SOIL AND WATER QUALITY AS INFLUENCED BY LANDUSE IN KORATTY, KERALA

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In partial fulfillment of the requirement for the award of the degree of

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by

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CERTIFICATE

This is to certify that the research work presented in the thesis entitled **“ Soil and Water Quality as Influenced by Landuse in Koratty, Kerala”** is based on the authentic record of original work done by Mr. Prasanth K.M (Reg. No. 3840) under my supervision at Kerala Forest Research Institute, Peechi, Thrissur, in partial fulfillment of the requirements of the degree of Doctor of Philosophy and that no part of this work has previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title or recognition. All the relevant corrections and modifications suggested by the audience during the pre synopsis seminar and recommendations by the Doctoral Committee of the candidate has been incorporated in the thesis.

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DECLARATION

The research work presented in the thesis entitled ***“ Soil* and Water Quality as Influenced by Landuse in Koratty, Kerala*”*** submitted in partial fulfillment of the requirements of the degree of Doctor of Philosophy is a bonafide record of the research work done by me under the supervision of Dr. Thomas P Thomas, Scientist F & HOD (Rtd.), Soil Science Department and Dr. S. Sankar, Scientist G (Rtd.), Kerala Forest Research Institute, Peechi, Thrissur. No part of this work has previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title or recognition.

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Prasanth, K.M.

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CHAPTER 1

GENERAL INTRODUCTION

Landuse is the human use of land. It has been defined as "the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it" (FAO, 1998).

The term landuse denotes all human use of the land including that for agriculture, industries and domestic purposes. Such activities have transformed the land surface of the earth (DeFries *et al.*, 2004; Foley *et al.,* 2005). Conversion of natural landscapes to such modified ecosystems affects their structure, function, dynamics and overall health (Adeel *et al.,* 2005; Matson *et al.,* 1997; Tscharntke *et al.,* 2005).

Kerala's environment, especially the land environment, has undergone degradation to various levels due to multitude of factors. Changes in landuse pattern, indiscriminate use of fertilizers and pesticides, urbanization and industrialization have all contributed their share in polluting and degrading the air, water and soil. Landuse changes are manifested, generally, as change in cropping pattern, conversion from one crop to another, slope modification, quarrying, filling of wet lands, clay mining etc. Most of these lead to land degradation.

Industries, essential for the development of any country, while producing useful products are also forced to release harmful byproducts or effluents that pollute the air, water and soil. Industrial effluents are, more often than not, discharged into drainage channels or water courses polluting and contaminating them for several kilometers downstream (Balakrishnan *et al.,* 2008 and Jaya and Lekshmi*,* 2007).

Koratty region has always attracted industries. Madura Coats, Government of India press, Carborandum Universal, Kerala Chemicals and Proteins Ltd., KINFRA etc., were some of the major industries that provided local employment and thus resulted in affluence of the locality. Labour unrest and demand for higher wages and amenities followed and most of these impressive establishments had to pull down their shutters or cut short their wings. Madura Coats got transformed to Vaigai Threads with much reduced capacity and turnover while Kerala Chemicals and Proteins was taken over by Nitta Gelatin, a joint venture company.

But a renewed surge is being witnessed recently with many industrial enterprises getting established in Koratty. The Government of Kerala is all out to support the development of Koratty due to its locational advantage being very near to Kochi air port and seaport. Kerala Industrial Infrastructure Development Corporation [KINFRA] and INFOPARK are two major recent initiatives in this regard. CARE KERALAM is another ambitious project launched in Koratty. While KINFRA has thirty industries listed in its programme with thirteen of them already running, CARE KERALAM a confederation for ayurvedic renaissance visualizes an assemblage of ayurvedic medicine manufacturers under one roof by facilitating infrastructure and testing and quality control. The recently inaugurated INFOPARK, third one of its kinds in the State after Techno Park and Smart City project attracts many IT industries to the area. All these developmental activities, while adding affluence to the region, will also take its toll on the environment.

Agriculture is the mainstay of the people in the region with 89.2 per cent of the land being used for the purpose. Mixed crops, paddy, rubber, coconut, vegetables and banana constitute the major crops. High input agriculture is resorted to by the farmers in most of these crops compelling application of synthetic fertilizers and pesticides. All these chemicals contaminate soil and water.

Synthetic chemicals affect the soil properties adversely. The soil pH is immediately influenced and the reduction in soil pH in turn affects many soil processes and organisms. This is particularly important considering the lateritic soils of Kerala, which are naturally acidic due to processes in its genesis. Physicochemical and biological processes in the soil are adversely affected by increasing soil acidity. Some of the chemicals employed in high input agriculture are directly toxic to soil flora and fauna also. Heavy metals are toxic to most organisms.

Water quality is similarly affected by pollutants released from agriculture, industries and urban landuse. Its pH gets modified by different chemicals affecting quality. Dissolved solids, suspended sediments, temperature, electrical conductivity etc., also decide the quality of water. Other important properties that determine the health of the water body are DO, BOD and COD. Presence of heavy metals even in minute quantities also affects the quality of water. Nutrients, especially nitrates and phosphates, encourage algal growth restricting the penetration of light and oxygen and these “algal blooms” on decomposition and eutrophication further degrade the water body.

Koratty being thickly populated like the rest of Kerala compels residence in the proximity of industries. No documented evidence exists as to the level of pollution of soil and water in Koratty. It is, therefore, imperative that studies are conducted to reveal the state of these natural resources with regard to its contamination and results documented so that further changes can be monitored and mitigation measures planned by the authorities.

The study was contemplated along these lines to document the landuse pattern as well as the environmental quality with particular reference to soil and water.

The study has the following specific objectives:

Objectives

1. To identify the landuse pattern in Koratty region and delineate areas accordingly
2. To study the soil and water quality in Koratty region
3. Relate the soil and water quality to the landuse, especially the impact of industries

CHAPTER 2

REVIEW OF LITERATURE

2.1 SOIL QUALITY

Nature provides everything that man needs to lead a healthy life. It helps him meet his basic needs of clean air, water, food, shelter, medicines and recreation facilities (Daily *et al.,* 1997). Healthy environments sustain robust economies (Hall, 1994; USEPA, 1996) and protect all species in the ecosystem. But man's greed has led to over exploitation of the natural resources and is threatening the ecological and social sustainability of our planet (Karr and Chu, 1995, 1999; Brown *et al.,* 1997). Population explosion, rapid industrialization and production and consumption of synthetic chemicals as also modern high input agriculture utilizing such chemicals has accelerated the pace of environmental degradation.

Soil is an important natural resource, which has suffered the brunt of such fast development (Luo *et al.,* 2007; Karim *et al.,* 2014). We expect the soil to perform many functions at the same time often exceeding its capacity. Such increasing demands make the soil less resilient and more vulnerable (Prelty, 2008). The Commission of the European Communities had identified several threats to the soil including decline in organic matter, contamination, compaction, loss of biodiversity, salinisation and landslides. These threats affect the natural functioning of soils and thus impact food security as also water security.

Contamination of soil by hazardous elements (Luo *et al.,* 2007; Sun *et al.,* 2010; Karim *et al.,* 2014) is a serious issue in both developed and developing countries due to their toxicity, non bio degradable properties and accumulation (Islam *et al.,* 2014a). Rapid industrialization and urbanisation have often been cited as causing soil contamination by toxic metals (Chen *et al.,* 2010; Sun *et al.,* 2010). Identification of the sources and the distribution pattern in different landuses has been considered necessary to arrive at the pollution status of the soil (Afshin *et al.,* 2009; Acosta *et al.,* 2011., Yuan *et al.,* 2014). Islam *et al.,* (2014b) recorded serious air, water and soil pollution in Dhaka, Bangladesh from traffic congestion and industrial and urban wastes.

A soil pollutant is any material that deteriorates the quality of the soil in terms of its capacity to sustain the organisms present in it and the plants and animals that depend on it (Scheffer *et al.,* 2001) and such pollution or contamination threatening the natural functions of the soil are almost always caused by man (Foley *et al.,* 2005).

Heavy Metals

Elements with metallic properties and with higher atomic weight are loosely termed 'Heavy metals' because 'heavy' is not fixed and some so called heavy metals such as arsenic and antimony are in fact, semi metals or metalloids. These heavy metals occur naturally in rocks and thus in the soil derived from these rocks. Arsenic, lead, cadmium, chromium, copper, mercury, nickel and zinc are generally considered as heavy metals in the context of their impacts on the environment and the health of human beings. Some of these are needed for human health at low levels but most of them are toxic even at minute quantities.

Human activities such as burning fossil fuels, mining, smelting, agriculture and industries release heavy metals (Canbay *et al.,* 2010) and the soil acts as a repository for these toxic materials locking them in the soil thus preventing their release especially to the water bodies. These locked up heavy metals gradually become available depending on the soil properties, especially soil pH, and get absorbed by the crops and reach animals and man in the food chain getting biomagnified along route (Thornton, 1991; Brinkmann, 1994; Skeppard, 1998; Morgan, 2013).

Soil contamination by heavy metals is particularly important due to their toxicity and persistence (Facchinelli, 2001; Mico, 2006; Haque *et al.,* 2008; Lim *et al.,* 2008). Soil health gets impaired by heavy metal pollution from anthropogenic activities. (Khaleel *et al.,* 1981; Cressie, 1988; Gregori and Senadhira, 1993; Smith *et al.,* 1993; Li *et al.,* 2011; Pourrut *et al.,* 2011). Developed countries have documented the distribution of heavy metals in soil but developing countries have comparatively less data to rely on (Thuy *et al.,* 2000). Contamination of soil happens from fossil fuels as well as other raw materials excavated from the interior of the earth that are deposited on the land through air, water or terrestrial transport (Senesi *et al.,* 1999). Pollution originates from clearly defined point sources as also from diffuse sources.

Occurrence

Though heavy metals occur normally in rocks and thus in the soil developed from these rocks its level remain within limits that are not harmful to man and animals. Vehicular emissions, urban and industrial wastes, chemical fertilizers and pesticides, biomedical and municipal wastes have all contributed to accelerated pollution of the environment including the soil (Bailey *et al.,* 1999; Chartzoulakis and Klapaki, 2000; Heberer 2002; Fayiga *et al.,* 2004; Canbay *et al.,* 2010; Wei and Yang, 2010; Karim *et al.,* 2014).

Heavy metal accumulation in soils of urbanized areas from coal and fuel combustion, vehicle emissions, industrial discharges and municipal wastes have been reported by several researchers (Wei and Yang, 2010; Karim *et al.,* 2014) and their persistence in soil by others (Alloway and Ure, 1990).

Lead (Pb) from gasoline combustion and Cu, Zn and Cd from other vehicle components contribute to urban soil pollution (Chen *et al.,* 1997; Lu *et al.,* 2005). Increase in magnetic susceptibility of soil has also been reported due to addition of industrial and urban dusts containing magnetic particles (Lu *et al.,* 2008; Blundell *et al.,* 2009). Magnetic particles emitted from vehicular sources contain metals such as Cu, Pb and Zn (Beckwith *et al.,* 1986). Paint, fuel additives, tyre and brake dust also release heavy metals (Blundell *et al.,* 2009). Lu *et al.,* (2008) also reported significant correlations between Cu and Zn in roadside soils and its magnetic properties.

Accumulation of hazardous elements Cr, Ni, Cu, As, Cd and Pb in urban soils of Bangladesh indicated concentration of Cr in the range of 2.4-1258 mg kg^{-1}, Ni of 8.3-1044 mg kg^{-1}, Cu of 9.7-823, As of 8.7-277, Cd of 1.8-80 mg kg^{-1} and Pb in the range of 13-842 mg kg^{-1}. Seventy per cent of the soils had higher than permissible levels of these heavy metals in the soil. The descending order of contaminants was Cd<As<Cu<Pb<Ni<Cr (Islam, 2014a).

Sediment samples had varied concentrations of heavy metals. Chromium(Cr) was found to be present in concentrations of 34.1-141 mg kg^{-1}, Cu 14.4-94.6, Ba 116-846, Fe 13600-85700, Mn 130-3870, Pb 1.2-89.2, Cd 0.20-1.91, Ti 385-9360, As 0.1-49.1, and Hg 0.004-1.030 mg kg^{-1}. The mean concentrations of these metals were found to be 80.9, 46.2, 264, 42482, 955, 31.7, 0.57, 6088, 23.4 and 0.249 mg kg^{-1} in the sediments (Wang *et al.,* 2014).

Assessment

Contamination of soil by heavy metals can be assessed either near a known source or hot spot or by analyzing the spatial distribution in a region from several diffuse sources. Methods include the estimation of total heavy metal concentration (Juang *et al.,* 2008; Tavares *et al.,* 2008;

Zhao *et al.,* 2008; Yange *et al.,* 2009; Chu *et al.,* 2010; Lin *et al.,* 2010; Van Meirvenne and Meklit 2010; Wang *et al.,* 2014) or the estimation of weakly extractable heavy metals (Juang *et al.,* 2004; Spijiker *et al.,* 2011) or the hazard quotients (Lee *et al.,* 2007; Zeng *et al.,* 2009) or by estimating crop uptake.

Several indices such as enrichment factor (EF), contamination factor (CF), pollution load index (PLI) along with geo accumulation index (I geo) to reveal the contribution from geological sources have been widely used to assess soil contamination by heavy metals (Rashed 2010; Silva *et al.,* 2011, 2012).

Lead, copper and nickel generally were found to be more in the surface soil layers that are richer in organic carbon while cadmium exhibited homogenous distribution throughout the soil profile. In river sediments, heavy metals Pb, Cu, Cr and Ni were more in the surface layers. Concentration of these elements were found to be 26.85 mg kg^{-1}, 26.58, 63.62 and 28.30 mg kg^{-1} respectively in 0-3cm layer of the sediment, concentrations of all these decreased with depth (Tamer *et al,* 2013).

Availability

Heavy metals accumulate in the soil because they do not easily migrate or get broken down by natural vegetation. Linear positive correlation existed between Pb, Cu, Zn and Fe. Chromium on the other hand was negatively correlated with Cu, Pb, Zn and Fe. The mobility and bio availability of heavy metals vary significantly with soil properties. Most heavy metals are mobile in acidic soil and their mobility increases with decreasing soil pH. This is particularly true in the case of cadmium. Crop uptakes of heavy metals are thus dependent more on the soil pH than the metal concentration in the soil. Heavy metals directly inhibit soil microbial activity also which can affect adversely the physical and chemical soil properties and reduce nutrient supply to the plants.

(Goovaerts *et al.,* 1997; Giller *et al.,* 1998; Chartzoulakis *et al.,* 2000; Heberer, 2002; Nicholson *et al.,* 2003; Romic and Romic, 2003; Tipping *et al.,* 2003; Khan *et al.,* 2008; Papa *et al.,* 2010). The accumulation of hazardous elements are detrimental to soil health (Cui *et al.,* 2004; Li *et al.,* 2009; Yu *et al.,* 2012; Yuan *et al.,* 2014).

Heavy metals can cause health problems in plants animals and man. Chronic exposure to Cd can cause lung cancer, kidney malfunction and hyper tension. Arsenic can cause skin irritations and lung cancer. Lead is known to cause anemia, nephropathy, gastro intestinal disorders and central nervous system disfunction (Zukowska and Biziuk, 2008). Cr is a known carcinogen while nickel can cause chronic bronchitis, emphysema and asthma. Heavy metals are also absorbed through dust inhalation (Goovaerts *et al.,* 1997; Lombi *et al.,* 2002; Tipping *et al.,* 2003; Boruvka *et al.,* 2005; Khan *et al.,* 2008).

2.1.1 SOIL QUALITY AS AFFECTED BY LANDUSE

Landuse directly influence the soil and its properties. Change in landuse more often than not lead to land degradation particularly the soil and water quality. Inappropriate landuse is known to affect human health also (Patz *et al.,* 2004; Pielke, 2005; Xu *et al.,* 2008). Conversion of land for urban use results in the contamination of soil by urban waste i.e mostly domestic, traffic, bio-medical and e-waste. Industrialization contributes effluents that end up in the soil and deteriorate it. High input agriculture also contributes its share in degrading the soil through over use of chemicals as fertilizers, fungicides, bactericides, insecticides, weedicides etc. (Papa *et al.,* 2010; Cui *et al.,* 2004; Li *et al.,* 2009; Yu *et al.,* 2012; Yuan *et al.,* 2014).

Fertilizers, especially phosphatic fertilizers, contain As, Pb and Cd as impurities which accumulate in the soil since these are not easily degradable. The commonly used pesticides DDT, BHC, chlorinated hydrocarbons, organophosphates, aldrin, malathion, dieldrin, furadan, etc., persist in the soil and thus contaminate it.

2.2 WATER QUALITY

Water is essential for the sustenance of life on earth. Man needs it for drinking and other domestic uses, irrigation and power, production of industrial goods, recreation and transportation. It is impossible to substitute it and difficult to depollute it. The well being of living organisms depend on the availability of clean water.

But availability of fresh water is getting reduced fast. Discharge of industrial effluents, agricultural chemicals, detergents, urban and domestic sewage, biomedical waste, e-waste etc., has polluted most of the water bodies in both developed and developing countries. The pollutants include nitrates, phosphates, sulphates, sulphides, cyanides, dyes, pigments, ammonia, bleaching agents, several toxic biocidal organic compounds and heavy metals.

Industries consume large quantities of water and often discharge their effluents through drainage channels or water courses including rivers without pre-treatment or partial treatment. Mass casualty of fish and other aquatic fauna have been reported from several places due to such contamination of water (Hussain, 1976; Michael *et al.,* 1987; Barton and Turelli, 1990; Stormer *et al.,* 1996; Cognetti., 1994; Degetto *et al.,* 1997; Jensen, 2003; Cognetti, 1999; Benovic *et al.,* 2000; Cognetti and Maltagliati, 2000; Dufresne *et al.,* 2002).

The concern for pollution of water has been increasing the world over, more so due to their toxic effects on human health. Conventional purification methods are not capable of removing some of the pollutants. The nature of a pollutant thus assumes greater significance (UNDTCD,1991). Industries produce synthetic substances many of which are bio degradable. Persistence of such substances in the environment lead to increase in its concentration (UNDTCD,1991). Many of these toxic substances build up in the food chain leading to biomagnifications several times before reaching man.

Pollution of water occurs from discrete point sources such as water sewage and industrial effluents. Agricultural chemicals get diffused around through the soil and water causing non point pollution. Both point source pollution and non point pollution from water and agricultural areas can become hazardous and the effects subtle and indirect (Hoffmann and Parsons, 1991; Hoelzel, 1998; Aggergaard and Jensen, 2001). The common pollutants include plant nutrients that stimulate algal blooms, oxygen demanding organic substances such as phenolic compounds, inorganic and organic toxic substances and pathogenic organisms (Cornish and Mensahh, 1999).

Natural forested ecosystems developed in a region as climax system that is most suited to the particular eco-climatic, geologic and topographic conditions is capable of protecting and sustaining the environment, particularly soil, water and air, the basic natural resources. Water courses originating from such forests maintain good water quality that is potable and suitable for diverse aquatic fauna (Das and Sinha, 1993; Sahu *et al.,* 1994; Stormer *et al.,* 1996; Evans *et al.,* 1999; Leonard, 2002; Huertas *et al.,* 2002; Jensen, 2003).

Urbanisation, industrialization and high input chemical farming contribute wastes that contaminate the water bodies. Rivers have thus been subjected to increasing levels of pollution affecting its water quality (Mathur, 1965; Verma and Shukla, 1969; Verma *et al.,* 1978; Ambasht, 1990; Ashutosh *et al.,* 1993; Binkley and Brown, 1993; Karl *et al.,* 1997; Rajaguru and Subburam, 2000; Rakesh *et al.,* 2005).

Industries are mostly established on river banks or other water bodies since they require plenty of water for its functioning. While producing utilities, they are also faced with the release of by products and wastes which they conveniently get rid of in the surrounding area without proper treatment or recycling. Industries manufacturing various products such as pulp and paper, fertilizers, pesticides, herbicides, detergents, alcohol, leather goods, dyes, tyres and other automobile accessories, galvanizing and electroplating units, oil extraction and several others make use of chemicals and produce wastes (Trivedi and Goel, 1984). The same water bodies that supply water to these industries are thus forced to receive such water or contaminants. Urban and domestic wastes also reach local drainage channels as is the agriculture chemicals.

Ground water also gets contaminated by such pollutants and once contaminated, it is difficult to restore its quality even though the soil acts as a sieve trying to remove as much pollutants as its exchange sites can hold.

Minerals are also found in excess in several ground water sources since excess minerals in the soil are bound to reach down with percolating water (Reghunath, 1987). Household wells are also polluted by kitchen, laundry and coliform bacteria including faecal coliforms: Animal wastes pollute ground water with nitrates, heavy metals and bacteria. Many of the water borne diseases such as cholera, typhoid, dysentry, hepatitis, gastro enteritis etc are attributed to pathogenic bacteria and toxic chemicals in ground water.

The impact of urbanisation on the environment and its health assumes greater importance with increasing population. The state of environment in Kerala and its progressive degradation has been accelerated by the population pressure as also by its social development centered on consumerism and fragmented land holdings. Land has become extremely costly with the result that small plots with big concrete housing have become the pattern. This has added to the deterioration of water quality. Surface water in water courses and ponds and ground water in open wells are polluted due to domestic sewage, municipal waste, industrial effluents and agricultural chemicals. Untreated water contains disease causing microbes also (Clark John, 1997). The case of river Periyar, the biggest one with many hydel projects upstream, is an excellent example of exploitation and consequent degradation. Its lower reaches supply water for many large industries and receive their waste water in return. Many researchers have documented the high pollution levels of Periyar (Jayapalan *et al.*, 1976; Paul and Pillai 1978, 1986; Devi *et al.*, 1979; Joseph *et al.*, 1984; Sankaranarayanan *et al.*, 1989; Joy, 1989). Reduction in dissolved oxygen (DO), eutrophication due to nutrient enrichment and consequent increase in Biochemical oxygen demand (BOD), low pH, high temperature, high turbidity, high chloride content, less phytoplankton diversity etc., were observed in both pre and post monsoon seasons.

Silas and Pillai (1976) reported fish mortality in the river. Paul and Pillai (1978, 1986) reported high levels of pollutants such as Ra 228, PO_4, Zn and Mn in sediments even 2 kilometres down water courses of industrial outlets. Most other rivers out of 44 small and big ones draining the slopes of Kerala hills and foot hills are suffering various levels of pollution caused by man and his unjustified demands on the ecosystem on which he depends.

