Assessment of groundwater quality for drinking purposes in Amaravathi river basin

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Abstract. Groundwater assessment has become a demanding issue due to the scarcity of freshwater. Heavy textile based industrialization in Amaravathi river basin has caused over exploitation, decline in water levels and deterioration of water quality. Pre and Post monsoon analysis of samples from 31 observation wells over the period of thirty years (1988-2017) revealed that pH (8.18-8.22), Ca (67.87-73.79 mg/L), SO\textsubscript{4} (122.37-125.64 mg/L), HCO\textsubscript{3} (226.36-243.85 mg/L) and F (0.31-0.42 mg/L) are within the admissible limits and EC (0.05-0.50 d Sm\textsuperscript{-1}), TH (489.4-518.29 mg/L), TDS (1021-1022 mg/L), Cl (304.68-306.51 mg/L), NO\textsubscript{3} (24.90-26.21 mg/L) and Mg (78.76-82.75 mg/L) exceeds the admissible limits for the entire basin during Pre and Post monsoon periods. The quality of groundwater is classified as excellent (<25), good (25-50), Poor (50-75) very poor (75-100) or unfit (>100) for human consumption based on the calculated Water Quality Index values (WQI). Hydro chemical assessment of groundwater quality for domestic and drinking utility were worked out using WQI and ranged from 8.1 to 56.8 during Pre monsoon and 9.0 to 66.7 during post monsoon periods, indicating the water quality of excellent to poor and excellent to very poor categories for potable purposes during pre and post monsoon respectively. Instantaneously some proportion of excellent water quality wells are shifted into good quality wells over three decades.

Keywords: - Groundwater Quality, Water quality index, Industrialization, physico-chemical parameters

1. Introduction

Groundwater is an invaluable natural resource as it accounts for more than 30 percent of all available natural freshwater in the world. Most of the arid and semi-arid regions in India solely depend on groundwater as its primary source of drinking water. With the extensive usage of bore well technologies, groundwater is being extracted at a rapid pace that often the recharges of these sources are insufficient. Additionally, factors like industrial wastes, agriculture leachate and municipal solid wastes are polluting the available water resources.

India’s freshwater resources are plummeting and it faces an acute shortage of drinking water of permissible quality. The United Nations world water development report categorized India as one of the worst countries in terms of water quality, and its ability and commitment to ameliorate the situation. The quality of surface and groundwater are in a steady decline due to multitude of factors viz., increasing population, industrial developments, climate change, and pollution viz., by human, industrial and agricultural wastes.

Numerous researches has been conducted to assess the water quality, including modelling techniques, multimetric indices and multivariate statistical approaches. The water quality index designed by Horton (1965) and Brown (1970) has been developed further and ample formulas and techniques are available to compute the WQI. These techniques efficiently crunch numerous physical

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and chemical parameters into a single value that represents the level of water quality, thus eliminating
the differences between the parameters used individually in the assessment. Shivanna and
Nagendrappa (2015) used Water Quality Index approach to evaluate the water quality of certain tank
waters, Tumkur District, Karnataka, India and found that overall water quality index of the studied
tanks ranged from 46.72 to 92.22 indicating the quality ranged from good quality to very poor
quality. The results of the study on water quality in the rivers of Lake Taihu basin using WQI method
revealed that WQI value during the study period was 59.33 and the water quality was considered as
moderate (Zhaoshi Wu et al. 2018).

Over extraction of groundwater increases the concentration of dissolved and ionic
constituents. Over exploitation, receding water levels, declining water quality are major concerns in
many regions of India. Variation of groundwater quality in a locale is a function of physico-chemical
parameters that are influenced by anthropogenic activities and geological formations. From the
perspective of the above mentioned circumstances, quality of potable groundwater was assessed in
Amaravathi river basin by using the Water Quality Index.

2. Materials and methods

2.1. Study area

The study was conducted with an objective to assess the suitability of water quality for drinking
purposes in Amaravathi river basin which lies between latitudes 10°06’52’’N and 11°02’10’’N and
longitudes 77°03’24’’E and 78°13’06’’E with catchment area of 8544 km² comprising of four districts
viz., Coimbatore, Tirupur, Dindigul and Karur in TamilNadu. The basin is bounded by the Vaigai
basin on the South, Noyyal basin on the North, Parambikulam Aliyar basin on the West and Ayyalur
basin and Kadavur hills on the East.

