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Full Length Research Paper

Investigation of heavy metals in crystalline aquifer groundwater from different valleys of Bangalore, Karnataka

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Fifty-one groundwater samples were collected during South-west monsoon 2009 from Challaghatta, Vrishabhavathi, Kormangala and Hebbal valleys, Bangalore, which is an unconfined/crystalline aquifer to investigate Fe, Mn, Cu, Zn, Pb, Cd, Cr, Ni concentrations and other parameters like temperature, pH, electric conductivity (EC) and total dissolved solid (TDS). The TDS and EC variation confirmed light-salty nature of groundwater found to be contaminated by Salty water intrusion, which is attributed to over-extraction. Comparison between presence, abundance and frequencies of trace elements in groundwater samples is in the order of Fe (84) > Zn (72) > Mn (68) >Pb (45) >Cu (41) >Cr (35) >Ni (33) >Cd (21), indicating that Fe in groundwater is in origin. The TDS, Pb, Fe, Mn and Cd concentrations in groundwater samples are beyond the permissible limit prescribed by World Health Organization (WHO).

Key words: Groundwater, heavy metals, lithologic physico-chemicals, sewage.

INTRODUCTION

The dominant industries are textile, cement, liquor, tobacco, gold, electronic, food and industrial metal manufacturing like iron and electroplating. The Bangalore aquifer, which is located in the southern part of the Karnataka, provides a source of water for domestic, industrial and agricultural use. The dense industrial land use affects the groundwater quality negatively; Vrishabhavathi, Koramangala, Challaghatta, and Hebbal valleys are situated on the Bangalore aquifer, which is an unconfined/crystalline aquifer. The valleys encompass urban and industrial areas as well as are surrounded by cultivated coconuts, traditional vegetable farms and green house cultivations, where farming activities whole years due to the favorable climate. In the study area, the urban, industrial and agricultural expansions have led to greater demand for freshwater as such groundwater drowns provided through hand open and bore wells. Heavy metals are probably the most harmful insidious pollutants because of their non biodegradable nature and their potential to cause adverse effects to human beings at concentration higher than permissible limits (Lokhande and Keikar, 2000).

In aquatic medium, heavy metals can exist in three physical states, viz., colloidal, dissolved or particulate forms. The major sources of heavy metals in groundwater include weathering of rock minerals, discharge of sewage and waste effluents on land besides runoff water.

MATERIALS AND METHODS

Sampling area

A thickly populated settlement area of Vrishabhavathi, Kormangala, Challaghatta and Hebbal valleys, Bangalore was selected as study area. The sewerage network here is interconnected to several tanks. Bangalore represents part of Cauvery basin situated in the southeast corner of Karnataka (Prakash, 2002) (Figure 1). It spans over a geographical area of 713 km^2. It is blessed with uneven landscape with intermingling hills and valleys. The western part is rocky and bare rocky out crops rise upto 60 - 90 m. The southern and western parts represent rugged topography of granitic gneisses.North of Bangalore is more or less level plateau lying between 839 - 962 m above mean sea level. The prominent ridges run parallel towards NNE-SSW direction. The particular

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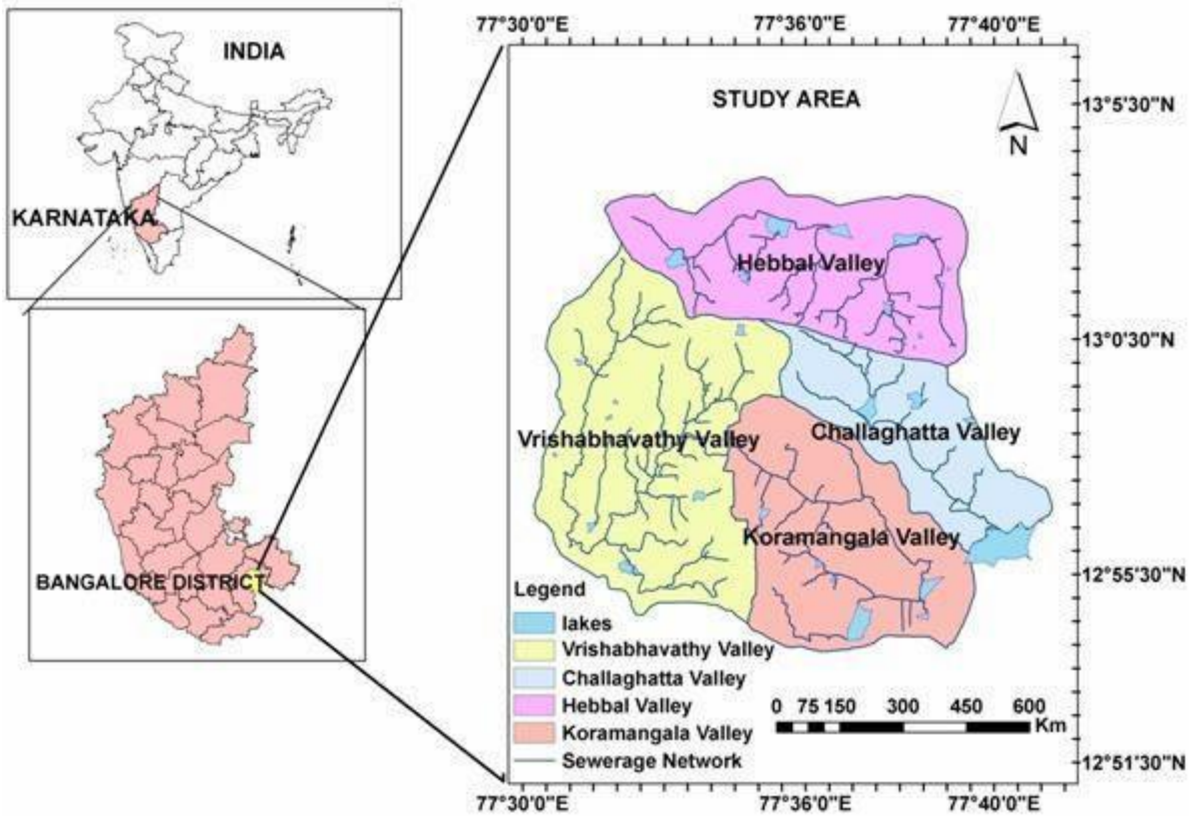

