I.J.S.N., VOL. 3(3) 2012: 555-562 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

MONITORING OF WATER QUALITY IN THE HIPPARAGI IRRIGATION COMMAND AREA, KARNATAKA, INDIA

Jagadeesh, K.C. Chandrashekar, J.S. and Somashekar, R.K.
Department of Environmental Science, Bangalore University, Jnanabharathi, Bangalore – 560056
Karnataka, India.

ABSTRACT
This paper discusses the quality of surface and groundwater quality in Hipparagi irrigation command area, Karnataka, India and compared to BIS standards. The water in the study area is slightly acidic to slightly alkaline in nature EC exceeded the acceptable limits in bore well and open well samples. Most of the bore well and open well and river samples exceeded acceptable limits of BIS for TDS. Sulphates of bore well samples (63%) and open samples (33%) showed higher than acceptable limits of BIS. Phosphates showed within the acceptable limits in bore well and open well samples, but river water showed higher than acceptable limits and it indicate that surface water is polluted by phosphates by washing and other domestic activities. Fluorides exceeded the acceptable limits of BIS in both bore well and open well samples indicating few samples showed lowest values than the required and few samples exceeded the limits. The exceeded values of K^+ in bore well samples due to leaching of agricultural wastes in the study area. Hardness of water in the study area falls between soft to very hard water, and 36% of the bore well samples and 17% of open well samples exceeded the acceptable limits of BIS standards. For both Ca and Mg, 74% of bore well samples and river water in the study area exceeded the acceptable limits. COD values were high in open well samples compared to bore well and river water samples, it indicated that open wells contaminated by organic pollution. Groundwater samples were polluted compared to river in the study area it needs immediate attention for implementation of remedial measures.

KEY WORDS: Total dissolved solids, fluorides, total alkalinity, chlorides, BIS standards.

INTRODUCTION

Water is an essential component of the environment and it sustains life on the earth. Human beings depend on water for their survival. Water is also a raw material for photosynthesis and therefore, is important for crop production. Obviously, an optimum agricultural production depends on water and soil quality. The composition and concentration of substances in ground and surface water is a resultant of two factors: the geological structure of the earth's crust, including the intensity with which it is leached, and anthropogenic activity associated with agriculture, industry and public utilities. As water travels through the soil's profile, various water-soluble substances are released (Pulikowski et al., 2006). Groundwater is a replenishable resource and is considered to be least polluted as compared to other inland water resources (Srinivas et al., 2002). The utilization of groundwater for domestic industrial and irrigation purposes has been constantly increasing particularly where perennial surface water resources are absent. Though, ground water is a replenishable resource of water, which has inherent advantages over surface waters, however, it has some limitation on its utilizable potential. In comparison with surface water pollution, groundwater pollution is difficult to control. Rapid growth of urban areas results in over exploitation of ground water which may lead to lowering of water level below the economic levels of pumping. Wastewater disposal from industries and the returns from agricultural fields may contribute to ground water pollution. Under natural circumstances, the ground water quality of any aquifer is dependent on the lithology/mineralogy of aquifers, the hydrogeological environment and the direction of ground water movement. Thus the composition of ground water depends upon its source and the type of strata over which they flow (Rengaraj *et al.,* 1996).

The geochemistry of ground water may influence the utility of aquifer systems as sources of water. The types and concentrations of dissolved constituents in the water of an aquifer system determine whether the resource, without prior treatment, is suitable for drinking-water supplies, industrial purposes, irrigation, livestock watering, or other uses. Changes in the concentrations of certain constituents in the water of an aquifer system, whether because of natural or anthropogenic causes, may alter the suitability of the aquifer system as a source of water. Assessing ground-water quality and developing strategies to protect aquifers from contamination are necessary aspects of water-resource planning. The objective of the present paper is to study the physicochemical characteristics of bore well, open well and river samples in Hipparagi irrigation command area.

MATERIALS AND METHODS

Study area

The Hipparagi irrigation command area situated in the Krishna river basin falls in Athani and Chikkodi taluks of Belgaum district and Jamakhandi taluk of Bagalkote district, Karnataka, India and envisages feed at an 800 km^2 mainly in Athani taluk with 5 barriers to reserve the water that also act as a flood mitigation reservoir (Fig. 1). The area encompasses diverse land use pattern and cropping pattern. It is Deccan trap area having diversified geology and enjoys arid climate with temperature ranging between 28°C and 35°C. The study area receives annual rainfall of 160 cm and most of the rainfall occurs during monsoon season

.

