ASSESSMENT OF GROUNDWATER QUALITY IN THE SOUTH 24-PARGANAS, WEST BENGAL COAST, INDIA

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The suitability of groundwater quality for drinking and agricultural purposes was assessed in the South 24-Parganas district of West Bengal (India), based on various water quality parameters. The study area falls under a monsoon type of climate. For the present study forty-six representative groundwater samples were collected randomly from tube wells/bore wells to monitor the water chemistry of various ions. The results showed that the concentrations of these ions are above the permissible limits for drinking and irrigation purposes. The pollution with respect to chloride, nitrate and fluoride is mainly attributed to the extensive use of fertilizers and large-scale discharge of municipal wastes into the open drainage system of the area. Most of the groundwater samples of the study area fall into the U.S. Salinity Laboratory Classification C3-S1 (high salinity-low SAR). According to the Wilcox irrigation water classification, 46% of the water samples fall under good to permissible category and 37% under the permissible to doubtful category. A classification based on conductivity shows most of the groundwater samples fall in the “tolerable” to “safe” category. Based on a groundwater chloride classification, 54% of water samples are “safe” to “tolerable”, and 22% of water samples fall under a “health hazard” category.
INTRODUCTION

Groundwater plays a pivotal role in human life and development. An understanding of the chemical quality of groundwater is essential in determining its usefulness for domestic, industrial and agricultural purposes. Good quality of water has the potential to cause better crop yields under good soil and water management practices. The suitability of irrigation water depends upon many factors including the quality of water, soil type, salt tolerance characteristics of plants, climate and drainage characteristics of soil (Michael, 1990). Groundwater always contains small amounts of soluble salts. The kind and quality of these salts depend upon the sources for recharge of the groundwater and the strata through which it flows. An excess of soluble salts can be harmful for many crops. Hence, an understanding of the chemistry of groundwater is essential to properly evaluate groundwater quality for drinking and irrigation purposes.

Presentation of geochemical data in the form of graphical charts such as the U.S. salinity diagram and Wilcox salinity diagram help to recognize various hydrogeochemical types in a groundwater basin. Analysis of the chemical constituents of groundwater also sheds light on the geochemical evolution of groundwater, as well as identification of recharge areas. The present study has been undertaken with the objective of (a) chemical characterization of groundwater of the study area and (b) evaluation of the suitability of groundwater in the study area for drinking and irrigation purposes.

The northern portion of the study area (which is a part of Bengal delta) has features of a mature delta and was formed earlier than the southern portion. The delta building process is still going on in the southern part of the study area, which is covered by the Sundarban forest.

The morphological features in the district include the levees along the rivers Hooghly, Malta and Bidyadghari, and marshes bordering the levees and the islands. The district is drained by the Hooghly, Malta, Bidyadghari, and Thakuran rivers and their many tributaries and distributaries, which form a network of rivers and tidal creeks, especially in the Sundarbans region. Thick sequences of quaternary sediments cover the entire district. Soils vary from deep fine loamy to deep fine clayey soils. In the southern part, the soil is saline in nature.

The climate is characterized by hot summers, cool winters, high humidity, and heavy rainfall during the monsoon. The average rainfall is 1,722 mm. Mean annual temperature ranges from 25°C to 27.5°C. Mean summer maximum temperature is around 40°C and mean winter temperature is around 10°C.

The study area is rich in mangrove forest resources, with total forest cover in the district about 1,706 sq. km. The Sundarbans mangrove forest harbors a wide diversity of flora and fauna. It is the only mangrove tiger habitat on earth.

The population is predominantly rural and agriculture is the main occupation. Net area available for cultivation is 3,928 sq. km. Rice is the main crop followed by vegetables and pulses. Orchards and gardens are localized in and around Baruipur. Only 15% of the total geographical area is under irrigation. Important industrial centers are Bata, Budge Budge, Birlapur, Falta, Sonarpur and Baruipur. Main industries are cotton and jute textile, engineering, metallurgical, plastic and polyethylene, leather, drugs and pharmaceutical products.

