



PHYSICO-CHEMICAL CHARACTERISTICS OF DRINKING WATER

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Received -29.01.2015; Reviewed and accepted -25.02.2015

ABSTRACT

The study was conducted in water supply of different localities of Ludhiana with the objective to screen the concentration of trace elements (As B Ca Co Cr Cu Fe K Mg Mn Na Ni Pb Zn). The study revealed that concentration of Pb, Cu, Fe, Cr, K, Na, Co, and Ca in twenty one drinking water samples analyzed from three different water utilities [Municipal Corporation (12), hand pumps(6) and submersible pumps (3)] were much below the permissible limits described by WHO and BIS. Zinc was detected in 95.45% of drinking water samples in the range 0.001-0.14 and boron detected in 85.71% of drinking water samples in the range of (0.002-0.1327) whereas Arsenic was detected in 19.04% of the water samples analyzed in the range of 0.006-0.01 mg/l. All the 21 samples depicted Nickel (Ni) and 57.14% of samples had Ni concentration >0.1mg/l (BIS), while in rest of the samples Ni was present in ranges of 0.0091-0.047mg/l. Only one sample out of 21 samples contained Arsenic and Manganese above permissible limit.

Key Words: Water supply, WHO, BIS, Permissible limit.

INTRODUCTION

Trace elements are distributed in groundwater from a variety of natural and anthropogenic sources (Mondal *et al.*, 2010). Various anthropogenic activities under the shadow of urbanization and the industrial development have resulted in effluent disposal, which when introduced in the groundwater system has resulted in high concentration of trace metal as evident from reports. Trace metals like Fe, Mn, Cu, Zn, Co, and Ni are micronutrient for living system, their deficiency or excess can lead to a number of disorders in human body (Jinwal *et al.*, 2009). Some trace metals like Cd, Pb and Cr can be lethal to human beings even at low concentration because of their tendency to accumulate in the body.

The study was conducted in water supply of different localities of Ludhiana with the objective to screen the concentration of trace elements (As B Ca Co Cr Cu Fe K Mg Mn Na Ni Pb Zn). The probe elements were further categorized as toxic (Pb,As), alkaline earth metals (Mg and Ca), alkali metals (Na and K), transition metals (Mn, Co, Ni), metallic elements (Cu Cd Fe Zn Cr), and non metallic element (B).

MATERIAL AND METHOD

Inductive coupled argon plasma-atomic emission spectrophotometer (ICAP-AES) was employed to determine the concentration of these trace elements in water samples. In ICAP-AES, the first step that take is the desolvation of the droplet with the water molecules stripped away; it then becomes a solid particle. The sample moves further into plasma, the solid particle changes first into gaseous form and then into a ground state atom. The final process of conversion of an atom to an ion is achieved mainly by collision of energetic argon electrons with ground state atom. The ion then emerges from plasma and is directed into the interface on the mass spectrometer. The measurement determines the parts per millilitre (ppm) of anions and cations in the sample.

RESULTS AND DISCUSSION

In the present study a total of twenty one water samples from twelve Municipal Corporation (Malsian Bhaike, Sherpur Khurd, Haibowal, Jawahar Nagar, Civil Lines, Madho Puri, Amar Nagar, Guralp Nagar, Shakti Nagar, Maya Puri, Rojoana Kalan and Rojoana Kalan.), six Hand pump sources from different areas (Baisal jargon, Kotminch, Mastafapur, Jargon, Chededwal and Malsian Bhaike) and three Submersible pump water samples (Khuakke, Hathoor and Chapper) of Ludhiana city were evaluated.

Toxic elements (As and Pb)

Lead (Pb): The concentration of Lead (Pb) in the study area ranged from 0.0001-0.0138 mg/l. All the 21 drinking water

samples were within the permissible limit of 0.05mg/l (IS-10500:1991). The concentration (ppm) of Lead in Municipal Corporation water samples was 0.012, 0.0119, 0.0109, 0.008, 0.0085, 0.0066, 0.0057, 0.0057, 0.0057, 0.0046, 0.003, 0.0029 from Rojoana Kalan, Guralp Nagar, Madho Puri, Jawahar Nagar, Amar Nagar, Sherpur Khurd, Haibowal, Civil lines, Malsian Bhaike, Shakti Nagar, Maya Puri, and Rojoana Kalanes areas of Ludhiana city respectively, much below the permissible limit. Its consumption in higher quantity may cause hearing loss, blood disorders, hypertension and eventually, it may prove to be fatal.

