Chapter 1

INTRODUCTION

The significance of environmental soil and water quality issues has been increasingly recognised over the last few decades. The modern civilization, industrialization, urbanization and increase in population have led fast degradation of our soil and water resources. Thus, the need for soil and water quality monitoring at a global level grows and increases exponentially as land and water use intensifies. India is also currently facing critical soil and water quality problems. As such, the need is for a more systematic and careful study eliminating all possible sources of error and to build up a reliable database.

In this chapter, a short review of existing literature on soil and water quality, broad objectives of the research problem, scope and purpose of the study are presented.

1.1 Review of Literature

The growth of literature and database on soil and water chemistry has been really tremendous during the last several years. Current literature available on soil and water quality tends to be conceptual, analytical, or prescriptive in terms of standard setting. An exhaustive literature survey is a near impossible task and, therefore, only a sample of the published literature, having relevance directly and indirectly to our research work has been given here.

1.1.1 Soil quality

The impetus to define and assess soil quality is in many ways derived from outside the scientific community, being related to the concern of society with the overall quality or health of the environment. Thus, the onus is placed on the soil scientist or land manager to characterise and define soil quality. However, this can pose a major difficulty in that while water and air quality can be readily defined in regard to human and animal consumption, a similar scenario does not apply to soil. Soil, as a living system, is a fundamental resource with various functions and only indirectly influences human or animal health. Thus, soil is one of the most important components of the earth's biosphere and is indispensable for the continued existence of life on the planet. Interest in assigning quality to soil has been an ongoing concern of scientists and land managers for many years. Early concerns were mainly expressed in the need to rate soils for their suitability for crop growth and other uses. Presently, evaluation of the quality and health of our soil resources has been stimulated by increasing awareness that soil functions not only in the production of food and fiber but also in ecosystems function and the maintenance of local, regional, and global environmental quality (Glanz, J.T., 1995). The quality and health of soils determine agricultural sustainability (Acton and Gregorich, 1995), environmental quality (Pierzynski *et al.*, 1994), and, as a consequence of both, plant, animal, and human health (Haberern, 1992). Like water, soil is a vital natural resource essential to civilisation but, unlike water, soil is non-renewable on a human time scale (Jenny, 1980).

1.1.1.1 Defining soil quality

A simple definition of soil quality could be 'fitness for use'. However, definitions of soil quality have been subjected to an ongoing development. Anderson and Gregorich (1984) proposed that soil quality be defined as *"the sustained capability of a soil to accept, store and recycle water, nutrients and energy"*. However, agriculture is now regarded as part of a much broader ecological system, which interacts with, and affects other various parts of the system. This development is expressed in the expanded concept of soil quality evident in the work of Larson and Pierce (1994). They define soil quality *"as the capacity of a soil to function within its ecosystem boundaries and interact positively with the environment external to that ecosystem".* According to the definition soil serves other functions both within and beyond agricultural ecosystems. Soil quality is also defined as "the capacity of a soil to sustain biological production, maintain environmental quality, and promote plant and animal health" (Cameron, 1995). So, soil quality may be categorised into chemical, physical and biological components. A more detailed definition has been developed by the Soil Science Society of America (1995) as follows: *"Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation."* which is similar to that of Doran *et al.*, (1996) where soil quality is the *"capacity of a soil to function, within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal and human health".* A soil is not considered "healthy" if it is managed for short-term productivity at the expense of future degradation (Doran *et al.*, 1998). For healthy growth of plants, it is necessary that all the requirements of plants be met effectively.

1.1.1.2 Soil as a nutrient store

Plant requirements for nutrients such as N, S, P, K and trace elements are met wholly or in part by mineralisation of organic matter (Allison, 1973) in natural ecosystems. Soil organic matter act as a massive nutrient reserve as the nutrients are accumulated there. A soil with 1% organic C in the top 0-10 cm will contain about 1200 kg of organic N per ha. Biological nitrogen fixation accumulates this N of which subsequent decomposition by soil micro organisms incorporates it into the soil organic reserve. Biological processes also mineralise the organic reserves to plant-available inorganic forms. Over one year, some 1-5% of the organic N will typically mineralise, so a soil with 1200 kg N will provide around 50 kg inorganic N/ha. In a wheat-legume rotation in Australia about one third to one half of the annual nitrogen requirement of a cereal crop is met from organic matter reserves (Angus, 1992). To maintain production where yields are N limited, any depletion of the N reserve will need to be substituted by fertiliser.

Nutrient supply can be encapsulated in the Quantity-Intensity concept (Schofield, 1955). This concept recognises three supply attributes: quantity, intensity and buffer capacity. Although the availability of all the essential nutrients can be described in terms of quantity, intensity and buffer capacity, different processes govern these attributes for different nutrients. These processes can be mainly microbially-driven [as for nitrogen (N)], or thermodynamically-driven [as for phosphorus (P) and the cationic macronutrients].Whereas intensity can be undestood as the activity of nitrate plus ammonium in the soil solution for N, and the activity of orthophosphate in the soil solution for P, the meaning of quantity and buffer capacity of these nutrients is not as unequivocal. Quantity of N is the potential amount of organic N which can be mineralised during the growing season. Quantity of P is the amount of P adsorbed on surfaces which is capable of desorbing into the soil solution in response to a lowering of the activity of orthophosphate in the soil solution due to plant uptake. Apart from an adequate quantity of organic N being present for potential mineralisation, other conditions must be satisfied for a soil to supply sufficient N during the crop cycle. Loss processes of volatilisation and denitrification must be minimal, the organic matter must have a low C/N ratio to prevent immobilisation, and must be of a chemical composition which is amenable to microbial decomposition. These last two factors can be thought of as the buffer capacity term for N. To supply sufficient P, the soil requires a large pool of surface-adsorbed P which is readily released into the soil solution. To supply sufficient cationic macronutrients, the activity ratio of each cation (i.e. activity of the cation/ sum of the activities of all cations in the soil solution) must be optimal, and there must be a sufficient quantity of the cation on the exchange complex (or in soluble soil minerals) to supply the quantity of nutrient required. It is apparent from the above that to assess the ability of a soil to adequately supply each nutrient, different soil chemical analyses will be required; there is no universal soil test capable of assessing the ability of the soil to "store and gradually release nutrients." The sufficiency, or otherwise, of each nutrient will need to be assessed individually, an impractical proposition for defining chemical quality.