Water quality of Indian rivers have also been investigated by many other researchers (Ghatak and Kumar, 1992; Jameson and Rana, 1996; Abbasi *et al.*, 1996; Gyanath, 2000; Baruah *et al.*, 2003) who reported varying levels of degradation. Water quality deterioration due to various pollutants from several sources has been reported in 70 per cent of water bodies (Citizen's Report, 1982). Various causes such as domestic, commercial, industrial and others have been attributed to the degradation in water quality (Vimal and Talashikar, 1985; Allan, 2004).

Among the physico chemical properties affecting water quality, pH assumes great importance because it controls various other reactions. It is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration (UNESCO, WHO & UNEP, 1996). Most metals become more soluble and toxic under acidic pH range. Toxicity of cyanides, sulfides and some of the heavy metals such as Hg and Cd increase with decreasing pH of water (Salequzzaman *et al.,* 2008).

Electrical Conductivity (EC) of water is another important property affecting water quality. Inorganic ions, especially of salts increase the electrical conductance of water (Mosley *et al*., 2004). It is regulated by total dissolved solids (TDS) in the water (Tariq *et al*., 2006). Water with high TDS or EC render the water unfit for drinking and affect aquatic biota adversely. Such water is also not good for irrigation as it corrodes the pipes and reduce crop yield (Nadia, 2006).

Total suspended sediments (TSS) in the water also affect its quality adversely by inhibiting light penetration and consequent algal growth and productivity. It further impacts the productivity of aquatic macro invertebrates, a major food source of fish. High turbidity supports exotic microbiota accelerating microbial pollution.

Human and animal wastes as well as industrial and agricultural chemicals contain a mixture of complex organic substances such as carbohydrates, proteins and fats (DANIDA, 1998). These are biodegradable and are quickly decomposed by microbes. Some of the organic matter is oxidized to carbon dioxide and water while some portion is utilized by the microbes themselves which is further released on death and decay of these organisms or consumed by other decomposers (Lamb, 1985). Microbes involved in these transformations consume dissolved oxygen (DO) in the water for respiration. Easily biodegradable wastes thus cause rapid depletion in DO levels of water. In extreme cases of high oxygen demand by wastes, anaerobic organisms take up the decomposition releasing toxic chemicals such as hydrogen sulphide, methane and mercaptans. These relationships are made use of to measure the amount of oxygen consumed during oxidation of organic matter and is termed biochemical oxygen demand (BOD). Higher DO values and lower BOD values support the proliferation and growth of diverse organisms in the water and thus improve its quality.

Chemical oxygen demand (COD) is another property that denotes the total quantity of oxygen required to oxidize all organic matter without differentiating into biologically available and inert organic matter. COD values are thus always greater than BOD values.

Nutrients-Nutrient Load

Nutrients, mainly nitrogen and phosphorus released from fertilizers used in agriculture affects water quality by boosting phytoplankton production resulting in algal bloom that restrict air and light penetration (Ngoye and Machiwa, 2004; Woli *et al.*, 2004). Death and decay of these plants cause eutrophication of water bodies. Nutrients are also released from livestock farms, poultry farms, piggery, fisheries etc. to the water bodies (Sonoda *et al.,* 2001; Lee *et al.,* 2009; Sun *et al.,* 2013; Haidary *et al.,* 2013; Wan *et al.,* 2014). These effects would become more severe in future warmer climate enhancing its toxicological effects (Camarago and Alonso, 2006).

River water quality is affected by point source pollution, mostly from domestic, municipal and industrial discharge during the dry season and by diffuse pollution from several sources mainly agricultural runoff. Positive relationships exist between urbanisation and dissolved carbon and nutrients (Buck *et al.*, 2004; Galbraith and Burns, 2007; Morrice *et al.*, 2008; Haidary *et al.*, 2013).

Heavy metal

Heavy metal contamination is a major issue in both surface and ground water. Major heavy metals that contaminate water bodies are lead, cadmium, zinc, nickel, chromium etc., (Chino, 1981). Major source of heavy metal in water is from industries such as tanning, smelting, welding, paint and other chemical industries. Discarded batteries, burning of petroleum products, agricultural residues, fertilizers, pesticides etc., also release immense amount of heavy metal to the surrounding water sources (Adriano, 2001).

Heavy metals get deposited to the soils and sediments from the atmosphere also (Nguyen*et al.,* 2005). Wu *et al.*, 2014) reported that heavy metal pollution in sediments was more serious because the sediment can act as sink for all the contaminants. Sediments also act as an internal source of heavy metal pollution because they release these back to the water bodies through anthropogenic or natural phenomenon (Bryan and Langston 1992; Savvides *et al.,* 1996).

Cadmium is a bio available and toxic heavy metal that interferes with metabolic processes in plants. It can bio accumulate in aquatic organisms and enter the food chain (Adriano, 2001). Consumption of Cd leads to nausea, vomiting, pain, pulmonary disease, emphysema and chronic renal tubular disease (Hayes, 2000).

Lead is a highly toxic metal which is harmful to all living organisms. It is a component of batteries, petrol additives, alloys, pigment and compounds. Leaded gasoline is another major source of lead (Chino, 1981). The presence of lead, copper, zinc and cadmium in fish leads to bio accumulation and cause serious health problems in humans (Mdamo, 2001). Heavy metal contamination in drinking water leads to high health risks for the kidney, liver, circulating system and nerve tissue (Salem *et al.,* 2000; Liu *et al.,* 2011). Heavy metal, enter the water bodies mainly through human activities although these heavy metal are natural contaminants of the earth is crust (Szefer *et al.,* 1998).

2.2.1 WATER QUALITY AS AFFECTED BY LANDUSE

Landuse has direct relationship with the quality of water that drains the watershed. Analyses of such relationships were carried out by many researchers (White, 1976; Rimer *et al.,* 1978; Johnson *et al.,* 1997). Vegetated catchments, especially those having natural forests release good quality water year round (Tong and Chen, 2002; Li *et al.,* 2009) whereas agricultural and urban landuses have been reported to degrade the water downstream (Baker, 2003; White and Greer, 2006; Lee *et al.,* 2009; Walker *et al.,* 2009). Multiple land use generates both point source pollution that can be easily identified and non point source pollution that cannot be attributed to a singlelanduse. Urban, industrial, agricultural and transportation infrastructure including vehicular traffic are landuses that occur together in a landscape (Tong and Chen, 2002; Liu *et al.,* 2009; Ribolzi *et al.,* 2011).

Agricultural landuse has been reported to release sediments, nutrients, heavy metals and pesticides to the water bodies affecting its quality negatively (Sonoda *et al.,* 2001; Lee *et al.,* 2009; Tu, 2011; Liu *et al.,* 2012; Adamowski *et al.,* 2013; Wan *et al.,* 2014). Urban landuse contribute several wastes, mostly phosphorus (Ahearna *et al.,* 2005; Galbraith and Burns, 2007; Lee *et al.,* 2009; Liu *et al.,* 2012; Haidary *et al.,* 2013; Tu, 2011, 2013; Wan *et al.,* 2014). Urban dominated areas were also studied by Allan (2004) Buck *et al.,* (2004) Lathrop (2007) Pratt and Chang (2012) and Li *et al.,* 2013) with respect to its impact on water quality. Effects of individual landuses on water quality cannot be separated in such landscapes and most critical activities threatening the water quality are prioritized and studied (Wang, 2001) and future management planned on the basis of the results obtained.

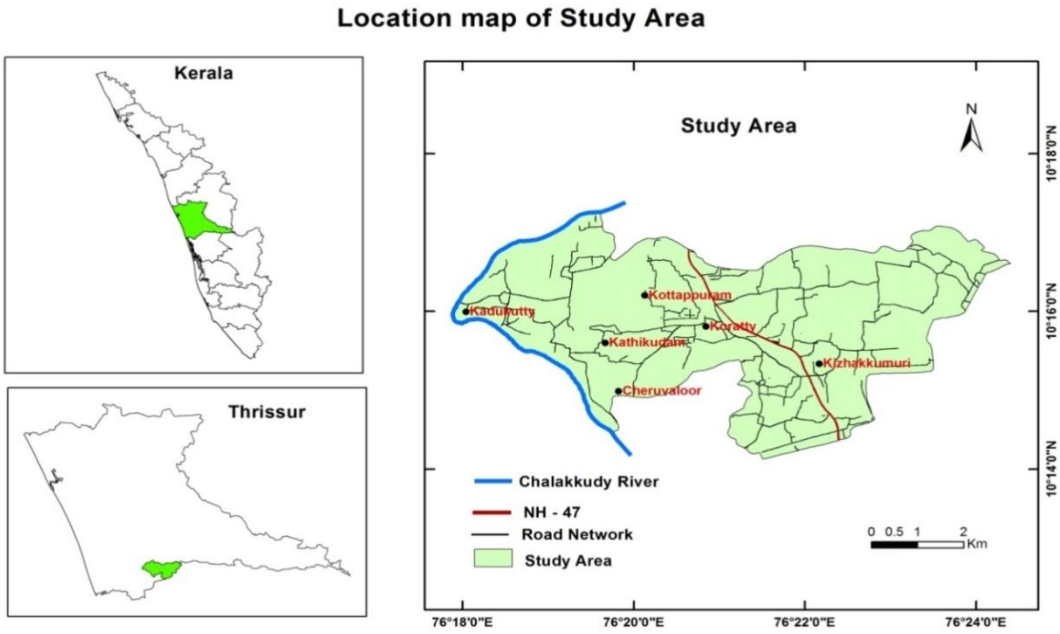
CHAPTER 3

STUDY AREA

Koratty region in Thrissur district of central Kerala is located in Chalakkudy Taluk between 10^{0} 14’ 10” – 10^{0} 17’ 20”N latitudes and 76^{0} 17’ 55”- 76^{0} 24’ 20” E longitudes with a total geographic area of 36 sq.km.

Koratty region is bound by Parakkadav and Karukutty panchayaths of Ernakulum district in the south, Karukutty panchayath in the east, Melur panchayath in the north and Annamanada panchayath in the west. Being very near to Ernakulam, it is influenced by the fast growth and development of Kochi. The seaport and airport contribute much to the pace of agricultural and industrial development of Koratty region.

Koratty is well connected to other parts of Kerala and India by the railways and the National highway, both of which cuts through the middle of the study area.



Map 3.1. Location of study area

Geology

Archaen crystalline rocks mainly of igneous and metamorphic origin and consisting of mostly charnockites and charnockitic gnesisses constitute the geology of the region. Laterite out crops indicative of exposure and degradation are also present in some of the areas. Paddy fields, in general, have a layer of fluvial sand deposit below the clay layer.

Geomorphology

The land is undulating with mild to moderate slopes and with all aspects. Valleys and bottoms are almost flat. The elevation is more (upto 100amsl) in the north eastern part and it decreases gradually to the south western part to as low as 10m or less.

Climate

The climate of the region is hot humid tropical with southwest and northeast monsoons contributing around 2500mm annual rainfall, most of it falling during the south west monsoon season of June to September. The temperature ranges from 18^0C in the winter to 39^0C during the summer months. Relative humidity is around 80% during most of the months.

Soil

The soils of the region generally are lateritic in the uplands with high content of iron, aluminium and manganese and low levels of silica and bases. It is coarse textured with varying contents of gravel, sand and finer separates of silica and clay. It is well drained with granular to massive structure. The colour ranges from brown to reddish brown in the surface to reddish/yellowish in the sub surface. In the low lands, clayey soils are met with varying contents of silt and fine sand. Clay pans underlie the paddy fields in most of the region.

Eight soil series were identified in this region. Koratty, Kozhukully, Velappaya, Anjur and Pariyaram series are the garden land soils while

Kolazhy and Mulayam are the wet land soil series identified in this region. Most of the wetlands in the panchayath have been converted to agroforestry systems comprising coconut, banana, nutmeg, tapioca etc.

Land Capability Classification

Land capability classification is an interpretative grouping of land to show their suitability to different kinds of uses along with management based on the limitations imposed on the sustained use of soils by their inherent soil characteristics, external land features and environmental peculiarities. This classification is made on the basis of data obtained by standard soil survey. There are eight land capability classes. Class II occupies majority of the area (89%), i e, good for all types of cultivation. Class III (9.5%) is the second leading class. Remaining are classes IV, V and VIII. Water bodies constitute 0.15%. The details of land capability classes are shown in the table 3.1.

Table 3.1. Land Capability Classes

SI.No.	Class	Total Area (Ha.)	Percentage
1	II	3145.20	87.83
2	III	425.88	11.89
3	IV	1.96	0.05
4	V	1.2	0.03
5	VIII	1.84	0.05
6	Water bodies	5.54	0.15
Total		**3581.62**	**100**

Source: Soil Survey Department, GOK

Water resources

Ground water

Average depth of ground water table varies from 2-10m in this region. Bore well have no salinity problems and yield at a depth of 7-15m from the surface. (Ground water department, Thrissur).

Koratty region has a good network of water courses. Perumbithodu, Korattychal, Mangattumbilly thodu, Erappanparathodu, Valungamuri thodu, Kottanchirathodu, Mallanchirathodu, Koottalappadam thodu, Vadakkechal, Perumthodu, Thavalachal thodu etc are some of the major perennial water courses. The drainage pattern is dendritic.

Irrigation in the panchayath is mainly from wells and ponds using pump sets. Canals, ponds and water courses also supplement irrigation substantially. Devamatha, Vazhichal, Kattappuram, Pongam, Parakkoottam, Elavankunnu, Thirumudikkunnu and Mudappuzha are the lift irrigation schemes functioning in the area. A number of ponds in the panchayath are also used for lift irrigation. Many branch canals of Chalakkudy irrigation project passing through the region also serve as source of irrigation. Idathukara main canal, Koratty branch canal, Chirangara branch canal, Kizhakkumury branch canal, Meloor branch canal and Konoor branch canal passes through this region.

Landuse pattern

Total geographic area of the region is 3600ha. The major crops of Koratty region are mixed crops, paddy, banana, vegetables and rubber, the agronomic practices differing from crop to crop. The land is used mostly for agriculture. Industries and other establishments including the leprosy sanatorium, builtup area, roads and railways and stone quarries occupy rest of the area.

Mixed crop

Mixed crop, which occupies maximum area, consists of coconut as the main crop along with arecanut forming the top canopy and with nutmeg, banana, fruit trees, yams, and other vegetables forming the second and third storeys. Most of the homesteads have such a cropping pattern that provide essential food, fiber, shade as also reasonable income from the cash crops. Organic and inorganic manures are applied to supply nutrients to these crops. Plant protection measures are also adopted though with widely varying patterns.

Paddy

Rice being the staple food of Keralites, paddy is an important agricultural crop in this region. High yielding varieties of paddy that require huge inputs through fertilizers and pesticides have replaced the local varieties. Paddy fields that served the purpose of water conservation also are gradually being converted to other landuses. Fertilizers and pesticide application is very common in cultivation, though a basal dose of farm yard manure application is in vogue in most of the areas.

Banana

Another major crop occupying an area of 60ha. is banana. It is mostly cultivated in paddy lands. The use of chemical fertilizers and pesticides is more in banana cultivation. It is often cultivated by farmers on leased land with the sole intention of making maximum profit in minimum time. Synthetic fertilizers are liberally applied to boost yield. Pesticides also are unjudiciously applied to thwart expected pests even from the time of planting the suckers in pits.

Rubber

Rubber is cultivated in an area of 250ha. most of the sites being present in the north eastern part of the region which has higher elevation and slopping terrain with good drainage. Fertilizers and manures are applied to get maximum latex yield. Bordeaux mixture and bordeaux paste application is common to prevent fungal diseases.

Vegetables

Vegetables are cultivated only in a limited area of 170ha. It is mostly cultivated in paddy fields by forming ridges and furrows to drain excess water. Fertilizers and pesticides are applied liberally as is the case with banana to maximise yield.

Industries

Major industries in the region are Vaigai threads, Govt. of India Press, Carborandum Universal Ltd., KINFRA, INFOPARK and Nitta Gelatin India Ltd.

KINFRA Small Industries Park has an area of 30 acres. Its vision is to create a Kerala where industry thrives in the midst of the rich green environs where people work in an environment that fosters growth and the freedom to innovate. Thrust areas are ceramic products, building materials, plastic products, spices, light and general engineering and herbal products.

A new venture for manufacturing and quality control of Ayurvedic medicines promoted jointly by Kinfra and major ayurvedic medicine manufactures (Pankajakasthuri, The Arya Vaidya Pharmacy, Vaidyaratnam Oushadasala, Nagarjuna, Sitaram, Sreedhareeyam, S.D. Pharmacy, Kandamkulathy, Dhanwantari and Kerala Ayurveda Pharmacy) namely Confederation of Ayurvedic Renaissance-Keralam Pvt. Ltd (CARe-Keralam) is also functioning in 10 acres (40,000 m^2) of land.

Carborandum Universal Limited has an area of 18 acres. Silicon carbide is produced here. Electro Minerals Division of CUMI is in the business of Brown Fused Alumina, White Fused Alumina, Silicon Carbide and High Quality Micro Grits. The Division also offers other Fused and Sintered products for various applications.

Silicon Carbide is a man made mineral of extreme hardness and sharpness. It is the ideal abrasive for grinding/sanding materials of low tensile strength such as Cast Iron, Brass, Aluminum, Bronze etc. Its thermal properties make it an excellent medium for use in the manufacture of refractory products and crucibles.

Silicon Carbide is produced by a process involving the electrochemical reaction of silica in the form of quartz with Carbon in the form of raw petroleum coke. The stoichiometric mixture is reacted in an electrical resistance furnace at a temperature greater than 2200˚C to yield high quality crystals. The large crystals are then segregated, crushed, cleaned of magnetic impurities in high intensity magnetic separators and classified into narrow size fractions to suit the end use. Dedicated lines produce products for different applications.

Silicon Carbide Grains are also used in marble and granite polishing, manufacture of Kiln furniture and as a deoxidizer in Iron and steel making.

Vaigai Thread Processors was formerly J&P Coats. The facility at Koratty was started in 1952 on 98 acres of land given on a 99-year lease by the State government. It got merged with Madura Coats Limited in 1980. The company was later handed over to Vaigai Thread in 1996. For setting up Infopark at Koratty, the government had retrieved some land from that given on lease to Vaigai Thread Processors. Sewing thread is the major product of the industry.

Infopark, Thrissur is located at Koratty in 17.40 Acres obtained on lease which is around 45 KM from Kochi. It is approximately 20 Km from Cochin International Airport at Nedumbassery. The park is situated very close to the National Highway 47. Currently Infopark, Thrissur possesses 30 acres of prime land. It is expected that some more land also will be added to the Park in the near future. Many IT companies have come up in Infopark and many more are expected.

Govt. of India press established as early as 1960s has been catering to the stationery requirements of the Govt. of India. It being the only such press in Kerala had been enjoying a pride of place, but is presently underutilized due to various reasons.

NGIL Ltd, a Japanese multi-national joint venture between Nitta Gelatin Inc., and the Kerala State Industrial Development Corporation (KSIDC) with a view to manufacturing Gelatin, Ossien and Di Calcium Phosphate also function in the region. The joint venture company was incorporated in 1975 and commercial production commenced in 1979. Initially, the major chunks of company's shares were held by the KSIDC. The fundamental production process that takes place in the Kathikudam factory is the manufacture of Ossien from the bones of slaughtered animals. The primary materials in the production process are crushed animal bones, hydrochloric acid, lime and water. Though, during the initial years the factory used to process only 18 tonnes of bones, today it has increased to about 120 tonnes per day. In one lot about 35-40 tonnes of bones, are processed. Normally three lots are processed every day. The plant also uses about 1.2 lakh litres of hydrochloric acid and 20 million litres of water every day.

Other small industries in the region

Stone quarries, granite crushing companies, hollow bricks units, flour mills, wooden furniture production units, cottage industries, copra making units, press, bakery, oil mills, soda making units, ice factory, paper cover production, dye works, automobile workshops, metal industries, polythene products, rice mills, surgical instrument production units etc., function in the region.

CHAPTER 4

LANDUSE PATTERN IN KORATTY REGION

4.1 INTRODUCTION

Landuse and land management practices have a major impact on natural resources including water, soil, nutrients, plants and animals (Walters, D., 2007) and landuse information can be used to develop solutions for natural resource management issues such as soil and water quality deterioration.

4.2 METHODOLOGY

The landuse study was divided into the following four phases

1. Base map preparation
2. GPS field Survey
3. Primary landuse map preparation
4. Ground truthing
5. Final map preparation and data analysis

The study area Koratty region in Thrissur district of Kerala was extracted in 1:50000 toposheets 37B and 38B and its boundaries delineated. Georeferencing of various landuses such as agriculture land, industrial establishments, road and rail network, irrigation and drainage channels as well as other water bodies was carried out using GPS model Garmin e trax-30.

Landuse was classified by the visual interpretation and vectorisation techniques using open layer functionality of QGIS 1.8 with help of the GPS field survey data. Google map (Astrium satellite image of

30/01/2014) was used for the interpretation at mapping scale 1:5000. WGS 1984 was the coordinate system used for mapping.

Primary map and vectorised data were verified by thorough ground truthing. Final map preparation and landuse analysis were carried out using Arc GIS 9.2 software after incorporating the ground truth data. WGS 1984 / UTM zone 43N Projection was used for the analysis. Digital elevation map and slope map were prepared using 30 m SRTM data.

4.3 RESULTS AND DISCUSSION

4.3.1 Agriculture and Cropping Pattern

Major agricultural crops include mixed crops and mono crops. Coconut based mixed cropping is the major pattern. Coconut, nutmeg, banana, areca nut, vegetables and fruits are the main mixed crops in this region. Monocrops includes paddy, banana and rubber.