Figure 1. Study area along with sewerage network system.

physiographic setting of gentle slopes and valleys on either side of this ridge hold better prospects of groundwater utilization and harvesting. The low lying area is marked by a series of tanks and small ponds.

The granitic ridge running from NNE to SSE governs the drainage pattern of Bangalore North. Towards east the drainage is made up of network of canals generally flowing from west to east with storage tanks along the canals, ultimately feeding the South Pinakini River. In the west, the drainage pattern is made up of network of canals generally flowing from east to west with storage tanks along the canals ultimately feeding the Arakavathi River. The Bangalore south drains drain towards east, into Pinakini basin and to the west into the Arakavathi. The Vrishabhavathi is a minor river marked with series of tanks. The chief rock types occurring in the Bangalore North are granites and gneisses intruded by basic dykes. The western portion of Bangalore is composed of only one type of gneissic granites belonging to Precambrian age. The gneissic granites are exposed as a continuous chain of mounds rising 90 - 150 m above the ground on the western portion constituting the Bennerghatta groups of hills. Inclusions of quartz and pegmatite were occurring in this region (Figure 1).

Groundwater occurs under water table in the weathered mantle of the granitic gneisses and joints, cracks and crevices of basement rocks. The depth of water table is dependent upon the rate of weathering and topographic factors (Singh and Parowana, 1999). Chief source of groundwater is infiltration and recharge of rainwater. Considering the climatic water balance, soil charac-teristics account for nearly 70% allowing only 20% rainfall being added again to groundwater pool. Percolation and recharges in the groundwater account for 10% discharge through wells. Bangalore receives rainfall from both the northeast and the southwest monsoons and the wettest months are September, October and August, in that order. Typical monsoonal climate prevails in the study area with major contribution of rainfall during southeastern monsoon.

Preparation of standards

Standard solutions which will be required for the analysis were prepared by dilution of 1000 mgL-1 stock solution obtained from Siso Research Laboratories Pvt. Limited (SRL) using micropipette and glass wear clean by soaking in 10% HNo.3 for 24 h and rinsed gently with deionized water. Use and stored for more than 2 days of standard solutions were prepared with deionized water before.

Atomic absorption spectrometer method

Atomic Absorption Spectrometry is a one of the most resourceful standard analytical techniques available for the analysis of trace metals in Environmental samples. The principle involved is that when a solution containing a metallic salt (or some other metallic compounds) is aspirated into a flame (e.g. of acetylene burning in air), a vapor which contain atoms of metal is formed. Some of these gaseous metal atoms may be raised to an energy level which is sufficiently high to permit the emission of radiation characteristics of the metal. However, a much larger number of the gaseous metal atoms normally remain in an unexcited state or, in the other words, the ground words, the ground state. These ground state atoms are capable of absorbing radiant energy of their own resonance wavelength is passed through a flame containing the atoms in question, the part of the light will absorbed and the extent of absorption will proportional to the number of ground state atoms present in the flame.

Flame atomic absorption spectrophotometer

The Atomic Adsorption Spectrophotometer consists of a source of light, an atom cell, a monochromatic and a read-out system. An Atomic Adsorption Spectrophotometer generates a source of light to be adsorbed and passes through the gaseous state of the sample that has been sprayed into a flame and the sample is determined by measuring the adsorption of the constant intensity of EMR that passes through the flame.

