ABSTRACT

In this study, the level of penetration of polluted riverwater on the adjoining aquifers were carried out. Various tools such as Sodium Absorption Ratio (SAR), Wilcox diagram, United States Salinity Laboratory (USSL) and Geographical Information System (GIS) were used to evaluate the quality of water and its suitability for various consumption purposes. Results of SAR show that many of the wells during premonsoon illustrate high values indicating the unsuitable nature of groundwater for irrigation but during postmonsoon, SAR values found to be decreased due to the dilution effect of precipitation by monsoon. Wells belonging to the 1st layer demonstrates very high SAR value and the subsequent layers show diminished values indicating the effect of percolation is not significant as the distance increases. Similar results were found in the case of Wilcox diagram which also substantiates the results of SAR that the wells pertaining to the 1st layer is not suitable for irrigation whereas the 2nd layer wells display permissible to doubtful reflecting that some of the wells may be used for irrigation. USSL and Wilcox result clearly state that the wells belonging to the 3rd to 5th layer are suitable for irrigation. Spatial distribution diagram using GIS illustrate that the first zone belonging to the 1st layer is highly affected and the last zone (5th zone) is the least affected with regard to the percolation of the polluted water from River Noyyal. Overlay map shows that the wells falling in the northern part of River Noyyal are less polluted compared to the wells in the southern part.

Keywords: Groundwater, water quality, River Noyyal, Overlay analysis

1. Introduction

Globally, water-dependent terrestrial ecosystems are receiving increased attention due to growing recognition that water must be available for ever to meet the fast growing urbanization and industrialization (Münch and Conrad, 2007; Krause et al., 2007). Water of adequate quantity and most importantly of standard quality is required to meet growing household, industrial, and agricultural needs. Keeping in view of the importance of water, several studies have been carried out to evaluate the natural and man-made phenomena that govern the chemical composition of groundwater. Generally, the quality of water is controlled by many factors that include composition of recharge water, geological structure and mineralogy of the watersheds and aquifers as well as the residence time and reactions that take place within the aquifer and anthropogenic factors (Drever, 1988; Fetter, 1994; Appelo and Postma, 2005).

Industrial pollution has been and continues to be a major factor causing the degradation of the environment around us, affecting the water we use, the air we breathe and the soil we live on. But of these, the pollution of water is arguably the most serious threat to current
human welfare. Water is polluted not only by industries but also by households. Both industries and household wastewater contain chemicals and biological matter that impose high demands on the oxygen present in water. Urban rivers have been associated with water quality problems and the practice of discharging untreated domestic and industrial waste into the water course has emerged to an alarming level (Hall, 1984).

The aim of this study is to assess quality of groundwater near River Noyyal which passes through Tiruppur, the textile town of South India where the water gets polluted due to the indiscriminate discharge of effluents from textile industries (dyeing and bleaching factories) located in this region. The suitability of the ground water for domestic and irrigation was studied using various tools, namely, TDS, Wilcox diagram, US Salinity Laboratory (USSL), sodium adsorption ratio (SAR) etc. From the point of view of water quality and pollution, critical evaluation of the above factors becomes pertinent, so that specific sources of pollution can be identified. In this work, in order to achieve this objective, the groundwater quality near River Noyyal is studied in detail. Such studies contribute to effective management and utilization of the surfacewater resources.

2. Study area

The study area is located in the central part of Tamil Nadu (lat. 11°06’19”N; long. 77°30’14”E and lat.11°03’51”N; long. 77°47’52”E). The region is basically an agricultural area with paddy as the main crop. The river Noyyal is a seasonal river and it originates from Vellingiri Hills in the Western Ghats of Coimbatore District. It flows through Coimbatore, Tiruppur, Erode and Karur districts and finally joins into Cauvery River near Noyyal village. It flows over a distance of 175 kilometers. The catchment area of the river is 3.49 lakh hectares. Throughout its distance on both sides of the banks of river Noyyal more than 100 villages are situated. Noyyal was the major source for irrigation, drinking water and other activities of the people living on both sides of the river and even for people living beyond 3 km from the river. The industrial effluent released by dyeing and bleaching factories in Tiruppur, a major hosiery centre in South India has become a serious issue because it has severe impact on water bodies. There are 1500 Knitting units, 700 Dyeing & Bleaching Units, 500 Fabric Printing, 2500 Garmenting, 250 Embroidery, 300 Compacting and Calendaring and 500 other ancillary units are functioning (Palanivel and Rajaguru, 1999, www.tiruppur.tn.nic.in). Many dyeing units in Tiruppur are within a radius of 5 km from the Noyyal River. Dyeing units come under Red category since they produce hazardous wastes near the natural water resources. Many dyeing and bleaching units discharge their effluents amounting 80 to 100 MLD into the River Noyyal after semi-treatment or without treatment.

