CS/AR-26/1997-98

GROUNDWATER QUALITY MONITORING AND EVALUATION IN AND AROUND GREATER GUWAHATI (ASSAM)

PART - III : TRACE ELEMENTS

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ABSTRACT

Toxicity of a metal depends on its concentration, which adversely affects any biological activity. Almost all the metals are toxic at higher concentration; few of them are toxic in low quantity but few others are toxic even in trace e.g. As, Pb, Hg, Cd etc. The presence of such metals in groundwater is a subject of serious concern. Groundwater which contains higher amount of metals and large or trace quantity of toxic metals, affects public health to a great extent when it is used for drinking and domestic purposes. The impact of trace elements in drinking water is generally cumulative, by which the prolonged use of such waters is dangerous for health. Hence the measurement of trace elements concentration and analysis of their periodicity of fluctuation and trend is necessary.

The present work deals with the detection of trace elements viz. Pb, Cu, Co, Cd, Zn, Fe, Mn and Ni in ground water of Guwahati and its adjacent areas. In the present study, ground water samples were collected from 29 dug wells using grid network pattern and quality was compared with the standards laid by WHO, Bureau of Indian Standards (BIS) and Indian Council of Medical Research (ICMR) with respect to trace elements content in the ground water. Study revealed that the concentrations of Fe, Zn, Cd and Mn crossed the maximum permissible limits of WHO in most of the sites and are in alarming condition. Lead (Pb) was found absent from all the sampling sites, while concentration of Cu, Co and Ni are well within the maximum permissible limit of WHO. The maximum concentration of Cu, Co, Cd, Zn, Fe, Mn and Ni were recorded as 0.018, 0.101, 0.015, 24.175, 4.805, 7.325 and 0.330 respectively. By taking the advantage of equal grid network pattern of sampling for different sites, thematic maps have also been prepared. ORP and pH were also measured to see the stability field of iron in pH-ORP diagram.

1.0 INTRODUCTION

The environmental pollution is caused by a variety of pollutants in water, air and land. One of the pollutants of major concern in living environment is the "Hazardous Metal" also termed "Trace Elements". Trace elements is used in the geochemical and biochemical literature to refer to a group of otherwise unrelated chemical elements that occur in nature at low concentrations. Their concentrations in different natural environments vary widely.

Mining processes, discharge of industrial effluents containing metallic solutions, dumping of solid wastes which contain metal salts and some agricultural practices such as the use of mercury based biocides introduce toxic metals to water. Battery manufacturing industries, paint manufacturing industries, electroplating industries, viscose-rayon manufacturing industries, copper picking industries and galvanizing and rubber processing industries are some of the important industries the effluents of which contain considerable amounts of heavy metals. The primary metals considered to be toxic are lead, arsenic, copper, cadmium, mercury, and nickel.

Contaminations of ground water with toxic metals prevent the further use of the water for industrial purposes and drinking purposes. Arsenic and lead particularly make the water dangerous to drink. These toxic materials are reported to cause chromosome damage and thus interfere with the process of heredity. In human beings, a concentration of 80 micrograms of arsenic per 100 grams of blood causes poisoning in adults. It is also reported that lead above the level of 40 micrograms per 100 grams of blood cause brain damage to children. Small increases in mercury levels are reported to cause damage to the growth of aquatic algae. Copper in about 2 parts per hundred million parts of water is fatal to sticklebacks. the lethal concentration of nickel, lead and zinc is about 1 ppm.

In many fresh water bodies, such as some lakes, ponds or rivers and ground water resources, due to geochemical origin, heavy metal content may be higher than in others. This arises from the gradual solubilization of the heavy metals from the soil, which could be rich in these metals, and this process is aided by active pH values. Air pollutants such as particles setting on water, acid rain dissolving metallic dusts and run off from polluted soil could also contribute to heavy metal load of water. The use of phosphate fertilizers on land has been shown to enhance leaching of cadmium from soil, which reaches the ground waters. However, the major bulk of the heavy metals reach water through domestic and industrial effluents.

Mining and mineral processing industries including foundries, electroplating, chemical laboratories, chemical industry using metal casting, solid waste dumps, chemical accidents, transport of ores, metal catalyst in industry, corrosion of pipes and joints, metal salts used in pest control are the sources for heavy metals reaching water bodies, depending on the pH and quality of water and soil. The metal can be bound to soil or humus in the sediment, they can be precipitated as hydroxides, they may exist as on pairs, colloidal suspensions or suspended particles or may get absorbed on or absorbed by biota. Valency changes also take place and an equilibrium may exist between sediment and water regarding partition of metallic species.

A wide variety of pollutants - physical, chemical, biological and radiological have been identified in the environment consequent to urbanization industrialization and new technological developments. Heavy metals though naturally occurring can be present in some areas in sufficient concentrations and physico-chemical forms that might create pollution problems. Sources of pollution of trace metals Hg, Pb, Cd, As, Cr, Zn, Cu, Mn and Fe are mainly aquatic releases from industrial operations, atmospheric releases from fossil fuel burning, domestic sewage discharges and land run-off. These elements exhibit varying environmental behavior and toxicity to aquatic organism and man. The background levels of some of the trace metal very widely depending upon the location. Several fold increase in the concentrations of Zn, Cd, Hg etc., have been observed in some rivers and ground waters in the country. For evaluation of impact of heavy metal in aquatic environmental further investigations are needed.

In addition of the wastes discharged into the waterways, pollution of the aquatic environments originate from atmospheric inputs, land drainage and run off and seepage through land as in the case of ground water.

Among the metals present in higher quantity, the most problematic are mercury, lead, cadmium, arsenic, chromium, copper, zinc, sodium, manganese, iron, potassium, calcium, tin, etc. Sometimes a very small concentration (or lack thereof) of a minor constituent may be of great importance to human health and to plant nutrition. After it was discovered in the 1930s that fluoride in drinking water could aid in preventing tooth decay, fluoride determination became routine in analyses of water for public supply. Very pure water supplies that lack even a trace of iodine have led to thyroid problems and the development of goiters. It is interesting that although trace elements are essential, just a little more than the required amount of some elements is toxic, inhibiting growth or in extreme cases even causing death. Zinc in trace amounts stimulates growth in many plants, but in larger amounts zinc poisons the soil to such an extend that plants won't grow at all. Boron is an essential trace element for all plants, but when it is present in irrigation after in concentration of as little as 1ppm it inhibits the formation of fruit on orange and lemon trees. Similar examples could be cited for other essential elements.

On the other hand, some trace elements in water are apparently not only essential for living organisms, they may be quit harmful even in very small amounts. Lithium is an element seldom determined in routine irrigation water analyses, but research in California has shown that as little as 0.05-0.10 ppm of lithium in irrigation water can be toxic to citrus and avocado trees and to red kidney beans.

High concentrations of inorganic trace elements in irrigated soils and shallow ground water pose a threat to agricultural production and the health of humans and animals. They do so in three ways: 1) Trace elements can accumulate in plants to levels that cause phytotoxicity; 2) trace elements in plants can adversely affect humans and animals that consume those plants; and 3) trace elements can migrate with seepage through the root zone and into ground water, possibly re-emerging with subsurface drainage in surface waters, thereby affecting wildlife, or with ground water pumped for domestic use, thereby threatening the health of humans.

Many trace elements are biologically beneficial at very low concentrations, but become toxic or otherwise detrimental to the health of organisms and plants at low to moderate concentrations. Long-term exposure at sublethal concentrations to certain trace elements may result in chronic biological effects. Some trace elements can accumulate to potentially harmful levels in soils and sediment through chemical immobilization, in plants through bioconcentration, or via a food chain through biomagnification.

The quality of ground water depends on number of individual hydrological, physical, chemical, geological and biological factors. The objective of the present study is to assess the ground water quality in and around Greater Guwahati area in Kamrup district of Assam state and to discuss suitability of it for human health with special reference to trace elements content. With the rapid increase of environmental pollution, it has become absolutely necessary to ascertain the potability of water before use for human consumption. Water is one of the major carrier of several diseases of both chemical and trace elements origin. Hence careful assessment of physico-chemical and trace elements quality of water has attracted considerable attention in the last few years.

2.0 REVIEW

Heavy metal contribute to a very serious type of pollution in fresh water because they are stable compounds and are not readily removed by oxidation, precipitation or other means and effects the activity of the animals (Costa, 1965). In recent years heavy metal pollution has been increased in fresh water because of indiscriminate discharge of industrial wastes into them. Occurrence of copper and zinc in industrial discharge and their toxic effect has been well documented (Shaw and brown, 1974; Pickering et al., 1977). The widespread use of copper salts for vegetation control and their subsequent introduction into water bodies is becoming a lethal factor for various aquatic organisms (Ramamurthi et al., 1982; Murthi and Shukla, 1984 and Sambasiva Rao, 1984).

2.1 Metal Toxicity

Toxicity of some of the selected metals encountered in water is being described here :

Toxicity of Arsenic

Acute poisoning by arsenic involves the central nervous system leading to coma and for doses of 70-180 mg/L to death. Arsenic in the environment is usually present in the from of compounds of sulphur and also with other metals like copper, cobalt, Zinc and lead etc. (Commission of European communities, 1979). Many of their compounds are water-soluble and thus contamination of water can occur. Marine fish contains higher level of arsenic. Shellfish contains more than 50mg/kg.

Inorganic arsenic is more toxic than organic. Trivalent inorganic arsenic is more toxic than pentavalent. 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 tumours in the vital organs may also occur (Anonymous, 1980).

Arsenates are known to simulate plant growth, however excessive amount of arsenic in irrigation water reduces the yield of crops. Arsenic toxicity has been observed in plants growing on soil treated with arsenic insecticides.

This heavy metal is also quite toxic and reaches water bodies from the wastewaters of tanneries, ceramic industry, chemises and indiscriminate use of certain insecticides such as lead arsenate.

Effluents discharged from fertilizer factories are also reported to contain traces of arsenic. Coal and petroleum on burning may also yield some arsenic in their fumes.

Excessive use of arsenic insecticides may indirectly cause iron deficiency in plants. In animals and man arsenic reduces the appetite and body weight and causes stomach and skin disorders.

Arsenic is present in the soil usually in the pentavalent form whereas the pollutant arsenic introduced into the environment is in the trivalent form. Arsenic due to its high toxicity is used as insecticide or weedicide, generally in the form of trioxides. Trivalent and pentavalent forms are used in the treatment of parasitic diseases. Arsenic is a carcinogen, affects liver and heart, causes arsenosis. Inhibition in respiration is caused even before any external symptoms are observed.

Toxicity of Cadmium

Drinking water normally contains very low concentrations of cadmium. Most food stuffs contain traces of cadmium. Acute effects have been seen where food has been contaminated by cadmium from plated vessels, severe gastrointestinal upsets have been reported.

Cadmium ranks next to mercury in its toxicity. The principal contributor of cadmium is electroplating industry. Cadmium tends to concentrate in the liver, kidneys, and thyroid of human beings and animals. Once it enters the body, it is likely to remain.

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 material, 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, anemia and renal stones. 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 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 ostomolacia and skeletal deformation. There was sever pain in body and joints and the people cried ITAI-ITAI (Ouch-Ouch).

In India zinc smelters in Rajasthan and Kerala also produce some quantities of cadmium. There are reports of cadmium occurrence in river waters in different parts of the world in the wide range of 1 to 100 mg Cd per kg of sample. In sea water its concentration is on an average 0.15mg/L. A guideline value of 0.005mg/L of cadmium is recommended. The prevalence of hypertension has been correlated with renal Cd in various geographic areas of the world (Schroedre et al., 1973). Environmental cadmium is implicated in human hypertension and cardiovascular problems. Total cadmium in cigarette smoke varies from 15 to 18 ug per 20 cigarettes; this represents about 70% of the cadmium content of cigarette tobacco.

Toxicity of Chromium

Chromium is absorbed through both the gastrointestinal and respiratory tracts, the amount absorbed differs in each system and depends on the form of chromium. Chromium appears to be necessary for glucose and lipid metabolism and for utilization of amino acids in several systems. It also appears to be important in the prevention of mild diabetes and atherosclerosis in humans.

It occurs in earth's crust in small amounts; contamination of water may be due to industrial emission. Trivalent and hexaveient chromium occur in biological media, but only the trivalent form is stable. Since hexavalent chromium is readily reduce by a variety of organic species (Towill, 1978).

The major source of water contamination of 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 (Commission of European Communities, 1979).

The harmful effects in man are due to hexavalent chromium whereas trivalent is considered non toxic. The disease atherosclerosis among the people is mild or virtually absent than the people of area where, this disease is endemic having lower levels of chromium. 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 (Kaufman, et.al., 1970). High levels of hexavalent chromium cause intestinal and lung cancer in man (Anonymous, 1980, Commission of European Communities, 1979; Teleky, 1936). Industrial exposure of hexavalent chromium to skin can cause nasal mucousmembrane ulcers and dermatitis.

Chromium is toxic in high concentrations to both plants and animals. It is reported to cause perforations, bronchiogenic carcinoma etc. in continuously exposed human.

Chromium in hexavalent form is the most common contaminant of drinking water while trivalent Cr is not so common. A large number of chromate salts are used in industries. It is used in wool dyeing, tanneries, electroplating, ceramics, explosives, corrosion control units, etc. Cotton dyeing especially in the dyeing of Khaki dress clothes Cr is discharged in wastewater.

Hexavalent chromium is toxic to plants and animals. It causes yellowing of leaves of wheat and paddy. The maximum permissible limit of Cr in drinking water as recommended by the W.H.O is 0.05 mg/L.

Toxicity of Lead

Lead in high doses has been recognized for centuries as a cumulative general metabolic poison. It is one of the natural constituents of earth's crust and exists in the form of galena (lead sulfide). Even before Romans, lead water pipes were used in 1285, and the first cistern of lead was constructed in the city of London to convey water (STOW,1945). In many places contamination of environment due to lead occurs as a result or from use of products made from it. Consequently it is present in air, water, soil, dust, food and snow. It is used for manufacturing of acid accumulators, alkali lead compounds for gasoline, tetra ethyl lead as antiknock compound, pigment and paints, ammunition, caulking, cable sheathing, roofing material, piping material, including for drinking water, in manufacture of sulphuric acid, lead arsenate, insecticide, rubber etc.

It has cumulative property in human system and some symptoms of acute poisoning like tiredness, lassitude, abdominal discomfort, irritability, anemia, and in the case of children behavioral changes (WHO, 1977). Lead at low levels can reduce the activity of enzyme to synthesis hemoglobin resulting in anemia (WHO, 1977). It has property to bind with mitochondria resulting in interference in regulation of oxygen transport and energy generation (Dril, 1979). Among mentally retarded children lead has been found above 400ug/liter of blood (Moore, et. al., 1977).

Lead also replaces calcium in the bone. Children are most sensitive to lead poisoning compared to adults. Lead poisoning in children can produce brain damage.

Plants grown in lead mining area are known to accumulate high levels of Pb. Plants near highways accumulate atmospheric dust containing Pb as foliar deposits, from the combustion of petrol as well as absorb if from soil.

This is a highly poisonous element, used in industries and as antiknock agent in automobile fuels. This elements has the property of getting accumulated in increasing concentrations over a period of time, in the body of organisms but likely in natural water its content is very low (less then 20 ug/L). Industries, mines smelter discharges and automobile fumes are the chief sources of its spread into the ecosystems. Lead plumbing of water pipes is a common and in soft, slightly acidic waters lead from such pipes reach in our drinking waters. Fossil fuel fall out also released some quantity of lead. For human beings and other animal, lead is poisonous. It affects bone marrow, and formation of blood hemoglobin. Plants, which grow in lead rich soil, are reported to absorb this element and accumulated it in their body and can therefore pass on to grazing animals

Lead is a major pollutant of air mainly due to the use of trimethyl lead as antiknock in the fuel. Therefore, the plants growing near the highways contain more lead deposition on their leaves than those away from traffic zones. Forty per cent of the lead content can be washed away with water. Most of the salts of lead are water soluble and, therefore, is a threat to water pollution especially when lead or lead coated pipes are used as water pipes. Lead thus dissolved can reach the soil resulting in soil contamination, besides, the mining areas of lead also show a high lead content in their soil.

Lead thus brought into the environment on interaction with living organisms causes chronic poisoning. Lead accumulates in brain and kidney and causes acute body poisoning.

Toxicity of Mercury

In very recent years, a lot of attention has been given to the problems of mercury poisoning. Natural waters contain only a few parts per billion of mercury. Mercury enters the biosphere as a waste product from a number of industrial activities. A major source is the production of chlorine where mercury is used as an electrode in the electrolysis of brine. Paper and pulp industries, oil refining industries, plastic industries and battery manufacturing industries also contribute to mercury pollution. Mercuric compounds are also used as fungicide to prevent seeds from rotting and for the protection

But the use of mercuric compounds as fungicide and insecticide are declining due to the acute poisoning nature. Metallic mercury in the liquid from is not toxic. But the vapors of mercury affect the central nervous system. The most widely used organic compound of mercury is methyl mercury. This is most injurious and poses the greatest environmental threat.

Mercury in the environment is chiefly contributed by natural degassing of earth's crust in the range 2,500 to 1,50,000 tones 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. Reduction of photosynthesis in fresh and marine phytoplankton are reported for organomercurial fungicides for concentrations as low as 0.001ppm.

Mercury is commonly regarded as a great threat to man's welfare. It is steadily increasing in amounts as a result of its use in many products and subsequent release in the environment. Mercury is discharged into streams from crop lands treated with mercurial fungicides into the air from incineration of electrical equipment, from metal smelters, and from the combustion of coal and petroleum.

The mercury present into waste products gets converted into two forms by anaerobic bacteria (Jensen and Jernelov,1969). The dimethyl form is volatile and escapes into the water from sediment and is converted into the methyl form at low pH. The ion is soluble, and in this form absorbed by fishes.

In Japan, human illness and death occurred in the 1950's among fisherman who ingested fish, crabs and shellfish contaminated with a simple alkali mercury compound from Japanese coastal industries. This mercury poisoning produced a crippling and often fatal disease known as `Minamata' disease. The world Health Organization (WHO) has proposed a permissible level of 0.5 ppm for fish. In the minamata episode, crabs contained as much as 24 ppm, while kidney's from human victims contained 144 ppm. Chloralkali plants and primary mercury processing plants are known to emit mercury into the atmosphere in sufficient quantities to create a public health problem. Poisoning of mercury may cause anxiety, insomnia, muscular tremor and other psychological disturbances.