Table 4.1. Area under different crops

Sl.No.	**Crops**	**Area (Ha.)**	**Area (%)**
1	Mixed cultivation	1121.38	48.6
2	Paddy	450.32	19.5
3	Rubber	251.63	11
4	Coconut	249.80	11
5	Vegetables	168.10	7.2
6	Banana	61.67	2.7
Total		**2302.90**	**100**

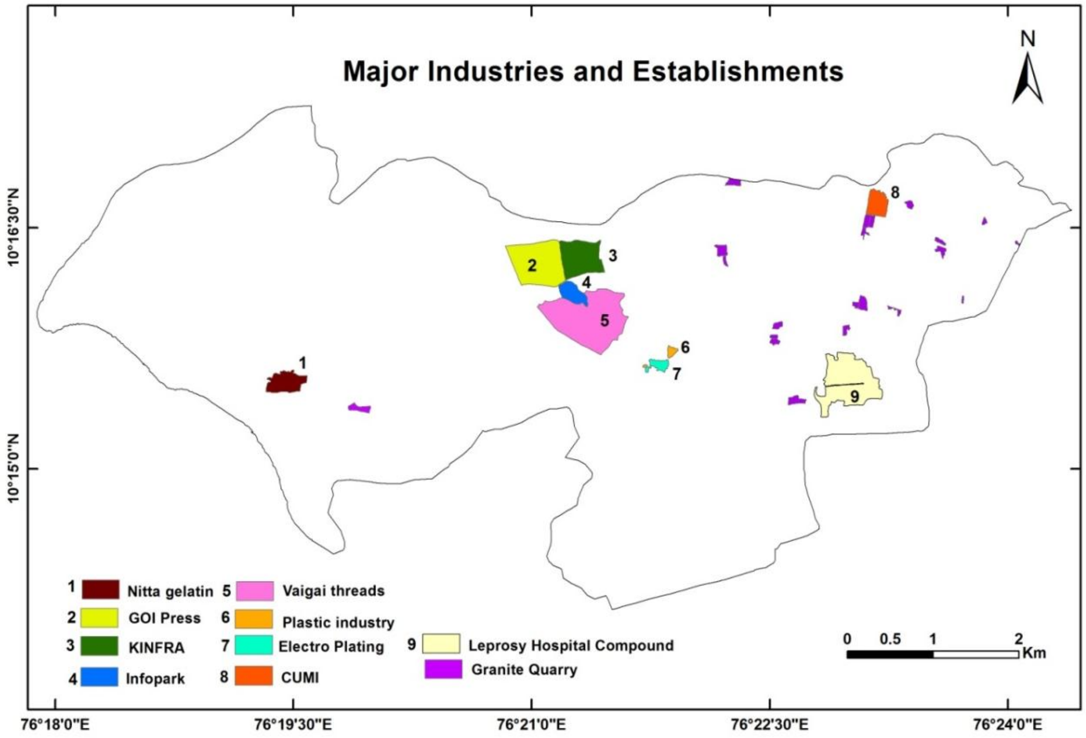
Mixed crop with coconut as the major one in and around homesteads occupy an area of 1121.38ha out of a total of 2302.90ha constituting 48.6 per cent (Table 4.1). Paddy the next in acreage occupy 19.5 per cent of the geographical area accounting for 450.32ha. Rubber and coconut occupy 11 per cent each followed by vegetables covering 7.2 per cent and banana 2.7 per cent of the land area. The practice followed in the cultivation of these crops is aimed at maximizing production necessitating the application of fertilizers, manures as well as plant protection chemicals including fungicides, bactericides, insecticides and weedicides. Pesticides that are commonly used include organochlorine, organophosphates, pyrethroids and copper fungicides. Conversion of paddy fields to vegetables and banana has resulted in the present acreage under paddy cultivation.

4.3.2 Major Industries and other establishments

The major industries in Koratty are strategically located along or near the National Highway except Carborandum Universal in the north east and NGIL in the southwest part (Map 4.1). Other small industries are scattered throughout the region.

Government of India press, one of the earlier establishments in around 100ha has presently shrinked to around 20ha after giving away land for the newly established KINFRA park and for the expansion of adjoining national highway. The press intended to print stationeries for the government is functioning much below its installed capacity at present. Carbon and dyes used for the manufacture of stationeries and print contribute to pollution around the industry.

KINFRA, the industrial park, in an area of around 20ha has more than 30 numbers of units functioning at present with many more in line to come up. Care Keralam, an ambitious project intended to promote research and quality control of ayurvedic medicines, established with the active involvement of ayurveda medicine manufacturers is one of the major industries. Others include Kerala Solvent Extraction Ltd., ceramic products, building materials, plastic products, spices, light and general engineering industries etc. The multitude of industries producing different products also may leave a wide variety of waste products in the vicinity.



Map 4.1. Location of major industries

Vaigai threads, formerly Madura coats, occupying an area of around 20ha after releasing around 20ha for the establishment of Infopark and losing appreciable area for the widening of the National Highway is presently engaged in dyeing of sewing threads. This minimum activity is also presently hampered by labour unrest. Pollution from dyes utilized in the past is expected to remain in the soil around the industry.

Infopark, a recent venture, has many IT industries established inside with many more following suite. An area of around 70,000 square feet has been occupied by these industries. IT industries are expected to contribute E-waste in the region.

Carborandum universal mineral industries (CUMI) occupies an areas of around 12ha in the north eastern part of Koratty. The industry produces silicon carbide using silica and coke. The product is used as an abrasive as also for grinding hard materials. Sulphur and its oxides as well as carbon particles escape to the atmosphere during the manufacturing process of silicon carbide.

Nitta Gelatin India Limited (NGIL), a joint venture of Kerala State Industrial Development Corporation (KSIDC) and a Japanese multinational company, Nitta Gelatin, established in Kathikudam on the western part of Koratty manufactures Ossein, a valuable product used in the manufacture of capsules. The raw material of animal bones is processed with concentrated HCL to obtain Ossein. Around 1.2 lakh litres of conc. HCL is being consumed every day. HCL fumes pollute the air and the fluid effluents are released to the near by Chalakudy river from where around 20 million litres of water is drawn daily for the functioning of the factory.

Other industries include automobile, fabrication, food processing, drug, interior designing materials, electroplating, painting, welding and other engineering industries. Stone quarries, granite crushing companies, hollow brick units, flour mills, wooden furniture production units, cottage industries, copra making units, press, bakery, oil mills, soda making units, ice factory, paper cover production and poly fibre production units also function in the region.

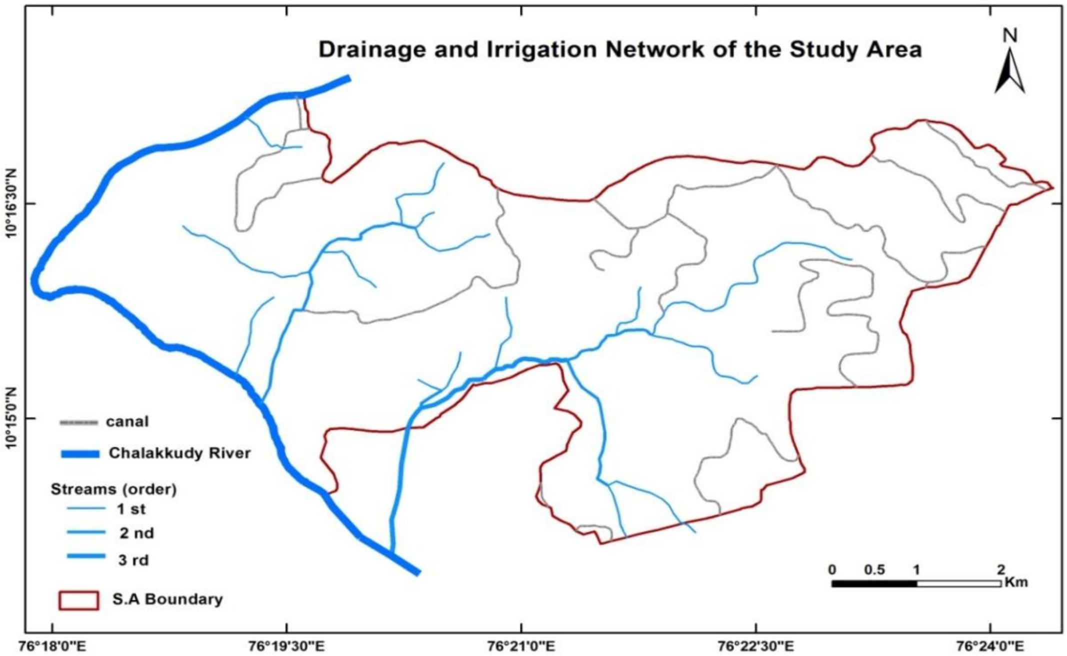
Thus, there are six major industries and more than 50 small scale industrial units present in Koratty region. Together they occupy 114 ha of land. These are shown in the map 4.1 given above.

4.3.3 Drainage and Irrigation Network

Koratty region has a good network of water courses and irrigation canals. The major source of water is from Chalakkudy River. The drainage pattern is dendritic. Some of the major water courses are Perumbi thodu, Koratty Chal, Koottalappadom thodu, Erappanpara thodu, Vadakkechal, Kuriyanparambu thodu, Mangalassery thodu, Kadavanappadam thodu, Moodapuzha, Kaithappadam and Perum thodu.

Well water is the major drinking water source in the region. Average depth of water table varies from 2-10 m in this region. Bore well have no salinity problems and yield at a depth of 7-15 m from the surface.

Irrigation in the Panchayath is mainly from wells and ponds using pump sets. Canals, ponds and water courses also supplement irrigation substantially. Koratty region has a good number of water courses and ponds, which can be utilized for irrigation. Some of the ponds in the region are also used for lift irrigation. The major ponds are Mangattumbilli pond, Puthenkulam, Poottukuzhikulam, Leprosy hospital pond, Erattachira pond, Kottanchira pond, Elavankunnu pump house, Elavankunnu pond, Mallanchira pond, Vellamchira pond, Puthenkulam pond and Pallikkulam pond.



Map 4.2. Water courses in the study area

Table 4.2. Irrigation canals

Sl.No	Ward	Name	Total Length
1	1	Lift irrigation canal	880
2	2,14,16	Chalakkudy lift irrigation canal	3220
3	14,15	R.B. Branch canal	3840
4	2,6,4	R.B. Main canal	5880
5	5	R.B. Branch canal	2000
6	8,10	Lift irrigation canal	2900
7	4,7	Chalakkudy irrigation canal	5800
8	9,10	Chalakkudy irrigation canal	7840
9	7	Chalakkudy irrigation canal	3820
		Total	**36,180**

Many branch canals passing through the region also serve as source of irrigation. Water is supplied through the canal and Chalakkudy irrigation project, R.B. Main canal, Idathukara main canal, Koratty branch canal which passes through this region. These together cover 36180m in length. The details are shown below in Table 4.2.

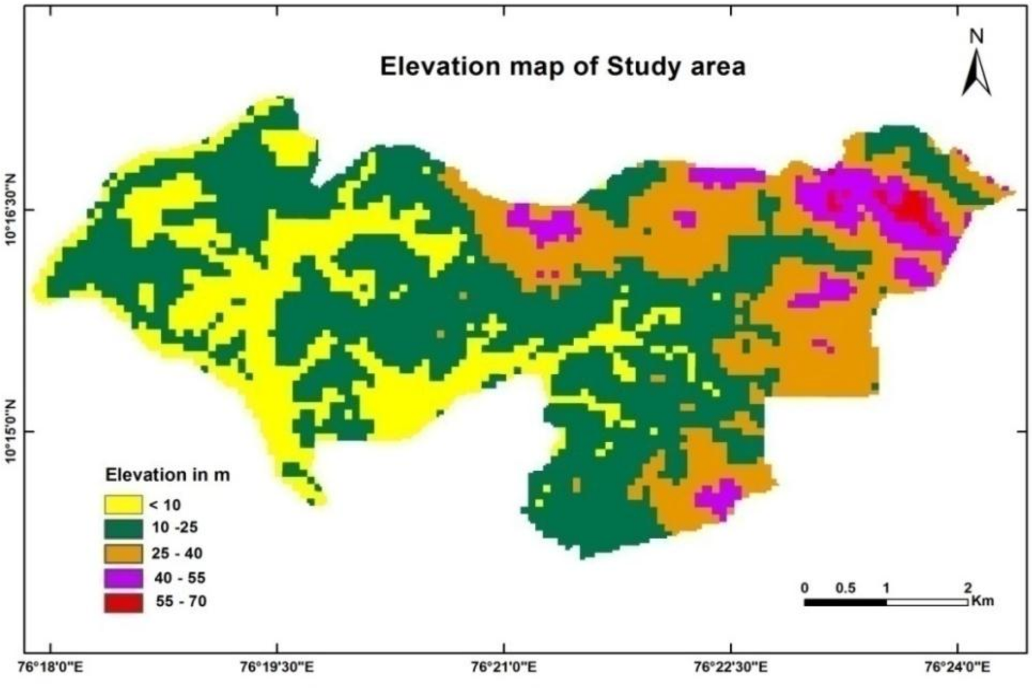
4.3.4 Elevation of the Study Area

The elevations of Koratty region vary from 10m to 80m above MSL. Topography ranges from flat to almost flat in the wetlands and undulating to steeply dissected in the garden lands especially in higher elevations. Higher elevated areas occur on the north eastern side with highest elevation of 80m and lower elevation is seen in south west area with around 10 m elevation. The details are shown in the table 4.3 below.

Table 4.3. Land distribution based on elevation classes

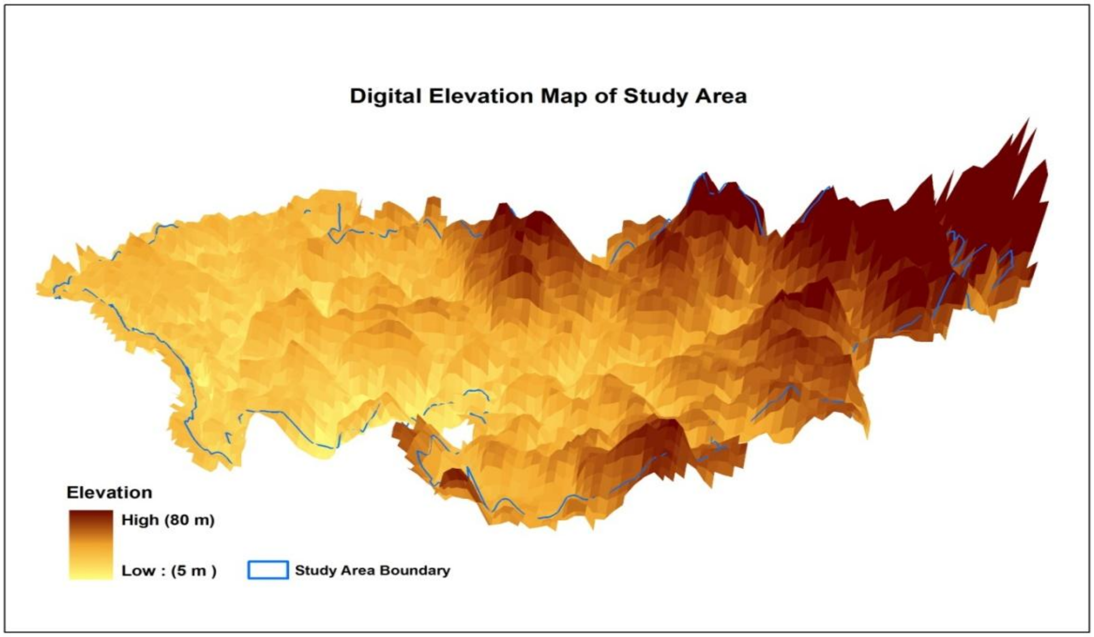
Elevation (m)	Area (ha)	Percentage
< 10	765.9	21.38
10-25	1740.00	48.58
25-40	800.64	22.35
40-50	227.16	6.34
50-80	47.88	1.33
Total	**3581.58**	**100**

It can be seen from the table 4.3 and map 4.3 that half of the land (48.58%) falls in the elevation class of 10-25 m. Land with elevation <10 m occupy 21.38% and that with 25-40 m occupy 22.35% of the land area. Upper slope classes of 40-50 m and 50-80 m only 6.34% and 1.33% of the total geographical area.



Map 4.3. Elevation Map

Elevation map of the region given above helps in identifying the spatial distribution of land falling in different elvation class. It is easy to understand that higher elevation areas are restricted to the north east and the lower elevation areas to the south west part. The overall picture is one of low elevations in most of the study area.



Map 4.4. Digital Elevation Map

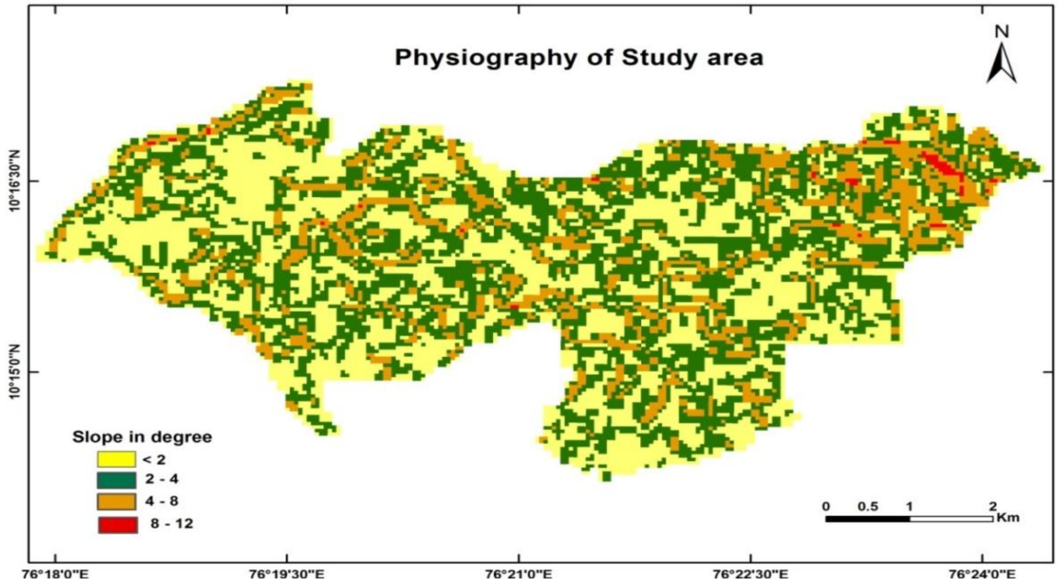
Digital elevation map of Koratty region given above provides a three dimensional view of the landscape (Map 4.4). It is very evident that the land slopes down from the northeast to the southwest in a regular manner though the rugged topography creates a mosaic of small hillocks and valleys.

4.3.5 Physiography of study area

Physiography of Koratty region as shown in the map can be observed to be with level to gentle slope in most of the region. North eastern part alone had steep slopes of 8 to 12 degree. It can be seen from the table below that 83 per cent of the land had less than 4^0 slope. Slightly higher slopes of 4 to 8 degree were seen in around 17 per cent of the land and 8 to 12 degree slope was present in hardly 0.45 per cent of the land area (Table 4.4; Map 4.5).

Table 4.4. Slope classes and their extent in the study area

Slope in degree	Area (ha)	Percentage
<2	1532.75	42.75
2-4	1429.25	39.98
4-8	602.5	16.80
8-12	16.25	0.45
Total	**3581**	**100**



Map 4.5. Physiography map of the Koratty region

Physiography of the region isrugged as mentioned earlier with undulating terrain resulting in a mosaic of slope classes that intermingle at close range. Most of the region was detected to have gentle slopes of less than 4 degree with 4-8 degree class dispersed alongwith. The higher class of 8-12 degree is restricted to the northeastern fringes only.

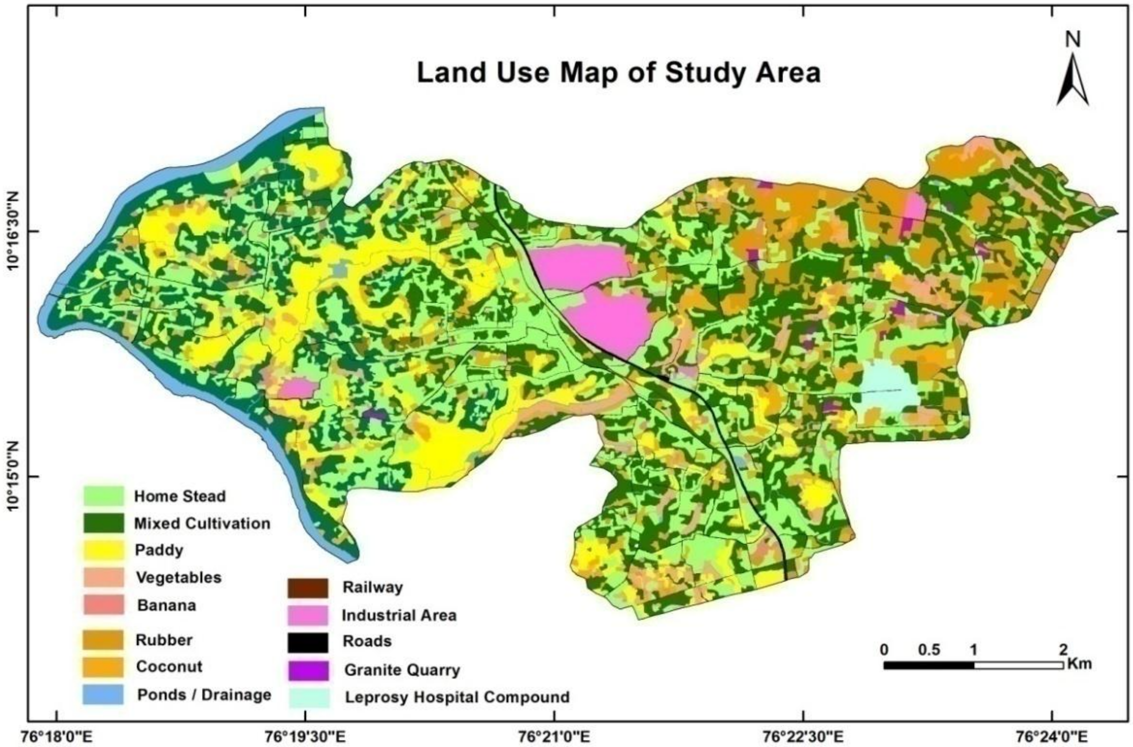
4.3.6 Land use pattern in study area

The land in Koratty is mainly utilized for agriculture. Major cropping pattern includes mixed and monocrops. Mixed crops include coconut, nutmeg, banana, areca nut, vegetables and fruits etc. Monocrops of paddy, banana, vegetables and rubber occupy rest of the area.Mixed crops in homesteads and around covered more than half of the land area of 3486.73 ha. Paddy comes next with 450.32 ha followed by rubber and coconut in around 250ha each. Vegetables cover 168 ha while banana occupy 61.67 ha of land area (Table 4.5).