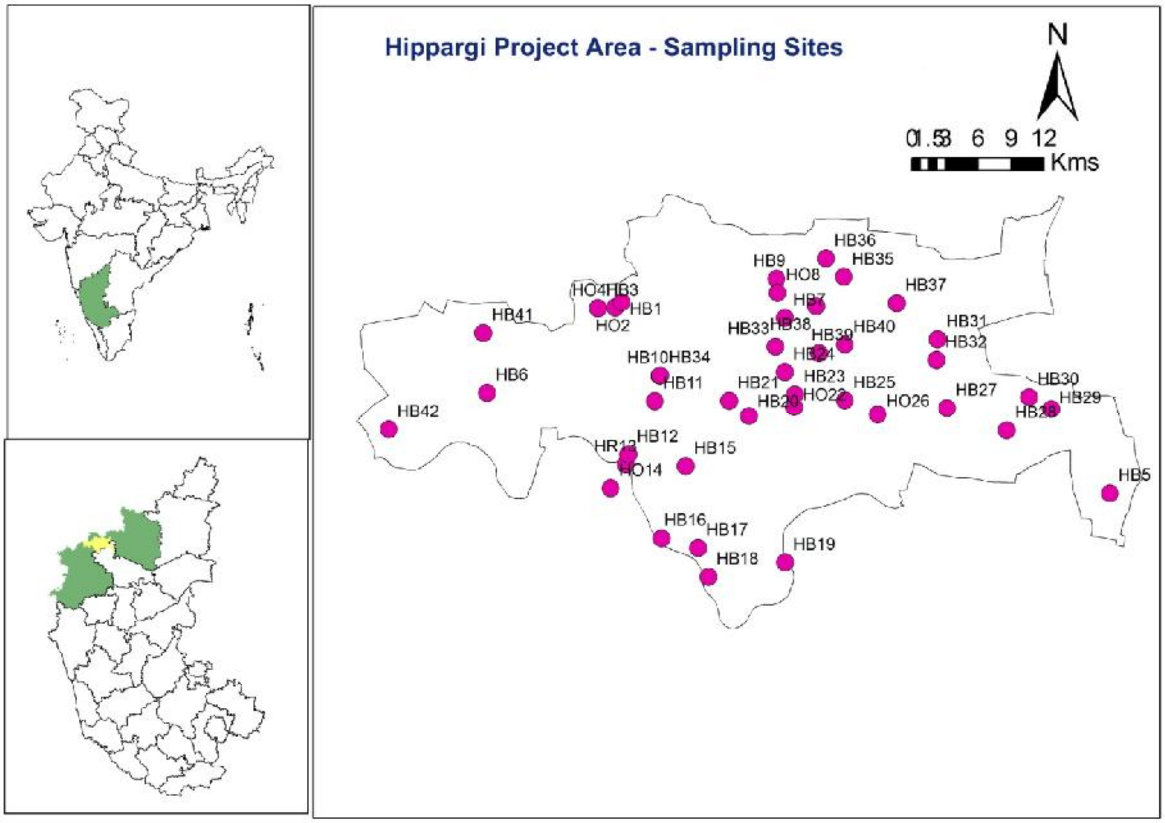

FIGURE 1. The study area Hipparagi Irrigation Command area, Karnataka, India.

Sampling and analysis

To analyze the groundwater and surface water quality of the study area, 35 samples from bore wells (HB) and 6 samples from open wells (HO) were drawn, and one river (HR) sample was drawn and physicochemical characteristics of water was carried out (Fig 1). The water quality parameter were analyzed for color (Electrode method), turbidity (Electrode method), pH (Electrode method), electrical conductivity (Electrode method), total dissolved solids (Electrode method), sulphates (Spectrophotometry), phosphates (Spectrophotometry), nitrates (Spectrophotometry), fluoride (SPADNS method), boron (AAS), total alkalinity (Titrimetry), sodium (Flamephotometry), potassium (Flamephotometry), total hardness (EDTA method), Ca^{2+} (EDTA method), Mg^{2+} (EDTA method), chlorides (Titrimetry-Argentometry) and chemical oxygen demand (Titrimetry) following APHA (2005). Statistical calculations like range, mean and standard deviation were calculated in MS-Excel 2007 for physicochemical characteristics of water for interpretation.

