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Research article

ASSESSMENT OF GROUND WATER QUALITY IN GHATKESAR AND BIBINAGAR AREAS OF ANDHRA PRADESH, INDIA

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ABSTRACT: The study was carried out to assess the fluoride (F^-), bromide (Br^-), chlorides (Cl^-), sulfates (SO_4^{2-}), nitrates (NO_3^-) and phosphates (PO_4^{-3}) using Ion Chromatograph (IC) in the ground water samples of Ghatkesar and Bibinagar areas of Andhra Pradesh, India, where groundwater is the main source of drinking water. The anionic concentrations in the water samples ranged between; F^- (2.01 to 8.51 mg/L), Cl^- (38.35 to 542.35 mg/L), Br^- (0 to 12.60 mg/L), NO_3^- (15.30 to 434.30 mg/L) and PO_4^- (35.60 to 343.1 mg/L) and SO_4^{2-} (0 to 12.10 mg/L). The anionic concentrations for F^-, Cl^-, NO_3^- and PO_4^{-3} exceed the permissible limits of the World Health Organization (WHO) and the Bureau of Indian Standards (BIS) guidelines for drinking water quality. Overall water quality of the study area was found unsatisfactory for drinking purposes.
Key words: Groundwater, Fluoride, Ion Chromatograph, anions.

INTRODUCTION

Nearly 12 million tons of fluoride deposits on the earth's crust are found in India. These fluoride deposits are the reason for fluorosis in 17 states of India [1]. The most seriously affected areas are Andhra Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Tamil Nadu and Uttar Pradesh. In the Indian continent the higher concentration of fluoride in groundwater is associated with igneous and metamorphic rocks. It is estimated that around 200 million people, from among 25 nations of the world, are exposed to fluorosis. India and China, the two most populous countries of the world, are the worst affected. It has been estimated that 65% of India's villages are exposed to fluoride risk [1]. High groundwater fluoride concentrations associated with igneous and metamorphic rocks such as granites and gneisses have been reported from India, Pakistan, West Africa, Thailand, China, Sri Lanka and Southern Africa [2]. High fluoride concentration is found where fluoride rich volcanic rocks are common. The distribution of fluoride content in the ground water of individual states is reported on the analysis of ground water quality monitoring data. Due to its strong electronegativity, fluoride is attracted to positively charged calcium in teeth and bones. Major health problems caused by fluoride are dental fluorosis, teeth mottling, skeletal fluorosis and deformation of bones in children as well as adults. Fluoride exposure disrupts the synthesis of collagen and leads to the breakdown of collagen in bone, tendon, muscle, skin, cartilage, lungs, kidney and trachea. Fluoride stimulates granule formation and oxygen consumption in white blood cells, but inhibits these processes when the white blood cell is challenged by a foreign agent in the blood. Fluoride confuses the immune system and causes it to attack the body's own tissues, and increases the tumor growth rate in cancer prone individuals. Fluoride inhibits antibody formation in the blood and promotes development of bone cancer [3]. The major chemical parameter of concern is fluoride. Ground water is ultimate, most suitable fresh water resource with nearly balanced concentration of the salts for human consumption. Over burden of the population pressure and dumping of the polluted water by various industries at inappropriate place enhance the infiltration of harmful compounds to the ground water [4, 5]. The high fluoride concentrations in ground water in Nalgonda district reported by many researchers [6-9]. Ground water is the main source for drinking water in the areas such as Ghatkesar, Bibinagar and Bhongiri areas, the people have highly depend on hand pumps and jet pumps to extract ground water. From last few years it has been observed that the ground water quality of these areas has been deteriorating. The objective of this work is to assess the quality of drinking water in these areas.

The present study presents data collected pertaining to the concentrations of fluoride (F^-), chlorides (Cl^-), sulfates (SO_4^{2-}), nitrates (NO_3^-) and phosphates (PO_4^{-3}) found in the ground water samples of Ghatkesar and Bibinagar areas of Andhra Pradesh state of India.