1.1.1.3 Contamination of soil

Throughout much of the twentieth century there has been very little concern about soil quality. In part, this has been because we have had a resource which whilst not infinite has not, until recently been considered scarce. In addition, in contrast to the other key components of the environmental system, air and water, there are few immediate public perceptions that the quality of the soil is declining. With respect to air there has been public outcry when, as a result of pollution through the combustion of fossil fuels, the air quality is such that the population have suffered respiratory problems, and similarly with water, when the water has proved to be unfit for human consumption or the aquatic life has been killed, there has been publicly expressed concern. This 'visual' evidence for changes in air and water quality has lead to widescale public concern, and in many countries this has lead to 'health related' standards for air and water, on the basis of 'fit to breath' and 'fit to drink' criteria. With the soil there has been few such 'visual' indicators, perhaps the most widely observed by the general public is that of soil erosion, and in some cases this has possibly lead to an over emphasis on indicators of soil quality linked to erosion. A further problem with the soil is that these changes often take place gradually and it may be difficult to observe differences except over timescales of tens of years. The current concern with soil quality has arisen from two broad sources, the concern with land that has been contaminated by what might be broadly described as our industrial and agricultural activities, the concern to view our land use activities in the long term, and in particular to assess whether these activities are sustainable.

Addressing the problem of contaminated land has provided much of the focus for recent developments in the standardisation of methods of soil analysis for the assessment of soil quality and the setting of soil quality reference or indicator values. The setting of these standards has raised many problems, both for the soil scientists and for the legislators, in part these problems have arisen because the soil is such a diverse material consisting of varying proportions of mineral material, organic material, water and air (Shepherd *et al.*, 1992). The interactions between these materials are complex and the nature of these interactions must be considered in the development of reference values. It is often the case that even where indicator or reference values are given for particular soil quality levels these are difficult to use because of the poor or incomplete definition of the methods to be used in the analysis of the soil. For example within the United Kingdom the Interdepartmental Committee on Redevelopment of Contaminated Land (ICRCL) of the Department of the Environment produced a set of 'Trigger Concentrations' in 1983 and revised in 1987 (ICRCL, 1987) which attempted to set 'action values' for potentially contaminated land. The Netherlands produced a similar set of guidelines in 1983 (Moen *et al.*, 1986; Moen, 1988) which provide a development on the concept of 'trigger concentrations'.

An estimate (1990) showed that 10% of the fertile soil of the planet has been transferred by human activities from forest into deserts, while 25% or more is at risk (Reid, 1998). Municipal waste water containing significant loadings of heavy metals will cause a rise of heavy metal content in the soil, especially the topsoil, as has been documented for the Werribee Sewage Farm (Johnson *et al.*, 1974; Evans *et al.*, 1978).

On this farm pastures on heavy clay soils with slightly acid to alkaline reaction had been irrigated with sewage for up to 73 years at the time Johnson *et al.*, (1974) investigated the soils. Taking total soil lead concentrations as an example, they found that in the upper 2.5 cm the total Pb concentration was up to six times higher than in a control (non-irrigated) soil (44 mg/kg), but at 25-45 cm depth there was no great difference between the irrigated and non-irrigated soil. Similarly, cadmium had increased more than 3-fold in the upper 2.5 cm from the control (0.17 mg/kg), and only slightly at 25-45 cm depth. Soil phosphate showed a similar trend. Evans *et al.*, (1978) show heavy metal concentration profiles in the soils of Werribee which mostly illustrate the tendency for the soil to immobilise the heavy metals in the top 20 or 30 cm. Intensive agricultural practice with continuous negligence of nutrient replenishment has led to depletion of the fertility of soils in most parts of India. But unfortunately, much less is known about the fertility status and management of the soils in North Eastern India. Available literature shows that the long-term exploitation of soil under the tea gardens in Assam has led to impoverishment of soil fertility and stabilization of yields, despite increasing application of external inputs such as fertilizers and pesticides (Bhuyan & Sarma, 2006; Dutta *et al.*, 2008, 2009).

1.1.1.4 Buffering of toxicants by soil

Excessively acidic, saline, sodic, mineralised and anthropogenically contaminated (generally with heavy metals or pesticides) soils are likely to have toxic effects on plant growth. The diagnosis of the first three limitations to plant growth can conveniently be achieved by the use of the indicators of pH and electrical conductivity (EC), both of which are intensity measurements. Soil solution pH measures the activity of the hydrogen ion (and, by inference in mineral soils, aluminium activity), and diagnoses excessively acidic soils. Electrical conductivity is a measure of cumulative ion activity, and combined with pH, diagnoses saline and alkaline sodic soils. Remediation of acidic, saline, or sodic conditions is assisted by the soil having a low buffer capacity. Thus, a low pH buffer capacity means that only small additions of lime will be required to ameliorate aluminium or manganese toxicity in an excessively acidic soil. Buffer capacity with respect to pH is determined by organic matter content, clay content, and change in EC with change in pH (Aitken *et al.*, 1990). Likewise, a soil with a low cation buffer capacity (as reflected by a low EC) will require less gypsum for the correction of sodicity than one of high EC, because the extent of the cation exchange surfaces in the soil governs the size of the reservoir of exchangeable sodium. Unless soil is from a recognised contaminated or mineralised site, it is unlikely to have a pre-existing heavy metal (cadmium, zinc, arsenic, chromium) toxicity problem, although there may be concern about the levels of Cd in soils with a long history of P fertiliser application (eg. Horticultural soils).Soils in urban and peri-urban locations are increasingly being considered for use as recipients of heavy metal wastes, and where the soil is expected to fulfil this function, a high buffer capacity for the particular heavy metal/s is required. This enables large amounts of contaminants to be added to the soil without causing unacceptable increases in the concentration (i.e. the intensity) of the contaminant in the soil solution. As in the case of the other toxic conditions, the buffer capacity of the soil for the toxic element is the key factor in determining the quality of the soil. Buffer capacity with respect to heavy metals depends on the particular element, but soil pH, organic matter content, EC, and clay content can be considered to be the major factors (Alloway, 1990).

