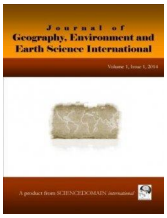

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Groundwater Quality Assessment for Drinking Purpose Using Water Quality Index Method in Industrial Area of Dindigul Corporation, Tamilnadu, India

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Authors' contributions

This work was carried out in collaboration between both authors. Author JM designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript, managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The present study comprised to evaluate the status of physico-chemical contaminants in groundwater of Dindigul Corporation, Tamilnadu, India. Thirty ground water samples were collected from different locations in the study area. The physico-chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Chloride (CL) and Sulphate (SO_4) have been analysed. An attempt has been made to find the suitability of groundwater quality for drinking purpose through water quality index (WQI) method by comparing with the WHO Standard. As the result, all the

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ground water samples sites fall under exceeding the permissible limit which indicates unsuitable for drinking purpose. The different type of industrial activities is spread over in the study area. Especially the tanneries are found in western part of the study area which caused high mineral contents in the ground water.

Keywords: Groundwater; Tannery; Dindigul Corporation; pH; WQI.

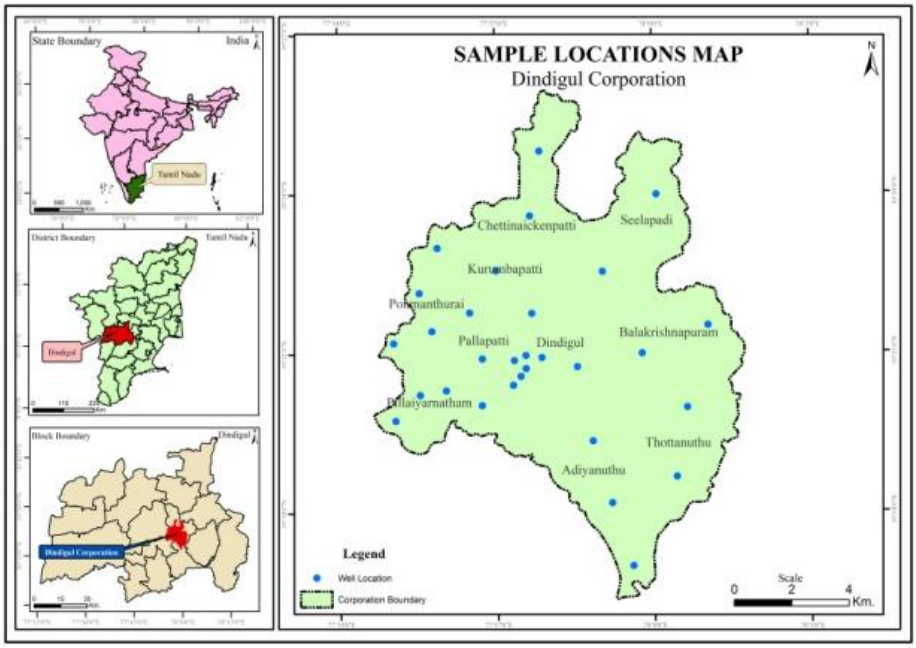
1. INTRODUCTION

Groundwater is an important natural resource serving as a reliable source of drinking water for many people worldwide, especially in developing countries. In India groundwater is the major source of drinking water in rural as well as in urban area. The hydro-chemical characteristic of groundwater of Dindigul Corporation, Tamilnadu, India was selected to evaluate the suitability of groundwater for drinking purposes. The study area has a suitable location to found the different type of industries such as lock industries, leather tanneries, cotton industries, soap industries, flour mills etc. More than 65 tannery units are located in the western part of the study area. The tanneries discharged solid and liquid waste into the nearer surface. The groundwater contaminated due to the toxic effluent from these tanneries. Groundwater quality in the study area for drinking purpose was examined by analysing various chemical parameters such as pH, Electric conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Chloride (CL) and Sulphate (SO4) by comparing with the WHO standards.