3. Materials and Method

Fifty groundwater samples were collected during pre-monsoon and post-monsoon seasons in a grid pattern at five selected zones and five samples each at northern and southern part of the river is collected at a distance of about 500 m, 1000 m, 1500 m, 2000 m and 2500 m from River Noyyal in order to study the level of penetration of polluted water into the aquifer system (Figure 1). Samples were collected during July 2008 (pre-monsoon); December 2008 (post-monsoon); July’ 2009 (pre-monsoon) and December 2009 (post-monsoon). Surface water samples were collected using Aqua trap water sampler. For collection, preservation and analysis of the samples, the standard methods (APHA, 1995) were followed. Electrical conductivity and pH of water samples were measured in the field immediately after the collection of the samples using portable pH and electrical conductivity meters. Na+ and K+
were measured by using a flame photometer. Total dissolved solids (TDS) were measured by evaporation and calculation methods (Hem, 1991). Ca\(^{2+}\) and Mg\(^{2+}\) were determined titrimetrically using standard EDTA. Chloride was estimated by AgNO\(_3\) titration. Sulphate was analysed using the turbidimetric method (Clesceri et al. 1998). Nitrate was analysed using UV–visible spectrophotometer (Rowell, 1994).

![Figure 1: Study area map showing the sampling locations](image_url)

4. Results and Discussion

The statistical results of the analytical geochemical data of the groundwater such as minimum, maximum and mean in the study area are presented in table.1

**Table 1:** Summary statistics of the physico-chemical parameters

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<td></td>
<td>Mini</td>
<td>Maxi</td>
<td>Mean</td>
<td>Mini</td>
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<td>5</td>
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<tr>
<td>Cl</td>
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<td>1485</td>
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<td>25</td>
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<tr>
<td>NO(_3)</td>
<td>4</td>
<td>115</td>
<td>20</td>
<td>5</td>
</tr>
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</table>

(All other parameters are expressed in mg/L; EC expressed in µS/Cm)
4.1 Sodium absorption ratio (SAR)

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium absorption ratio (SAR) is calculated by the relation (Karanth, 1997)

\[
\text{SAR} = \frac{\text{Na}^+}{[(\text{Ca}^{2+}+\text{Mg}^{2+})^{1/2}]/2}
\]

Where, concentrations are reported in meq/l.

SAR concentration ranges from 1.03 to 15.44 with a mean of 6.18 for pre-monsoon and from 0.6 to 13.0 with a mean of 5.2 in post-monsoon. During premonsoon, 26 out of 50 wells show SAR values greater than 6.0. In the case of post-monsoon, 15 out of 50 wells had shown SAR value greater than 6.0. Layerwise study of SAR indicates that all the wells belonging to the 1\textsuperscript{st} layer (about 500m away from the polluted Noyyal River) is found to be above 6.0 and most of the samples show more than 10.0 (high SAR value) irrespective of monsoon. Most of the wells belonging to the 3\textsuperscript{rd} to 5\textsuperscript{th} layer (1500 to 2500m away from River Noyyal) show lower SAR values indicating that the percolation effect is not significant to the water bodies at this region. Hence, this study clearly demonstrates that the wells belonging to the 1\textsuperscript{st} and 2\textsuperscript{nd} layer are found to be affected with respect to SAR.

4.2 Wilcox diagram

Wilcox (1948) used % sodium and specific conductance in evaluating the suitability of groundwater to irrigation. Percentage Sodium is determined from the ratio of sodium to the total cations, namely, sodium, potassium, calcium and magnesium. Percent sodium is calculated as follows:

\[
\%\text{Na} = 100\times \frac{\text{Na}}{\text{Na}+\text{K}+\text{Ca}+\text{Mg}}
\]

The classification of groundwater samples from the study area with respect to percent sodium and EC are shown in Figure.2. Results show that the wells belonging to the 1\textsuperscript{st} layer, that is, 500 m away from the River Noyyal is found to fall in the unsuitable and doubtful to unsuitable region which clearly indicate that these wells are not suitable for irrigation. In the case of 2\textsuperscript{nd} layer wells (about 1000 m away from River Noyyal), it is observed that except one well, all other wells are found to fall in the permissible to doubtful and doubtful to unsuitable region indicating that most of the wells in this region also not fully suitable for irrigation. Wells belonging to 3\textsuperscript{rd} layer (about 1500 m away from River Noyyal) demonstrate that 40% of the wells are found to be good for irrigation and the remaining 60% fall in the region of permissible to doubtful. In the case of wells belonging to 4\textsuperscript{th} and 5\textsuperscript{th} layers, most of them fall in the very good to good and good to permissible region indicating that these wells are very much suitable for irrigation. The results of the present study clearly demonstrate that the influence of polluted riverwater to the groundwater aquifers is highly significant only within 1 km from River Noyyal on both north and south directions.
To determine the suitability of water to irrigation, two important parameters, namely, salinity hazard and sodium hazard are highly required. In the USSL diagram these two parameters are used to clearly indicate whether the water under study is suitable for irrigation or not. The total concentrations of soluble salts in irrigation water can be classified into low (C1), medium (C2), high (C3) and very high (C4) salinity zones. These zones (C1 to C4) have the value of EC less than 250 µS/cm, 250 to 750 µS/cm, 750 to 2,250 µS/cm and more than 2,250 µS/cm, respectively. Higher EC in water creates a saline soil. If water used for irrigation is high in Na+ and low in Ca²⁺, the ion-exchange complex may become saturated with Na⁺, which destroys soil structure, because of dispersion of clay particles.

