Subsurface Hydrogeochemical Processes in Lower Bhavani River Basin, Tamil Nadu, India

S.Anandakumar[1]
Department of Civil Engineering
Kongu Engineering College, Erode - 638 052
Tamil Nadu, India.
Email: anandkeccivil@yahoo.co.in

T.Subramani[2]
Department of Civil Engineering (Geology)
Government College of Engineering
Salem - 636 011, Tamil Nadu, India.
Email: geosubramani@yahoo.com

Ramasamy Nagarajan[3]
Department of Science and Mathematics
School of Engineering and Science
Curtin University of Technology,
98009Miri, Sarawak, Malaysia.
Email: nagarajan@curtin.edu.my

L.Elango[4]
Department of Geology, Anna University Chennai - 600 025, Tamil Nadu, India.
Email: elango@annauniv.edu

Abstract - **Bhavani River is one of the important tributaries of Cauvery River, and originates in the Silent Valley range of Kerala State, India. The Lower Bhavani River Basin lies between 11° 15' N and 11° 45' N latitudes and 77° 00' E and 77° 40' E longitudes with an area of 2,475 km^2. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations, recharge-discharge mechanisms of groundwater and anthropogenic activities. The correlation of groundwater chemistry with hydrologic and geologic environments gives valuable information to understand the effect of these processes and to properly manage aquifer systems. A detailed study has been carried out to understand the subsurface hydrogeochemical processes that are responsible for the quality variation of groundwater. Residence time of groundwater was also considered to be an important parameter to study groundwater evolution. The NETPATH computer code was used to model the major subsurface processes contributing to the evolution of groundwater chemistry. The occurrence of such chemical processes as silicate weathering, carbonate dissolution, ion exchange and dilution due to rain were verified by performing inverse mass balance modeling using the same code. The net geochemical mass balance reactions between initial and final water were identified and quantified based on the flow in selected well pairs. The model output shows that dilution, ion exchange and illite precipitation are the dominant processes that control the chemistry of the groundwater along the flow paths. Calcite and NaCl dissolution are also involved to a certain extent. Reverse ion exchange process is also observed in two models.**

Keywords:* *Lower Bhavani River Basin, Hydrogeochemical Processes, South India.

I. INTRODUCTION

Water is essential to people and the largest available source of fresh water lies underground. It is extracted for domestic, agricultural and industrial applications all over the world. It is preferred to surface water due to its wide distribution and low risk of contamination. The quality of groundwater is very important in evaluating its utility for agricultural, domestic and industrial purposes. The correlation of groundwater chemistry with hydrologic and geologic environments gives valuable information to understand the effect of these processes and to properly manage aquifer systems (Hudson and Golding 1997). The occurrence of chemical processes such as silicate weathering, carbonate dissolution, ion exchange and dilution due to rain were verified by performing inverse mass balance modeling using NETPATH code (Plummer et al 1991).

II. METHODOLOGY

Data pertaining to seven years groundwater quality for 15 open wells (2000-2006), 11 years monthly groundwater levels for 43 wells (1995-2006), rainfall of 9 rain gauge stations (1995-2004), borehole lithology and pump tests at 19 wells, and details regarding cropping patterns, population statistics, groundwater abstraction and irrigation were collected from reliable sources (PWD, 2006). Various thematic maps pertaining to groundwater studies were prepared with the help of Survey of India toposheets and IRS-ID-LISS III satellite imageries. Groundwater samples were collected from 43 monitoring wells during July 2006 and February 2007 for analyzing physico-chemical parameters, major anions, cations and trace elements using standard methodologies. To understand spatial variations of groundwater quality, isoline and zonation maps for various major ions were prepared using Geographical Information System (GIS). Subsurface lithological variations, groundwater flow directions and groundwater quality were also included in this study. Finally, the subsurface hydrogeochemical processes were identified using NETPATH model.

III. Study Area

Bhavani River is one of the important tributaries of Cauvery River, and originates in the Silent Valley range of Kerala State, India (Figure. 1). The Lower Bhavani River Basin lies between 11° 15' N and 11° 45' N latitudes and 77° 00' E and 77° 40' E longitudes. The area is comprised of hilly regions and plain terrain with maximum and minimum altitudes of 1,487 m and 215 m above mean sea level (MSL), respectively. The terrain slopes towards south-east. The study area includes reserve forest, built-up lands, agricultural fields and barren lands. Tanks are mainly rain-fed and remain dry throughout the year, except during rainy seasons. The Bhavani River flows from west to east in the study area and confluences with the Cauvery River at Bhavani Town. The major crops are paddy, banana, groundnut and sugarcane. Bhavani, Gobichettipalyam, Satyamangalam and Andiyur are the major settlements in this region.

