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GROUND WATER QUALITY ASSESSMENT OF DROUGHT PRONE AREA - A CASE STUDY

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ABSTRACT

Ground water quality is an important criterion for evaluating the suitability of water for drinking and irrigation. The physico-chemical characteristic of ground water quality of drought prone area of Maharashtra, India has been investigated with an objective to assess the water quality status for drinking and irrigation purposes. The water quality parameters considered in the present study were pH, electrical conductivity (EC), temperature, total dissolved solids (TDS), alkalinity, hardness, chlorides, calcium, magnesium, phosphate, sulphate sodium and potassium. The quality parameters were compared with the drinking water standards laid by World Health Organization (WHO), BIS and APHA. The physico-chemical analysis reveals that the ground water of study area is hard to very hard and alkaline in nature. Top priority should be given to water quality monitoring and some technologies should be adopted to make water fit for drinking after treatment. A SAR (Sodium Absorption Ratio) and % sodium value shows that water from all the sampling stations is good for irrigation.

Keywords: Drought Prone Area, Physico-Chemical Characteristics, Groundwater Quality, Drinking Water, Irrigation

INTRODUCTION

Groundwater is the most important source of domestic, industrial and agricultural water supply in the world. Of the total amount global water, only 2.4% is distributed on the

main land, of which only a small portion can be utilized as a fresh water. The available fresh water to man is hardly 0.3 – 0.5% of the total water available on the earth and therefore, its

judicious use is imperative [1]. The fresh water is limited resource [2]. The utilization of water from ages has led to its over exploitation coupled with the growing population along with improved standard of living as a consequence of technological innovations [3, 4]. Therefore, quality of groundwater is deteriorating at a faster pace due to pollution. Groundwater quality also reflects inputs from the atmosphere, soil and water rock reactions as well as pollutant sources such as mining, land clearance, agriculture, acid precipitation and domestic and industrial wastes [5, 6].

Suitability of water for various uses depends on type and concentration of dissolved minerals and groundwater has more mineral composition than surface water [7].

The quality of groundwater is constantly changing in response to daily, seasonal and climatic factors. Continuous monitoring of water quality parameters is highly crucial because changes in the quality of water have far reaching consequences in terms of its effects on man and biota [8].

In India, groundwater resources are under increasing pressure in response to threats of rapid population growth, couples with establishment of human settlements lacking proper water supply and sanitation services. A number of factors such as weathering,

atmospheric precipitation, evaporation and crystallization control the chemistry of water. Apart from natural factors influencing water quality, human activities such as domestic and agricultural practices impact negatively on groundwater resources.

In rural parts of India, groundwater resource is widely exploited for irrigation and other domestic purposes in addition to drinking purpose. Peoples mainly depend on groundwater for their drinking water. Concentration of pollutants more than their permissible limits in drinking water leads to health problems, such as water borne diseases, like flurosis, typhoid, jaundice, cholera, premature baby and other problems, especially in infants [9].

Water quality data is essential for the implementation of responsible water quality regulations for characterizing and remediating contamination and for the protection of the human health and ecosystem. Regular monitoring of groundwater resources thus play a key role in sustainable management of water resources. This study conducted seeks to serve as a preliminary study to access the groundwater quality in terms of drinking and agricultural uses in drought prone area (Dist. Ahmednagar) in India. Thus, in the present research work an attempt has been made to access the physical and chemical parameters

of groundwater like pH, electrical conductivity (EC), temperature, total dissolved solids (TDS), alkalinity, hardness, chlorides, calcium, magnesium, phosphate, sulphate sodium and potassium. The analyzed data was compared with standard values recommended by World Health Organization (WHO), BIS and APHA.

MATERIALS AND METHODS

Study Area

This study focuses on the ground water quality index of the drought prone area of Maharashtra (Dist. Ahmednagar), India (**Figure 1**). Climatically, it falls in the rain shadow zone of the Sahyadris, the situation that hinders agricultural development in particular leaching to overall underdevelopment. The region is very irregular and hilly, consisting of a series of plateaus and tablelands at various heights, the highest of them being the Kanhur plateau, formed by the widening out of the Harischandragadh range. Its average height is about 900 meters above mean sea level though a few points rise to above 1000 meters. The Ahmednagar district can be located between $18^{\circ} 49' 40''$ N and $19^{\circ} 21' 13''$ N. Latitude and $74^{\circ} 10' 22''$ E. and $74^{\circ} 38' 34''$ E. Longitude. Rainfall throughout is very scanty. The annual average rainfall of the area is 574 mm. It is always very erratic

and uncertain leading to frequent crop failures and consequent drought. A hot summer and general dryness characterize the climate during major part of the year except during southwest monsoon season. The cold season commences from December and ends in the month of February. The period from March to the first week of June is the hot season. It is followed by the southwest monsoon season, which lasts till the end of September; October and November constitute the post-monsoon season.