1.1.1.5 Evaluation of soil quality

Soil quality is evaluated separately for each individual soil using soil quality indicators that reflect changes in the capacity of the soil to function. Useful indicators are those that are sensitive to change, and change in response to management. The type and number of indicators used depends on the scale of the evaluation (i.e., field, farm, watershed, or region) and the soil functions of interest. For example, changes in soil organic matter, including active organic carbon or particulate soil organic matter, may indicate changes in productivity. Increased bulk density may reflect limits to root growth, seedling emergence, and water infiltration. Measurements of indicators can be made with simple to somewhat complex field tests, or sophisticated laboratory analyses. To evaluate soil quality, indicators can be assessed at one point in time or monitored over time to establish trends. Soil quality can only be assessed by measuring properties and, therefore, involves both an observer and an interpreter. The range of observers, from individuals to interest groups to society as a whole, and the concomitant range in their value systems, ensures diverse views on soil function and, consequently, measures of soil quality. Linked with this is recognition of the intrinsic value of soil due to it irreplacability and uniqueness, and the idea of a relationship between people and soil (Warkentin, 1995).

An assessment provides information about the current functional status or quality of the soil. Various studies have attempted to identify sets of attributes or properties which can characterise a soil process or processes in regard to a specific soil function (Doran and Parkin, 1994; Gregorich *et al.*, 1994; Larson and Pierce, 1994). Once a property is identified for a specific soil type or situation, information is needed in regard to soil quality standards for a given set of conditions. This involves information on the critical level and range of the attribute (property) that is associated with optimum crop production. Development of soil quality standards can be a difficult process, especially defining the limits or critical range (Pierce and Larson, 1993). Identifying key soil attributes that are sensitive to soil functions allows the establishment of minimum data sets (MDS) (Larson and Pierce, 1994). Such data sets are composed of a minimum number of soil properties that will provide a practical assessment of one or several soil processes of importance for a specific soil function. Ideally, the property should be easily measured, and the measurements be reproducible and subject to some degree of standardisation. In cases where the property of interest may be difficult or expensive to measure, an indicator or pedotransfer function may provide an alternative estimate. Thus, the assessment must start with an understanding of the standard, baseline value, or reference value to be used for comparison.

Assessments can be made to help identify areas where problems occur, to identify areas of special interest, or to compare fields under different management systems. Land managers can use this information, along with data from soil surveys, fertility tests, and other resource inventory and monitoring data, to make management decisions. Two methods for interpreting soil test results are generally practised by most public soil test laboratories for making fertilizer and lime recommendations. Eckert (1987) referred to them as the "Sufficiency Level" (SL) and "Basic Cation Saturation Ratio" (BCSR) concepts. Dynamic soil quality for crop production is concerned with changes in soil quality attributes or properties due to land use and management. The soil chemical component of quality relates to how the soil fulfils functions such as (a) storage and gradual release of nutrients, (b) buffering of habitat against rapid changes of potentially toxic materials, and (c) recycling of organic materials in soils to release nutrients for further synthesis into new organic materials (Warkentin, 1995). It is noted that each of these functions deals with nutrient or toxic element supply to the soil solution, which is the ultimate source of these elements to the plant root. It is suggested that the best approximation is to assess soil quality based on indicators, which in a generalised sense, are related to nutrient buffer capacity. This approach is underpinned by the assumption that fertiliser of some kind will probably need to be applied even to soils which are assessed as fulfilling the nutrient release criterion of soil quality. The indicators which are most critical for nutrient buffer capacity are organic matter content (important for N, and to a lesser extent, P), clay content (important for P and cationic macronutrients), and pH. The latter indicator has ramifications for N in terms of the activity of the microbial population which mineralises the organic matter, for P in terms of the clay mineralogy which determines buffer capacity, and for the cationic macronutrients in terms of their likely saturation of the exchange complex, and consequently, their activity ratios in the soil solution.

1.1.1.6 Monitoring change in soil quality

Monitoring is the regular surveillance of the condition of something. While monitoring the quality of air and water has been commonplace for the last few decades, in general, soil quality has not been monitored. Even the large scale effects of erosion on soil productivity are not well known (Pierce, 1995), prompting Lal (1987) to conclude that, in spite of billions of dollars invested in the erosion problem, we cannot say for sure what effect the loss of a unit of soil depth has on crop yield. The National Resources Inventory (NRI), a monitoring survey of over 800,000 sampling locations in the United States completed every 5 years since 1977, does not contain any data that assesses changes in soil quality during that period (Pierce and Nowak, 1994). One of the goals of sustainable agricultural systems is to maintain soil quality. Thus evaluation of soil quality, in addition to characterising functions, identifying attributes, and developing MDS also requires strategies to evaluate soil quality change. Larson and Pierce (1994) discuss both the *comparative assessment* and *dynamic assessment* approach to evaluate soil quality change. The former is commonly used and involves a single comparison of one system against another. However, this approach may provide little information on trends in soil quality over time. In contrast, dynamic assessment compares or evaluates soil quality attributes over time. Larson and Pierce (1994) identify both computer models (which use attributes as variables) and statistical (i.e. temporal pattern of attribute mean and standard deviation) control as a means to assess soil quality change over time. Statistical control theory suggests that once a sample point exceeds a defined number of standard deviations from the mean, then this forms an outlier. However, it requires a thorough examination of the changing soil fertility status to establish whether this was an aberrant spike or a longer-term trend. Other approaches are use of archived soil and plant samples from long term experiments, and geostatistical methods. In regard to change in soil quality, standards are needed to assess if the recorded changes are within natural variation or optimum range of the soil attribute in question, or if the changes are related to management practices that may require changes if quality is deteriorating. Since within a minimum data set individual attributes or indicators may show opposite or various changes (e.g., organic matter increasing, but porosity decreasing), the interpretation of such changes and the required management response underlines the importance of 'experience' and 'skill' in the soil manager. Thus, monitoring soil quality does not in itself change the soil condition, but serves only to indicate if changes in management are required. Therefore, sustainable land management practices must be designed to ensure that the processes that regulate soil quality are operating in a positive manner, and that soil quality is under control. Pierce and Larson (1993) emphasise that sustainable land management should include the following assessment: evaluate land suitability for specific use, identify key soil quality attributes for the specific system and derive a minimum data set, establish soil quality standard limits, identify management inputs that strongly influence soil quality attributes (e.g., residue levels influence soil organic matter), employ soil quality control techniques to monitor the system, modify management as needed to maintain soil quality control.