1.1 Study Area

Dindigul is a city located in the south Indian state of Tamilnadu and lies between 10°26'00" N to 10°16'00" North latitude and 77°55'00" E to 78°2'00" E longitude. Its mean sea level is 280.11 and covering a geographical area of 110.20 sq.km. Dindigul Corporation includes 10 villages.

Dindigul municipality upgraded to a municipal corporation in April 2013. The study area is a plain area and lies at an elevation of about 280 meters above mean sea level which covered by crystalline metamorphic rocks. Two major groups of soil such as black and red soils are found in the study area and receive rainfall during northeast monsoon and southwest monsoon. The total population of the study area is 3,24,378 persons as per 2011 census.



Map 1.

2. MATERIALS AND METHODS

Within the study area 30 ground water samples were collected in one litter polythene bottles from bore wells in August 2018. The bottles were cleaned and rinsed with sample water before sampling [1]. The water samples were sent to the laboratory to analyse the parameters. Water quality parameters were analysed through pH, EC, TDS, TH, Ca, Mg, Na, K, CL, and SO_4 for drinking purpose by comparing with WHO standard [2].

The Weighted arithmetic index method (Brown, 1972) used for the calculating Water Quality Index (WQI) of the ground water for drinking purpose in following formula.

$$WQI = \sum_{n=1}^{n} q_n W_n / \sum_{n=1}^{n} W_n \quad (1)$$

Where, $\mathbf{W_n}$- unit weight for the $\mathbf{n^{th}}$ parameter, $\mathbf{q_n}$ - Quality Rating index for $\mathbf{n^{th}}$ water quality parameter

The following steps are used to calculate WQI

(i) Calculation of Sub Index of Quality Rating (q_n)

The value of ***qn*** is calculated using the following equation.

$$q_n = 100[V_n - V_{io}]/[S_n - V_{io}] \quad (2)$$

Where, $\mathbf{V_n}$ = Estimated value of the $\mathbf{n^{th}}$ parameter at a given sampling station.
$\mathbf{S_n}$ = Standard permissible value of the $\mathbf{n^{th}}$ parameters
$\mathbf{V_{io}}$ = Ideal value of $\mathbf{n^{th}}$ parameter in pure water.

(ii) Calculation of Quality Rating for pH

For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5 (for polluted water) [3]. Therefore, the quality rating for pH is calculated from the following relation:

$$q_{pH} = 100\ [(V_{pH} - 7.0)/ (8.5 - 7.0)] \quad (3)$$

Where, $\boldsymbol{V_{pH}}$ = observed value of pH during the study period.

(iii) Calculation of Unit Weight (W_n)

Calculation of unit weight ($\mathbf{W_n}$) for various water quality parameters are inversely proportional to the recommended standards value $\mathbf{S_n}$ of the corresponding parameters [4].

$$W_n = K/S_n \quad (4)$$

Where, ***Sn*** = Standard value for $\boldsymbol{n^{th}}$ parameters.

K = Proportional constant, and calculate using the following equation:

$$K = 1/\Sigma\ (1/S_n) \quad (5)$$

3. RESULTS AND DISCUSSION

pH is a measure of the hydrogen ion concentration of a solution. The solutions with a high concentration of hydrogen ions have a low pH and solutions with a low concentration of hydrogen ions have a high pH [5]. In general, water with a pH <7 is considered as acidic and with a pH >7 is considered as alkaline. Water with pH 7 is neutral. Based on WHO standard, the permissible limit of groundwater for drinking purpose tends to have pH value in between 6.5 to 8.5. Almost all the groundwater samples in the study area are within the permissible limit [6]. The pH values of the groundwater samples have ranged from 6.6 to 8.4. Within the study area three sample locations fall under pH <7 which represent acidic water. One sample location namely Adiyanuthu central part comes under neutral. Remaining 26 sample locations fall into pH >7 which represent alkaline water. Maximum of 8.4 pH value has found in south-western part of Ponmanthurai. Low pH value of 6.6 has found in southern part of Pallapatti.