MATERIALS AND METHODS

Water sampling

Ground water samples were collected in poly propylene bottles from 42 bore wells using a hand pumps. The bottles were thoroughly washed and rinsed with demineralized water prior to collecting the samples using standard procedures [10]. The samples were collected from Ghatkesar and Bibinagar areas Andhra Pradesh (Figure 1).

Physico-Chemical parameters

Hydrogen Ion concentration (pH), Electrical Conductivity (EC) and Total Dissolved Solids (TDS) in the water samples were analyzed using a pH/EC meter (Thermo Electron Corp. Orion 5 star), and standard procedures [10].

Preparation of water sample for IC analysis: About 100 ml of the each water sample was filtered using Whatman 45 micron filter paper to remove the macro particles or dirt. The filtrate was collected in a sample bottle and was diluted accordingly and these samples were injected into Ion Chromatograph.

Ion Chromatograph analysis (IC): The ground water samples were analyzed for fluoride (F^-), chlorides (Cl^-), sulfates (SO_4^{2-}), nitrates (NO_3^-) and phosphates (PO_4^{-3}) using Ion Chromatograph system (make: Metrohm, Switzerland). The chromatograph was equipped with a separating column Metrosep A supp 5 – 100, column size; 4.0 x 100mm, filled with a cation exchanger in the H^+ form. An aqueous solution of sodium carbonate and bicarbonate (3.2 mM Na_2CO_3/1.0 mM $NaHCO_3$) was used. The volumetric flow rate of the eluent was 0.70 ml/min. with a conductivity detector at the temperature of 20^o C, pressure of 6.1 MPa. Calibration was carried out using anion standard for F^-, Br^-, Cl^-, SO_4^{2-}, NO_3^- and PO_4^{-3} obtained from Fluka, Switzerland.

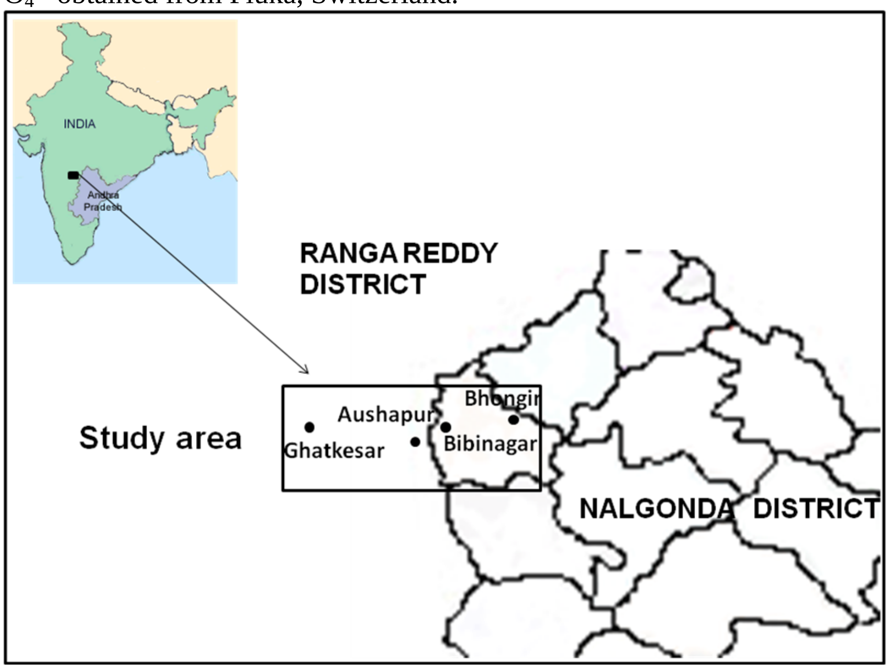

Fig. 1 Location map of the study area, Andhra Pradesh, India.

