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Research paper

Understanding the hydrochemical behavior of groundwater and its suitability for drinking and agricultural purposes in Pondicherry area, South India – A step towards sustainable development

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ABSTRACT

Optimal utilization of groundwater in Pondicherry area is needed to ensure future wellbeing of this region as the demand for water is exponentially increasing due to population growth. A study was carried out with an objective to assess the groundwater quality in different aquifers for its suitability to drinking and agriculture usage. The current trends in chemical quality were compared to that of historical data in order to ascertain the declining quality of groundwater in this region. Results indicate that excepting a few anomalies most of the parameters were within the permissible limits. pH, calcium, magnesium and chloride concentrations were high in 20%, 20%, 48% and 10% of the analyzed samples respectively, as compared with BIS (2012) prescribed limits. Indicators such as SAR(adj), RSC and Na% that qualify the water for irrigation suitability were found to be under permissible to excellent category. A few water samples fall under doubtful to unfit category, which could be due to presence of high bicarbonate. A comparison with historical data indicates that salinity (EC) and sodium hazard have been higher in the present scenario and the increase in electrical conductivity was found to be about 100–300 μS/cm. Statistical analysis of the data indicated that rock weathering and saline water have affected the groundwater chemistry in this region in addition to contributions of anthropogenic activities. A combination of tank rejuvenation and artificial recharge of groundwater by rainwater can yield better results for improving not only the groundwater quality but also quantity in this region for future times.

1. Introduction

Due to the ever increasing demand for potable and irrigation water and limited availability of surface water the importance of groundwater is increasing exponentially. Another reason for high dependency on groundwater is due to their less susceptibility to surface pollution as various pollutants get either diluted or chemically and biologically degraded in the unsaturated zone (vadose zone) before reaching the groundwater table. However, intensive use of groundwater and increased inputs from anthropogenic activities are posing a greater threat to the groundwater resources in terms of both quantity and quality (Foster, 1995). This scenario is widely witnessed in the coastal aquifers especially in high population zones (Ramanathan et al., 2009); Bhattacharya et al., 2008; Jones et al., 1999). Coastal aquifers are typically characterized by variations in groundwater quality in space and time, and are easily influenced by increasing population leading to high stress on the local groundwater system. In addition, rising sea level due to climate change could potentially impact the coastal aquifers through salt water intrusion and/or inundation of the coastal regions (Grant and Gleeson, 2012). Thus monitoring the coastal aquifers especially in urbanized zones warrants at most importance due to their vulnerability to seawater intrusion, anthropogenic contamination and climate change.

There are several reports on seawater intrusion and adverse impacts of anthropogenic activities on groundwater along the east coast of India, especially in Tamil Nadu state. Groundwater contamination in coastal Chennai (formerly Madras) by anthropogenic activities (municipal and industrial activities) was reported during late nineties by Somasundaram et al. (1993). Groundwater quality was found to be deteriorated by agriculture, industrial and domestic activities in different parts of Tamil Nadu

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(Srinivasamoorthy et al., 2008). Contamination of coastal groundwaters by upward leakage of highly mineralized water was reported in Kazhuveli basin by Nathalie et al. (2003). Saline water intrusion through percolation from the local shrimp farms into the fresh aquifers of Rameswaram–Dhanushkodi coastal tract was reported by Ramachandramoorthy et al. (2009). Pratheepa et al. (2015) observed that seawater intrusion is governing the salinity in the groundwaters of northeastern parts of coastal Tamil Nadu while reverse ion exchange is the major process controlling the hydrochemical evolution in the southwest parts. Similar findings were also reported by Thilagavathi et al. (2012) where higher salinity in groundwater of southeastern part of Pondicherry was attributed to salt water ingress, while central and western parts are affected by leaching of minerals. In another study, Chidambaram et al. (2009) and Thilagavathi et al. (2014) reported that the hydrochemistry of the Alluvium, Tertiary and Cretaceous formations is influenced by the groundwater interaction with kankar, calcareous sandstone and limestone. Microbial studies on this region suggested that reducing conditions in deeper aquifers of Cretaceous and Tertiary formations and availability of Marcasite in these formations may lead to possible arsenic contamination in groundwater (Keesari et al., 2015).

