PHYSICO-CHEMICAL ANALYSIS OF DRINKING WATER QUALITY OF BEMETARA TOWN OF CHHATTISGARH STATE

Deepak Sinha
Department of Chemistry Govt. Nagarjuna Postgraduate College of Science,
Raipur, Chhattisgarh, India

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ABSTRACT *Water quality is an important factor for evaluating the sustainability of human society, besides biological, analysis for physical and chemical properties of drinking water areverysignificant forpublichealth. During present study drinking water samples of three sources (Hand Pump, Municipal tap and Bore well) were collected from different sites of Bemetara districtarea and have been analyzed for seventeenphysico-chemical parameters viz. Temperature, pH,Alkalinity, Total dissolved solids (TDS), Free CO_2, Dissolved oxygen (DO), Biological oxygen demand (BOD), Chemical oxygen demand (COD, Total suspended solids (TSS), Chloride, Total hardness (TH),Calcium hardness, Magnesium hardness, Nitrate, Iron, Phosphate and Sulfate, considering all three season (summer, rainy and winter) and observedvalues have been compared with standard values recommended by World Health Organization (WHO).In general the present investigation revealedthat the maximum parameters are not at a level of pollution. However, iron is slightly increased, BOD & COD are slightly increased in hand pump & tap water and DO in bore well water is a little more than recommended value (WHO).*

Keywords: *Drinking water, Water quality, Physico-chemical, Bemetatra district*

INTRODUCTION:

Water is one of the most important and most precious natural resources. It is essential in the life of all living organisms from the simplest plant and microorganisms to the most complex living system known as human body. It is significant due to its unique chemical and physical properties (Onifade and Ilori, 2008; Obi and Okocha, 2007;Bhalmeet al., 2012; Jena&Sinha, 2017a).Asthemostessentialcommodityforhumanconsumptionwaterisoneofthemostimportantrenewableresources,whichmustbepreventedfromdeteriorationinquality.

Access to safe drinking water is key to sustainable development and essential to food production, quality health and poverty reduction. Safe drinking water is essential to life and a satisfactory safe supply must be made available to consumers (Venkatesharaju*et al*., 2010; Ackah, et al., 2012). Water is thus becoming a crucial factor for development and the quality of life in many countries. In individual arid areas it has even become a survival factor (Eddy and Ekop , 2007). Therefore, water intended for human consumption must not contain pathogen germs or harmful chemicals; because water contaminated with microorganisms is the cause of epidemics. That is good drinking water is not a luxury but one of the most essential requirements of life itself. However, developing countries, like Ethiopia, have suffered from a lack of access to safe drinking water from improved sources and to adequate sanitation services (WHO, 2004, 2006). The WHO revealed that seventy five percent of all diseases in developing countries arise from polluted drinking water.

Acceptable quality shows the safety of drinking water in terms of its physical, chemical and bacteriological parameters. The problems associated with chemical constituents of drinking water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure, of particular concern are contaminants that have cumulative toxic properties. The most common problems in household water supplies may be attributed to hardness, iron, sulfides, sodium chloride, alkalinity, acidity, and disease-producing pathogens, such as bacteria and viruses. Various physico-chemical parameters like pH, alkalinity, total hardness, total dissolved solid, calcium, magnesium, nitrate, sulphate have a significant role in determining the portability of drinking water (Gawas*et al*., 2006; Jitendra*et al.,* 2008; Solanki, 2012; Tiseer*et al*., 2008; Udhayakumar*et al.,* 2006; Venkatasubramani*et al*., 2007; Khalid *et al*., 2011; Shrivastava et al., 2014a; Shrivastava&Chandel, 2014b; Reda, 2016; Jena and Sinha, 2017b).

The major sources of drinking water supply in our country are groundwater, which is being tapped on a large scale by wells, tube-wells and borings. However, the quality of drinking water is extremely poor and except 15-20% of Indian population, who get piped filtered clean drinking water the rest have to depend upon unfiltered natural water. So far as the state of Chhattisgarh is concerned, the situation regarding drinking water standard is deplorable like many other states in India and abroad. Keeping in view

the aforesaid facts the present investigation has been performed to assess the quality and suitability of drinking water consumed by people of Bemetataradistrict, a newly created district of Chhattisgarh state, by scientific study of physico-chemicalpropertiesinvarioussamples of availabledrinkingwater.

EXPERIMENTAL AND MATERIAL DETAILS:

Survey and Water sample Collection –In order to assess the quality of drinking water available or supplied and consumed by urban as well as rural people resides within Bemetara district of Chhattisgarh state in India, an exhaustive survey for consideration of source of drinking water in practices was done and three categories of drinking water on the basis of their source were taken into investigation viz. Hand-pump water (Hw), Municipal water / Stored tank water or Tap-water (Tw) and Bore well water (Bw). Study area was divided in three zones i.e. urban, semi urban and rural area and five sites were determined in each area.The samples of drinking water of each source from different sampling sites of all study area were collected periodically in all three seasons (summer, rainy and winter) during present course of investigation. Temperature and pH was measures at the sites of collection, using digital thermometer & pH meter and water samples into sterilized bottle were carried out to the laboratory for analysis of different physico-chemical parameter of drinking water.