Industries come next in importance. Six major industries and more than 50 small scale industrial units are present in Koratty region. Together they occupy 114 ha of land.Leprosy sanatorium (32 ha), granite quarries, water bodies, irrigation canals, built-up area and roads occupy rest of the area.

Table 4.5. Landuse pattern in Koratty Region

Sl No	Landuse	Total Area (Ha.)
1	Homesteads	891.08
2	Mixed cultivation	1121.38
3	Paddy	450.32
4	Rubber	251.63
5	Coconut	249.80
6	Vegetables	168.10
7	Banana	61.67
8	Industrial Area	114.33
9	Water courses	45.04
10	Ponds	11.40
11	Railway	6.60
12	Roads	68.38
13	Granite quarry	14.91
14	Leprosy Hospital Compound	32.12
15	Chalakkudy river	94.84
	Total	**3581.6**



Map 4.6. Landuse Map of the study area

It can be seen from the Map 4.6 that the region is a mosaic of different crops scattered throughout in spaces most suitable for their existence. Industries can be seen dotted in between with the major ones clustered in the middle region along the national highway exceptions being CUMI in the northeast and NGIL in the south west. Homesteads and mixed cultivation together occupy most of the area with paddy closely following it. Rubber can be seen restricted to the north eastern part.

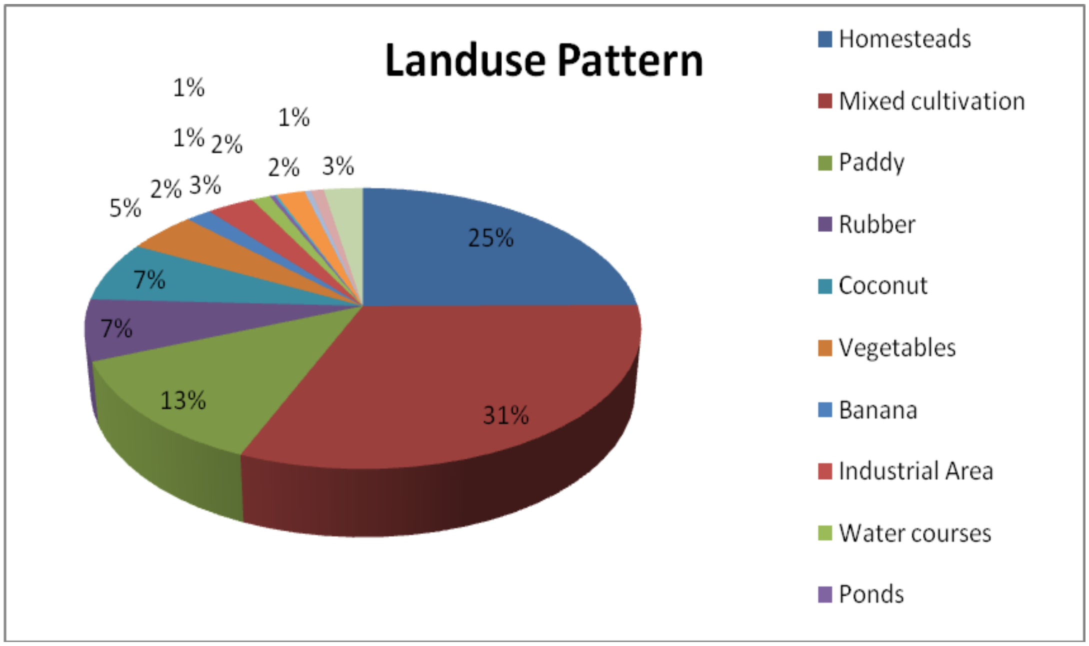


Figure 4.1. Landuse pattern

The percentage distribution of land as shown in figure 4.1 above reveals that homesteads and mixed cultivation together occupy 56 per cent of the land. Next comes paddy with 13 per cent, coconut and rubber with 7 percentages each and vegetables with 2 per cent. Rest of the area is occupied by industries, ponds, railways, roads etc.

4.4 SUMMARY

Koratty region though dominated by agriculture was also influenced by a multitude of major and minor industries. Agriculture occupies 89.2% of the total land area. Industries come next in importance, major and minor industries together occupying 3.27% of the land area.

Mixed crops and homesteads together covered more than half of the land area which was followed by paddy, rubber, coconut, vegetables and banana in the order of decrease. Water bodies, roads, irrigation canals and buildings occupy rest of the area.

CHAPTER 5

SOIL QUALITY AS INFLUENCED BY LANDUSE

5.1 INTRODUCTION

The environment of Koratty, especially which related to soil and water has undergone degradation to various levels due to multitude of factors. Changes in landuse pattern, indiscriminate use of fertilizers and pesticides, urbanization and industrialization have all contributed their share in polluting and degrading the air, water and soil. Change in cropping pattern, conversion from one crop to another, slope modification, quarrying, filling of wet lands, clay mining etc; also add to the degradation process.

Fertilizers and pesticides are being used indiscriminately by farmers for boosting productivity with the result that the soil turns barren and inhospitable to below ground biodiversity that used to sustain the health of soil by improving the physical, chemical and biological properties. The residues of these agrochemicals reach the water bodies also leading to eutrophication and related water quality problems. Urbanization is another developmental issue that degrades the environment by contributing various kinds of solid and liquid wastes that are creating health problems to the population. Industries while producing useful products are also forced to release harmful byproducts or effluents that pollute the air, water and soil.

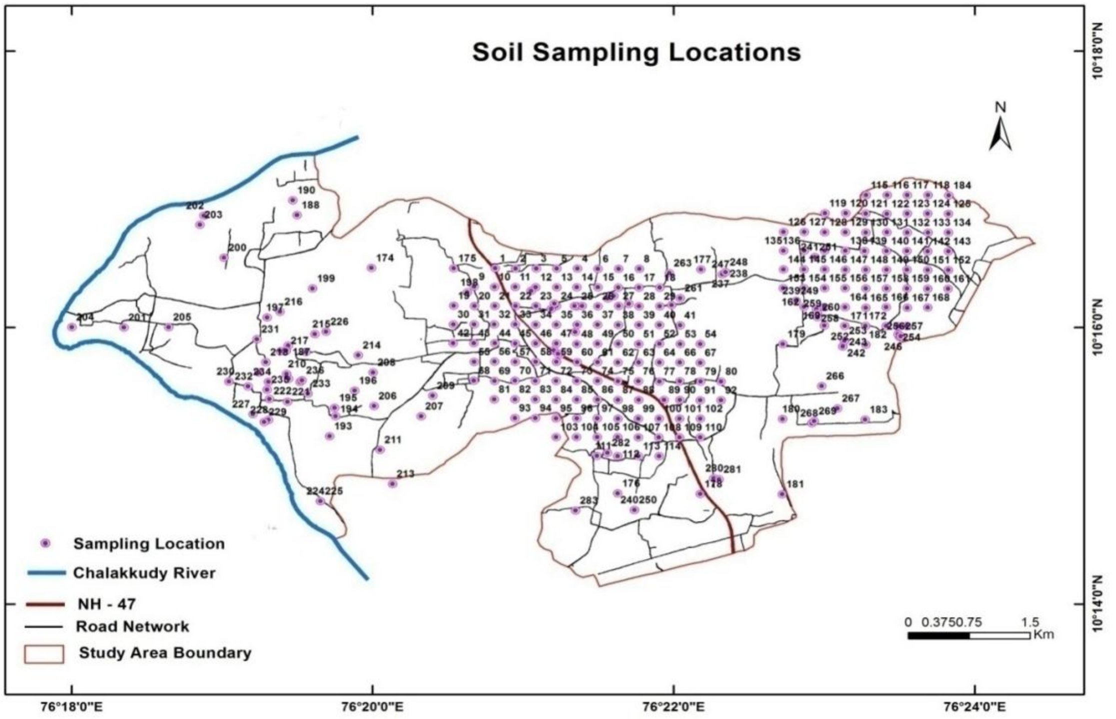
Soils in Koratty region were studied to reveal their quality with respect to physico-chemical and biological attributes. Soils in major landuses were characterized and compared.

5.2 METHODOLOGY

Locations for soil sampling were decided giving weightage to hot spots in and around major industries and intensive agriculture. Intense sampling at 250 x 250m grids were resorted to in these sites while wider sampling was carried out in other areas. Enough samples to represent all landuses were taken systematically.

5.2.1. Soil sampling and analysis

Soil pits of 0-60 cm depth were dug in every grid and samples collected from 0-30 cm and 30-60 cm depths to represent the surface and subsurface horizons. Collected soil samples were air dried in shade, powdered, sieved and stored for analysis.



Map 5.1. Soil Sampling Locations

pH

Soil pH was determined by pH meter in 1:2 soil:water suspension (Jackson, 1973). 5g soil sample was weighed and transferred to a 50 ml beaker. To this 25 ml water was added. It was then stirred thoroughly with a glass rod and suspension was allowed to settle for 30 minutes. pH meter was then standardized with the buffer and the pH reading of the sample was recorded.

EC

Electrical conductivity was also estimated in 1:2 soil:water suspension using conductivity meter by dipping the electrode in the clear supernatant solution (Jackson, 1973).

Organic Carbon

Organic carbon in the soil samples were estimated by oxidizing the organic matter using potassium dichromate – conc. H_2SO_4 and estimation using ferrous ammonium sulphate following Walkley and Black (1934) method.

Heavy metals

0.5g of the powdered soil sample was taken in a digestion tube and 10 ml con: H_2SO_4 and a pinch of salicylic acid were added. The mixture was kept overnight and digested using a block digester in a digestion chamber by adding 5 ml H_2O_2 in every two hours, at a temperature 340^0C till the sample was clear. After the completion of digestion, the digestion tubes were taken from the blocks and allowed to cool. Each digested samples was transferred to a 100 ml standard flask. The content of Ni, Cd, Cr, Pb, Co, Fe, Cu, Zn and Mn in the digested samples was determined using an Atomic Absorption Spectrometer (Varian-240).

Heavy metal fractions

Soil fraction studies were done to estimate the accumulation of heavy metals in soil. Extraction was done following hydrogen peroxide digestion and estimation using Atomic Absorption Spectrophotometer. The various fractions studied, namely, exchangeable, reducible, oxidizable and residual fractions were determined following the BCR (European Community Bureau of Reference) procedure (Ure *et al.*, 1992). Degree of contamination was calculated using the formula $Cdeg=\sum C^{i}_{f}$ where contamination factors of all the elements are taken into account. Contamination factor of each element was calculated using the formula $C^{i}_{f}= C^{i}_{0-1}/C^{i}_{n}$. Enrichment factor gives an indication of heavy metals added to the environment other than from natural sources and was determined using the formula, $EF_{X}=[X_{S}/E_{S}\ (ref)]/[X_{c}/E_{c}\ (ref)]$. Geo accumulation index (Igeo) which gives an estimate of contamination with reference to background levels. Igeo = log Cmetal / 1.5 Cmetal (control).

5.3 RESULTS AND DISCUSSION

Results of soil analyses are presented below in tables 5.1 to 5.60, maps 5.1 to 5.30 and figures 5.1 to 5.25 and discussed along with. Soil maps are also presented to visualize the distribution of these properties and to understand the soil quality in the region.

5.3.1. Soil Quality

Soil pH

The soil was found to be highly acidic in all the agricultural areas (Table 5.1). The pH values in the surface soil (0-30 cm) was around 4.4 in paddy, vegetables and banana while mixed crop and rubber had a soil pH of 4.9 in the same depth. There was a slight increase of pH in sub surface (30-60 cm) soil in all the crops. No significant difference was noted between the crops in the case of soil pH.

Table 5.1. Soil pH in agricultural lands

Agriculture	**0-30cm**			**30-60cm**		
	Mean±SE	Min.	Max.	Mean±SE	Min.	Max.
Paddy	$4.4^{b}\pm0.1$*	3.75	5.4	$4.7^{bc}\pm0.10$	4.2	5.2
Vegetables	$4.4^{b}\pm0.15$	3.91	5.3	$4.6^{b}\pm0.14$	4.0	5.4
Banana	$4.5^{b}\pm0.16$	4.10	5.4	$4.6^{b}\pm0.13$	4.0	5.2
Mixed crop	$4.9^{b}\pm0.05$	4.47	6.0	$5.0^{bc}\pm0.05$	4.5	6.2
Rubber	$4.9^{b}\pm0.06$	4.10	5.5	$4.9^{bc}\pm0.06$	4.3	5.8

*similar alphabets in superscript denote insignificant difference

Industrial areas were not much different from agricultural areas in the pH of surface soil (Table 5.2) though significantly lower values (4.0 to 4.1) were recorded near CUMI and NGIL compared to the other industrial sites of GOI press, KINFRA, Vaigai threads and Infopark where the pH values ranged from 4.9 to 5.2. There was no significant difference in soil pH with increasing depth; the sub surface soil had similar values as the surface soil. Significantly lower pH was recorded in CUMI and NGIL sub soil as was the case in surface soil.

Table 5.2. Soil pH in industrial sites

Industries	**0-30cm**			**30-60cm**		
	Mean±SE	Min.	Max.	Mean±SE	Min.	Max.
GOI Press	$5.2^{b}\pm0.14$*	4.5	5.5	$5.0^{bc}\pm0.13$	4.8	5.5
KINFRA	$4.9^{b}\pm0.17$	4.2	5.1	$4.9^{bc}\pm0.09$	4.7	5.4
VAIGAI	$4.9^{b}\pm0.15$	3.7	5.5	$5.0^{bc}\pm0.15$	4.9	5.1
CUMI	$4.1^{a}\pm0.11$	3.7	4.4	$4.1^{a}\pm0.13$	4.0	5.0
INFO Park	$5.0^{b}\pm0.15$	4.7	5.5	$4.9^{bc}\pm0.17$	4.8	5.5
NGIL	$4.0^{a}\pm0.12$	3.7	4.5	$4.1^{a}\pm0.13$	4.0	5.0

The graph given below (Fig. 5.1) shows soil pH of 0-30 cm depth. Lowest soil pH values are seen in the industrial sites of CUMI and NGIL followed by paddy, vegetables and banana. Other sites, both industrial and agricultural, had almost similar pH with values around 5.0 indicating soil acidification in these landuses also, though not to that extent.

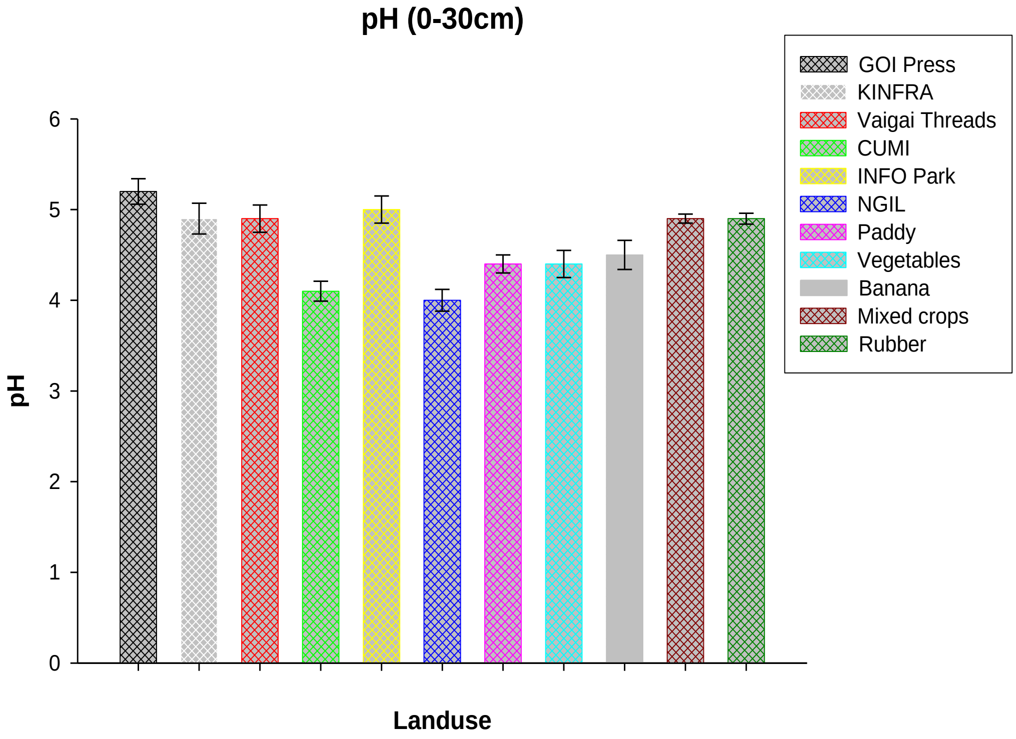


Figure 5.1. Variation in pH of surface soil with different landuses

Soil pH of 30-60 cm depth was similar to that of 0-30 cm as seen in the graph above except that variation between the landuses is slightly less (Fig. 5.2).

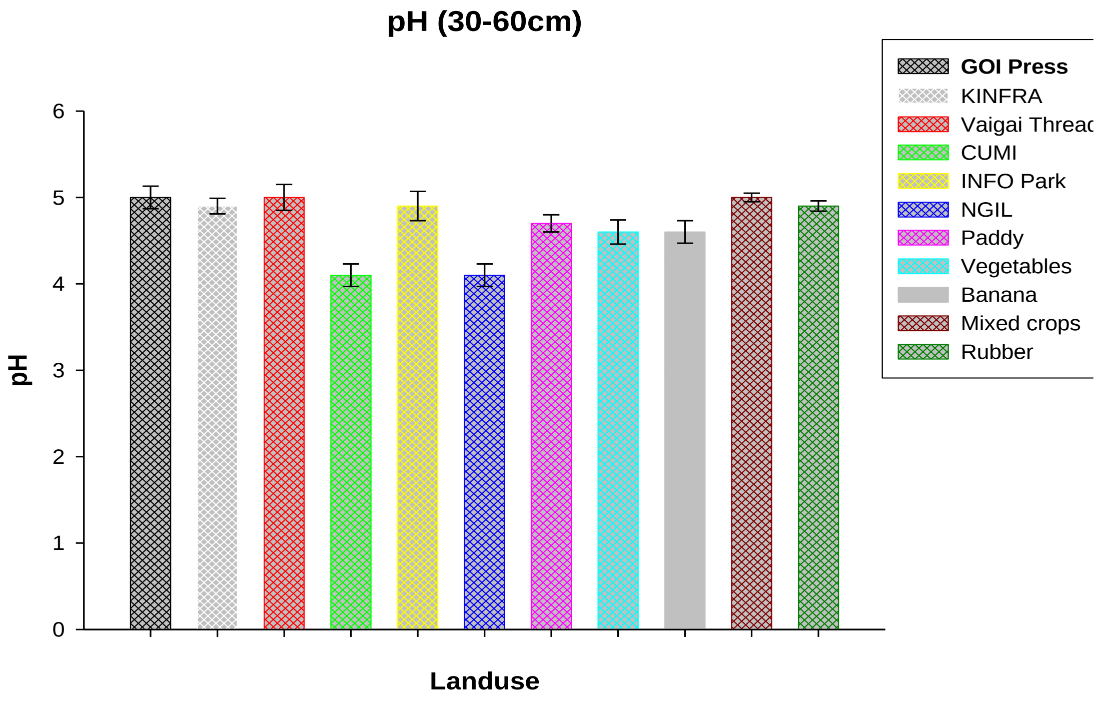
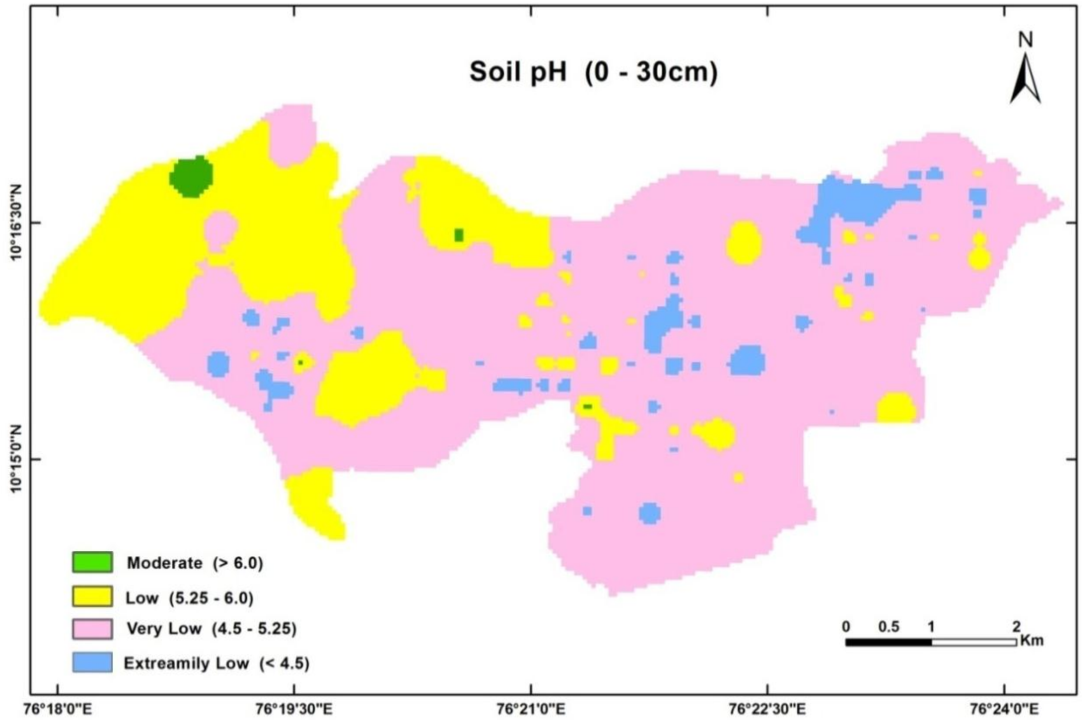


Figure 5.2. Variation in pH of subsurface soil with different landuses

The map 5.2 given below shows the distribution of soil acidity as expressed in the soil pH of the study area. Soil pH values were segregated into four classes as those falling in pH <4.5, 4.5 - 5.25, 5.25 – 6.0 and >6.0. It can be seen that most of the area falls in the group 4.5 – 5.25 followed by 5.25 – 6.0. Areas with pH of <4.5 and >6.0 are negligible; 94.87 per cent falls in the 4.5 – 6.0 pH class while, 70.79 % of the region has a pH of 4.5 – 5.25. The low pH values indicating high acidity can be due to atmospheric gases as also due to the high input agriculture employing synthetic fertilizers, most of which are acidic. The extremely low pH areas are located near the industrial belt.

