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GROUND WATER QUALITY IN GREATER GUWAHATI, ASSAM WITH REFERENCE TO TRACE ELEMENTS

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PREFACE

Ground water quality assessment and town planning are closely related. For any proper town planning, whether long range or short term, before going into alternative plans for development it is very essential to combine it with ground water quality problems, hydrology and analysis. For proper utilization of water for various purposes, understanding of geo-chemical controls and study of the extent of ground water contamination are of paramount importance.

In most of the city localities of Greater Guwahati pipe water scheme is remain elusive as a pipe dream. Because of this situation most of the city residents have to depend on ground water drawn either from the ring wells or from the tube wells. The quality of ground water is important to humans when the water is used as a drinking water supply. Ground water forms the major source of water supply for drinking purposes in Greater Guwahati. Not much of quantitative studies have been done in this region with reference to the available ground water resources. It was therefore proposed to take up study on ground water quality in and around Greater Guwahati with a view to examine the suitability of water with reference to trace elements.

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ABSTRACT

Ground water is one of the most important sources of drinking water in India. Degradation of ground water quality due to heavy metals has received considerable attention during recent years. Pollutants are being added to the ground water system through human activities and natural processes. Solid waste from industrial units is being dumped near the factories, which is subjected to reaction with percolating rain water and reaches the ground water level. The percolating water picks up a large number of heavy metals and reaches the aquifer system and contaminates the ground water. The quality of ground water is dependent on the geologic, climatic, environmental, biological and other anthropogenic activities. Several reports are available which indicate that samples collected from shallow aquifers shows higher concentration of heavy metals than those from deeper aquifers.

In the present report, ground water quality of Greater Guwahati is presented with reference to trace element contamination. The various elements analysed include Cu, Co, Cd, Fe, Zn and Pb. The trace element analysis of ground water samples has revealed that the concentration of iron in ground water is much higher than the tolerance limit prescribed for drinking water. The maximum concentration recorded was 3.58 mg/L. The presence of iron above acceptable limit in drinking water often imparts alien taste and inky flavour. It can also discolour cloths, plumbing fixtures and cause scaling which encrusts pipes. Excessive concentration of iron may promote bacterial activities in pipes and cause objectionable odours and red-rod disease in water.

1.0 INTRODUCTION

Ground water is one of the most important sources of drinking water in India. Apart from the exploitation of surface water resources, an estimated amount of 180 km^3 of ground water is being used annually for domestic purposes, irrigation and industry. It is further estimated that by the year 2000 A.D., about 250 km^3 of ground water will be required and the amount is likely to increase to 350 km^3 by 2025 A.D. (Handa, 1994).

The adverse effects on ground water quality are the result of man's activity at ground surface, unintentionally by agricultural and industry, unexpectedly by sub-surface disposal of sewage and industrial waste water and solid waste dumps, illegally by small workshops and unfortunately by the abstraction of ground water itself. As a result the quality of ground water in many instances has steadily deteriorated with severe consequences for the use of water for several purposes, especially for drinking water.

The evaluation of ground water quality is of great importance in determining the suitability of a particular ground water for a certain use like public water supply, irrigation, industrial application etc. The quality of ground water is the resultant of all processes and reactions that act on the water from the moment it is condensed in the atmosphere to the time it is discharged by a well or spring. Therefore, the quality of ground water varies from place to place, with the depth of water table, and from season to season and is primarily governed by the extent and composition of dissolved solids present in it. Further, one must realize, owing to the generally very low flow velocity, ground water once contaminated will often remains so for many generations.

The problems of ground water quality are more acute in the areas, which are densely populated, thickly industrialized and have shallow ground water table. Ground water is mostly polluted from the effluents discharged by industries on land, seepage from the sewage line and sewage tanks, application of pesticides and insecticides on agricultural land, etc. Therefore, the monitoring of ground water quality is very essential because it is the most important source of water supply for drinking purposes.

Heavy metals today have a great ecological significance due to their toxicity and accumulative behaviour. These elements, contrary to most pollutants, are not biodegradable and undergo a global eco-biological cycle in which natural waters are the main pathways. The determination of the concentration levels of heavy metals in these waters, as well as the elucidation of the chemical forms in which they appear is a prime target in environmental research today. The sources of metal pollution in the environment and their health hazards have been discussed in en earlier report (Jain, 1993).

Handa (1994) has briefly described the status of ground water contamination in India. The physico-chemical characteristics of waste effluents being released to the environment by various industries depend upon several factors, the most important being the type of industry and the in-house treatment of waste effluents.

Chowdhary et al. (1994) reported the status of toxic elements in ground water of Greater Varanasi. It is reported that the tube well water in the region is generally free from toxic heavy metals, viz., cadmium, copper, lead and iron and their contents are far below the safe prescribed limits. However, all the dug wells contained appreciable amount of these elements indicating their pollution from surface and sub-surface sources. Several other reports are also available on water quality studies in Varanasi, which point out the presence of heavy metals in ground water (Chowdhary, 1990; Gupta et al., 1991 a-c). Presence of toxic elements in ground water were also reported earlier by Handa (1983) and Hasan et al. (1986). Srivastava et al. (1991) reported chromium contamination in the carpet belt of Eastern Uttar Pradesh including Varanasi district.

Chromium occurs in drinking water in its +3 and +6 valence states with +3 being more common. The level of disinfection and presence of reducing organics affect the valence of the ion. Primary sources in water are old mining operations, wastes from plating operations, and fossil fuel combustion. Chromium III is nutritionally essential, nontoxic, and poorly absorbed. Deficiency results in glucose intolerance, inability to use glucose, and other metabolic disorders. Chromium VI is toxic, producing liver and kidney damage, internal hemorrhage, and respiratory disorders. Subchronic and chronic effects include dermatitis and skin ulceration. Chromium VI has been shown to cause cancer in humans and animals through inhalation exposure, but it has not been shown to be carcinogenic through ingestion exposure. The USEPA classifies chromium as a carcinogen.