Chemical analysis of samples –Physico-chemical analyses were carried out applying the standard methods (APHA, 1995, 1998) and Kumar and Ravindranath (1998). Standard guidelines in this concern were followed during collection, preservation and estimation & examination of various parameters.

Total Alkalinity –The alkalinity of a water sample is a measure of its capacity to neutralize acids. Alkalinity of sample can be estimated by titration with standard sulfuric acid (0.02N). Take 50ml of sample in conical flask and add 2-3 drops of phenolphthalein indicator. If pink colour develop titrate with 0.02 N H_2SO_4 till it disappears or pH is 8.3 note the volume of H_2SO_4 required. Then add 2-3 drop methyl orange to the same flask, and continue titration till pH down to 4.5 or yellow colour change to orange and not the volume of H_2SO_4 add. Calculate Total (T), phenolphthalein (P) and methyl orange alkalinity as follows-

P – Alkalinity, mg/liter as $CaCO_3$ = A × 1000/ml sample

T – Alkalinity, mg/liter as $CaCO_3$ = B × 1000/ml sample

In case H_2SO_4 is not 0.02 N applied the following formula:

Alkalinity, mg/liter as $CaCO_3$ = [A/B × N × 50000] / ml of sampl.

Where A= ml of H_2SO_4 required to bring the pH to 8.3;

B = ml of H_2SO_4 required to bring the pH to 4.5; N = Normality of H_2SO_4 used.

Total dissolved solids (TDS) – For the estimation of total dissolved solids firstly take an oven dried weighed (W in mg) porcelain dish place in the desiccators. 100ml pond water sample pour in the porcelain dish and evaporate it to dryness by using oven maintaining a temperature of 105±2°C for 2 hours and cool it in the desiccators and then record the weight of porcelain dish plus residue (W_1 in mg). Calculate the value of total dissolved solids in the following manner:-

Total dissolved solids (TDS) in mg/liter = [(W_1 - W) X1000] / Vol. of Sample (in ml)

Where, W1 = Weight of porcelain dish plus residue; W = Weight of porcelain.

Dissolved Oxygen (DO) - DO was determined by Azide modification of Winkler method (APHA-AWWA-WPCF 1992). 300 ml sample was collected in BOD bottle. 2ml. Each of manganese sulphate and alkali-iodide-azide reagents was added. Bottle was shaken for about 15 minutes, allowing the precipitate to settle down. Then 2ml. conc. H_2SO_4 was added to dissolve the precipitate. 100 ml of this solution was titrated against 0.025 N sodium thiosulphate solutions in presence of starch indicator. DO $mg.l^{-1}$ = [A × N × 1000 × 8] / V_1-V

Where, A = ml titrant used; B = Normality of titrant

V_1 = ml of sample, V = ml of $MnSO_4$ + alkali-iodide azide

Biochemical Oxygen Demand (BOD) - Azide modification of Winkler method was used to measure the initial DO and DO after 5 days incubation of the sample at 20 degree C in BOD incubator. The BOD value was calculated with the help of following formula –

BOD $mg.l^{-1}$ DO (initial) - DO (5 days x dilution factor); Where, DO (initial) = dissolved Oxygen of the sample for the first BOD Bottle, which is not incubated.

DO (5 days) = Dissolved Oxygen of the sample after 5 days, incubation in dark.

Chemical Oxygen Demand (COD) - 2ml of sample was diluted to 50 ml with distilled water and simultaneously running distilled water blank. 0.2 gm $HgSO_4$ was added to this then 5 ml 0.25 N Potassium dichromate. Solutions and 15 ml conc H_2SO_4 the solution was refluxed for 2 hour s. Excess of Potassium dichromate was titrated against 0.1 N ferrous ammonium sulphate using ferroin indicator.

COD mg/L = [(a-b) ×N ×1000 ×8] / ml of sample

Where, a = ml titrant, used for blank, b = ml titrant, used for sample; N = Normality of titrant.

Free CO_2 -

Free carbon dioxide existing in the water sample can be determined by titrimetric method with an alkaline titrant, 0.0454N sodium carbonate (Na_2CO_3) also using phenolphthalein as indicator. Take 100ml of water sample and add 5 to 10 drops of Phenolphthalein indicator and titration done with the titrant 0.0454 N, Na_2CO_3 till the colour of water sample just changes to pink. Record the volume of titrant in ml consumed during the titration.

$$\text{Free } CO_2 \text{ mg/liter} = \frac{\text{Volume of titrant (in ml) consumed} \times 1000}{\text{Volume of water sample}}$$

Physical and chemical analyses of pond water samples were measured according to APHA, 1998.