Research work with plants has shown that mercury can produce genetic and chromosomal changes (Liptak, 1974).

Toxicity of Nickel

Many nickel salts are water soluble, therefore contamination of water can arise. Garnierite, nickeliferous limonite and pentiandite are the important source minerals. Nickel is relatively non-toxic element. The levels of nickel usually found in food and water are not considered a serious health hazard (CEC, 1979, Underwood, 1977), however high doses (1600mg/kg in diet) are shown in early animal studies to cause mineral toxic effects (Underwood, 1977).

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 (WHO, 1973) and no systemic poisoning from nickel is known. But ``Nickel itch" (nickel dermatitis) has been reported among industrial workers. High level occupational exposure has been associated with renal problem, vertigo and dyspnoea (Commission of European Communities, 1979). Certain nickel compounds have carcinogenic effects on animals, however soluble compounds are not currently regarded as human or animal carcinogens (NRC, 1777).

Toxicity of Zinc

The major source of Zinc is sphalerite, smithsonite, hemimorphite and franklinite. Zinc is an essential element for both animals and man and is necessary for the functioning of various enzyme systems. It is found abundantly in earth's crust. The water resource may be contaminated with zinc through air, and industrial waste.

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 (Prasad, et, al., 1961; Halsted, et. al.,1972). This syndrome having characters of retarded growth, sings of immaturity, and anemia is probably caused by low intestinal absorption of zinc. Its complete cure was observed by administration of large dozes of zinc sulfate.

Symptoms of zinc toxicity in humans include vomiting dehydration, electrolyte imbalance, abdominal pain, nausea lethargyness, dizziness and lack of muscular co-ordination (Prasad and Oberleas, 1976). Acute renal failure caused by zinc chloride has also been reported (Csata, 1968). Zinc unlike Hg, Pb or Cd is an essential trace element for organism and plays a vital role in the physiological and metabolic processes of many organisms. However, in high concentrations, Zinc can be toxic to the organisms.

Zinc is an essential trace element for plants and animals including human begins, and it plays vital role in metabolic processes.

In most of the natural waters zinc is found in traces, less than 1 mg/L i.e. well within the safe limits. Concentrations above 5 mg/L causes disagreeable taste. In drinking water the level of zinc usually ranges from 0.005 to 1 ppm or mg/L, but in certain regions of the world it may exceed upto 7.0 mg/L. Only a much higher than this range is toxic to organisms. This metal is quite widely used in galvanizing iron. It reaches aquatic ecosystem in toxic concentration zinc mining operations and industries manufacturing zinc containing fungicides, viscose rayon fibers, zinc smelters, dezincification units, and through gradual degalvanization of iron and dezincification of brass, etc. Excessive zinc may give a white scum or greasy layer on water surface. Zinc sulphide is the common ore and through smelting the metal is extracted. In rivers passing near zinc smelters the zinc load of water has been reported upto 25 mg/L.

Zinc is an essential and beneficial element in human metabolism and in small quantity does not appear to have a serious effect on health.

It has been shown that zinc increases the fiber strength of cotton and that if cotton seeds are soaked in a zinc solution before sowing, or if zinc applied to the roots of cotton seedlings, the zinc is translocated to actively growing parts of the plant. However an excess of zinc in soil suppresses phosphorus uptake by plants and can cause leaf chlorosis.

The most common effect of zinc poisoning in humans are non fatal `metal-fume' fever, caused by inhalation of zinc oxide fumes, and illness arising from the ingestion of acidic foods prepared in zinc-galvanized containers. Zinc salts, particularly zinc chloride produce dermatitis upon contact with the skin.

Zinc has proved to be beneficial when applied in small amount but show detrimental effects on plants as well as on human beings when in excess.

Toxicity of 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 (WHO, 1981), but no adverse effects have been noted among humans deficient in manganese levels.

In 1947, the cause of ebcephelitis like disease in Japan was attributed to contaminated well water having manganese of 14mg per liter of water. In other area of Japan there was no adverse effect found among population consuming water having 0.75 mg of manganese per liter of water. In addition to mining operations of Mn ores, industrial sources like iron and steel ferromanganese, dry cell batteries, and fossil burning are sources of environmental Mn. Use of pyrolusite in industry, as in uranium extraction from ores, can be source of Mn input into the aquatic systems.

Mn in trace amount is an essential nutrient element required for normal function of cell, however it is toxic in higher concentrations, Chronic exposure caused neurological disorders.

In traces Mn is an essential nutrient element for plants and animals. This required for activity of some dehydrogenases, decarboxylases, kinases, oxidases, peroxidases etc. It is required for photosynthetic evolution of oxygen. This metal is not a serious pollutant as in most waters its concentration is quite low ranging from 0.005 to 1 mg/L. Potassium permanganate is used in very small doses to disinfect well water particularly in Indian villages. In certain marine fishes its accumulation is well marked. Water containing more than 1 mg/L manganese may impart objectionable staining property of clothes during laundry operations.

Toxicity of Copper

The toxicity of Cu to aquatic organism very with the chemical species presents in water and other environmental parameters like temperature, pH, turbidity, hardness etc. Main dissolved species of CU in aquatic environments are $Cu\,(OH)_+$ Cu_{++}, and $Cu\,CO^3$. Hydrous oxides of Fe and Mn control the dissolved species of Cu in water. Sorption of Cu to these minerals result in reduced toxicity of Cu.

Copper in small quantity is an essential element for plants and animals and an adult human requires about 2mg of this everyday. Even in slightly higher concentration than the prescribed limit in water, it imparts a disagreeable taste. In nature, its higher concentration in waters may be due to several sources as copper is a widely used substance in many kinds of daily use articles, chemicals, and pesticides. Copper mining and operations connected with its extraction processes release enough copper in aquatic bodies. Copper salts are used in water supply systems to control the growth of algae and fungi. This, and corrosion of copper containing pipes contribute copper to drinking water. Copper sulphate with calcium carbonate is one of the commonest fungicide called Bordeaux mixture and through runoff from crop fields copper reaches water bodies. Copper oxide is a common component of paints which too slowly enters environment. Copper in water retards the growth of algae and macrophytes even at low and otherwise permissible levels. Plants in general are more sensitive to copper than animals including man as plants begin to show pollution symptoms at 1ug/L level while for aquatic invertebrates and fishes the lethal level is reported by Lopez and Lee (1977) as 0.015to3mg/L.

Copper is an essential and beneficial element in human metabolism. Deficiency of copper results in nutritional problem in infants. Small amounts are not generally regarded as toxic, but very large doses may cause sickness and in extreme cases liver damage. Copper toxicity is a fundamental cause of Wilson's disease. Patients of Wilson's disease exhibit through out their life both a deficiency of the plasma copper. In average 10-20 mg of copper in diet per year is sufficient to cause Wilson's disease.

Copper sulphate may cause acute poisoning in men when injected accidentally or by having acidic foods or drinks like vinegar, citrus juices, carbonated beverages which have been in contact with the metal.

Excess amount of copper sulphate also shows detrimental effect on botanical environment. Copper in ionic from is very toxic to the photosynthesis of the green alga, Chlorella pyrenoidosa and the diatom, Nitzchiz palea in concentrations of copper normally found in natural waters.

Copper accumulates progressively in soils where copper fungicides are used, particularly in vineyards and orchards, which are spread repeatedly. Thus, it is seen that though copper is essential to life and health, its deficiency or excesses both cause adverse effects.

Toxicity of Cobalt

The main sources of cobalt are water and food (particularly beer). Excess dosage (1.5 ppm) of cobalt results in polycythaemia and hyperlipaemia. Cobalt is also considered as a goitrogenic agent. Cobalt normally occurs at levels of < 10ug/L in natural water. Wastewater may contain higher concentration. Cattle have been injured when fed diets spiked with level of soluble salts of Co that exceed 10 mg/kg. Concentration of Co in forages is normally from 0.01 mg/kg to 0.3 mg/kg. Although Co is apparently an element that can penetrate the soil-plant barrier, no instances of animals being injured from excessive plant-absorbed Co in their diets have been reported. Cobalt seldom found in natural water, it is often present in industrial waste water as a corrosion product of stainless steel, nickel or cobalt, and from metal plating bath. 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 Co 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 then 1mg/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 USSR-1 mg/L.

Toxicity of Iron

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. Most of the iron in plants is present as a constituent of organic molecules, enzymes and carriers catalase, peroxidase and cytochromes which play important roles in cellular metabolism. Iron is indispensable for the synthesis of chlorophyll molecules. Deficiency of iron in plants causes chlorosis. It is one of the most immobile elements in plants. Gopalan et al. (1980) have reported the iron content of some Indian crops as follows (on mg/100 g dry weight basis) : Bajra, 5.0; Barley, 3.0; Wheat whole, 4.9; Rice, 2.8; Legumes and pulses, 10.2.

Iron is also 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 hemoglobin molecule. It is more often suggested that iron deficiency predispose children to lead poisoning. Deficiency of iron with other trace elements is the cause of pica (a morbid appetite for unusual or unfit food, as clay, chalk, ashes, bricks etc., showing itself especially in hysteria, pregnancy, and chlorosis). Iron deficiency also affects the transport of lead to the tissue. 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 amount adversely affect the human system, which may result in haemochromatosis. Iron absorption is enhanced by heame, ascorbic acid, amino acids and inhibited by tannins, calcium, phosphate, phytic acid and fibers. Although the human body contains only about 0.004% iron, this element plays a central role in the life processes. As a constituent of the respiratory pigment hemoglobin, iron is essential for the functioning of every organ and tissue of the human body. Over half of the iron is present in the form of hemoglobin; the remaining iron is stored mainly in the liver. Nutritional anemia is one of the most prevalent deficiency diseases throughout the world. Although anemia may result from many different causes, the form most frequently encountered is iron-deficiency anemia (Tsai, 1975). Anemia is a major health problem in India, with over half of ever-married women having the condition. The problem clearly requires immediate attention and intervention.

In concentrations exceeding 1-2 mg/L, iron appreciably affects the taste of beverages, while precipitation of iron salts on the food products, on fabrics, paper etc. affects the quality of these products and also increased cost of water treatment. Iron deposits can also be formed in boilers and as such iron concentrations in water to be used for industrial purposes should be low (Handa, 1993). Iron interfere with laundering operation, impart objectionable stains to plumbing fixtures, and cause difficulties in distribution systems by supporting growth of bacteria. Iron also imparts a taste to water, which is detectable at very low concentration. For these reasons water supplies ought not to contain more then 0.3 mg/L of iron. Deposition of iron in lungs with nil or minimal fibrosis creates problems in human body (Jindal, 1987).

Iron usually exists in natural water both in ferric and ferrous forms. The form of iron however may be altered as a result of oxidation or reduction due to the growth of bacteria in the water during storage, usually the ferric form is predominant in the most of the natural waters. Iron in water may be either in true solution, or in a colloidal state or in the form of relatively coarse suspended particles. The iron determination is helpful in assessing the extent of corrosion and aiding in the solution of these problems. Research on corrosion and methods of corrosion control require the use of many types of tests to evaluate the extent of metal loss. The most important one of them is the iron determination (Sawyer, 1978). In India 0.3 mg/L is the highest desirable level and 1mg/L the maximum permissible limit in absence of alternative source.

2.2 Quality Criteria for Livestock and Wildlife Watering

The permissible daily intake of substances is greatly dependent on the concentrations of the substances and the quality of water ingested. The daily water requirements of animals vary with a number of factors such as temperature and humidity, the water content of the food, the degree of exertion of the animal and the salinity of the water supply. Therefore, the recommended concentrations of specific substances are based on typical usage.

The more critical parameter of concern is the salinity of the water. Excessively saline waters can cause physiological upset and death of the range of water salinity and their effect of animals. The concentration of toxic substances which render a water undesirable are dependent on many variables. These include age, sex, species, physiological state of animal etc.

The recommended standard levels are shown in Table 2.1.

2.3 Water Quality for Irrigation

The required quality of irrigation waters varies substantially, depending principally upon the salinity, soil permeability, toxicity and some miscellaneous concerns such as excessive nitro loading or unusual pH of water. The recommended water quality criteria for irrigation is shown in Table 2.2

Table 2.1 : Levels of toxic substances in drinking water for livestock

Constituent	Upper limit(mg/L)
Aluminium (Al)	5
Arsenic (As)	0.2
Beryllium (Be)	No data
Boron(B)	5.0
Cadmium (Cd)	0.05
Chromium(Cr)	1.0
Cobalt (C0)	1.0
Copper (Cu)	0.5
Fluoride (F)	2.0
Iron (Fe)	No data
Lead (Pb)	0.1
Manganese (Mn)	No data
Mercury (Hg)	0.01
Molybdenum (Mo)	No data
Nitrate(N03-N+NO2-N)	100
Nitrite(NO3-N)	10
Selenium(Se)	0.5
Vanadium(V)	0.10
Zinc(Zn)	24
TDS	10000

(After National Academy of Sciences and National Academy of Engineering 1972).

Table 2.2 : Summary of Water Quality Criteria for Agricultural Irrigation

Parameter	National Academy of Science,1972	U.S.E.P.A., Oct.1973	
		Long Term	Short Term
Aluminum	5.0	5.0	20.0
Arsenic	0.1	0.1	2.0
Fecal Coliform	1000/100ml	1000/100ml	-
Beryllium	0.1	0.1	0.5
Boron	1	-	-
Cadmium	0.01	0.01	0.05
Chloride	-	0.4-1.8	-
Chromium	0.10	0.1	1.0
Cobalt	0.050	0.05	5.0
Copper	0.2	0.2	5.0
Fluoride	1.0	2.0	15.0
Iron	5.0	5.0	20.0
Lead	5.0	5.0	10.0
Lithium	2.5	2.5	-
Manganese	0.2	0.2	10.0
Molybdenum	0.01	0.01	0.05
Nickel	0.2	0.2	2.0
pH	4.5-9.0	-	-
Phenols	-	-	-
Selenium	0.02	0.02	-
SAR	1	1	-
Total Dissolved Solids	3	3	-
Sulphate	-	-	-
Vanadium	0.10	-	-
Zinc	2.0	-	-

Branson et. al.(1975) have studied the plant tolerance to trace elements. The table summarized by Lioyd and Heathcote is included here (Table 2.3).

Table 2.3 : Recommended maximum concentration of trace elements in irrigation water

Elements	For water used continuously on all soil(mg 1-1)	For use up to 20 years of fine-textured soils at
Aluminium	5.0	20.0
Arsenic	0.10	2.0
Beryllium	0.10	0.50
Boron	0.75	2.0-10.0
Cadmium	0.010	0.050
Chromium	0.10	1.0
Cobalt	0.050	5.0
Copper	0.20	5.00
Fluorine	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5	2.5
Manganese	0.20	10.0
Molybdenum	0.010	0.050
Nickel	0.20	2.0
Vanadium	0.10	1.0
Zinc	2.0	10.0

3.0 STUDY AREA AND METHODOLOGY

A detailed description of the study area has already been provided in the report named "Ground water Quality Monitoring and Evaluation in and around Greater Guwahati (Assam), Part-II : Chemical Analysis" (Kumar et al., 1998). In the description a broad aspects like physiography, climatic condition, drainage, land use pattern, pollution sources, water supply and sewerage problems, commercial activities, sources of industrial pollution, environmental problems etc. have been described elaborately.

In order to achieve the objective of the study, a number of water quality and trace elements parameters have been determined for several sites by taking samples and doing analysis in the laboratory. The following methodologies have been followed in the study :

3.1 Site Selection

The factors, identified for proper selection of ground water sampling sites within Greater Guwahati include objectives of the study, location, number and spacing of wells, vertical location of screen material, type of well casing and screen, surrounding environmental conditions, public interference, general use of the wells and industrial activities in the region (Table 3.1).