Light source

In most atomic absorption methods, the most widely used light source is the hollow cathode lamp because it accounts for a narrow line source. A hollow cathode lamp is made of a glass envelope with a cathode inside made of the element being analyzed and a suitable anode. The closed glass envelope contains an inert gas, typically neon or argon at a pressure of torr. When a high voltage of about 600 V and 2 - 30 mA is applied between the electrodes the inert gas becomes charged and attracted to the cathode which causes the metal atoms to become excited and sputter (dislodge the element used in the cathode) out of the cathode and further collisions excite the atoms and then a characteristic spectrum of the metal is produced. Some advantage of using hallow cathode lamps as a light source is that they generate very narrow spectral lines necessary to measure that peak adsorption because it is imperative that the width of the sources line must be much narrower than the width of the adsorption line, more advantages of hollow cathode lamps is that they are simple to operate, produce a stable and intense light, economical, and that hollow cathode lamps are available for all chemical elements that can be analyzed by atomic adsorption.

Atom cell

The most widely used atom cell is the flame. The flame is characterized by the gases involved, the temperature of the flame itself, the flow of gases, the form in which the gases are mixed, its shape and size. Air-acetylene (operating temperature of 2300°C) and nitrous oxide-acetylene (operating temperature of 3000°C) are the most commonly used flames. Atoms are farmed within the flame by the atomization process. The dissolved sample in solution is heated to the point of the solvent evaporating, followed by the solids being heated to high enough temperatures to decompose into compounds and eventually decompose into individual atoms in the gaseous state then adsorbs EMR from the light source.

Light disperser

The purpose of the light disperser is to isolate a single atomic resonance line from the spectrum of linens emitted from the light source. Most AAS use dispersive gratings that have resolutions in the 0.2 to 0.02 nm range to separate light into wavelengths.

Detector and read out system

The most common type of detector is photomultiplier tube. The photomultiplier produces an electrical signal which is proportional to the intensity of EMR of the wavelength separated by the light dispersing monochromator. The signal from the detector is transferred to the computer, and the analytical result (output) is seen on the monitor of the computer.

Sampling

Fifty-one bore well samples were collected during South-west monsoon 2009 from Vrishabhavathi, Kormangala, Challaghatta and Hebbal valleys, Bangalore (Figure 2). Samples were collected in polyethylene bottles, which were thoroughly cleaned with nitric acid and rinsed several times with distilled water, after 10 min of initial pumping and transported to laboratory at 10°C to prevent any contamination. Care was taken to avoid contamination during sampling and storage. Immediately after sampling, other parameters like temperature, pH, electric conductivity (EC) and total dissolved solid (TDS) were measured in the field itself using ELICOPE PE-138 field Kit and salinity of water was classified according to Handa (1969).

Driller's well logs were reviewed for information on the lithology, screen interval and relationship of water bearing sections of the lithology above and below the screen in the well.

Preparation and analysis

One hundred mili liters of each samples was filtered with watchman no. 41 (0.45µm pore size) filter paper for the estimation of dissolved heavy metals content. The filtrate and collected water samples were preserved with 1 ml of concentrated nitric acid (samples<2 pH) digested using microwave, setting pressure at 5 minutes, power 500 watts and ventilation 2 minutes, as per the methods for the investigation of water.

The dissolved samples were analyzed for heavy metals Standard Methods (APHA, 2005). The analysis was performed using flameless Atomic Absorption Spectrophotometer (AAS) . The quality control was monitored using 10% sample blanks and 10% sample duplicates in each set of sample analysis.

RESULTS AND DISCUSSION

Groundwater heavy metals and physico-chemical constituents were analyzed by considering WHO standards for drinking water purposes. Drinking water should satisfy many quality criteria, as it is the most sensitive among various uses. Variation in groundwater chemistry with host lithology because groundwater undergoes chemical reactions with the aquifer(s) through which it passes or the host lithology in which it resides, one might expect its geochemistry to vary with host lithology (Railsback, 1996) (Figure 2).

The fluctuation of temperature in the study area is between 19 and 28.5°C and higher water temperature were recorded in Vrishabhavathi and Kormangala valleys (Figure 5). A medium level temperature in the remaining locations is due to prevailing cloudy weather (Uyeno, 1966). Temperature fluctuations in groundwater were influenced considerably by meteorological factor such as air temperature, humidity, winds, solar radiation and thermal pollution. The pH value of groundwater is an important indication of its quality and it is dependent on the CO_2, CO_3 and HCO_3 equilibrium (Hutchinson, 1957). Acid-base reactions are important in groundwater because of their influence on pH and the ion chemistry. According to the Karnataka State Pollution Control Board's analysis of groundwater samples taken from