Untreated electroplating wastes released into the environment have become important sources of chromium contamination of ground water in Varanasi, Faridabad and Ludhiana (Handa, 1988b, 1992; Kakar et al., 1989). Electroplating is one of the most polluting industries and is unique because the wastes are not principally organic in nature. Rather, they are toxic because they contain heavy metal ions such as chromium, nickel, lead, copper, zinc etc., which interfere with metabolism of living environmental systems. Chromium is well known for adverse health effects (Towill et al., 1978). Chromium can cause urinary tract cancer and digestive disorder in man. Nickel appears to be relatively non-toxic to mammals and exhibit only low toxicity but cause reduction in fecundity and survival by 50% at 1.6 mg/L (Pickering, 1974). A high concentration of chromium has also been reported in ground water of Kanpur due to discharge of untreated waste effluents by industries manufacturing chromium pigments (Handa, 1988b). In Ludhiana high cyanide and nickel contents were reported (Handa, 1978a) in waste effluents as well as in ground water.

Degradation of ground water quality due to heavy metals has also been reported in Faridabad district, Haryana (Khurshid et al., 1997). Solid waste from industrial belt of Faridabad is dumped near the factories, which is subjected to reaction with percolating rain water and reaches the ground water level. The percolating water picks up a large number of heavy metals and reaches the aquifer system and contaminates the ground water. It was further reported that samples collected from shallow aquifers shows higher concentration of heavy metals than those from deeper aquifers.

Iron is an essential constituent in both plant and animal metabolism. It is indispensable for the synthesis of chlorophyll in green plants, although it does not enter in the constituent of the chlorophyll molecule. Deficiency of iron in plants causes chlorosis. Iron is widely distributed in human body where it exists in the ionic (loosely bound, inorganic iron) and nonionic (tightly bound organic form) state. It is also a constituent of haemoglobin molecule. Depending upon the age, sex and body weight minimum daily requirement of iron varies from 7-15 mg Fe/day. Pregnant and lactating females require about 18 mg Fe/day. Thus while normal amount of iron is essential, the normally large amounts adversely affect the human system, which may result in haemochromatosis.

The concentration of iron in natural water is controlled by both physico-chemical and microbiological factors. In ground water iron generally occurs in two oxidation states, i.e., Ferrous (Fe^{2+}) and Ferric (Fe^{3+}) forms. In aqueous solutions iron form iron hydroxides. The presence of iron above acceptable limit in drinking water often imparts alien taste and inky flavour. It can also discolour clothes, plumbing fixtures and cause scaling which encrusts pipes. Excessive concentration may promote bacterial activities in pipe and service mains, causing objectionable odours and red-rod disease in water. Mehta et al. (1994) has reported that iron rich ground water in Bhubaneshwar city poses a serious problem in water supplies from borewells.

The iron concentrations in potable water are limited to 0.1 mg/L with upper limit of 0.3 mg/L (WHO, 1984). The BIS has given desirable limit of 0.3 mg/L which may be extended up to 1.0 mg/L in absence of alternative sources (ISI, 1983). According to the ICMR the maximum iron permissible in drinking water is 1.0 g/L (ICMR, 1975). Iron in irrigation water should not exceed 20 mg/L in natural or alkaline soils and 5 mg/L in acidic soils.

Manganese is an another essential element, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Higher values of manganese sometimes found in freely flowing water is usually associated with industrial pollution (Russell, 1979; WHO, 1984).

Higher concentration of manganese in ground water is generally due to industrial effluents particularly industries manufacturing iron and steel. In general concentration of manganese in ground water is low due to geo-chemical control. A concentration of 0.1 mg/L is recommended for drinking water.

Zinc is an essential element in human nutrition and even 15 mg/L in potable waters has no adverse effect. Zinc is also an essential element for plants and for acid soils 2 mg/L and for natural to alkaline soils 10 mg/L is permitted. However, zinc is extremely toxic to aquatic biota and limits of 0.05 mg/L are prescribed. The zinc smelter plant at Debari in Udaipur discharges its waste effluents into Berach river. The polluted river water, containing high zinc content has seeped into ground water from the river course and affected ground water quality (Gupta et al., 1981; Handa, 1992). High zinc concentrations were also observed in some water samples from Modinagar-Ghaziabad area, apparently due to seepage of industrial waste effluents. High zinc concentrations have also been reported in some parts of Betwa basin, Phulbani district of Orissa and in Hyderabad city, although the exact source of zinc has not been reported (Handa, 1992).

In Greater Guwahati rapid industrial and population growth has taken place during the last two three decades. This is likely to become manifold in near future with increasing industrialization and urbanization of the region. Guwahati saw its first burst of expansion during the period 1960-1965 with the setting up of the Oil refinery, the New Guwahati Goods Yard, the Army Cantonment and the Oil India Campus. The second burst of explosion witnessed the city was in 1972, when the State Capital was shifted to Dispur, on the south-eastern tip of the city. Within a very short time, population of the city incremented by lakh, creating a tremendous pressure on infrastructural facilities. At present the population of the city is about ten lakh. The municipal water supply system serve only the capital complex of about 15,000 people, while the rest of the city depend on ground water sources like dug wells and tube wells.

Considering the above aspects of ground water contamination, it was proposed to study ground water quality in and around Greater Guwahati with an objective to investigate the possible impact of trace elements on ground water quality of Greater Guwahati to see the suitability of water for drinking purposes. The present study primarily aimed to see the suitability of ground water as a source of drinking water supplies and deals with the trace element contents in ground water and their environmental aspects.

2.0 METAL TOXICITY

2.1 Manganese

Manganese in water may be present in higher concentrations depending upon the location and reducing conditions of the water. It may gain entry into the body by inhalation, consumption of food and through drinking water. Its presence in drinking water is inversely related to cardiovascular mortality. In animals experimentally induced or naturally occurring manganese deficiency has resulted in a variety of symptoms, but no adverse effect have been noted among humans deficient in manganese levels.

A study was conduced at Industrial Toxicological Research Centre, Lucknow to find out the causative factors for the endemic areas of Unnao district in Uttar Pradesh, India. It was found that the affected people consumed the Kesari dal which contained β-oxalyl amino alinine (BOAA), a neurotoxic constituent and drunk well water having high manganese content. However it was surprising to note that 8 persons of a family who consumed the well water having 2.1 mg manganese per litre, 42 times higher than the permissible limit of 0.05 mg/litre (WHO, 1971) were all victims of the disease. It was therefore hypothesized that etiological factors of the disease may be either due to consumption of BOAA, alone, manganese in drinking water or their synergistic effect (ITRC, 1975).