Lead is metal found in natural deposits. It is found in food, paint, dust, soil, smoke and even in drinking water. The possible source of contamination in minute concentration of Municipal corporation waters supply with Pb may be old piping and industrial discharge. Lead may also contaminate drinking water when soft acid water corrodes Lead or galvanized pipe or corrodes solder used in pipe fittings. The uncontrolled disposal of lead acid batteries and spent petroleum products probably may be reason for the detection of Pb in groundwater.

The level of Pb in water samples analyzed from Hand pump was 0.0138, 0.0046, 0.0021, 0.0008, 0.0005 and 0.0001 mg/l respectively in the Kotminch, Malsian Bhaike, Jagroan, Chuhedwal Baisal jargon and Mastafapur area of Ludhiana city respectively, Further the concentration of lead in Submersible pump water samples was 0.0028, 0.0019 and 0.0017 mg/l in Khuakke, Chapper and Hathoor respectively. It is inferred that water with respect to concentration of Pb is safe.

The source may be lead containing insecticide, high octane gasoline, vehicle discharge and industrial effluent, which contaminate normal water bodies resulting in ground water contamination through leaching.

Arsenic (As): The permissible level of Arsenic is 0.01mg/l (IS-10500:1991). A total of twenty one water samples were analyzed for the presence of Arsenic [Municipal corporation (12), Submersible pumps (3) and hand pumps (6)]. Arsenic was detected in range of 0.002-0.01 in 25% of Municipal Corporation water samples. The concentration of Arsenic in Municipal Corporation water samples was 0.006mg/l and 0.002mg/l in Maya Puri and Madhopuri respectively. The concentration of Arsenic in Shakti Nagar was equivalent to threshold level as recommended by BIS.

The mere presence of Arsenic in Municipal Corporation tap water may be old casing pipes in distribution system, effluents of industries discharged into unlined drains.

Arsenic was detected in 16.66% of Hand pump water sample, the concentration being 0.004mg/l. The water might have been polluted through pesticides, insecticides and herbicides. Arsenic was not detected in either samples tested from Submersible pump, may be because of their higher depth, at more depth ground water is naturally protected from surface water pollution.

Metallic elements (Zn, Fe, Cr, Cu)

Zinc (Zn)

The permissible level of Zinc is 5.0mg/l (IS-10500:1991).The concentration of Zinc in Municipal corporation water samples (12) ranged from 0.0013 -0.14 mg/l .The highest concentration of 0.14 mg/l in Malsian Bhaikhe followed by 0.0656, 0.0433, 0.0199, 0.0144,0.0062, 0.0062 0.0059, 0.005, 0.0019 and 0.0013mg/l in Madho puri, Rojoana Kalan, Sherpur Khurd, Rojoana Kalan, Maya Puri, Civil lines, Haibowal, Amar Nagar, Jawahar Nagar, Guralp Nagar respectively.

Where as in Hand pump water samples, it was 0.715, 0.0216, 0.0214, 0.0135, 0.0099 and 0.003 mg/l from Baisal Jagraon, Kotminch, Malsian, Jagron, Mastafapur, and Chehedwal respectively. The Concentration of Zn in Submersible pump water samples was 0.1751, 0.1531 and 0.0889mg/l in Hathoor, Chapper and Khuajke respectively.

The effects of large scale industrialization in Ludhiana and laxity in proper treatment of effluents before discharging into drains may be the possible reason of mere presence of Zn in drinking water.

Zinc is an essential micronutrient of plant and animals, it has significant role in the enzymatic system of human body as aldolase, and alkaline phosphates are dependent on zinc. It is also essential for the normal functioning of the cells including protein synthesis, carbohydrate metabolism, cell growth and cell division (ATA and TF 1996). The zinc deficiency results into retardation of growth, anorexia, lesions of the skin and impaired development and function of reproductive organs. On the other hand when zinc concentration is exceeded then it causes fever, depression, malaise, cough, vomiting, salivation and headache. However its toxicity is less than that of other heavy metals like Cd, As and Sb.

