 

# Physico-chemical and heavy metals evaluation of the groundwater for the irrigation purpose with the water quality index studies at the Ratnagiri District, Maharashtra, India

**Ajay Vilas Goud[1], Ashish Shantaram Musale[2], Pandurang Yashwant Patil[3]**
[1,1,1]Department of Environmental Science, University of Mumbai, Charitrakar Padma Bhushan Dr. Dhananjay Keer Ratnagiri Sub-Campus, P-61 MIDC, Mirjole, Ratnagiri 415639
*Corrosponding Author: Pandurang Y. Patil, Associate Professor
Department of Environment Science, Ratnagiri Sub-Campus pypatilratnagiri.mu.ac.in

## ABSTRACT

Groundwater sources are widely used for domestic and agricultural purposes by human beings and Water Quality Index (WQI) quantifies the suitability for the use. Although, groundwater resources are getting polluted by the various anthropogenic activities. Ratnagiri is an urbanising city and polluting activities are increasing nowadays. The study area chosen is from a 74 km stretch of coastal areas at the Ratnagiri district, Maharashtra, India. A total of 25 no. of samples from different locations were collected for the physicochemical, heavy metals analysis and water quality index (WQI) have dominantly carried out for the suitability of drinking and irrigation purposes in the present study. Water analysis methods are followed from the bureau of Indian standards (BIS) and world health organization (WHO) guidelines and compared accordingly to the BIS (ISO10500:2012) permissible limits. Chloride (Cl), Total dissolved solids (TDS), and Total Hardness (TH) values were above the permissible limit during the pre-monsoon period (PRM). Lead and Zinc values have increased (2 locations), which may lead by continuous human interventions. From the piper-trilinear diagram, it was observed that most of the samples are mixed type with $Ca^{2+}$ as predominant cation, especially in the pre-monsoon period. According to the permeability index (PI), sodium percentage (SSP), Kelly's Ratio (KR), Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), Percent Sodium (NA%), and Residual Sodium Carbonate (RSC) all the samples during PRM and post-monsoon period (POM), were found to be good for the irrigation purpose. As per the WQI, excellent water quality during PRM is observed only at one location (1 sample of 25) and during POM it has increased by 48 % (12 samples of 25), showing that the groundwater quality has increased after the monsoon. A suggestion is that to minimize pollution of groundwater, rainwater harvesting be preferably done.

**KEYWORDS:** Groundwater, Physico-chemical, Water Quality Index (WQI), Irrigation, Ratnagiri

## INTRODUCTION

All over the world, water sources are available as oceanic resources, surface water resources and groundwater resources. Groundwater resources have been broadly used for industrial, agricultural, and domestic purposes (Patil and Saptarshi 2012; Taiwo et al. 2011; Korany et al. 2013; Popoola et al. 2019; Adan and Iqbal 2014; Aydin 2007) by applying some of the necessary treatments. Earth contains 97.2 % water as saltwater in oceans, while 2.15% water is frozen in the form of ice and the remaining 0.65% water is available in the form of surface or groundwater (Santra 2001). The sources of water have been critically polluted by the various materials and anthropogenic activities such as effluents from industrial treatment

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plants, transportation of toxic & hazardous material from residential & industrial areas via leaching into the underground, municipal landfills, microbiological and chemical contamination, and extensive use due to population growth, and urbanization (Kumar et al. 2009; Longe and Balogun 2010; Adan and Iqbal 2014; Kupwade and Langade 2013). Also, groundwater contamination is being a very percussive problem for decades. Patil and Saptarshi (2012) opined in their study that the groundwater resources although are renewable and inexhaustible, considering the present conditions should be treated as an exhaustible and depletable resource. As looking into the world, India uses groundwater for agricultural purposes on a large scale which can nominate India as the biggest user of groundwater in the world (Dahariya et al., 2016). In India, there are 15,32,850 water bodies over all the states and 46,851 water bodies are in the Maharashtra state (Ministry of Jal Shakti, India 2022).

Water Quality Index (WQI) is developed to assess the groundwater and surface water for drinking as well as irrigation purposes dominantly (Banerji and Mitra 2019). Several researchers in Maharashtra have assessed the groundwater quality for drinking and irrigation purposes, on the basis of Sodium Absorption Ratio (SAR), Kelly's Ratio (KR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Percent Sodium (%Na), Permeability Index (PI), Magnesium Hazard (MH) and Magnesium Ratio (Mg/Ca Ratio) (Panaskat et al. 2014; Elbeltagi et al. 2021; Aher 2017; Anbazhagan and Nair 2014; Wagh et al. 2016). The researchers found the suitability of groundwater for drinking and irrigation purposes with some exceptions due to the contamination from industrial, domestic and/or agricultural waste. Industries showing faster development in the areas of Ratnagiri and Raigad which are emerging to the contamination sources of groundwater through toxic effluents discharge to surface and waste disposal in industrial areas (Raje et al. 2005). Patil (2013), studied the groundwater quality at Kalbadevi estuary in Ratnagiri Tahsil and concluded that the seawater intrusion makes adjoining groundwater unsuitable for drinking purposes and also, reduces the availability of water for human consumption and agriculture. Ratnagiri is at the coastal area of the Konkan region in Maharashtra, where the groundwater resources are dominantly used by the people for domestic and agriculture purposes in rural as well as in urban areas. Several studies have been carried out by the researchers for the WQI mostly for non-coastal cities in Maharashtra, but there are no studies according to the WQI for the Ratnagiri coastal area. So, in the current region, this study is aimed to assess the groundwater quality at various locations of Ratnagiri district during the pre and post-monsoon season from the perspective of Physico-chemical, heavy metals as well as WQI study for drinking and irrigation purposes.