2.2 Mercury

Mercury in the environment is chiefly contributed by natural degassing of earth's crust in the range 2,500 to 1,50,000 tonnes each year. In addition, it is also contributed by industrial discharge in its production and use in making many gadgets, use of mercury in production of chlorine and sodium hydroxide etc. It exists in nature in mono and divalent salts, and as organomercury compounds, of which the important and most toxic compound is methylmercury. The microorganisms present in the aquatic sediments and sewage sludge convert the inorganic mercury to methylmercury, this process is of reverse nature. Fish and mammals absorb and retain methyl mercury to a greater extent than inorganic one.

In Japan, methyl mercury poisoning through consumption of methyl mercury contaminated fish and shell fish precipitated "Minamata disease" characterised by "madness, paralysis, loss of speech, vision and emotional control, crippling of limbs followed by wasting of muscle, coma and finally death. This disease had precipitated among 111 fishermen and their families living along the shore of Manamata Bay, who consumed methyl mercury contaminated fish and 44 people died during the years (1953-60). The affected individuals suffered from neurological symptoms and brain damage and many of the survivors were paralized for life. Infants born to women had mental retardness, spasticity, chronic seizures and blindness; but mothers had no symptoms

2.3 Arsenic

Arsenic in the environment is usually present in the form of compounds of sulphur and also with other metals like copper, cobalt, zinc and lead etc. Many of their compounds are water soluble. Inorganic arsenic in more toxic than organic form. Trivalent inorganic arsenic is more toxic than pentavalent. Acute poinsoning by arsenic involves the central nervous system leading to coma and death. Poisoning may appear with doses as low as 3-6 mg/day over extended period. Chronic poisoning is manifested by general muscular weakness, loss of appetite and nausea, leading to inflammation of the mucous membrane in the eye, nose, and larynx and rarely skin lesions may occur. Neurological manifestations and malignant tumors in the vital organs may also occur.

2.4 Cadmium

Cadmium is found in earth's crust in very trace amounts. It is produced during extraction of zinc and is used in plating industry, pigments, in manufacture of plastic materials, batteries and alloys. The water is contaminated with cadmium by industrial discharge, leaches from land filled area. Drinking water is generally contaminated with galvanized iron pipe, plated plumbing fitting of the water distribution pipes.

Workers exposed to cadmium fumes and dust have shown to have the adverse effect like bronchitis, emphysema, anaemia and renal stones. It is accumulated in kidney of human beings (WHO, 1971; USEPA, 1977). The symptoms of the poisoning are proteinuria, glucosuria, and aminoaciduria ((USEPA, 1980). In Japan cadmium from mining and refinery factories polluted Jinzo river water which was used for irrigation to raise the paddy crop. The rice grown on such irrigated fields absorbed cadmium which the humans consumed through water and food chain and caused ostomalacia and skeletal deformation. There was severe pain in body and joints and the people cried Itai-Itai.

2.5 Chromium

It occurs in earth's crust in small amounts. The contamination of water generally occurs due to industrial emission. Trivalent and hexavalent chromium occur in biological media, but only the trivalent form is stable, since hexavalent chromium is readily reduced by a variety of organic species. The major source of water contamination due to chromium is through industrial discharge by their use in making chrome alloys, chrome plating, chrome tanning of leather, oxidizing agent, corrosion inhibitor, manufacture of chromium compounds. There is a tendency for the higher levels of chromium to be associated with the water of greatest hardness.

The harmful effects in man are due to hexavalent chromium whereas trivalent is considered non toxic. Hexavalent chromium at 10 mg./kg. Body weight will result in liver necrosis, nephritis and death in man, lower dozes will cause irritation of the gastro-intestinal mucosa. High levels of hexavalent chromium causes intestinal and lung cancer in man. Industrial exposure of hexavalent chromium to skin can produce cutaneous and nasal mucous-membrane ulcers and dermatitis.

2.6 Lead

It is one of the natural constituents of earth's crust and exists in the form of galena (lead sulfide. In many places contamination of environment due to lead occurs as a result of mining and smelting processes used or from use of products made from it. Consequently it is present in air, water, soil dust, food and snow. It is used to manufacture of acid accumulators, alkyl lead compounds for gasoline, tetra ethyl lead as antiknock compound, solder, pigment, and paints, ammunition, caulking, cable sheathing, roofing material, piping, material, including for drinking water, in manufacture of sulfuric acid, lead arsenate, insecticide, rubber etc.

The lead reaches human system through air, water and food and exhibits toxicological symptoms when route to entry to body is through inhalation, skin absorption, ingestion through drinking water and food in higher concentrations. It has cumulative property in human system and exhibits some symptoms of acute poisoning like tiredness, lassitude, abdominal discomfort, irritability and behavioral changes (WHO, 1977). Lead at low levels can reduce the activity of enzyme to synthesise haemoglobin resulting in anaemia (WHO, 1977).

2.7 Copper

It occurs in the earth in free native state and in the form of its ores depending upon the geographical location, and proximity of industry. Copper is an essential element for body building and in enzyme activity. But excessive large doses may lead to mucosal irritation and corossion, widespread capillary damage, hapatic and renal damage and central nervous system (depression). Necrotic changes in the liver and kidney could occur. Excess of copper in water has unpleasant and astringent taste.

2.8 Nickel

Nickel in very small quantity is found in earth's crust. The river water may be contaminated by discharge of industrial waste containing nickel. Nickel may be essential to human nutrition and no systemic poisoning from nickel is known. But "Nickel itch" (nickel dermatitis) has been reported among industrial workers. Certain nickel compounds have carcinogenic effects on animals, however, soluble compounds are not currently regarded as human or animal carcinogens.