3.2 Sampling and Preservation

By considering these above considerations ground water samples were collected from different dug wells (29 sites) of the study area in grid network pattern. In this pattern whole area was divided into equal grids as shown in Fig. 3.1. The water sample of a well was collected in such a way as to represent the entire water column by using depth integrating sampler, as suggested by

Table 3.1 : Identification and general use of sampling wells

S. No	Site No.	Sampling Source	Location	Well Type	Use of the Well	Locality
1	W- 1	Dug well	Dipar Beel	Temple well	General use	Swampy area
2	W- 2	Dug well	Boragaon	Personal well	Drinking & domestic	Near NH
3	W- 3	Dug well	Katakipara	Personal well	Drinking & domestic	Near NH
4	W- 4	Dug well	Beharbari	Personal well	Drinking & domestic	Residenttial area
5	W- 5	Dug well	Goseva Beltola	Personal well	Drinking & domestic	Hilly and forest area
6	W- 6	Dug well	Nutan Bazar	Community well	General use	Market place
7	W- 7	Dug well	Eight Mile	Community well	Drinking & domestic	Cattle farm
8	W- 8	Dug well	Ajra	Personal well	Drinking & domestic	Airport area
9	W- 9	Dug well	Jalukbari	Personal well	Drinking & domestic	Residential area
10	W-10	Dug well	Gita Nagar	Community well	Drinking & domestic	Hilly and forest area
11	W-11	Dug well	Fatasil Ambari	Community well	Drinking & domestic	Residential area
12	W-12	Dug well	Odal Bokra	Community well	General use	Residential area
13	W-13	Dug well	Hathigaon	Personal well	Drinking & domestic	Residential area
14	W-14	Dug well	Down Town	Personal well	Drinking & domestic	Residential area
15	W-15	Dug well	Bagharbari	Personal well	Drinking & domestic	Residential area
16	W-16	Dug well	Maligaon	Personal well	Drinking & domestic	Residential area
17	W-17	Dug well	Durga Sarovar	Temple well	General use	Temple area
19	W-19	Dug well	Rukmani Nagar	Community well	General use	Near petrol pump
20	W-20	Dug well	Hengrabari	Community well	Drinking & domestic	Hilly area
21	W-21	Dug well	Sathgaon	Personal well	Irrigation & general	Agricultural area
22	W-22	Dug well	Dolgobinda	Temple well	General use	Temple area
23	W-23	Dug well	Paltan Bazar	Community well	General use	Market place
24	W-24	Dug well	BamuniMaidan	Community well	Drinking & domestic	State bank colony
25	W-25	Dug well	Shyam Mandir	Community well	Drinking & domestic	Temple area
26	W-26	Dug well	Bonda Gaon	Personal well	Drinking & domestic	Residential area
27	W-27	Dug well	Durgeshwari	Temple well	General use	Temple area
28	W-28	Dug well	Rudreshwari	Temple well	General use	Residential area
29	W-29	Dug well	Noonmati	Community well	Drinking & domestic	School area
30	W-30	Dug well	Kharguli	Community well	Drinking & domestic	Hotel area

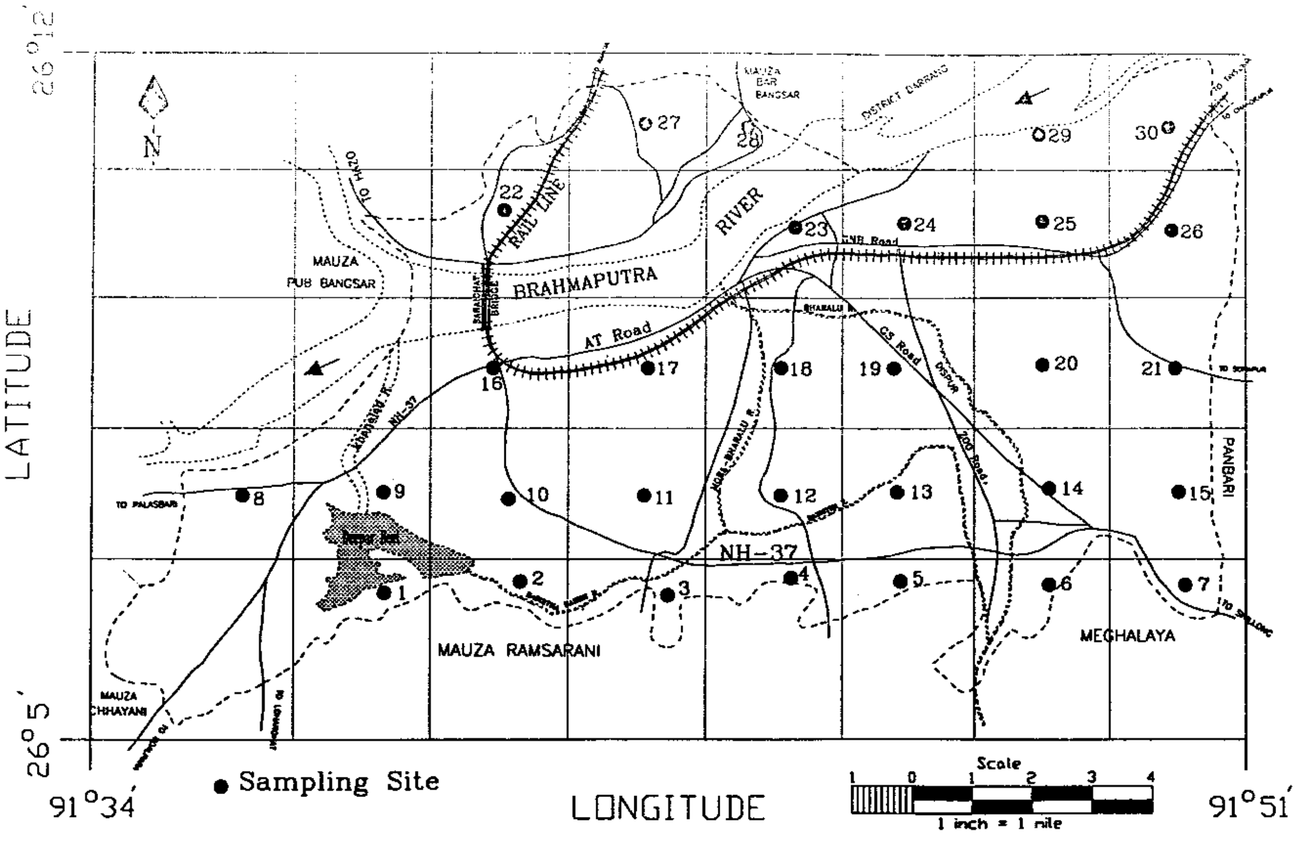

FIG. 3.1 : STUDY AREA MAP OF GREATER GUWAHATI SHOWING SAMPLING SITES

Raghunath (1987). Water samples were collected by dip or grab sampling method using standard water sampler (Hydro-Bios, Germany, Fig. 3.2). 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).

3.3 Metal Detection Technique

Different methods of estimation of trace metals in water, sediment and organisms are now available with the advent of new analytical techniques. In the case some metals, direct determination from water sample is possible whereas in other cases preliminary concentration procedures like copreciption, solvent extraction, ion exchange or reduction in volume by evaporation, are to be adopted. In the case of sediments and organisms, solubilisation of the heavy metals has to be without loss of volatile components. The analytical methods commonly used in estimation of heavy metals are:

- Atomic absorption spectrophotometry.
- Colorimetric methods.
- Polarographic estimations.
- X-ray fluorescence methods.
- Neutron activation.
- Mass spectrometry.
- Ion selective electrodes.

Extreme care should be taken in sampling and analysis to prevent contamination. Purification of the reagents used is a prerequisite.

In the present study samples were collected in polyethylene containers. These water

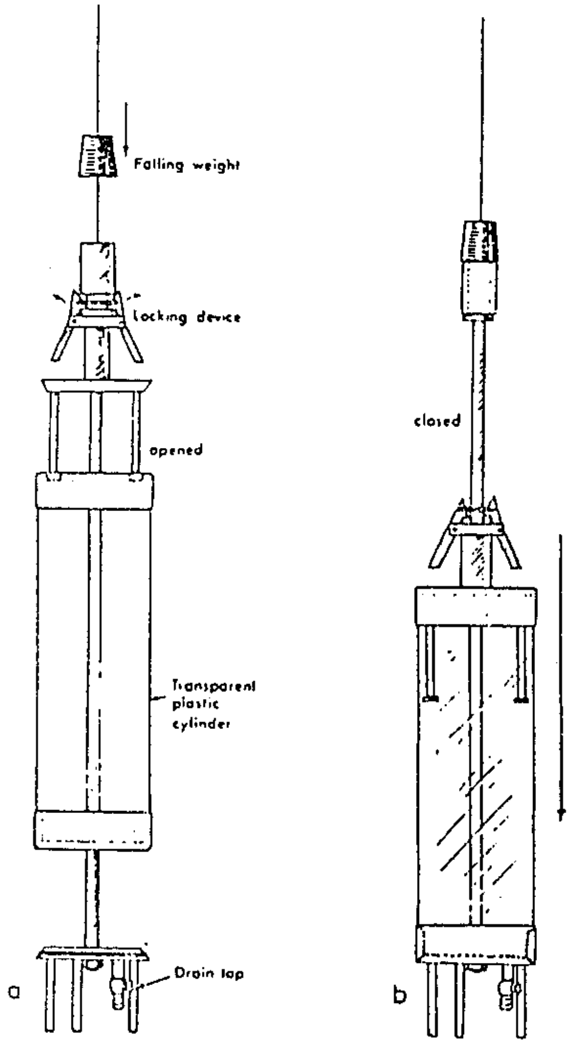

FIG. 3.2 : STANDARD WATER SAMPLER FOR GRAB SAMPLING
(a) OPEN AND (b) CLOSED

samples were prepared for the determination of heavy metals, viz., copper, cobalt, zinc, cadmium, lead, nickel, iron and manganese by atomic absorption spectrophotometer. This instrumental technique, was developed by Asian Walsh in 1955 by means of 'Atomic Absorption Spectrophotometer' (AAS) and since then AAS techniques have been considered as most reliable and have become more common in recent times although the colorimetric/spectrophotometric techniques have also been in use because of the exorbitant cost of the AAS. AAS techniques are usually favored due to its rapidity, accuracy and controllability while other methods do not respond if the metals are present in traces. It is generally employed when exact quantity of interfering radicals or ions is known.

The study was carried out on Perkin-Elmer model-23280 double beam atomic absorption spectrophotometer using air-acetylene flame. Some physical parameters like pH, oxidation reduction potential etc. were determined in the field at the time of sample collection by using portable testing kits. Depth of ground water table below ground level (bgl) of different observation wells during sampling were also measured to see the impact of water table on concentration of trace elements.

3.4 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 hrs. and finally rinsed with de-ionized water several times prior to use.

4.0 RESULTS AND DISCUSSION

Toxicity of trace elements in ground water is not a new problem. Many countries in the world have experienced menace of metal pollution in water and large number of people have been affected. Causes of this pollution have been well documented. However the main source of metal toxicity in ground water has been thought to be natural occurrence and subsequent degradation of the environment.

Of all the elements present on the earth's crust, H, C, N, O, Na, Mg, P, S, Cl, K, Ca, constitute 99.9 percent of all living matter. In addition 14 elements viz. B, F, Si, V, Cr, Mn, Fe, Co, Cu, Se, Mo, Sn and I are the essential trace elements. Rest of the elements are either not essential for growth and development of organisms or their function in the biological systems has not been established. Some of the trace metals Hg, Pb, Cd, As, Cr, Zn, Cu, Mn, Fe whether they are essential ones or not, when present in aquatic environment above certain levels may constitute contamination. A wide variety of pollutants - physical, chemical, biological and radiological have been identified in the environment consequent to urbanization, industrialization and new technological developments. Heavy metals though naturally occurring can be present in some areas in sufficient concentrations and physico-chemical forms that might create pollution problems. Sources of pollution of trace metals Hg, Pb, Cd, As, Cr, Co, Zn, Ni, Cu, Mn and Fe are mainly aquatic releases from industrial operations, atmospheric releases from fossil flue burning, domestic sewage discharges and land run-off. These elements exhibit varying environmental behavior and toxicity to aquatic organism and man. The background levels of some of the trace metal very widely depending upon the location. Several fold increase in the concentrations of Zn, Cd, Hg, Fe etc., have been observed in ground water of some particular region in the country. For evaluation of impact of heavy metal in aquatic environmental further investigations are needed.

The metals in general, whether they are toxic heavy metals or essential metals, when administrated in excess, act on living system, through their property of ligand bonding. These interactions of metals with either simple molecules (viz. vitamins, coenzymes, amino acids) or macromolecules (like proteins, Nuleic acids etc.) interfere with the biochemical functioning of livings and can cause either short term pathological abnormalities (like carcinogenesis, teratogonosis etc.). Due to this many agencies like WHO, USPH, BIS and ICMR etc. have established the standard criterion for drinking water and such guidelines are shown in Annexure-I for reference.

Total twenty nine samples from twenty nine locations were collected and analyzed on annual basis. Their concentrations are tabulated in Table 5.1. In order to find out the fluctuation of various trace elements in the whole area, their mean, standard deviation and population variance were also calculated and presented in table 5.1. Increasing status of trace elements with different sampling sites are shown in Figs. 5.1 to 5.10. Depth of ground water table is also measured from each location during sampling to see the variation of concentration with depth of ground water. Depth wise increasing and decreasing trends of different parameters are plotted and shown in Figs. 5.11 to 5.19. Location wise vertical distribution of different trace elements and other parameters i.e. pH, ORP and depth of water table were also plotted and shown in Figs. 5.20 to 5.29. pH-ORP diagram also prepared for iron to see the stability field (Fig. 5.30). Water quality of ground water bodies in a region can be studied by plotting the results of analysis of water samples on maps and by means of lines of equal concentration of specific ions (i.e. contour lines). Using these techniques, areas of concentration of specific elements and problematic zones can be identified and corrective measures can be employed. The water quality maps may be shaded to identify areas of water having particular range of concentration. To see these advantages, variation of trace elements with pH, ORP and depth

Table 5.1 : Contraction of Trace Elements in Ground Water of Guwahati during July-1996

S. No	Site No.	Sampling Source	Location	Concentration of Trace Elements for July 1996 (ppm)								Depth of water table ft.bgl	ORP mv	pH
				Cu	Co	Cd	Zn	Fe	Mn	Ni	Pb			
1	W- 1	Dug Well	Dipar Beel	0.018	0.014	0.006	8.000	1.006	0.647	0.320	0.000	3.937	193	6.27
2	W- 2	Dug Well	Boragaon	0.006	0.005	0.004	7.870	3.214	1.827	0.272	0.000	2.297	185	6.26
3	W- 3	Dug Well	Katakipara	0.016	0.072	0.010	21.575	0.898	7.325	0.289	0.000	6.234	178	5.79
4	W- 4	Dug Well	Beharbari	0.000	0.026	0.000	5.610	0.075	0.132	0.289	0.000	18.044	164	5.65
5	W- 5	Dug Well	GosevaBeltola	0.000	0.041	0.004	9.000	0.247	0.049	0.215	0.000	8.629	181	6.12
6	W- 6	Dug Well	Nutan Bazar	0.000	0.030	0.003	2.610	0.000	0.096	0.264	0.000	2.625	179	5.95
7	W- 7	Dug Well	Eight Mile	0.002	0.038	0.007	7.925	0.416	1.260	0.263	0.000	3.740	180	6.08
8	W- 8	Dug Well	Ajra	0.000	0.021	0.009	0.310	0.123	0.195	0.277	0.000	1.968	189	5.91
9	W- 9	Dug Well	Jalukbari	0.005	0.040	0.003	5.325	0.000	0.205	0.237	0.000	1.968	189	6.40
10	W-10	Dug Well	Gita Nagar	0.010	0.060	0.011	8.775	1.455	1.693	0.270	0.000	3.182	209	6.95
11	W-11	Dug Well	FatasilAmbari	0.000	0.076	0.011	13.450	1.074	2.269	0.240	0.000	7.218	198	6.48
12	W-12	Dug Well	Odal Bokra	0.000	0.075	0.011	2.950	0.000	0.131	0.250	0.000	40.354	218	7.00
13	W-13	Dug Well	Hathigaon	0.013	0.072	0.010	5.300	0.146	0.185	0.264	0.000	16.732	201	6.70
14	W-14	Dug Well	Down Town	0.001	0.076	0.013	6.325	0.143	0.394	0.268	0.000	7.382	238	7.60
15	W-15	Dug Well	Bagharbari	0.000	0.088	0.009	7.950	0.000	0.926	0.256	0.000	10.499	196	6.46
16	W-16	Dug Wll	Maligaon	0.005	0.091	0.014	24.175	1.002	0.142	0.272	0.000	2.625	200	6.54
17	W-17	Dug Well	DurgaSarovar	0.000	0.097	0.007	12.400	4.805	2.680	0.315	0.000	5.577	183	6.21
19	W-19	Dug Well	RukmaniNgr.	0.000	0.043	0.012	0.210	2.538	1.166	0.304	0.000	9.186	181	5.98
20	W-20	Dug Well	Hengrabari	0.000	0.093	0.012	7.990	0.000	0.106	0.303	0.000	20.735	182	6.10
21	W-21	Dug Well	Sathgaon	0.005	0.101	0.015	8.025	0.000	0.107	0.330	0.000	6.890	203	6.72
22	W-22	Dug Well	Dolgobinda	0.000	0.062	0.007	6.200	0.187	0.131	0.250	0.000	7.546	181	6.08
23	W-23	Dug Well	Paltan Bazar	0.000	0.067	0.010	0.860	0.000	0.655	0.280	0.000	16.732	236	7.50
24	W-24	Dug Well	BamuniMaidan	0.000	0.079	0.011	0.530	0.389	0.676	0.269	0.000	18.701	243	7.50
25	W-25	Dug Well	Shyam Mandir	0.000	0.083	0.009	2.030	1.692	0.109	0.260	0.000	1.640	178	5.82
26	W-26	Dug Well	Bonda Gaon	0.000	0.077	0.013	4.290	0.341	0.640	0.318	0.000	10.827	202	6.60
27	W-27	Dug Well	Durgeshwari	0.000	0.077	0.012	9.050	1.552	1.432	0.315	0.000	3.970	198	6.45
28	W-28	Dug Well	Rudreshwari	0.000	0.042	0.010	11.000	0.347	0.140	0.259	0.000	15.912	193	5.99
29	W-29	Dug Well	Noonmati	0.000	0.072	0.007	0.110	0.000	0.205	0.314	0.000	13.123	205	6.60
30	W-30	Dug Well	Kharguli	0.000	0.042	0.008	0.420	0.007	0.496	0.260	0.000	15.748	192	6.30
			Max	0.018	0.101	0.015	24.175	4.805	7.325	0.330	0.000	40.354	243.0	7.60
			Min (next to zero)	0.001	0.005	0.003	0.110	0.007	0.049	0.215	0.000	1.640	164.0	5.65
			Avg	0.003	0.061	0.009	6.906	0.747	0.897	0.277	0.000	9.697	195.8	6.41
			Var	2x10^{-6}	0.001	12x10^{-6}	32.705	1.233	1.969	0.001	0.000	64.855	332.2	0.25
			S.Dev	0.005	0.026	0.004	5.719	1.111	1.403	0.028	0.000	8.053	18.2	0.50

Abbreviations : Max - Maximum, Min - Minimum, Avg - Average, Var - Population Variance
S.Dev - Standard Deviation

of ground water table of Guwahati area are presented in isocon form (Fig. 5.31 to 5.40). The prepared isocon maps projects the regional behaviors with areal extent of particular concentration zone in very simple visualize way.

It is evident from the study that toxic metal lead (Pb) is remain absent from all the sampling sites. The general observations of individual metals, which were made, are discussed below.

4.1 Status of Trace Elements in Ground Water

Copper (Cu)

Data showed that the level of Cu in the ground water of Greater Guwahati varied from 0.000 mg/L to 0.018 mg/L. The highest concentration of copper is found in Dipar Beel site. It is observed that the average concentration of Cu in the study area is 0.003 mg/L with standard deviation of 0.005 and population variance of 2.5×10^{-5} The data of Cu showed that in ground water of Guwahati, concentration of Cu is well within the desirable and acceptable limits of WHO, BIS and ICMR and there is no toxicity of Cu in the ground water.