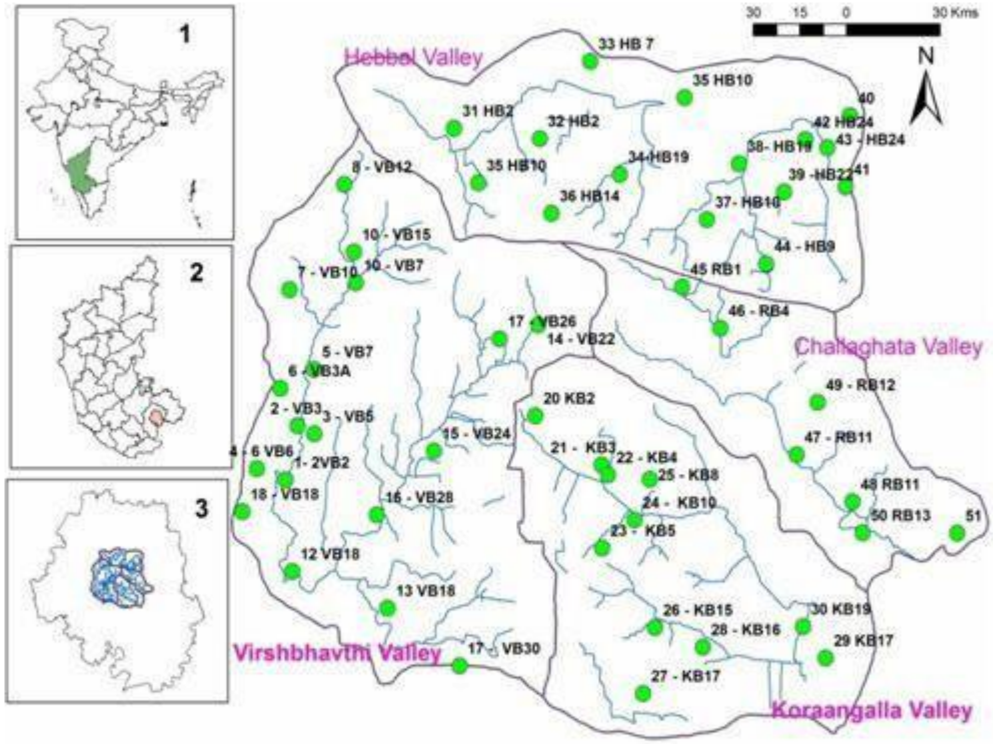

Figure 2. Sampling locations.

these places in 2008, the pH level ranged between 6.and 8.2, whereas, the pH value of our studies in 2009 varied between 6.2 and 8.6 (Figure 6). pH of groundwater in locations like Bangalore University, Nagarabhavi, Kempanna-layout, Narayanpura, NG-layout, BTB-layout, Jai-Bheemanagar, Mathyalnagar, Devinagar, Divandra-palya, Gedahalli, Freezer town, Betanary road and BTM-layout was low; this is attributed to discharge of acidic water by agricultural, domestic and industrials activities. Seventy percent of alkaline pH levels observed during southwest monsoon and a value of 7.2 to 8.6 indicates the presence of carbonates of calcium and Magnesium.

The EC of groundwater in Arakavathi and Vrishabhavathi basins varied from 500 to 2200 µS/cm (Figure 7). The locations close to sewerage line showed high values indicating sewage intrusion into groundwater. The groundwater with high EC was predominant with sodium and chloride ions, indicating anthropogenic pollution. According to Handa (1969) and from the EC and TDS variation, contour shows that the majority of the locations fall in 'light-salty' category (Figure 8), which is attributed to the over-extraction. This was evident at places like Sumannahalli, GKW-layout, Peenya, Kurubarahalli, Near Bangalore University, Adiali, Kavika-layout, Ramachandrapuram, Shantinagar, BTB-layout, Jai-Bheemanagar, Agara, Sarjapur road, Muthyalnagar, Devinagar, SBM colony, Kerenal- layout, Kalyannagar, Betanary road, Murgesh-palya and Krishnareddy-layout. High TDS account for the presence of HCO_3, SO4, Cl, CaH, MgH, and Na (Nawlakhe et al., 1995). The dissolution of soil particles containing minerals under slightly alkaline condition favors higher TDS concen-tration in groundwater.

Heavy metals in the groundwater may accumulate to acutely toxic levels without visible geological phenomenon such as ore formation, weathering of rocks and leaching or due to increased population, urbani-zation, industrial activities and agricultural resources. The aquatic environment is frequently the ultimate recipient of heavy metal pollution (Obasohan et al., 2006).

Manganese, copper, zinc, lead, etc. are the major trace elements that occur in the crystal structure of minerals found in rocks. They also occur as trace metals in groundwater. Their distribution and occurrence depends on the degree of weathering and mobility during weathering (Handa, 1986).

The investigation groundwater samples from the Vrishabhavati, Koramangala, Challghatta and Hebbal valleys of Bangalore has thrown up some alarming statistics about the water that we drink every day (KSPCB,). According to the report, heavy metals - zinc and iron are frequent in all the samples while other metals like nickel, cadmium, chromium, lead and arsenic were not detected in 2008. Sewage and domestic waste are percolating into the groundwater table and have contaminated the city's bore and open wells.