2.9 Zinc

It is found abundantly in earth's crust. The water resources may be contaminated with zinc through air and industrial waste. This may be contributed by water distribution system due to leaching of zinc from galvanized pipes.Zinc is essential element for body system for functioning of various enzyme systems. In Egypt endemic zinc deficiency syndrome among young men has been reported. This syndrome having characters of retarded growth, signs of immaturity and anaemia is probably caused by low intestinal absorption of zinc. Its complete cure was observed by administration of large dozes of zinc sulfate.Sympotms of zinc toxicity in humans include vomitting, dehydration, electrolyte imbalance, abdominal pain, nausea lethargyness, dizziness and lack of muscular coordination. Acute renal failure caused by zinc chloride has also been reported.

3.0 STUDY AREA

3.1 Physiography

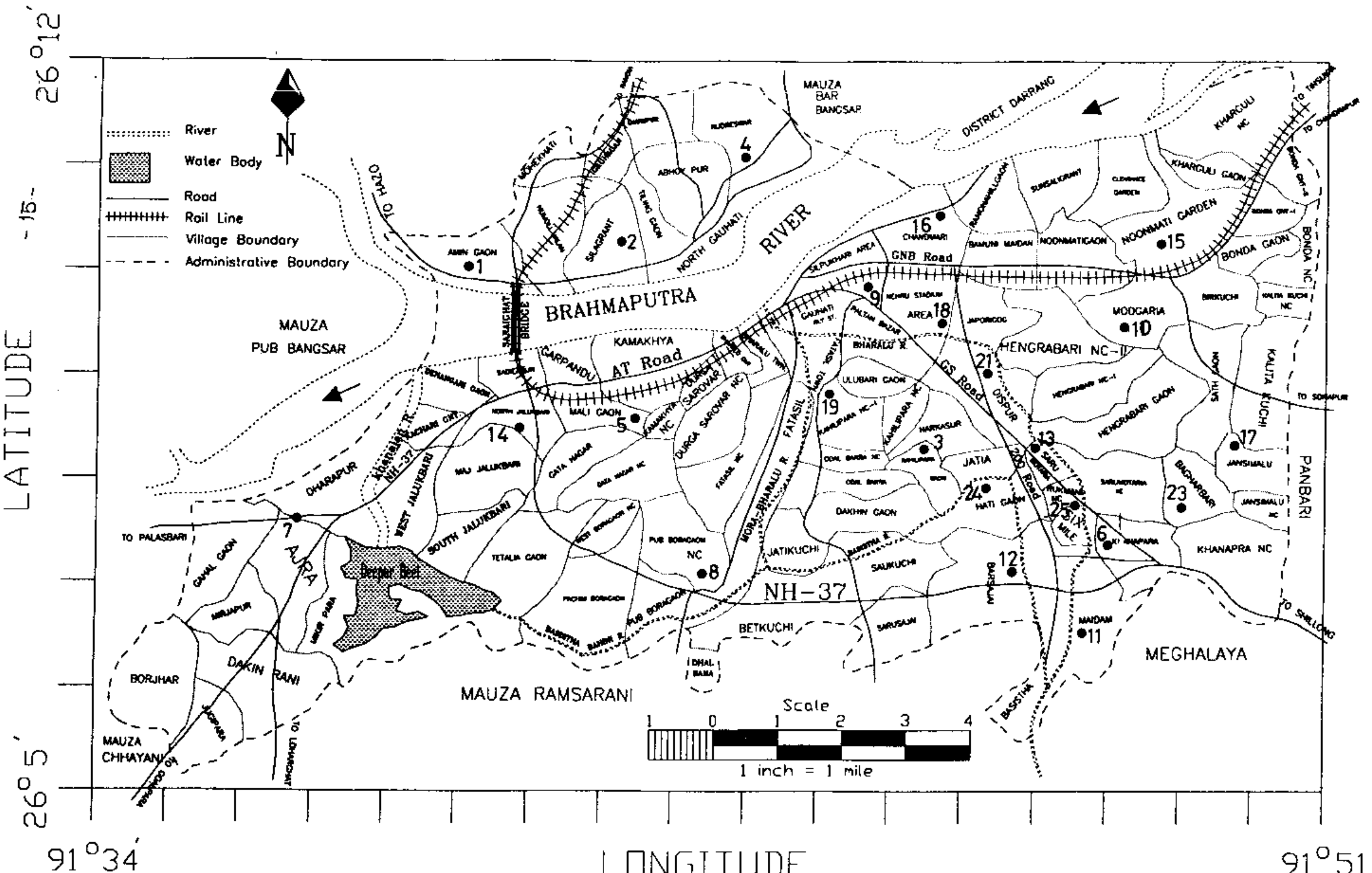
Guwahati, the ancient city of Pragjyotishpura, is bounded between 26° 7'-26°12' N latitude and 91° 40' - 91° 48' E longitude. The mighty Brahmaputra flows along the city's northern periphery. The southern and the eastern sides of the city are bounded by hills. The Jalukbari-Azara plain constitute the western boundary of the city.

3.2 Climate

Because of the uneven topography with built up area, marshy land and hills surrounding the valley giving it the shape of a bowl, the temperature distribution is not uniform on the surface throughout the year. Ground level inversion of temperature is a very common phenomenon in winter season. Low level thermal stratification is also observed in the bowl area. The distribution of rainfall in the city is not uniform. The rainy season extends from March to October. The average annual rainfall is 160 cm. The humidity in the city is very high and it does not go below 70%.

3.3 Drainage

There is no integrated grid for supply of water in the Master Plan of Guwahati. The piped drinking water supply is available to only 15% of its population, leaving the rest to fed themselves with tube wells, shallow wells, ponds etc. The city has no sewage disposal system. As a rough estimate, about 50% of the area is served by septic tanks discharging untreated effluent into cutting roadside drains that have become the breeding grounds of mosquitoes and flies, the other 50% being served by that abomination called the pit latrine. The streets and roads



• -SAMPLING SITE

FIG. 1: STUDY AREA AND SAMPLING LOCATIONS

are littered with garbage as the Guwahati Municipal Corporation does not have any effective system of garbage collection and disposal. Storm water drainage takes place through the Bharalu and Basistha rivers either directly or indirectly through the Dipar Beel and the Khana river to the Brahmaputra. In the North bank of the master plan area, the storm water discharge is either directly to the river Brahmaputra or via the Ghorajan river. However, due to rapid growth of the city and obstructions to the drainage channels by illegal occupation and construction activities, the existing capacity of the natural channels are found to be inadequate to carry the storm water and other surface runoff during the monsoon months.