Cobalt (Co)

It was observed that cobalt concentration in the ground water of Guwahati ranged from 0.005 mg/L to 0.101 mg/L and in this range it is not harmful for living organisms. The maximum concentration of Co as found in the sampling site at Sathgaon. The average concentration of Co in the study area is 0.061 mg/L with standard deviation of 0.026 and population variance of 0.001.

Cadmium (Cd)

The variation shown by cadmium content in the ground water was observed between 0.000 to 0.015 mg/L. The maximum value as recorded at Sathgaon site and the minimum was at Behar Bari. Overall average value is 0.009 mg/L with standard deviation of 0.004 and population variance

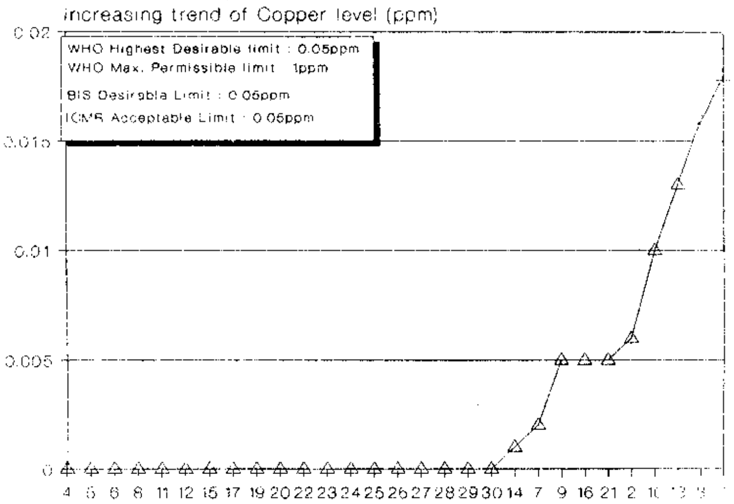

Fig.5.1: Status of Copper in gr. water

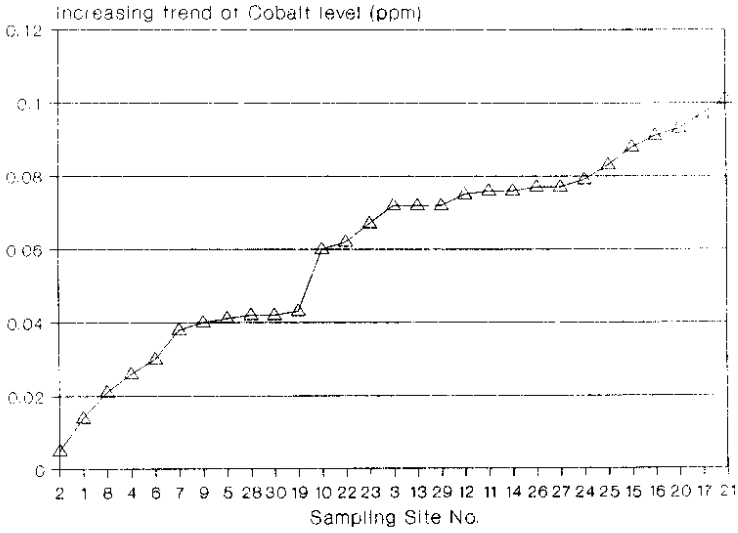

Fig.5.2: Status of Cobalt in gr. water

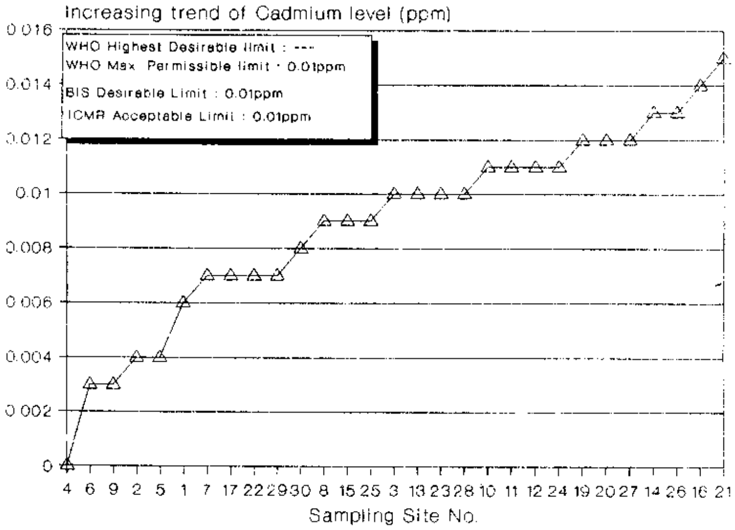

Fig.5.3: Status of Cadmium in gr. water

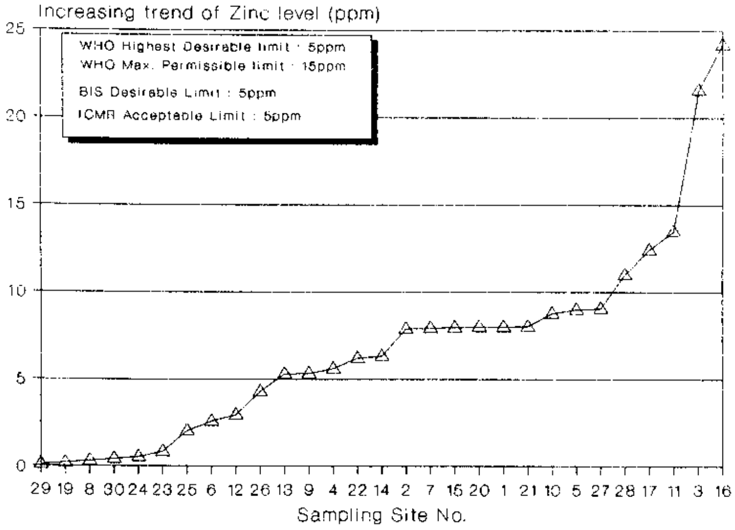

Fig.5.4: Status of Zinc in gr. water

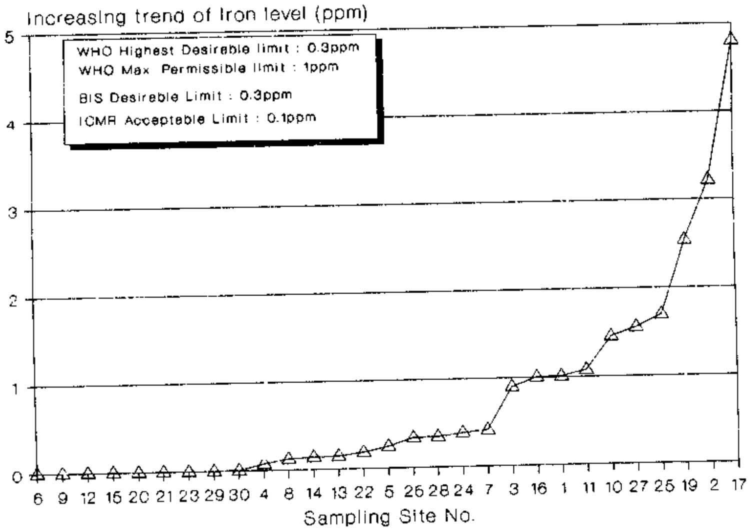

Fig.5.5: Status of Iron in gr. water

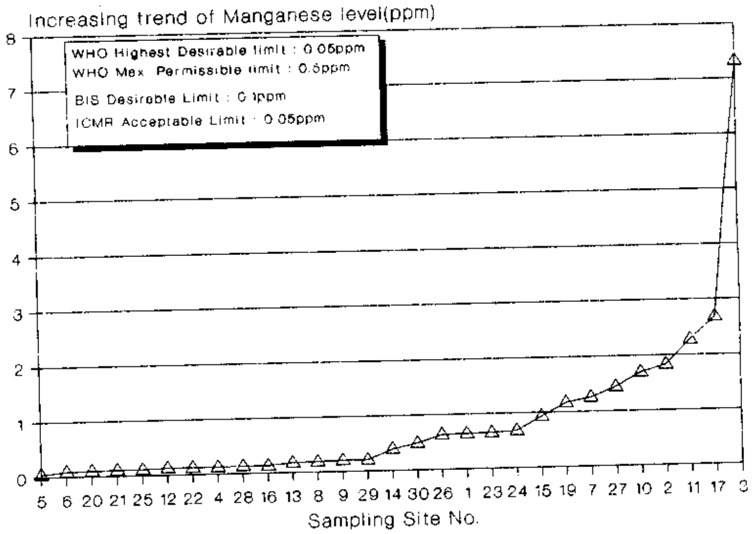

Fig.5.6:Status of Manganese in gr. water

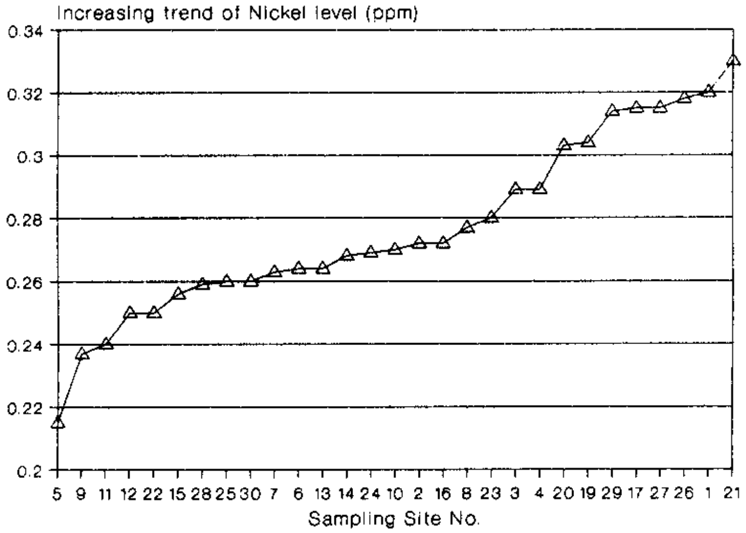

Fig.5.7: Status of Nickel in gr. water

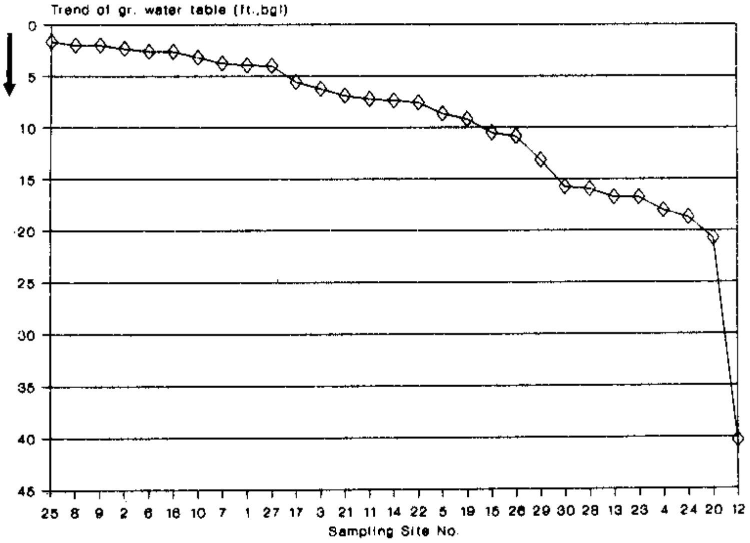

Fig.5.8: Status of gr. water table (ft.)

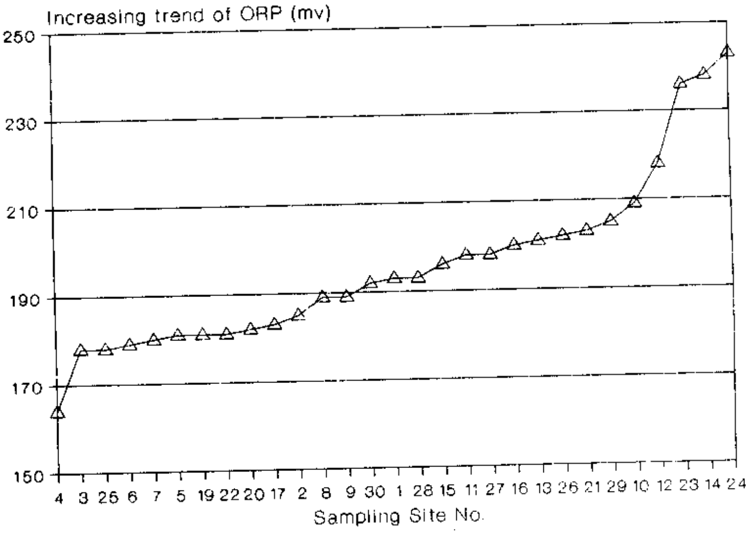

Fig.5.9: Status of ORP in Gr. Water

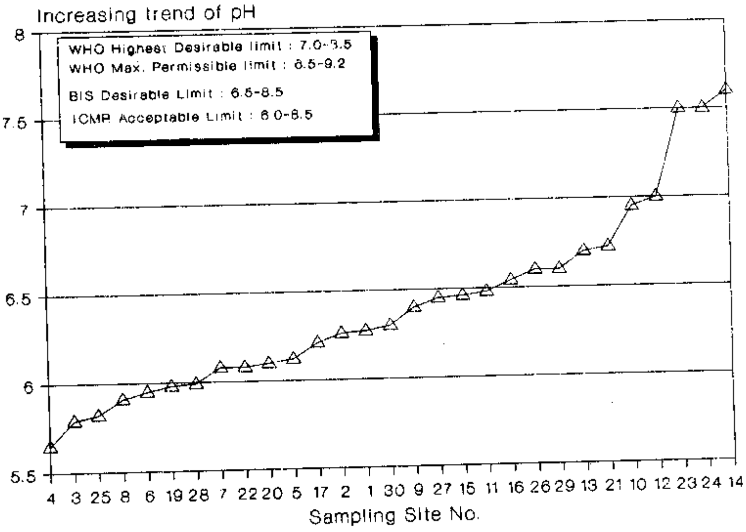

Fig.5.10: Status of pH in gr water

of 1.2x10^{-5}. Toxic behavior of ground water with respect to Cd may be occurred at Gita Nagar, Fatashil Ambari, Odal Bokra, Down Town, Maligaon, Rukmani Nagar, Bamuni Maidan, Hengra Bari, Sathgaon, Bonda Gaon and Durgeshwari because Cd level in ground water of these locations crossed the maximum permissible limit (0.010 mg/L) of WHO.

Zinc (Zn)

The concentration of zinc ranged between 0.110 to 24.175 mg/L. The maximum and minimum concentrations were found in Maligaon and Noonmati respectively. Zinc, an essential and beneficial element for man with a permissible limit of 5 mg/L, is presents at all the sampling sites in Guwahati.

The concentration of zinc, in the water samples at Katakipara and Maligaon sampling stations, was found much more then the maximum permissible limits (15 mg/L) prescribed for drinking water quality as proposed by WHO. Even the average concentration value of Zn for Guwahati (6.906 mg/L) is more then the desirable and acceptable limit (5 mg/L) of WHO, BIS and ICMR. The standard deviation and population variance are 5.719 and 32.705 respectively.

Iron (Fe)

Study on the iron content of the ground water in Guwahati has shown that most of the dug wells contain high iron content. The concentration of iron in ground water of the study area ranges from 0.000 to 4.805 mg/L. The average content of iron for dug well water in the study area is 0.747 mg/L, while standard deviation and population variance values are 1.111 and 1.233 respectively. The highest iron content (4.805 mg/L) was found at Durga Sarovar (site no. 17).

The data from different observation wells exceeded the WHO guideline value of 0.3 mg/L except the observation well Nos. 6, 9, 12, 15, 20, 21, 23, 29, 30, 4, 8, 14, 13, 22 and 5. Iron content other then these sites crossed the maximum permissible limit of WHO, BIS and ICMR and not suitable for drinking purpose without treatment. During observation period, even average iron content (0.747 mg/L) in the study area was found more then the desirable limit of WHO and BIS (0.3mg/L).

Redox reaction influences the mobility of metal ions in solution. The redox conditions encountered along a flow system are important in controlling the chemistry of metal ions and solids species or solids containing sulfur and dissolved gases containing carbon. It is possible in some flow system to define redox zones. These zones are parts of an aquifer in which ORP is controlled by a dominant redox couple. From the fig. 5.30, it is revealed that iron content in the ground water of Guwahati is in the form of ferrous ($Fe2+$) iron in most of the sites. This is an important information before applying the iron removal technique from ground water for designated purposes.

Manganese(Mn)

Manganese, which may be considered as non-toxic metal as always present in the ground water of Guwahati. The lowest value of Mn was found to be 0.049 mg/L at Goseva (Beltola), while the highest was 7.325 mg/L at Katakipara. In general, the concentration of Mn is always higher then the desirable and acceptable limit (0.05 mg/L) of WHO and ICMR. The mean of total area was found 0.897 mg/L, with standard deviation of 1.403 and population variance of 1.969. The mean value of Mn for Guwahati area itself is more then the maximum permissible limit of WHO (0.5 mg/L). This may be due to mixing of $KMnO4$ in the well for disinfect well water and due to cumulative deposition it has been reached to alarming stage.

Nickel (Ni)

The Ni content varied from 0.215 mg/L to 0.330 mg/L in the ground water of Guwahati. The minimum value of Ni as observed at Goseva (Beltola) site while the maximum at Sathgaon. The mean value for the study area as found to be 0.277 mg/L and standard deviation and population variance is to be 0.028 and 0.001 respectively.

Lead (Pb)

It is evident from the study that toxic metal lead (Pb) is remain absent from all the sampling sites in the ground water of Guwahati area. At each spot the lead concentration was not detected at all.

pH, ORP and Gr. Water Table

The findings related to pH, ORP and fluctuation of ground water table in the study area have been discussed in an earlier report (Kumar et al., 1995) and in this report only isocon plots are presented in detail.

4.2 Trend of Trace Elements with Depth of Ground Water Table

During sampling of ground water, depth of ground water table was also measured from each location to see the general trend of variation of concentration with depth of ground water. Depth wise increasing and decreasing trends of different parameters are plotted and shown in Figs. 5.11 to 5.19. From the figures it can be seen that concentration of Cd and Co show increasing trend while other trace elements viz. Cu, Zn, Fe, Mn and Ni are inclined towards decreasing trend. This clears that toxicity is more in shallow ground water then deep ground water.