At any point in time, the quality of a soil can be defined and compared with that of other soil types. In contrast to this static comparison, soil quality can also be monitored over time to determine whether a particular land management system (be it effluent disposal, crop rotation etc.) is causing the quality of the soil to degrade. Soil quality in this latter context requires discrimination of the temporal trends in different quality indicators from trends which are a consequence of the land management. To achieve this discrimination requires the application of statistical quality control which is best captured in control charts similar to those used for analytical methodology (Larson and Pierce, 1994). A minimum data set is defined, and control charts are constructed for each indicator of the set. Separation of short term temporal changes from long term trends in the control charts allows assessment of a particular land management system; the long term trend of an indicator (either upwards or downwards) identifies whether that indicator in the minimum data set is aggrading or degrading. Since quality is composed of several indicators, some of which may be aggrading, while others are degrading, the overall assessment of the effects of the land management system on soil quality requires an integration of these trends. Pierce *et al.*, (1983) calculated a normalised sufficiency for several indicators in the minimum data set, and then determined a productivity index (PI) based on the product of the sufficiencies of the individual indicators of soil quality. By comparing the PI's of several alternative land uses, it is possible to identify the systems which are improving, or degrading, soil quality. Whereas consideration of changes in some minimum data set indicators can be restricted to the surface layer (0-10 cm, or depth of tillage), changes in other indicators must be considered on a whole of profile basis. For example, surface application of liming materials might ameliorate acidity in the zone of incorporation, leading to an improvement in the soil pH indicator. However, further down the profile, the management system may be causing accelerated acidification. Taken over the entire profile, soil pH is actually declining (i.e. this indicator is degrading). Similar considerations apply to the indicator of electrical conductivity because of the consequences of subsurface salinity on root growth and function. Furthermore, because pedogenesis leads to horizonation, it is possible that the variation in soil properties down the profile may offer a continuum which satisfies all soil quality functions, but at different depths. Thus, Barry *et al.*, (1995) found that the buffer capacities for P and heavy metals of the horizons in an Alfisol varied widely, and whereas the highest P buffer capacity occurred in the B2 horizon (120-150 cm), the highest Cd buffer capacity occurred in the A11 and A12 horizons (0-25 cm).

1.1.2 Water Quality: An Overview

Water (H_2O) is always two parts hydrogen (H) to one part oxygen (O). Beyond that, its composition depends on where it comes from, how it is processed and handled. Water covers about 71% of earth surface and hence the most abundant resource on earth (Miller T G J, 1991). On Earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapor, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Oceans hold 97% of surface water, glaciers and polar ice caps 2.4%, and other land surface water such as rivers, lakes and ponds 0.6%. A very small amount of the Earth's water is contained within biological bodies and manufactured products. Water can be hard or soft, natural or modified, bottled or tap, carbonated or still. People can survive days, weeks or months without food, but only about four days without water. The body uses water for digestion, absorption, circulation, transporting nutrients, building tissues, carrying away waste and maintaining body temperature. Thus, access to safe water is one of the key millennium development goals. It is an important foundation for sustainable poverty reduction also.

Water quality determines the suitability of water for a particular purpose. Pure water means different things to different people. Homeowners are primarily concerned with domestic water problems related to colour, odour, taste, and safety to family health, as well as the cost of soap, detergents, "softening," or other treatments required for improving the water quality. Chemists and engineers working for industry are concerned with the purity of water as it relates to scale deposition and pipe corrosion. Regulatory agencies are concerned with setting standards to protect public health. Farmers are interested in the effects of irrigation waters on the chemical, physical, and osmotic properties of soils, particularly as they influence crop production; hence, they are concerned with the water's total mineral content or content of ions "toxic" to plant growth (Thodore B.Shelton, 2005). So, water quality is the physical, chemical and biological characteristics of water.(Diersing, Nancy ,May 2009).

Drinking water or potable water is water of sufficiently high quality that it can be consumed or used without risk of immediate or long term harm. Drinking water can be defined as the water delivered to the consumer that can be safely used for drinking, cooking and washing. Safe drinking-water, as defined by the guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Quality of drinking water is ascertained by measuring the pysical, chemical and biological parameteres and drinking water standards have been set to ensure that these parameteres are well within limits, so as not to cause advese health effects over a long time consumption. Safe drinking-water is suitable for all usual domestic purposes, including personal hygiene.

Presently, drinking water quality has become a serious issue of concern for human health, mainly in developed and developing countries worldwide (WHO,2004). Since the focus on our water resources is often on the volume of water available for particular purposes, the water quality problem is particularly magnified as the water suitable for drinking is in very short supply. A concerted effort should be made by scientist, industry, the community, environmental groups, state and local governments to achieve a drinking-water quality as safe as practicable.

1.1.2.1 Access to safe drinking water

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection. Most recently, the U. N General Assembly declared the period from 2005 to 2015 as the International Decade for Action, "Water for Life".