**Figure 2:** Specific conductance and percent sodium relation for rating irrigation water

**4.3 USSL diagram**

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US Salinity Laboratory’s diagram (US Salinity Laboratory Staff, 1954) is used widely for rating the irrigation waters. Plot of geochemical data of groundwater samples of the study area in the USSL diagram is illustrated in Figure.3. During both the monsoon seasons, wells belonging to the 1st layer fall in the C$_4$S$_2$ and C$_4$S$_3$ region. C$_4$S$_2$ and C$_4$S$_3$ are not good for irrigation and since all the wells of 1st layer falls in this region, water in this region is unsuitable for irrigation. 2nd layer of well samples falls in the C$_5$S$_2$ and C$_3$S$_1$. This rating indicates high salinity and low-medium sodium hazards and the wells falling in this region are also not suitable for irrigation. Third layer also follows the same pattern as that of 2nd layer. 4th and 5th layer of wells falls in the C$_3$S$_1$ and C$_2$S$_1$ and the water from these wells can be used for irrigation as these contain low sodium content.

Figure 3: Rating of water samples in relation to salinity and sodium hazard

4.4 Spatial distribution and overlay analysis

Contour plots of TDS illustrates that during pre-monsoon (July 2008), wells belonging to the 1st layer in both north and southern direction of River Noyyal shows high TDS and the entire region is found to be affected due to the percolation of polluted water (Figure.4). It may be noted that the fifth zone wells in the 1st layer shows reduced values which may be due to the location of these wells far away from the Orathapalyam dam. In the case of pre-monsoon (July 2009), similar distribution pattern is observed but the contour pertaining to the TDS value of 2000 to 2500 mg/L demonstrates a continuum from the 1st zone to the 4th zone in the 1st layer reflecting that the percolation of polluted water further worsening the wells falling in this layer. Wells belonging to the 2nd layer illustrates lower TDS values compared to the 1st layer and during July’ 2008, most of the wells falls in the TDS range of 1500 to 2000 mg/L. Spatial distribution pattern of the subsequent layers show that the water from these wells are not much affected and many of these wells shows low TDS. Almost similar pattern of spatial distribution is observed in the case of postmonsoon values and except the 1st and 2nd layer, all other wells show very low TDS and suitable for both domestic and irrigation purposes. Seasonal effect is found to be significant as many wells in the contours illustrating the affected region decreases during postmonsoon due to dilution of chemical composition. The integrated overlay of the contours belonging to the four periods was carried out and the overlay map shows clearly that the zone 1 of layer 1 is the most affected which is found to exist very close to the polluted water stored in the Orathapalyam dam. Zone 2 of layer 1 also indicates that the wells are highly affected but to a slight lesser degree compared to zone
1 of layer 1 wells. The overlay map shows that the wells falling in the northern part of River Noyyal are less polluted compared to the wells in the southern part. The integrated map clearly demonstrates that the wells belonging to the 3rd, 4th and 5th layer are not polluted and the influence of River Noyyal is not significant at these levels.

**Figure 4:** Map showing the overlay analysis of different periods
5. Conclusions

The overall findings of the present study were summarized below:

1. SAR values clearly demonstrates that the seasonal effect on the chemical parameters is significant.
2. Layerwise study of SAR demonstrates that all the wells in the 1st layer (viz., wells at about a distance of 500m from River Noyyal) are highly polluted since the SAR values are very high in this region.
3. The effect of percolation is not significant in the 3rd to 5th layer in the study area since these layers fall away (1500 to 2500m) from River Noyyal.
4. Results of Wilcox diagram clearly indicates that all the wells belonging to the 1st layer is not suitable for irrigation but the wells pertaining to 2nd layer illustrates partly permissible to irrigation
5. Wilcox results demonstrate that wells belonging to 4th and 5th layers are very much unsuitable for irrigation.
6. The influence of polluted river water to the groundwater aquifers is highly significant about 1 km from River Noyyal on both north and south directions.
7. Results of USSL diagram also found to be complementary with the above findings.
8. Contour plots illustrate that the first zone belonging to the 1st layer is highly affected and the last zone (5th zone) is the least affected with regard to the percolation effect of the polluted water from River Noyyal.
9. Overlay map shows that the wells falling in the northern part of River Noyyal are less polluted compared to the wells in the southern part. This indicates that the wells in the northern part of the study area are more confined and the nature of soil may also play a dominant role in the variation of percolation.

6. References