## ABOUT STUDY AREA

In this study, a patch (an area) from the western coastal part of India had been chosen for the study which lies in the district of Ratnagiri, Maharashtra state, India. Ratnagiri district is placed at the latitude 16° 59' 39.9984" N and longitude 73° 18' 0.0108" E. This area is at the southwest part of Maharashtra state and falls on the western coast of India and this coastal is popularly known as the Konkan Coast. The coastal length of Ratnagiri district is about 167 km.

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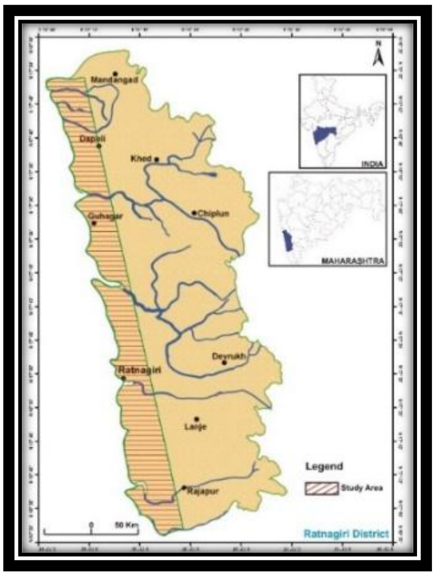


**Figure 1** Map of the Study area

## MATERIALS AND METHODS

Total 25 no. of sampling locations were selected and samples are analysed for one year or two seasons like summer and winter. The samples were collected in the pre-monsoon period i.e. of summer in 2016 (summer in India is from Feb-May) and post-monsoon period i.e. winter of 2016 (winter in India is from Oct-Jan). The samples were collected in a plastic container and then brought to the laboratory for further analysis. The methods for groundwater sample collection and preservations were followed through different standards of international and national method APHA, AWWA, WPCF (1998), BIS- 1991-10500.

Piper tri-linear plot itself states that it has three components, at the base there are two triangulated diagrams and a triangle representing the cations at its lower left and the anions are shown at lower right triangle. Aqua-chem 4.0 software is used for piper plots.
WQI method has been used for the appraisal of the groundwater quality. For the calculation of WQI parameters which analysed are; pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), bicarbonate (HCO3), sulfate ($SO_4$), nitrate ($NO_3$), and phosphate ($PO_4$) (Hamza et al. 2017; Wagh et al. 2016; Adimalla et al. 2018). For the calculations and as of the standards the World Health Organization (WHO, 2011) limits have been used.

The relative weight (RWi) is calculated with following equation,

RWi = Awi /∑ AWi; Where, RWi = Relative weight, AWi = Assigned Weight, n = Number of parameters

The quality rating scale for each parameter is expressed with the following equation,

qi = (ci/si)*100; Where, qi = Quality rating for $i^{th}$ parameter, Ci = Concentration of $i^{th}$ chemical parameter of water sample (mg/l), Si = permissible standard for $i^{th}$ parameter set by BIS

Sub index (SIi) for each parameter is calculated by equation,

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SIi = RWi * qi ; Where, SIi = sub index of $i^{th}$ parameter, qi = rating based on concentration of $i^{th}$ parameter

Finally, WQI is proposed by following equation,
WQI = ∑SIi; Where, SIi indicates the sub index of $i^{th}$ parameter
Irrigation Water Quality classification is based on the several calculations of Kellies Ratio (KR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Magnesium Hazards (MH), and Sodium Percentage (Na%), Ion exchange Processes (CAI 1 and CAI 2) (Adimalla et al. 2018; Elbeltagi et al. 2021; Panaskar et al. 2016; Aher 2012; Aher et al. 2019; Panaskar et al. 2016).
Kellies Ratio (KR)

$$\text{Kelly's Ratio} = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$$

Soluble Sodium Percentage (SSP)

$$SP = \left(\frac{Na^{+}}{(Ca^{2+} + Mg^{2+} + Na^{+})}\right) * 100$$

Residual Sodium Carbonate (RSC)

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

Magnesium Hazards (MH)

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

Sodium Percentage (Na%)

$$\% Na = \left(\frac{Na^{+} + K^{+}}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}\right) * 100$$

## RESULTS AND DISCUSSION

*Physico-chemical Parameters*

pH is a measure of acidity or alkalinity of water (Thangavelu 2013) and from the analysis of samples of the present study area, it ranged from 6.52 – 7.3 and 6.52 – 7.41 (Table No. 1) for pre and post-monsoon season respectively. The pH values show that the groundwater samples lies under the permissible limit of potable. Temperature plays a major role in the dissolution of various chemical ions and cations in water. The temperature of the sample varies from 26 to 290C (Table No. 1). The water samples in the case of drinking water should be clean in visualization. The suspended sediments in the water give a muddy or turbid appearance in the study area ranging from 0.55 to 3.75 NTU with a mean of 1.54 NTU for PRM season, while the turbidity ranges from 0.30 to 2.15 NTU with a mean of 0.93 NTU for POM season (Table No. 1). EC is an important measure of salinity and it affects the taste of water (Thangavelu 2013). EC ranged during the pre-monsoon period 323 – 2904 µs/cm and during the post-monsoon period 128 – 845 µs/cm (Table No. 1), which shows medium conductivity for 11 samples during pre-monsoon season as of the post-monsoon season. Chloride can be found naturally in all types of water. The pre-monsoon sample is having high chloride concentration due to evaporation of water and intrusion of salt seawater into groundwater.