RESULTS AND DISCUSSION

The statistical study of physicochemical characteristics was presented in Table 1 and 2. The results were compared with Bureau of Indian Standards (BIS - IS: 10500: 1991). The bore well water samples of the study area are slightly acidic to slightly alkaline in nature with a mean pH value of 7.0 ranging from 6.3 to 8.1 with a standard deviation of 0.4. About 17% of the bore well samples exceeded the acceptable limits of BIS standards. Open well water showed pH values in the range of 6.2-6.9 with a mean value of 6.5 and 17% of the samples showed lower pH compared to acceptable limits of BIS standards. Water with a low pH can be acidic, soft and corrosive and can leach metals from pipes and fixtures, such as copper, iron, lead, manganese and zinc. It can also cause damage to metal pipes and aesthetic problems, such as a metallic or sour taste, laundry staining or blue-green stains in sinks and drains, and higher pH can also cause health effects on human (Rose, 1986; WHO 1986; Gupta et al., 2009). Colour and turbidity of the groundwater samples showed below the acceptable limits of BIS standards. Conductance is a function of water due to presence of dissolved salts in ionic form. Higher the concentration of electrolytes in water the more is its electrical conductivity (EC). In the present study, bore well samples recorded EC values in the range of 462-7960 with a mean value of 1986, open well samples recorded EC in the range of 452-1880 with a mean value of 1148 and river sample recorded 1077 EC, and 46% of bore well samples and 17% of open well samples exceeded the acceptable limits of BIS standards. Some of the groundwater samples showed more than 3000 EC and are unsuitable for drinking purposes.

TABLE 1. The statistical study of bore well water in Hipparagi irrigation command area

Parameters	Observed Range	Mean (n=35)	Standard limits (BIS: IS:10500:1991)		Standard deviation	Percentage of samples exceeding acceptable limits of standards (%)
			Acceptable limit	Maximum permissible limit		
Col (hazen Unit)	1.0-1.0	1.0	5	25	0.0	0
TURB (NTU)	0.05-0.05	0.05	10	10	0.0	0
pH (pH unit)	6.3-8.1	7.0	6.5 – 8.5	No relaxation	0.4	17
EC (μmhos/cm)	462-7960	1986	1500	3000	1781	46
TDS (mg/L)	232-3830	1019	500	2000	864	74
SO_4^{2-} (mg/L)	15-893	401	200	400	272	63
PO_4^- (mg/L)	1.67-4.43	2.0	5	No relaxation	0.5	0
NO_3^- (mg/L)	2-100	12.1	45	100	17.1	3
F^- (mg/L)	0.1-0.8	0.4	0.6 – 1.2	1.5	0.2	83
B (mg/L)	0-69	6.2	1	No relaxation	21.3	26
TA (mg/L)	75-650	351	200	600	135	86
Na^+ (mg/L)	11-1315	250	100	No relaxation	310	57
K^+ (mg/L)	0.3-102.5	9.0	10	No relaxation	18.0	23
TH (mg/L)	40-770	278	300	600	195	37
Ca^{2+} (mg/L)	15-410	150	75	200	111	74
Mg^{2+} (mg/L)	12-450	128	30	100	105	74
Cl^- (mg/L)	30-980	366	250	1000	307	49
COD (mg/L)	53-293	203	250	No relaxation	61	20

TABLE 2. The statistical study of open well water in Hipparagi irrigation command area

Parameters	Observed Range	Mean (n=6)	Standard limits (BIS: IS:10500:1991)		Standard deviation	Percentage of samples exceeding acceptable limits of standards (%)
			Acceptable limit	Maximum permissible limit		
Col (hazen Unit)	1-1	1	5	25	0	0
TURB (NTU)	0.05-0.05	0.1	10	10	0	0
pH (pH unit)	6.2-6.9	6.5	6.5 – 8.5	No relaxation	0.3	0
EC (μmhos/cm)	451-1880	1148	1500	3000	460.2	17
TDS (mg/L)	274-927	610.5	500	2000	210.4	83
SO_4^{2-} (mg/L)	155-403	239.3	200	400	111.7	33
PO_4^- (mg/L)	1.96-2.06	2.1	5	No relaxation	0.1	0
NO_3^- (mg/L)	2-9	5.7	45	100	2.7	0
F^- (mg/L)	0.3-0.7	0.5	0.6 – 1.2	1.5	0.1	83
B (mg/L)	0-34	16.3	1	No relaxation	15.2	67
TA (mg/L)	188-575	439.8	200	600	139.3	83
Na^+ (mg/L)	5-127	71.8	100	No relaxation	42	17
K^+ (mg/L)	0-2	2	10	No relaxation	4	17
TH (mg/L)	65-400	243.3	300	600	109	0
Ca^{2+} (mg/L)	40-195	128.3	75	200	52.2	83
Mg^{2+} (mg/L)	25-285	115	30	100	88.9	83
Cl^- (mg/L)	70-420	179	250	1000	126	17
COD (mg/L)	240-320	267	250	No relaxation	29	67