RESULTS AND DISCUSSION

Physico-chemical properties of water samples

The pH of ground water samples ranged from 6.83 to 10.22 with a mean of 7.88, According to Indian standards Institute (BIS) for permissible limits for drinking water quality of pH is 6.5 to 8.5. Thus, the pH in the study area was found to be slightly higher than permissible limits of WHO and BIS. The statistical analysis of physico-chemical properties of the ground water samples in the study area and permissible limits of BIS and WHO drinking water quality are given in Table 1. The electrical conductivity (EC) of ground water samples ranged from 505 to 3640 µS/cm with a mean of 1483 µS/cm. The EC in the study area was found to be within the permissible limits of WHO and BIS (1500 µS/cm).

The Total dissolved solids (TDS) in water samples were between 338.35 to 2438.8 ppm with a mean of 993.62 ppm. Thus, the TDS in the waters of the study area exceed the permissible limit of WHO and BIS (< 600 ppm). The concentration of fluoride (F^-), chloride (Cl^-), sulfate (SO_4^{2-}), nitrate (NO_3^-) and phosphate (PO_4^{-3}) in the drinking water samples of the study area are presented in Table 1. The concentration distribution maps of the study area for various elements in water samples were prepared using Golden surfer 9 software.

Table 1. The statistical analysis of physico-chemical properties and anionic concentrations in ground water samples of the study area.

	Minimum	Maximum	Mean	Permissible limits of BIS	Permissible limits of WHO
pH	6.83	10.22	7.88	6.5 to 8.5	6.5 to 8.0
EC (µS/cm)	505	3640	1483.02	1500	1500
TDS (mg/L)	338.35	2438.8	993.62	< 600	< 600
F^- (mg/L)	2.01	8.51	3.17	1.5	1.5
Cl^- (mg/L)	38.35	542.35	237.16	250	200
Br^-(mg/L)	0	12.60	1.75	0.5	0.5
NO_3^- (mg/L)	15.30	434.30	112.90	45	50
SO_4^{2-} (mg/L)	0	12.10	1.18	200	200
PO_4^-(mg/L)	35.60	343.1	119.3	-	5

Fluoride (F^-)

The concentration of fluoride in the drinking water samples is from 2.01 to 8.51 mg/L with the mean of 3.17 mg/L. The BIS permissible limit of fluoride is specified as 1.5 mg/L for drinking water. Thus, all the samples exceed the permissible limits of BIS. Fluoride concentration distribution map of the study area is shown in Figure 2. High fluoride concentration was observed in Aushapur and Bibinagar areas of Nalgonda district, Andhra Pradesh. As per the desirable and maximum permissible limit for fluoride in drinking water suggested by WHO [11] and BIS [12], groundwater samples at 20 sampling stations in the study area were found unfit for drinking purposes. Moreover, dental and skeletal fluorosis is found at an alarming rate among the local residents of these areas [6, 7]. The results from this study have documented the distribution of groundwater fluoride in the Nalgonda district, which is due to the presence of fluoride bearing minerals in host rocks and their interaction with water is considered to be the main cause for fluoride in groundwater [13, 14]. The rocks of this area possess fluoride content higher than the world average. Weathering of rocks and leaching of fluoride bearing minerals are the major reasons which contribute to elevated concentration of fluoride in groundwater. The basement rocks provide abundant sources of Fluoride in the form of amphibole, biotite, fluorite and apatite and whole-rock concentrations of Fluoride in the aquifer are in the range 240–990 mg/kg. Calcretes from the shallow weathered horizons also contain comparably high concentrations of F, in the range 635–950 mg/kg. The concentrations of water-soluble F in the granitic rocks and the calcretes are usually low (1% of the total or less) but broadly correlate with the concentrations observed in ground waters in the local vicinity. The water soluble fraction of calcretes is relatively high in Weathered calcretes compared to fresh samples. The other important natural phenomenon that contributes to high fluoride is evaporation. Suit-able measures such as defluorinating the ground-water before use and recharging the groundwater by rainwater harvesting need to be practiced to improve the groundwater quality in this area [14].

