Physico-Chemical analysis of groundwater samples in the Varahanadi watershed, India
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doi:10.6088/ijes.00202030050

ABSTRACT

Groundwater quality analysis was carried out in the Varahanadi basin. In the last few years, groundwater has become one of the main sources of irrigation in this area, supplementing the canal surface irrigation system. In the tail end villages of Puducherry, groundwater is the only source of irrigation. Groundwater samples collected from sixteen villages were analysed for various physico-chemical parameters and compared with the standard desirable limits of water quality parameters prescribed by Bureau of Indian Standards and World Health Organisation. It was observed that the bed rock of the study area influenced the groundwater quality resulting in higher concentrations of calcium, potassium and phosphates in the groundwater samples.

Keywords: Groundwater, Varahanadi basin, Water quality parameters, Puducherry, Tamil Nadu.

1. Introduction

Groundwater, the water contained in an aquifer matrix located below the surface in the saturated zone, act as the primary buffer against drought for both human requirements and plant production (Siebert S. et al., 2010). Importance of groundwater irrigation in India has increased in the recent years, mainly due to the fact that groundwater offers reliability and flexibility in access to water that irrigation canals can hardly match.

Groundwater naturally contains mineral ions dissolved from soil particles, sediments and rocks as water travels along mineral surfaces of the aquifer (Harter T., 2003). Factors like climate, slope, drainage conditions and residence time of groundwater contributes to the groundwater quality (Rao N. S., 2006).

The monitoring of water quality is one of the major tools for Sustainable development and provides important information for water management (Vasanthavigar M., 2010). Groundwater quality in South India is strongly dependant not only on bedrock geology and climate but also on agricultural and industrial pollution (British Geological Survey, 1999).

The present study was carried out in the Varahanadi watershed to assess the quality of groundwater as a part of natural resource management study on water related issues. The study area includes both the state of Tamil Nadu as well as the Union Territory of Puducherry. In the last few years, groundwater has become one of the main sources of irrigation in this area, supplementing the canal surface irrigation system. In the tail end villages of Puducherry, groundwater is the only source of irrigation.
2. Materials and Methods

The study area forms a part of the Varahanadi Watershed, including areas both under Puducherry and Tamil Nadu. It starts from the Veedur Reservoir, in the Villupuram district of Tamil Nadu extending from North latitude 12° 05’ 00” to 11° 55’ 00” and East longitude 79° 35’ 00’’ to 79° 45’ 00’’. The study area includes eleven villages from Tamil Nadu and five from the Union Territory of Puducherry. The sixteen villages were 1.Veedur, 2.Siruvai, 3.Pombokur, 4.Ivyeli, 5.Ponnampundi, 6.Korakkeni, 7.Nemili, 8.Eraiyyur, 9.Thollamir, 10.Kondalankuppam, 11.Kadagampattu, 12.Katterykuppam, 13.Lingaredypalayam, 14.Pudukkuppam, 15.Suthukeny and 16.Thettampakkam, respectively.

The bedrock of the area mainly consists of hard rock crystalline charnockite gneiss belonging to Achaean age. The Puducherry region consists of Vanur - Ramanathapuram sandstone of upper Cretaceous age. The Vanur sandstone is encountered in both sides of River Gingee in the study area and comprises of calcareous sandstones and limestone. Groundwater occurs in the fractured and weathered zone of the crystalline rocks.

A total of forty eight samples, with three samples per village were taken for the analysis. The groundwater samples were taken from already running motor pumps or after operating the motor pumps for about ten minutes.

The samples were collected in pre-cleaned one litre polythene bottles from open and boreholes during the month of December 2009 to September 2010 (post-monsoon, summer, pre-monsoon). Parameters like pH and Electrical Conductivity (EC) were measured using digital meters. Calcium, potassium and sodium were analysed by flame photometer and nitrate (4500-NO₃⁻ B) and phosphate (4500-P D. Stannous chloride method) by spectro-photometric method (APHA, 2005). Five heavy metals, namely, Copper (Cu), Zinc (Zn), Manganese (Mn), Lead (Pb) and Cadmium (Cd) were also analysed using Atomic Absorption Spectrophotometer.