Total dissolved solids (TDS) are the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. Water containing TDS concentrations below 1000 mg/l is usually acceptable to consumers, although acceptability may vary according to circumstances. However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances (WHO, 1996). In the study area, bore well samples recorded TDS values in the range of 230-3830 mg/l with a mean value of 1019 mg/l, open well samples recorded TDS in the range of 274-927 with a mean value of 610.5 mg/l and, 74% of the bore well samples, 83% of open well samples and river sample exceeded the acceptable limits 500 prescribed by BIS.

Sulphates are part of naturally occurring minerals contained within soil and rock formations. As water percolates down through soil, these minerals can dissolve releasing sulphates into drinking water. Health concerns regarding sulphate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate. The present study recorded sulphates in the range of 15-893 mg/l with mean value of 401 mg/l, Open well samples recorded in the range of 155-403 mg/l with a mean value of 239 mg/l, and 63% of bore well samples and 33% of open well samples exceeded the acceptable limits prescribed by BIS. Therapeutic effects are commonly reported to be experienced by people consuming drinking water containing sulphate in concentrations exceeding 600 mg/l, although it is also reported that humans can adapt to higher concentrations with time (WHO, 2004). The present study recorded phosphate values in the range of 1.67 – 4.43 mg/l in bore well samples and 1.96-2.06 mg/l in open well samples and are within the acceptable limits prescribed by BIS and river water exceeded the acceptable limits.

Groundwater pollution occurred due to nitrates both naturally and anthropogenic sources. The most common sources of nitrate in groundwater are atmospheric fallout, sanitation facilities, irrigational activities and domestic effluents (Ritzi et al., 1993). Waste materials are one of the anthropogenic sources of nitrate contamination of groundwater. Potential nitrate contamination of groundwater due to the disposal of human and animal sewage, industrial wastes related to food processing, and some polyresin facilities (Hallberg and Keeney, 1993). Nitrates of the bore well samples in the study area ranged between 2 and 100 with mean value of 12.1 and 3% bore well samples exceeded the acceptable limits of BIS standards. Nitrates in open well and river samples showed within acceptable limits of 45 mg/l prescribed by BIS. Nitrates in groundwater >50 mg/l would indicated nitrate pollution (Mondal et al., 2008). Fluoride is one of the toxic elements in water and also it's an essential element in ground water. Small concentration of fluoride in drinking water has an enormous beneficial effect on human body if consumed in standardized quantity. The consumption of drinking water having high concentrations of fluorides causes fluorosis. In the study area, bore well samples recorded fluoride values in the range of 0.1-0.8 with a mean value of 0.4 mg/l, open well samples recorded in the range of 0.3-0.7 mg/l with a mean value of 0.5 mg/l, and 83% of both bore well samples and open well samples exceeded the limits of 0.6 – 1.2 mg/l prescribed by BIS. River water showed low values of fluorides compared as desired by BIS standards (Table 3). Boron is an important trace metal for growth of plants hence it has important value in water for irrigation purposes. The present study recorded Boron values in the range of 0-69 with a mean value of 6.2 mg/l, open well samples recorded in the range of 0-34 mg/l with a mean value of 16.3 mg/l, and 26% of bore well samples, 67% of open well samples and river water exceeded the acceptable limits of BIS standards.

TABLE 3. The physicochemical characteristics of river water in Hipparagi irrigation command area

Parameters	River sample (n=1)	Standard limits (BIS: IS:10500:1991)	
		Acceptable limit	Maximum permissible limit
Col (hazen Unit)	1	5	25
TURB (NTU)	0.05	10	10
pH (pH unit)	6.7	6.5 – 8.5	No relaxation
EC (μmhos/cm)	1077	1500	3000
TDS (mg/L)	585	500	2000
SO_4^{2-} (mg/L)	327	200	400
PO_4^- (mg/L)	2.06	5	No relaxation
NO_3^- (mg/L)	2	45	100
F^- (mg/L)	0.2	0.6 – 1.2	1.5
B (mg/L)	12	1	No relaxation
TA (mg/L)	450	200	600
Na^+ (mg/L)	90	100	No relaxation
K^+ (mg/L)	1.1	10	No relaxation
TH (mg/L)	210	300	600
Ca^{2+} (mg/L)	110	75	200
Mg^{2+} (mg/L)	100	30	100
Cl^- (mg/L)	155	250	1000
COD (mg/L)	267	250	No relaxation

