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Hydrogeochemical characteristics and groundwater contamination in the rapid urban development areas of Coimbatore, India

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ABSTRACT

The Singanallur Sub-basin is one of the major waterways and it supplies water to the Coimbatore city. Currently, it is vulnerable to pollution due to an increase of unplanned urban developments, industrial, and agricultural activities that compromise both the quality and quantity. In the present study three major hydrochemical facies were identified (mixed Ca-Mg-Cl, Ca-Cl, and Ca-HCO_3). Irrigation suitability indexes are specifies that the groundwater in the areas has very high salinity hazard and low to medium alkali hazard. The mechanism controlling groundwater chemistry originally regulated by the evaporation process is dominated by reason of arid condition and anthropogenic activities existing throughout the region. The multivariate statistical analysis (Correlation analysis (CA), principal component analysis (PCA) and Hierarchical cluster analysis (HCA)) indicates, most of the variations are elucidated by the anthropogenic pollutant predominantly due to population growth, industrial effluents, and irrigation water return flow. This study demonstrates enhanced information of evolution of groundwater quality by integrating hydrochemical data and multivariate statistical methods are used to understand the factors influencing contamination due to natural and anthropogenic impacts.

1. Introduction

Groundwater is the most vital natural resource, which forms the core of the ecological system. It has become the major source of water supply for drinking, domestic, household, agricultural, industrial, recreational, and environmental activities etc. This has led to an increase in the demand of water supply which is met mostly from the exploitation of groundwater resources. Nowadays groundwater is a very important concern for mankind since it is directly linked with human safety. Determination of physical, chemical and bacteriological quality of groundwater is important for assessing various usages. Variation in groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by natural processes such as geological formations and anthropogenic activities. In fact, industrial waste and the municipal solid waste have emerged as one of the leading cause of pollution of surface and ground water [13]. Globally many researchers have carried out a study on groundwater quality and pollution sources influenced by industrial and natural process [21–23,28,44,50]. The principles governing the chemical characteristics of groundwater and influence of anthropogenic activities are well documented in many parts of the India [3,8,11,14,16,19,24,26,27,33,34,38,39,42].

Groundwater contamination in an urban environment is a major issue, especially in industrial urban areas. The Coimbatore city is one of the most industrialized districts and major textile mills for the entire south India. In due Course, its glory gets deteriorated due to various internal and external diseconomies which were adversely influenced by the textile industries. On parity with a textile industry, engineering industry also dominated the economy of the district in the past. As against the receding trend of the textile industry, engineering industry still holds its unique position in spite of tremendous growth experienced in the country for the past few decades by different sectors of the economy. The groundwater of Coimbatore has been deteriorated due to industrialization along with agricultural activities and rapid urbanization in its surroundings areas [6]. Increased population and industrial activities make it essential to assess the quality of groundwater system to ensure the long-term sustainability of resources [46].

The Singanallur area is also predominantly an industrial zone with dense population and agriculture activities. In this region, there is no proper drainage or sewerage system and hence the sewage is discharged into the river. Thus the polluted water reaches the different tanks which form the part of the Noyyal river system [32]. A decrease in various quality characteristics clearly indicates the possibilities of pollution due to industrial activities such as leather tanning, textiles,

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and foundries in and around Coimbatore city [20], with population density, has also a strong impact of surface water pollution as well as groundwater. The evolution hydrochemistry of groundwater in Singanallur region is inadequate because most of the studies focused for drinking and irrigation suitability on a few regions of Coimbatore district [17,18,20,32,45]. Singanallur stream as it receives waste water discharge from point sources such as spinning mills, four mills, small scale industries, and congested residential areas unrestricted domestic sewage effluents [9] and the higher pollution load discharged into stream was carried out to the tank ultimately resulting in deterioration of surface water, as well as groundwater in an aquatic environment. [15], accounted that a domestic and untreated industrial discharges into the Singanallur lake is probably responsible for the high concentration values of electrical conductivity, COD, alkalinity, and turbidity. Many of the earlier works in the city provide a preliminary and superficial assessment of groundwater quality without characterizing the exact causative factors controlling the water quality and the samplings are random. But, the present manuscript has taken the large extent of the study region covering urban settlement, industrial zone, irrigational zones etc., for understanding the water quality changes due to anthropogenic influences through graphical representations and multivariate statistical techniques.