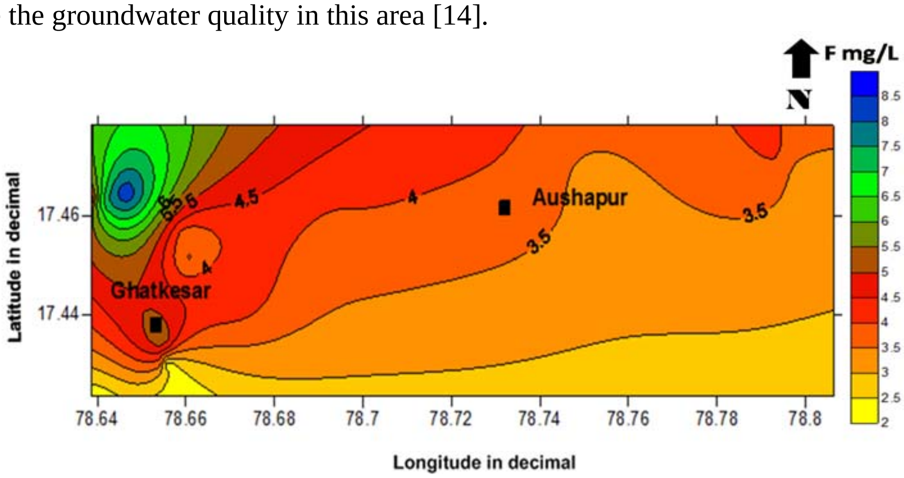

Fig.2 Fluoride ion concentration distribution map of the study area.

Chloride (Cl^-)

The concentration of chloride in the drinking water samples ranged between 38.35 to 542.35 mg/L with the mean of 237.10 mg/L, while the BIS permissible limit of chloride is specified as 250 mg/L for drinking water. About 52.38% of the samples exceed the permissible limits of BIS. Chloride concentration distribution map of the study area is illustrated in Figure 3. High chloride concentration was observed in Ghatkesar, Aushapur and Bibinagar areas of the Nalgonda district, Andhra Pradesh. A role for chloride in sodium-sensitive hypertension has been proposed, which seems to indicate that both sodium and chloride are required for a hypertensive effect [15]. Chloride is generally present at low concentrations in natural surface waters. It is highly soluble in water and moves freely with water through soil and rock. Chloride is widely distributed in nature, generally as the sodium (NaCl) and potassium (KCl) salts; it constitutes approximately 0.05% of the lithosphere. The presence of chloride in drinking water sources can be attributed to the dissolution of salt deposits. Ground water contains a wide variety of dissolved inorganic chemical constituents in various concentrations, resulting from chemical and biochemical interactions between water and the geological materials. Inorganic contaminants including salinity, chloride, fluoride, nitrate, iron and arsenic are important in determining the suitability of ground water for drinking purposes. The downward percolating water is not inactive, and it is enriched in CO_2 .It can also act as a strong weathering agent apart from general solution effect. Consequently, the chemical composition of ground water will vary depending upon several factors like frequency of rain, which will leach out the salts, time of stay of rain water in the root-zone and intermediate zone, presence of organic matter etc. There are several other reactions including microbiological mediated reactions, which tend to alter the chemical composition of the percolating water. For example, the bicarbonate present in most waters is derived mostly from CO2 that has been extracted from the air and liberated in the soil through biochemical activity. Some rocks serve as sources of chloride and sulphate through direct solution. The circulation of sulphur, however, may be greatly influenced by biologically mediated oxidation and reduction reactions. Chloride circulation may be a significant factor influencing the anion content in natural water.