Pondicherry, a coastal area of south India enclosed on three sides by Tamil Nadu, is endowed with substantial water resources due to wide network of tanks (natural ponds), two rivers (Gingee and Ponnaiyar) that flow into Bay of Bengal through this region. About 90 per cent of the Pondicherry region comprises Alluvial aquifers with water levels in the wells ranging between 12 and 14 m below ground level. A study on groundwater utilization for agricultural intensification by CGWB (Suresh, 1996) indicated that nearly 80% of groundwater in Pondicherry region is used for agriculture. There are more than 15,000 tube wells tapping both shallow and deep aquifers, which are supplying groundwater to irrigate 14,000 ha area (Thangarajan and Thyagarajan, 2003). The drinking water requirement is also met by groundwater supplied through 107 tube wells constructed around Pondicherry town and another 200 wells to supply 179 villages (Thangarajan and Thyagarajan, 2003). There are about 40 large scale, 115 medium scale and 6000 small scale industries located at different industrial estates in this region. The excessive extraction of groundwater for all the above uses has resulted in water table decline at a number of locations viz., Katterikuppam, Krishnapuram, Sorapet and Ariyur. The declining trend over past 10 years is of the order of 15–30 m in the west and about 7 m in the eastern part of Pondicherry (Noémi et al., 2006). In the Auroville area, the water level in Vanur sandstone aquifer was at 7 m above mean sea level in 1975, which after about 35 years is 57 m below mean sea level (Gilles, 2005). Agriculture is one of the main occupations in this region, which adds to the volume of water extracted from the aquifer and further leads to the deterioration of the groundwater quality by fertilizers. Urban sprawl has also contributed to the lowering of recharge through reduction of vegetation cover and wetlands. The shallow aquifers in certain areas like Kalapet, Muthialpet, Mudaliarpet, Kirumambakkam and Panithittu along the coast show signs of salinity due to overpumping (Nathalie et al., 2003). The industrial estates in Mettupalayam, Sedrapet and Kirmampakkam have also contaminated the groundwater with heavy metals, salts and fluoride.

Even though, the available literature accounts the groundwater quality issues and depleting groundwater levels, there is no systematic study carried out on declining water quality over a period of time. In this paper, we present the hydrochemical data of the year 2009 and compare it with that of the prehistoric period. These temporal trends in chemical quality help in understanding the rate at which groundwater quality is declining. This paper addresses the specific issues like, i) assessment of the water chemistry from different aquifers and compare with historical data, ii) evaluating the drinking and irrigational suitability of groundwaters and iii) identifying the sources and processes affecting groundwater quality.

2. Study area description

Pondicherry and its environs cover about 293 km^2 and extends between latitudes 11° 46′-12° 03′ N and longitudes 79° 37′-79° 53′ E (Fig. 1). This region is a flat peneplain with an average elevation of about 15 m above mean sea level (msl). The northwestern region of the area is a high ground with steep slopes which lowers gradually in the southern and southwestern parts. The study area enjoys humid and tropical climate with hot summers, significant to mild winters and moderate to heavy rainfall. The temperature in the study area is maximum at 42 °C during the month of May and minimum at 22 °C during the month of January. The study area receives rainfall almost throughout the year and especially during southwest (June to September) and northeast (October to December) monsoons. The annual rainfall is about 1250 mm (http://statistics.puducherry.gov.in).

This region is covered by sedimentary formations ranging in age from Lower Cretaceous to Recent. The oldest sedimentary formations belong to the Cretaceous period of Mesozoic era and are exposed in the northwestern part of the area and northern part of River Gingee. These formations comprise calcareous sandstones, siliceous and fossiliferous limestone (Sukhija et al., 1987). Ramanathapuram, Vanur, Ottai and Turuvai formations represent Cretaceous period. The Paleocene formations of Lower Tertiary are represented by Kadaperikuppam and Manaveli formations and mostly calcareous sandstones. Cuddalore sandstone represents the Upper Tertiary deposits. This formation is composed of thick succession of pebbly and gravely, coarse grained sandstones with intercalated clays. Major portion of the study area comprises recent alluvium and laterites (CGWB, 1993). These deposits were built up along the courses of the Rivers Ponnaiyar and Gingee. The Alluvium consists of sand, clay, silt, gravel and kankar. Lignite is observed in the form of bands in the Cuddalore, Vanur and Ramanathapuram formations (CGWB, 1993). This area is affected by tectonic disturbances because of which there is a large variation in the thickness and lateral extent of different formations.

A general subsurface succession of this area has been given in Table 1. Groundwater in Cretaceous and Tertiary formations exists under confined conditions whereas in alluvial aquifers it occurs under semi-confined to water table conditions (CGWB, 1993).

3. Sampling and measurement

A total of 44 water samples were collected from tube wells, hand pumps and dug wells tapping different depths and covering different communes of Pondicherry region during the end of northeast monsoon in 2009. Sample locations along with rivers, major tanks and geology are shown in Fig. 1. Thirty six locations are shown in the location map and at eight locations samples were collected from both shallow and deeper depths. Samples collected were filtered using 0.45 μm pore size membrane filters and stored in polyethylene bottles, which were initially washed with concentrated HNO_3 and rinsed thoroughly with distilled water. Another set was collected and acidified to $pH < 2$ by adding ultra pure concentrated HNO_3 for cation measurements (APHA, 1995). Physical parameters like pH, conductivity and temperature were measured in situ whereas chemical analysis was carried out in the laboratory. Alkalinity was measured in the field by titration of 10 ml of water sample with 0.02N H_2SO_4. A mixed indicator (Bromocresol green - Methyl red) was used to mark the end point of the reaction at pH