In the present investigation, manganese and copper content of groundwater was in the range of BDL to 2.155

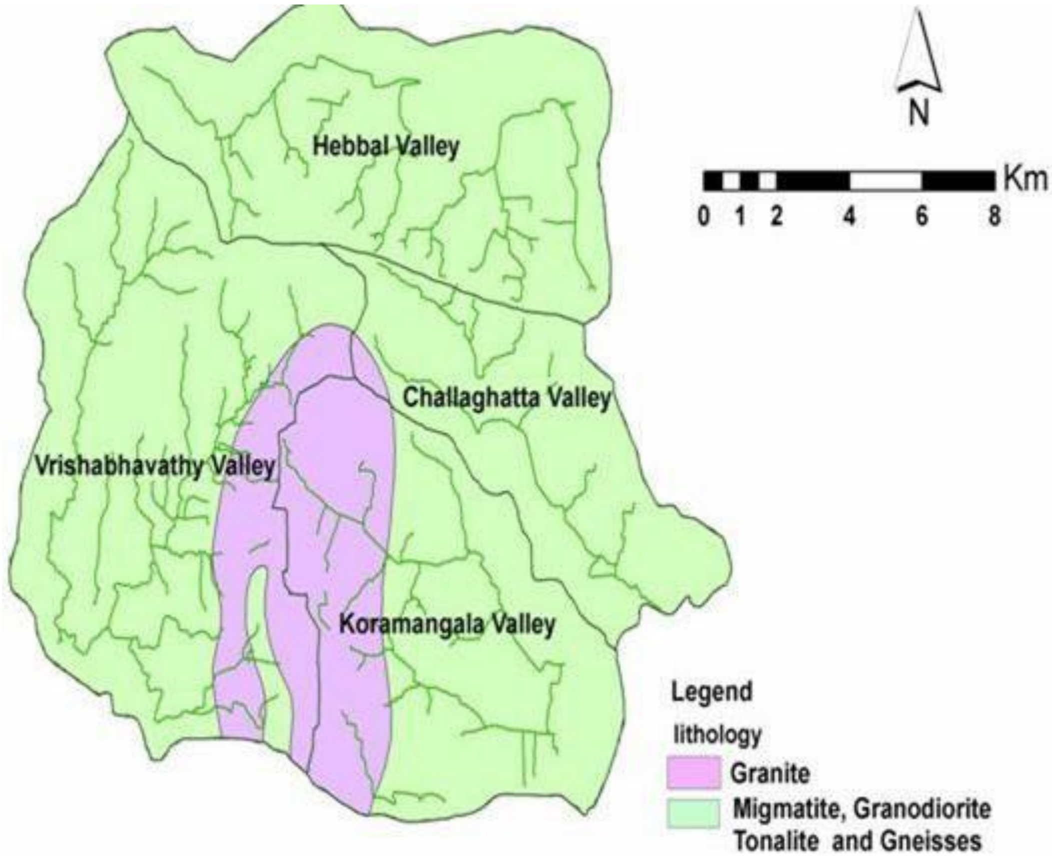

Figure 3. Adjacent areas along with lithology and lineaments in Bangalore city.

and BDL to 0.019 mg/l with 21% of Mn concentration in samples beyond the WHO permissible limit (BPL) of 0.4 mg/l, (Figure 4b) . Manganese tends to be adsorbed on to the clay, organic matter, freshly precipitated hydrated iron oxides, aluminates, silicates and calcite (Mehrotra and Mehrotra, 2000) . The level of copper in all samples is however (Figure 4c) below the WHO guidelines (2 mg/l).

The concentration of zinc in groundwater of the study area varied from BDL to 0.063 mg/l. Agricultural activity (fertilizers and micronutrient fertilizer) is no major source for low concentration of zinc in the groundwater of the study area. Nevertheless, to get an idea about the relative variations of Zn in groundwater was plotted in Figure 4d. Lead in the groundwater samples was found to be much higher than the other elements except Fe. A comparison between concentration of trace elements in groundwater samples shows the abundance in the order of Fe (84) > Zn (72) > Mn (68) >Pb (45) >Cu (41) >Cr (35) >Ni (33) >Cd (21), indicating lithogenic origin of Fe in groundwater (Figure 3). The concentration of Pb and Fe ranged from BDL to 0.021 and BDL to 69.987 mg/l with an average of 0.004 and 6.285 mg/l in the groundwater samples respectively.

Higher levels of Fe and Pb were detected in groundwater samples from locations like Sumannahalli, Girinagar, Kempanna-layout, Shantinagar, Narayanpura, Murgesh-palya and Jayanagar, NGEF layout, Frezer town (Figures 4a and e), besides locations like near Bangalore University, Apurva-layout, Kurubarahalli, Mahalaxmi-layout, Kempanna-layout, Kavika-layout, Manishwaranagar, Shankarapuram, N.G-palya, BTB-layout, Jai-Bheemanagar, Devinagar, SBM-colony, Pillana-garden, were at levels that were averagely forty-four and nine times higher than the WHO accepted drinking water quality standard (0.3 and 0.001 mg/l).