Iron (Fe)

Iron limit for drinking water is based on aesthetic parameters rather than on toxicity. Iron is mainly present in water in two forms either soluble ferrous ion or the insoluble ferric ion. Water containing ferrous is clear and colourless, when exposed to air in the pressure tank or atmosphere, the water turns cloudy and a reddish substance begins to form. The sediment is the oxidized or ferric form of iron that is dissolved in water. Iron is essential for good health, iron helps to transport oxygen in the blood, and dissolved ferrous iron gives disagreeable taste.

The concentration of Iron in drinking water samples was found in the range of 0.0004-0.05 mg/l, which is within permissible limit (0.3mg/l IS-10500:1991) .The concentration of Iron in Municipal Corporation water samples (12) was 0.005mg/l (Amar Nagar), 0.005 mg/l (Shakti Nagar, Jawahar Nagar and Civil Lines), 0.004mg/l (Madho Puri, Maya Puri and Guralp Nagar), 0.0036mg/l (Haibowal), 0.003mg/l (Rojoana Kalan), 0.0026 mg/l (Sherpur Khurd), 0.0022 mg/l (Malsian Bhaikhe), 0.002mg/l (Rojoana Kalan).

The concentration of Fe in submersible pump water samples was 0.007mg/l (Chapper), 0.005mg/l (Hathoor) and 0.0017 mg/l (Khuajke).The concentration of Fe in Mastafapur, Chehedwal, Baisal Jagroan, Kotminch, Jagron and malsian Bhaikhe was 0.0552, 0.0037, 0.0035, 0.003, 0.001 and 0.0004mg/l respectively.

The possible source of contamination of drinking water by iron may be industrial effluents, vehicle discharged and polluted environment and may be old casing pipes, which are still in use in Water distribution system, Submersible pumps and Hand pumps.

Chromium (Cr)

The permissible level of Chromium is 0.5mg/l (BIS 10500:1991). Chromium concentration in drinking water sample was in the range of 0.0001-0.049 mg/l, in all the 21 samples analyzed, Municipal Corporation (12), Hand Pump (6) and Submersible pump (4), were within the permissible limit. The concentration of Chromium (Cr) in Malsian bhaikhe, Civillines, Haibowal, Sherpur Khurd, Rojoana Kalan, Jawahar Nagar, Amar Nagar, Shakti Nagar, Rojoana Kalan, Guralp Nagar, Maya Puri, and Madho Puri was 0.049, 0.0047, 0.0022, 0.002, 0.0018, 0.0017, 0.0013, 0.0006, 0.0005, 0.0005, 0.0005, and 0.0003mg/l respectively.

Cr value from Submersible pump water sample varies from 0.0062mg/l (Hathoor), 0.0018mg/l in Chapper and 0.0019mg/l Khuajke. The concentration of Chromium in water samples from Hand pump was Malsian Bhaikhe 0.0044mg/l, Kotminch 0.0017 mg/l, Chehedwal 0.002mg/l, Baisal Jagron 0.001mg/l, Jagroan 0.0001mg/l and Mastafapur 0.0007 mg/l.

Detection of chromium may be because of the presence of basic rocks or anthropogenic origin probably paper mills/industrial effluents.

Copper (Cu)

Copper is an essential element in human metabolism and considered non toxic within permissible limit of 0.05mg/l in drinking water (BIS 10500:1991). On evaluation of drinking water samples, the concentration of Cu in Municipal Corporation water samples (12) ranged from 0.0002-0.0057mg/l, with highest and above permissible limit was in Shakti Nagar (0.057mg/l) followed by below permissible limits, 0.0052, 0.0037, 0.0033, 0.0021, 0.0019, 0.0016, 0.0003, 0.0004 and 0.0002mg/l in Amar Nagar, Rojoana Kalan, Maya Puri, Civil Lines, Madhu Puri, Jawahar Nagar, Sherpur, Haibowal kalan and Guralp Nagar respectively of Ludhiana city. The main source of Cu pollution may be due to accumulation in old distribution pipes piping system and solder pipes and joints.