2. Study area

2.1. Geological and hydrogeological setting

The study area, Singanallur is located within latitudes 10°59'42"N to 11°1'30"N and longitudes 77°0'18"E to 77° 2'6"E (Fig. 1). Singanallur Lake is one of the major parts of Coimbatore district. The lake is fed by canals derived from Noyyal River. The length of the lake extends to 3102 m and water spread area of 1.153 km^2 and has an average depth of 4.25 m. The altitude is 362 m. The mean annual precipitation is estimated of 614–647 mm with the Northeast and the Southwest monsoons contributing to 47% and 28% respectively to the total rainfall. The average maximum and minimum temperature is 39.4 °C and 20.7 °C respectively. There are four major types of soil can be identified mainly for black cotton soil, reddish brown/brown loamy soil, alluvium and colluvium. Lithological of Coimbatore is wide range of high grade metamorphic rocks of the peninsular gneissic complex which are extensively weathered and overlain by recent valley fills and alluvium at various places. The major rock types are charnockites, granites, complex gneisses mainly hornblende biotite, gneiss and silimanite gneiss with basic and ultra basic intrusive, crystalline lime stones, syenite, pegmatite and quartz veins. Kankar is followed by top soils in many places. The important aquifer systems in the regions are mainly constituted by unconsolidated formations and weathered with fractured crystalline rocks. Groundwater occurs at shallow levels under semi-confined and unconfined formation.

3. Climate and environmental issues

Singanallur has the highest population density in the region while other parts of Coimbatore have a low population density. 1012 families are residing in the area and the total populations of 3550 of which 1782 are males while 1768 are females and the total number of rural habitations is 2238 (Census, 2011). The major occupation of the people is agriculture and industries, mainly textile and engineering industries. Singanallur is one of the major tanks and wetland areas of Coimbatore. It receives more amount of water from river Noyyal and Sanganur drain and sewage. The registered irrigated areas is 337.1 (ha) and 15,974 acres of agricultural lands, in and around the city, are irrigated by the Noyyal river system. The river and the river-fed wetlands support a large number of plants. The wetlands are main sources of freshwater for drinking, domestic and agricultural uses. In the recent years it cannot be considered for drinking and domestic purposes due to variety of pollutants and contaminants from multiple sources such as industrial outflows, irrigation return flow, domestic discharges and hospital disposals, aggregating the situation water pollution and contamination. Most of these wetlands get dried in summer and serves as a dumping yard for garbage and industrial wastes. According to 2006 report, the lake was encroached by water hyacinth and polluted due to effluents released into the lake. Water-borne diseases have reported in many places of the area where proper sanitation facilities are lacking. This along with garbage dumping and encroachments has led to degradation of water bodies and depletion in the groundwater table. Lack of proper waste management infrastructure and deterioration of water bodies are the main environmental problem in the Singanallur areas. Groundwater level has gone down significantly in a few places. Recent reports with the Tamil Nadu Water Supply and Drainage Board suggests that the average drop in water level is five meters. Categorization based on groundwater extraction the Singanallur region has over exploited as per Central Ground Water Board [7] report. Coimbatore corporation plans to improve water supply to Singanallur region in July 2014.

4. Methodology

The sampling plan for this study was planned to collect site-specific information related to the influence of industrial and agricultural activities near the sampling sites. The samples have been collected in a monthly interval for a period of 12 months (April 2015 to March 2016) since, the whole 12 months period has no rainfall and the hottest climate prevailed, the variation in the monthly interval could not be differentiated. Therefore the values are shown an average of 12 months. Depth to water level is shallow between 15.4 and 18.6 m below ground level (mbgl). pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) are taken in the field immediately after tapping water samples by using Hanna water quality meter (HI-9828, USA) and then kept in 500 mL polyethylene bottles. The groundwater samples collection and analysis were followed by standard methods [1]. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations were determined by complex-cation using EDTA (Ethylenediamineteracetate) with the ammonium purpurate as an indicator for the determination of Ca2+ content alone, and "Eriochrome Black T" for both Ca^{2+} and Mg^{2+}content. Digital flame photometer was used to identify the sodium (Na^{+}) and potassium (K^{+}) contents. Chloride (Cl^{-}) ion was determined with the standard silver nitrate (.01N) titration method and in the presence of 1 mL of potassium chromate (5%) as an indicator. The determinations of carbonate and bicarbonate concentrations were estimated by volumetric methods using .01N H_2SO_4. Sulfate (SO_4^{2-}) and NO_3^{-} was estimated by using the UV–Visible spectrophotometer. The analytical results checked using charge-balance error for major ionic contents, calculated using Microsoft Excel and the software package AQUACHEM, did not exceed 8%.

The irrigation suitability of groundwater was examined based on Total Hardness (TH), Sodium Adsorption Ratio (SAR) in associated with electrical conductivity values, Sodium Percentage (Na%), Permeability Index (PI) and Magnesium Ratio (MR) as calculated by the following formulas,

$$TH\,(asCaCO_3) = (Ca^{2+} + Mg^{2+})meq/l \times 50$$

$$SAR = Na/\sqrt{\frac{(Ca + Mg)}{2}}$$

$$Na\% = \frac{(Na + K)}{Ca + Mg + Na + K} \times 100$$

$$PI = \frac{(Na + \sqrt{HCO3})}{(Ca + Mg + Na)} \times 100$$