The concentration of cadmium ranged from BDL to 0.021 mg/l with an average (0.004 mg/l). Higher concentrations of cadmium were found in SBM colony (Mathikere) (Figure 4f) only, and the concentrations of several heavy metals have changed in the past few years with decrease in Cd and increase in Pb and Fe, suggesting the contamination from an accidental release of industrial waste.

The lowest and highest amount of chromium and nickel ranged between BDL to 0.021 and BDL to 0.024 mg/l, whereas WHO recommended values in drinking water are 0.05 and 0.02 mg/l respectively. The reason for higher values of these parameters may be ascribed to the disposal of sewage wastes and wastes from household activities (Lokhande and Keikar, 1998). But, these values

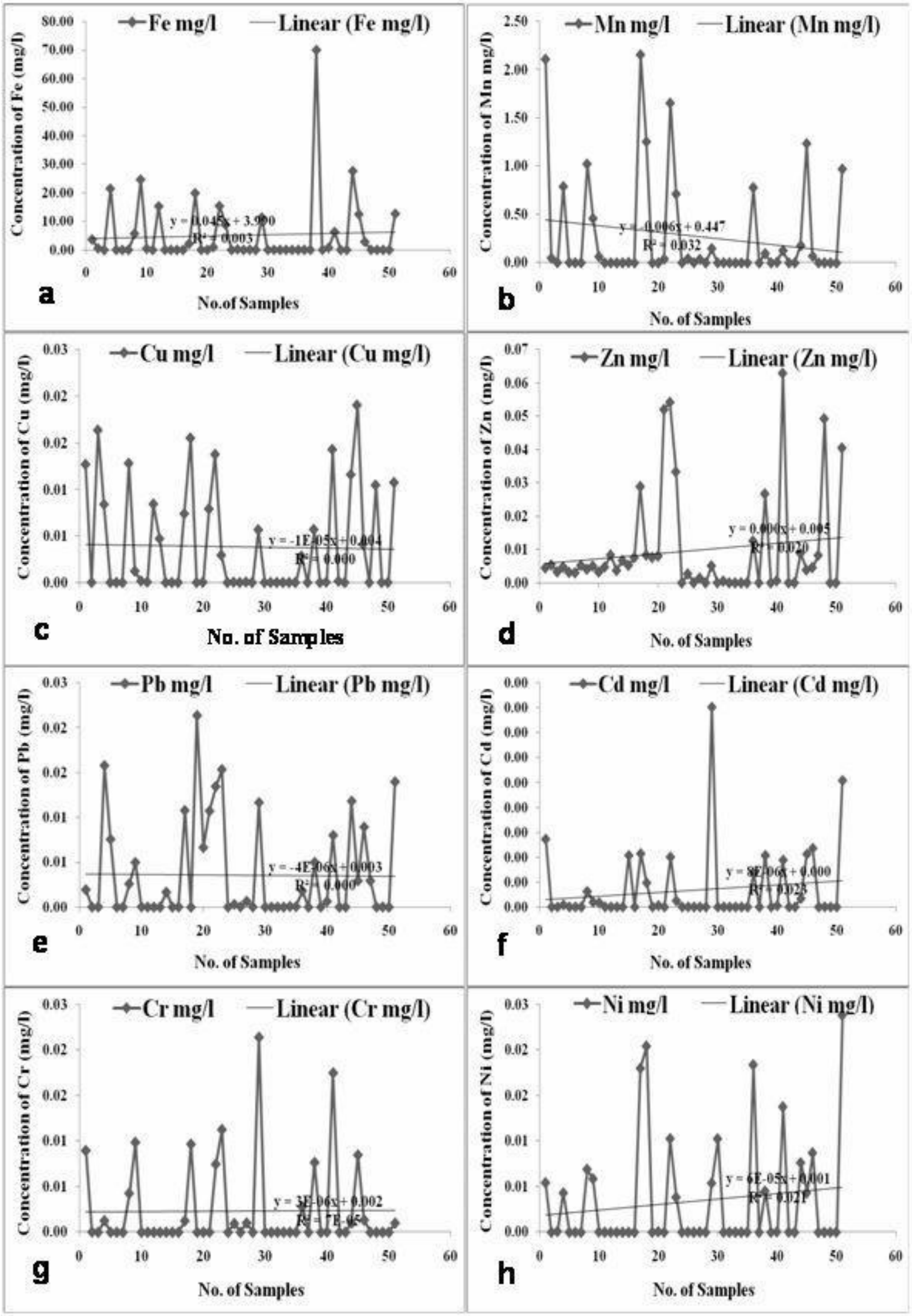

Figure 4. Variations of heavy metals in groundwater samples.