Total Suspended Solids (TSS) –

Total suspended solids are the portion of solids that usually remains on filter paper. Suspended solids consist of clay, silt and sand fine particles of organic and inorganic matter. For TSS analysis, known amount of sample was filtered through the pre weighted filter paper. Filter paper was then dried at 103-105°C. TSS was determined by the following formula.

$$\text{Total Suspended Solid mg.l}^{-1} = \frac{(A - B) \times 1000}{\text{ml of sample volume}}$$

Where, A = weight of filter paper + weight of dried residue (mg)
B = weight of filter (mg)

Total hardness as $CaCO_3$ - EDTA complex metric titration method using Erichrome black T indicator was used for the estimation of total hardness in pond water.100 ml sample was taken in a conical flask. 5 ml buffer solution was added to raise the pH between 10 + 0.1. This solution was titrated against standard EDTA of 0.01 M, using Erichrome black T indicator .The total hardness was calculated using the following formula-

$$\text{Total hardness as mg/l } CaCO_3 = [\text{ml EDTA used} \times 1000] / \text{ml of sample}$$

Calcium and Magnesium hardness - Calcium and Magnesium have been estimated by EDTA (Ethylene Diamine Tetra Acetic acid) titrametic method. Cataions present in the exchange complex of the sample has been removed by leaching the sample with Ammonium Acetate solution.The EDTA has got a stronger affinity towards Ca^{++} and Mg^{++} and, therefore by addition of EDTA the former complex is broken down and a new complex of blue color is formed. 50 ml of sample was taken in a conical flask, and was added 1ml of buffer solution (16.9 gm NH_4Cl in 143 ml of conc. NH_4OH were dissolved and 1.179 gm of disodium EDTA and 0.780 gm of $MgSO_4.7H2O$. In 50 ml of distilled water , both the solutions were mixed and diluted to 250 ml with distilled water), 100 mg of Erichrome black T indicator (0.40 gm of Erichrome black T mixed with 100 gmNaCl), the solution turned wine red . This solution was titrated against EDTA solution (3.723 gm of disodium salt of EDTA in distilled water was dissolved to prepare 1 liter of solution). At the end point, color changed from wine red to blue;

Calculation - Calcium/Magnesium mg/L = [A×400.8×V] / V×1.645×10,000×S

Where, A =Volume of EDTA, used for Calcium (ml); B =Volume of EDTA, used for Ca^{++} Mg (ml)
S = Weight of sample, taken (50gm); v = Volume of sample titrated (ml).

Chloride - Mohr's method was applied for the determination of the chloride, present in the sample water. 100 ml of the sample was titrated with silver nitrate using potassium chromate as an indicator. The chloride content was calculated using the following formula-

Cl mg/L= [(A-B) ×N ×35.45 ×1000] / ml of sample

Where, A = ml titrant, used for sample; B = ml titrant, used for blank; N = Normality of titrant.

Iron – Iron in water may be present in dissolved, colloidal or suspended form. Generally the ferric form is predominant in pond water. In present work Phenanthroline method was followed for the detection of Iron. In this method take 50ml of pond water sample in conical flask and add 2ml of concentrated HCl and 1ml of hydroxylamine-hydrochloride solution. After added few glass beads in the sample, boil it for 20 to 25 minutes, for the complete dissolution of Iron existing in the sample. Allow the sample to cool down to room temperature, after that add 10ml of ammonium acetate solution, followed by addition of 2ml phenanthroline solution and then dilute the sample to 100ml. After proper mixing Orange-red color develop. Simultaneously prepare a 50ml blank solution of Iron free water with followed exactly same procedure. Measure the absorbance value of sample by spectrophotometer using 1cm light path and 510 nm wave-length by setting zero absorbance at the color intensity of blank solution.

Nitrate (NO_3) - 50 ml sample and simultaneously with distilled water taken as blank 1 ml sulphanilamide solution was added. Then, after 2 minutes, 1 ml napthyl ethylene diaminedihydrochloride solution was added. Intensity of pink color was measure at 543 nm with the help of digital spectrophotometer (Systronics model 106), Amount of NO_2-N was determined with the help of standard curve.

Sulphate (SO_4) – Sulfate ions usually occur in natural waters. Many sulfate compounds are readily soluble in water. Sulphate ions (SO_4^-) are precipitated in an acetic acid medium with Barium Chloride ($BaCl_2$) so as to form Barium Sulphate ($BaSO_4$) crystals of uniform size and measure by a nephelometer. Take 100ml of pond water sample in Erlenmeyer flask and add 20ml buffer solution, mix well. Keep the flask constantly stirred with the help of stirrer. Add 1 spatula $BaCl_2$ crystals with stirring. Continue stirring for 1 minute after addition of $BaCl_2$. Measure the $BaSO_4$ turbidity after stirring period has been ended by nephelometer.