The main crops grown within the study area include pearl millet, wheat, sorghum, pea, moong, onion as well as various types of oilseeds [10]. Agricultural water management system can be categorized as either those under complete water control with short duration crops. The entire area lies under rain-fed or partial water control systems where small dams or groundwater supplies are used for supplementary watering to grow crops during the monsoon (Kharif) season and dry winter (Rabi) [11].

Experimental Work

Sampling was carried out at random, covering at least one sample in a square kilometer area. Water from bore wells was extracted using hand pumps. Samples were collected in clean and sterile two liter polythene cans and stored in an icebox. Date, time of collection and

locality of the area were recorded properly. Five to six water samples were collected from each sampling station. The samples were analyzed for physical parameters such as pH, electrical conductivity (EC), temperature, total dissolved solids (TDS) (using water quality analyzer) and chemical parameters such as alkalinity, hardness, chlorides, calcium, magnesium (using titrimetric method), phosphate, sulphate (using spectrophotometer) and sodium and potassium (using flame photometer). Analytical techniques as described by Trivedi and Goel are adopted for physico-chemical analysis [12]. The results are summarized in **Table 2**.

Estimation of Water Quality Index (WQI)

The concept of Water Quality Index (WQI) is to represent gradation in water quality (**Table 1**). It indicates a single number like a grade which gives the overall water quality at a certain area and time based on several water quality parameters. It is also defined as a rating reflecting a composite influence in overall quality of water and a number of water quality parameters. But the uses of water are manifold and quality of water required for each use varies tremendously. Water Quality Index (WQI) is very useful tool for communicating the information on overall quality of water [13, 14]. It is very useful and

efficient method for assessing the quality of water [15].

To determine the suitability of the groundwater for drinking purpose, WQI is computed adopting the following formula [16],

$$\text{WQI} = \text{Antilog} [\sum W_n^n \log_{10} q_n] \dots\dots\dots(1)$$

Where,

W, Weightage factor (W) is computed using the following equation,

$$W_n = K/S_n \dots\dots\dots(2)$$

and K, proportionality constant is derived from,

$$K = [1/\sum_{n=1}^n 1/S_i] \dots\dots\dots(3)$$

S_n and S_i are the WHO / ICMR standard values of the water quality parameter.

Quality rating (q) is calculated using the formula,

$$q_{ni} = \{[(V_{\text{actual}} - V_{\text{ideal}}) / (V_{\text{standard}} - V_{\text{ideal}})] * 100\}$$

.....(4)

Where,

q_{ni} = Quality rating of i^{th} parameter for a total of n water quality parameter obtained from laboratory analysis.

V_{actual} = Value of the water quality parameter obtained from laboratory analysis.

V_{ideal} = Value of that water quality parameter can be obtained from the standard tables.

V_{ideal} for pH = 7 and for other parameters it is equal to zero.

V_{standard} = WHO/ICMR Standard of the water quality parameter.

Based on the above WQI values the groundwater quality is rated as excellent, good, poor, very poor and unfit for human consumption.

RESULTS AND DISCUSSION

Groundwater Quality Assessment for Drinking

The physico-chemical results have been subjected to statistical analysis and given in **Table 2**. Groundwater quality assessment,

carried out to determine suitability of water samples in terms of domestic and agricultural purposes.

Temperature is one of the most important ecological and physical factors which have profound influence on the biotic and abiotic components of the environment. Temperature helps in controlling the solubility of gases. The water temperature of all the samples analyzed varied from 21.9 – 29.4°C.

pH is the measure of the hydrogen ion concentration in water and indicates whether the water is acidic or alkaline. The measurement of alkalinity and acidity of pH is required to determine the corrosiveness of the water. The pH value of water samples in the study area varied from 7.6-9.4. The standard values of pH for drinking water by BIS is between 6.5-8.5 [17] while, WHO it is between 7.0-8.5 [18]. High value of pH may result due to waste discharge, microbial decomposition of organic matter in the water body [19].