As per the United Nations estimates (2002) at least 101 billion people don't even have access to safe drinking water and 2.4 billion don't have adequate sanitation facilities. Increasing population and expanding development would further increase the demands for water. It is estimated that by 2024, two thirds of the world population would be suffering from acute water shortage (Kaushik, A and Kuashik, C. P, 2004). The water quality in the rural drinking water supply has emerged as a major issue for improved health status. Most of the health problems affecting rural population in the developing countries like India can be ascribed to lack of wholesomeness of available water sources. Escalating demand and shrinking supplies of water illustrate that our progress towards sustainable management of this vital resource has been inadequate. Global drinking water consumption has outpaced population growth over the past few decades while misuse and mismanagement have resulted in a rapid and widespread decline in source, water quality and supply. Human use of fresh water has registered a 35 fold increase in the last 300 years. As a whole, 3240 km^3 of fresh water was withdrawn from different sources throughout the world in 1987 with a world average per capita use of 660 m^3 (WRI, 1992). Of these 69% went to agriculture, 23% in industry and 8% to domestic uses. Today, the whole world has been facing a tremendous fresh water crisis as 110,000 km3 falls on land out of total 500,000 km3 of precipitation received by the earth every year and again 65% of precipitation received by the land is evaporated back to the atmosphere. A part of the remaining 35% fills the rivers, lakes, wet lands and reservoirs and the rest enters the ground and is stored in the aquifers (WRI, 1992). The world human population has tripled during the last decade and the demand for freshwater has increased sevenfold (Das S. K., 2007). The average availability of water remains more or less fixed according to the natural hydrological cycle but the per capita availability reduces steadily due to an increasing population. In 1955, the per capita availability was 5,300 cubic metres (cu.m) per person per year which came down to 2,200 cu.m in1996.(). Average per capita use in India is estimated to be 612 km^3 against the world average of 660 km^3. India has 16 per cent of the world's population and four percent of its fresh water resources. It has been estimated that surface and ground water availability is around 1,869 billion cubic metres (BCM). Of this, 40 per cent is not available for use due to geological and topographical conditions (Gupta, A., *et al.*,2006). It can be revealed that populations, consumption and source degradation of water are increasing as if there were no limits to the supply of clean water (Watson *et al.,* 2003).

1.1.2.2 Contamination of drinking water

Although our ability to predict contaminants in water from a given area or aquifer is still rather limited, knowledge of their occurrence and distribution has improved greatly over the last few years. Despite the advances made in recent years in understanding where contaminants in waters are likely to exist on a regional scale, predictability on a local scale is still poor and probably will always be so.

Naturally occurring and man-made contaminants in drinking water are of concern to all of us. Chemically pure water does not exist for any appreciable length of time in nature. Even while falling as rain, water picks up small amounts of gases, ions, dust, and particulate matter from the atmosphere. Then, as it flows over or through the surface layers of the earth, it dissolves and carries with it some of almost everything it touches, including that which is dumped into it by man. These added substances may be arbitrarily classified as biological, chemical (both inorganic and organic), physical, and radiological impurities. These impurities may give water a bad taste, colour, odour, or cloudy appearance, and cause hardness, corrosiveness, staining, or frothing. They may damage growing plants and transmit diseases. In fact, industrial waste and the municipal solid waste have emerged as one of the leading cause of pollution of surface and ground water. The Central Pollution Control Board, India has identified 22 sites in 16 states as critical for groundwater pollution due to industrial effluents. In many places of the country available water is found non-potable because of the presence of heavy metal in excess. There have been instances of heavy metals like lead, cadmium, zinc and mercury being reported in groundwater in Gujarat, Andhra Pradesh, Kerala, Delhi and Haryana (CPCB, 2007). Contamination of water resources available for household and drinking purposes with heavy elements, metal ions and harmful micro organisms is considered to be one of the serious major health threats. Throughout the world, the most common contamination of raw water sources is from human sewage and in particular human faecal pathogens and parasites. Cities and towns in under developed countries have neither sewage systems nor sewage treatment facilities and therefore, pathogenic contamination of public water supplies has remained the main threat to human health. In 2006, waterborne diseases were estimated to cause 1.8 million deaths each year while about 1.1 billion people lacked proper drinking water. (U.S. Centers for Disease Control and Prevention. Atlanta, GA. "Safe Water System: A Low-Cost Technology for Safe Drinking Water." Fact Sheet, World Water Forum 4 Update. March 2006). The drinking water supply can be broken down into three parts: the source water, the drinking water treatment system, and the distribution system which carries the treated water to consumers. The plumbing inside home is an extension of the distribution system. As drinking water travels on its journey to the consumer, it can become contaminated in many ways. Another way that drinking water can become contaminated is by the products and materials with which it comes into contact. Water is a solvent and can leach metals and other chemicals from pipes, fittings, fixtures, and other products. Excess of these impurities make the water unsafe for drinking purposes. It can be generally concluded that the pollutants, besides making water treatment a very costly affair, have important health implications for human and aquatic life forms.

Pollution of fresh water occurs due to three major reasons- excess nutrients from sewage, wastes from industries, mining and agriculture (Mayback *et al.,* 1989). Anthropogenic activities like mining, ultimate disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates (Amman, *et al.*, 2002) from different industries also pollute water. The indiscriminate use of heavy metal containing fertilizers and pesticides in agriculture resulted in deterioration of water quality rendering serious environmental problems posing threat on human beings (Lantzy and Mackenzie, 1979; Nriagu, 1979; Ross, 1994) and sustaining aquatic biodiversity (Ghosh and Vass, 1997; Das, *et al.*, 1997).

EPA sets standards for approximately 90 contaminants in drinking water. Main contaminants of water are lead, arsenic, fluoride, mercury, cadmium, Zinc, iron, manganese, copper, sulphate, phosphate, nitrate, chloride, TSS, Coliform bacteria, Fecal Coliform and E coli, *Cryptosporidium and* Turbidity etc . Chemicals in drinking water which are toxic may cause either acute or chronic health effects. An acute effect usually follows a large dose of a chemical and occurs almost immediately. Besides the physical and chemical characteristics, the quality of water sources also depends on its biological characteristics (Dash, J. R *et al.*, 2007).

The problem of groundwater pollution due to heavy metals has now raised concerns all over the globe and results reported by various researchers have been alarming (Chi-Man L. and Jiu J.J., 2006 ; Demirel Z., 2007; Nganjc *et al.*, 2007; Yasuhiro *et al.*, 2007). Their excess in water causes many diseases in plants and animals, though some of the metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for life processes in plants and micro organisms, on the other hand metals like Cd, Cr and Pb have no known physiological activity, but they are proved detrimental beyond a certain limit (Marschner, 1995; Bruins, *et al.*, 2000). The deadlier diseases like edema of eyelids, tumor, congestion of nasal mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented (Johnson, 1998; Tsuji and Karagatzides, 2001;. Abbasi, *et al.*, 1998). Therefore, monitoring these metals is important for safety assessment of the environment and human health in particular.