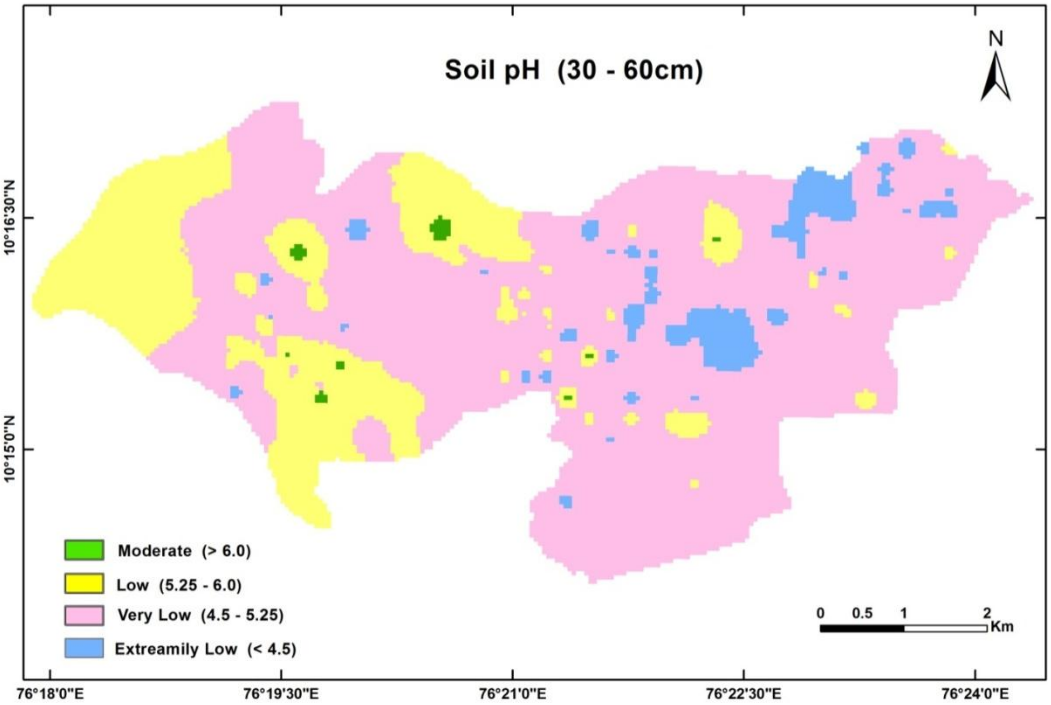


Map 5.2.Distribution of soil pH in 0-30 cm

Table 5.3. Extent of area under different classes

Class	Area (ha)	Percentage
<4.5	162.75	4.54
4.5-5.25	2537.00	70.79
5.25-6	863.00	24.08
>6	21.00	0.59
Total	**3583.75**	**100**

The distribution of soil acidity in the sub surface soil does not differ much from the surface soil except that a slight increase in the lower classes, i.e, higher acidity class is noted in Map 5.3 below. The area affected is the same indicating the same causes.



Map 5.3. Distribution of soil pH in 30-60 cm

Table 5.4. Extent of area under different classes

Class	Area (ha)	Percentage
<4.5	179.80	5.02
4.5-5.25	2558.00	71.38
5.25-6	832.80	23.24
>6	13.00	0.36
Total	**3583.75**	**100**

Electrical Conductivity

Soil in agricultural landuse had extremely low values of electrical conductivity with values less than 0.02 dS/m in both surface and sub surface horizons (Table 5.5). No significant difference could be observed between different crops in influencing the electrical conductivity. Values ranged from as low as 0.001 to a maximum of 0.06 dS/m in the surface soil; the respective figures in the sub surface soil were 0.0008 and 0.04 dS/m.

Table 5.5. Electrical conductivity (dS/m) of soil in agricultural areas

Agriculture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	0.02^{a}±0.002*	0.008	0.04	0.015^{a}±0.002	0.009	0.02
Vegetables	0.02^{a}±0.003	0.007	0.05	0.013^{a}±0.002	0.005	0.019
Banana	0.03^{a}±0.003	0.009	0.06	0.020^{a}±0.004	0.006	0.04
Mixed crop	0.004^{a}±0.001	0.001	0.01	0.002^{a}±0.001	0.0008	0.005
Rubber	0.005^{a}±0.001	0.001	0.01	0.003^{a}±0.001	0.0009	0.005

*similar alphabets in superscript denote insignificant difference

Electrical conductivity of soil in industrial areas were not much different from that of agricultural areas (Table 5.6). No significant difference was noted between industries in this respect. Values ranged from 0.0012 to 0.05 dS/m in the surface soil and 0.0009 to 0.03 in sub surface soil.

Table 5.6. Electrical conductivity (dS/m) of soil in industrial areas

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	0.01^{a}±0.002*	0.0012	0.02	0.006^{a}±0.006	0.001	0.01
KINFRA	0.03^{a}±0.002	0.0013	0.05	0.01^{a}±0.002	0.005	0.03
VAIGAI	0.009^{a}±0.004	0.0025	0.03	0.004^{a}±0.005	0.0009	0.02
CUMI	0.01^{a}±0.001	0.004	0.04	0.007^{a}±0.003	0.002	0.01
INFO Park	0.008^{a}±0.002	0.0045	0.02	0.005^{a}±0.005	0.001	0.01
NGL	0.01^{a}±0.006	0.005	0.05	0.008^{a}±0.002	0.002	0.02

*similar alphabets in superscript denote insignificant difference

Variation in electrical conductivity of 0-30 cm soil depth as depicted in the graph (Fig. 5.3) reveals comparatively higher values in KINFRA and banana sites. Lowest values were seen in mixed crops and rubber. Other sites fall in between with slightly higher values in paddy and vegetables.

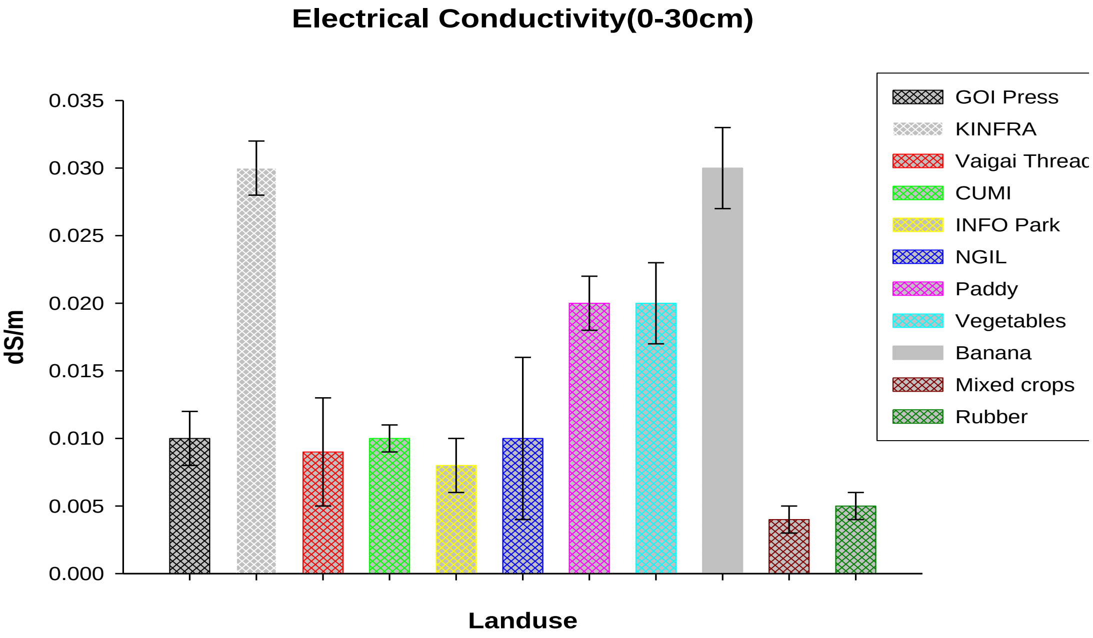


Figure 5.3. Variation in electrical conductivity of surface soil with different landuses

Electrical conductivity was insignificantly low in the subsurface soil also (Fig. 5.4). The trend in EC values shows a different pattern. Comparatively higher EC values were seen in banana, paddy and vegetables and lowest values in mixed crop and rubber.

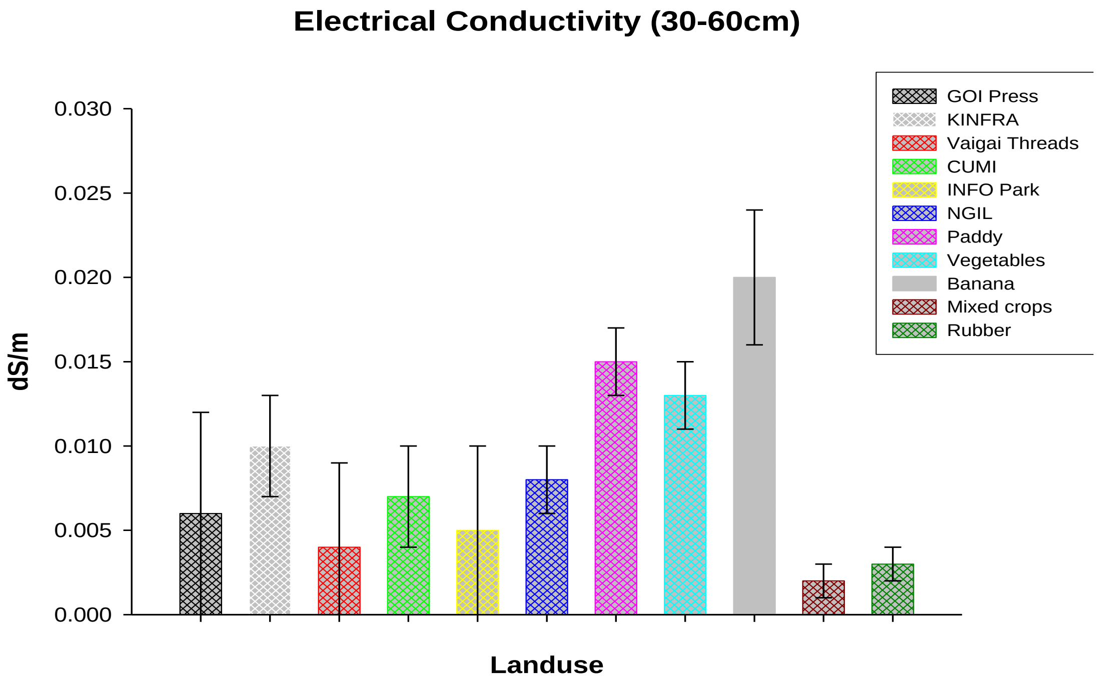
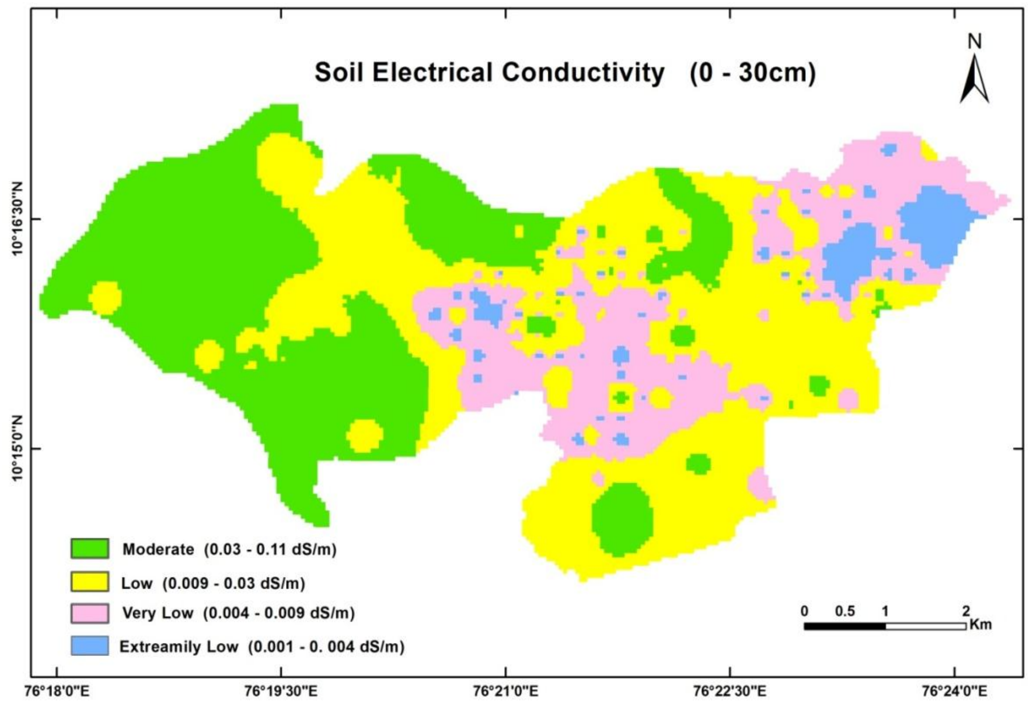


Figure 5.4. Variation inelectrical conductivity of subsurface soil with different landuses

Electrical conductivity was extremely low in both surface and sub surface soils; it was extremely low and of no impact as regards the soil and its characteristics (Map 5.4). The distribution of electrical conductivity in the surface soil as shown by the map indicates that most of the area (95.3%) had EC values of 0.004 to 0.11 dS/m which are extremely low. Very low levels can be seen to be located in the middle and northeast while most of the comparatively moderate levels are seen in the southwest localities.

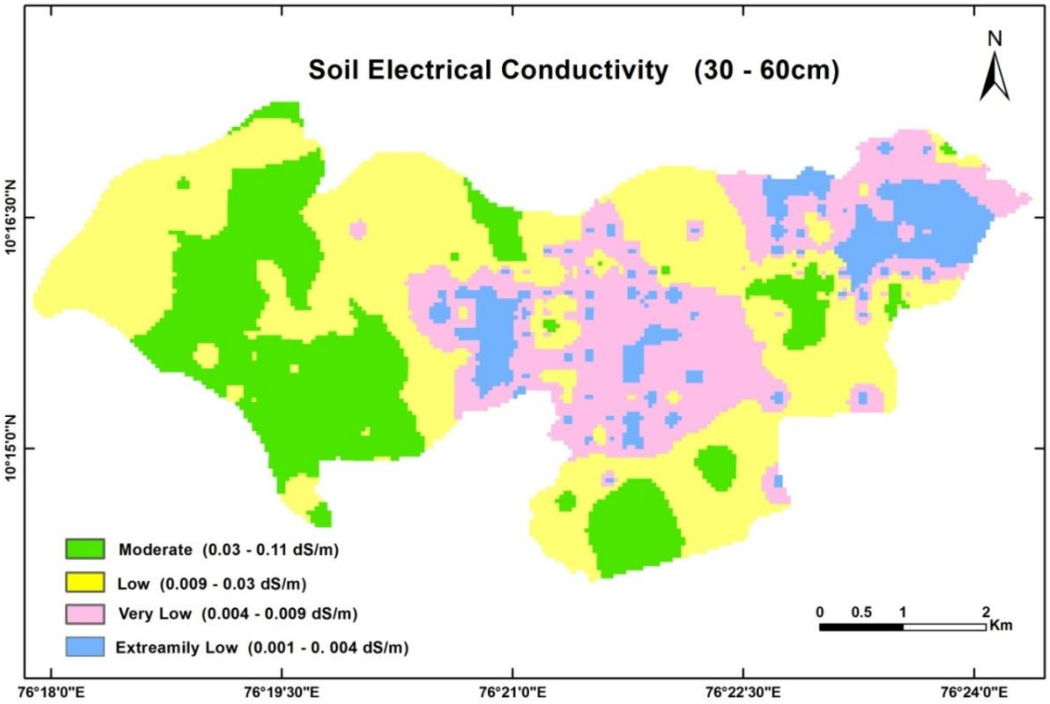


Map 5.4.Distribution of soil EC in 0-30 cm

Table 5.7. Extent of area under different classes

Class (dS/m)	Area (ha)	Percentage
0.001-0.004	154.25	4.30
0.004-0.009	705.25	19.68
0.009-0.03	1433.00	39.99
0.03-0.11	1291.25	36.03
Total	**3583.75**	**100**

The electrical conductivity of soil in the 30-60 cm layer was also negligible and with 91 per cent of the area having EC values of 0.004 to 0.11 dS/m only (Map 5.5). The three upper classes are seen occupying most of the area. A perceptible reduction in the moderate level area and an increase in the extremely low level area is evident in the map. The low value locations are in the central and northeast region as was the pattern in 0-30 cm soil.



Map 5.5.Distribution of soil EC in 30-60 cm

Table 5.8. Extent of area under different classes

Class (dS/m)	Area (ha)	Percentage
0.001-0.004	314.50	8.78
0.004-0.009	824.50	23.01
0.009-0.03	1581.00	44.11
0.03-0.11	864.00	24.11
Total	**3583.75**	**100**

Soil Organic Carbon

Organic carbon content of soil is given in Table 5.9. It can be seen that the surface soils are high in organic carbon content and it decreases with depth. Lowest OC value was observed in banana with surface soil having 0.7 per cent and sub surface having 0.4 per cent. Highest value of 1.6 per cent OC was recorded from mixed crop in the surface soil. The sub surface soil of mixed crop had an organic carbon content of 0.9 per cent. Mixed crop soil had significantly higher OC content in both depths. Other sites had values in between these two landuses.

Table 5.9. Soil organic carbon (%) in agricultural areas

Agriculture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	$1.1^{a}\pm0.21$*	0.60	1.4	$0.6^{a}\pm0.23$	0.30	0.9
Vegetables	$1.0^{a}\pm0.27$	0.43	1.2	$0.5^{a}\pm0.16$	0.23	0.7
Banana	$0.7^{a}\pm0.15$	0.40	1.0	$0.4^{a}\pm0.18$	0.20	0.7
Mixed crop	$1.6^{b}\pm0.07$	1.0	2.0	$0.9^{b}\pm0.08$	0.5	1.1
Rubber	$1.2^{ab}\pm0.18$	0.9	1.3	$0.7^{ab}\pm0.17$	0.3	0.8

*similar alphabets in superscript denote insignificant difference

Industrial sites also had appreciable levels of organic carbon in the soil (Table 5.10). Highest value of 1.5 per cent was recorded in GOI press compound followed by Nitta, CUMI and others. Lowest OC value was recorded from Infopark. There was no significant difference between landuses. OC content decreased with depth in all the industrial sites. No significant difference could be noted in the sub surface soil also.

Table 5.10.Soil organic carbon % in industrial areas

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Mini.	Max.	Mean ± SE	Min.	Max.
GOI Press	$1.5^{b}\pm0.23$*	0.8	2.08	$0.8^{a}\pm0.12$	0.4	1.1
KINFRA	$0.8^{a}\pm0.35$	0.4	1.13	$0.5^{a}\pm0.18$	0.3	0.8
VAIGAI	$0.8^{a}\pm0.12$	0.5	1.10	$0.4^{a}\pm0.19$	0.3	0.9
CUMI	$1.0^{a}\pm0.14$	0.7	1.20	$0.5^{a}\pm0.13$	0.4	0.6
INFO Park	$0.7^{a}\pm0.23$	0.5	1.00	$0.3^{a}\pm0.14$	0.2	0.5
NGIL	$1.1^{a}\pm0.09$	0.7	1.5	$0.6^{a}\pm0.16$	0.4	0.8

*similar alphabets in superscript denote insignificant difference

Organic carbon content of surface soil was comparatively higher in GOI press compound, mixed crop and rubber with values above 1.2 per cent (Fig. 5.5). Low carbon content was observed in Kinfra, Vaigai threads, Infopark and banana. Other landuses were intermediate with around 1 per cent organic carbon.

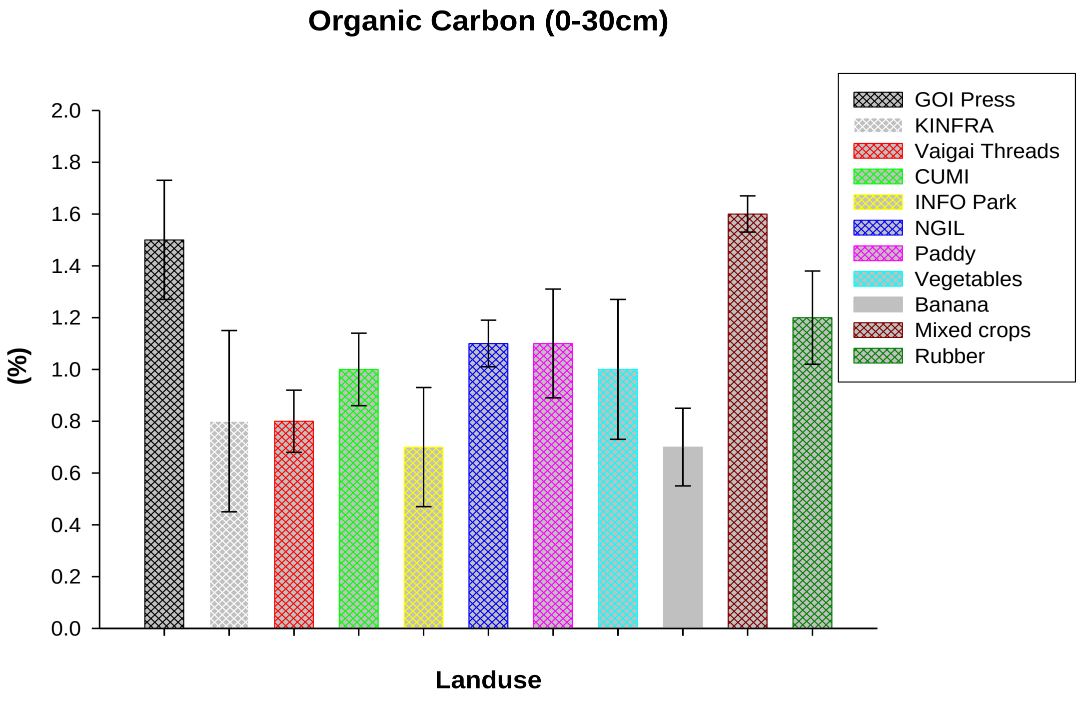


Figure 5.5. Variation in organic carbon of surface soil with different Landuses

Figure 5.6 given below depicts the status of organic carbon in the sub surface soil under different landuses was seen to be comparatively higher in GOI press, mixed crop and rubber followed by NGIL, paddy, CUMI, vegetables, Kinfra, Vaigai threads and Infopark in decreasing order.