RESULT AND DISCUSSION:

Variation in the values (mean ±SD) of different Physico-chemical parameters of drinking water samples, as observed during present investigation have been computed inTable–1 and diagrammatically presented in Figure – 1 to 4; whereas the tape water was not found in rural area. The range value of each parameters considering the source wise and area wise have been compared with standard value as recommended by WHO, as mentioned in Table – 2 and Table– 3 respectively.

The pH values were found slightly alkaline in all sources of drinking water that ranges from 7.32 to 7.88. The temperature of sample water was found maximum during summer season and minimum in winter season that ranges from 18.44^{0}C to 30.58^{0}C. Total alkalinity was observed minimum in bore well water while maximum in tap water. Variation in the value of DO was found from 2.96 mg/l to 8.26mg/l that is more than standard value recommended by WHO. High DO level, especially of bore well water, in community water supply is good because it makes drinking water taste better, however high DO level speed up corrosion in water pipe. The B.O.D. of the samples were found ranges from 1.87mg/l to 5.74mg/l, whereas the maximum value was observed in hand pump water (2.86mg/l – 5.74mg/l) as well as in tap water (3.45 mg/l – 5.45mg/l). The maximum value of COD was recorded in tap water while minimum in bore well water, varied from 8.78mg/l to 10.74 mg/l. Total hardness of drinking water was found maximum in bore well water (169.8mg/l–193.6mg/l). The variation in the value of Nitrate, Phosphate and Sulphate was also observed, which are lesser than standard value, as recommended by WHO. Similarly value of Chloride and Iron were also observed with variable range whereas Chloride was lesser than standard value while Iron was higher than standard value (WHO). TDS was observed 152.54 mg/l to 189.86 mg/l and TSS was varied from 15.75mg/l to 21.67mg/l. Except iron & BOD and some samples COD (HPW & TW) and DO (BWW), the value of all parameters were observed within recommended limit.

CONCLUSION:

In spite of variation, the observed value of Physico-chemical parameters show generally under the range of standard / recommended value accept four parameters that are DO, COD ,BOD and Iron. The values of the parameters in the most of the samples have found more than permissible limit. Similarly the value of Iron was found more than standard value, whereas the Chloride, Nitrate and Sulphate show very less presence than that of standard value.

Through the present investigation confer the Physico-chemical properties of drinking water used by the public of Bemetara district and findings reveal the fact that the drinking water of this area of newly established district is more or less safe for human community, however need to proper management and careful, especially for municipal water (TW) in urban are and hand pump water in rural area.

This study is alarming the management system of drinking water supply in this district. In order to meet the quality of ground water it is recommended that continuous monitoring with proper action is essential to ensure the supply of safe drinking water.

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TABLE- 1: Physico-chemical properties of different samples of drinking water collected from available sources during different season.