Electrical conductivity value of the study area varies from 411.8 $\mu\text{s}/\text{cm}$ to 1420 $\mu\text{s}/\text{cm}$. It is found that all the water samples except in one (1420 $\mu\text{s}/\text{cm}$) are below the maximum permissible limit [18]. This might be due to leaching of effluents driven out by sugar factory in nearby area of the sampling station.

Electrical conductivity is ability of water to carry an electric current. This ability depends on total soluble salts [20]. Conductivity measurement gives rapid and practical estimate of the variations in the dissolved mineral contents of water. Conductivity measurement gives rapid and practical estimate of the variations in the dissolved mineral contents of water. One of the reason of salinity is the high concentration of cations such as sodium, calcium and magnesium whereas chloride, phosphate and nitrate as anions [21].

Total dissolved solids (TDS) of water samples ranged from 198.4ppm – 764.0ppm. The maximum permissible limit for total dissolved solids is 1500ppm [22]. Water containing more than 500 mg per liter of TDS causes gastrointestinal irritation. High values of TDS indicate that the water is unfit for human consumption. In the present study, it is found that almost all samples have TDS values less than prescribed standards and is fit for drinking purposes.

The alkalinity ranged between 134-1094ml/l. 92.3% water samples indicated high alkaline nature of water. The excess of alkalinity could be due to the minerals, which dissolved in water from mineral rich soil. The various ionic species that contribute mainly to alkalinity includes bicarbonates, carbonates,

phosphates, hydroxides, organic acids, silicates and borates. In some cases, ammonia or hydroxides are also accountable to the alkalinity [23]. Water alkalinity is not harmful to human beings [24].

Hardness concentration in the water samples analyzed ranged from 44 – 675 mg/l. 6.7% water samples were found to exceed the limit of potability [25]. Hardness in water is caused by certain salts held in solution. The most common are the carbonates, fluorides and sulphates of calcium and magnesium. Although hardness has no known adverse effects on human health. In some cases it may be advantageous as it prevents the corrosion of pipes by forming thin layer of scale [26].

In the present study, chloride concentration of water samples varied from 20.7 – 247.1 mg/l. It is observed that almost all the samples lie within the maximum permissible limit [27]. Presence of chloride concentration in ground water may be due to the solubility of NaCl and KCl and due discharge of industrial effluents [28]. The chloride concentration serves as an indicator of pollution by sewage. People accustomed to higher chloride in water are subjected to laxative effects [29]. Water with high chloride content usually has unpleasant taste and may be objectionable for some agricultural purposes.

Calcium, magnesium and total hardness in the water are interrelated. Calcium and magnesium, when combined with bicarbonate, carbonate, sulphates and other species, contribute to hardness of natural waters. Magnesium are essential elements for all organisms. In the present study, water samples exhibited calcium and magnesium from 16.0 – 151.2mg/l and 0.9 – 87.1 mg/l respectively. Concentration of both calcium and magnesium content were considerably less than the maximum permissible limit for potability [30].

In natural waters, calcium concentrations are normally below 15 mg/l although this can rise to 100 mg/l where waters are associated with carbonate-rich rocks. Magnesium concentration also vary widely and can be from 1 to over 50 mg/l depending upon the rock types within the catchment [31].

Phosphate concentration in the study area ranged from 0.01 – 0.9 mg/l. The major sources of phosphate are domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste water.

Sulphate content in water samples varied from 0.6 – 56.9 mg/l. It is found that all the water samples are below the maximum permissible limit [18, 27 and 32]. A sulphate ion is one of the major anions occurring in natural waters. Many sulphate compounds are

readily soluble in water. Most of them originate from oxidation of sulphite ores, presence of shales and the solution of gypsum and anhydrite. In absence of dissolved oxygen, nitrates and sulphates serve as a source of oxygen for biochemical oxidation produced by the anaerobic bacteria. Under anaerobic conditions, sulphate ion is reduced to sulphide ion, which establishes equilibrium with hydrogen ion to form hydrogen sulphide. The presence of hydrogen sulphide leads to corrosion of pipes [23].

Sodium content of water samples varied from 5.0 – 29.5 mg/l. In study area, sodium concentration was within the safe limits of 200 mg/l recommended limit for drinking water. The potassium concentration of the samples ranged from 0.0 – 61.0 mg/l. 23.07% water samples were found to exceed the permissible limit which might be due to improper or faulty applications of irrigation water and overuse of chemical fertilizers [33]. Although, the abundance of potassium in earth crust is similar to that of sodium, its concentration in ground water is usually less than 1/10th of that of sodium [30].