3. Results & Discussion

Several studies have been carried out on groundwater quality with respect to drinking as well as irrigation purposes in different parts of the country.

In the Muthupet region of Tamil Nadu it was found that groundwater increases its major ion concentrations in the summer as compared to the post and pre monsoonal period (Venkatramanan S. et al., 2009). This was attributed to the evaporation, precipitation and environment weathering in the study area. Ballukraya and Ravi (1999) and Elango.L and N. Rajamohanan (2004), reported increase in the concentration of major ions during post monsoon attributing it to the rising water table dissolving more matter from soil, thus increasing the salinity of water after monsoon.

Studies were conducted on the groundwater quality in the Tondiar basin lying adjacent to the Varahanadi basin having similar geological formations (Ramesh K. and Elango L., 2006, 2011). Tondiar River is a tributary to the Varahanadi basin. The results obtained in the present study were compared with the Tondiar basin groundwater quality. Table 1 provides the values of the various physico-chemical water quality parameters with their minimum, maximum, mean and standard deviation values for the three sampling seasons. Table 2 shows the correlation matrix of the twelve parameters.
### Table 1: Water Quality parameters for three seasons

| Parameter  | Standards          | Post-Monsoon | Summer | Pre-Monsoon |
|------------|--------------------|--------------|--------|-------------|
|            | BIS, 1991, WHO, 2003 | Min | Max | Mean | SD | Min | Max | Mean | SD | Min | Max | Mean | SD |
| pH         | 6.5-8.5, 6.5-9.5   | 5.6 | 9.7 | 7.4 | 0.8 | 5.2 | 7.7 | 7.1 | 0.49 | 5.58 | 8.9 | 7.06 | 0.59 |
| EC (mS/cm) | -                  | 0.1 | 2.2 | 0.95 | 0.56 | 0.11 | 1.89 | 0.8 | 0.44 | 0.12 | 1.9 | 0.79 | 0.46 |
| Nitrate    | 45-100             | 0.1 | 38.4 | 10.8 | 9.3 | BDL | 44.9 | 9.9 | 12.02 | 0.1 | 43.4 | 9.9 | 10.04 |
| Phosphate  | -                  | 0.1 | BDL | 3.1 | 0.3 | 0.4 | 0.3 | 1.4 | 0.55 | 0.24 | 0.2 | 1.2 | 0.39 | 0.19 |
| Sodium     | 50                 | 0.2 | 41.1 | 14.69 | 12.5 | 0.7 | 46.6 | 12.1 | 9.4 | 0.1 | 58.8 | 12.8 | 11.69 |
| Potassium  | 10                 | 0.2 | 15.4 | 13.6 | 2.6 | 0.5 | 12.5 | 11.4 | 1.9 | 2.8 | 14.1 | 12.8 | 1.94 |
| Calcium    | 200                | 10.0 | 810.1 | 275.47 | 288.9 | 89.2 | 974.1 | 453.1 | 248.3 | 10.8 | 754.1 | 277.9 | 214.9 |
| Lead       | 0.05               | 0.05 | BDL | 0.77 | 0.05 | 0.14 | BDL | 0.09 | 0.01 | 0.02 | BDL | 0.1 | 0.02 | 0.02 |
| Zinc       | 5-15               | BDL | 0.03 | 0.02 | 0.005 | BDL | 0.12 | 0.004 | 0.02 | BDL | 0.37 | 0.02 | 0.06 |
| Manganese  | 0.1-0.3            | BDL | 0.21 | 0.08 | 0.03 | BDL | 0.62 | 0.03 | 0.13 | BDL | 0.13 | 0.01 | 0.03 |
| Copper     | 0.05-1.5           | BDL | 0.02 | 0.08 | 0.004 | BDL | 0.01 | 0.005 | 0.002 | BDL | 0.013 | 0.005 | 0.004 |
| Cadmium    | 0.01               | BDL | 0.02 | 0.01 | 0.004 | BDL | 0.006 | 0.001 | 0.001 | BDL | 0.01 | 0.003 | 0.003 |