Study Area	Source of drinking water	Season	PHYSICO-CHEMICL PARAMETERS																
			Temp.^{0}C	pH	Alkalinity (mg/l)	TDS (mg/l)	Free CO_2 (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	Chloride mg/l	Total hardness mg/l	Ca hardness mg/l	Mg hardness mg/l	NO_3mg/l	Fe ppm	PO_4mg/l	SO_4mg/l
URBAN AREA	Handpump water	Summer	28.36 ±1.7	7.64 ±0.5	83.2 ±2.7	165.34 ±3.43	21.84 ±2.2	4.38 ±1.2	5.74 ±1.1	12.57 ±1.82	20.45 ±2.42	41.45 ±2.62	172.3 ±3.78	43.2 ±2.7	44.6 ±2.4	0.62 ±0.3	0.73 ±0.4	0.086 ±0.06	7.87 ±1.8
		Rainy	26.58 ±1.7	7.88 ±1.1	88.5 ±2.9	172.28 ±2.86	23.48 ±1.7	4.94 ±2.2	4.67 ±1.3	13.68 ±2.34	17.36 ±1.64	34.97 ±3.08	178.6 ±3.83	37.8 ±3.6	34.7 ±2.3	0.67 ±0.2	0.62 ±0.2	0.067 ±0.03	6.39 ±1.5
		Winter	18.44 ±1.8	7.53 ±1.4	90.7 ±2.6	152.54 ±3.63	25.35 ±2.4	5.13 ±2.3	4.16 ±1.3	12.13 ±2.15	18.52 ±2.12	36.93 ±2.84	156.2 ±3.47	35.6 ±2.5	29.5 ±2.3	0.73 ±0.5	0.68 ±0.3	0.084 ±0.02	6.96 ±1.8
	Tap water	Summer	30.58 ±2.2	7.66 ±1.1	92.6 ±2.3	178.24 ±3.82	23.64 ±1.8	3.12 ±2.6	5.45 ±1.3	14.65 ±2.64	21.25 ±2.21	29.32 ±2.75	159.5 ±3.55	39.8 ±2.7	40.8 ±2.4	0.93 ±0.3	0.72 ±0.8	0.067 ±0.03	5.58 ±1.4
		Rainy	27.45 ±1.9	7.74 ±1.3	94.3 ±3.2	181.46 ±2.75	24.77 ±2.5	3.56 ±2.4	4.33 ±1.6	15.16 ±2.33	18.16 ±1.35	28.85 ±2.26	168.4 ±3.08	36.5 ±3.4	26.8 ±3.3	0.95 ±0.8	0.61 ±0.3	0.068 ±0.02	5.86 ±1.7
		Winter	19.73 ±1.8	7.57 ±1.4	95.2 ±2.5	158.28 ±2.83	25.23 ±2.7	3.77 ±1.5	3.45 ±1.2	13.56 ±2.05	19.43 ±1.82	27.38 ±2.65	158.6 ±3.55	36.4 ±2.4	35.6 ±3.2	0.91 ±0.3	0.59 ±0.8	0.084 ±0.02	5.87 ±1.7
	Bore well water	Summer	28.42 ±1.6	7.32 ±0.7	75.7 ±2.5	162.65 ±3.74	25.48 ±2.3	5.68 ±1.7	2.48 ±0.6	10.24 ±1.74	19.87 ±2.32	45.75 ±2.93	186.2 ±3.74	38.8 ±2.8	38.6 ±2.3	0.67 ±0.5	0.67 ±0.2	0.066 ±0.03	7.38 ±1.8
		Rainy	26.35 ±1.8	7.48 ±1.3	78.8 ±2.7	174.82 ±2.94	24.82 ±2.6	6.85 ±1.7	2.16 ±0.9	10.74 ±2.43	15.75 ±2.45	44.19 ±2.33	193.6 ±3.08	30.5 ±2.7	25.7 ±2.4	0.76 ±0.4	0.57 ±0.6	0.063 ±0.07	6.43 ±1.5
		Winter	19.36 ±1.8	7.48 ±1.2	73.8 ±2.3	156.21 ±2.85	25.15 ±2.2	7.34 ±1.6	1.87 ±0.9	9.65 ±2.12	18.58 ±2.15	44.68 ±2.96	191.6 ±3.58	21.6 ±2.5	30.3 ±2.6	0.67 ±0.4	0.68 ±0.3	0.086 ±0.04	6.84 ±1.7
SEMI-URBAN AREA	Hand pump water	Summer	28.42 ±1.8	7.73 ±1.3	97.6 ±3.4	161.85 ±3.68	19.74 ±1.5	4.33 ±2.4	3.48 ±1.7	11.95 ±2.64	20.68 ±2.18	27.84 ±2.74	183.5 ±3.65	41.3 ±2.6	38.6 ±2.8	0.58 ±0.5	0.71 ±0.3	0.077 ±0.04	8.48 ±1.6
		Rainy	27.34 ±1.6	7.66 ±1.2	112.2 ±3.5	171.65 ±2.73	18.94 ±1.6	4.47 ±1.5	3.84 ±1.3	12.17 ±1.63	18.24 ±1.58	26.96 ±2.64	176.4 ±3.78	36.4 ±2.7	32.5 ±2.6	0.58 ±0.7	0.68 ±0.5	0.086 ±0.04	7.27 ±1.4
		Winter	19.67 ±1.8	7.68 ±0.8	96.6 ±3.4	158.74 ±3.68	17.86 ±2.7	5.14 ±2.4	3.15 ±1.2	11.63 ±2.06	18.24 ±2.18	23.06 ±2.55	172.4 ±3.54	36.2 ±2.7	33.7 ±3.4	0.62 ±0.8	0.58 ±0.4	0.088 ±0.04	7.56 ±2.5