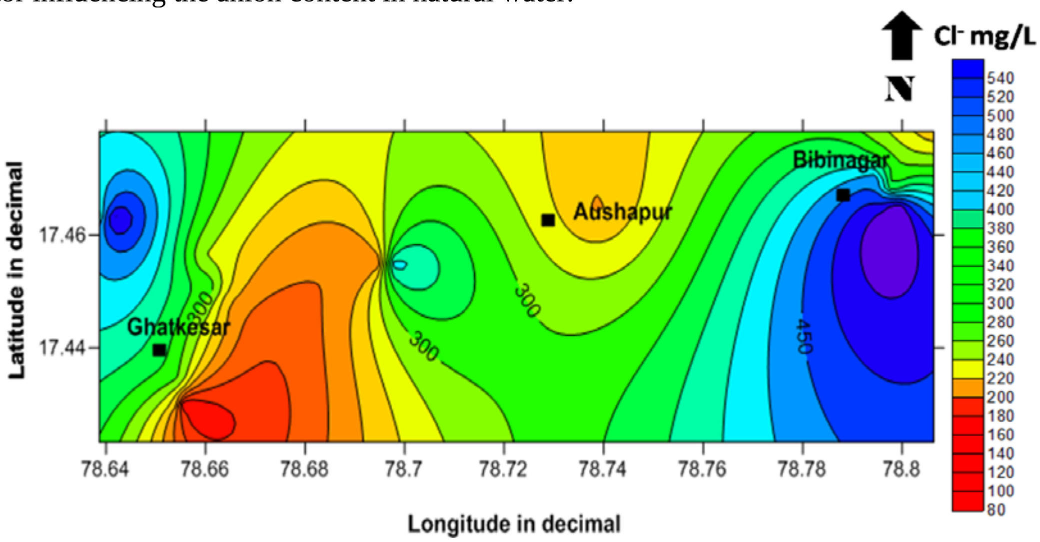

Fig.3 Chloride anion concentration distribution map of the study area.

Bromide (Br^-)

Bromide concentration ranged from 0 to 12.60 mg/L with an average of 1.75 mg/L in water samples. The limit for Bromide concentration for drinking water is specified as 0.5 mg/L [12, 16]. About 31.1% of the samples exceed the permissible limits. The concentration distribution map for bromide in water samples of the study area is shown in Figure 4. High Bromide concentration was found in Bibinagar area of Nalgonda district, Andhra Pradesh. Bromide ion has a low degree of toxicity; thus, bromide is not of toxicological concern in nutrition. Limited findings suggest that bromide may be nutritionally beneficial; for example, insomnia exhibited by some haemodialysis patients has been associated with bromide deficiency [17]. Bromide was once used as an anticonvulsant and sedative at doses as high as 6 gm/day. Clinical symptoms of bromide intoxication have been reported from its medicinal uses. Large doses of bromide cause nausea and vomiting, abdominal pain, coma and paralysis.

Doses of bromide giving plasma levels of 12 mmol/l (96 mg/l plasma) produce bromism (the chronic state of bromide intoxication), and plasma levels greater than 40 mmol/l (320 mg/l plasma) are sometimes fatal. Bromine is corrosive to human tissue in a liquid state and its vapor irritates eyes and throat. Bromine vapors are very toxic upon inhalation. The most important health effects that can be caused by bromine-containing organic contaminants are malfunctioning of the nervous system and disturbances in genetic materials. The signs and symptoms of bromism relate to the nervous system, skin, glandular secretions and gastrointestinal tract. Because of the rapidly increasing population, several environmental problems are created which includes groundwater quality degradation. Any ion in groundwater present beyond the limit that cannot be admitted by the human body can be considered as pollution of the groundwater. Bromide is a minor constituent in natural waters and toxicity of bromide in human leads to vomiting, nausea, drowsiness, mental dullness and loss of motor coordination. In urban areas, due to treatment of water for drinking by disinfection processes, bromide gets converted into bromate which is a potential carcinogen [18].