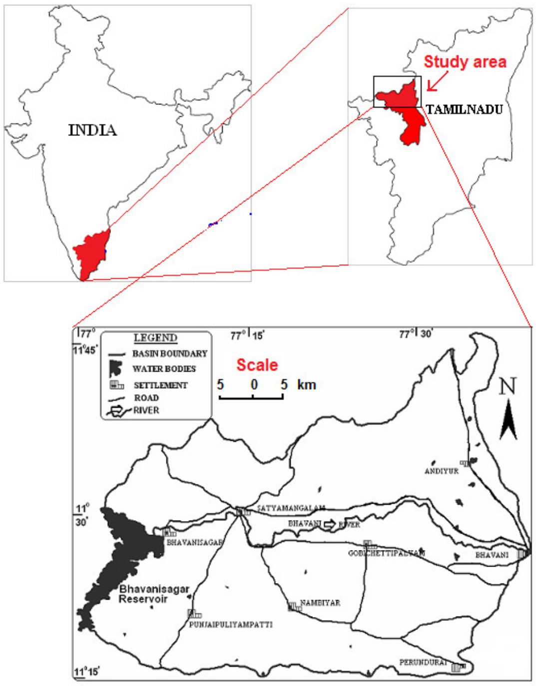

Figure 1. Location map of Lower Bhavani River Basin

A. *Climate*

The climate of the study area is dry, except during the monsoon season. The first two months of the year are pleasant. During March, the sky is clear and the mercury gains an upward trend, which persists till the end of May. Highest temperature is normally recorded during May. During pre-monsoon period, the mercury reverses its trend, and by September the sky gets overcast. In spite of the heavy overcast sky, the rains are meager during September (PWD 2002). The north-east monsoon gets vigorous only during October or November. The average annual rainfall of the basin is 618 mm.

B. *Topography*

Topography, in general, plays a vital role in groundwater management for understanding the slope of the terrain and surface runoff. The topography of this region mainly controls the occurrence of groundwater, land use and drainage pattern. Scattered hillocks of moderate elevation occur within the uplands. The plains area is characterized by gentle undulations with a general gradient due east and south-east.

C. Drainage

A well-developed dendritic to sub-dendritic drainage system is generally noticed in the basin, which indicates the occurrence of rocks of uniform resistance (Thornbury 1969). The basin area is drained by the Bhavani River and its tributaries. The Bhavani River, which has its origin in the Silent Valley range of Kerala State, enters the study area about 30 km west of Bhavanisagar Reservoir and flows more or less in an easterly direction and confluences with the Cauvery River at Bhavani Town. A number of streams have their origin in the hill ranges of the Eastern Ghats and have their flow direction towards south.

D. Geology

The Archean and Proterozoic basement of the study area comprises (GSI, 1995) fissile horn - blende- biotite gneiss, charnockite, garnetiferous-quartzofeldspathic gneiss, hornblende- biotite gneiss, quartzite, pyroxene granulite, ferruginous quartzite, talk-tremolite schist, amphibolite, gabbro/anorthosite, pink migmatite, dolerite dykes and granite intrusions (Figure. 2). Most of the basin area is occupied by fissile hornblende-biotite gneiss. Charnockite mostly occurs in the northern part as hills. Garnetiferous-quartzo -feldspathic gneiss and hornblende biotite gneiss are the other major rock types in this region.

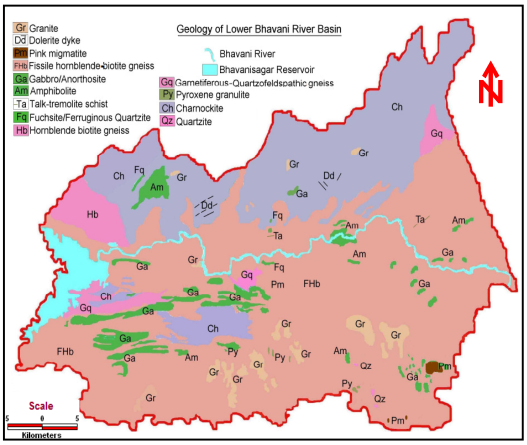

Figure 2. Geology map Lower Bhavani River Basin

E. Soil

Soil characteristics of a terrain are important, since they meet the basic needs of all agricultural production. Different soils that occur are derived from a wide range of geological materials. Knowledge about the types of soils, their extent and occurrence are of primary importance. Basement rocks of the basin are covered by various types of soils, namely red non-calcareous soil, redcalcareous soil, brown soil and black soil. Red soils of calcareous and non-calcareous varieties occupy most of the basin area. Brown and black soils occur as pockets in some places. Forest soil is confined to the reserved forest area in the northern part of the basin, where a surface layer of organic matter is present.