4.3 Vertical Distribution Diagram

Vertical distribution diagram is also a way of presentation for concentration of different water quality parameters. In the present case vertical distribution diagrams have been presented by considering the sampling sites on vertical axis and concentration of trace elements on horizontal axis. In the diagram, sites having similar concentration will have same identical shape and locations can

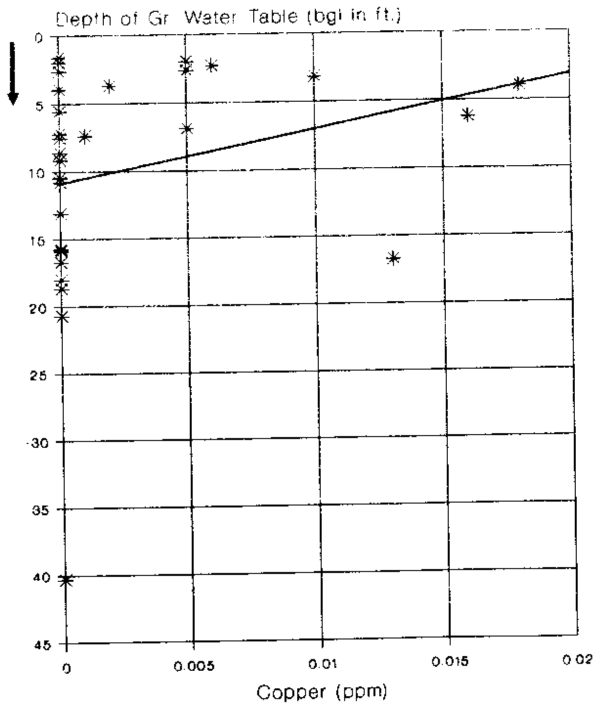

Fig.5.11 : Variation of Cu with depth of gr. water table

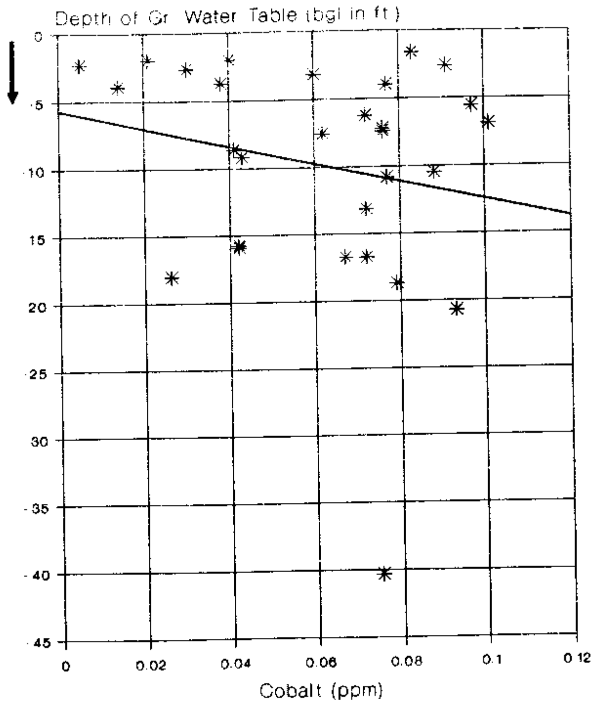

Fig.5.12 : Variation of Co with depth of gr. water table

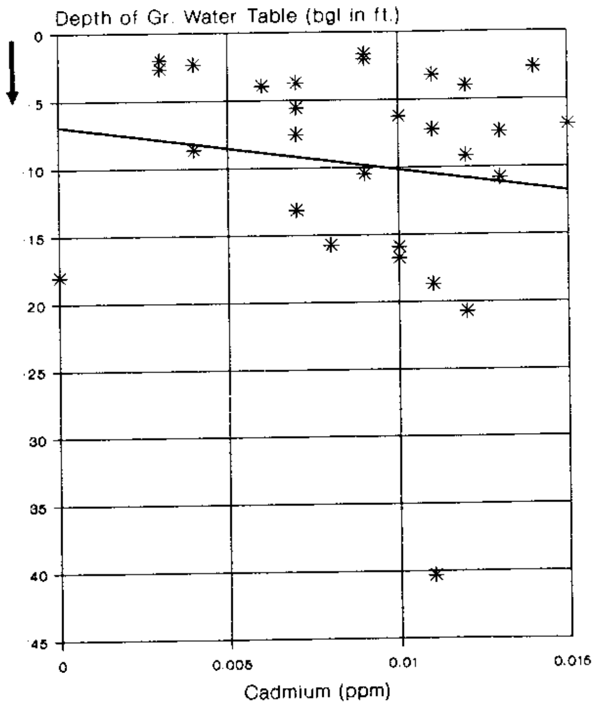

Fig.5.13 : Variation of Cd with depth of gr. water table

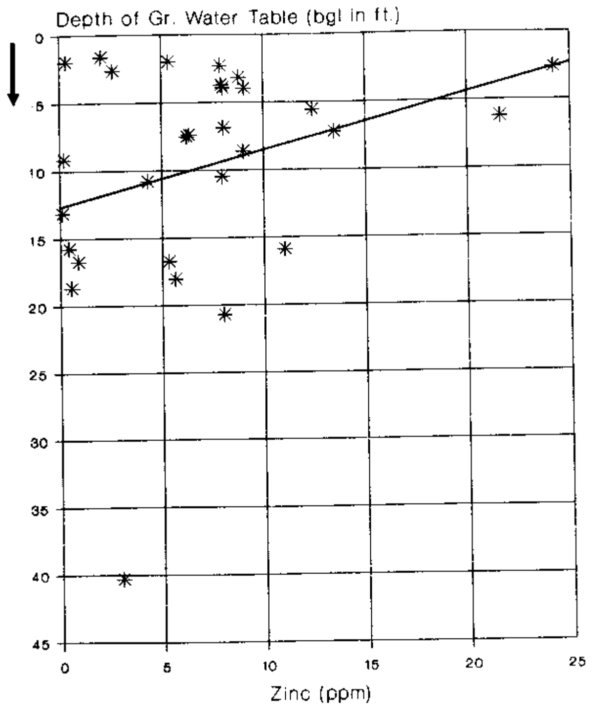

Fig.5.14 : Variation of Zn with depth of gr. water table

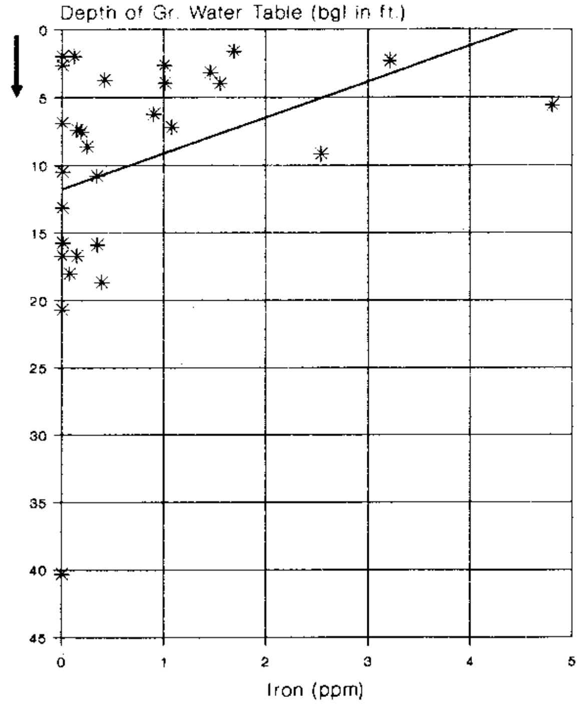

Fig.5.15 : Variation of Fe with depth of gr. water table

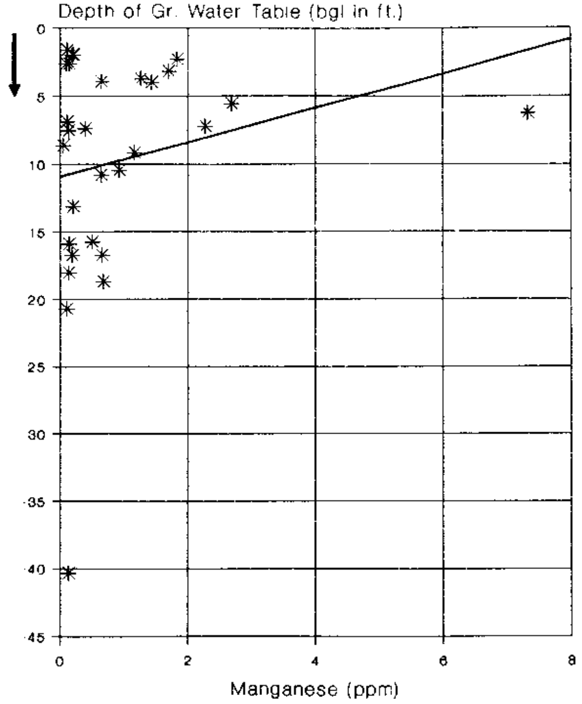

Fig.5.16 : Variation of Mn with depth of gr. water table

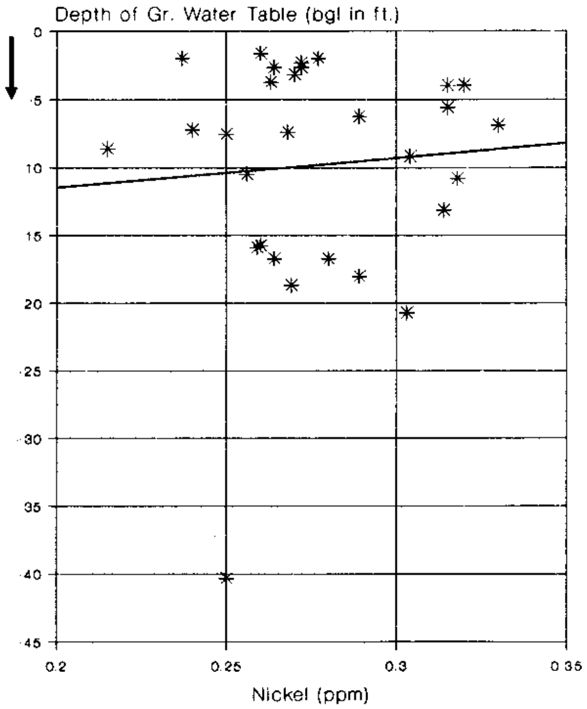

Fig 5.17 : Variation of Ni with depth of gr. water table

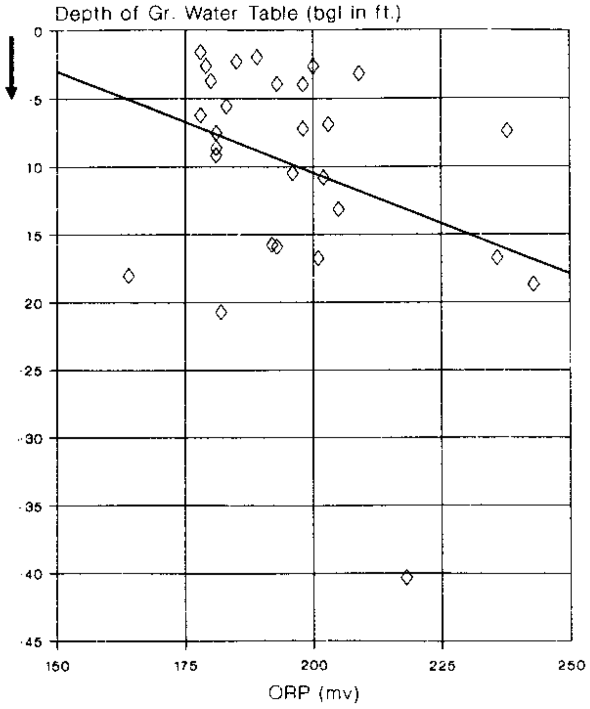

Fig.5.18 : Variation of ORP with depth of gr. water table

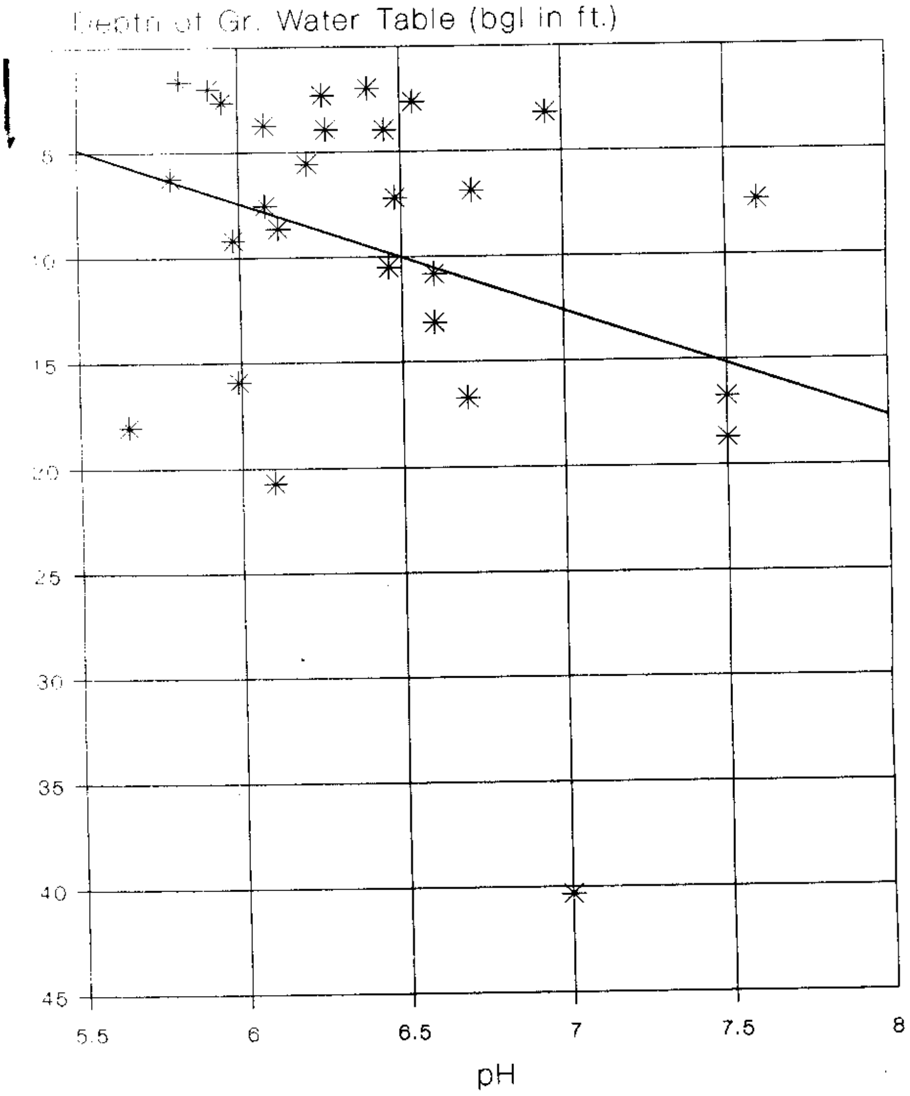

Fig.5.19 : Variation of pH with depth of gr. water table

be separately identified for same toxic problems on the basis of similar size and distribution very easily just like stiff pattern diagram for presentation of cations and anions. These diagrams are shown in figs. 5.20 to 5.29.

4.4 Thematic Maps

Water quality of ground water bodies in a region can be studied by plotting the results of analysis of water samples on maps and by means of lines of equal concentration of specific ions (i.e. contour lines). Using these techniques, areas of concentration of specific elements and problematic zones can be identified and corrective measures can be employed. The water quality maps may be shaded to identify areas of water having particular range of concentration. To see these advantages, variation of different trace elements in ground water of Guwahati area are presented in isocon form (Figs. 5.31 to 5.40). The prepared isocon maps projects the regional behaviors with areal extent of particular concentration zone in very simple visualize way. In that way any general public can know the quality of ground water and their behavior and effects on different applications in his locality with reference to concentration of different trace elements. From this technique areal extension of particular concentration can also be identified.

If this type of isocon maps will be clubbed together with other information of the study area like landuse map, soil type map, geological information map, climatological information, industrial or urban activities etc. using map overlays technique in GIS platform, will provide very useful tool for decision makers and management and modeling purposes also.