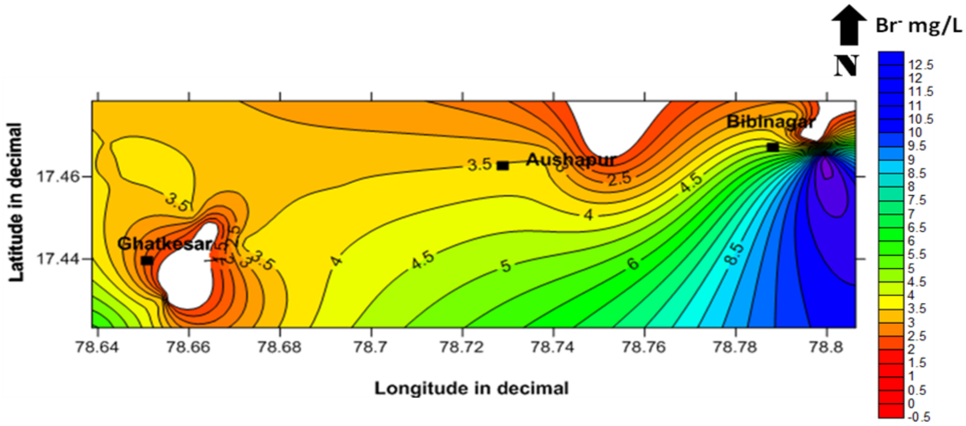

Fig.4 Bromide anion concentration distribution map of the study area.

Nitrate (NO_3^-)

The concentration of NO_3^- in the drinking water samples is observed from 15.30 to 434.30 mg/L with the mean of 112.90 mg/L. The BIS permissible limit of NO_3^- is specified as 45 mg/L for drinking water. About 97.61% of the samples exceed the permissible limits of BIS. NO_3^- concentration distribution map of the study area is shown in Figure 5. High NO_3^- concentration was observed in Aushapur and Bibinagar areas of Nalgonda district, Andhra Pradesh. The effects of exposure to nitrates in drinking water on the incidence of birth defects have been evaluated in several epidemiologic studies [19]. Nitrates and nitrites are known to cause several health effects. The most common effects are reactions with haemoglobin in blood, nitrite causing the oxygen carrying capacity of the blood to decrease, and nitrite causing decreased functioning of the thyroid gland. The health hazards from consuming water with nitrate are related to the direct toxicity of nitrite that is, its ability to directly oxidize hemoglobin, changing it to methemoglobin, which cannot bind oxygen. High nitrate concentration in groundwater of this area is due to leaching from indiscriminate dumping of animal waste. Anthropogenic activities like application of fertilizers for agriculture contribute only little to the groundwater nitrate [18, 20].

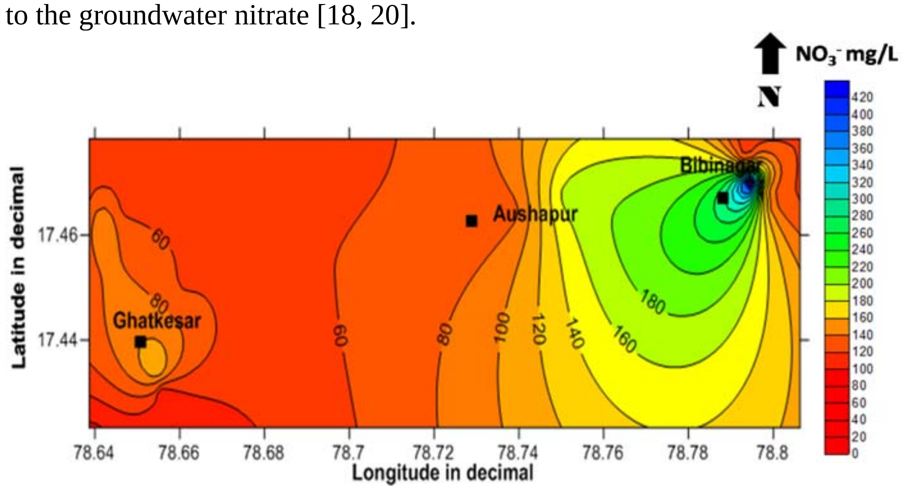

Fig.5 Nitrate anion concentration distribution map of the study area.

Sulphate (SO_4^{2-})

Sulphate concentrations varied from 0 to 12.10 mg/L with an average of 1.18 mg/L in water samples. The limit for sulphate concentration for drinking water is specified as 200 mg/L [16]. All the samples are within the permissible limits. The concentration distribution map for sulphate in water samples of the study area is shown in Figure 6. The highest sulphate concentration was found in Ghatkesar area, but it was well below the WHO limit. Uncontrolled observations indicate that sulfate in drinking water at concentrations exceeding 500 ± 700 mg/liter is associated with diarrhea in adults and infants. The distribution of sulphate is due to sulphur minerals, sulphides of heavy metals, which occur commonly in igneous rocks and metamorphic rocks. Apart from these natural sources, sulphates can be introduced through the application of sulphatic soil conditioners.