Regional disparity in development is very prominent in this district. While the northern and northeastern parts, i.e., the area adjacent to Calcutta, have experienced marked development, the Sundarbans region shows very low level of development in all respects.
MATERIALS AND METHODS

Groundwater samples were collected from the tube wells/bore wells and analyzed for various chemical parameters as described by the American Public Health Association (APHA, 1995). Figure 1 shows the geographical location of the study area. These parameters include pH, electrical conductivity, total dissolved solids, and important cations such as calcium, magnesium, sodium and potassium as well as anions such as carbonates, bicarbonates, chlorides, nitrates, sulfates and fluorides (Table 1). The pH and electrical conductivity (EC) were measured in the field by means of a pH meter and digital conductivity meters, respectively. Sodium and potassium were determined by flame photometer. Total hardness (TH) as CaCO3, calcium (Ca2+), magnesium (Mg2+), carbonate (CO32-), bicarbonate (HCO3-) and chloride (Cl-) were analyzed by volumetric methods. Nitrate (NO3-) and fluoride (F-) were determined using ion analyzer. Sulfates (SO42-) were estimated by

Figure 1. Administrative divisions of South 24-Parganas District.
using the calorimetric technique. Groundwater quality for drinking purposes was analyzed by considering the WHO (1971) and ISI (1983) standards. The quality parameters like salinity (EC), permeability index (Doneen's Permeability Index, Doneen, 1964), toxicity due to chloride and sodium (SAR), and parameters causing miscellaneous problems to soil-water-plant relationships (bicarbonate, RSC, sulfate) were determined to assess the irrigation suitability of the groundwater. The data was also plotted on a Wilcox diagram and a U.S. Salinity Laboratory diagram (USSL Staff, 1954).

**RESULTS AND DISCUSSION**

**Suitability of ground water for drinking purpose**

The analytical results of different parameters of groundwater in the study area are given in Table 1. The pH values of groundwater in the study area range from 7.3 to 8.1, indicating an alkaline
type of groundwater. The electrical conductivity (EC) values range from 753 to 4120 micromhos/cm. The larger variation in EC is mainly attributed to anthropogenic activities and to geochemical processes prevailing in this region. Total dissolved solids (TDS) in the study area vary in the range 594-2802 mg/l. TDS values obtained in the study area are beyond the desirable limits, but only two samples have TDS values more than the permissible limits (ISI, 1983), making the water unsuitable for various domestic activities. The groundwater in the study area falls under fresh (TDS<1000 mg/l) to brackish (TDS>1000 mg/l) types of water (Freeze and Cherry, 1979). In the study area, the sodium concentration in groundwater ranges from 22-685 mg/l. The concentration of calcium in the study area ranges from 10-146 mg/l. The major source of magnesium in the groundwater is due to ion exchange of minerals in rocks and soils by water, and the samples of the study area vary in the range of 6-98 mg/l. The concentration of potassium varies from 1 mg/l to 50 mg/l.

Bicarbonate is the dominant anion, followed by chloride and sulfate. Bicarbonate in the study area ranges from 360-1080 mg/l, the source of most of the bicarbonates in the water being sewage and various human activities. Water with a high concentration of bicarbonates, if used for irrigation, may cause white deposits on fruits and leaves, which is undesirable (Subrahmanyam and Yadaiah, 2001). The concentration of chloride ranges from 28-823 mg/l; the large variation is attributed to geochemical processes, and to contamination by sewage wastes. Groundwater samples 10, 28 and 46 showed extraordinary high values of chloride. Nitrate concentration in the study area varies in the range of 0.3-55 mg/l, and all samples fall below the desirable limits, except for sample 7. The main source of nitrate in the groundwater is attributed to decaying organic matter, sewage wastes, and increased usage of fertilizers (Karanth, 1989). Sulfate varies from 1.1-110 mg/l. The fluoride content in the groundwater shows a range of 0.05-1.6 mg/l. The occurrence of low fluoride concentration in the groundwater may be either due to absence of fluoride containing minerals in the strata through which the groundwater is circulating. It could be also due to too rapid freshwater exchange, with the result that the normal process of concentration through evaporation or evapotranspiration is not very effective in raising the fluoride content of the groundwater to high values prevalent in some parts of the study area.

**Suitability of groundwater for irrigation purposes**

Irrigation water containing a high proportion of sodium will increase the exchange of sodium content of the soil, affecting the soil permeability and texture. This makes the soil difficult to plough and unsuitable for seeding emergence (Triwedy and Goel, 1984). If the percentage of sodium is high in irrigation water, calcium and magnesium exchange with sodium, thus causing deflocculation and impairment of the tilth and permeability of soils (Karanth, 1987). A sodium percentage of more than 60% is considered unsafe for irrigation. The values for the percent sodium in the study area range from 12-94%. Based on conductivity classification (Table 2) 52 % groundwater falls in “tolerable” (1000-1500 micromhos/cm) and 28 % under “safe” (<1000 micro mhos/cm) category. For groundwater classified on chloride (Table 3), 37 % of water sample is “safe”, 17% is “tolerable” and 22 % of water samples fall under the “health hazard” category.