The maximum limit of the Electric Conductivity (EC) in drinking water is prescribed as 1500 µ Siemens/cm. The EC value of the samples ranged from 1060 to 5060 µ Siemens/cm. Based on EC value 4 sample locations fall in suitable for drinking purpose and remaining 26 sample locations unsuitable for drinking purpose. EC is good estimator of TDS. Within the present study all sample location comes under above permissible limit (WHO -500 mg/l). The highest TDS value of 3238.4 mg/l is found in Ponmanthurai Village which is surrounded by Tanneries.

Calcium is the fifth most abundant natural element and it presents in groundwater in soluble form [7]. The desirable limit of Calcium concentration for drinking water is specified as 75 mg/l (WHO). In the study area the calcium varies from 4 mg/l to 258 mg/l. 6 sample locations are suitable for drinking purpose and

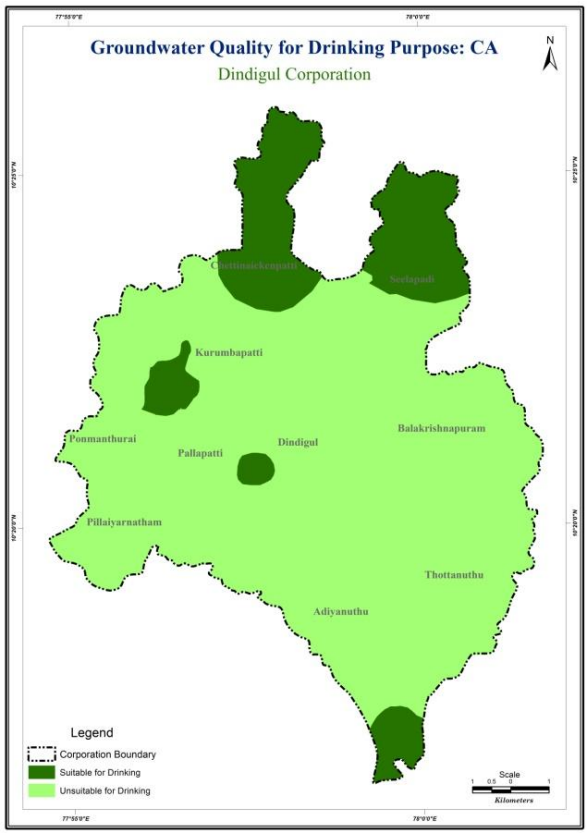
remaining 24 water sample locations are not suitable for drinking purpose. The content of calcium is highly occurred in western part of the study area which included Ponmanthurai, Pallapatti.

According to WHO standard the permissible limit of magnesium should be 30 mg/l. In the study area the Mg range is from 4.8 mg/l to 164.7 mg/l. The highest Mg value about 164.7 mg/l is found in Pallapatti village. 12 sample locations fall under permissible limit which inclusive of North and Southern part of the study area shows suitable for drinking purpose. Remaining 18 sample locations are not suitable for drinking purpose.

Total hardness of groundwater is very important parameter in determining the groundwater quality for drinking purpose [8].

Table 1. Evaluation of ground water quality for drinking purpose based on chemical parameters

Parameters	Who permissible limit	No of sample location suitable for drinking purpose	No of sample location not suitable for drinking purpose
EC	1500	4	26
TDS	500	Nil	30
TH	100	1	29
Ca	75	6	24
Mg	30	12	18
Na	200	10	20
K	12	Nil	30
Cl	75	8	22
SO4	200	7	23



Map 2.

Water hardness is measured by the concentration of calcium and magnesium.