	Tap water	Summer	28.95 ±1.8	7.54 ±1.3	117.4 ±3.7	182.44 ±3.76	23.55 ±1.9	2.96 ±2.3	4.68 ±1.6	13.05 ±2.12	21.67 ±2.37	28.51 ±3.08	188.3 ±3.45	39.2 ±2.5	36.8 ±2.7	0.86 ±0.3	0.63 ±0.7	0.076 ±0.06	6.38 ±1.7
		Rainy	28.26 ±1.8	7.55 ±1.4	105.3 ±3.4	187.42 ±2.64	22.34 ±2.5	3.57 ±1.7	3.95 ±1.7	12.85 ±2.35	18.58 ±1.24	27.89 ±2.95	186.2 ±3.85	28.5 ±2.4	27.6 ±2.7	0.78 ±0.3	0.58 ±0.5	0.068 ±0.02	6.26 ±1.5
		Winter	20.33 ±2.1	7.67 ±1.2	96.3 ±2.7	166.22 ±3.43	22.48 ±2.1	4.35 ±1.6	3.64 ±1.5	12.18 ±1.94	19.83 ±1.64	26.01 ±2.24	183.4 ±3.47	33.7 ±3.8	33.4 ±2.6	0.84 ±0.8	0.57 ±0.4	0.064 ±0.06	6.96 ±1.5
	Bore well water	Summer	28.48 ±1.7	7.52 ±1.3	91.4 ±3.7	169.45 ±3.32	18.75 ±2.4	7.34 ±2.4	2.65 ±0.7	10.15 ±2.64	20.15 ±1.84	37.79 ±2.83	187.2 ±3.55	39.4 ±2.7	31.8 ±2.6	0.78 ±0.7	0.68 ±0.3	0.078 ±0.04	8.88 ±1.5
		Rainy	26.82 ±2.1	7.65 ±1.2	77.3 ±3.1	177.76 ±3.23	18.85 ±2.5	7.63 ±2.3	2.86 ±0.6	9.85 ±2.56	16.62 ±2.26	35.14 ±2.34	186.8 ±3.32	28.8 ±2.3	19.3 ±3.6	0.87 ±0.3	0.58 ±0.7	0.077 ±0.02	8.26 ±1.5
		Winter	20.78 ±1.8	7.53 ±0.8	85.6 ±2.9	162.34 ±2.94	17.74 ±1.8	8.26 ±1.8	2.16 ±0.9	9.83 ±1.85	18.86 ±2.21	34.88 ±2.58	185.6 ±3.85	30.4 ±2.6	32.3 ±2.3	0.85 ±0.5	0.69 ±0.6	0.079 ±0.03	8.46 ±1.3
RURAL AREA	Hand pump water	Summer	28.24 ±2.2	7.66 ±1.3	95.3 ±3.2	186.52 ±3.83	18.83 ±2.3	3.47 ±1.5	3.72 ±0.7	14.28 ±1.94	21.32 ±2.44	25.96 ±3.44	170.4 ±3.65	37.9 ±2.5	40.5 ±2.6	0.76 ±0.6	0.68 ±0.7	0.075 ±0.03	5.98 ±1.5
		Rainy	26.77 ±2.4	7.73 ±1.2	92.8 ±3.3	189.86 ±3.58	18.23 ±1.4	3.64 ±2.1	3.94 ±0.9	13.49 ±2.33	17.24 ±1.85	24.34 ±3.07	167.2 ±3.53	27.6 ±2.4	31.8 ±2.6	0.73 ±0.2	0.64 ±0.4	0.068 ±0.03	5.46 ±1.4
		Winter	19.83 ±1.6	7.64 ±1.4	96.2 ±3.3	172.34 ±3.86	16.66 ±2.3	4.33 ±2.3	2.86 ±0.6	13.34 ±2.07	18.86 ±2.23	24.16 ±2.64	169.7 ±3.46	31.5 ±2.6	32.5 ±2.5	0.87 ±0.4	0.59 ±0.5	0.088 ±0.03	5.78 ±1.7
	Tap water	Not Available	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bore well water	Summer	28.56 ±2.1	7.48 ±1.2	66.4 ±2.6	174.32 ±3.45	15.66 ±1.5	7.17 ±2.6	2.55 ±0.9	9.65 ±2.44	20.76 ±1.64	33.98 ±2.84	176.5 ±2.95	38.4 ±3.4	33.8 ±3.2	0.68 ±0.3	0.67 ±0.5	0.069 ±0.01	7.46 ±1.5
		Rainy	26.65 ±1.8	7.55 ±1.1	73.6 ±3.1	182.35 ±2.86	15.85 ±2.3	7.46 ±1.8	2.32 ±0.3	8.89 ±2.63	17.32 ±1.86	32.76 ±2.77	173.2 ±2.34	22.8 ±2.8	25.4 ±2.7	0.71 ±0.3	0.61 ±0.7	0.058 ±0.02	6.78 ±1.7
		Winter	19.84 ±2.1	7.34 ±1.4	77.8 ±2.8	163.73 ±3.84	16.84 ±1.7	8.17 ±1.6	2.08 ±0.5	8.78 ±2.32	18.93 ±2.15	32.33 ±2.32	169.8 ±3.43	36.2 ±2.5	28.5 ±2.7	0.67 ±0.5	0.66 ±0.5	0.096 ±0.05	6.96 ±1.7

TABLE - 2: Comparison of observed data (Physico-chemical properties of drinking water from different sources with standard recommended by WHO