1.1.2.3 Indian scenario

Water supplies in India are no longer unlimited. In many parts of the country, water supplies are threatened by contamination and future water supplies are uncertain. Studies on hydrochemistry and water pollution in India have received tremendous momentum in recent times. Only a sample of published literature has been given here. Most of the studies are however, related to rivers (Kataria, H.C., and Jain, O.P., 1995; Sing, B.N.

and Rai, S., 1999; Rajeswari Devi. R.K *et al.*, 2007; Reginna. B. and Nabi. B. 2003; Sing. R.K. *et al.*,2000; Balaji, S. and Sharma, M. P., 2007) although world wide river systems have been more extensively studied than the rivers in India. Singh *et al.*, (2007) studied the seasonal variations in water quality of natural lakes of Nainital and reported that different physico-chemical parameters were found to be high during summers (Singh, A P, 2007). Remya *et al.*, compared the water quality on the dug wells of a tsunami affected area after tsunami with the water quality value made in December, 2004, three weeks before the tsunami and found that after tsunami most of the well water becomes contaminated (Remya, L *et al.*, 2007). Excess fluoride in ground water in 17 states of India has caused severe problem on human health and physiological activities (Meenakshi *et al.*, 2004).

High level of fluoride distribution in ground water sources of certain districts of Haryana, Tamil Nadu, Andhra Pradesh, Karnataka, Assam etc. have been observed (Kumar, A. Kaushic *et al.*, 2002; Santhi, D. 2002; Reddy, M. C. and Somasekhara. 1998; Sarma, H. P and Bhattacharya, K. G, 1999; Suma Latha *et al.*, 1999). Chemical quality of drinking water in the tea garden belt of Lakhimpur district, Assam was studied by Bhuyan *et al.*, 2006, where they found high level of iron in some locations (Bhuyan. B *et al.*, 2006). Mathias *et al.*, studied the bacterial contamination of drinking water supplied to residential and work places of Bangalore (Mathias, A. J. *et al.*, 2007). Water from dug and bore wells has been known to contain high concentration of minerals and coliform organisms (Rao, S. K,1989). There is also evidence of prevailing heavy metal contamination of groundwater in many areas of India (Dixit R.C., *et al.*, 2004; Bhattacharjee S. *et al.*, 2005; Ram, P. and Singh, A.K., 2007; Minaxi B. L., *et al.*, 2008; Begum A., *et al.*, 2009). Toxic elements like Sc, Cr, Se, Cd, Sb, Hg are also not uncommon (Rao, S. K *et al.*, 1994; Tripathi, I. P *et al.*, 1996; Singhananam, M and Rao.

K. S, 1996; Rao, S. K *et al.*, 1992; Rao, S. K,1993). In a study conducted at Roorkey, the tube well water was found to be unaffected by seasonal variations while well water in Varanasi was found to contain radioactive substances (Garg, D. K *et al.,* 1990; Naik, S and Purohit, K. M,1996; Patel, M. K and Tiwari, T. N, 1988; Dang, H. S. *et al.,* 1984). In Visakhapattanam, it was found that the ground water quality was affected by urban waste and chemical fertilizers (Subba, R. N and Rao, G. K, 1991; Rao, J. K and Shantaram, M. V, 1994). The additions of large quantities of effluents due to movement of fertilizers, agricultural ashes, industrial effluents and anthropogenic wastes particularly in the down streams of the river raise heavy metal concentration in Cauvery River and was found to be maximum in sediments, phytoplanktons and fish.(Begum, Abida *et al., 2009)*.. The main water pollutant of the major rivers like Godavari, Kadawa, Girna, Punad, and Mosam of Nashik district is phosphate due to agricultural run off as farmers use organophosphates insecticides including malathion,, diarithion, parathion etc. and phosphate fertilisers (.Kharat, S.J. *et al.,* 2009). Arsenic above permissible limits of 0.01mg/L along with high content of iron and manganese has been reported in tubewell waters of Sahebgunj district, Jharkhand (S. Bhattacharjee *et al.,* 2005). Presence of various hazardous chemicals like fluoride, arsenic, nitrate, sulphate, pesticides and other heavy metals etc. in groundwater has been reported from different parts of India (Anita Sahu and M.M.Vaishnav,2006). Use of large amounts of nitrogenous fertilizers has been shown to be responsible for very high levels of nitrate in the natural water of U.P., Bihar, Haryana, Delhi and Punjab (Shamsh, P and Pandey, G. S,1994; Taheruzzaman, Q and Kushari, D. P.,1995; Gupta, S. C.,1981; Olaniya, M. S.,1969; Singh, R,1988; Bhatia, R and Deve, J. M,1980). In the North Eastern region of India, the well water of Tripura (Kumar, S. P. *et al.*, 1990) and Arunachal Pradesh (Das, H. B, 1989) has been found to have high bacteriological contamination. Ground water in India has also been reported to have considerable fluoride content besides nitrate, which is thought to be due to weathering of fluoride bearing rocks (Gupta, M. K. *et al.*, 1994; Gupta, S. C. *et al.*, 1993; Tripathi, A. K and Singh, R. C, 1996; Gupta, S. C., 1991; Gopal, R and Ghosh, P. K., 1985). In India, fluorosis was first detected in Nellore district of Andhra Pradesh in1973 (Short, H.E., *et al.*,1973). Around 62.5 million people have been reported suffering from disorder of teeth or bones through fluorosis (Susheela A K,1999) in India, which is due to consumption of fluoride-rich water. Groundwater arsenic contamination in West Bengal, India and adjoining Bangladesh is well publicized and perhaps one of the most grotesque natural calamities of the world related to drinking water. An isolated observation in the mid eighties confined to a few families from one village of 24 Parganas district in West Bengal snowballed into an international crisis involving two countries and endangering millions of people (Garai, R. *et al.*, 1984). The spread and depth of groundwater arsenic contamination in India may be gauged from the recent survey carried out by School of Environmental Studies (SOES), Jadavpur University, Kolkata, which finds that groundwaters of 2700 villages in 9 districts out of a total of 18 in West Bengal are arsenic contaminated (arsenic content 50 ppb). About six million people from these districts having a total population of 42 million are consuming arsenic contaminated water and about 30,000 of them are threatened with visible symptoms of arsenic poisoning. In Bangladesh, groundwaters of 2000 villages in 50 out of a total of 64 districts have been identified as containing arsenic above permissible level of 50 ppb (Chakraborti, D. *et al.*, 2002). Recently Chakraborti *et al.*, (2003) surveyed groundwaters of a village in Bhojpur district in Bihar, India situated in the middle Ganga plain of upstream Ganga. Integrated investigations on water quality, pathological and neurological manifestations established the presence of very high concentration of arsenic and other metals in tube-well waters of the particular village and its adverse impact on health (Datta *et al.*, 1976). Based on these observations combined with an earlier report and some additional recent findings by other researchers (Tandukar, N., 2001), Chakraborti and co-workers tried to sensitize about the possible future danger of more arsenic outbreaks. According to them this arsenic belt may stretch over the entire upper, middle and lower Ganga plain. Shah, M. C. *et al., 2008*, carried out the ground water quality assessment of Ghandhinagar, Tulaka, Gujrat and revealed that the water quality of bore wells of Gandhinagar taluka is poor for drinking purpose as per Water Quality Index.