Chloride of samples was found above permissible (<250 mg/l) limit in 17 samples of 25 i.e. 68%. TDS is an amount of inorganic salts & small amounts of organic matter dissolved in water (Thangavelu 2013). Total, 14 samples out of 25, have TDS above the permissible limit (<500mg/l) according to the Indian Standards (IS 10500:2012). Total hardness is the presence of multivalent metal ions which come from minerals dissolved in water and if in excess causes kidney problems (Godghate et al. 2013). During PRM 76% of samples fall under the very hard category which is considered unsuitable (without treatment) for drinking, domestic, and irrigation purposes. During the PRM period, it is clearly seen that 76% (19 samples) of the samples are found to be very hard water category, which is not suitable for drinking purposes. There is no permissible limit for DO, COD, and BOD as per the standards (ISO10500:2012). In the present study area, the values of DO ranged from 4.2 – 6.2 mg/l; COD values ranged from 10 - 58 mg/l; BOD values ranged from 4 – 25 mg/l (Table No. 1). Values of the samples for sulfate and nitrate ranged from 12 to 200 mg/l and 2 to 40 mg/l respectively, which are under the permissible limit (Table No. 1).

**Table 1** Parameters range of Samples

| Sr. No. | Parameters | Parameters Range | ISO Standards | Unit |
|---|---|---|---|---|
| 1 | pH | 6.52 – 7.3 | 6.5-8.5 | -- |
| 2 | Temperature | 25 – 29 | --- | ºC |
| 3 | Turbidity | 0.7 – 3.5 | 1 | NTU |
| 4 | EC | 323 – 2904 | --- | µs/cm |
| 5 | Cl | 90 – 650 | 250 | mg/l |
| 6 | F | 0.0029 – 0.0042 | 1.0 | mg/l |
| 7 | Salinity | 0.163 – 1.174 | --- | mg/l |
| 8 | TDS | 210 – 1888 | 500 | mg/l |
| 9 | TH | 150 – 769 | 200 | mg/l |
| 10 | TA | 26 – 130 | 200 | mg/l |
| 11 | $SO_4$ | 12 – 200 | 200 | mg/l |
| 12 | $NO_3$ | 2 – 40 | 45 | mg/l |
| 13 | TKN | 0.63 – 12.6 | --- | mg/l |
| 14 | COD | 10 – 58 | --- | mg/l |
| 15 | BOD | 4 – 25 | --- | mg/l |
| 16 | DO | 4.2 – 6.2 | --- | mg/l |