Total alkalinity (TA) is a measure of the ability of the water to neutralize acids. The constituents of alkalinity in neutral system include mainly carbonate, bicarbonate, hydroxide and other components like $H_2BO_3^{2-}$, HPO_4^{2-} and HS^-. These compounds result from dissolution mineral substances in the soil and atmosphere (Nagarajan et al., 1993; Patel et al., 1994; Manivasakam, 1996). Alkaline water may decrease the solubility of metals. The alkalinity varies in accordance with the fluctuation in the pollution load (Parashar et al., 2006). In this study, TA values of bore well samples ranged between 75 and 65 mg/l with a mean value of 351 mg/l, open well samples recorded in the range of 188-575 mg/l with a mean value of 439.8 mg/l and 86% of the bore well samples, 83% of open well samples and river sample exceeded the acceptable limits prescribed by BIS. This water is not suitable for industrial purposes in this region.

Sodium and potassium occur naturally in groundwater by weathering of feldspar and clay (Hem, 1985) and also due to anthropogenic activities like discharge of industrial wastes, sewage, fertilizers, water softener discharge (Sayyed and Bhosle, 2011). In the present study, Na^+ values recorded in the range of 11-1315 mg/l with a mean value of 250 mg/l in bore well water, open well water recorded in the range of 5-127 with a mean value of 71.8 mg/l and river water showed 90 mg/l. 57% of the samples from bore wells and 17% of open well samples exceeded the acceptable limit of 100 mg/l prescribed by BIS. K^+ values recorded in the range of 0.3-102 mg/l with a mean value of 9 mg/l in bore well samples, open well water recorded in the range of 0.0-2.0 mg/l with a mean value of 2.0 mg/l and river water showed 1.1 mg/l. 57% of the bore well samples from exceeded the acceptable limit of 10 mg/l prescribed by BIS. Both open well and rive water samples showed within the acceptable limits for K^+. The exceeded values of groundwater in bore well samples due to leaching of agricultural wastes in the study area.

Hardness in water is caused by certain salts held in solution. The most common are the carbonates, fluorides and sulphates of calcium and magnesium. The principal hardness causing cations are calcium, magnesium, strontium, ferrous and manganese ions. The cations plus the most important anions that contributes are bicarbonates, sulphates, chlorides, nitrates and silicates. The hardness may be advantageous in certain conditions; it prevents the corrosion in the pipes by forming a thin layer of scale, and reduces the entry of heavy metals from the pipe to the water (Shrivastava et al., 2002). Hardness is one of the very important properties of ground water from utility point of view for different purposes. In the study area, bore well samples recorded TH values in the range of 40-770 mg/l with a mean value of 278 mg/l and falls between soft to very hard water, and 36% of the bore well samples and 17% of open well samples exceeded the acceptable limits of BIS standards. River water sample showed TH values within acceptable limits of BIS. The principal natural sources of hardness in water are dissolved polyvalent metallic ions from sedimentary rocks, seepage and runoff from soils. Both calcium and magnesium are essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences. Recommended daily intakes of each element have been set at national and international levels. Individuals vary considerably in their needs for and consumption of these elements (WHO, 2011). In the study area, bore well samples recorded Ca values in the range of 15-410 mg/l with a mean value of 150, open well samples. Mg values ranged between 12 and 450 mg/l with a mean value of 128. For both Ca and Mg, 74% of bore well samples and river water in the study area exceeded the acceptable limits of 75 mg/l prescribed by BIS.

Chlorides are salts resulting from the combination of the gas chlorine with a metal. Some common chlorides include sodium chloride (NaCl) and magnesium chloride ($MgCl_2$). Chlorine alone as Cl_2 is highly toxic and it is often used as a disinfectant. In combination with a metal such as sodium it becomes essential for life. Small amounts of chlorides are required for normal cell functions in plant and animal life. The chlorides recorded in bore well samples in the study area ranged from 30-980 with a mean value of 366 mg/l, and 49% of the bore well samples and 17% of open well samples exceeded the acceptable limits of 250 mg/l prescribed by BIS. The presence of chlorides in drinking water is generally not considered to be harmful to humans or animals. The most noticeable effect of high chlorides is a salty taste. If a water softener is being used, the taste will be even more pronounced. In mineralized waters (high TDS), chlorides contribute to the corrosion of household appliances and domestic plumbing by preventing the formation of protective oxide films on exposed surfaces. However, the relaxation was fixed at 1000 mg/l in the absence of other sources for chlorides. COD is indirect measure of organic compounds in the water. In the present study, COD values of bore well samples ranged between 53 and 293 mg/l with a mean value of 203 mg/l, open well ranged between 240 and 320 mg/l with a mean value of 267 mg/l, and 2% of the bore well samples, 67% of the open well samples and river sample exceeded the acceptable limits of 250 prescribed by BIS. However, no relaxation of COD is given BIS standards, as it indicate the organic pollution of water body.