There is evidence of prevailing contamination of water resources in many areas of Assam. Although information on drinking water quality of North Eastern India is very little, results reported by various agencies have been alarming. Available literature shows that groundwater in Assam are highly contaminated with iron (Aowal 1981). The occurrence of fluoride contamination in Darrang, Karbi Anglong and Nagoan district of Assam in the form of fluorosis were already reported (Kotoky *et al.,* 2008; Sushella 2007; Chakravarti *et al.,* 2000). High level of fluoride and iron distribution in ground water sources of certain districts of Assam has also been observed (Baruah *et al.*, 1995; Das *et al.*, 2003). River water of Lakhimpur district, Assam is totally unfit for drinking purposes due to the presence of high number of bacteria and tube well water at some places of the district is not fit for drinking due to the presence of excess amount of As, Fe and Pb (Saikia.S & Sarma, H.P.,2008) Unfortunately, the basic facts in the Tea garden belt of Darrang are that the people are still unaware of water contamination and its hazardous effects. The governmental efforts are much less than needed to mitigate the crisis. Hence, the immediate involvement of research community is urgent to combat the slow onset disaster and save the poor people of the district.

1.1.2.4 Drinking water quality and health

The intake of poor quality untreated water is the primary cause of outbreak of several waterborne diseases. Examples of acute health effects are nausea, lung irritation, skin rash, vomiting, dizziness, and, in the extreme, death. The levels of chemicals in drinking water, however, are seldom high enough to cause acute health effects. They are more likely to cause chronic health effects, effects that occur after exposure to small amounts of a chemical over a long period. Examples of chronic health effects include cancer, birth defects, organ damage, disorders of the nervous system, and damage to the immune system. Evidence relating chronic human health effects of a contaminant in drinking water differs widely, depending on whether a person consumes the water over a long period, briefly, or intermittently. Different studies reveal that water born diseases are the largest killer of children due to unsafe drinking water (Vijayalakshmi, I.B., 2007). WHO and many other studies have reported that water pollution is highly responsible for serious health effects in developing countries (Parikh Y., 2004; Tambekar *et al.*, 2004; Singh H., 2005). There are no estimates of the public health consequences of groundwater pollution as it involves methodological complexities and logistical problems. Nevertheless, levels of toxicity depend on the type of pollutant. The main threats from heavy metals have been extensively studied and their effects on human health regularly reviewed by international bodies such as the WHO (Järup 2003). Mercury is reported to cause impairment of brain functions, neurological disorders, retardation of growth in children, abortion and disruption of the endocrine system, whereas pesticides are toxic or carcinogenic. Generally, pesticides damage the liver and nervous system. Tumour formation in liver has also been reported. High fluoride content is often detected from such symptoms on human beings as yellowing of teeth, damaged joints and bone deformities, which occur from long years of exposure to fluoride containing water. Due to this reason, by the time the community realises the "menace", a large section of the population is already affected. A recent survey by the International Water Management Institute (IWMI) in north Gujarat showed 42 per cent of the people covered in the sample survey (28,425) were affected; while 25.7 per cent were affected by dental fluorosis, 6.2 per cent were affected by muscular skeletal fluorosis and 10 per cent by both. The potential biological and toxicological effects of using fluoride contaminated water are also dangerous. Study on fluorotic populations of north Gujarat revealed an increase in frequency of sister chromatic exchange in fluorotic individuals indicating that fluoride might have genotoxic effect. Fluoride had been reported to cause depressions in DNA and RNA synthesis in cultured cells. Another study on the effects of fluorides in mice showed significant reductions in DNA and RNA levels. Conditions including ageing, cancer, and arteriosclerosis are associated with DNA damage and its disrepair. Prolonged exposure to water containing salts (TDS above 500ppm) can cause kidney stone, a phenomenon widely reported from north and coastal Gujarat. Arsenic contamination of drinking water causes a disease called arsenicosis, for which there is no effective treatment, though consumption of arsenic free water could help affected people at early stages of ailment to get rid of the symptoms of arsenic toxicity. Arsenic contamination is by far the biggest mass poisoning case in the world putting 20 million people from West Bengal and Bangladesh at risk though some other estimates put the figure at 36 million people (Chatterjee, A. *et al.,* 1995). Heavy metals are harmful and insidious pollutants because of their non biodegradable nature and their potential to cause adverse effects in human beings beyond certain level of exposure and absorption. Heavy metals can cause biochemical effects such as inhibition of enzymes, genetic damage and hyper tensions. There is an increase in epidemiological and other evidences indicating an association between water quality and mortality from cardio-vascular and other chronic diseases. It has also been observed that diseases other than cardiovascular have been associated with heavy metals in water (Nayak, M. S and Sawant, A. D, 1996). The direct effects of improved water and sanitation services on health are most clearly seen in the case of water-related diseases, which arise from the ingestion of pathogens from contaminated water or food, and from exposure to insects or other vectors associated with water. Esrey *et al.,* (1991) calculated that access to safe drinking water and basic sanitation services for populations currently at risk would result in 200 million/year fewer diarrhoeal episodes, 2.1 million/year fewer deaths caused by diarrhea, 76 000 fewer dracunculiasis cases, 150 million fewer schistosomiasis cases and 75 million fewer trachoma cases. The health problems due to poor water quality in India are enormous. It is estimated that each year around 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to waterborne disease. The major chemical parameters of concern for chemical contamination of water are fluoride and arsenic. Iron is also emerging as a major problem with many habitations showing excess iron in the water samples.