3.4 Land Use

The master plan area of Guwahati covers about 262 km² of which nearly 62% is usable land. The unusable land consists of hills, water bodies and low-lying areas. A large amount of land is also used for transport and communication. The extremely small amount of land for parks and recreation is very conspicuous. There has been a steady increase in land utilized for residential, commercial and industrial purposes.

3.5 Pollution Sources

A large number of small, medium and large industries are located within the master plan area of Guwahati. According to 1991 census there were 669 industrial units, of which 19.73% were engaged in various metal products, 17.34% in chemicals, 15.40%, in paper products and printing, 11.5% in repair and servicing, 9.72% in wood products and 6.58% in food products. Only 43 units were located inside the industrial estate, while all the others were scattered all over the city. The growth of industries can be termed as environmentally unsafe. Some of the large and medium scale industries in the city include:

- Thermal Power Station, Fertichem Ltd. and NTC's Spun Mill at Chandrapur.
- Statefed Vanaspati Plant, Kamrup Paper Mills, Assam Ispat Limited, Chemical Units and Assam Caffeine Industry at Amingaon.
- Dye House and Nezone Tubes Limited at Pub-Boragaon.
- Assam Carbon Products Limited at Birkuchi (eastern part of the city).
- Indian Oxygen Limited's Plant, Jalan Industrial Corporation, G. L. Industries, Jalan Iron and Steel Company and Guwahati Roller Flour Mill at G. S. Road.
- Brahmaputra Jute Mill at Kalapahar Area.
- Assam Asbestos Limited at Narengi.

Besides these, a number of large printing presses, hospitals, nursing homes, big hotels, saw mills, soap factory, dairy industry etc. are located in various parts of the city.

4.0 EXPERIMENTAL METHODOLOGY

4.1 Sampling and Preservation

The ground water samples were collected in polyethylene bottles during 1994 and 1995 by dip or grab sampling method using standard water sampler (Hydro-Bios, Germany). The water samples collected were stored in acid leached polyethylene bottles and preserved by adding ultra pure nitric acid (5 mL/lit.) (APHA, 1985; Jain and Bhatia, 1987).

4.2 Chemicals and Reagents

All chemicals used in the study were of analytical reagent grade (Merck/BDH). Standard solutions of metal ions were procured from Merck, Germany. De-ionized water was used throughout the study. All glassware and other containers were thoroughly cleaned by soaking in detergent followed by soaking in 10% nitric acid for 48 h and finally rinsed with de-ionized water several times prior to use.

4.3 Metal Ion Analysis

Metal ion concentrations were determined by flame atomic absorption spectrometry using Perkin-Elmer Atomic Absorption Spectrometer (Model 3110) using air-acetylene flame. Operational conditions were adjusted in accordance with the manufacturer's guidelines to yield optimal determination. Quantification of metals was based upon calibration curves of standard solutions of respective metals. These calibration curves were determined several times during the period of analysis. The detection limits for various elements are 0.001, 0.006, 0.0005, 0.003, 0.0008 and 0.01 for copper, cobalt, cadmium, iron, zinc and lead respectively.

5.0 RESULTS AND DISCUSSION

The intensive use of natural resources and the large production of wastes in modern society often pose a threat to groundwater quality and have already resulted in many incidents of ground water contamination. Among all the uses of water, domestic use of water has prime importance. In domestic use water is required for essential daily routine works like drinking, cooking, washing, bathing etc.

The quality of ground water depends on a large number of individual hydrological, physical, chemical and biological factors. Generally higher proportion of dissolved constituents are found in ground water then in surface water because of greater interaction of ground water with various materials in geologic strata. The water used for drinking purpose should be free from any toxic elements, living and nonliving organism and excessive amount of minerals that may be hazardous to health. Some of the heavy metals are extremely essential to humans, for example, cobalt, copper, etc., but large quantities of them may cause physiological disorders (Trivedy and Goel, 1986). Therefore it is necessary to know the trace element characteristics of the water bodies before use.

The major sources of trace elements in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. These elements in ground water may be present as complexes of inorganic and organic ligands, adsorbed onto suspended matter and as simple hydrated ions. The extent to which a trace element is present as simple hydrated ion depend upon several factors, viz., the nature of the ion, the Eh and pH of the aqueous system, nature and content of suspended matter, presence of other dissolved species etc. Dissolved carbon dioxide, pH and Eh of water affects the nature of aqueous ion species present in the water. The toxicity of heavy metals in water is affected by pH, hardness, alkalinity and organic materials. Higher levels of hardness, pH and alkalinity tend to reduce toxicity of metals in water (Train, 1979).

Ground water is an essential source of drinking water in Greater Guwahati. The physico-chemical characteristics of the ground water of Greater Guwahati has been discussed in an earlier report (Kumar et al., 1995) The trace element data of ground water samples collected during 1994 and 1995 from Greater Guwahati is presented in Table 1(a to d). The toxic effects of these elements and extent of their contamination in ground water is discussed in this chapter.

Copper (Cu)

Copper occurs in the earth in free native state and in the form of its ores depending upon the geographical location and proximity of industry. It is an essential element for human body. But excessive large doses may lead to mucosal irritation and corrosion, widespread capillary damage, hapatic and renal damage and central nervous system (depression).

Copper is commonly found in drinking water. Low levels (generally below 20 μg/L) can derive from rock weathering. Some industrial contamination also occurs, but the principal sources in water supplies are corrosion of brass and copper pipe and addition of copper salts during water treatment for algae control. The concentrations of copper found in natural waters are not known to have adverse effects on humans, though copper in excess of 1.0 mg/L may impart some taste to water (Train, 1979). The toxicity of copper to aquatic life is dependent on the alkalinity of the water. At lower alkalinity, copper is generally more toxic to aquatic life.