Open wells showed lowest pH compared to ground and river water samples. Bore well samples recorded highest values of EC, TDS, nitrates, Na^+, K^+, TH, Ca^{2+}, Mg^{2+}, sulphates, and chlorides compare to open well and river water samples. Open well samples recorded highest values of TA and F^- compared to groundwater and river water samples (Fig. 2 and 3). Few samples of Open well and river water were exceeded the acceptable limits indicating that pollution due to organic load.

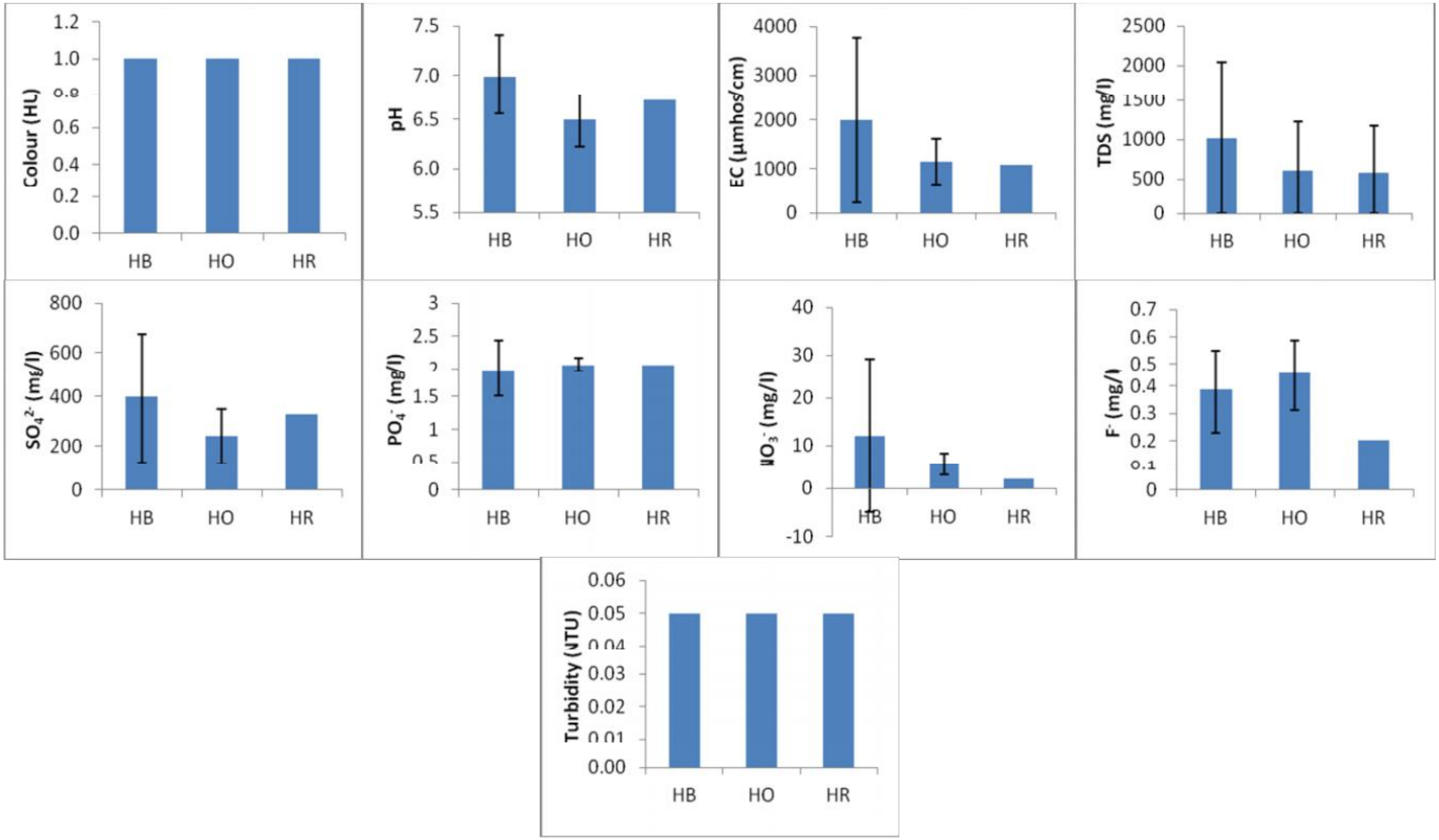

FIGURE 2: Comparison of physicochemical characteristics of bore well (HB), open well (HO) and river (HR) water samples in Hipparagi irrigation command area, Karnataka, India.

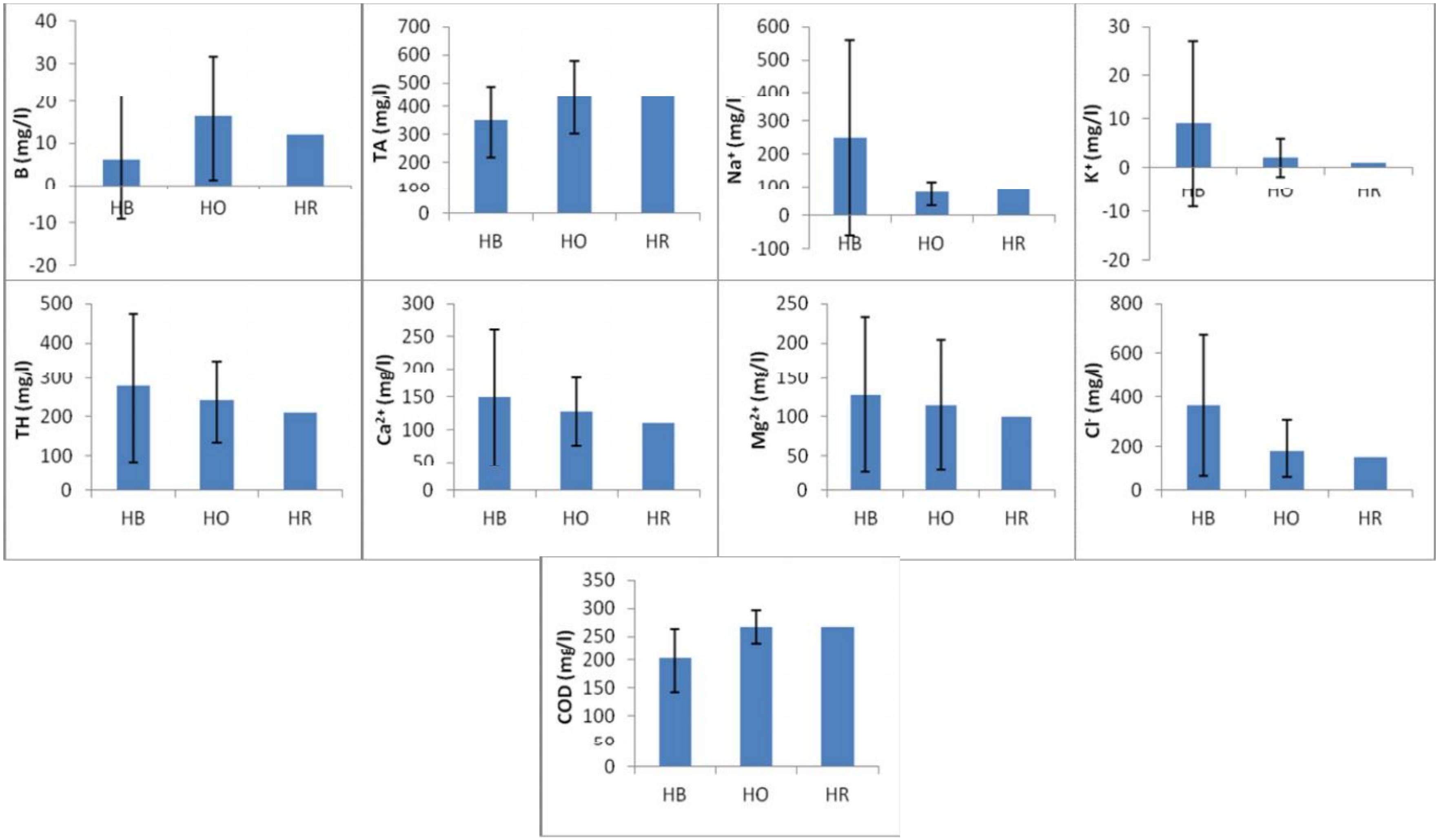

FIGURE 3: Comparison of physicochemical characteristics of bore well (HB), open well (HO) and river (HR) water samples in Hipparagi irrigation command area, Karnataka, India.