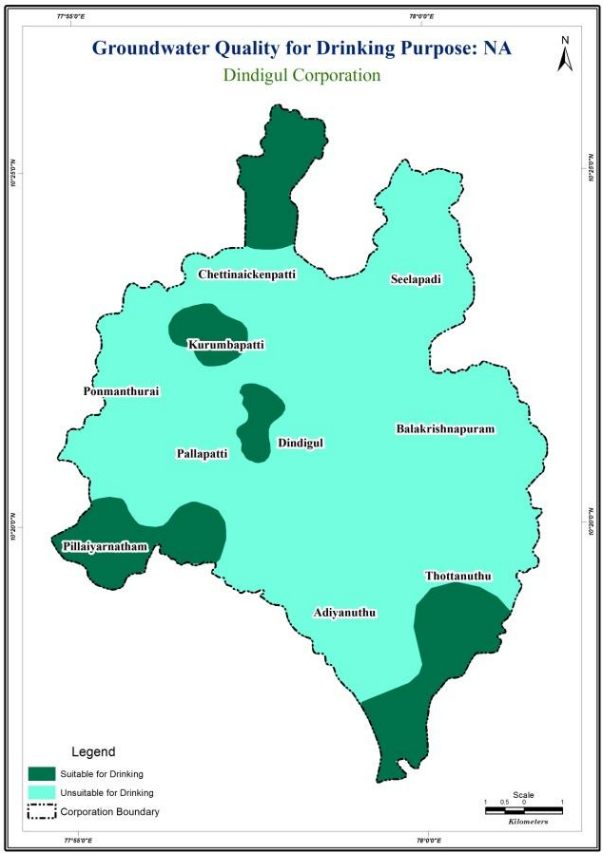
TH = ppm of Ca x 2.50 + ppm of mg x 4.12 (6)

According to WHO standard specifications for drinking water the desirable limit of TH is 100 mg/l [9]. All the water sample locations having above the permissible limit and represent not suitable for drinking purpose except one sample location namely southern part of Chettinaikenpatti in the study area (10 mg/l).

Sodium is a highly soluble chemical element. The high sodium concentration within the study area is caused by tannery effluent [10]. The WHO permissible limit of sodium is 200 mg/l. The sodium concentration of this study area ranges from 78.2 mg/l to 579.14 mg/l. 10 sample location fall under permissible limit and remaining 20 sample location are not suitable for drinking purpose.

Potassium components are used in tanning process. The intake of potassium compounds may be harmful. According to WHO standards, the permissible limit for Potassium is 12 mg/l. In the present study potassium range varies from 19.6 mg/l to 109.7 mg/l [11]. The potassium concentration of all water samples indicate above the permissible limit and it indicates not suitable for drinking purpose [12]. Within the study area chloride range varies from 88.75 to 837.8 mg/l [13]. The WHO limit for chloride in drinking water is 200 mg/l. About 8 sample locations fall under suitable for drinking purpose and 22 water sample location comes under unsuitable for drinking purpose.

Sulphate has laxative effects and imparts an unpleasant taste of water. High concentration of sulphate can cause diarrhoea in human especially infants [8]. The sulphate concentration in the present study varies from 48 mg/l to 1612.8 mg/l. WHO limit for sulphate is 200 mg/l. Within the study area 7 water sample locations fall under permissible limit which indicate good quality water for drinking purpose [14]. The remaining areas come under unsuitable for drinking purpose.



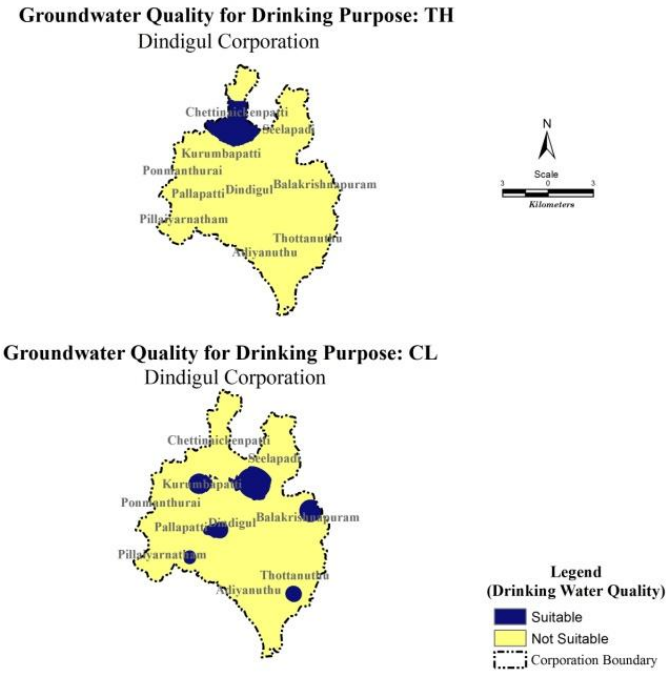
Map 3.