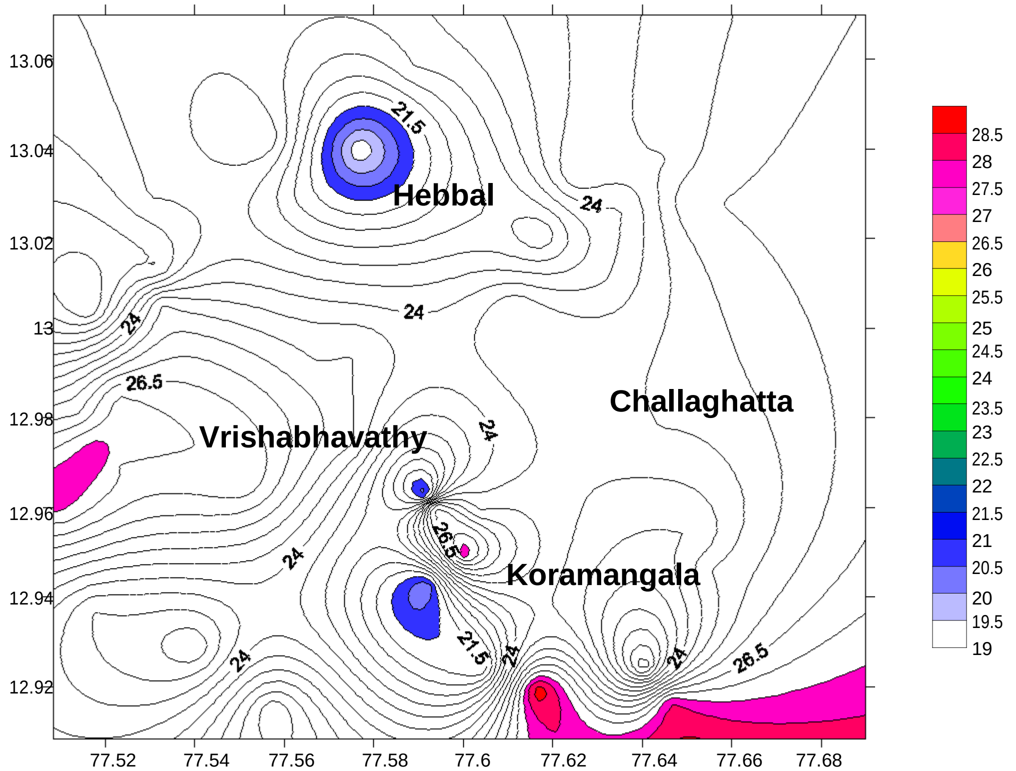

Figure 5. Contour diagram for the water temperature in study area.

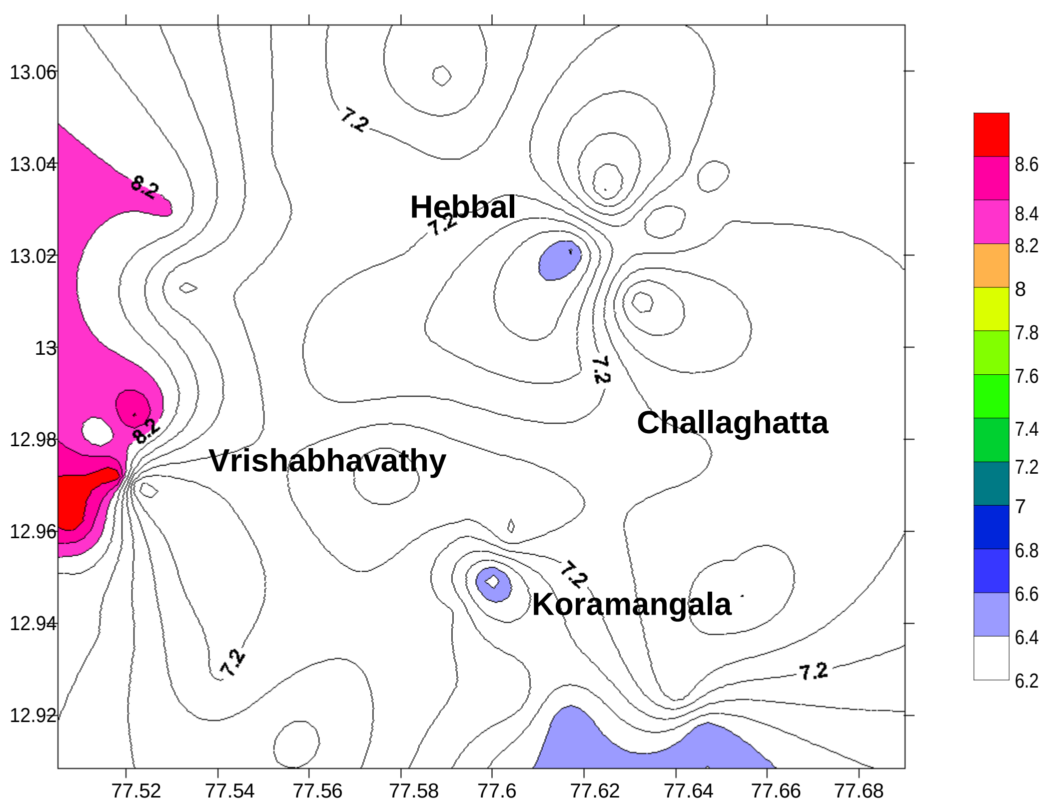

Figure 6. Contour diagram for the water pH in study area.