Table 1(a). Trace element data of ground water samples of Greater Guwahati (July 1994)

S.No.	Location	Concentration in mg/L					
		Cu	Co	Cd	Fe	Zn	Pb
1	Amingaon	ND	ND	ND	1.07	0.20	0.01
2	Dol Govinda	ND	ND	ND	0.96	0.20	0.01
3	Khalipara	0.01	ND	ND	0.16	0.08	ND
4	Durgeshwari	0.01	0.03	ND	1.15	0.05	ND
5	Maligaon	ND	ND	ND	1.30	0.02	0.01
6	Khanapara	0.03	0.01	ND	0.05	0.11	ND
7	Ajra	ND	ND	ND	0.25	0.11	ND
8	Boragaon	0.01	0.05	ND	2.59	0.05	0.04
9	Poltan Bazar	ND	0.01	ND	0.07	0.04	ND
10	Zoo Narangi	ND	0.01	ND	0.04	0.21	ND
11	Nutan Bazar	0.01	0.01	ND	0.16	0.02	0.03
12	Barsajai	ND	ND	ND	0.40	0.04	ND
13	Rukmanigaon	ND	ND	ND	0.30	0.01	0.01
14	Jalukbari	0.01	0.01	ND	0.69	0.05	0.01
15	Noonmati	ND	ND	ND	0.14	0.12	ND
16	Chandmari	ND	0.03	ND	0.35	0.06	0.01
17	Punjabari	0.01	0.01	ND	0.45	0.15	0.01
18	Lachit Nagar	0.01	0.03	ND	0.75	0.18	0.03
19	Bhangagarh	0.01	0.01	ND	0.32	0.02	0.04
20	Hatigarh	ND	ND	ND	0.01	0.01	0.03
21	Usha Nagar	ND	ND	ND	0.45	0.02	0.04
22	NIH Plot	ND	0.01	ND	0.03	0.04	0.02
23	Mathura Nagar	ND	0.01	ND	1.49	0.02	0.03
24	Hathigaon	...	...	...	...	...	...
25	Rukmani Nagar	...	...	...	...	...	...

ND - Not detected
... Data not available

Table 1(b). Trace element data of ground water samples of Greater Guwahati (December 1994)

S.No.	Location	Concentration in mg/L					
		Cu	Co	Cd	Fe	Zn	Pb
1	Amingaon	...	...	...	...	...	...
2	Dol Govinda	ND	ND	ND	2.02	0.03	0.04
3	Khalipara	ND	0.03	ND	0.44	0.01	ND
4	Durgeshwari	ND	0.08	ND	1.8	0.01	0.07
5	Maligaon	ND	0.01	ND	2.02	0.04	ND
6	Khanapara	0.01	0.01	ND	0.05	0.03	0.03
7	Ajra	ND	ND	ND	0.3	0.01	0.05
8	Boragaon	0.01	0.05	ND	3.02	0.02	0.04
9	Poltan Bazar	ND	0.01	ND	0.13	0.02	0.03
10	Zoo Narangi	0.01	ND	ND	0.22	0.02	0.03
11	Nutan Bazar	ND	ND	ND	0.28	0.27	0.01
12	Barsajai	ND	ND	ND	0.50	0.10	ND
13	Rukmanigaon	ND	0.06	ND	1.23	0.69	0.01
14	Jalukbari	...	...	...	...	...	...
15	Noonmati	ND	0.04	ND	0.41	0.06	0.01
16	Chandmari	0.01	0.05	ND	0.55	0.15	0.02
17	Punjabari	0.01	0.08	ND	1.13	0.16	0.01
18	Lachit Nagar	0.01	ND	ND	2.09	0.04	0.03
19	Bhangagarh	0.01	ND	ND	0.54	0.13	0.01
20	Hatigarh	...	...	...	...	...	...
21	Usha Nagar	0.01	0.01	ND	0.70	0.05	0.05
22	NIH Plot	ND	ND	ND	0.07	0.05	0.05
23	Mathura Nagar	0.01	0.07	ND	2.02	0.16	0.01
24	Hathigaon	0.01	0.06	ND	0.34	0.55	0.04
25	Rukmani Nagar	0.01	0.06	ND	0.68	0.07	ND

ND - Not detected
... Data not available

Table 1(c). Trace element data of ground water samples of Greater Guwahati (April 1995)

S.No.	Location	Concentration In mg/L					
		Cu	Co	Cd	Fe	Zn	Pb
1	Amingaon	...	...	...	...	...	...
2	Dol Govinda	0.01	0.05	ND	2.48	0.23	ND
3	Khalipara	ND	0.04	ND	0.68	0.05	ND
4	Durgeshwari	ND	0.05	ND	2.03	0.19	ND
5	Maligaon	ND	0.03	ND	2.02	0.07	ND
6	Khanapara	0.04	0.06	ND	0.12	0.10	ND
7	Ajra	ND	0.03	ND	0.4	ND	ND
8	Boragaon	ND	0.14	ND	3.58	0.36	ND
9	Poltan Bazar	ND	ND	ND	0.24	0.08	0.05
10	Zoo Narangi	0.01	0.01	ND	0.31	0.13	0.10
11	Nutan Bazar	...	...	...	...	...	...
12	Barsajai	...	...	...	...	...	...
13	Rukmanigaon	ND	0.03	ND	1.45	0.78	ND
14	Jalukbari	...	...	...	...	...	...
15	Noonmati	0.02	0.06	ND	0.60	0.14	0.02
16	Chandmari	ND	0.03	ND	0.74	0.07	ND
17	Punjabari	0.01	0.02	ND	1.41	0.04	ND
18	Lachit Nagar	0.01	ND	ND	2.12	0.24	0.05
19	Bhangagarh	0.01	0.04	ND	0.71	0.05	0.07
20	Hatigarh	...	...	...	...	...	...
21	Usha Nagar	ND	0.05	ND	0.87	0.14	ND
22	NIH Plot	0.01	0.05	ND	0.08	0.19	ND
23	Mathura Nagar	...	...	...	...	...	...
24	Hathigaon	0.01	ND	ND	0.56	0.04	ND
25	Rukmani Nagar	ND	0.04	ND	0.82	0.08	ND