3.1 Water Quality Index

Water Quality Index (WQI) is computed to reduce the overall water quality data to a single numerical value, reflects the composite influence of different water quality parameters. In the study, ten parameters were chosen for calculating of water quality index [15]. The WQI has been determined by using a standard of the drinking water quality recommended by World Health Organization. Table 2 represent water quality index level and status. WQI of each sample locations of the study area are summarised using above mentioned formula. Table 3 shows calculation of water quality index for sample location 1 and remaining sample locations also calculated as per method.

Table 2. Water quality index level and status

Water quality index level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking



Map 4.

Table 3. Calculation of water quality index in sample (1)

Parameters	Observed value V_n	Standard values S_n	Unit weight w_n	Quality rating q_n	w_nq_n
PH	7.1	8.5	0.4471	83.5294	37.3426
EC	1810	1500	0.0025	120.6667	0.3057
TDS	1158.4	1000	0.0038	115.8400	0.4402
TH	325.1	500	0.0076	65.0200	0.4942
Ca	122	75	0.0507	162.6667	8.2418
Mg	4.8	30	0.1267	16.0000	2.0267
Na	244.9	200	0.0190	122.4500	2.3266
K	35.2	12	0.3167	293.3333	92.8889
SO4	288	200	0.0190	144.0000	2.7360
Cl	330.2	250	0.0152	132.0800	2.0076
			Σw_n=1.01	**Σq_n=1255.59**	**Σw_nq_n =148.81**
WQI = Σq_nw_n / Σw_n = 148.81/1.01= 147.60					

Table 4. Water quality index value of sample locations in Dindigul Corporation

Samples	WQI	Samples	WQI
S1	147.60	S16	136.85
S2	150.09	S17	443.70
S3	186.41	S18	218.19
S4	164.51	S19	227.58
S5	191.81	S20	954.55
S6	134.32	S21	411.81
S7	131.49	S22	125.57
S8	334.22	S23	146.41
S9	160.64	S24	179.81
S10	184.96	S25	182.35
S11	134.05	S26	283.36
S12	142.08	S27	174.19
S13	137.11	S28	211.55
S14	169.95	S29	164.90
S15	147.57	S30	126.66

Table 4 shows that Water Quality Index value of 30 sample locations within the study area. The WQI result in the present investigation shows that all the sample locations are found above 100 values [16]. Generally, in the study area, salt and major ion concentrations in the groundwater are high due to tannery effluent and other industrial activity. Most of the parameters are exceeding the permissible limits as prescribed by WHO standards. As the result, WQI value revealed that the status of the groundwater samples is unsuitable for drinking purpose at all the sample locations in the study area.

4. CONCLUSION

The result of analysis carried out in the present study showed the following concentration ranges: PH (6.6 to 8.4), TH (10 mg/l to1147.6 mg/l), Ca (4 to 258 mg/l), Mg (4.8 to 164.7 mg/l), Na (78.2 to 579.1 mg/l), K (19.6 to 109.7 mg/l), Cl (88.7 to 837.8 mg/l), SO4 (48 to 1612.8 mg/l), HCO_3 (30.5 to 646.6 mg/l). The sample locations analysed were above the guidelines set by WHO standards for drinking water. Assessment of groundwater samples of various parameters indicates that ground water in most part of the study area is chemically unsuitable for drinking purpose especially the western part of the city which is surrounded by tanneries. The suitability of the groundwater for drinking purpose is also determined by Water Quality Index (WQI). As the result all the ground water samples sites fall under exceeding the permissible limit which indicate unsuitable for drinking purpose.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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