*All values are in mg/L except pH and EC; BDL = Below Detectable Limits*
pH & EC

The average value of pH was from 7.0 to 7.4 during all the three seasons. Only one village (Kadagampattu) had pH less than 6.5 for each of the three sites in all the three seasons. The groundwater pH in the Tondiar basin showed a similar trend with an average value of 7.04.

EC, the electrical conductivity, of water is a proxy for the Total Dissolved Solids (TDS) (Jameel A. A. and Sirajudeen J., 2006). The EC values in all the sixteen villages ranged from a minimum of 0.1 mS/cm to a maximum of 2.2 mS/cm with higher values during post monsoon. This may be due to the increased dissolution of salts along with the monsoon rains into the groundwater. During post monsoon, in the Tondiar basin 57% to 62% of the samples were above the desirable limit of 1.5 mS/cm, whereas in the study area only 14% of the samples were above this limit.

Nitrate (NO$_3^-$)

The higher values of nitrate are the most common indication of agricultural impact on groundwater quality. Nitrate values for all the villages were within the permissible limits according to the WHO standard (2003) for irrigation water (50 mg/l). The maximum was observed during summer with a value of 44.9 mg/l. In the Tondiar basin, the nitrate values ranged from 5 to 62 mg/l.

Phosphate (PO$_4^{3-}$)

Phosphates may enter the groundwater from phosphate containing rocks, fertilizers or percolation of sewage and industrial waste. The WHO standard for phosphates in drinking water is 0.1 mg/l (Dey, A. K., 2002). Usually groundwater contains only a minimal phosphorus level because of the low solubility of native phosphate minerals and the ability of soils to retain phosphate (Rajmohan N. and Elango L, 2005).

The phosphate concentration in the study area varied from BDL to 3.1 mg/l during post monsoon. During summer and pre-monsoon, 100% of the samples exceeded the permissible limits with a concentration ranging from a minimum of 0.2 mg/l to a maximum of 1.4 mg/l. The increase of phosphate concentration can be due to the agricultural runoff from irrigated lands because of the increased use of phosphatic fertilisers. Jameel A. A. et al., (2006) and Usharani, K. et al., (2010) found similar trends in the groundwater samples were observed in the Perur and Thiruchirappalli region of Tamil Nadu.

Sodium (Na$^+$) and Potassium (K$^+$)

Sodium and Potassium are the most important mineral occurring naturally. There may be an increased concentration of sodium and potassium ions due to the decomposition of granitic terrain (Jameel A. A. et al., 2006). High sodium concentration in irrigation water results in absorption of Na$^+$ ion by the clay particles resulting in reduced permeability of the soil and poor internal drainage. Such soils become hard when dry (Collins and Jenkins, 1996).

For sodium, all the samples in this study were within the permissible limits, with higher values observed during pre-monsoon (58.8 mg/l). A similar trend of higher concentration of sodium during pre-monsoon in groundwater was observed in the Thirumanimuthtar sub-basin of Tamil Nadu (Vasanthavigar M. et al., 2010).
For potassium, most of the samples exceeded the permissible range with maximum values (15.4 mg/l) during the post-monsoon. Higher values of Na+ and K+ were observed in the Tondiar basin as compared to the study area with values between 10 to 490 mg/l and 1 to 212 mg/l respectively.

**Calcium (Ca\(^{2+}\))**

Granitic terrain is a natural source for calcium and contains large concentration of these elements (Jameel A. A. et al., 2006). High concentrations of Ca\(^{2+}\) was found in the Tondiar basin with values ranging from 42 to 232 mg/l. Similar trend was observed in this study but with much higher values during summer (974.1 mg/l) followed by post-monsoon (810.1mg/l). Around 66% of the samples were above the permissible limits during summer. The major source of Ca\(^{2+}\) in this area is due to ion exchange of minerals from the rocks (Ramesh K. & Elango L., 2011).