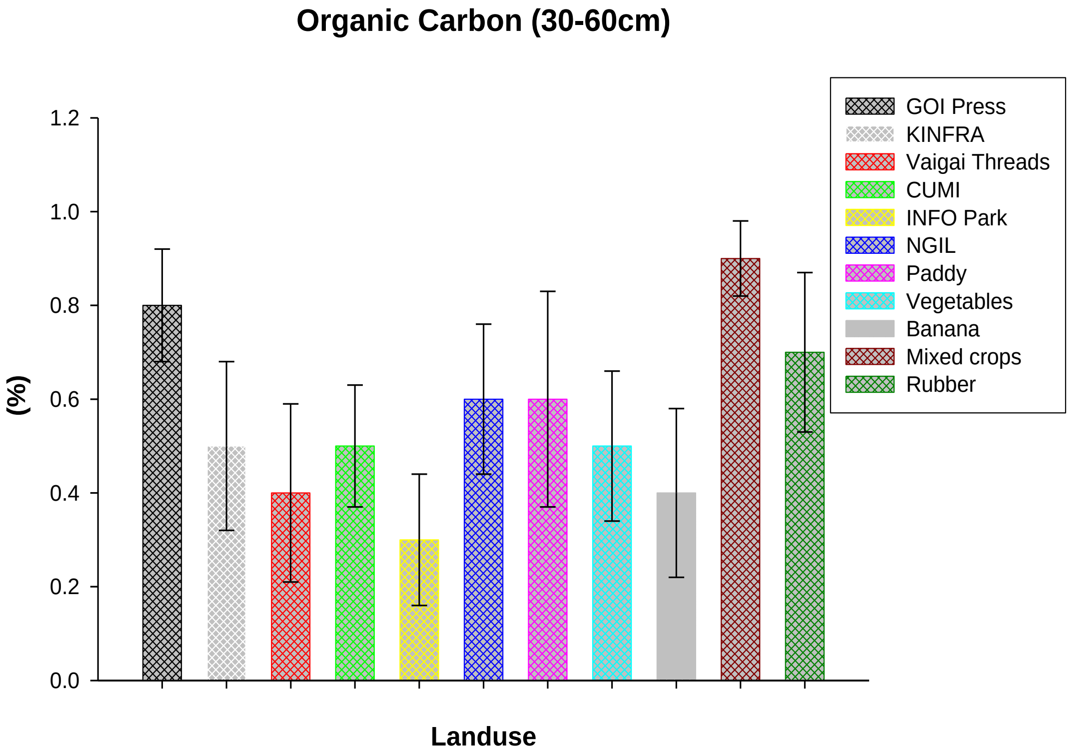
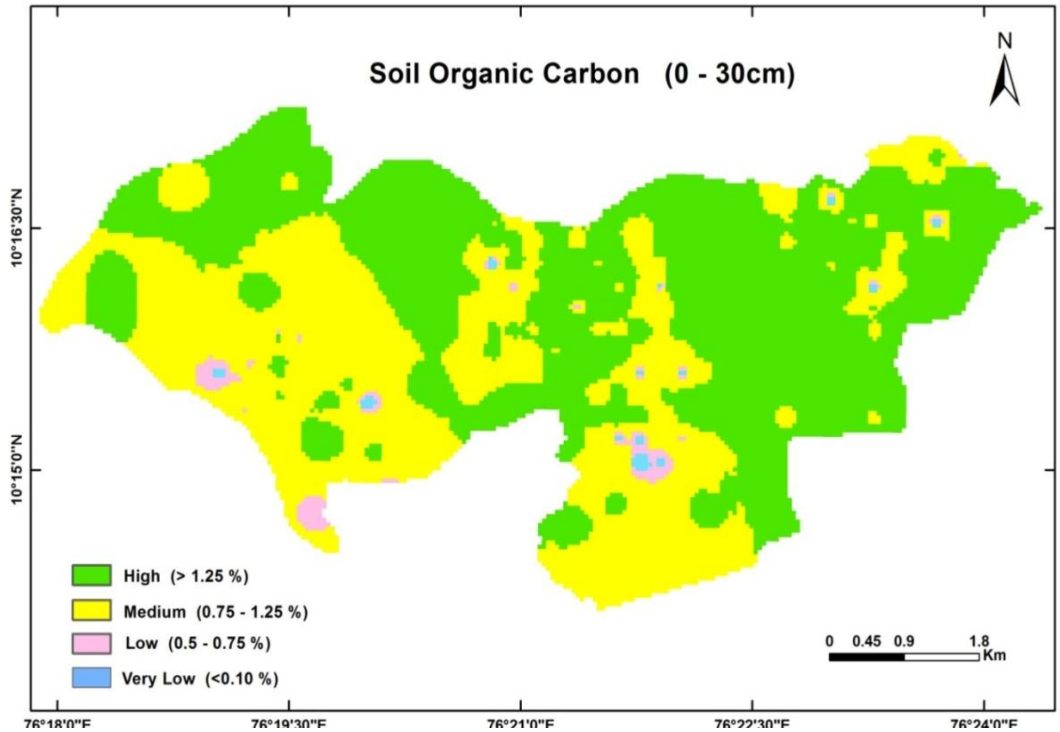


Figure 5.6. Variation in organic carbon of subsurface soil with different landuses

Organic carbon was found to be very high in the study area, the OC values ranging from 1.2 to 2.2 per cent in 0-30 cm soil layer. In 30-60 cm soil the value ranged from 1.2 to 2.62 per cent. These values are very high indicating ample supply of organic matter. Significantly higher values were observed in the soils around Carborandum Universal and lower values around Nitta Gelatin and banana. The organic carbon per cent decreased with soil depth.

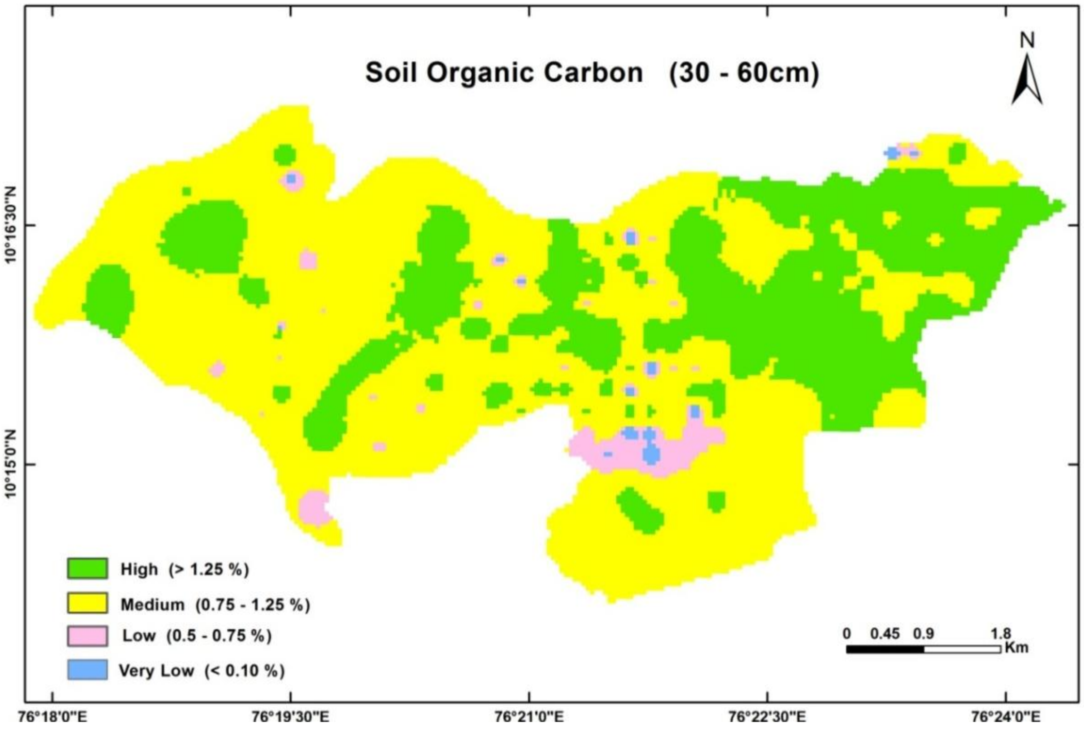


Map 5.6. Distribution of soil organic carbon in 0-30 cm

Koratty region can be seen to be medium to high in soil organic carbon status; the higher levels being present in the north and northeast regions accounting for 99.5 % of the area table 5.11. Low levels are seen in a few small pockets scattered across the landscape and the area is insignificant.

Table 5.11. Extent of area under different classes

Class (%)	Area (ha)	Percentage
< 0.10	2.75	0.08
0.50-0.75	12.75	0.36
0.75-1.25	1724.85	48.13
> 1.25	1844.62	51.44
Total	3583.75	100



Map 5.7. Distribution of soil organic carbon in 30-60 cm

The pattern of soil organic carbon distribution in the sub surface soil was slightly in different with an increase in area of the medium class and decrease in the high class. As was the case in the surface soil these two classes together occupy 99.5% of the area (Table 5.12).

Table 5.12. Extent of area under different classes

Class (%)	**Area (ha)**	**Percentage**
<0.10	2.50	0.07
0.50-0.75	16.50	0.46
0.75-1.25	2194.34	61.22
> 1.25	1371.20	38.25
Total	3583.75	100

Soil Iron

Iron content in soils of different crops is given in table 5.13. It can be seen that the content of iron exceeded permissible levels of 100 mg kg^{-1} in banana, mixed crops and vegetables in the surface soil. Paddy and vegetables had significantly lower values of around 90 mg kg^{-1}. Wide variations were seen between samples as indicated by the minimum and maximum values. Sub surface soils had similar levels and trends of iron distribution in respective crops, though values were slightly higher than the surface soil.

Table 5.13. Soil iron content (mg kg^{-1}) in agricultural areas

Agriculture	0-30cm			30-60cm		
	Mean±SE	Min.	Max.	Mean±SE	Min.	Max.
Paddy	88.3^{a} ±7.72*	42.30	198.00	93.62^{a} ±7.82	45.2	205
Vegetables	93.8^{a} ±10.44	55.80	189.20	100.06^{a} ±8.23	35.50	195.2
Banana	142.9^{b} ±8.52	43.90	189.10	151.38^{b} ±6.81	50.10	185.3
Mixed crop	115.5^{b} ±6.71	44.0	189.60	127.35^{b} ±9.39	70.60	201
Rubber	119.9^{b} ±8.54	53.00	201.10	120.2^{b} ±7.81	58.20	198.3

*similar alphabets in superscript denote insignificant difference

Surface soils in industrial sites had higher levels of iron with values exceeding 100 mg kg^{-1}. No significant difference could be noted between the sites (Table 5.14). Wide variation was observed between samples in these sites. Iron content in sub surface soil was similar as in the surface soil; the pattern remained almost the same as regards site differences also.

Table 5.14. Soil iron content (mg kg^{-1}) in industrial areas

Industrial Area	0-30cm			30-60cm		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	147.08^{ab} ±5.12*	56.8	243.9	141.22^{ab} ±7.42	41.0	220.0
KINFRA	135.12^{ab} ±2.48	55.1	289.1	127.94^{ab} ±4.99	62.0	247.0
VAIGAI	127.7^{ab} ±10.16	74	234.6	130.2^{ab} ±10.29	65.9	245.3
CUMI	118.7^{a} ±5.17	41.6	186.3	110.15^{a} ±7.08	59.8	261.1
INFO Park	150.6^{ab} ±6.16	39	254.1	144.31^{ab} ±5.69	68.3	249.3
NGIL	120.6^{a} ±7.01	38.5	252.7	117.76^{a} ±6.23	43.5	221.1

*similar alphabets in superscript denote insignificant difference

Iron content in sites with different landuses as shown by the histogram below (Fig. 5.7) indicates that the Government of India press compound, Kinfra and Infopark compounds as also the banana cultivated sites had higher iron content. Paddy and vegetable croplands had the lowest levels of soil iron.

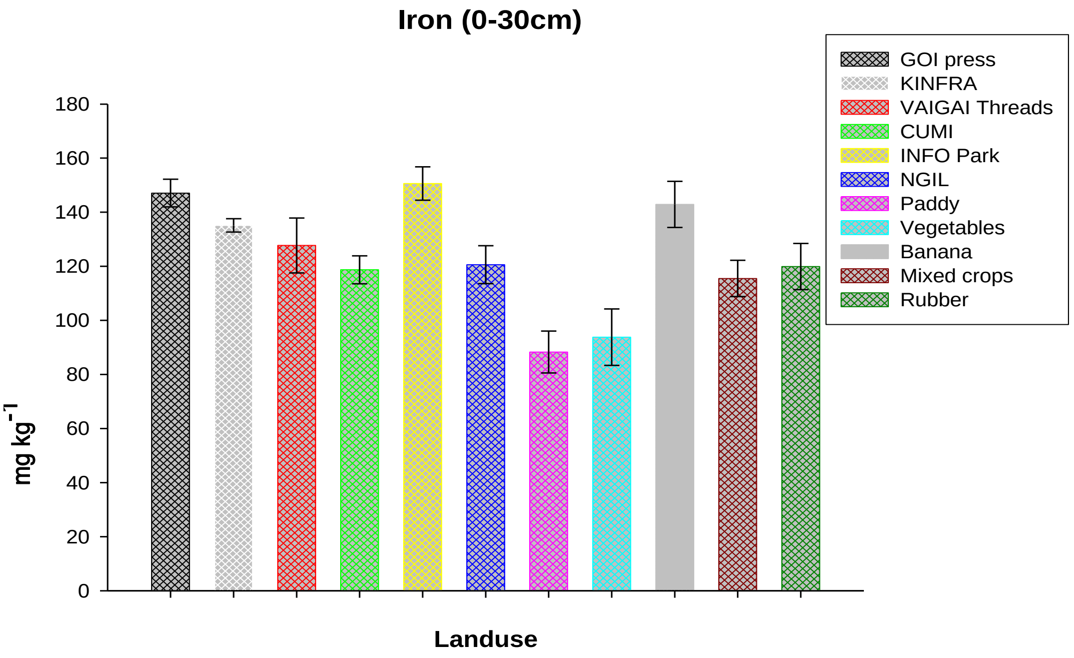


Figure 5.7. Variation in iron of surface soil with different landuses

The pattern remains almost unaltered in the sub surface soil also; the uplands have more soil iron than the low lands (Fig. 5.8). Loss of organic matter along with the surface soil layers by runoff and soil erosion exposes the subsurface layers that contain comparatively greater quantity of iron. The upland slopping terrains have probably suffered such degradation more compared to the low lands where paddy and vegetables are grown.

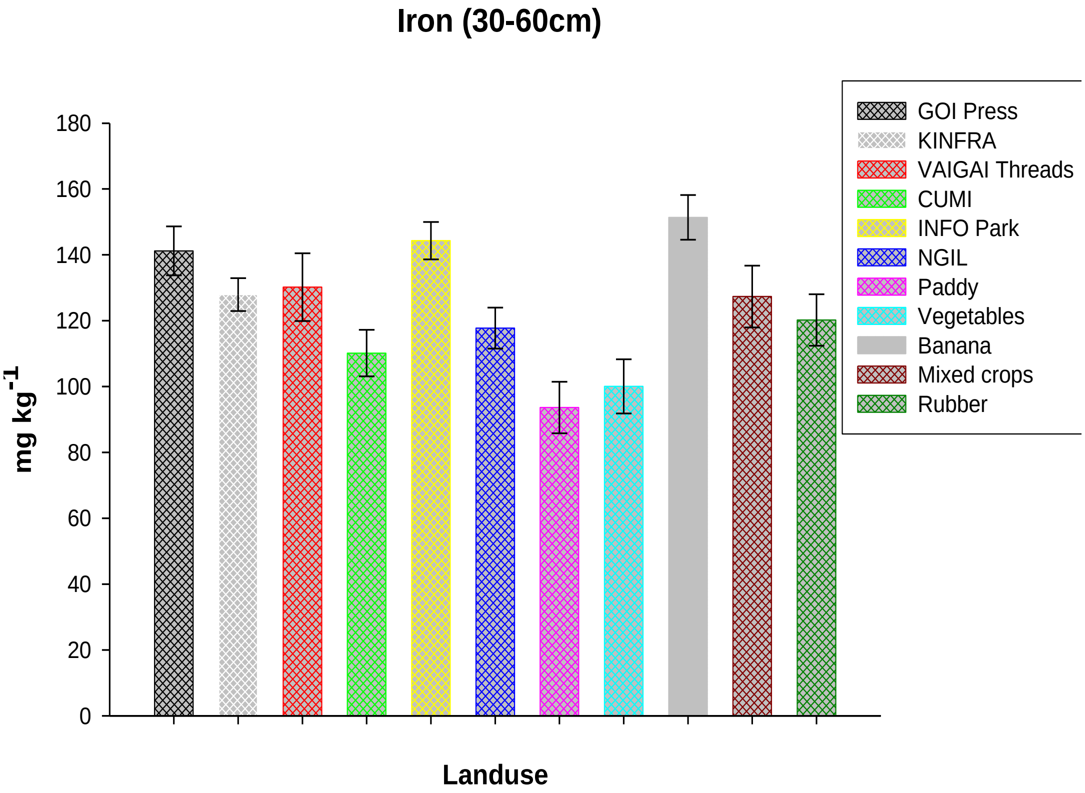
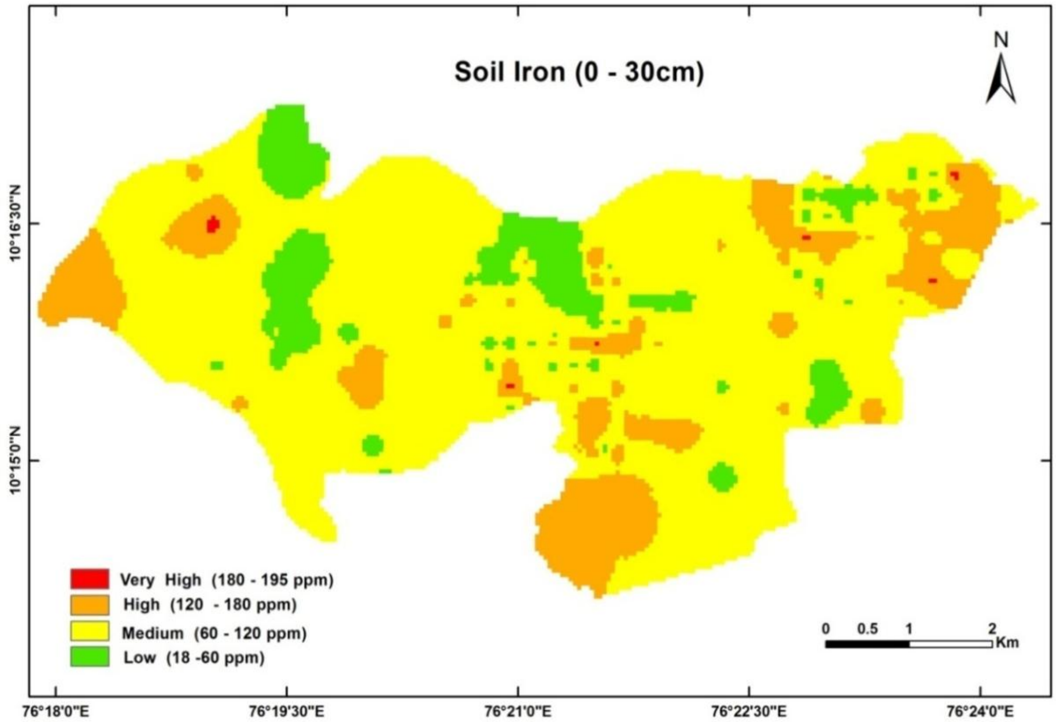


Figure 5.8. Variation in iron of subsurface soil with different landuses

The map showing the presence of iron in different classes (Map 5.8) indicates that most of the area had iron content of 60 to 120 mg kg^{-1} in the surface soil. This class occupies 73 per cent of the area. The next higher class 120 to 180 mg kg^{-1} occupies around 17 per cent; both classes together occupy 90 per cent of the area.

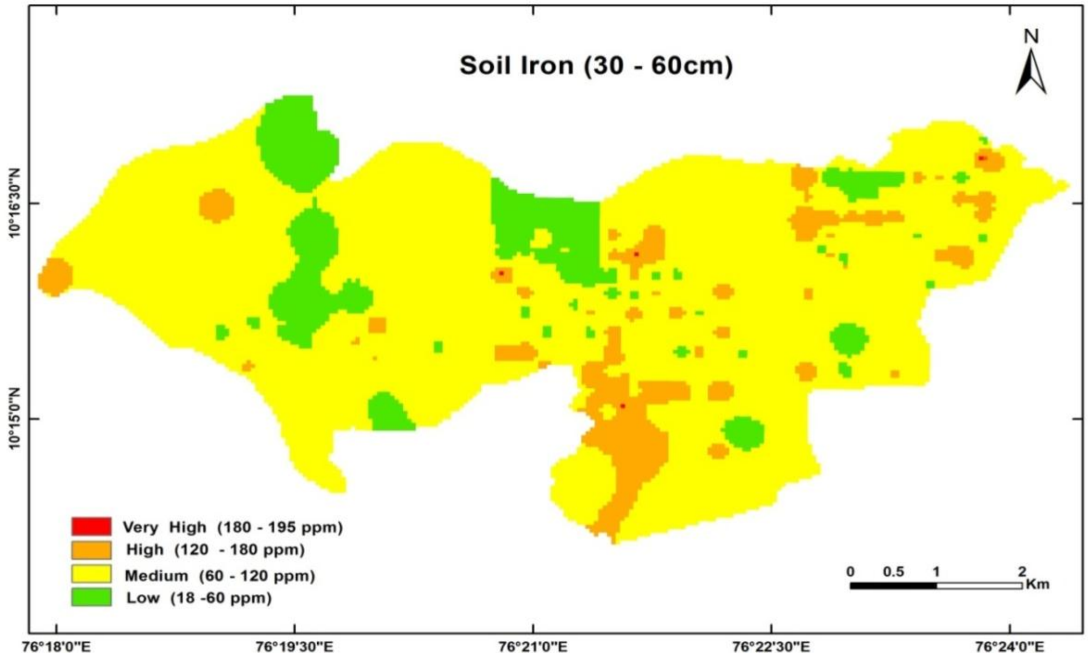


Map 5.8. Distribution of soil iron in 0-30 cm

Table 5.15. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
18 - 60	361.50	10.09
60 - 120	2611.50	72.87
120 - 180	601.00	16.77
180 - 195	4.75	0.13
Total	**3583.75**	**100**

The trend of distribution of iron in the sub surface soil remains almost the same with around 80 per cent of the area representing the class 60-120 mg kg^{-1} (Map 5.9). Considering the next lower class along with will push the total percentage to 91 per cent; i.e, areas with iron content of 18 - 120 mg kg^{-1}.



