slightly to moderately affected waters	0.5–6.6	3,4,5,6,7,8,9,10,11,12,14,16
Severely affected waters	>6.6	-

3.4 Percentage Sodium

Sodium concentration in groundwater is a very important parameter in determining the irrigation quality. The formula used for calculating the sodium percentage was

$$\% Na = \frac{(Na^+ + K^+)}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \qquad (4)$$

Where all the ionic concentrations are in meq/l. The determined valued of sodium percentage lies between 5.62 and 84.65. The maximum allowable limit of sodium percentage in groundwater is 60 % [10]. In irrigation water if the sodium concentration became high, sodium ions tends to replace the Mg^{2+} and Ca^{2+} ions by absorbed clay particles.

Hence, water and air circulation is restricted during wet conditions, and such soils become hard in dry conditions [1], [12], [13]. Chemical weathering of rock forming minerals, dissolution–precipitation of secondary carbonates, and ion exchange between water and clay minerals are some of the general reactions responsible for the geochemical constitution of the groundwater. Dissolution of both primary silicate and carbonate minerals may lead to the increase of calcium, sodium, magnesium, and bicarbonate, which increase the value of pH [8]. The low sodium in some of the samples is due to the ion exchange with calcium and magnesium in clays, which is common in saline groundwater [2].

Table 3: Classification of irrigation water on the basis of percentage sodium.

Class	% Na (standard)	% Na for study area(observed)
Excellent water	<20	5.62-16.96 (samples 7, 10, 11,12, 15,16)
Good water	20-40	21.11-33.33 (samples 2,4,6,8,13,14)
Permissible water	40-60	42.36-56.3 (Samples 1,3,5)
Doubtful water	60-80	-
Unsuitable water	>80	84.65 (Sample 9)

3.5 Kelley's ratio (KR)

Kelley's ratio was used to classify the irrigation water quality [6], which is the level of Na^+ measured against calcium and magnesium. The formula for calculating the Kelley's ratio is as follows:

$$KR = \frac{Na^+}{(Ca^{2+} + Mg^{2+})} \quad (5)$$

Where the concentration of ions are in meq/L. Kelley's ratios for all the groundwater samples are calculated and it lies between 0.05 and 5.46 meq/L. Kelley's ratio value less than one is suitable for irrigation and more than one is unsuitable [14], [15]. According to this classification, all the samples were suitable for irrigation except the samples S_5 and S_9.

3.6 Residual Sodium Bicarbonate (RSBC)

The RSBC is calculated by the following equation [5].

$$RSBC = HCO_3^- - Ca^{2+} \quad (6)$$

Where concentrations are expressed in meq/L. Gupta and Gupta (1987) classified water on the basis of ''RSBC''. RSBC was classified as satisfactory (<5 meq/L), marginal (5–10 meq/L) and unsatisfactory (>10 meq/L) [5]. The calculated values of ''RSBC'' are presented in table 1 for all the groundwater samples. The RSBC of groundwater samples ranged from -1.59 to 4.51 meq/L. According to the RSBC values, all groundwater samples collected were found to be satisfactory (<5 meq/L) according to the criteria set by [5]. The RSBC values are <5 meq/L and are therefore considered safe for irrigation purposes.

3.7 Magnesium Hazard (MH)

In most waters calcium and magnesium maintains a state of equilibrium. A ratio namely index of magnesium hazard was developed by [7]. According to this, high magnesium hazard value (>50 %) has an adverse affect on the crop yield as the soil becomes more alkaline.

$$MH = \frac{Mg^{2+}}{100 * (Ca^{2+} + Mg^{2+})} \quad (7)$$

In the study area the magnesium hazard values falls in the range of 14.93 to 62.79 % (Table 1). In the study area, all the samples collected showed MH ratio <50 % (suitable for irrigation) while two of them (samples 2 and 3) falls in the unsuitable category with magnesium hazard >50 %. The evaluation illustrates that >50% MH samples can cause adverse effect on the agricultural yield.