The level of copper in water samples analyzed from Hand pump ranged from 0.003mg/l-0.0064mg/l, within permissible limit. The concentration of Copper in Mastafapur, Kotminch, Malsian Bhaikhe, Baisal Jagroan and Chuhedwal was 0.0064mg/l, 0.0061, 0.0032 0.005 mg/l and 0.004mg/l respectively. Similarly the concentration of Cu in Submersible pump water samples was 0.0013mg/l (Chapper), 0.0008mg/l (Hathoor) and Khuajke (0.0002 mg/l).

The possible reason for mere detection of Copper in Hand pump and Submersible pumps may be leaching of Copper containing fertilizers during excessive rain or excessive irrigation. Copper level above the permissible limit can cause a bitter metallic taste in eater and result in blue green stains on plumbing fixtures. Stomach intestinal distress such as nausea, vomiting diarrhoea, stomach cramps and liver and kidney damage are the problems associated with Cu contaminated drinking water.

Boron (B)

Boron usually occurs as a non-ionized form as H_3BO_3 at pH < 8.5, but above this pH, it exists as an anion, $B(OH)_4^-$. Long-term exposure of humans to boron compounds leads to mild gastrointestinal irritation. The permissible level of Boron (B) is 1.0mg/l (BIS 10500:1991).

The concentration of Boron (B) in drinking water samples from three different water utilities, Municipal Corporation (12), Hand Pump (6) and Submersible pump (3), was in the range of 0.0024—0.369 mg/l and was within permissible limit. The concentration of Boron in Municipal Corporation water supply from Malsian Bhaikhe, Rojoana Kalan, Haibowal, Sherpur Khurd, Amar Nagar, Rojoana Kalan, Guralp Nagar, Shakti Nagar, Madho Puri, Maya Puri was 0.1327, 0.0795, 0.0323, 0.0259, 0.0024, 0.0241, 0.009, 0.009, 0.005 and 0.01 mg/l respectively.

The concentration of Boron in two submersible pump water samples were 0.0391 (Hathoor) and 0.0334 mg/l (Khuajke), where as in six hand pump water samples the concentration of boron was 0.369, 0.0618, 0.0573, 0.0224, 0.018 and 0.0091 in

samples of water samples from Jargon, Malsian Bhaike, Baisal jargon, Kotminch, Mastafapur and Chededwal respectively.

The possible reason for the mere presence of Boron in drinking water samples may be industrial, domestic effluents or through fertilizer application.

Cobalt (Co) : Cobalt in the study area ranged from 0.0001-0.018mg/l, which is within permissible limit 0.1mg/l ISI. The concentration of Co in Municipal Corporation tap water supply samples was Malsian Bhaike (0.018mg/l), Amar Nagar (0.0029), Maya Puri (0.0011mg/l), Jawahar Nagar (0.0018 mg/l), Guralp Nagar (0.0006mg/l), Sherpur Khurd (0.0006 mg/l) Haibowal (0.0006), Civil lines (0.0004), Rojoana Kalan (0.0002), Rojoana kalan (0.0001) and Shakti Nagar (0.0001mg/l).

The concentration of Co in drinking water samples from Baisal Jagroan, Kotminch, Chededwal, Mastafapur, Malsian Bhaike and Jagroan was 0.0025, 0.0025, 0.0018, 0.0004, 0.0006 and 0.0009mg/l respectively and the concentration of cobalt in Submersible pump water samples was Khuajke (0.0014mg/l), Chapper (0.001mg/l) and Hathoor (0.0005mg/l).

Nickel (Ni)

Water-insoluble nickel compounds including nickel sulfides, disulfides, and oxides readily enter the cell and are potent carcinogens. In contrast, water-soluble nickel compounds including acetate, chloride, nitrate, and sulfate do not enter the cells. Ni²⁺ induces carcinogenesis by binding to DNA through several processes including DNA hypermethylation, or DNA Mutation. It binds to phosphate backbone of DNA in place of Mg²⁺ and promotes the conversion of suppressor genes to the heterochromatin. Moreover, the binding to histone H4 leads to the inhibition of lysine acetylation, and subsequently DNA hypermethylation. These events play an important role in silencing of tumor suppressor genes and the other genes that are involved in carcinogenesis pathways.

The concentration of Nickel in the water samples from study area Ludhiana [Municipal Corporation (12), Hand Pump (6) and Submersible pump (3)] ranged from 0.004-1.478 mg/l where as the permissible limit of Nickel is 0.1mg/l (BIS 10500:1991).