**Table 2: Correlation Matrix of the various water quality parameters**

|     | Cd  | Ca   | Cu  | EC   | Pb  | Mn  | NO\(_3\) | pH  | PO\(_4\) | K   | Na  | Zn   |
|-----|-----|------|-----|------|-----|-----|---------|-----|---------|-----|-----|------|
| Cd  | 1   |      |     |      |     |     |         |     |         |     |     |      |
| Ca  | -0.51 | 1   |     |      |     |     |         |     |         |     |     |      |
| Cu  | -0.50 |     | 0.49|      |     |     |         |     |         |     |     |      |
| EC  | -0.56 |     |     | 0.99 |     |     |         |     |         |     |     |      |
| Pb  | -0.39 |     |     |     | 0.99| 0.98|         |     |         |     |     |      |
| Mn  | -0.40 | 0.99|     |     |     |     | -       |     |         |     |     |      |
| NO\(_3\) | -0.47 |     |     |     | 0.99| 0.99|         |     |         |     |     |      |
| pH  | -0.56 |     |     |     |     |     |         |     |         |     |     |      |
| PO\(_4\) | -0.25 |     |     |     |     |     |         |     |         |     |     |      |
| K   | 0.14 |     |     |     |     |     |         |     |         |     |     |      |
| Na  | -0.26 |     |     |     |     |     |         |     |         |     |     |      |
| Zn  | 0.99 |     |     |     |     |     |         |     |         |     |     |      |

**Heavy Metals**

Occurrence of heavy metals in groundwater is directly related to soil characteristics or anthropogenic causes that determine the rate of water movement (Burkat M. R. et al., 1999). Five heavy metals, namely, lead, zinc, manganese, copper and cadmium were analysed in the water sample.

For cadmium, copper and zinc, all the sample points were within the accepted limits. The
concentrations of Cu and Zn were found to be within similar range in the Tondiar basin as well with values ranging to a maximum of 0.022 mg/l and 0.372 mg/l.

Higher concentration of Pb (>0.05 mg/l) was observed during post-monsoon in the two villages of Thollamur and Kondalankuppam as compared to the Tondiar basin, where all samples were within the permissible limits except in one particular well.

For manganese, one sample point in Korakkeni exceeded the permissible limits both during post-monsoon and summer. All the other samples were within the permissible limits. The manganese values showed similar trends even in the Tondiar basin with values from 0.01 to 0.67 mg/l.

**Correlation Matrix**

In order to find out the relationship amongst physico-chemical parameters of the water samples, correlation coefficients were worked out (Usharani E., 2010). Very strong correlation was found between EC and pH (1.00). A strong positive correlation was observed for pH and EC with many of the parameters. A positive correlation of 0.92 was found between Na and K, Na and NO$_3$ (0.974) and also between PO$_4$ and Na and K. Ca showed strong positive correlation with Mn and PO$_4$ and strong negative correlation with K. The correlation matrix would need further investigation with reference to the relations between different parameters.

**4. Conclusion**

The geological formations have a great influence on the groundwater quality in the study area. Almost all the samples were within the permissible range for most of the parameters except for EC, phosphates, potassium, calcium and lead.

The sequence of abundance of major cations and anions in the study area is in the following order: Ca$^{2+}$ > Na$^+$ > K$^+$ and NO$_3^-$ > PO$_4^-$ . The sequence of heavy metals in terms of abundance is as follows: Pb > Mn > Zn > Cu > Cd.

More than 90% of the samples in the study area were found to be within the permissible limits for most of the parameters, including heavy metals. Care needs to be taken to monitor the interaction between the geological formations in the area and the groundwater, especially in the present scenario of over extraction of groundwater.

**Acknowledgement**

SV acknowledges the financial and lab-oriented support from Pondicherry University for carrying out this work.

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