4. CONCLUSIONS

The study concluded with 94% of the samples were leading to reverse ion exchange, potential salinity was slightly high making groundwater samples unfit for irrigation purpose. Cl^-/HCO_3^- ratio showed that 75% of samples are slightly to moderately affected for irrigation uses. The classification based on percentage sodium falls as excellent and good waters. 87% were suitable for irrigation as per Kelley's ratio. Magnesium hazard and RSBC results showed that groundwater was safe for irrigation purposes. The potential salinity and Cl^-/HCO_3^- ratio study showed that groundwater quality was unfit for irrigation purpose.

5. REFRENCES

1. Collins R, Jenkins A (1996) "The impact of agricultural land use on stream chemistry in the middle Hills of Himalaya, Nepal". J Hydrol 185(71):86
2. Cartwright I, Weaver TR, Fulton S, Nichol C, Reid M, Cheng X (2004) Hydrogeochemical and isotopic constraints on the origins of dryland salinity, Murray Basin, Victoria, Australia. Appl Geochem 19:1233–1254
3. Doneen LD (1964) Water quality for Agriculture. Department of Irrigation, University of California, Davis, p 48.
4. Groundwater Quality Series: GWQS/ 09/2006-2007 Status Of Groundwater Quality In India -Part-I Central Pollution Control Board (Ministry Of Environment And Forests)
5. Gupta SK, Gupta IC (1987) Management of saline soils and water. Oxford and IBM Publ. Co, New Delhi
6. Kelley WP (1940) Permissible composition and concentration of irrigation waters. In: proceedings of the ASCE 66, pp 607
7. Paliwal KV (1972) Irrigation with saline water) [Z]. Monogram No. 2 (new series). IARI, New Delhi, p 198
8. Rouabhia A, Baali F, Fehdi Ch, Kherici N, Djabri L (2009) Hydrochemical and isotopic investigation of a sandstone aquifer groundwater in a semiarid region, El Ma El Abiod, Algeria. Environ Geol 57(8):1699–1705
9. Revelle R (1941) Criteria for recognition of sea water in groundwaters. Trans Amer Geophys Union 22:593–597
10. Ramakrishna (1998) Groundwater, Handbook, India.
11. Schoeller H (1965) Qualitative evaluation of groundwater resources. In: methods and techniques of groundwater investigations and development, UNESCO, 99 54–63.
12. Saleh A, Al-Ruwaih F, Shehata M (1999) Hydrogeochemical processes operating within the main aquifers of Kuwait. J Arid Environ 42:195–209
13. Subramani T, Elango L, Damodarasamy SR (2005) Groundwater quality and its suitability for drinking and agricultural use Chithar River Basin, Tamil Nadu, India. Environ Geol 47:1099–1110
14. Srinivas Y, Hudson Oliver.D, Stanley Raj .A and Chandrasekar.N "Evaluation of groundwater quality in and around Nagercoil town, Tamilnadu, India: an integrated geochemical and GIS approach", *Applied water science-springer link*, vol-3, 2013, pp: 631-651.
15. Srinivasamoorthy.K, Gopinath.M, Chidambaram.S, Vasanthavigar.M and Sarma.V.S "Hydrochemical characterization and quality appraisal of groundwater from Pungar sub basin, Tamilnadu, India", *Journal of King Saud University-science direct journal*, vol-26, 2014,PP: 37-52.
16. Shivashankara G.P and Puneeta H.S "Quality status of water in village ponds for irrigation", *Nature Environment and Pollution Technology- Technoscience publications*, vol-3, No-2, 2004, PP: 243-247.
17. APHA 1998. Standard Methods for the Examination of Water and Wastewater. 20th ed. American Public Health Association, New York.
18. Thanushree M.S and Latha S "Quality status of groundwater around industrial area for irrigation", proceeding of the 2nd International Conference on Current Trends in Engineering and Management ICCTEM-2014.