For a rural and backward district like Darrang of Assam, where the majority of the people live below the poverty line, the provision of safe drinking water is one of the prior conditions for overall social development. If the people continue to use contaminated water, many will lose their health or die within a few decades. Those who will survive are in a danger of carrying genetic and other diseases to future generation.

1.1.2.5 Drinking Water Quality Regulation

Safe drinking-water is a basic need for human development, health and well-being, and because of this it is an internationally accepted human right (WHO, 2001). The nature and form of drinking-water standards may vary between countries and regions; no single approach is universally applicable. It is essential in the development and implementation of standards to take into account current and planned legislation relating to the water, health and local government sectors and to assess the capacity of potential regulators in the country.

W.H.O has given a set of guideline values for drinking water quality. The WHO Guidelines for Drinking-water Quality (WHO, 2004) cover both microbiological and chemical contaminants of drinking-water. They describe in detail the scientific approaches used in deriving guideline values for those contaminants. The guidelines thus provide a sound framework for ensuring an appropriate level of safety and acceptability of drinking-water. The guidelines list nearly 200 chemicals for which guideline values have been set or considered. This number may change over time. Theoretically, it is possible to assess (at national or local level) the health risks from chemicals in drinking-water for every chemical for which a guideline has been set. The World Health Organization (WHO) has published procedures for assessing chemical health risks (WHO, 19XX; WHO, 19XX – *Refs to WHO Environmental Health Criteria docs 170 and 210*). These guideline values, along with tolerance limits prescribed by the Indian Standard Institute (ISI) (Trivedy, R.K., 1990) and EPA standards of USA are also important in determining water quality (Train, R.E., 1979).

Water quality objectives are a refinement of the province-wide guidelines that are adapted to protect the most sensitive water use at a specific location, taking local circumstances into account. Nevertheless, the growing movement among government, scientists, private and public sectors to evaluate current practices, adopt more stringent quality control, and develop integrated and proactive resource management is encouraging. In this regard, some acts for prevention and control of pollution of water which is prevailing may be executed properly to maintain healthy water quality. The water (prevention and control of pollution) Act, 1974, establishes an institutional structure for preventing and abating water pollution. It establishes standards for water quality and effluent. The Central Pollution Control Board was constituted under this act. The water (prevention and control of pollution) Cess Act, 1977 provides for the levy and collection of fees on water consuming Industries and Local authorities. Environment protection Act, 1986 provides penal action against overexploitation of ground water. This led to formation of the Central Ground Water Board (CGWB).

1.2 Objectives

This research has been carried out with the following objectives:

- To study the water quality in the six selected tea gardens of Darrang district.
- To study the potability of water.
- To identify the principal contaminants of a wide range of water sources.
- To help users at national or local level to establish which chemicals in a particular setting should be given priority in developing strategies for risk.
- To study the chemical indicators of soil quality in selected tea gardens of Darrang district, Assam by estimating the available nutrients present in the soil, which basically determine fertility.
- To arrive at some over all conclusion regarding the water-soil environment in and around the tea gardens of Darrang district.

1.3 Purpose and scope of the study

Providing clean and safe drinking water to all people is still a far cry in many parts of India and as a result, this has remained at the top of the government agenda for last several years. Contamination of groundwater has raised its ugly head recently in Assam. Results reported by various agencies have been alarming. While some of the results may have been exaggerated and may have suffered from improper sample collection, lack of calibration of measuring instruments, use of non-standard methods and human errors, it is no longer possible to ignore the gradually accumulating data. The need is for a more systematic and careful study eliminating all possible sources of error and to build up a reliable database. Thus, every effort should be made to achieve a drinking-water quality as safe as practicable. This work will ensure whether safe and wholesome supply of drinking water is available or not. Moreover, the data set that will be developed during this research can be applied to more sites and the statistics can be examined more critically. In addition, the cost and practicality of the measure will also be considered. Developing regional database would allow inter-regional use of water chemistry data to increase national sampling efficiencies, increase local water chemistry knowledge and promote interaction and collaboration between GOs and NGOs. The present work has been undertaken with a specific view to further strengthen the water chemistry database as well as to educate and raise awareness so that concerted strategies can be adopted, at the planning level, to keep the chemical contamination of water at the minimum.

As one of Earth's most vital ecosystems, soil is essential for the continued existence of life on the planet. As sources, stores, and transformers of plant nutrients, soils have a major influence on terrestrial ecosystems. Soils are a key system for the hydrological cycle. Soils also provide an archive of past climatic conditions and human influences. Soil fertility or quality assessment is relatively new in Assam and the most of the studies have been confined to urban areas. In Assam, there is an almost dearth of reliable and quantitative data on soil properties (and variations in time and space). Database need to be established to assess the effects of various forms of environmental hazards, and to derive meaningful measures of soil quality in relation to human activities. Accurate soil tests can be an excellent management tool also. The real value of soil testing lies in finding out the information about the available nutrients present in the soil. Monitoring of nutrients in soil may reveal potential problems even before painful symptoms occur; the earlier problems are observed, the easier they are to treat. The present work will be helpful in predicting the fertility status of soil in the tea garden belts of Darrang district for future use.

This study describes the occurrence and distribution of soil and water quality parameters in six selected tea gardens of Darrang district, Assam. The predictability of soil and water contamination on a local scale is still poor and probably will always be so. Short-range (well-to-well) variability in soil and water contamination is often large. This means that individual sites need to be tested on a regular basis. Hence, the present study was carried out to provide an overview of the current state of knowledge on the occurrence and distribution of various soil and water contaminants in and around six selected tea gardens of Darrang district of Assam. Results from this work can be used to help regional-scale studies of soil and water quality in future. This report also includes a description of the sources of the data used; the approach used for screening the data; and statistical and graphical presentations of the data.