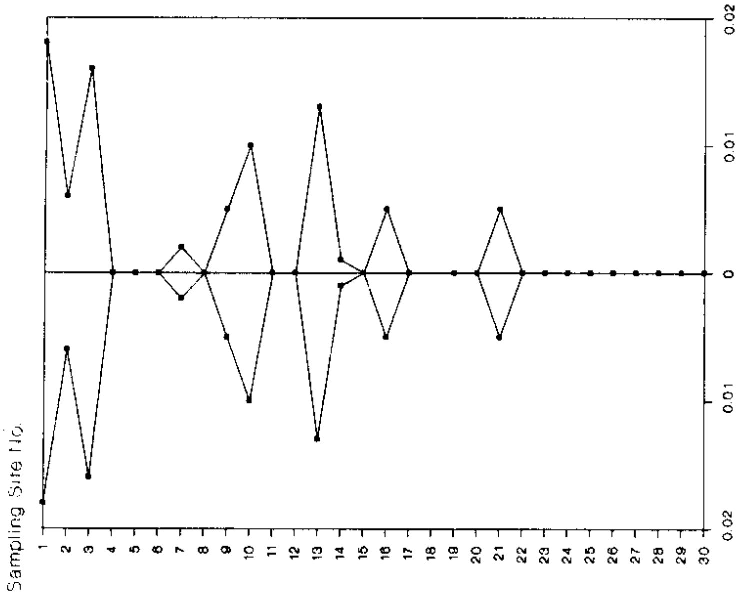

Fig.5.20 : Vertical distribution of Copper (ppm)

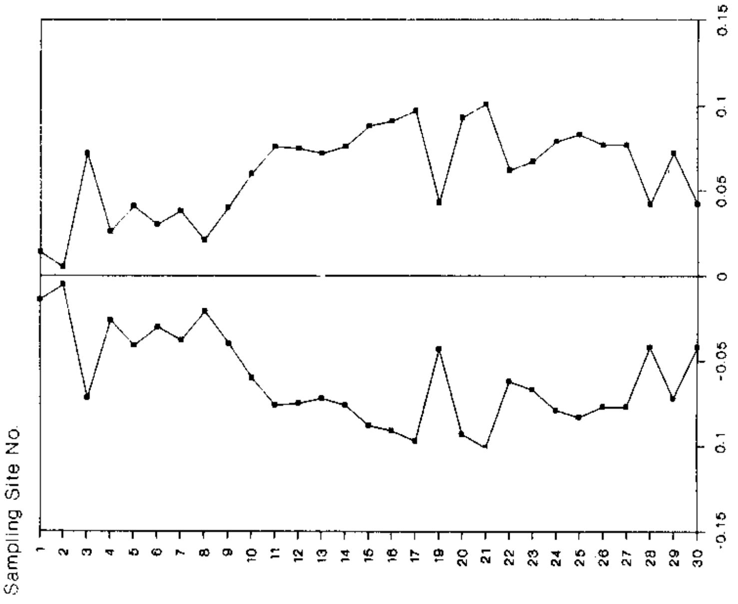

Fig.5.21 : Vertical distribution of Cobalt (ppm)

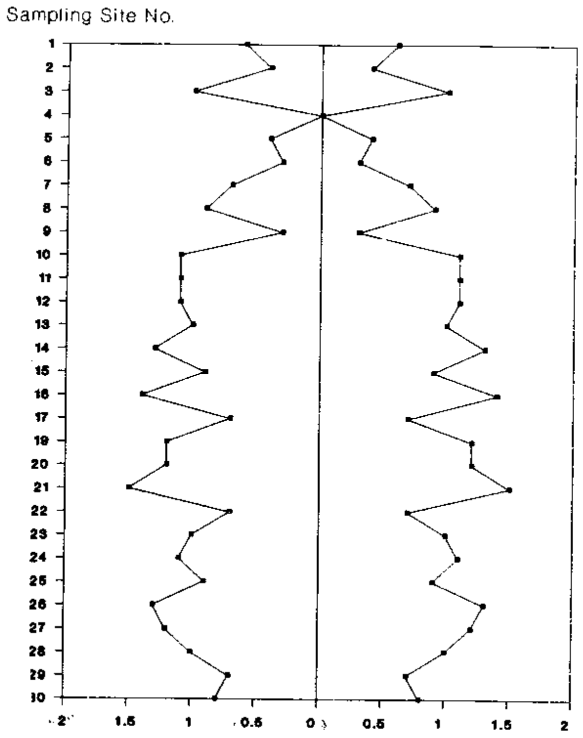

Fig.5.22 : Vertical distribution of Cadmium (ppm)

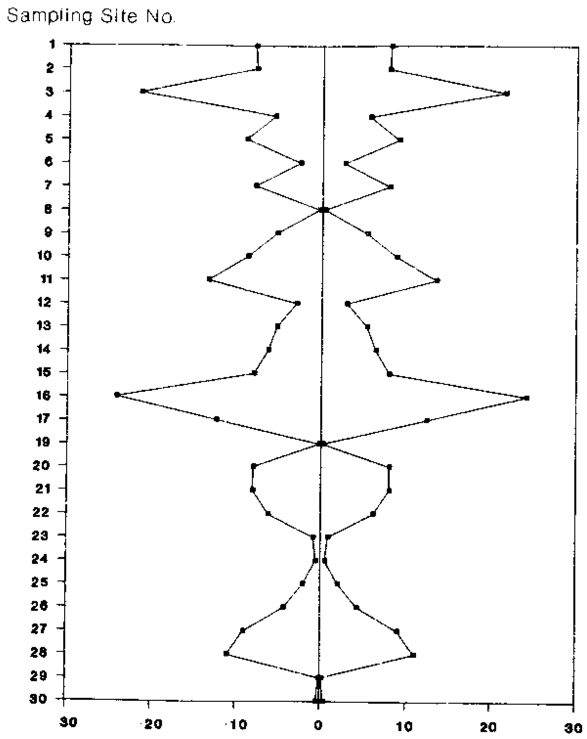

Fig.5.23 : Vertical distribution of Zinc (ppm)

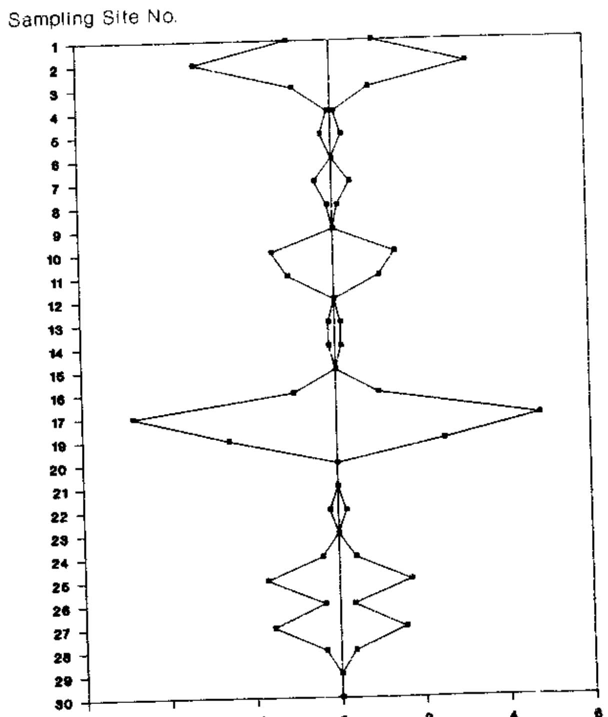

Fig.5.24 : Vertical distribution of Iron (ppm)

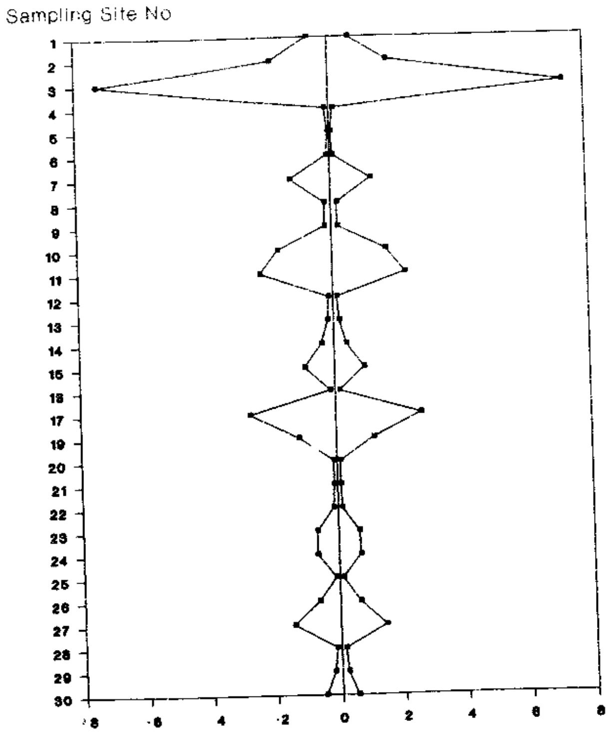

Fig.5.25 : Vertical distribution of Manganese (ppm)

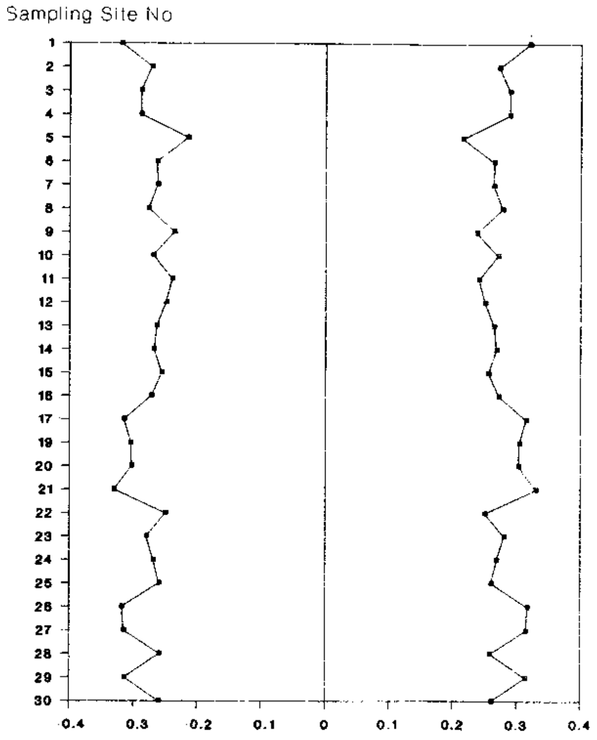

Fig.5.26 . Vertical distribution of Nickel (ppm)

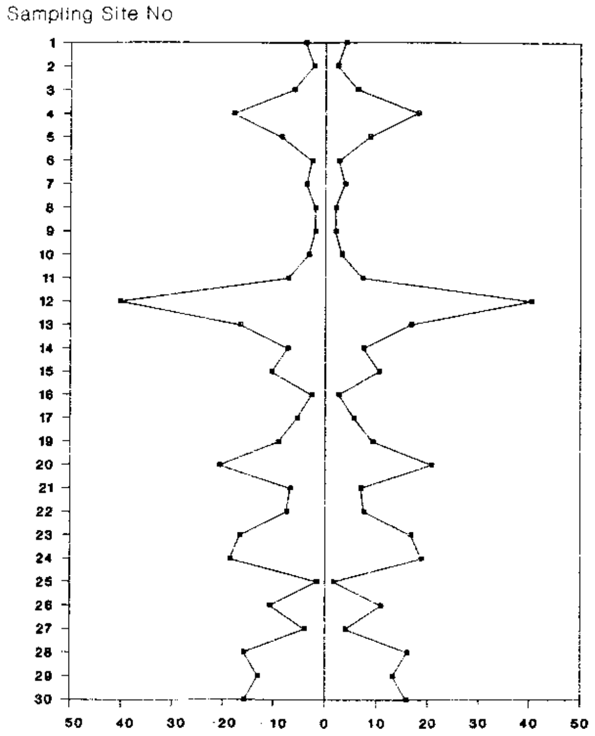

Fig.5.27 . Profile of Gr. Water Table (ft.bgl)

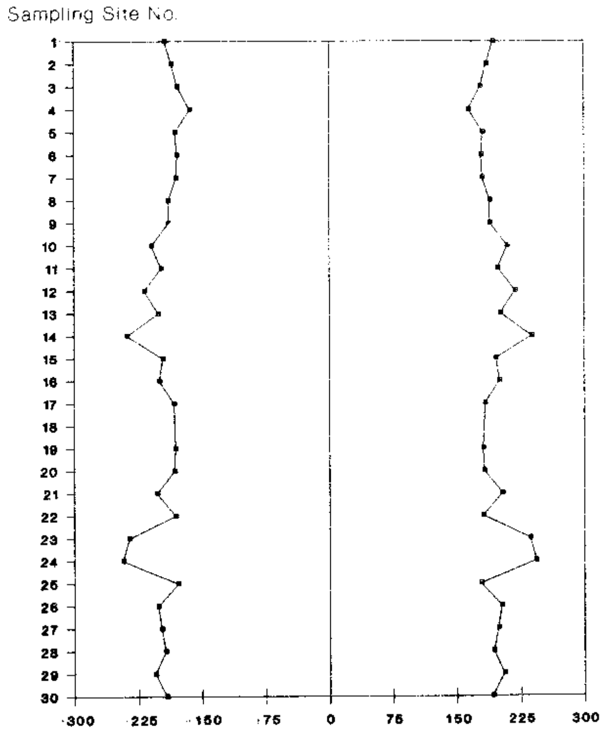

Fig.5.28 : Vertical distribution of ORP (mv)

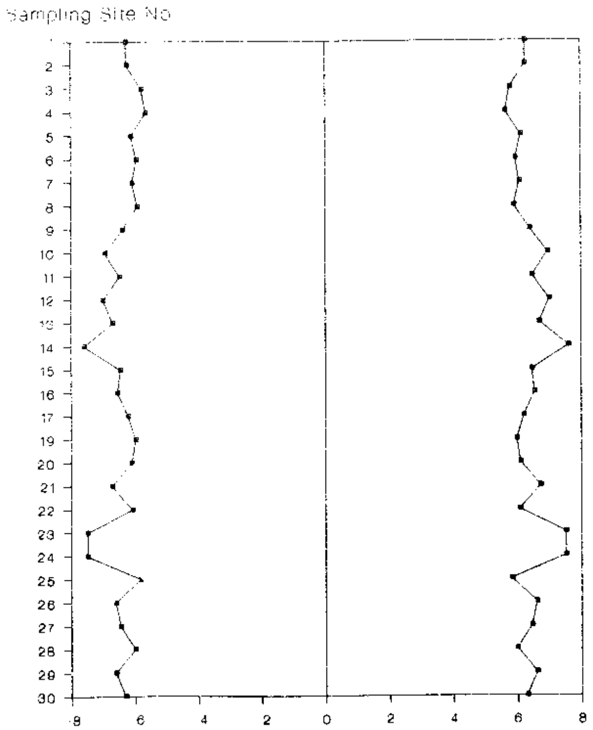

Fig.5.29 : Vertical distribution of pH

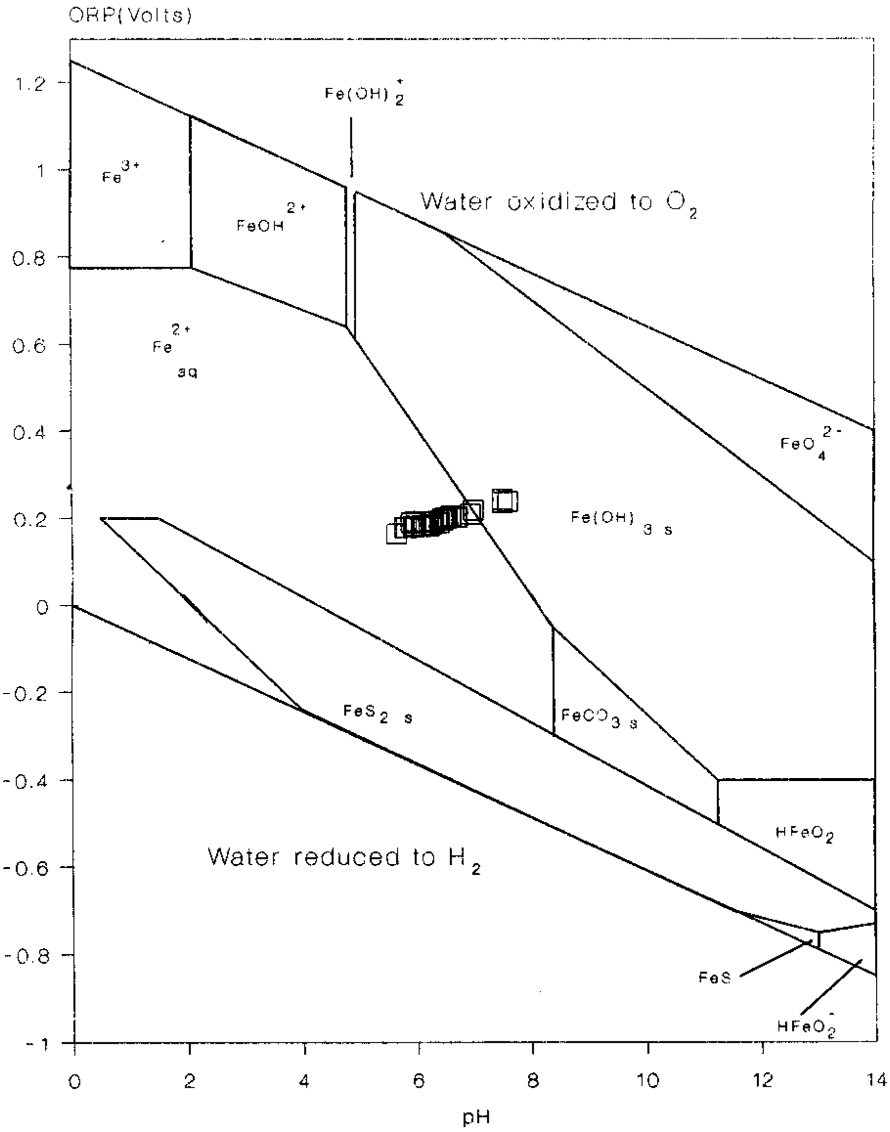

Fig.5.30 :Stability fields of Fe-CO2-S in pH & ORP Diagram

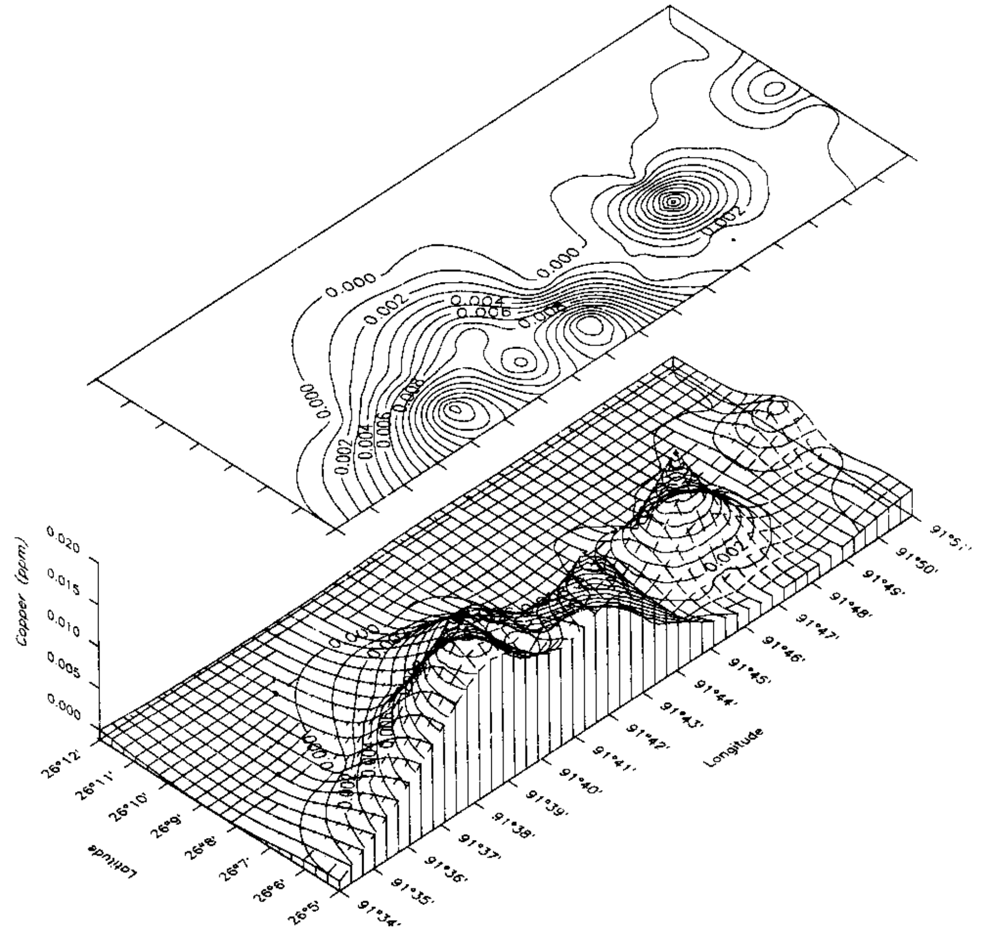

Fig. 5.31 : Isocon plots for variation of Copper (ppm) in ground water of Guwahati