CONCLUSION

Water is a valuable natural resource and is depends on a number of factors such as geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources due to anthropogenic activities. Groundwater samples were polluted compared to river in the study area. In comparison with surface water pollution, the groundwater contamination is difficult to control. Most of the groundwater samples exceeded the acceptable limits prescribed by BIS I 10500: 1991 standards for drinking water. The study revealed that groundwater is getting gradually deteriorated due to overexploitation ad has probable changed the surface-groundwater interface and it needs immediate attention for implementation of remedial measures. However, open wells are not using since availability of bore well and surface water is exist for drinking and other domestic purposes.

REFERENCES

BIS (1993) Bureau of Indian Standards, Drinking Water Standards IS: 10500.

Gupta, D.P., Sunita and J.P Saharan (2009) Physiochemical Analysis of Ground Water of Selected Area of Kaithal City (Haryana) India. *Researcher* 1(2), 1-5.

Hallberg, G.R. and D.R. Keeney (1993) Nitrate; in *Regional Groundwater Quality.* William A. (ed.), Van Nostrand Reinhold, New York.

Hem, J.D. (1985) Study and interpretation of the chemical characteristics of natural water. 3rd Ed. U.S. Geological Survey and Water Supply.

Manivasakam, N. (1996) Physical Chemical examination of water, sewage and industrial effluents. 3rd Ed. Pragati Prakashan, Meeret, India.

Mondal N.C., V.K. Saxena and V.S. Singh (2008) Occurrence of elevated nitrate in groundwaters of Krishna delta, India. *African J. Env. Sci. Tech.* 2(9), 265-271.

Nagarajan, S., M. Swaminathan and P.L. Sabarathinam (1993) *Poll. Res.* 12(4), 245 – 250.

Parashar C., S. Dixit and R. Srivastava (2006) Seasonal Variations in Physico-chemical characteristics in upper lake of Bhopal, *Asian J. Exp. Sci.* 20(2), 297-302.

Patel, M.K.. K. Mohanty, T.N. Tiwary and Patel, T.K. (1994) Assessment of the quality of groundwater in the Rourkela industrial complex: Part lphysicochemical parameters in rural area. *Indian J. Env. Prot.* 14(5), 373-379.

Pulikowski, K., S. Kostrzewa, J. Paluch and S.Z. Szewrañski (2006) Stêzenie i tadunek magnezu oraz wapnia w odciekach drenarskich. *J. Elementol.* 11(4), 483-493.

Rengaraj, S.. T. Elampooranan, L. Elango and V. Ramalingam (1996) Ground water quality in suburban regions of Madras city, India. *Poll. Res.* 15(4), 325-328.

Ritzi R.W.. S.L. Wright, B. Mann and M. Chen (1993) Analysis of temporal variability in hydro geochemical data used for multivariate analysis. *Groundwater* 31, 221–229.

Rose P. (1986) Alkaline pH and health: a review prepared for the Water Research Centre. Medmenham, Water Research Centre (Water Research Centre Report No. LR 1178-M).

Sayyed, J.A. and A.B. Bhosle (2011) Analysis of Chloride, Sodium and Potassium in Groundwater Samples of Nanded City in Mahabharata, India. *Eur. J. Exp. Biol.* 1(1), 74-82.

Shrivastava, V.S. and P.R. Patil (2002) Tapti river water pollution by industrial wastes: A statistical approach. *Nature, Environ. Poll. Tech.* 1(3), 279-283.

Srinivas, N.. S.R. Rao and K. Suresh Kumar (2002) Water quality in industrial areas of Vishakapatnam. *Nature, Environ. Poll. Tech.* 2, 197-200.

WHO (1986) World Health Organization Working Group. Health impact of acidic deposition. *Science of the total environment* 52:157-187.

WHO (1996) Guidelines for drinking-water quality, 2nd ed. Vol. 2. Health criteria and other supporting information. World Health Organization, Geneva.

WHO (2004) Sulfate in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality. WHO/SDE/WSH/03.04/114.

WHO (2011) Hardness in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality. WHO/HSE/WSH/10.01/10/Rev/1.