In 75% of drinking water samples from Municipal Corporation tap water samples tested, contain concentration of Nickel far above the permissible limit. The samples which crossed the recommended level of Nickel as recommended by BIS was 0.9402 mg/l (Haibowal), 0.8502 mg/l (Sherpur Khurd), 0.8166 mg/l (Jawahar Nagar), 0.7907 mg/l (Civil lines), 0.3641 mg/l (Amar Nagar), 0.3263 mg/l (Madho Puri), 0.2265 mg/l (Maya Puri), 0.1272 mg/l (Shakti Nagar) and 0.1244 mg/l (Rojoana Kalan).

The water distribution network is made of alloys containing heavy metals, the increase in the usage of nickel compounds and the spread of nickel due to its dissolution from nickel ore-bearing rocks may be the possible cause of high concentration of Nickel above permissible in drinking water samples from Municipal corporation.

The concentration of Ni crossed the permissible limit in the two out of three samples analyzed from Submersible pump (1.478mg/l and 1.222 mg/l in Hathoor and Chapper whereas in Khurajke concentration of Ni was 0.05mg/l).

Similarly in 16.6 % of samples from Hand pump found to contain Ni above recommended concentration (Baisal jagroan-0.1193mg/l). The concentration of Ni in rest of the hand pump water samples was 0.0353 mg/l (Malsian Bhaike), 0.031mg/l (Mastafapur), 0.026 mg/l (Kotminch), 0.0255 (Chededwal) and 0.0045mg/l (Jagroan).

The primary source of nickel in drinking-water samples from hand pumps and Submersible pumps may be the leaching of metals

from materials like pipes used in ground water extraction. Solid wastes dumped into the river which is likely to contain toxic materials including heavy metals may be important reason for leaching of Nickel into ground water.

Manganese (Mn)

Manganese is one of the most abundant metals in the earth's crust and usually occurs together with iron. The permissible limit of Manganese in drinking is 0.05 mg/l (BIS 10500:1991).

The concentration of Manganese in Municipal corporation water samples was 0.002mg/l (Rojoana Kalan, Amar Nagar, Guralp Nagar, Shakti Nagar, Maya Nagar, Madho Puri, Civil lines, Jawahar Nagar and Haibowal) followed by 0.003 mg/l in Sherpur Khurd, 0.0005 mg/l in Malsian Bhaike. In one hand pump water sample from Mastafapur, contained Mn above permissible limit, 0.184 mg/l whereas in rest of the samples, it was below permissible limit [Chededwal (0.0167) mg/l, Baisal Jagroan (0.0063mg/l), Jagroan (0.002mg/l) Kotminch (0.001 mg/l) and Malsian Bhaike (0.0009mg/l)]. The concentration of Mn in Submersible pump water samples was 0.0244 mg/l (Chapper) and 0.002 mg/l (Hathoor).

The contamination of surface and ground waters by industrial sewage and agricultural run-off may be the reason for presence of Manganese in drinking water sample.

Magnesium (Mg)

Magnesium is an essential cofactor for more than 350 enzyme systems and it is involved in energy metabolism, nucleic acid synthesis, cellular balance, cardiovascular health and hormonal functions. Low magnesium intake has been associated with osteoporosis, insulin resistance and increased risk of cardiovascular disease.

The concentration of magnesium in water samples, MC (12), Hand pump (6) and Submersible pump (3), ranged from 64.64-3.641mg/l where as permissible limit of Mg in drinking water is 30mg/l (BIS 10500:1991).

In 8.33% of Municipal Corporation water samples the concentration of magnesium was above the recommended threshold level of Mg, Malsian bhaike (64.64 mg/l) where as concentration of Mg in all other water samples tested from Municipal Corporation tap water was within the permissible limit, Rojoana kalan (16.91 mg/l), Amar nagar (11.42), Guralp nagar (11.03mg/l) Shakti Nagar (8.405), Maya Puri (6.798), Haibowal (6.777mg/l) Sherpur Khurd (6.473 mg/l), Madopuri (5.388mg/l), Jawahar Nagar (4.784 mg/l), Civil lines (3.893) and Rojoana Kalan (3.641).