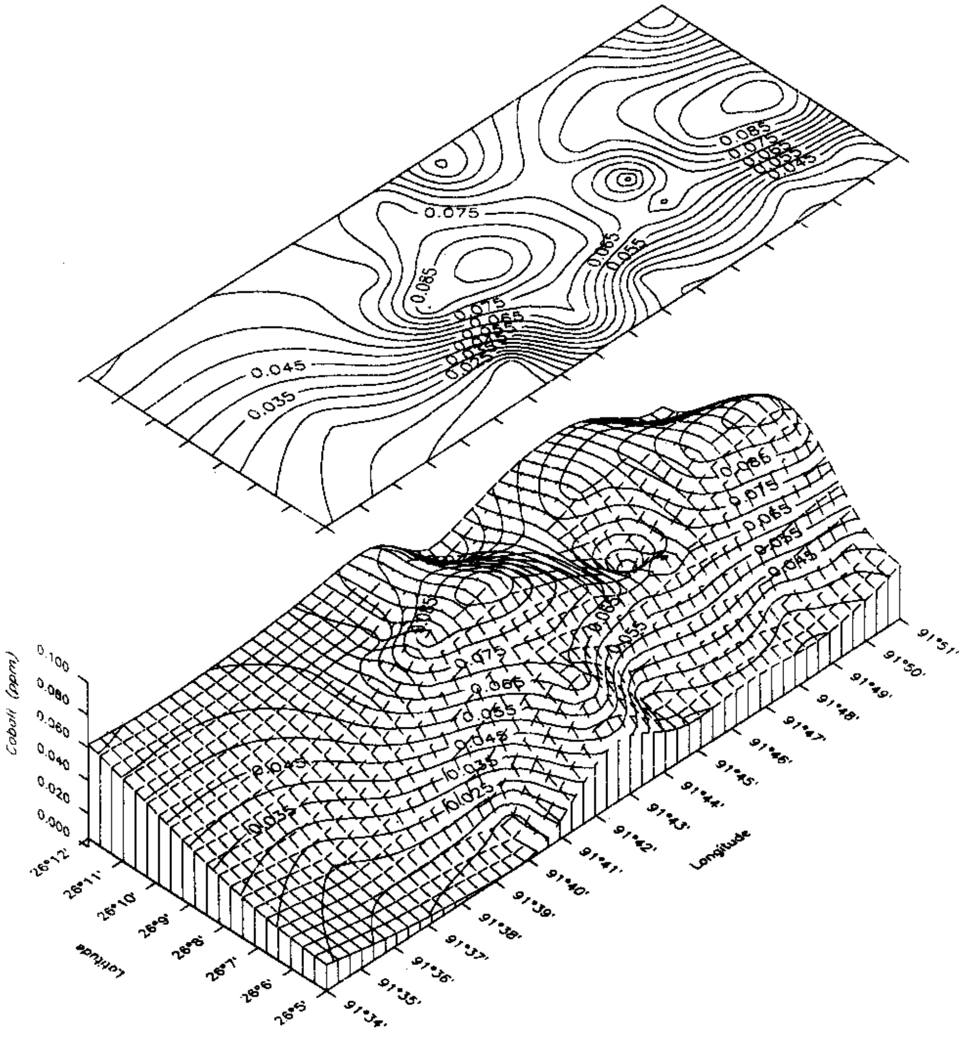

Fig. 5.32 : Isocon plots for variation of Cobalt (ppm) in ground water of Guwahati

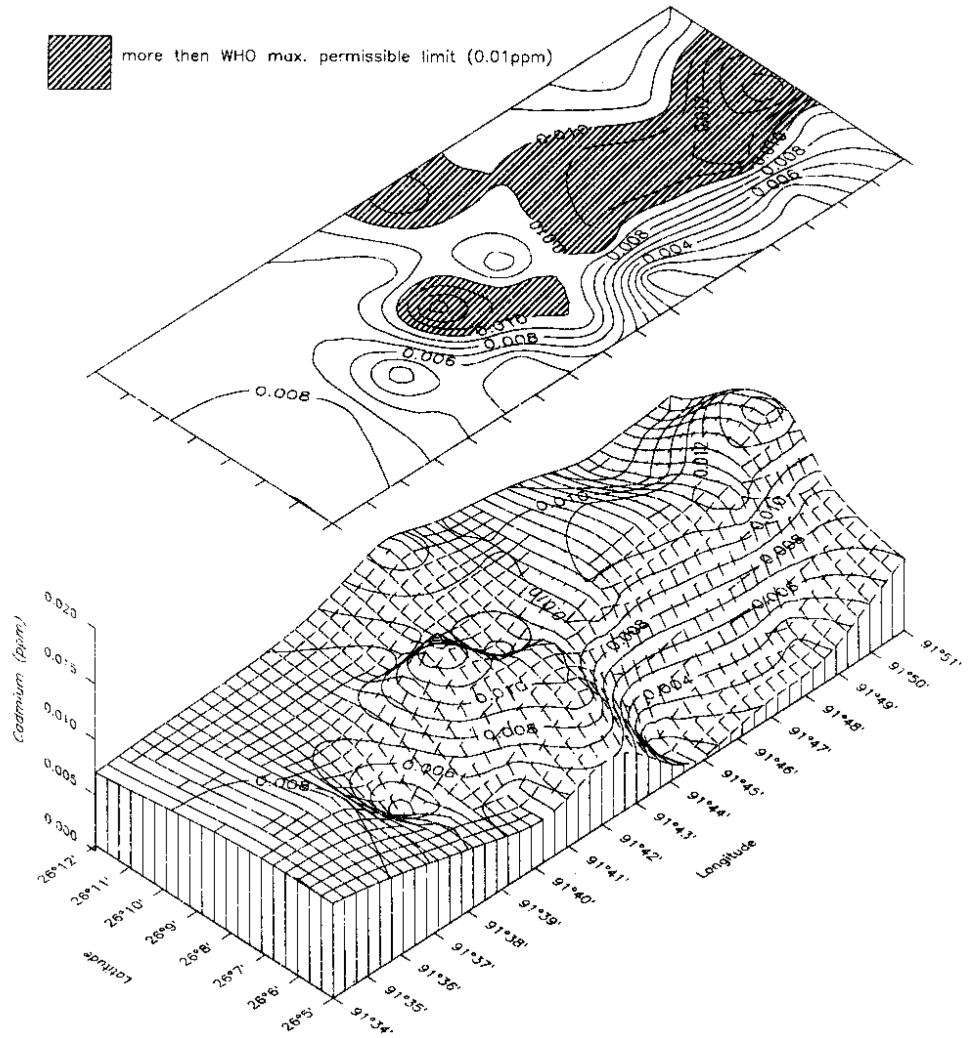

Fig. 5.33 : Isocon plots for variation of Cadmium (ppm) in ground water of Guwahati

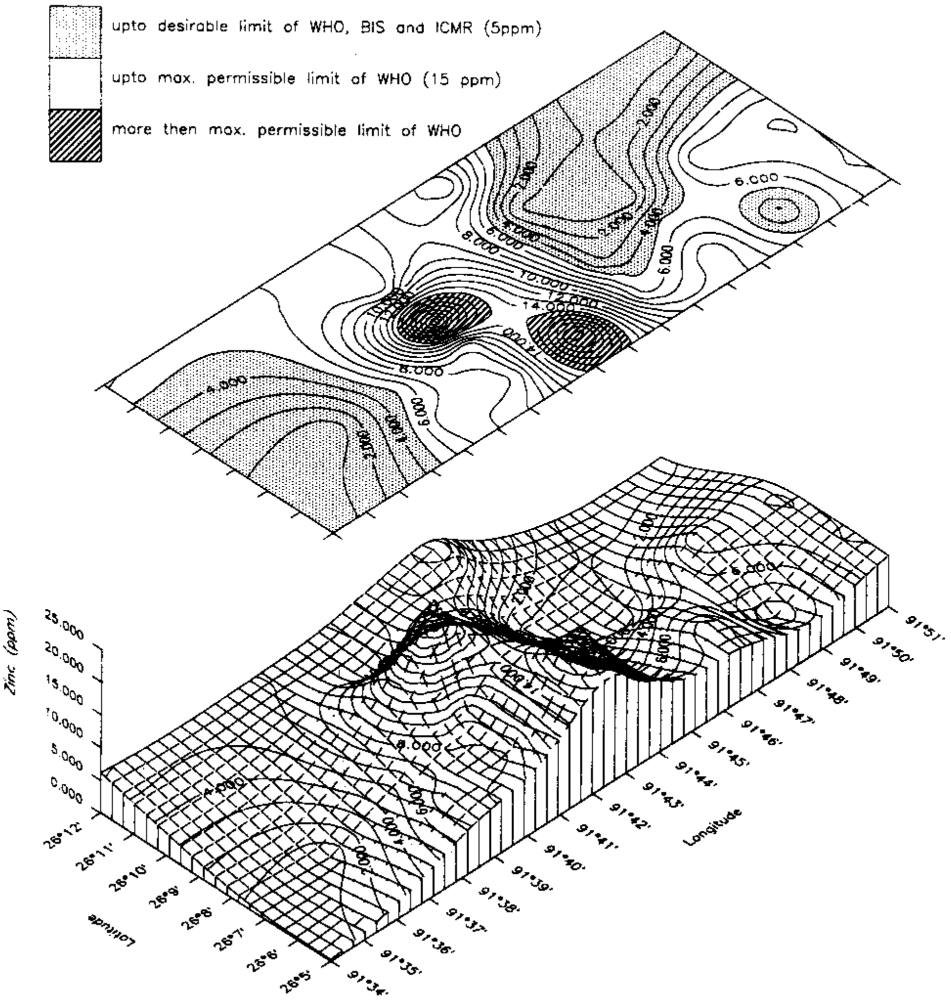

Fig. 5.34 : Isocon plots for variation of Zinc (ppm) in ground water of Guwahati

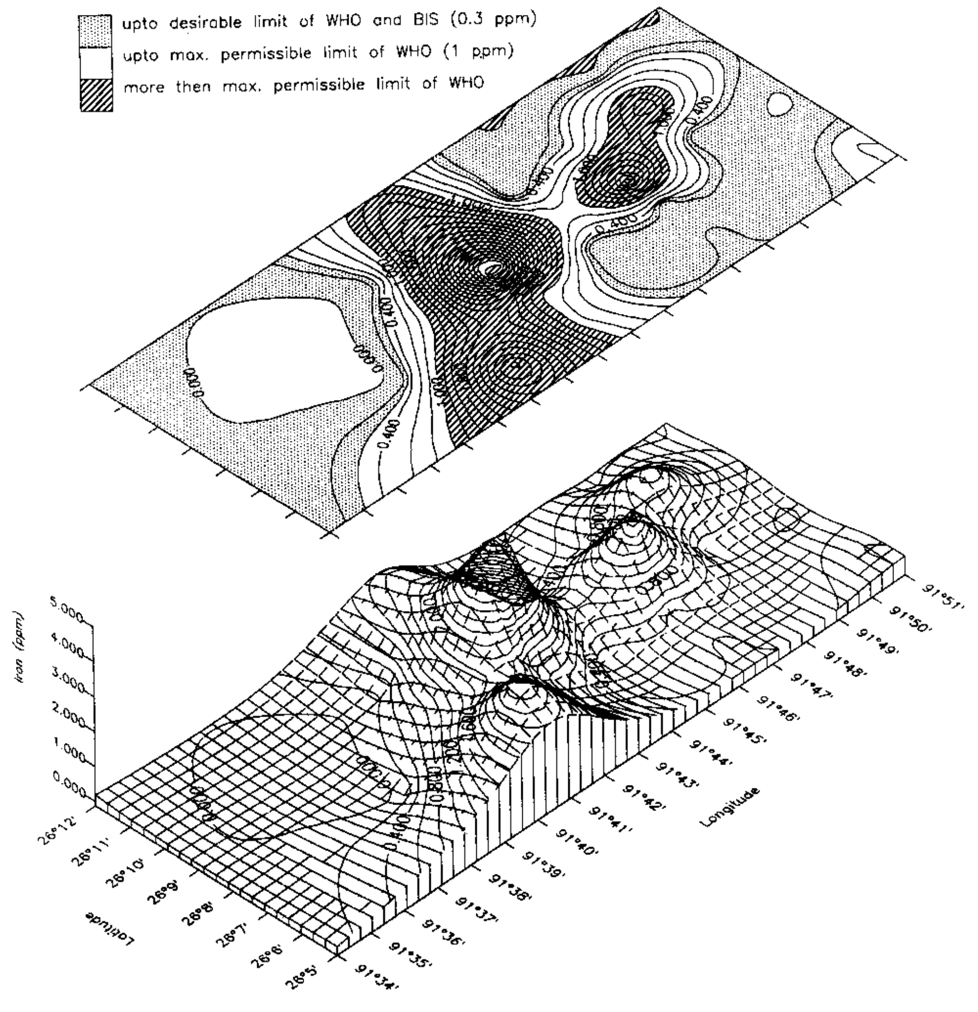

Fig. 5.35 : Isocon plots for variation of Iron (ppm) in ground water of Guwahati

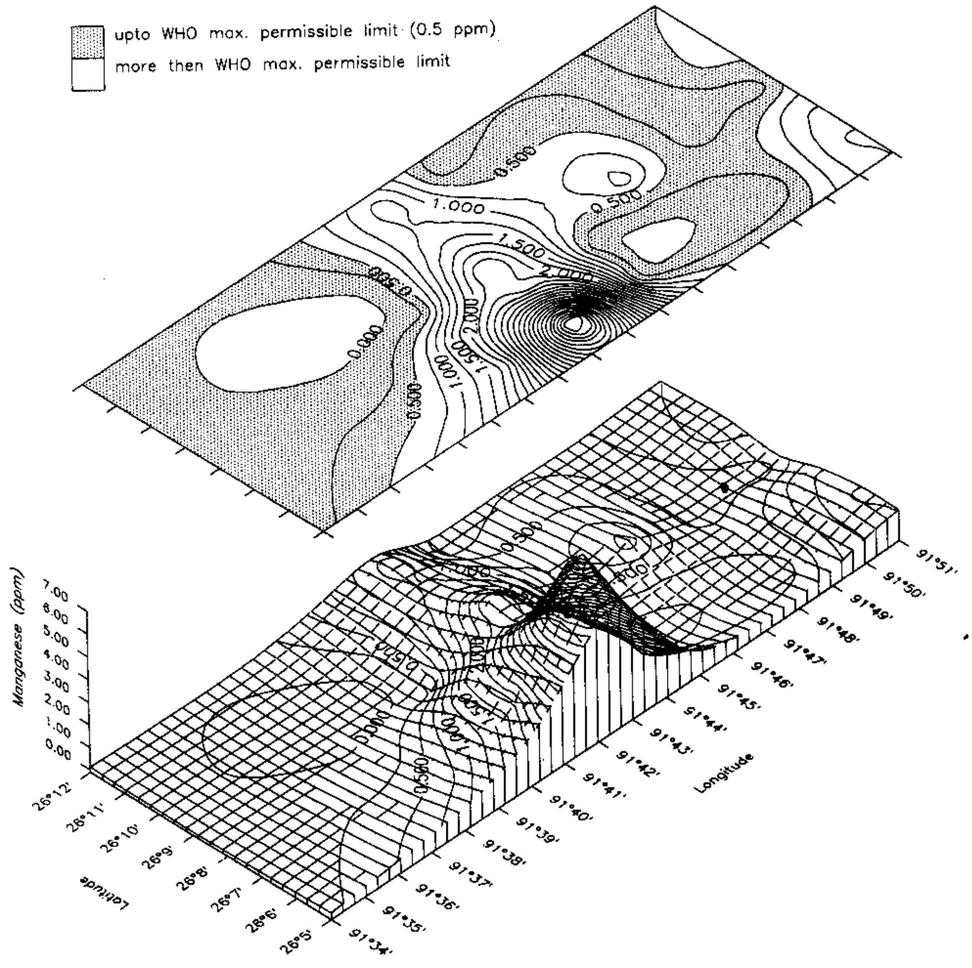

Fig. 5.36 : Isocon plots for variation of Manganese (ppm) in ground water of Guwahati