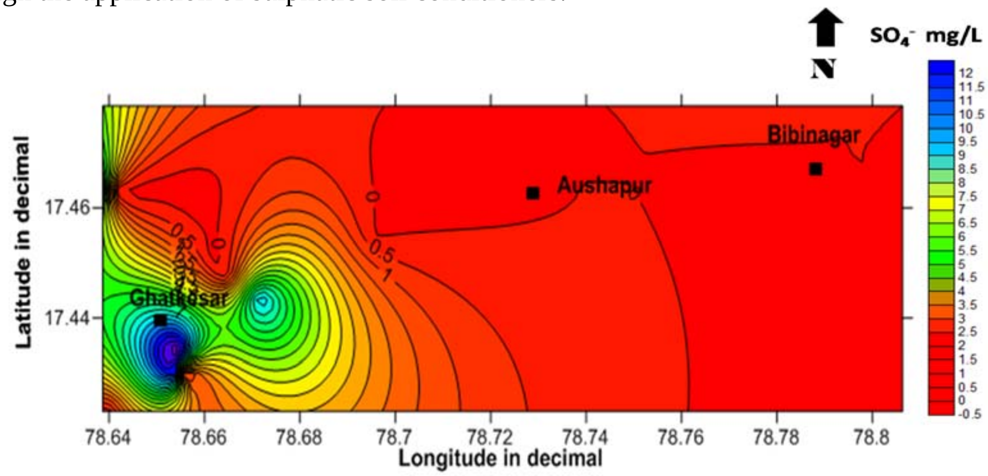

Fig.6 Sulphate anion concentration distribution map of the study area.

Phosphate (PO_4^{-3})

The concentration of phosphate in the drinking water samples was found to be from 35.60 to 343.1 mg/L with the mean of 119.3 mg/L. The BIS permissible limit of phosphate is specified as 5 mg/L for drinking water. All the samples exceed the permissible limits of BIS. The phosphate concentration distribution map of the study area is shown in Figure 7. High phosphate concentration was observed in the Aushapur and Bibinagar areas of the Nalgonda district, Andhra Pradesh. Phosphorus can be found in the environment most commonly as phosphates. Phosphates are important substances in the human body, because they are a part of DNA materials and they take part in energy distribution. Phosphates can also be found commonly in plants. Phosphate is a dietary requirement, with recommended intake of 800 mg/day. Humans have changed the natural phosphate supply radically by addition of phosphate-rich manures to the soil and by the use of phosphate-containing detergents. Phosphates were also added to a number of foodstuffs, such as cheese, sausages and hams. Too much phosphate can cause health problems, such as kidney damage and osteoporosis. Phosphate shortages can also occur. These are caused by extensive use of medicine. Too little phosphate can also cause health problems.

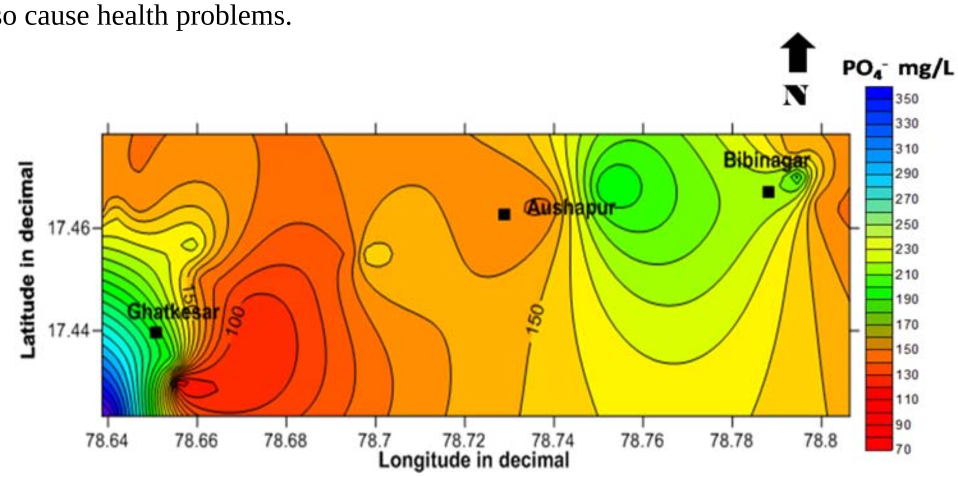

Fig.7 Phosphate anion concentration distribution map of the study area.