Water Quality Index (WQI)

Water quality index was calculated to determine the suitability of water for drinking purposes. WQI of study area revealed that 7.69% water samples are excellent with WQI

ranging from 0-25. 23.07% water samples are of good quality with WQI ranging between 26-50. At 30.76% sampling stations, water is of poor quality with WQI between 51–75 while 38.46% water samples are with WQI between 76–100 which is very poor and above 100 it is unfit for drinking.

Groundwater Quality Assessment for Irrigation

EC and Na⁺ play a vital role in suitability of water for irrigation. Higher EC in water creates a saline soil. Harmful effects of irrigation water increases with the total salt concentration, irrespective of the ionic composition. Higher salt content in irrigation water causes an increase in soil solution osmotic pressure [34]. The salts apart from affecting the growth of plants also affect the soil structure, permeability and aeration which indirectly affect plant growth.

Sodium Absorption Ratio (SAR)

SAR indicates sodicity or alkalinity hazard of irrigation water. The relativity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as Sodium Absorption Ratio (SAR), which is defined as,

$$\text{SAR} = \frac{\text{Na}}{\sqrt{(\text{Ca} + \text{Mg}) / 2}}$$

Where, a concentration of cations is in me/l.

Based on the values of SAR, waters can be rated into different categories.

Sodium concentration is very important in classifying irrigation waters. The Sodium Absorption Ratio (SAR value) of the ground water ranged from 0.80 to 4.29 (Table 3). The results obtained were in support the earlier report presented by [35].

Sodium Percentage

The sodium in water can be denoted by % sodium and SAR. %Na can be calculated by the formula,

The values are taken in mEq/L, Tolanur, 2004, [36].

$$\% \text{ Sodium} = \frac{Na}{Ca + Mg + K + Na} \times 100$$

As an evident from the data the ground water of the study area falls under the category of low sodium hazards (Table 4). Low sodium water can be used for irrigation on almost all soils. The sodium percentage varied from 5.73 to 38.08. As per BIS standards, a maximum of 60% sodium percentage is recommended for irrigation water. Thus, sodium percentage is below permissible limit, therefore ground water of water bore wells is excellent to good for irrigation.

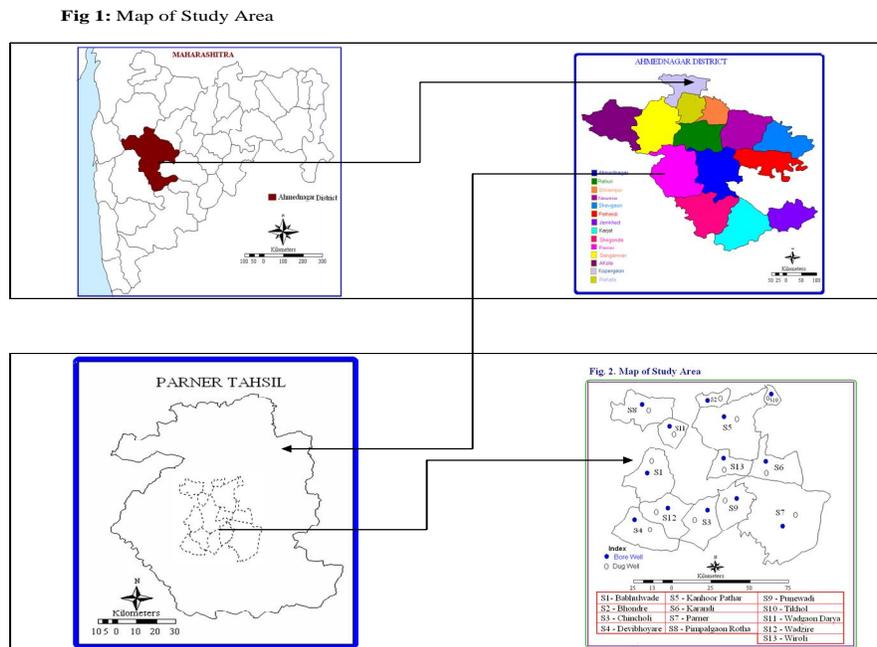


Figure 1: Study Area

Table 1: Water Quality Index Categories

Water quality index	Description
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for drinking

Table 2: Study of Physico-Chemical Water Characteristics of Bore Well From Study Area