Only one water sample from Hand pump crossed the permissible limit with respect to concentration of Magnesium (Baisal Jagroan 35.5mg/l). In rest of the water samples concentration of Magnesium was in the range of 5.85-24.18 mg/l, Chededwal (5.855mg/l), Kotminch (15.31mg/l), Mastafapur 23.14mg/l, Jagroan (24.17mg/l and Malsian Bhaike (24.18mg/l).

The concentration of Mg in all the Submersible pump water samples was in the range of 5.902-17.01mg/l, 17.01 mg/l (Khuajke), 5.902 mg/l (Chapper) and 7.129 mg/l (Hathoor).

The seepage of chemical constituents in the leachate formed as a consequence of continuous disposal of Municipal and industrial wastes at the landfill may be the possible source of detection of Magnesium.

Magnesium is common metal in rocks found on continents. It exists as salts of various types like magnesium chloride. Rainwater may erode the minerals in these layers and add magnesium into the ground water

Table 1: Mineral analysis of water samples

S.No	Area	Source	Arsenic 0.01mg/l	Boron 1.0mg/l	Calcium 75mg/l	Cobalt 0.1mg/l	Cr 0.5mg/l	Copper 0.05mg/l	Iron 0.3mg/l	K 12mg/l	Mg 30mg/l	Mn 0.1mg/l	Sodium 250mg/l	Nickel 0.1mg/l	Lead 0.05mg/l	Zn 5.0mg/l
1	Malsian Bhaikhe,ldh	MC	Nd	0.1327	67.44	0.018	0.049	0.0015	0.0022	9.635	64.64	0.0005	62.73	0.0471	0.0057	0.14
2	Sherpur Khurd,Ludhiana	MC	Nd	0.0259	15.11	0.0006	0.002	0.0003	0.0026	0.004	6.473	0.003	5.387	0.8502	0.0066	0.0199
3	Haibowal Kalon,Ludhiana	MC	Nd	0.0323	12.8	0.0006	0.0022	0.0004	0.0036	0.006	6.777	0.002	5.408	0.9403	0.0057	0.0059
4	Jawahar Nagar ,Ludhiana	MC	Nd	Nd	5.127	0.0018	0.0017	0.0016	0.0055	0.005	4.784	0.002	5.665	0.8166	0.008	0.0019
5	Civil lines,Ludhiana	MC	Nd	Nd	6.068	0.0004	0.0047	0.0021	0.0051	0.005	3.893	0.002	5.702	0.7907	0.0057	0.0062
6	Madho puri,ldh	MC-T	0.002	0.005	8.193	0.0001	0.0003	0.0019	0.004	0.004	5.388	0.002	6.993	0.3263	0.0109	0.0656
7	Amar nagar,ldh	MC-P	Nd	0.0024	15.37	0.0029	0.0013	0.0052	0.005	0.6923	11.42	0.002	11.03	0.3641	0.0085	0.005
8	Gurpal nagar,ldh	MC-P	Nd	0.009	2.995	0.0006	0.0005	0.0002	0.004	0.1999	11.03	0.002	8.862	0.027	0.0119	0.0013
9	Shakti nagar,ldh	MC-P	0.01	0.009	7.598	0.0001	0.0006	0.0057	0.005	0.3991	8.405	0.002	10.01	.1272	0.0046	Nd
10	Maya puri,ldh	MC-P	0.006	0.01	8.049	0.0011	0.0005	0.0033	0.004	0.004	6.798	0.002	7.135	.2265	0.003	0.0062
11	Rojoana Kalan,ldh	MC	Nd	0.0795	11.86	0.0002	0.0005	0.0037	0.003	1.646	16.91	0.002	25.16	0.1244	0.012	0.0144
12	Rojoana Kalan,ldh	MC	Nd	0.0241	15.85	0.0001	0.0018	0.0019	0.002	0.334	3.641	0.0002	4.325	0.0091	0.0029	0.0433
13	Baisal,jagroan,ldh	HP	Nd	0.0573	67.54	0.0025	0.001	0.005	0.0035	5.491	35.5	0.0063	47.32	0.1193	0.0005	0.715
14	Kotminch,ldh	HP	Nd	0.0224	40.28	0.0025	0.0017	0.0061	0.003	1.1	15.31	0.001	23.71	0.026	0.0138	0.0216
15	Mastafapue,ldh	HP	Nd	0.018	25.03	0.0004	0.0007	0.0064	0.0552	3.653	23.14	0.1849	22.24	0.031	0.0001	0.0099
16	Jagron,Ludhiana	HP	Nd	0.369	8.342	0.0009	0.0001	0.0036	0.001	4.284	24.17	0.002	9.24	0.0045	0.0021	0.0135
17	Chuhedwal,ldh	HP	0.004	0.0091	2.285	0.0018	0.002	0.004	0.0037	0.0037	5.855	0.0167	9.885	0.0255	0.0008	0.003
18	Malsian Bhaikhe,ldh	HP	Nd	0.0618	31.24	0.0006	0.0044	0.0032	0.0004	5.367	24.18	0.0009	28.92	0.0353	0.0046	0.0214
19	Malsian Bhaikhe,ldh	SP	Nd	0.0334	27.8	0.0014	0.0019	0.0002	0.0017	3.897	17.01	Nd	17.52	0.05	0.0028	0.0889
20	Hathoor,ldh	SP	Nd	0.0391	10.2	0.0005	0.0062	0.0008	0.005	0.005	7.129	0.002	12.33	1.478	0.0017	0.1751
21	Chapper,ldh	SP	Nd	nd	9.143	0.001	0.0018	0.0013	0.007	0.007	5.902	0.0244	6.319	1.222	0.0019	0.1531