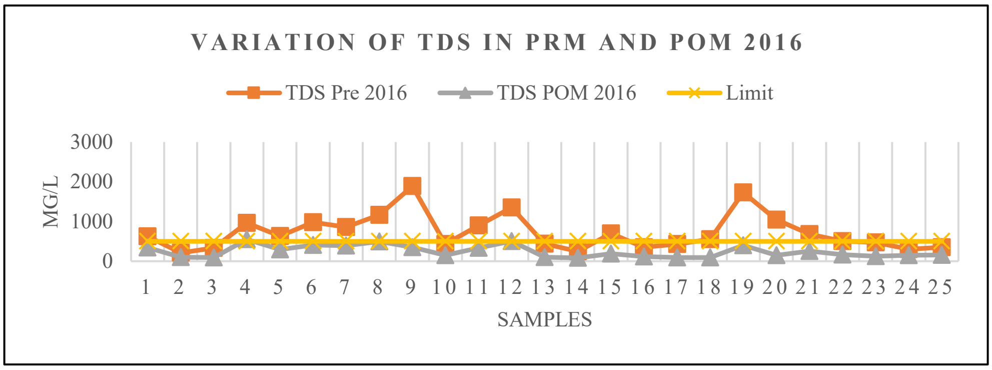



**Figure 2** Variation of TDS in PRM and POM 2016

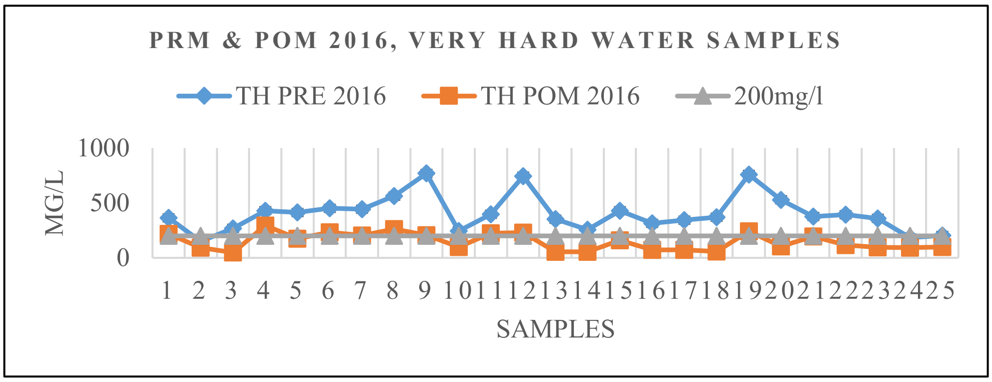
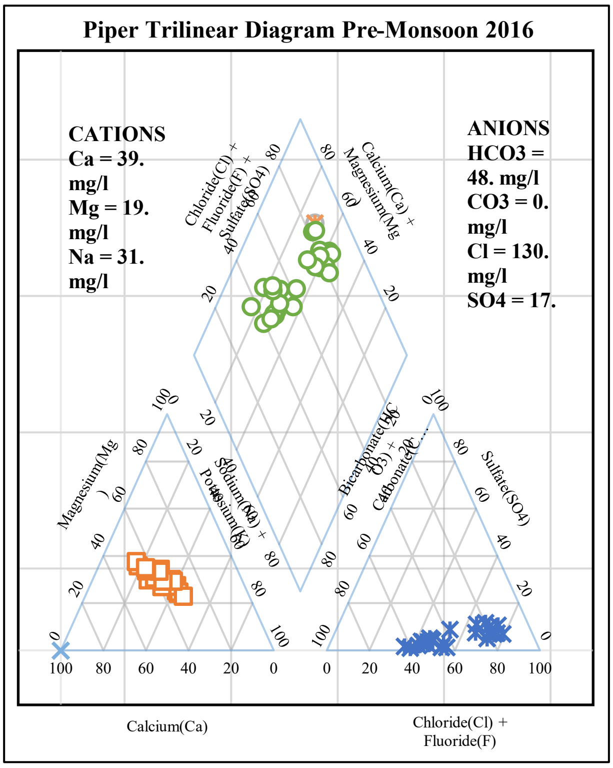



**Figure 3** PRM & POM 2016, Very Hard Water Samples



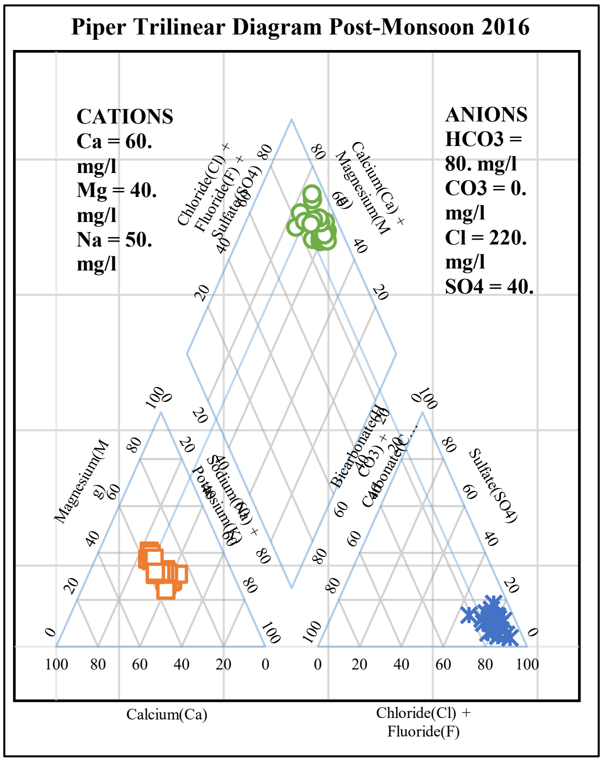




**Figure 4** Piper Trilinear Diagram Pre-Monsoon 2016 **Figure 5** Piper Trilinear Diagram Post-Monsoon 2016

Piper Trilinear observed that changing of Ca + Mg – HCO3 + CO3 to Na + K – SO4 + Cl is more in bore well than dug well (Rajmohan and Elango, 2005). This is due to a greater depth of bore well wherein, high residence time groundwater exists due to the increased rock-water interaction. On a spatial scale, it is observed that maximum samples are showing the Ca + Mg – HCO3 + CO3 water facies present along the hill slopes in the study area. While in the middle part Na + K – HCO3 + CO3 water facies develops during the summer months. In the downstream Na + K – SO4 + Cl water facies dominates as a result of evaporation dominance. The wells from alluvial aquifers show Na + K – SO4 + Cl dominance due to the excellent change of Ca with Na from clay minerals.

Four major groups of water facies were observed in the study area:

1) Ca + Mg > Na + K - HCO3 + CO3 > Cl + SO4 + NO3

2) Ca + Mg > Na + K - Cl + SO4 + NO3 > HCO3 + CO3

3) Na + K > Ca + Mg - HCO3 + CO3 > Cl + SO4 + NO3

4) Na + K > Ca + Mg - Cl + SO4 + NO3 > HCO3 + CO3

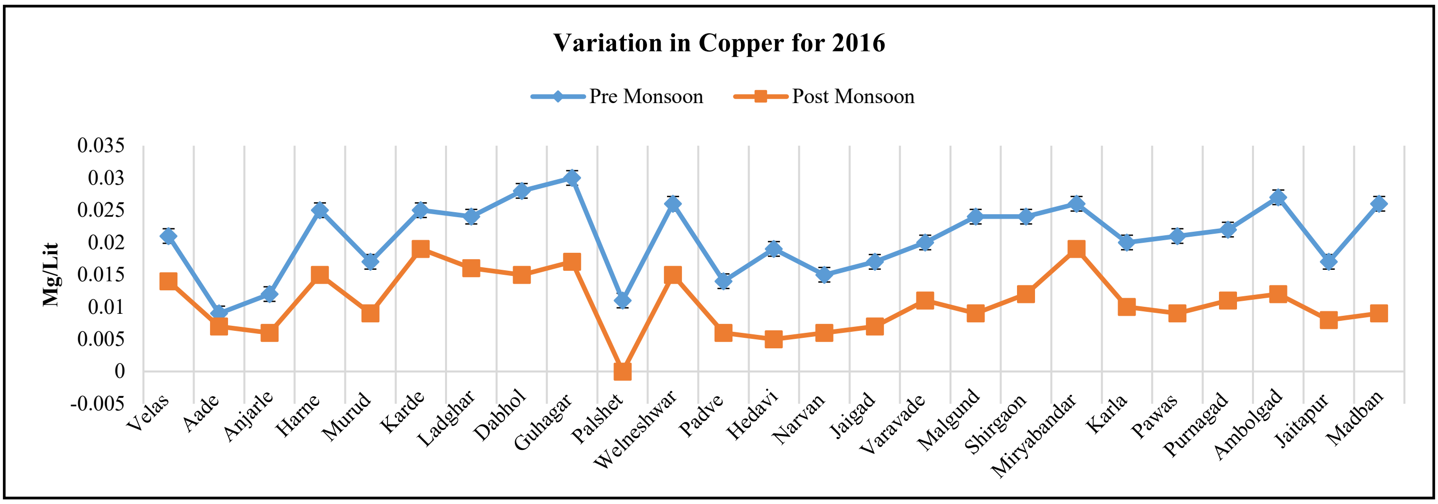



**Figure 6** Variation in Copper for 2016

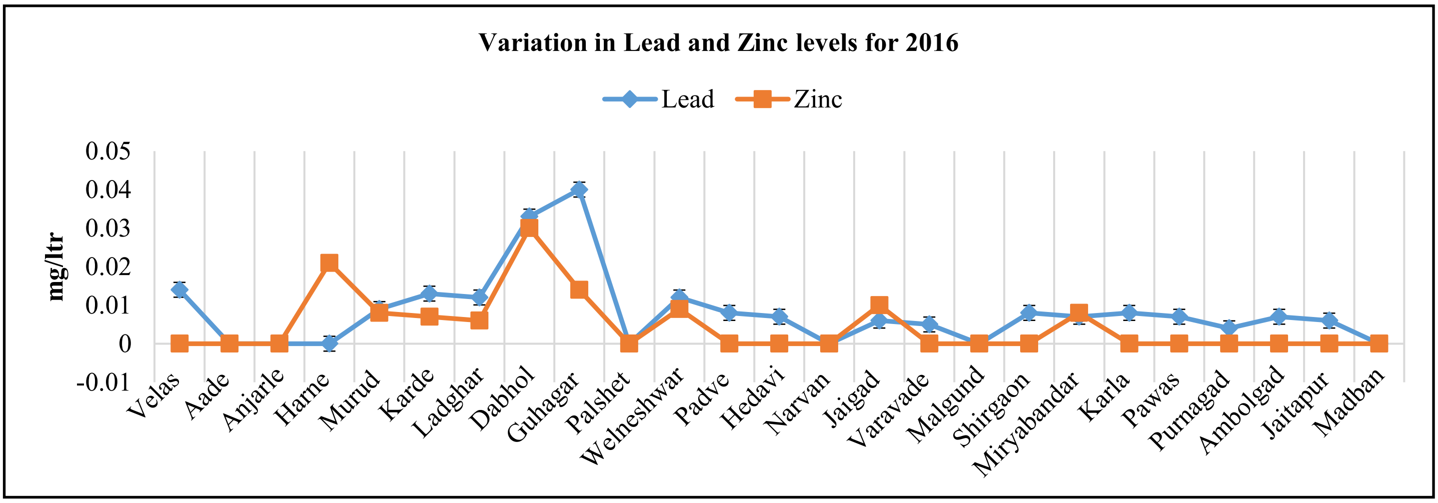



**Figure 7** Variation in Lead and Zinc for 2016

Heavy metals during pre-monsoon season have ranged; Copper (0.009 – 0.03 mg/l); Lead (0.004 – 0.04 mg/l); Zinc (0.006 – 0.03 mg/l); Iron (0.1- 0.28 mg/l) and Chromium, Cadmium, Arsenic, Mercury, and Magnesium are under below detection level (BDL). During post-monsoon season concentrations are ranging; Copper (0.005 – 0.019 mg/l); Lead (0.007 – 0.02 mg/l); Iron (0.07- 0.14 mg/l) and Chromium, Cadmium, Arsenic, and Mercury are under BDL. At only one location i.e. Ladghar, Zinc concentration is 0.011 mg/l and at Dabhol, Padve locations concentration of Manganese is 0.013 and 0.095 mg/l respectively. The levels of copper in the year 2016 were varying in all sampling locations. From Dabhol and Guhagar locations higher concentrations were found, reasoned higher population densities. However, the presence of copper at the locations is due to an interaction of geology and groundwater aquifers. The maximum concentration of copper was below 0.019 mg/l during both seasons. Also, during the post-monsoon period, higher concentrations of lead were observed at Dabhol and Guhagar locations. The continuous human interventions in this area may lead to an increase in the concentration of lead and zinc particularly.