2.1.1. Climate

The average annual rainfall of the study area is 653 mm. The monthly potential evapotranspiration
value varies from 66 mm to 130.9 mm. The maximum average wind speed is 32.6 kmph in the month
of June. The minimum average wind speed is 9.5 kmph in November.

2.1.2 Drainage

The drainage pattern of Amaravathi river basin is dendritic as shown in Fig 1. The river has major
tributaries such as Kuthiraiyar, Shanmuganadhi, Nallathangal Odai, Nanganjiyar and Kodaganar
from the south. All these tributaries originate from the adjacent valleys of Palani hills and join
the main river Amaravathi on the right side.

2.1.3 Geomorphology

The geomorphology of the study area is dominated by unit of a pediplain weathered / buried which
covers an extent of 666.3 km² (77.95%), as shown in Fig 2. In the study area, 3% of the area is mainly
covered with pediment inselberg complex.

2.1.4 Geology

The principal geological formations of Amaravathi river basin are Archean and Proterozoic rocks.
The Amaravathi basin is divided into three physiographic divisions such as undulating plains, plateau
and hill region with shallow and textures soil.

2.2 Groundwater quality

Assessment of water quality defined as the analysis of physical, chemical and biological
characteristics of water.
2.2.1. Water Quality Index

Horton (1965) states Water Quality index is the composite influence of individual quality attributes on the overall water quality. The pre and post monsoon quality data were collected for 31 observation bore wells located in Amaravathi river basin for the period of 1988 to 2017 from the office of State Surface and Groundwater Data Centre, Public Works Department, Taramani, Chennai, Tamil Nadu. Eleven Physico-Chemical parameters viz., i.e. pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Sulphate (SO$_4^{2-}$), Nitrate (NO$_3^-$), Calcium (Ca$^{2+}$), Chloride (Cl$^-$), Magnesium (Mg$^{2+}$), Bicarbonate (HCO$_3^-$), and Fluoride (F$^-$) were used to calculate WQI using the Weighted Arithmetic mean function.

The quality of groundwater is classified as excellent (<25), good (25-50), poor (50-75), very poor (75-100) or unfit (>100) for human consumption based on the calculated WQI values.

3. Results and Discussion

3.1. Water quality

Spatial analysis of potable groundwater quality was accomplished by interpolation of sampling points using the ‘Inverse Distance Weighted’ algorithmic method. The descriptive statistics of physico-chemical parameters for the samples in pre and post monsoon periods and desirable limits are provided in Table 1. The study reveals that the parameters pH, Ca, SO$_4^{2-}$, HCO$_3^-$ and F are within the admissible limits and EC, TH, Cl, TDS, NO$_3^-$, and Mg exceeds the admissible limit for the entire basin during the given period.

3.2. Water quality index (WQI)

Water quality index helps summarize voluminous water quality data points into simple label (eg. excellent, good, poor, very poor, etc.) for better comprehension and consistency in reporting. The label indicate the water qualities in different water bodies like lakes, rivers, streams and reservoirs. Calculation of water quality index is an important technique for demarcating groundwater quality and its drinkability. An index has been developed using the data collected from water resource monitoring program on physical, chemical and biological variables.

To compute the Water Quality Index, the eleven parameters have been assigned respective weights (Wi) and water quality ratings (Qi) according to the guidelines laid down by WHO. In this technique, the weights for the parameters are assigned to be inversely proportional to the recommended standards for the respective parameters. The computed grades of WQI values were classified under five labels for human understanding according to Jafar Ahamed et al., 2013. The number of wells that fall under each category are shown in Table 2.
Figure 1. Drainage density map of the study area