ND - Not detected
... Data not available

Table 1(d). Trace element data of ground water samples of Greater Guwahati (November 1995)

S.No.	Location	Concentration in mg/L					
		Cu	Co	Cd	Fe	Zn	Pb
1	Amingaon	...	...	...	...	...	...
2	Dol Govinda	ND	0.02	ND	2.41	0.2	ND
3	Khalipara	ND	0.03	ND	0.58	0.06	ND
4	Durgeshwari	ND	0.04	ND	2.34	0.08	ND
5	Maligaon	ND	0.01	ND	1.92	0.16	ND
6	Khanapara	0.02	0.03	ND	0.23	0.07	ND
7	Ajra	ND	0.01	ND	0.53	0.08	ND
8	Boragaon	ND	0.06	ND	3.50	0.06	ND
9	Poltan Bazar	ND	ND	ND	0.5	0.17	0.04
10	Zoo Narangi	ND	ND	ND	0.41	0.11	0.03
11	Nutan Bazar	ND	ND	ND	0.48	0.02	0.06
12	Barsajai	ND	ND	ND	0.76	0.13	ND
13	Rukmanigaon	...	...	...	...	...	...
14	Jalukbari	...	...	...	...	...	...
15	Noonmati	ND	0.04	ND	1.50	0.28	0.01
16	Chandmari	ND	0.03	ND	0.86	0.08	ND
17	Punjabari	0.01	0.02	ND	1.18	0.07	ND
18	Lachit Nagar	0.01	ND	ND	2.67	0.03	0.05
19	Bhangagarh	0.01	0.01	ND	0.81	0.12	0.01
20	Hatigarh	...	...	...	...	...	...
21	Usha Nagar	ND	0.02	ND	0.92	0.13	ND
22	NIH Plot	ND	0.02	ND	0.08	0.10	ND
23	Mathura Nagar	ND	0.03	ND	2.18	0.06	0.01
24	Hathigaon	ND	ND	ND	0.82	0.17	ND
25	Rukmani Nagar	ND	0.03	ND	0.8	0.12	ND

ND - Not detected
... Data not available

Copper in public water supplies enhances corrosion of aluminium and zinc utensils and fittings and when present in excess of 1.0 mg/L, it imparts an undesirable taste to drinking water and hence a guideline value of 1.0 mg/L is recommended. Staining of laundry and plumbing fixtures also occur when copper concentration in water exceed 1.0 mg/L (WHO, 1984). High intake of copper may results in damage to liver. The sources of copper that enhance the concentration in ground water include industrial effluents from electroplating units, textiles, paints and pesticides.

The concentration of copper recorded a maximum level of 0.04 mg/L in ground water of Greater Guwahati. At most of the places the content of copper were below the detection limit (0.001 mg/L) of the equipment. As such the ground water of Greater Guwahati can be safely used as a source of drinking water supplies.

Cobalt (Co)

Cobalt seldom found in natural waters, it is often present in industrial waste water as a corrosion product of stainless steel, nickel or cobalt, and from metal plating baths. It is also used as alloys in metal electroplating, in glass, porcelain, and enamels. Cobalt is considered to be relatively nontoxic to man. The toxicity of cobalt to aquatic life indicates that tolerances vary widely and are influenced by species, pH, synergetic effects and other factors.

Cobalt is an essential heavy metal to human but large quantity of this metal may cause physiological disorder. Concentration higher than 1 mg/kg of body weight may be considered a health hazard to humans. Since the concentration of cobalt as related to the potential toxicity in water is negligible, Health Authorities have not issued maximum contaminant levels with the exception of U.S.S.R. – 1 mg/L. In the study area concentration of cobalt varied from 0.01 to 0.08 mg/L and in this range it is not harmful for living organisms. At various locations the concentration of cobalt was found even below the detection limit (0.006 mg/L) of the equipment.

Cadmium (Cd)

Cadmium is found in earth's crust in very trace amounts. It is produced during extraction of zinc and is used in plating industry, pigments, in manufacture of plastic materials, batteries and alloys. Cadmium is biologically a non-essential, non-beneficial element known to have a high toxic potential (Train, 1979). It has cumulative and highly toxic effects on man. Acute effects have been reported with cadmium poisoning. Kobayashi (1970) reported an out-break of the bone disease "Itai-Itai" in Japan, due to high exposure of cadmium. Cadmium is virtually absent from the human body at birth and accumulates with age (upto about 50 years); the average body burden of cadmium at 50 years being 20-50 mg of cadmium.

Cadmium enters the environment from a variety of industrial applications, including mining and smelting, electroplating, and pigment and plasticizer production. The water is contaminated with cadmium by industrial discharges and leaches from land filled areas. Drinking water is generally contaminated with galvanized iron pipe and plated plumbing fittings of the water distribution system. USEPA has classified cadmium as a probable human carcinogen based on positive carcinogenicity testing.

Workers exposed to cadmium fumes and dust have shown to have the adverse effect like bronchitis, emphysema, anaemia and renal stones (NRC, 1977). It is accumulated in kidney of human beings (WHO, 1971). The symptoms of the poisoning are proteinuria, glucosuria and aminoaciduria (USEPA, 1980). In Japan cadmium from mining and refinery polluted Jinzo river water that was used for irrigation to raise the paddy crop. The rice grown on such irrigated fields absorbed cadmium which the humans consumed through water and food chain and caused ostomalacia and skeletal deformation. There was severe pain in body and joints and the people cried Itai-Itai.

Concentrations of the order of 1 μg/L or less are normally found in drinking water (WHO, 1984). The levels of cadmium in public water supplies are normally very low since generally only small amounts exist in raw water and many conventional water treatment processes remove much of the cadmium. The drinking water having more than 1 μg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals.

In ground water of Greater Guwahati all the values of cadmium concentrations were found below the detection limit (0.0005 mg/L) of the equipment. It is obvious, therefore, that the ground water of the region does not present any cadmium hazards to humans.