*Water Quality Index*

The WQI is used to quantify the suitability of groundwater for irrigation and drinking purposes. According to the water quality index of the samples, only 4% of samples (i.e. only 1 sample out of 25) falls under excellent water quality and 8% of samples are of very poor water quality, whereas, most of the samples fall under good (48%) and poor (40%) water quality during PRM (Table 1 & Fig. 8). So, it can be said that the human intervention to the groundwater is degrading the groundwater quality preventing the necessary use. Whereas, during the POM period groundwater quality seems to improve. Excellent water quality has increased by 48% (i.e. 12 samples of 25) that of PRM and there were no poor and very poor water quality have observed (Table 1 & Fig. 9). Hence, it can be said that after the monsoon, groundwater quality has been improved significantly. However, According to the PI, SSP, KR, SAR, MH, NA%, and RSC al the samples during PRM and POM, are found to be good for irrigation purposes.

Table 2 WQI based Water quality classification

| Sample ID | Pre-monsoon 2016 | Water quality | Post-monsoon 2016 | Water quality |
|---|---|---|---|---|
| 1 | 97.55 | Good | 61.92 | Good |
| 2 | 42.32 | Excellent | 29.67 | Excellent |
| 3 | 65.1 | Good | 21.73 | Excellent |
| 4 | 123.12 | Poor | 85.66 | Good |
| 5 | 103.94 | Poor | 52.39 | Good |
| 6 | 127.36 | Poor | 68.67 | Good |
| 7 | 124.45 | Poor | 63.8 | Good |
| 8 | 151.52 | Poor | 76.59 | Good |
| 9 | 226.85 | Very poor | 63 | Good |
| 10 | 64.82 | Good | 32.73 | Excellent |

| | | | | |
|---|---|---|---|---|
| 11 | 113.87 | Poor | 62.98 | Good |
| 12 | 195.7 | Poor | 75.7 | Good |
| 13 | 86.67 | Good | 22.73 | Excellent |
| 14 | 54.96 | Good | 22.5 | Excellent |
| 15 | 110.32 | Poor | 47.13 | Excellent |
| 16 | 74.71 | Good | 27.41 | Excellent |
| 17 | 85.01 | Good | 25.93 | Excellent |
| 18 | 93.36 | Good | 23.1 | Excellent |
| 19 | 221.24 | Very poor | 71.98 | Good |
| 20 | 141.64 | Poor | 34.18 | Excellent |
| 21 | 102.91 | Poor | 56.36 | Good |
| 22 | 92.25 | Good | 35.38 | Excellent |
| 23 | 85.81 | Good | 31.62 | Good |
| 24 | 51.83 | Good | 32.13 | Excellent |
| 25 | 58.88 | Good | 32.9 | Excellent |

**Table 3** Relative weights against each parameter

| Sr. No. | Chemical parameters | WHO standard (2011) | Weight (Wi) | Relative weight |
|---|---|---|---|---|
| 1 | pH | 6.5 -8.5 | 4 | 0.091 |
| 2 | EC | 500 | 4 | 0.091 |
| 3 | TDS | 500 | 5 | 0.114 |
| 4 | TH | 100 | 3 | 0.068 |
| 5 | Ca | 75 | 3 | 0.068 |
| 6 | Mg | 50 | 3 | 0.068 |
| 7 | Na | 200 | 4 | 0.091 |
| 8 | K | 10 | 2 | 0.045 |
| 9 | HCO3 | 500 | 1 | 0.023 |
| 10 | SO4 | 250 | 5 | 0.114 |
| 11 | Cl | 250 | 5 | 0.114 |
| 12 | NO3 | 45 | 5 | 0.114 |


**Figure 8** Water Quality % of Samples During PRM

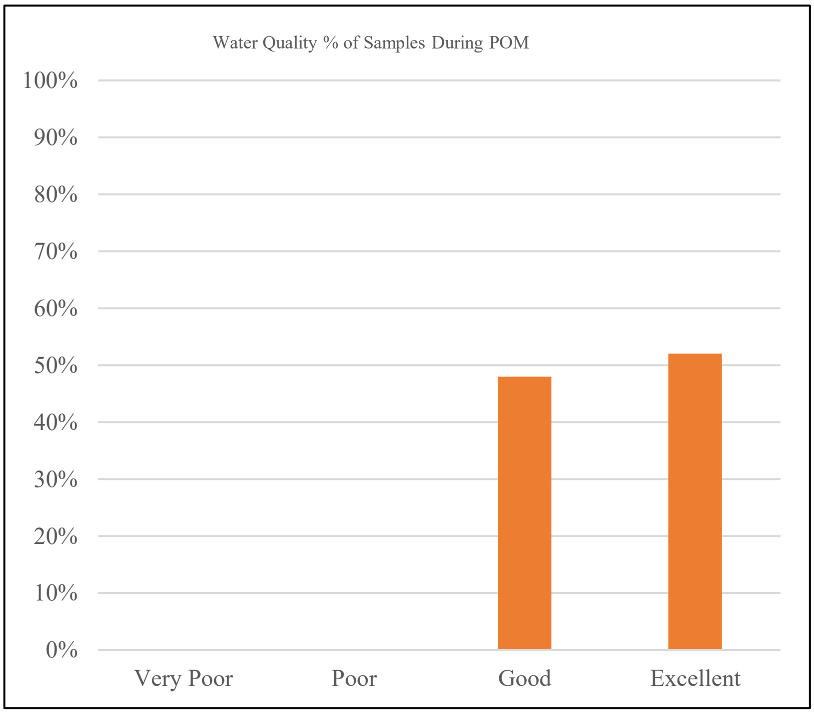
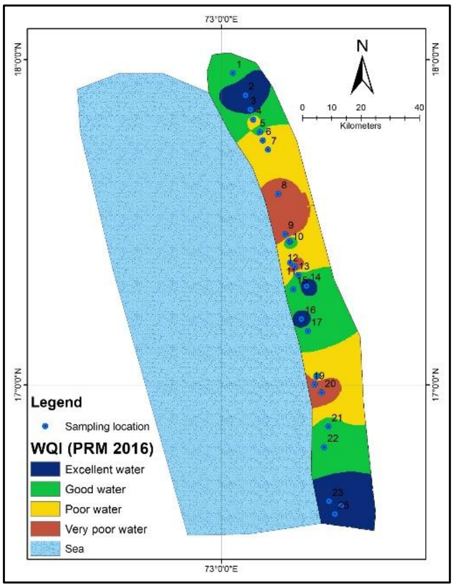