Sampling Stations	Temp. (°C)	pH	EC(μS/cm)	TDS (ppm)	Alkalinity	Hardness	Chlorides	Ca ⁺⁺	Mg ⁺⁺	PO ₄ ⁻⁻⁻	SO ₄ ⁻	Na ⁺ (mg/l)	K ⁺ (mg/l)
S-1	27.6	8.9	685.7	356.5	400.0	675.0	247.1	127.0	87.1	0.1	10.0	24.0	61.0
S-2	26.0	7.9	602.1	283.2	294.0	295.0	36.9	78.0	24.4	0.1	0.6	7.0	0.7
S-3	29.4	9.4	656.0	337.6	300.0	271.0	51.1	60.9	29.0	0.1	20.0	9.0	0.7
S-4	28.2	8.9	1420.0	764.0	366.0	395.0	195.1	70.1	53.6	0.1	56.9	29.5	0.0
S-5	27.8	9.3	778.4	351.5	214.0	315.0	53.1	43.8	50.1	0.9	7.5	6.5	0.0
S-6	24.5	7.8	752.4	331.0	306.0	335.0	50.3	78.0	34.1	0.0	7.5	8.5	4.0
S-7	21.9	9.1	1219.0	638.8	274.0	337.2	154.2	151.2	9.7	0.4	25.6	18.5	0.7
S-8	27.1	9.0	649.0	331.3	294.0	273.0	20.7	24.0	52.2	0.2	2.5	5.0	0.7
S-9	26.0	8.4	1235.0	595.2	334.0	441.2	122.1	126.2	30.8	0.6	49.4	13.0	0.0
S-10	24.2	8.3	411.8	198.4	134.0	44.0	55.7	16.0	1.0	0.0	8.1	12.5	3.4
S-11	24.1	7.6	1072.0	524.0	386.0	504.0	92.9	144.0	35.4	0.1	33.1	11.0	1.4
S-12	24.2	7.9	1109.0	540.0	1094.0	416.0	155.3	80.0	52.6	0.0	41.9	18.5	0.7
S-13	22.6	9.0	703.8	383.2	294.0	316.0	54.8	80.0	28.3	0.0	0.6	8.5	5.4
Average	25.7	8.6	868.8	433.4	360.8	355.2	99.2	83.0	37.6	0.2	20.3	13.2	6.0
Minimum	21.9	7.6	411.8	198.4	134.0	44.0	20.7	16.0	0.9	0.09	0.6	5.0	0.0
Maximum	29.4	9.4	1420.0	764.0	1094.0	675.0	247.1	151.2	87.1	0.9	56.9	29.5	61.0
Std. Devn.	2.3	0.6	304.9	163.4	231.1	145.9	69.8	43.2	22.0	0.3	19.4	7.4	16.6
%CV	8.9	7.1	35.1	37.7	64.1	41.1	70.4	52.1	58.7	140.4	95.6	56.1	275.7
Variance	5.2	0.4	92966.3	26687.6	53425.7	21274.2	4878.6	1867.0	485.3	0.1	376.2	54.7	275.8

NOTE: All Units Except Temperature, pH, EC and TDS are in mg/l

Table 3: Water Rating on the Basis of SAR

Water quality	SAR value	Number of samples
Safe	SAR < 10	13
Moderately safe	SAR < 10-18	---
Moderately unsafe	SAR < 18-26	---
Unsafe	SAR > 26	---

Table 4: Showing Sodium Percentage and Suitability of Water for Irrigation

Class of water	% Sodium	Suitability for irrigation	Number of samples
I	0 – 60	Excellent to good for irrigation	13
II	60 -75	Good to injurious. Harmful to sensitive crops	---
III	>75	Unfit for irrigation	---

CONCLUSION

Top priority should be given to water quality monitoring and surveillance. Low awareness about the importance of water quality at all levels is a major problem, therefore awareness about deterioration of water quality must reveal among the public. Water harvesting devices should be increased like bunds, shet-tale, baories etc. All traditional water harvesting devices should be adapted to make water fit for drinking after treatment such as

desalination etc. The safe drinking water in quality affected areas should also be provided by sanctioning schemes based on surface water sources.

Monitoring of pollution patterns and its trends with respect to modern agricultural practices in rural areas is an important taskforce achieving sustainable management of ground water. Present study proves to be an essential tool to evaluate and quantify the ground water quality. Spatial distribution maps of various

pollution parameters are used to demarcate the locational distribution of water pollutants in a comprehensive manner and help in suggesting ground water pollution control and remedial measures in holistic way.

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