Iron (Fe)

Normal adult man contain 4-5 g iron, which exists in complex forms bound to proteins either as porphyrin or heme compounds, particularly hemoglobin and myoglobin or as nonheme protein bound compounds such as ferritin and transferrin. The recommended dietary allowance for iron is quite high (10-18 mg/day)

The weathering of rock and discharge of waste effluents on land are the main source of iron in ground water. Iron migrates as adsorbed to suspended matter, insoluble hydrated iron compounds, complexed to inorganic and organic ligands and also as hydrated ions. Dissolved carbon dioxide, pH and Eh of water affects the nature of aqueous iron species present in the water.

Limits in water supplies for potable use have not been laid down from health consideration but due to the fact that iron in water supplies may cause discoloration of clothes, plumbing fixtures and porcelain wares. The "red rot" disease of water caused by bacterial precipitation of hydrated oxides of ferric iron with consequent unaesthetic appearance to water, clogging of pipes, pitting of pipes and occurrence of foul smells, is due to the presence of relatively high iron in water. Iron in concentrations exceeding 1 mg/L also causes astringent taste to water.

The concentration of iron in ground water of the study area ranges from 0.01 to 3.58 mg/L. High concentrations of iron at various places causes inky flavour, bitter and astringent taste. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. Studies on the iron content of the ground water in Greater Guwahati have shown that dug wells contain very high iron content. Mehta et al. (1994) also reported high concentration of iron in ground water of Bhubaneshwar City, which poses a serious problem in water supplies from borewells.

Zinc (Zn)

Zinc is an essential element for both animals and man and is necessary for the functioning of various enzyme systems, deficiency of which leads to growth retardation. Low intake of zinc results in retardation of growth, immaturity and anemia, condition known as 'zinc deficiency syndrome'. Symptoms of zinc toxicity in humans include vomiting, dehydration, electrolyte imbalance, abdominal pain, nausea lethargyness, dizziness and lack of muscular coordination.

Zinc imparts undesirable, bitter astringent taste to water at levels above 5.0 mg/L (WHO, 1984). Water containing zinc at concentrations in excess of 5.0 mg/L may appear opalescent and develop a greasy film on boiling. Toxic concentrations of zinc above recommended value causes adverse effect in the morphology of fish by inducing cellular breakdown of gills. Zinc deficiency in human body may result in infantilism, impaired wound healing and several other diseases.

Pollution from industrial and agricultural sources to a great extent is responsible for high concentration of zinc in ground water. The concentration of zinc in the study area ranges from 0.01 to 0.78 mg/L. Since the recommendations for domestic water supplies are 5 mg/L (ISI, 1991; WHO, 1984; Train, 1979), the levels of zinc in the ground water of Greater Guwahati are safe enough for drinking and other domestic purposes. Gupta et al. (1981) and Handa (1992) have reported zinc contamination in ground water of Udaipur. High zinc concentrations were also observed in ground water of Modinagar-Ghaziabad area due to seepage of industrial waste effluents.

Lead (Pb)

Lead is one of the natural constituents of earth's crust. It is used in the manufacture of acid accumulators, alkyl lead compounds for gasoline, tetra ethyl lead as antiknock compound, solder, pigment and paints, roofing material, piping material including for drinking water, in manufacture of sulfuric acid, lead arsenate, insecticide, rubber etc.

The exposure of lead occurs through air, soil, dust, paint, food and drinking water. It exhibits toxicological symptoms when route of entry to body is through inhalation, skin absorption, and ingestion through drinking water and food in higher concentrations. It has cumulative property in human system and exhibits some symptoms of acute poisoning like tiredness, lassitude, abdominal discomfort, irritability, anaemia, and behavioral changes (WHO, 1977). Lead at low levels can reduce the activity of enzyme to synthesize haemoglobin resulting in anaemia (WHO, 1977).

Among cumulative metal contaminants, lead represents an exclusive case because of its ubiquitous presence in the environment. Lead poisoning has been recognized as an occupational illness for centuries, and it is linked with both severe and subtle health damages (Cohen, 1973; Goyer, 1990). Lead has been found to induce adverse health effects at lower and lower levels of exposure (Davis, 1990). Higher concentration of lead in drinking water has adverse effect on central nervous system, blood cell and may cause brain damage. The permissible limit for lead in drinking water is 0.05 mg/L (ISI, 1991).

Lead is not a natural contaminant in surface waters or ground waters and is rarely found in source water. It occurs in drinking water primarily from corrosion of lead pipes and solders, especially in areas of soft water. Since dissolution of lead requires an extended contact time, lead is most likely to be present in tap water after being in the service connection piping and plumbing overnight.

Health effects of lead are generally correlated with blood test levels. Infants and young children absorb ingested lead more readily than do older children and young adults. Lead exposure across a broad range of blood lead level is associated with a continuum of physiological effects, including interference with heme synthesis necessary for formation of red blood cells, anemia, kidney damage, impaired reproductive function, interference with vitamin D metabolism, impaired cognitive performance, delayed neurological and physical development, and elevations in blood pressure.

The lead content in the study area ranged between 0.01 to 0.05 mg/L. At such levels no lead toxicity problems are to be expected from these waters. The lead guidelines for the drinking water supply (ISI, 1991; Train, 1979; WHO, 1984) are well within the prescribed limit for drinking water and therefore the ground water of Greater Guwahati can be safely used as a source of drinking water supplies.

6.0 CONCLUSIONS

Planning and implementation of ground water supply programme demands data pertaining to phisico-chemical characteristics of water. A system of continuous monitoring of ground water supply programme is necessary to assess the effectiveness of various water supply schemes of the entire area. Time series data is necessary for monitoring the quality of safe drinking water to protect it from possible sources of contamination.

The trace element analysis of ground water samples has revealed that the concentration of iron in ground water is much higher than the tolerance limit prescribed for drinking water which is responsible for the inky flavour, bitter and astringent taste to the ground water of the region. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity in the water. An understanding of the redox potential and pH conditions in the aquifer water as well as aquifer composition can help in locating the potential source of low iron water in confined and semi confined aq uifers, where conditions may be reducing. The optimum water quality may be best achieved by careful evaluation of accessible low iron ground water resource prior to the installation of wells and pumps. If alternate source of low iron water is not available the wells may be fitted with corrosion resistant pumps and pipes. Alternatively, iron removal plants may be installed.

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