Where : Mc:Municipal Corporation,Sp:Submersible Pump,Hp:Hand Pump, Cr:Chromium, K:Potassium, Mg:Magnesium Mn:Manganese,Zn:zinc,

Potassium (K)

The concentration of potassium in drinking water samples was found in the range of 0.003-9.635mg/l which is within the permissible limit (12mg/l BIS 10500:1991).The concentration of Potassium in Municipal Corporation water samples (12) was 9.635 mg/l (Malsian Bhaikhe), 1.646 mg/l (Rojoana Kalan), 0.6923 mg/l (Amar Nagar), 0.3991 (Shakti Nagar), 0.334mg/l (Rojoana Kalan), 0.1999 mg/l (Gurpal Nagar), 0.006 mg/l (Haibowal), 0.005 mg/l (Jawahar Nagar), 0.005 mg/l (Civil lines), 0.004mg/l (Maya Puri and Madho Puri) respectively.

The level of potassium in water samples analyzed from Hand pump ranged from 0.0037-5.491mg/l.The concentration of potassium in Baisal Jagroan (5.491mg/l), Jagroan (4.284 mg/l), Malsian Bhaikhe (5.367 mg/l), Mastafapur (3.653mg/l), Kotminch (1.1mg/l), Chhedwal (0.0037 mg/l), where as concentration of Potassium in Submersible pump water samples was 0.005mg/l, 0.007mg/l, and 3.897 mg/l in Hathoor, Chapper, and Khuajke respectively.

Potassium occurs widely in the environment, including all natural waters. It's detection in drinking water samples may be because of use of potassium permanganate as an oxidant in water treatment.

Calcium (Ca)

Calcium plays important roles in bone structure, muscle contraction, nerve impulses transmission, blood clotting and cell signaling; 99 percent of calcium is in bone and teeth and the remainder is in soft tissue. Low intake is associated with osteoporosis, rickets and hypertension. Consumption in drinking water also reduces the risk of kidney stones, probably by complexing with oxalates in the diet that compose some types of kidney stones.

Calcium concentration in drinking water samples was found in the range of 11.86-67.44 mg/l. All the samples analyzed were within permissible i.e. 75mg/l (BIS 10500:1991).

The highest concentration of Calcium (Ca) was found in Malsian Bhaikhe (67.44mg/l) followed by Rojoana Kalan (15.85mg/l) Amar Nagar (15.37mg/l) Sherpur Khurd (15.11 mg/l), Haibowal (12.8mg/l),Rojoana kalan (11.86mg/l) MadhoPuri (8.193 mg/l) Maya Puri (8.049mg/l), Shakti nagar (7.598mg/l), Civil lines (6.068mg/l), Jawahar Nagar (5.127) and Gurpal Nagar (2.995 mg/l).