IV. RESULTS AND DISCUSSION

A. Subsurface Geochemical Processes

The net geochemical mass balance reactions between initial and final water were identified and quantified based on the flow in the following selected well pairs: 19 and 18; 20 and 23; 26 and 36; 28 and 08; and 30 and 31; by considering July 2006 and February 2007 data (Figure. 3). Calcium, magnesium, sodium, potassium, chloride, carbonate and sulfate concentrations were considered for mass balance modeling. Geochemical processes considered for modeling were 1) Biotite equilibrium, 2) Hornblende equilibrium, 3) Ca/Na exchange, 4) Mg/Na exchange, 5) Illite equilibrium, 6) Calcite equilibrium, 7) NaCl equilibrium and 8) Dilution/ evaporation factor. These processes were selected based on the mineralogy of the rock formations in the study area. NaCl equilibrium was included to explain the increase of chloride along the flow path.

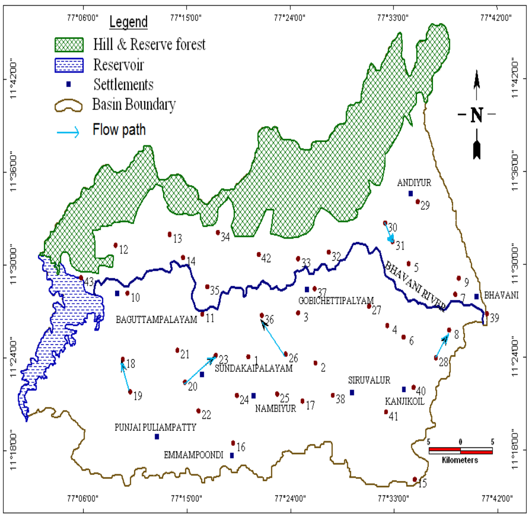

Figure 3. Selected flow paths for subsurface hydrogeochemical modeling .

B. Netpath modeling

A number of possible models have been suggested, each with certain chemical processes that would have given rise to the chemistry of final water. Certain chemical processes are not suggested in all these models because of differences in geological formations. However, the calcium, magnesium, sodium, potassium and bicarbonate ions present in considerable amounts in the study area might have come from different chemical processes. In order to obtain a single model, NETPATH modeling was repeated by considering these processes.

The mass balance model shows that dilution, ion exchange and illite precipitation are the dominant processes that control the chemistry of groundwater along the flow paths. Calcite dissolution and NaCl dissolution are also involved to a certain extent. These are responsible for the higher concentrations of Ca and Cl ions in groundwater in the charnockitic region. In ion exchange processes, the aquifer matrix adsorbs Ca and Mg ions and releases Na ion to groundwater (Elango et al 2003). Release of Ca ion to the groundwater, and adsorption of Na ion by the aquifer matrix were also observed in two models (reverse ion exchange), except in the flow path between well numbers 26 and 36, wherein the irrigation return flow could have increased the concentration of Na.

In certain parts of the study area, calcite dissolution, halite dissolution, reverse ion exchange and illite precipitation are found to increase the calcium, bicarbonate, sodium and potassium ion concentrations of groundwater. Silicate weathering is one of the main processes that have been proved by modeling. The models also indicate halite dissolution process in few models due to irrigation return flow. Biotite and hornblende dissolution might have increased the calcium and magnesium concentrations in the south-western part of the basin. Calcite-precipitate dissolution contributes relatively more Ca to the water along the eastern charnockitic domain, so that it is mostly of the $CaHCO_3$ type.

V. CONCLUSIONS

The groundwater of Lower Bhavani Basin is fresh water, except for a few samples that represent brackish water. Most of the groundwater samples are within the maximum permissible limit for drinking as per the WHO international standard, except for few samples. The subsurface hydrogeochemical model shows that dilution, ion exchange and illite precipitation are the dominant processes that control the chemistry of the groundwater along the flow paths. Calcite dissolution and NaCl dissolution are also involved to a certain extent. These are responsible for the higher concentrations of Ca and Cl ions in the charnockitic region. Reverse ion exchange process is also observed in two models.

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