Map 5.9. Distribution of soil iron in 30-60 cm

Table 5.16. Extent of area under different classes

Class (mg kg^{-1})	Area (ha)	Percentage
18-60	409.30	11.42
60-120	2856.00	79.70
120-180	317.30	8.85
180-195	1.00	0.03
Total	**3583.75**	**100**

High content of iron is expected in the ferrallitic soil that has accumulated iron in the process of its formation consequent to leaching down of silica and most of the bases and enrichment of iron aluminium and manganese in the soil profile under the intense weathering of parent material rich in sesquioxides.

Soil Manganese

The content of manganese in the surface soil of agricultural areas did not vary much between crops (Table 5.17). The values ranged from 170 to

264 mg kg^{-1} in different crops. Sub surface soil also had similar manganese levels with no significant difference between crops as was the case with the surface soil.

Table 5.17. Soil manganese content (mg kg^{-1}) in agricultural areas

Agricul-ture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	$264.3^{bcd}\pm29.68$*	25.6	617.4	$225.05^{b}\pm24.8$	25.6	617.4
Vegetables	$205.7^{abc}\pm24.52$	85.3	477.6	$205.39^{ab}\pm25.2$	64.2	477.6
Banana	$169.9^{ab}\pm19.67$	85.3	384.8	$192.39^{ab}\pm25.7$	74.1	409.4
Mixed crop	$226.9^{abc}\pm12.84$	71.8	724.0	$216.25^{ab}\pm10.3$	51.8	724.0
Rubber	$224.7^{abc}\pm22.25$	25.3	437.2	$219.51^{ab}\pm23.0$	25.3	547.8

*similar alphabets in superscript denote insignificant difference

Manganese content in the surface soil of industrial areas was found to be around 200 to 300 mg kg^{-1} and there was no significant difference between industries in this respect (Table 5.18). In the sub surface soil manganese levels ranged from 220 to 280 mg kg^{-1} with no significant difference between sites.

Table 5.18.Soil manganese content (mg kg^{-1}) in industrial areas

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	$269.8^{ab}\pm53.83$*	120.6	439.8	$223.12^{a}\pm45.59$	152.5	487.9
KINFRA	$298^{ab}\pm70.62$	147.8	352.0	$221.88^{a}\pm52.25$	120.6	439.8
VAIGAI	$201.9^{a}\pm48.23$	128.4	353.4	$246.96^{ab}\pm37.31$	147.8	381.6
CUMI	$251.6^{ab}\pm46.94$	125.8	396.2	$280.37^{ab}\pm59.52$	128.4	327.6
INFO Park	$223.5^{a}\pm50.91$	202.0	301.8	$278.84^{ab}\pm11.4$	101.4	348.4
NGIL	$226.02^{a}\pm8.51$	76.8	287.9	$205.92^{a}\pm7.76$	170.2	421.0

*similar alphabets in superscript denote insignificant difference

Manganese can be seen to be more in GOI Press compound, KINFRA, CUMI and Paddy fields and least in banana cultivated areas when the surface soil was considered (Fig. 5.9).

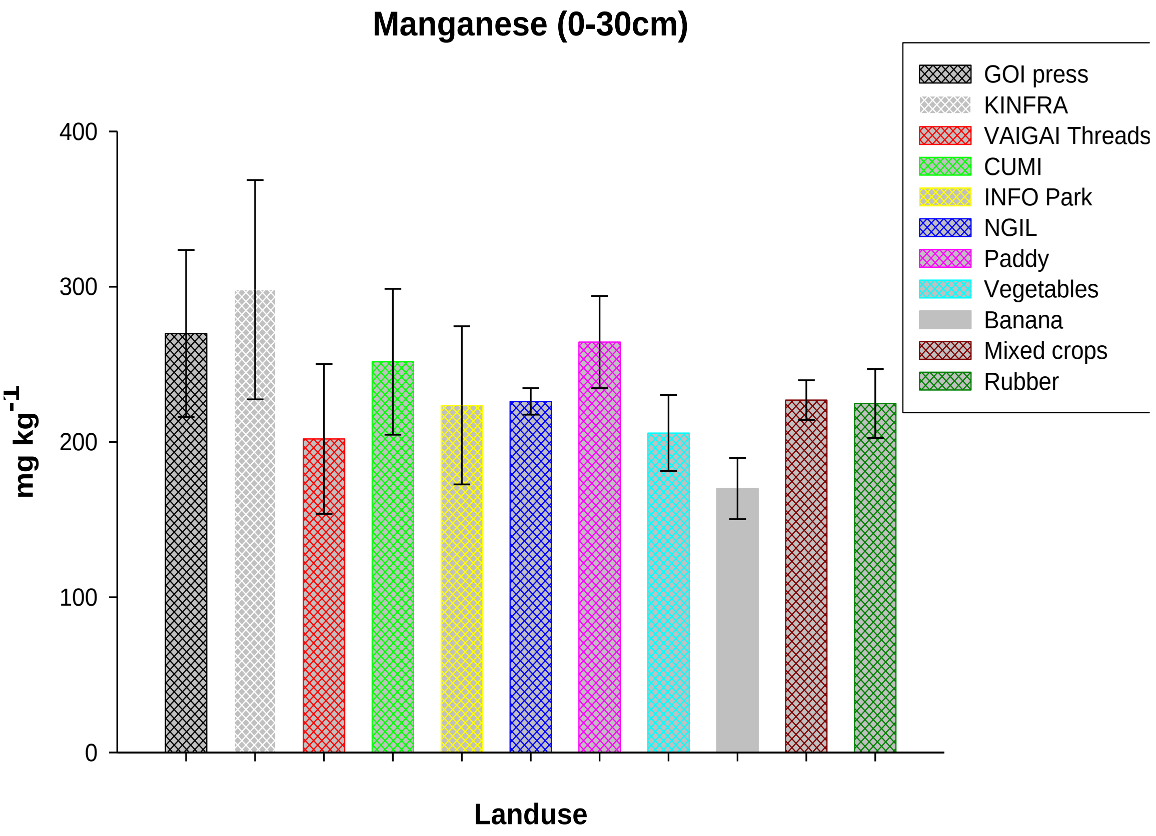


Figure 5.9. Variation in manganese of surface soil with different landuses

In the subsurface soil of 30-60 cm, the content of manganese was slightly more in CUMI and INFO Park areas; the rest of the sites did not exhibit remarkable variation (Fig. 5.10).

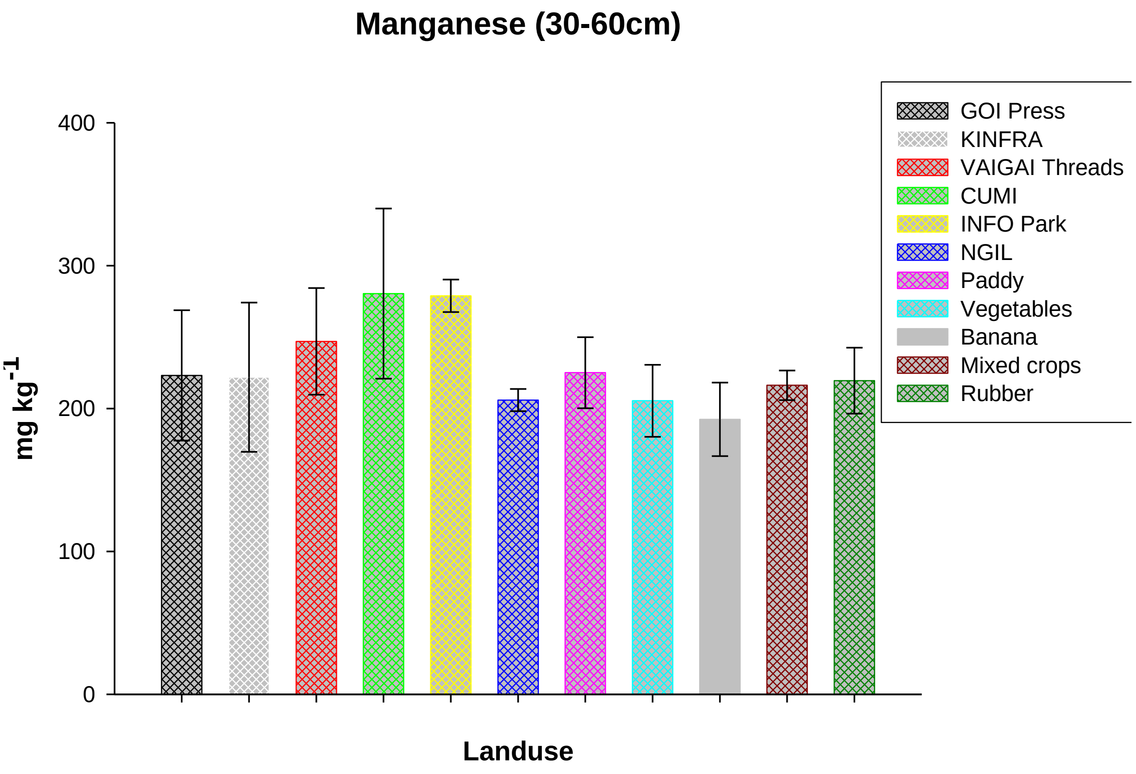
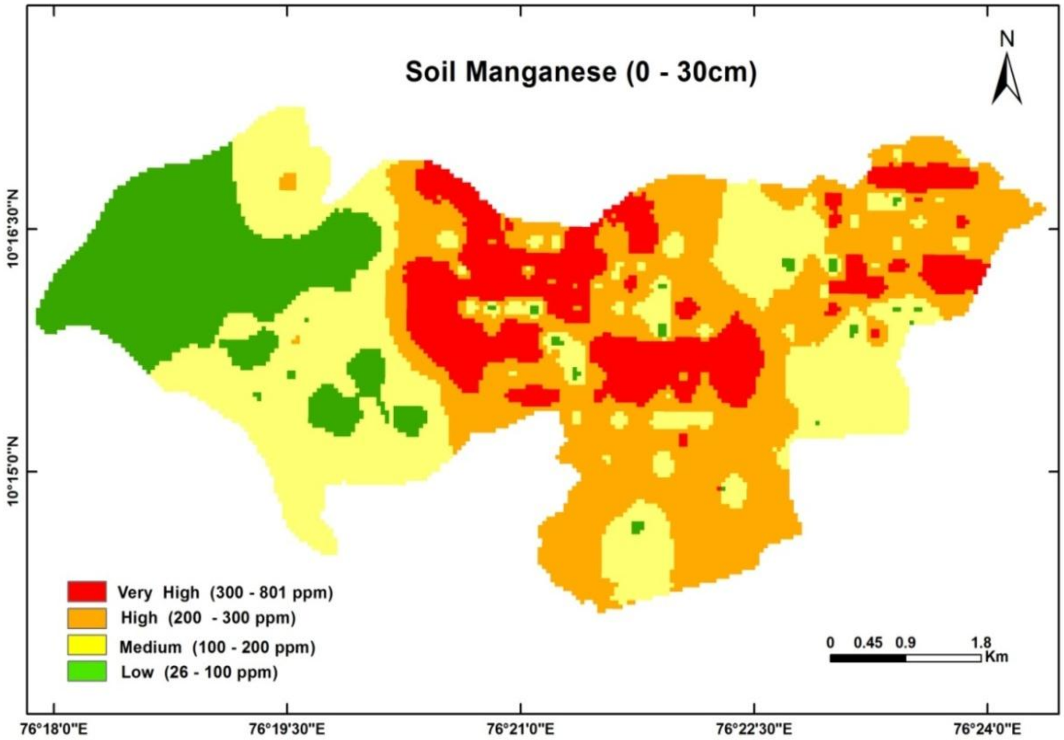


Figure 5.10. Variation in manganese of sub surface soil with different landuses

The pattern of distribution of manganese in 0-30 cm depth of the soil is shown in the map 5.10 below. It can be seen that all the four classes are represented across the land scape. Most of the area (83%) has manganese above 100 mg kg^{-1} which is the upper desirable level.

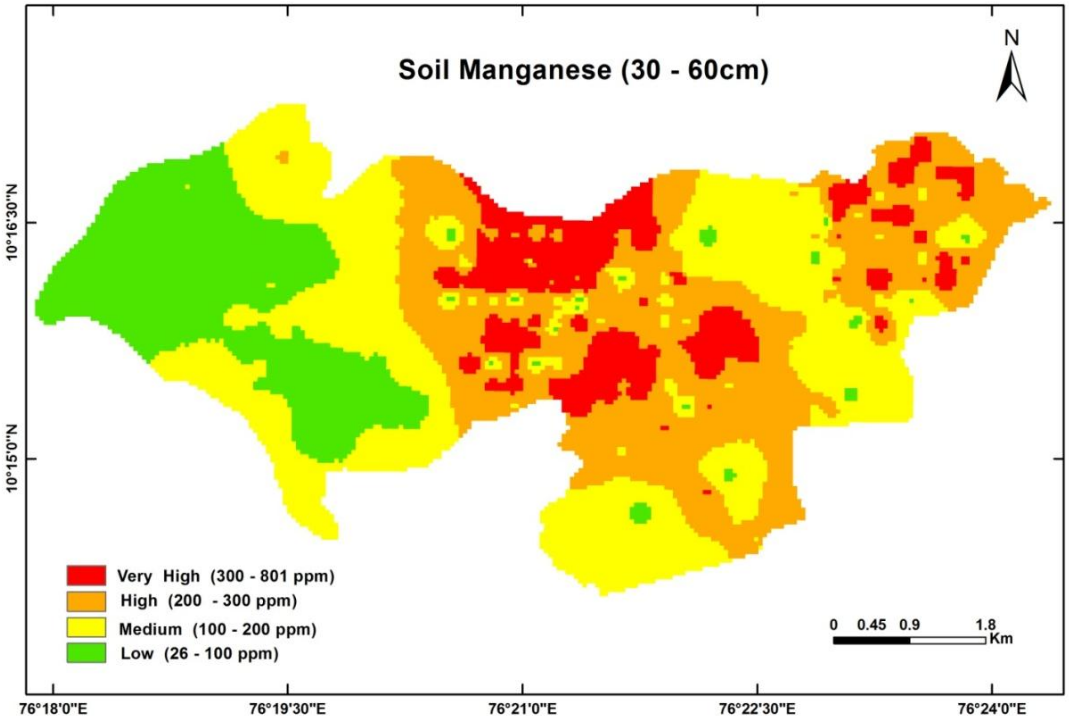


Map 5.10.Distribution of soil manganese in 0-30 cm

Table 5.19. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
26-100	616.25	17.20
100-200	1148.50	32.05
200-300	1261.75	35.21
300-801	557.25	15.55
Total	3583.75	100

Manganese concentration in 30-60 cm layer of the soil in the study area as represented by the Map 5.11 below shows that it is not much different from the surface soil; the area with higher than permissible level of manganese is almost the same. Higher levels of manganese in this soil are also justified by its origin.



Map 5.11. Distribution of soil manganese in 30-60 cm

Table 5.20. Extent of area under different classes

Class (mg kg^{-1})	Area (ha)	Percentage
26-100	710.30	19.82
100-200	1305.00	36.41
200-300	1150.00	32.10
300-801	418.30	11.67
Total	3583.75	100

Soil Zinc

Zinc in surface soils of agricultural area was found not to differ significantly between crops; its values ranged from 37 to 58 mg kg^{-1} (Table 5.21). Comparatively higher values were recorded in rubber and vegetables. In the sub surface soil the values did not differ much from the surface soil and the pattern also remained similar.

Table 5.21. Soil zinc content (mg kg^{-1}) in agricultural areas

Agriculture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	41.9^{bc}±4.8*	13.60	126.40	40.03^{bc}±3.68	12.12	126.40
Vegetables	52.8^{c}±6.5	8.06	101.60	47.60^{c}±5.03	2.28	101.60
Banana	37.4^{abc}±5.6	4.84	92.14	38.60^{bc}±4.00	4.84	92.14
Mixed crop	44.2^{bc}±1.7	3.14	121.12	47.66^{c}±2.15	3.14	134.00
Rubber	57.6^{c}±3.9	8.08	110.76	57.25^{c}±5.19	8.08	133.26

*similar alphabets in superscript denote insignificant difference

The content of zinc in the sub surface soil was found to vary from 18 to 81 mg kg^{-1} with different industrial sites (Table 5.22). It was seen that Infopark site had the least quantity of zinc (18.4 mg kg^{-1}) while CUMI site had the highest value of 81 mg kg^{-1} of zinc. GOI press, Vaigai threads and NGIL sites did not differ significantly, while significant difference was noted in Infopark, CUMI and Vaigai thread sites. In the sub surface soil also similar pattern of values and significant differences were observed.

Table 5.22. Soil zinc content (mg kg^{-1}) in industrial areas

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	50.9^{c}±7.1	32.80	54.90	51.30^{c}±7.52	9.00	95.00
KINFRA	29.1^{ab}±6.0	9.00	91.50	15.46^{a}±2.42	6.42	41.00
VAIGAI	57.3^{c}±10.6	6.42	41.00	44.19^{bc}±7.53	11.84	142.34
CUMI	81.4^{d}±6.5	20.22	142.34	79.61^{d}±10.69	47.08	120.62
INFO Park	18.4^{a}±8.06	62.74	98.18	24.14^{ab}±6.59	1.36	47.16
NGIL	45.28^{bc}±1.7	2.64	47.16	39.02^{bc}±2.29	28.90	54.90

*similar alphabets in superscript denote insignificant difference

Figure 5.11 presented below shows higher levels of zinc near CUMI and Vaigai threads followed by rubber, GOI press and vegetables.

Least zinc content was noticed in surface soils of Infopark. Other landuses fall in between these values as regards the content of zinc.

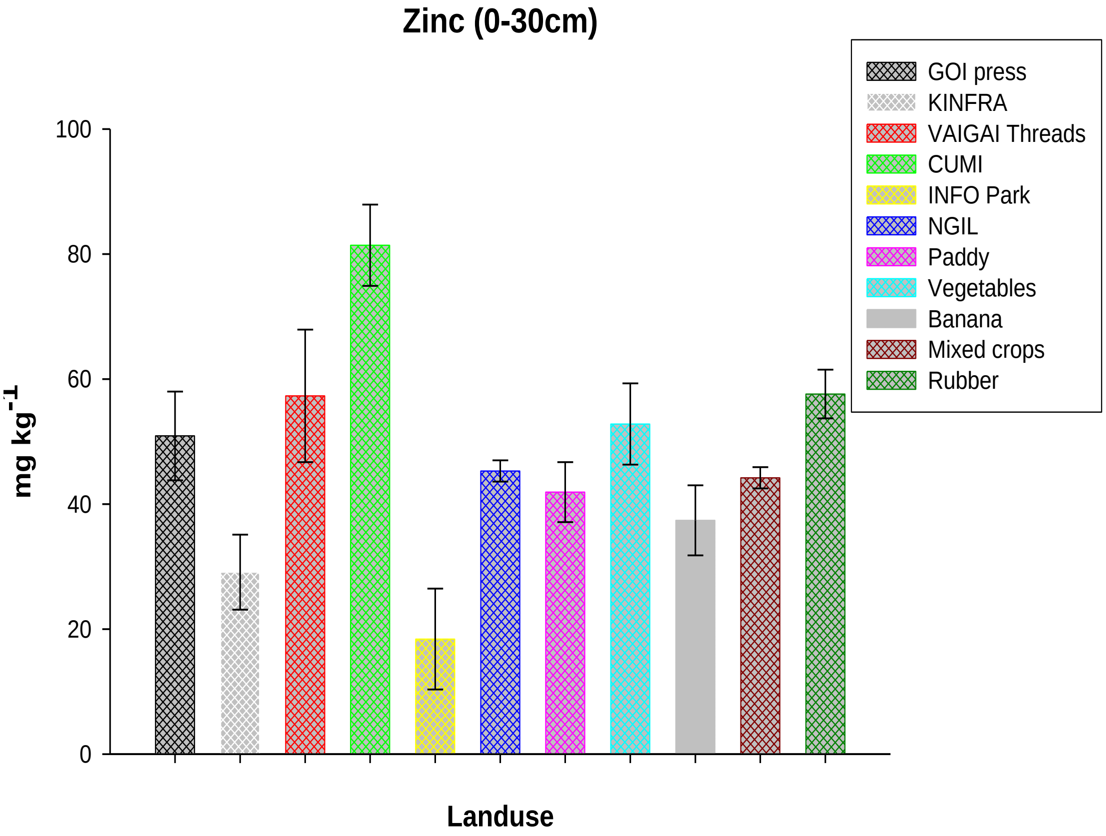


Figure 5.11. Variation in zinc of surface soil with different landuses

Zinc content in sub surface soils followed the same trend of higher levels in CUMI and rubber as in the surface soil except that lowest site was KINFRA closely followed by Infopark (Fig. 5.12).