The concentration of calcium in Hand Pump water samples from Baisal Jagroan, Kotminch , Malsian Bhaikhe, Mastafapur, Jagroan and Chhedwal was 67.54 mg/l , 40.28mg/l, 31.24mg/l, 25.03mg/l ,8.342mg/l and 2.285 mg/l. Calcium concentration in three Submersible pump water samples was 10.2 mg/l, 9.143mg/l and 27.8mg/l in Hathoor, Chapper and Khuajke.

Calcium is present in many sedimentary rocks, the most common being limestone and chalk. Rainwater may erode the minerals in these layers and add calcium into the ground water. They are also present in a wide variety of industrial products.

Sodium (Na)

The concentration of Sodium in Drinking water was found in the range of 4.32-62.75 mg/l, which is within permissible limit as recommended by WHO i.e. 250 mg/l.The concentration of Na in Municipal corporation water samples (12) was 62.75mg/l (Malsian Bhaikhe), 25.16mg/l (Rojoana kalan) , 11.03 mg/l (Amar nagar), 10.01mg/l (Shakti Nagar), 8.862 mg/l (Gurpal Nagar), 7.135mg/l (Maya Puri), 6.993 mg/l (Madho puri), 5.702 mg/l (Civil lines), 5.665 mg/l (Jawahar nagar), 5.408 mg/l (Haibowal), 5.387 mg/l (Sherpur Khurd) and 4.325 mg/l (Rojoana Kalan).

The level of Na in water samples analyzed from Hand pump ranged from 9.24-47.32mg/l.The concentration of Na in Baisal Jagroan, Kotminch, Mastafapur, Malsian bhaikhe, Chhedwal , Jagroan was 47.32 mg/l, 23.71 mg/l, 22.24mg/l, 28.92mg/l,9.885 mg/l and 9.24 mg/l respectively.And the concentration of Na in Submersible pump water samples was 6.319mg/l (Chapper), 12.33 (Hathoor), and 17.52 mg/l (Khuajke).

The possible source of Sodium in drinking water may be saline intrusion, mineral deposits, seawater spray, sewage effluents, and salt used in road de-icing can all contribute significant quantities of sodium to water. In addition, water-treatment chemicals, such as sodium fluoride, sodium bicarbonate, and sodium hypochlorite, may also result in detection of Na in drinking water. Domestic water softeners may also result in considerable amount of Na in drinking water.

Thus, the study revealed that concentration of Pb , Cu, Fe, Cr, K, Na, Co, and Ca in twenty one drinking water samples analyzed from three different water utilities [Municipal Corporation (12), hand pumps(6) and submersible pumps (3)] were much below the permissible limits described by WHO and BIS.

These elements Pb, Cu, Fe, Cr, K, Na, Co and Ca were present in 100% of the samples analyzed in range of 0.0001-0.0138mg/l, 0.0002-0.0064mg/l, 0.0004-0.05mg/l, 0.0001-0.049mg/l, 0.0003-9.635mg/l, 4.325-62.73mg/l, 0.0001-0.018mg/l and 2.288-67.44mg/l respectively. Zn was detected in 95.45% of drinking water samples in the range 0.001-0.14 and boron detected in 85.71% of drinking water samples in the range of (0.002-0.1327) whereas As was detected in 19.04% of the water samples analyzed in the range of 0.006-0.01 mg/l. All the 21 samples depicted Ni and 57.14% of samples had Ni concentration >0.1mg/l (BIS), while in rest of the samples Ni was present in ranges of 0.0091-0.047mg/l. Only one sample out of 21 samples contained Arsenic and Mn above permissible limit. Similarly over 9.52% of samples analyzed for Mg had Mg above the permissible limit.

Similar observation made by Momodu and Anyakora (2010) in which they reported 60% of samples had detectable level of lead while 36.73% of samples had lead above the permissible limit. Vijaya (2010) also analyzed Surface water and groundwater samples of certain locations namely Kallambella, Bugudanahalli, Maidala, Honnudiike, Kunigal, Kadaba and Hebbur, situated around Tumkur, Karnataka for the presence of heavy metals. Cu,

Fe, Ni and Zn were detected in all the samples and found in the range of 0.094-0.131, 0.958-12.537, 0.020-0.036 and 0.082-1.139 mg/L respectively in surface waters and these were in the range of 0.132-0.142, 0.125-1.014, 0.028-0.036 and 0.003-0.037 mg/L in ground-waters.

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