**Figure 9** Water Quality % of Samples During POM

a)




b)

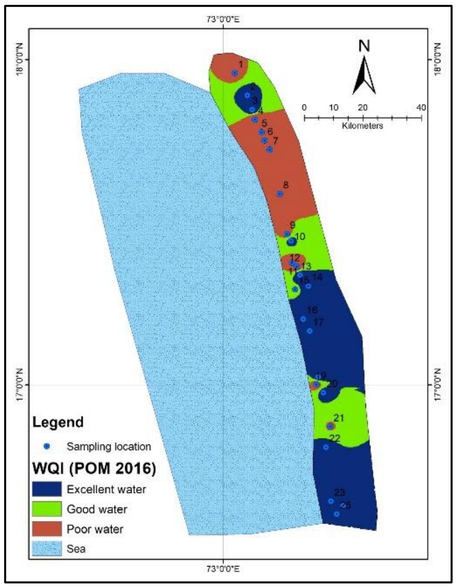



**Figure 10** a) Water Quality Index Map of PRM 2016 b) Water Quality Index Map of POM 2016

**Table 4** Groundwater quality index value for irrigation during pre-monsoon

| Sample ID | Na% | PI | RSC | KR | MH | SSP | CAI 1 | CAI 2 | SAR |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 39.23 | 46.5 | -5.057 | 0.6 | 48.47 | 37.81 | -7.651 | -0.49 | 2.21 |
| 2 | 25.73 | 40.68 | -1.85 | 0.31 | 46.56 | 23.91 | -8.783 | -0.29 | 0.79 |
| 3 | 25.75 | 33.3 | -3.376 | 0.31 | 51.16 | 24.15 | -4.547 | -0.28 | 0.95 |
| 4 | 35.04 | 41.17 | -6.298 | 0.5 | 47.39 | 33.58 | -9.174 | -0.43 | 2.14 |
| 5 | 38.97 | 45.63 | -5.905 | 0.59 | 47.46 | 37.34 | -13.74 | -0.54 | 2.35 |
| 6 | 39.06 | 46 | -7.204 | 0.61 | 47.02 | 37.91 | -11.74 | -0.6 | 2.5 |
| 7 | 38.93 | 45.62 | -7.188 | 0.6 | 45.61 | 37.5 | -8.83 | -0.53 | 2.62 |
| 8 | 47.12 | 52.31 | -8.309 | 0.85 | 50.61 | 45.96 | -11.56 | -0.66 | 3.94 |
| 9 | 41.22 | 46.37 | -11.56 | 0.66 | 45.14 | 39.79 | -8.19 | -0.55 | 3.63 |
| 10 | 28.05 | 33.48 | -3.88 | 0.34 | 52.84 | 25.86 | -5.27 | -0.3 | 1.1 |
| 11 | 38.5 | 42.8 | -5.81 | 0.59 | 48.79 | 37.14 | -15.49 | -0.51 | 2.28 |
| 12 | 42.06 | 47.68 | -11.54 | 0.68 | 49.42 | 40.72 | -13.55 | -0.57 | 3.86 |
| 13 | 43.01 | 49.04 | -5.99 | 0.7 | 46.14 | 41.37 | -12.96 | -0.56 | 2.59 |
| 14 | 28.15 | 32.68 | -4.64 | 0.33 | 50.71 | 25.33 | -21.57 | -0.41 | 1.05 |
| 15 | 40.22 | 46.79 | -6.77 | 0.63 | 46.65 | 38.76 | -10.31 | -0.54 | 2.68 |
| 16 | 27.48 | 34.4 | -5.31 | 0.33 | 51.37 | 25.06 | -6.72 | -0.34 | 1.24 |
| 17 | 36.85 | 45.25 | -3.74 | 0.54 | 43.73 | 35.21 | -9.19 | -0.4 | 1.94 |
| 18 | 37.94 | 44.7 | -5.72 | 0.57 | 43.65 | 36.33 | -12.64 | -0.48 | 2.21 |
| 19 | 42.297 | 47.795 | -12.33 | 0.69 | 51.89 | 41.11 | -9.81 | -0.62 | 3.87 |
| 20 | 48.864 | 54.089 | -8.865 | 0.916 | 47.309 | 47.818 | -15.862 | -0.723 | 4.187 |
| 21 | 40.373 | 45.716 | -7.52 | 0.637 | 42.187 | 38.93 | -9.083 | -0.59 | 2.611 |
| 22 | 39.301 | 44.964 | -6.484 | 0.605 | 49.229 | 37.686 | -11.711 | -0.57 | 2.293 |
| 23 | 39.257 | 45.401 | -6.619 | 0.605 | 48.47 | 37.703 | -12.186 | -0.568 | 2.339 |
| 24 | 28.014 | 35.645 | -3.5 | 0.348 | 43.942 | 25.826 | -4.75 | -0.365 | 0.953 |
| 25 | 30.144 | 36.007 | -3.394 | 0.375 | 49.14 | 27.271 | -5.298 | -0.341 | 1.128 |