Sl.No.	Physico-chemical Parameters	SOURCE OFDRINKINGWATER			STANDARDWHO
		Hand pump water	Tap water	Bore well water	
1	Temp.(0C)	18.44 – 28.42	19.73 – 30.58	19.36 – 28.56	15^0C to 31^0C
2	pH	7.53 – 7.88	7.54 – 7.74	7.32 – 7.65	6.5 - 8.5
3	Alkalinity (mg/l)	83.2 – 112.2	92.6 – 117.4	66.4 – 85.6	NA
4	TDS (mg/l)	152.54 – 189.06	158.28 – 187.42	156.21- 182.35	500 mg/l
5	FreeCO_2 (mg/l)	16.66 – 25.35	22.34 – 25.23	15.66 – 25.48	NA
6	DO (mg/l)	3.47 – 5.14	2.96 – 4.35	5.68 – 8.26	4 mg/l
7	BOD (mg/l)	2.86 – 5.74	3.45 – 5.45	1.87 – 2.86	2 mg/l
8	COD (mg/l)	11.63 – 13.68	12.18 – 15,16	8.78 – 10.74	10 mg/l
9	TSS (mg/l)	17.24 – 21.32	18.16 – 21.67	15.75 – 20.76	50 mg/l
10	Chloride(mg/l)	23.06 – 41.45	26.01 – 29.32	32.33 – 45.75	250 mg/ l
11	Total hardness (mg/l)	156.2 – 183.5	158.6 – 188.3	169.8 – 193.6	500 mg/l
12	Ca hardness(mg/l)	27.6 – 43.2	28.5 – 39.8	21.6 – 38.8	200 mg/l
13	Mg hardness (mg/l)	29.5 – 44.6	27.6 – 40.8	25.4 – 38.6	50 mg/l
14	NO_3 (mg/l)	0.58 – 0.87	0.67 – 0.95	0.67 – 0.87	45 mg/l
15	Fe (ppm)	0.58 – 0.73	0.57 – 0.72	0.57 – 0.71	0.01–0.5 mg/l
16	PO_4 (mg/l)	0.067 – 0.088	0.064 – 0.088	0.058 – 0.096	NA
17	SO_4 (mg/l)	5.46 – 7.87	5.58 – 6.96	6.43 – 8.88	205 mg/l

TABLE- 3: Comparison of observed data (Physico-chemical properties of drinking water from different study area) with standard recommended by WHO

Sl.No.	Physico-chemical Parameters	STUDYAREA			STANDARDWHO
		Urban area	Semi urban area	Rural area	
1	Temp.(0C)	18.44 – 28.42	19.67 – 28.42	19.83 – 28.56	15^0C to 31^0C
2	pH	7.32 – 7.88	7.52 – 7.73	7.34 – 7.73	6.5 - 8.5
3	Alkalinity (mg/l)	73.8 – 95.2	77.3 – 117.4	66.4 – 96.2	NA
4	TDS (mg/l)	152.54 – 181.46	158.74 – 187.42	163.73 – 189.86	500 mg/l
5	Free CO_2 (mg/l)	21.84 – 25.35	17.74 – 23.55	15.66 – 18.83	NA
6	DO (mg/l)	3.12 – 5.13	2.96 – 8.26	3.47 – 8.17	4 mg/l
7	BOD (mg/l)	1.87 – 5.74	2.16 – 4.68	2.08 – 3.94	2 mg/l
8	COD (mg/l)	9.65 – 15.16	9.83 – 12.18	8.78 – 14.28	10 mg/l
9	TSS (mg/l)	15.75 – 21.25	16.62 – 21.67	17.24 – 21.32	50 mg/l
10	Chloride(mg/l)	27.38 – 45.75	23.06 – 37.79	24.16 – 33.98	250 mg/ l
11	Total hardness (mg/l)	156.2 – 193.6	172.4 – 188.3	167.2 – 176.5	500 mg/l
12	Ca hardness (mg/l)	21.6 – 43.2	28.5 – 41.3	22.8 – 38.4	200 mg/l
13	Mg hardness (mg/l)	25.7 – 44.6	19.3 - 38.6	25.4 – 40.5	50 mg/l
14	NO_3 (mg/l)	0.62 – 0.95	0.58 – 0.87	0.67 – 0.87	45 mg/l
15	Fe (ppm)	0.57 – 0.73	0.57 – 0.71	0.59 – 0.68	0.01–0.5 mg/l
16	PO_4 (mg/l)	0.063 – 0.086	0.064 – 0.088	0.058 – 0.96	NA
17	SO_4 (mg/l)	5.58 – 7.87	6.26 – 8.88	5.46 – 7.46	205 mg/l