Table 1. Descriptive Statistics of the Groundwater Samples in Pre-Monsoon and post monsoon period from 1998 to 2017

| Parameter                  | Admissible limits | Per monsoon period (Average value) | Post monsoon period (Average value) |
|----------------------------|-------------------|-----------------------------------|-------------------------------------|
| pH                         | 6.5-8.5           | 8.18                              | 8.22                                |
| Electrical Conductivity (EC) - μ mhos/cm. | 0.05- 0.5        | 1.739                            | 1.738                               |
| Total Dissolved Solids (TDS) - mg/L | 500              | 1022.26                          | 1021.99                             |
| Total Hardness (TH) - mg/L      | 300               | 489.40                            | 518.29                              |
| Chloride (Cl) - mg/L        | 200               | 306.51                            | 304.68                              |
| Calcium (Ca) - mg/L         | 75                | 67.87                             | 73.79                               |
| Magnesium (Mg) - mg/L       | 30                | 78.76                             | 82.75                               |
| Sulphate (SO₄) - mg/L       | 250               | 125.64                            | 122.37                              |
| Bicarbonate (HCO₃) mg/L     | 500               | 226.36                            | 243.85                              |
| Nitrate (NO₃) - mg/L        | 10                | 24.90                             | 26.21                               |
| Fluoride (F) - mg/L         | 1                 | 0.31                              | 0.42                                |
| WQI                        |                   | 31.89                             | 36.92                               |
Table 2. Water quality rating with reference to WQI

| Water quality rating | Number of wells                                      |
|----------------------|-----------------------------------------------------|
|                      | Pre monsoon season | Post monsoon season |                      |
|                      | 1988-1997          | 1998-2007           | 2008-2017            |
| Excellent            | 24                 | 12                  | 18                   | 3 | 1 |
| Good                 | 7                  | 16                  | 24                   | 12 | 24 | 14 |
| Poor                 | -                  | 3                   | 6                    | 1 | 4 | 14 |
| Very poor            | -                  | -                   | -                    | - | - | 2  |
| Unfit                | -                  | -                   | -                    | - | - | -  |
3.3. **Pre monsoon water quality index**

During the pre-monsoon season, water quality index ranged from 8.1 to 56.8, and the labels varied from excellent to poor. During the pre-monsoon season over three decades, the number of excellent wells was drastically reduced from 24 to 1, good quality resources improved from 7 to 24, and also the poor quality wells rose from 0 to 6. Basin wise spatial distribution of decadal water quality index map (Fig 3) shows that the wells located in the entire inspected area are fit for drinking purposes.

3.4. **Post monsoon water quality index**

Water quality index of the inspected area ranged from 9.0 to 66.7 during the post-monsoon season representing the groundwater quality that ranges from excellent to very poor for human consumption. The number of excellent wells reduced and good quality and poor quality wells increased from 12 to 14 and 1 to 14 respectively and a couple of wells fell under the very poor quality during 2018-2017. From Post-monsoon basin wise spatial distribution of decadal water quality index map, it was found that the wells located at the northern part of the surveyed area fall under very poor quality.

![Figure 3. Spatial distribution of WQI over Amaravathi river basin (pre monsoon)](image-url)
4. Conclusion

The study was conducted to assess the potability of groundwater in the Amaravathi river basin. Groundwater in Amaravathi basin reveals high electrical conductivity (EC) level during both pre and post monsoon seasons. It might be due to the discharge of untreated waste-water, agricultural runoff and infiltration. The average value of sulphate for Amaravathi river basin is within the permissible limit as prescribed by WHO guidelines.

The water quality index of the inspected area varied from 8.1 to 56.9 during pre-monsoon and 9.0 to 66.7 during post-monsoon seasons. In terms of water quality labels, pre-monsoon ranged from excellent to poor and post-monsoon season, varied from excellent to very-poor. Number of excellent quality wells declined and good quality wells increased during the study period. The wells stationed at the northern part of the study area had very poor quality especially in the post monsoon season. Spatially, narrow variations in WQI were due to water mobility and shorter water retention time, thus the high mobility and rapid exchange reduced the spatial difference in the water quality. The maximum and minimum WQI values, might be due to accumulation or reception of large amounts of nutrients and organic pollution. With respect to temporal variation, a depreciation trend of best water quality might be due to easily treated variables, especially nutrients (Wu et al. 2014). This study establishes that regular monitoring of wells is very essential to maintain the sustainability of the ecosystem.

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