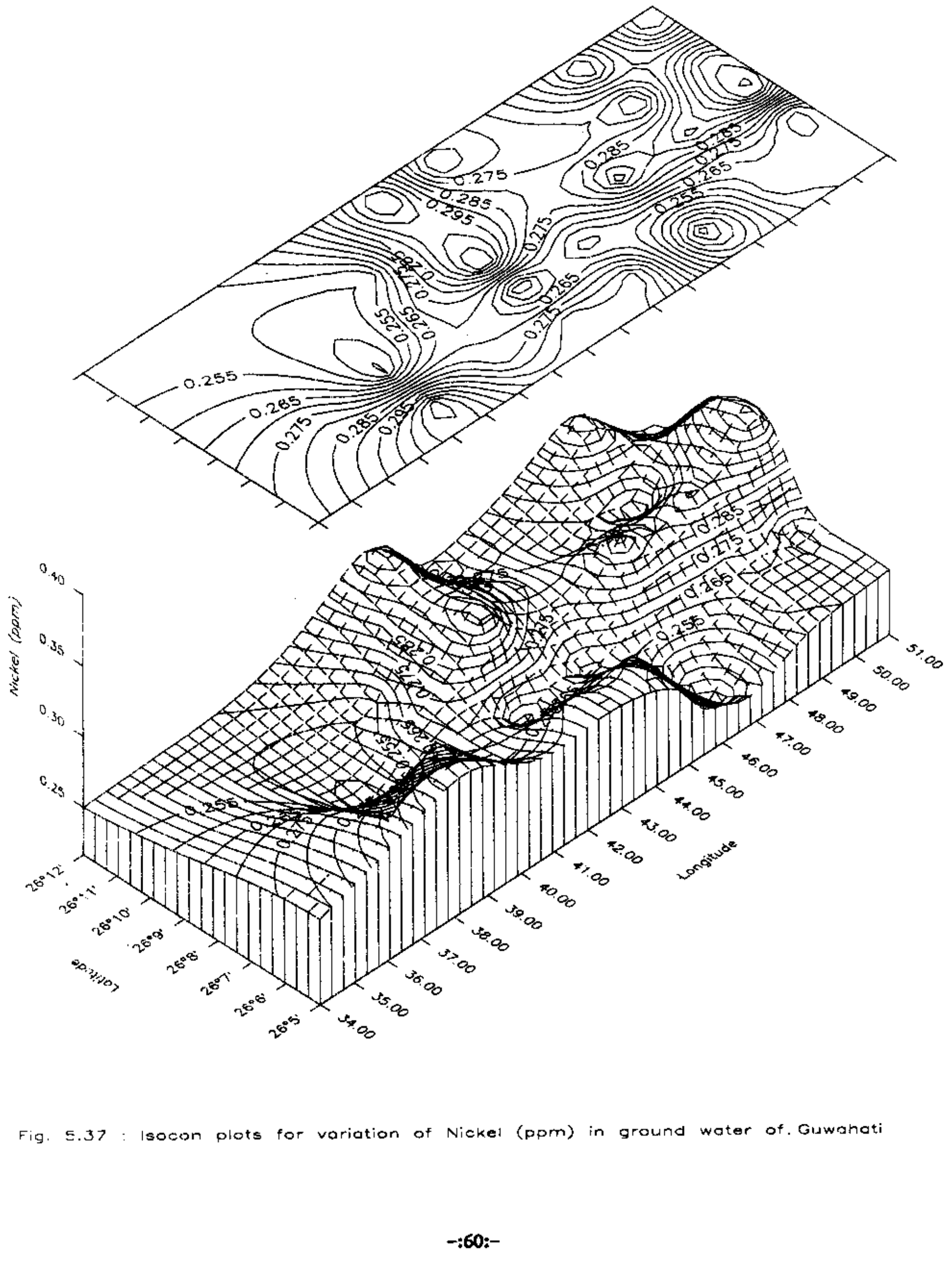

Fig. 5.37 : Isocon plots for variation of Nickel (ppm) in ground water of Guwahati

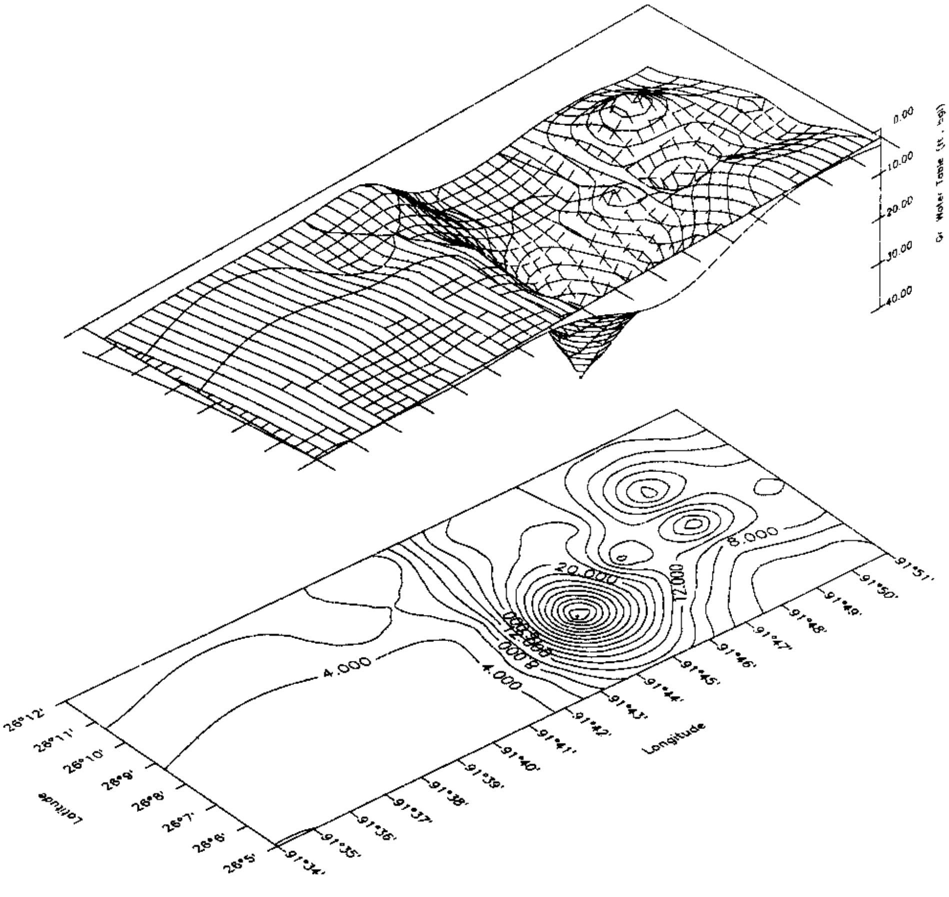

Fig. 5.38 : Isocon plots for variation of ground water table (ft.,bgl) in Guwahati

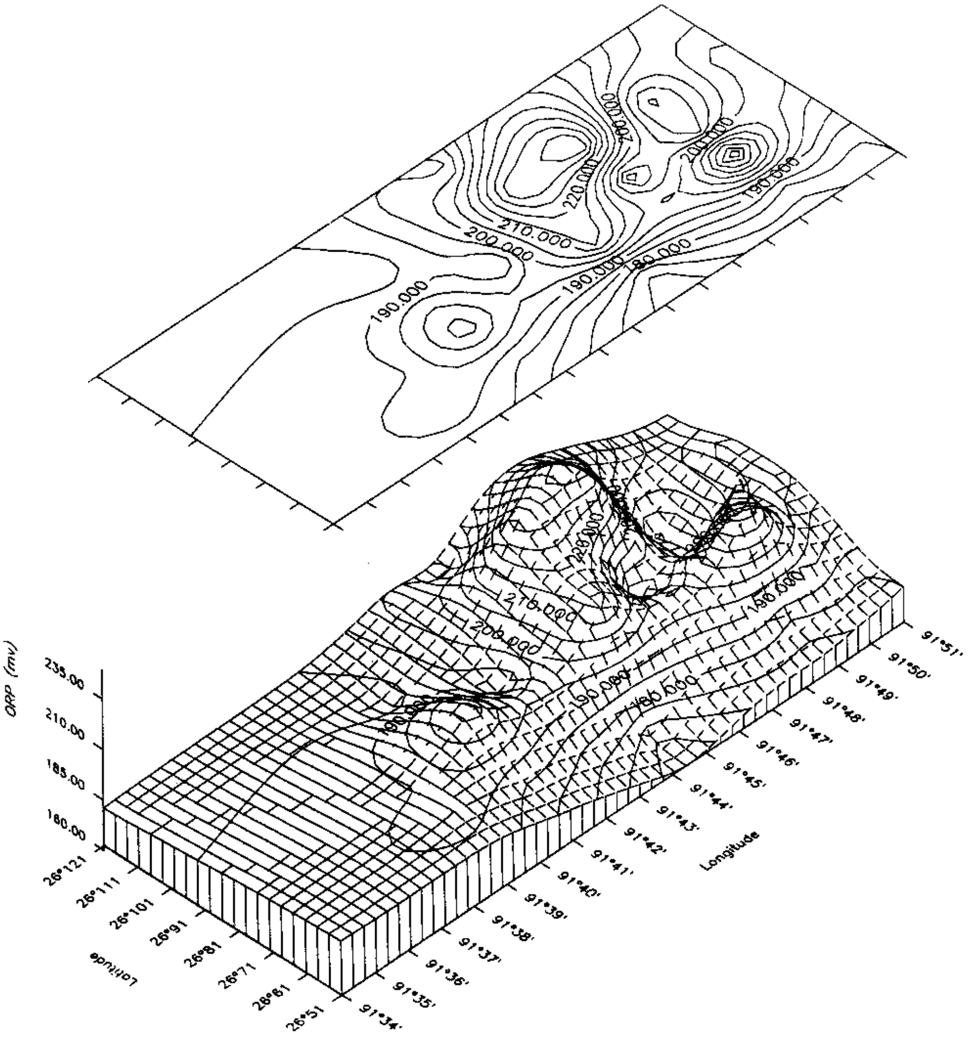

Fig. .5.39 : Isocon plots for variation of ORP (mv) in ground water of Guwahati

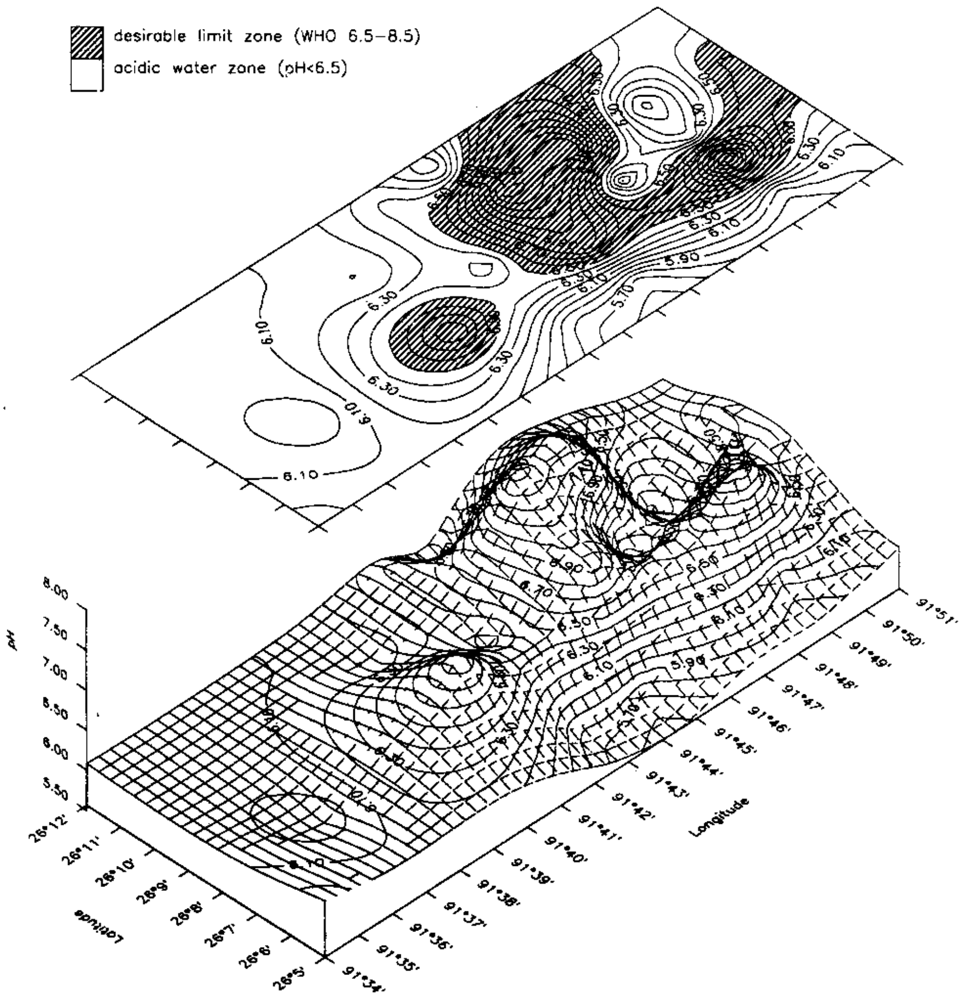

Fig. 5.40 : Isocon plot for variation of pH in ground water of Guwahati

5.0 CONCLUSIONS

The present work deals with the detection of trace elements contents viz. Cu, Co, Cd, Zn, Fe, Mn, Ni and Pb alongwith pH and ORP in ground water of Guwahati and its adjacent areas. The main objective of the study with respect to trace elements content in ground water of Guwahati was aimed at (i) to see the regional variation by means of isocon diagrams; (ii) to see the stable field of iron ion on pH-ORP diagram; (iv) to see the status of trace elements with fluctuation in ground water table; (v) to find out the similar concentration zones with the help of vertical distribution diagrams and (vi) to see the average status of ground water quality with the standards fixed by different agencies like WHO, BIS and ICMR for trace elements.

Enhanced levels of heavy metals in the aquatic environment cause concern because of :

- Possibility of accumulation of these metals in the human body and building-up with time to toxic levels.
- Bio-concentration/accumulation and magnification by aquatic organisms.
- Chronic and sub-lethal effects to organisms at low concentrations.
- Persistence in the environment with possibilities for environmental transformation into more toxic compounds.
- Possible intake through drinking water and aquatic food.
- Higher sensitivity of children for some of the heavy metals.
- Carcinogenic and teratogenic possibilities of some of the heavy metals and their compounds.
- Phytotoxicity of heavy metals.

Toxicity of a metal depends on its concentration which adversely affects any biological activity. The presence of such metals in natural water is a subject of serious concern. Natural water, which contains higher amount of trace elements, affects public health to a great extent if it is used for drinking and bathing purposes. The impact is generally cumulative, by which the prolonged use of such waters is dangerous for health. In most of the city localities of Guwahati, pipe water scheme is remain elusive as a pipe-dream and due to this reason groundwater is a favored source of potable water for city residents. Ground water forms the major source of water supply for domestic, irrigation and industrial purposes in Guwahati. In view of the results discussed in earlier chapter, it is concluded that the ground water of Guwahati area contains very high concentration of heavy metals viz. Cadmium, Zinc, Iron and Manganese. Lead is remain absent from all the sampling sites. This high concentration of heavy metals may be toxic to humans, animals, plants and aquatic life due to its alarming concentration. Further, it is concluded that the ground water can not sustain the disposal of industrial, municipal and other wastes any longer and they must be managed alternatively, so as to bring down the concentrations of toxic pollutants to safe limits. Prepared thematic maps of different trace elements for Guwahati will help for their acceptance limit of design criteria for different uses. Bad water quality zone can be detected very easily by clubbing other information like industrial activities, urban development, hydrological problems etc.

Heavy metals in general cause only local pollution problems. Environmental significance of these should be assessed in terms of the degree of toxicity and the extent of exploitation of the metal, its applications, and the consequent mobilization into the air, water and land. The water quality of the ground water varies from time to time and place to place, due to interaction of local factor. Here, the ground water is being used for drinking purposes by human beings, cattle's and wildlife. It is also a source of water for other purposes like domestic water supply, municipal water supply and agriculture etc. In order to evaluate the impact of heavy metals in the aquatic environments for further investigations are required on :

- The base line concentrations of heavy metals in different locations.
- Inputs of heavy metals into the aquatic system through various sources.
- Extensive monitoring of likely contaminated areas.
- Speciation of trace metals.
- Interaction of trace metals.
- Sub-lethal effects on organisms.
- Safe recipient capacity.

Maintaining the quality of water with respect to trace elements is the most important one for the existence of human being. So it is essential to evaluate the quality of drinking water systematically. A regular monitoring of drinking water sources with respect to trace elements not only prevents diseases and hazards but also checks the water resources from going further polluted.

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Annexure - I

Drinking Water Quality Standards for Trace Elements [As per ICMR (1975)]

S.No.	Toxic Metals	Acceptable Limit	Rejection
1.	Iron as Fe	0.1	1.0
2.	Manganese as Mn	0.05	0.5
3.	Copper as Cu	0.05	1.5
4.	Zinc as Zn	5	15
5.	Arsenic as As	0.05	0.05
6.	Cadmium as Cd	0.01	0.01
7.	Chromium as Hexavalent Cr.	0.05	0.05
8.	Lead as Pb	0.1	0.1
9.	Selenium as Se	0.01	0.01
10.	Mercury as Hg	0.001	0.001

Drinking Water Quality Standards for Trace Elements [As per WHO (1971)]

S.No.	Toxic Metals	Highest Desirable	Maximum Permissible
1.	Iron as Fe	0.1	1
2.	Manganese as Mn	0.05	0.5
3.	Copper as Cu	0.05	1
4.	Zinc as Zn	5	15
5.	Arsenic as As	----	0.05
6.	Cadmium as Cd	----	0.01
7.	Chromium as Hexavalent Cr.	----	0.05
8.	Lead as Pb	----	0.1
9.	Selenium as Se	----	0.01
10.	Mercury as Hg	----	0.001

Drinking Water Quality Standards for Trace Elements (BIS, 1983)

S.No.	Toxic Metals	Desirable Limit
1.	Iron as Fe	0.3
2.	Manganese as Mn	0.1
3.	Copper as Cu	0.05
4.	Zinc as Zn	5.0
5.	Arsenic as As	0.05
6.	Cadmium as Cd	0.01
7.	Chromium as Hexavalent Cr.	0.05
8.	Lead as Pb	0.1
9.	Selenium as Se	0.01
10.	Mercury as Hg	0.001

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ACKNOWLEDGEMENTS

While completing this part of the report acknowledgement is due to Sh. P K Sarkar (RA) and Sh. D M Rangan (Tech-III) for their help in water sampling.