Preventive measures

Water quality is affected by both point and non-point sources of pollution. These include sewage discharge, discharge from industries, run-off from agricultural fields and urban run-off. Water quality is also affected by floods and droughts and can also arise from lack of awareness and education among users. The need for user involvement in maintaining water quality and looking at other aspects like hygiene, environment sanitation, storage and disposal are critical elements to maintain the quality of water resources. Water quality monitoring is now being considered an important part of the government programme. Since 2000, water quality monitoring has been accorded a high priority and institutional mechanisms have been developed at national, state, district, block and panchayat levels. The government of India has also outlined requisite mechanisms to monitor the quality of drinking water and devise effective Information, Education and Communication (IEC) interventions to disseminate information and educate people on health and hygiene. The Government of India launched the National Rural Drinking Water Quality Monitoring and Surveillance Programme in February 2006. This envisages institutionalisation of community participation for monitoring and surveillance of drinking water sources at the grassroots level by gram panchayats and Village Water and Sanitation Committees, followed by checking the positively tested samples at the district and state level laboratories. One major problem when it comes to addressing the problems related to water is that the provisions for water are distributed across various ministries and institutions. With several institutions involved in water supply, intersectoral coordination becomes critical for the success of any programme. When it comes to dealing with maintaining water quality, the users and in large the communities have to play a key role in maintaining hygiene near water sources. One has to improve the ways in which we collect and store water so as to avoid contamination while collection, storage and use. With the decentralisation of programmes for water supply it is essential that communities and institutions like panchayats are actively involved in the planning, implementation and execution of programmes for water supply. These institutions will also have to undertake the monitoring of water sources and be made aware so simple remedial measures. It is true that this will require training and capacity building at a large scale. There can be little doubt that water is a basic necessity for the survival of humans. There is interplay of various factors that govern access and utilisation of water resources and in light of the increasing demand for water it becomes important to look for holistic and people-centred approaches for water management.

CONCLUSIONS

From the results obtained it can be concluded that anionic concentrations of fluoride (F^-), chlorides (Cl^-), nitrates (NO_3^-) and phosphates (PO_4^{-3}) exceed the permissible limits (WHO and BIS) for drinking water quality. High fluoride concentration was observed in Bibinagar area of Andhra Pradesh which are especially prone to contamination of various geological formations. Overall water quality of the study area was found unsatisfactory for drinking purposes. Pollution of the groundwater due to geogenic and anthropogenic factors often render the groundwater unsuitable as consumption of such water can lead to various health-related complications. There has been great focus on setting up and upgrading laboratories at the state and district levels, and on water monitoring through field testing kits. However, awareness, surveillance, monitoring and testing, mitigation measures, availability of alternate water sources and adoption of hygienic practices continues to remain roadblocks. There is a need to promote sanitary inspection along with the community based water quality monitoring and surveillance at the grass root level as a mechanism to identify problems and to take corrective measures. One of the greatest challenges has been the convergence of various departments associated with water: water and sanitation programmes have operated largely in isolation from programmes in health and education. A wider approach is needed where water and sanitation issues are looked at with the aim of reducing disease, improving hygiene, improving educational levels and reducing poverty. Suitable measures such as defluorinating the groundwater before use and recharging the groundwater by rainwater harvesting need to be practiced to improve the groundwater quality in this area. Many Defluoridation devices and techniques, the most feasible option for fluoride removal for rural regions seems to be magnesia. It is selective for fluoride removal as it binds well with fluoride ions.

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