A more detailed analysis, however, with respect to the irrigation suitability of the groundwater, was made by plotting the data as shown in Figure 2 (SAR and salinity hazard) according to the diagram of the US Salinity Laboratory of the Department of Agriculture (US Salinity Laboratory Staff, 1954) and Wilcox classification (Figure 3). According to the Residual Sodium Carbonate (RSC) concentration, groundwater sample falling under different categories is given in the Table 4.

According to this classification, low-salinity water (<200 mg/l) may be used for all types of soils. Most of the groundwater samples of the study area fall into the category of the good to moderate (C3-
Table 2. Classification of Groundwater According to Conductivity (micro mhos/cm)

<table>
<thead>
<tr>
<th>Conductivity range</th>
<th>Quality</th>
<th>Sample no.</th>
<th>Percentage of sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1000</td>
<td>Safe</td>
<td>1,3,4,6,16,17,22,24,27,33,34,38,40</td>
<td>28.26 %</td>
</tr>
<tr>
<td>1000-1500</td>
<td>Tolerable</td>
<td>5,7,8,9,12,18,19,20,21,23,25,26,29,30,31,32,35,36,37,39,42,43,44,45</td>
<td>52.17 %</td>
</tr>
<tr>
<td>1500-2000</td>
<td>Tolerable to some extent</td>
<td>2,11,13,41</td>
<td>8.69 %</td>
</tr>
<tr>
<td>2000-2500</td>
<td>Intolerable</td>
<td>14,15,46</td>
<td>6.52 %</td>
</tr>
<tr>
<td>&gt;2500</td>
<td>Health hazard</td>
<td>10,28</td>
<td>4.35 %</td>
</tr>
</tbody>
</table>

Table 3. Classification of Groundwater According to Chloride

<table>
<thead>
<tr>
<th>Chloride range (mg/l)</th>
<th>Quality</th>
<th>Sample no.</th>
<th>Percentage of sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>Safe</td>
<td>3,4,6,12,16,17,22,24,27,31,32,33,34,35,38,40,44</td>
<td>36.95 %</td>
</tr>
<tr>
<td>100-150</td>
<td>Tolerable</td>
<td>1,7,18,19,23,37,39,45</td>
<td>17.39 %</td>
</tr>
<tr>
<td>150-200</td>
<td>Tolerable to some extent</td>
<td>5,25,30,36</td>
<td>8.69 %</td>
</tr>
<tr>
<td>200-250</td>
<td>Intolerable</td>
<td>8,9,20,26,29,42,43,10,11</td>
<td>15.21 %</td>
</tr>
<tr>
<td>&gt;250</td>
<td>Health hazard</td>
<td>2,10,11,13,14,15,21,28,41,46</td>
<td>21.74 %</td>
</tr>
</tbody>
</table>

Figure 2. U.S. salinity diagram for classification of irrigation water (after Richards’ 1954).
Table 4. Classification of Irrigation Water on the Basis of Residual Sodium Carbonate (RSC) (USSL Staff, 1954)

<table>
<thead>
<tr>
<th>Category</th>
<th>RSC (meq/l)</th>
<th>Sample no.</th>
<th>Percentage of sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe</td>
<td>&lt; 1.25</td>
<td>9,14,15,21,22,23,24,26,27,29,30,35,36,38,40,41</td>
<td>34.78 %</td>
</tr>
<tr>
<td>Marginal</td>
<td>1.25-2.5</td>
<td>2,6,7,11,33,34,42</td>
<td>15.21 %</td>
</tr>
<tr>
<td>Unsuitable</td>
<td>&gt;2.5</td>
<td>1,3,4,5,8,10,12,13,16,17,18,19,20,25,28,31,32,37,39,43,44,45,46</td>
<td>50 %</td>
</tr>
</tbody>
</table>

S1) (59%) and 37 % under C3-S2 category. According to the Wilcox irrigation water classification scheme, the majority of the water samples (46 %) fall under a “good to permissible” category and 37 % under a “permissible to doubtful” category.

CONCLUSION AND RECOMMENDATIONS

Groundwater quality in the South 24-Parganas is analyzed to classify the groundwater into different categories for the drinking and irrigation purposes. The water quality in the study area is alkaline in nature. The overall groundwater quality of the study area is suitable for drinking purposes,
as well as for irrigation purposes. The ground water quality does not show any clear-cut regional trend in any direction (South-North or East-West). It is recommended to carry on the analytical work on ground water quality in greater detail and covering additional areas. Groundwater samples should be collected from many more sites to establish physicochemical variations and trends in the study area. A GPS-based ground water sampling strategy will be useful for accurate correlation of chemical signatures with subsurface hydrogeology.

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