**Table 5** Groundwater quality index value for irrigation purpose during post-monsoon

| Sample ID | Na% | PI | RSC | KR | MH | SSP | CAI 1 | CAI 2 | SAR |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 29.522 | 36.363 | -3.229 | 0.366 | 48.746 | 26.818 | -5.528 | -0.34 | 1.086 |
| 2 | 18.478 | 27.192 | -0.974 | 0.186 | 43.942 | 15.662 | -6.536 | -0.222 | 0.359 |
| 3 | 36.274 | 43.807 | -0.112 | 0.543 | 42.799 | 35.175 | -18.43 | -0.349 | 0.752 |
| 4 | 41.546 | 49.095 | -3.415 | 0.663 | 43.234 | 39.87 | -11.408 | -0.477 | 2.278 |
| 5 | 30.643 | 38.583 | -2.402 | 0.384 | 44.504 | 27.724 | -5.123 | -0.328 | 1.017 |
| 6 | 36.915 | 44.134 | -4.213 | 0.53 | 47.562 | 34.659 | -7.088 | -0.538 | 1.621 |
| 7 | 40.581 | 46.219 | -2.997 | 0.627 | 46.25 | 38.527 | -8.924 | -0.525 | 1.793 |
| 8 | 43.074 | 49.305 | -3.897 | 0.708 | 42.553 | 41.441 | -13.027 | -0.549 | 2.287 |
| 9 | 43.035 | 50.759 | -2.868 | 0.7 | 43.519 | 41.181 | -10.158 | -0.551 | 2.02 |
| 10 | 16.594 | 22.476 | -1.139 | 0.173 | 45.147 | 14.781 | -13.164 | -0.246 | 0.347 |
| 11 | 38.23 | 47.792 | -2.669 | 0.573 | 44.138 | 36.435 | -11.291 | -0.467 | 1.715 |
| 12 | 46.071 | 54.146 | -3.136 | 0.799 | 42.707 | 44.414 | -11.752 | -0.604 | 2.43 |
| 13 | 29.621 | 40.289 | -1.061 | 0.397 | 45.147 | 28.443 | -15.343 | -0.663 | 0.588 |
| 14 | 29.621 | 40.289 | -1.061 | 0.397 | 45.147 | 28.443 | -15.343 | -0.76 | 0.588 |
| 15 | 34.002 | 43.681 | -2.056 | 0.46 | 40.936 | 31.485 | -18.611 | -0.518 | 1.166 |
| 16 | 29.707 | 38.889 | -0.576 | 0.388 | 45.147 | 27.931 | -20.881 | -0.376 | 0.662 |
| 17 | 26.106 | 31.837 | 0.257 | 0.335 | 40.398 | 25.114 | -7.943 | -0.198 | 0.566 |
| 18 | 28.697 | 41.59 | -0.261 | 0.38 | 43.173 | 27.542 | -15.343 | -0.309 | 0.575 |
| 19 | 38.154 | 46.601 | -4.215 | 0.564 | 47.472 | 36.071 | -7.86 | -0.611 | 1.758 |
| 20 | 28.54 | 34.992 | -2.038 | 0.375 | 47.309 | 27.266 | -28.598 | -0.84 | 0.766 |
| 21 | 33.188 | 40.583 | -3.584 | 0.432 | 43.997 | 30.15 | -5.927 | -0.498 | 1.21 |
| 22 | 26.437 | 31.061 | -2.287 | 0.337 | 46.12 | 25.225 | -28.598 | -0.632 | 0.727 |
| 23 | 29.317 | 39.81 | -1.807 | 0.388 | 47.516 | 27.95 | -13.027 | -0.702 | 0.757 |
| 24 | 23.422 | 34.883 | -1.775 | 0.279 | 43.942 | 21.786 | -5.779 | -0.51 | 0.539 |
| 25 | 22.22 | 31.975 | -1.09 | 0.26 | 45.147 | 20.646 | -7.135 | -0.272 | 0.521 |

## CONCLUSION

Physico-chemical and heavy metal parameters of the study area compared with BIS (ISO10500) standards and has showed that more than 50% of samples have Cl, TDS, and TH values above permissible limits. Which interns shows unsuitability of water for potable. Also, lead (Pb) and zinc (Zn) values have increased (2 locations), which may lead by continuous human interventions. Piper plot observed that the maximum samples are showing the Ca + Mg – HCO3 + CO3 water facies present along the hill slopes in the study area. WQI study is being firstly assessed in this study area. Good, poor, and very poor water quality (48%), rather than excellent water quality (only 1 sample) is mostly observed during the PRM period. Where during the POM period excellent water quality has shown a 48% increase (12 samples of 25) which shows the decrease in pollution at the same locations after the monsoon. Also, from the PI, KR, SAR, MH, NA%, and RSC, all the samples during PRM & POM have found to be good for the irrigation purposes. However, the suggestion is to be made that rainwater harvesting can be purposely used to mitigate the contamination of groundwater.

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