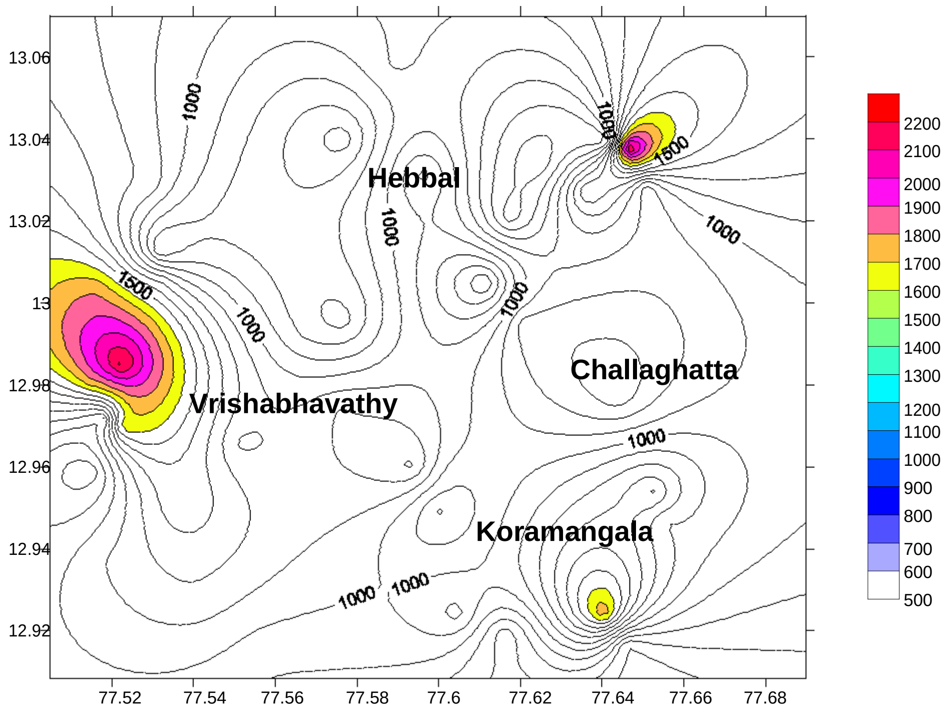

Figure 7. Contour diagram for the water electrical conductivity in study area.

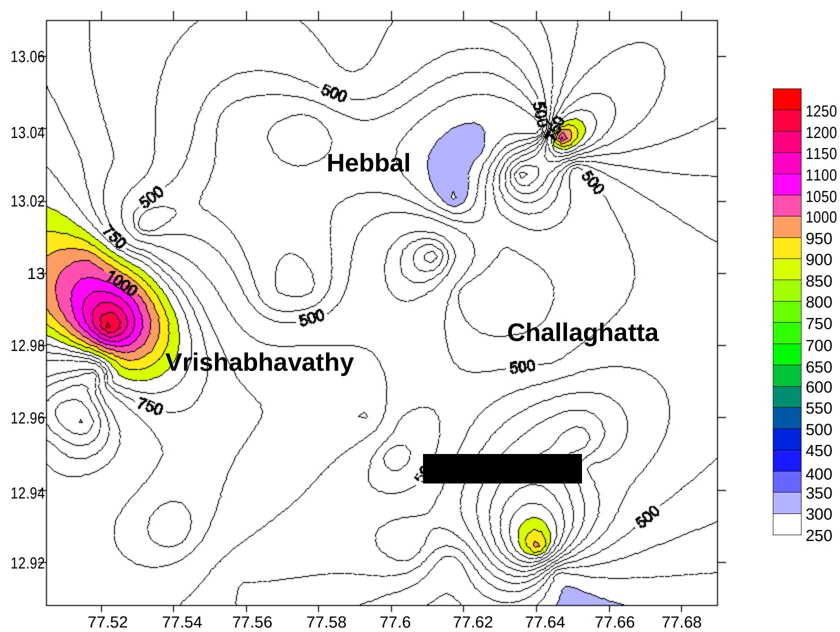

Figure 8. Contour diagram for the total dissolved solid in study area.

are below maximum limit (Figures 4g and h), indicating it may not be due to waste discharge into the groundwater from the variety of sources. Lower concentration of chromium and nickel in drinking water has no adverse effect.

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