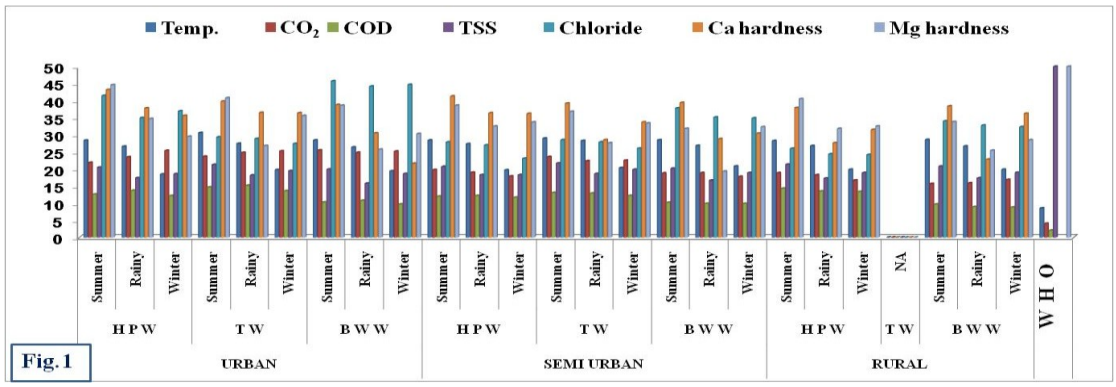

Fig.1

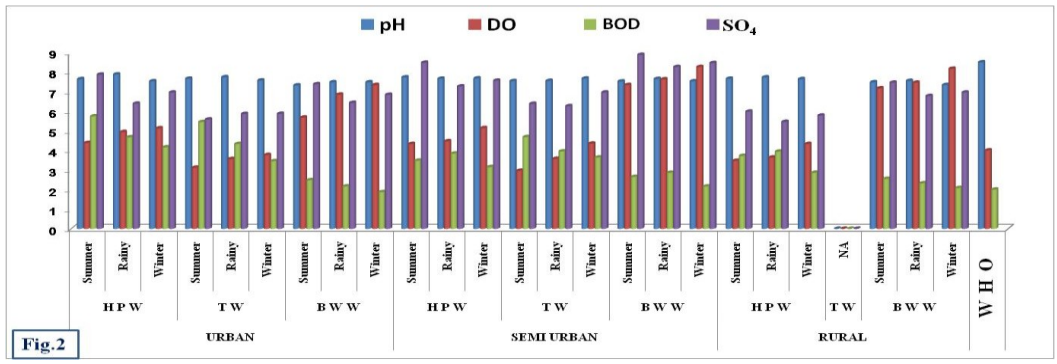

Fig.2

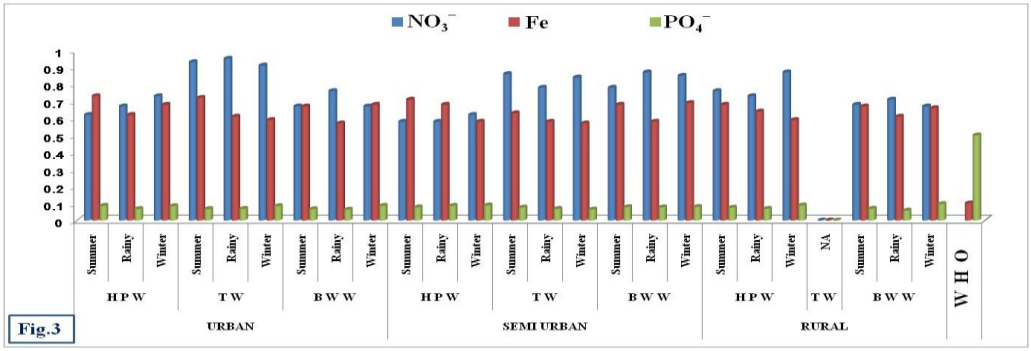
NO3⁻
Fe
PO4⁻
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Summer
Rainy
Winter
NA
H P W
T W
B W W
W H O
URBAN
SEMI URBAN
RURAL

Fig.3

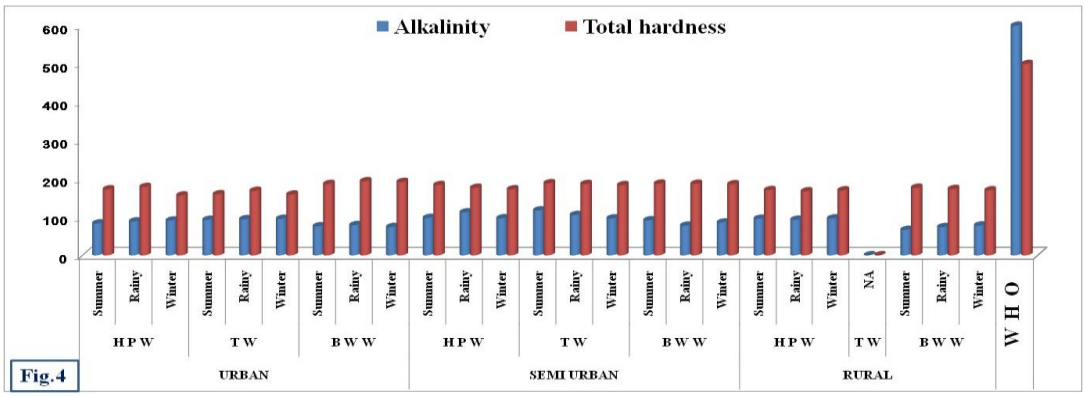
Alkalinity
Total hardness
600
500
400
300
200
100
0
Summer
Rainy
Winter
NA
H P W
T W
B W W
W H O
URBAN
SEMI URBAN
RURAL

Fig.4