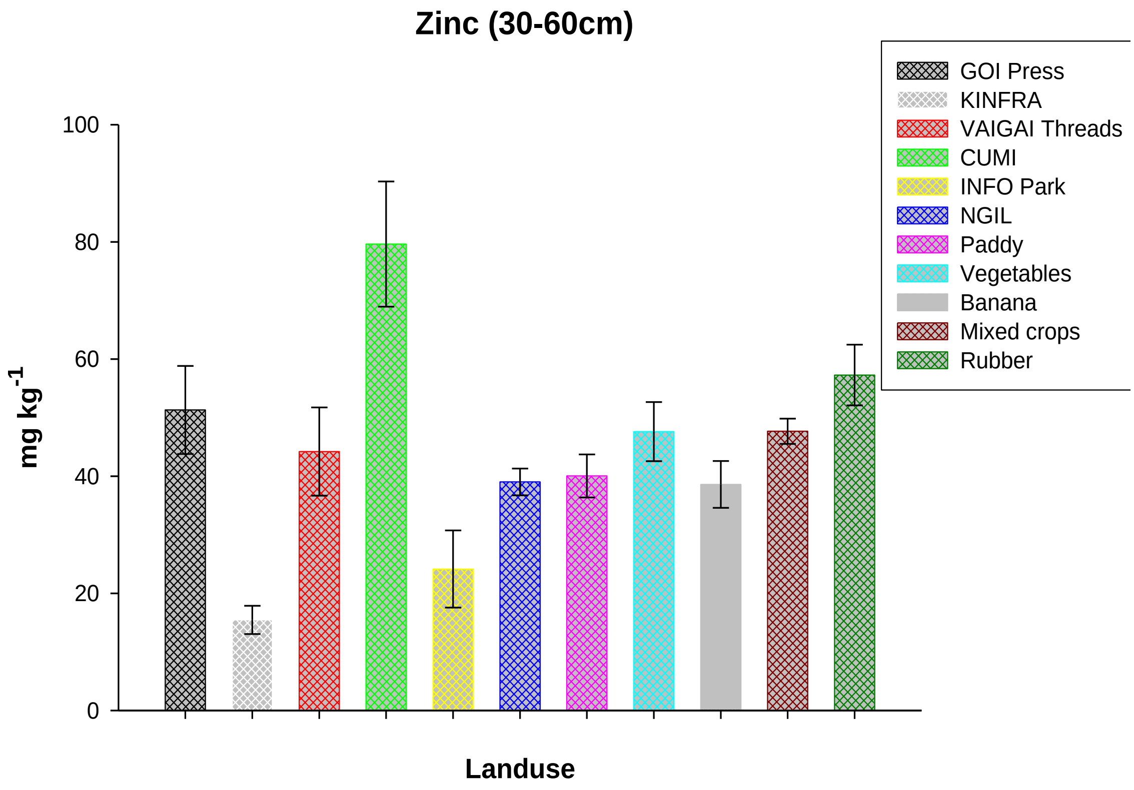
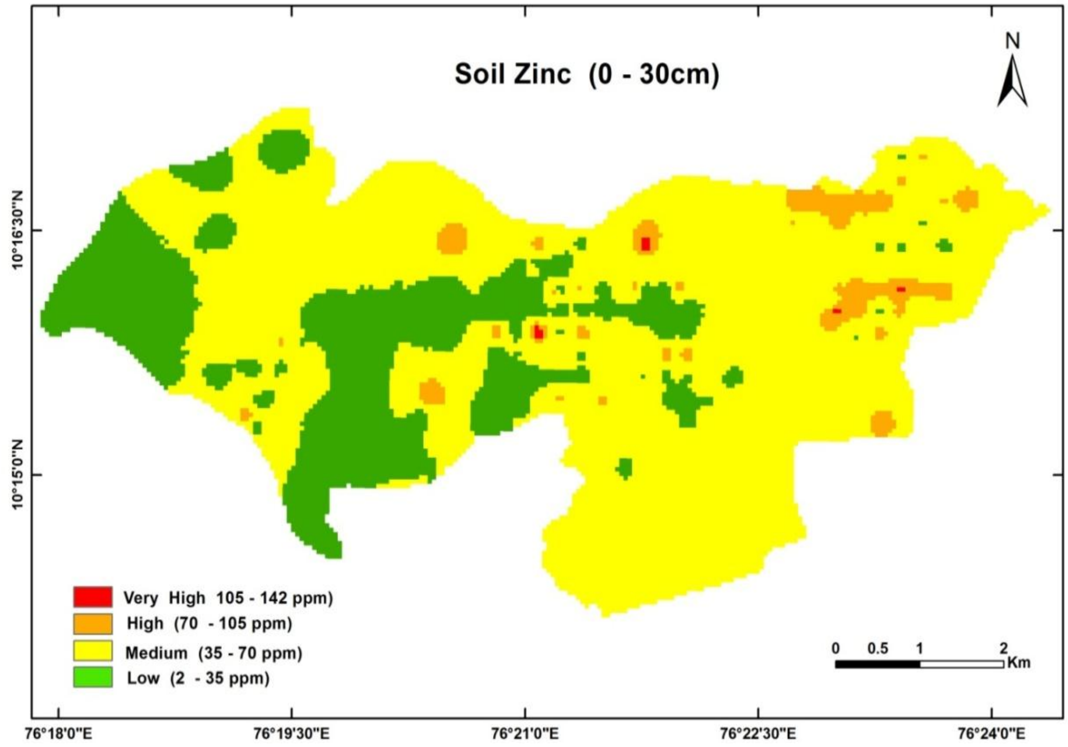


Figure 5.12. Variation in zinc of sub surface soil with different landuses

The distribution of zinc as seen from Map 5.12 shows that most of the area (71.71%) has a concentration of 35-70 mg kg^{-1} which is followed by slightly lower concentration of 2–35 mg kg^{-1} covering 24.38 per cent of the area. The area with 35-70 mg kg^{-1} is mostly located towards the central and eastern part while the area having 2-35 mg kg^{-1} is mostly seen towards the western part. The highest class of 105-142 mg kg^{-1} is seen scattered in the central and northern part seemingly associated with the presence of various industries.

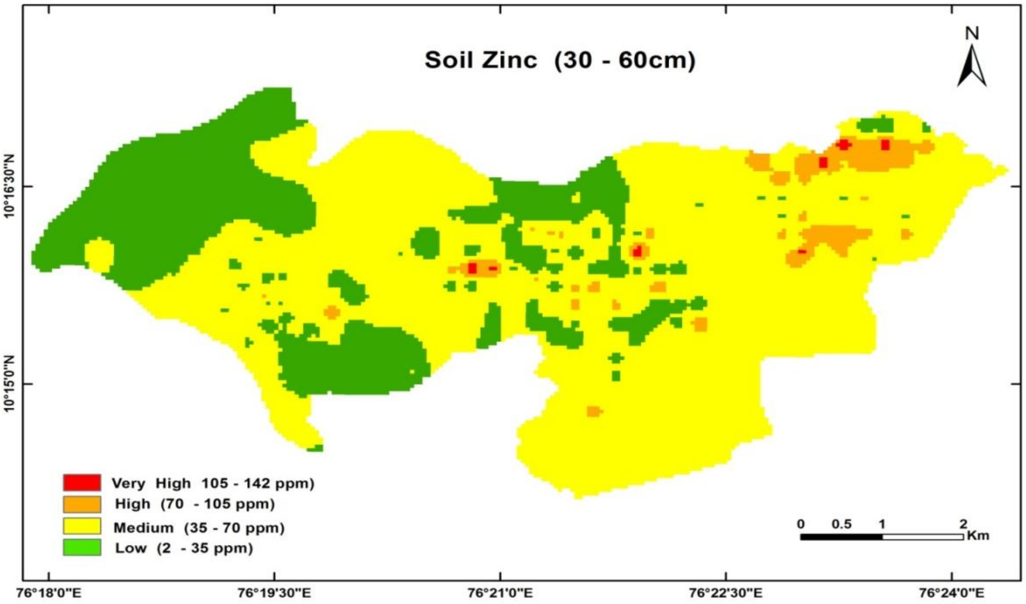


Map 5.12.Distribution of soil zinc in 0-30 cm

Table 5.23.Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
2-35	873.75	24.38
35-70	2570.00	71.71
70-105	136.25	3.80
105-142	3.75	0.10
Total	**3583.75**	**100**

The pattern remains almost same in the 30-60 cm soil layer also with around 70 per cent having 35-70 mg kg^{-1} and another 26.2 per cent with a concentration of 2-35 mg kg^{-1} of zinc (Map 5.13). The higher level of 70-105 mg kg^{-1} is seen distributed in pockets mainly in the central and eastern region. These pockets coincide with the occurrence of several industries. Rubber also occurs in these areas. Considering the fact that the permissible level is 50 mg kg^{-1} most of Koratty represent values exceeding this level.



Map 5.13. Distribution of soil zinc in 30-60 cm

Table 5.24.Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
2-35	941.30	26.26
35-70	2495.00	69.62
70-105	138.80	3.87
105-142	8.75	0.24
Total	**3583.75**	**100**

Soil Copper

Copper content in agricultural surface soils were slightly more than 60 mg kg^{-1} in all the crops except banana (48.6 mg kg^{-1}), and without any significant difference (Table 5.25). Wide variation was seen within sites. The sub surface soil exhibited a similar trend.

Table 5.25. Soil copper content (mg kg^{-1}) in agricultural areas

Agriculture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	$67.4^{ab}\pm6.3$*	15.40	141.20	$64.71^{ab}\pm7.22$	10.80	162.30
Vegetables	$65.2^{ab}\pm7.2$	19.30	165.70	$60.05^{ab}\pm7.1$	19.30	165.70
Banana	$48.6^{a}\pm5.0$	19.20	90.00	$47.49^{a}\pm5.1$	13.20	92.60
Mixed crop	$61.7^{ab}\pm3.4$	6.00	278.00	$61.38^{ab}\pm3.4$	4.60	278.00
Rubber	$66.5^{ab}\pm7.1$	6.80	123.80	$66.67^{ab}\pm6.8$	6.80	123.80

*similar alphabets in superscript denote insignificant difference

Industrial sites differed significantly in copper content in both surface and sub surface soil. Slightly higher values were noted around CUMI and NGIL (Table 5.26). Vaigai threads, CUMI and NGIL soil contained copper beyond permissible levels of 60 mg kg^{-1}. Within site variation was notable in this case also.

Table 5.26. Soil copper content (mg kg^{-1}) in industrial areas

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	$41.9^{a}\pm3.8$	14.40	63.00	$43.13^{a}\pm3.13$	39.90	117.90
KINFRA	$47.7^{a}\pm2.2$	42.40	55.80	$47.36^{a}\pm4.05$	14.40	63.80
VAIGAI	$62.4^{b}\pm20.5$	11.20	201.60	$69.69^{b}\pm20.82$	34.20	159.20
CUMI	$88.8^{b}\pm7.4$	73.40	122.00	$85.66^{b}\pm3.92$	11.20	219.00
INFO Park	$59.9^{ab}\pm15.7$	24.20	117.40	$59.68^{ab}\pm14.63$	23.40	122.00
NGIL	$66.8^{ab}\pm2.7$	45.80	79.70	$63.54^{ab}\pm4.7$	24.20	117.40

*similar alphabets in superscript denote insignificant difference

The bar diagram presented below (Fig. 5.13) shows that copper was present in all land uses with minor variations in the surface soil. Comparatively higher level was noted around CUMI while the lowest contents were in GOI press and KINFRA compounds and in banana cultivated sites.

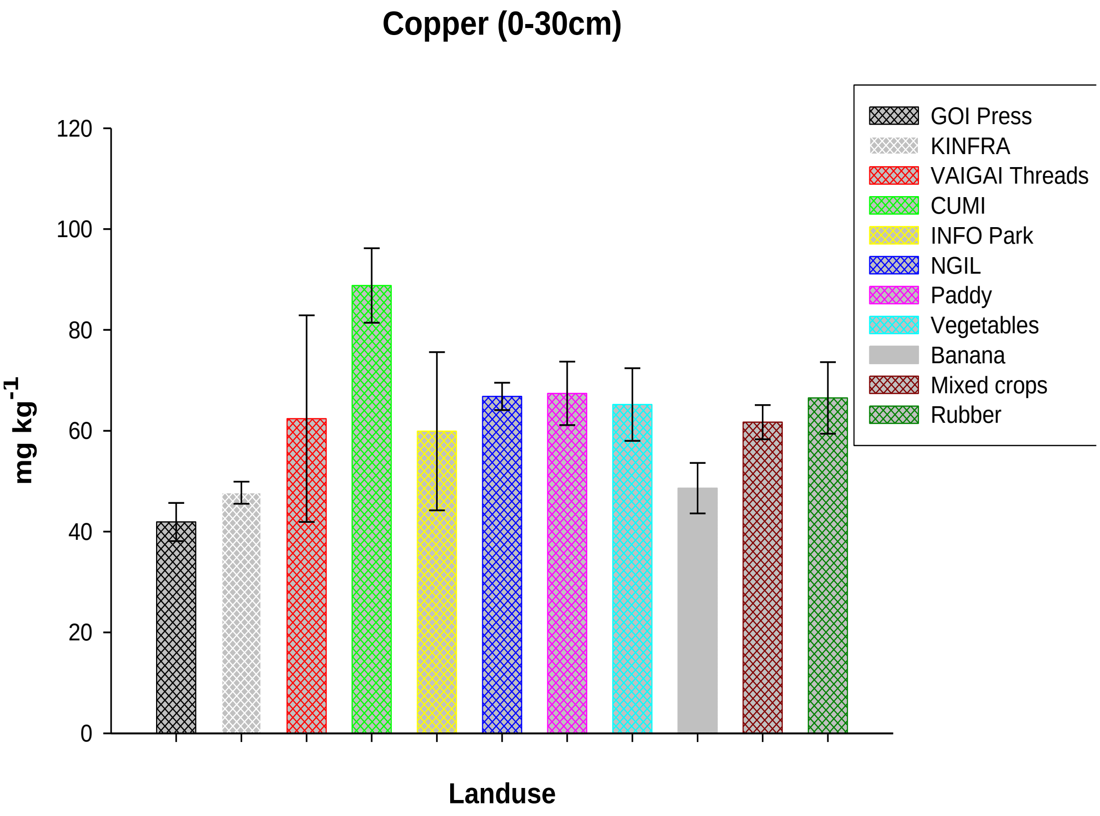


Figure 5.13. Variation in copper of surface soil with different landuses

Copper content in the subsurface soil of different landuses is presented in figure 5.14. It can be observed that comparatively higher values were obtained in the Vaigai thread and CUMI regions, though few other landuses also had copper above the permissible limits.

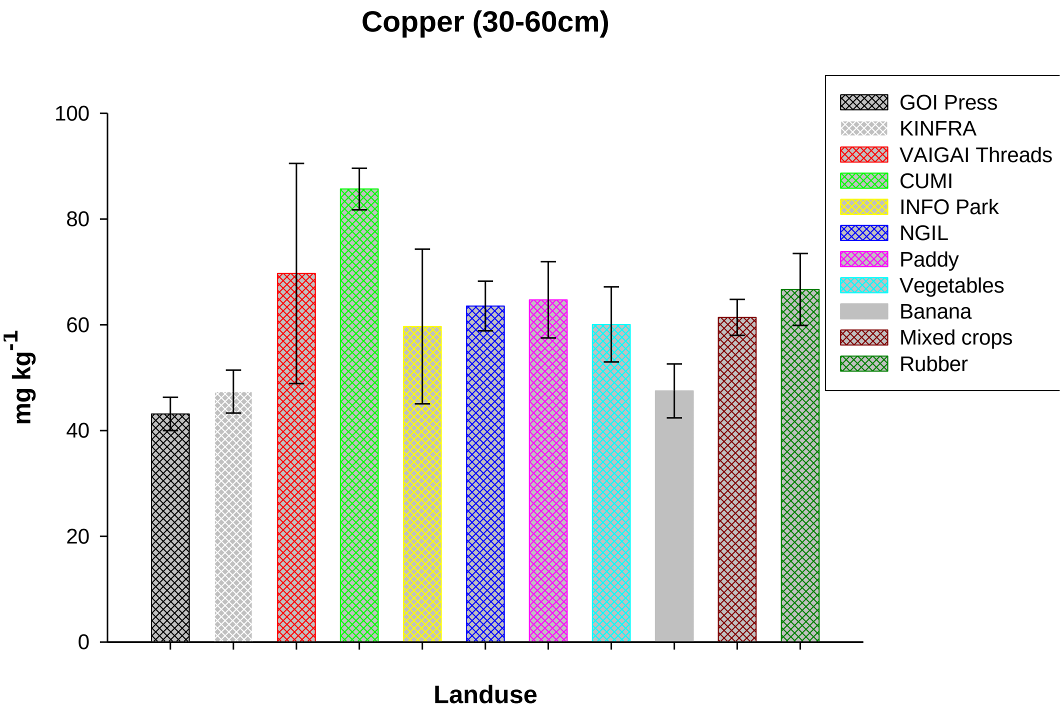
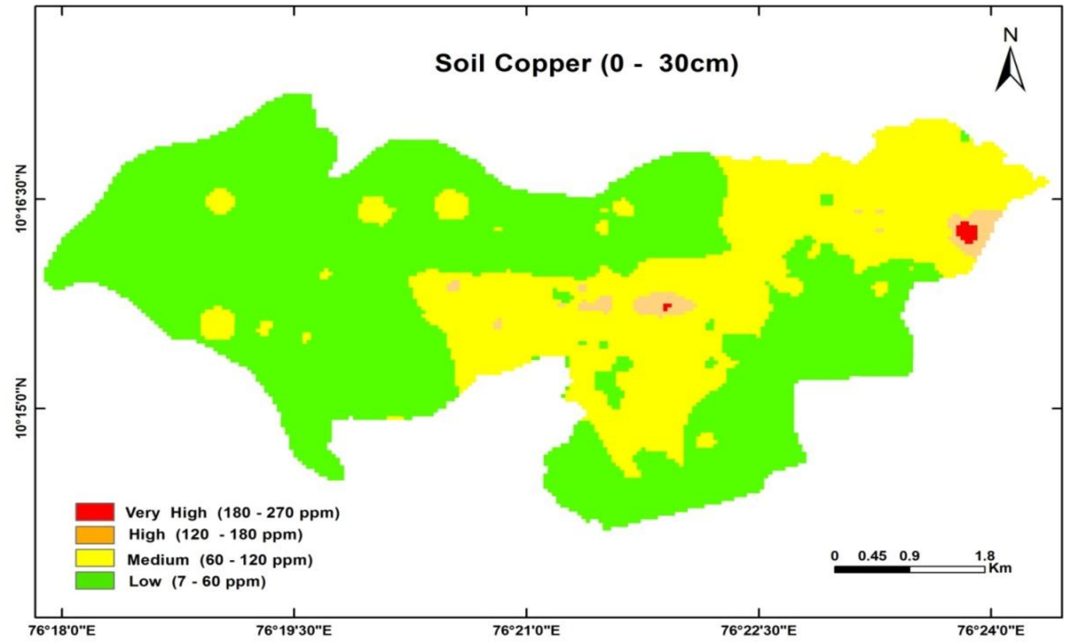


Figure 5.14. Variation in copper of sub surface soil with different landuses

Copper content in the surface 0-30 cm soil layer is shown in the map 5.14. It is clear that most of the area (65.54%) had lesser than permissible levels (<60 mg kg^{-1}) of copper. Rest of the area falls in the class 60-120 mg kg^{-1} covering 32.88 per cent. Highest levels of more than 120 mg kg^{-1} was seen restricted to a few small pockets in the central and eastern region which has many small and large industries.

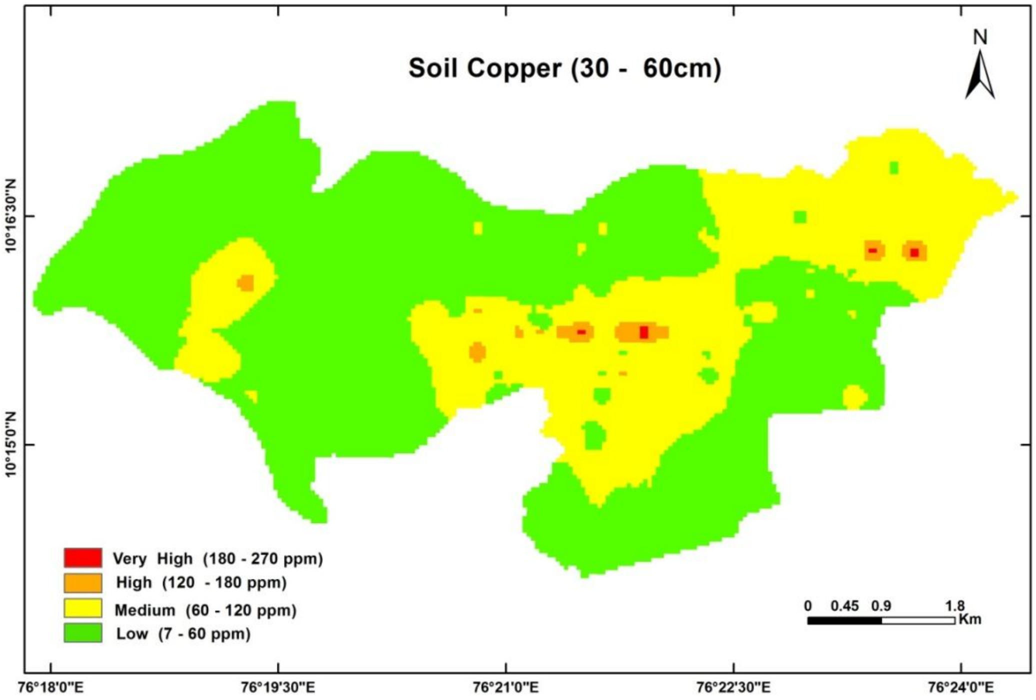
Table 5.27. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
7-60	2348.75	65.54
60-120	1178.25	32.88
120-180	50.25	1.40
180-270	6.50	0.18
Total	**3583.75**	**100**



Map 5.14. Distribution of soil Copper in 0-30 cm

The distribution of copper in the four designated classes shown in the map 5.15 reveals a pattern that is not much different from the surface soil. Maximum area of 65.39 per cent falls in the lowest class with less than 60 mg kg^{-1} which is the upper desirable limit. The next higher class occupies 33.32 per cent and very few areas have copper content beyond 120 mg kg^{-1} and these areas are located in the central and eastern region as was the case with the surface soil.



Map 5.15. Distribution of soil copper in 30-60 cm

Table 5.28. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
7-60	2344.00	65.39
60-120	1194.00	33.32
120-180	42.50	1.19
180-270	3.50	0.10
Total	**3583.75**	**100**

Soil Cadmium

Soils of agricultural landuse were similar in cadmium content (Table 5.29). They were all high with values around or exceeding 20 mg kg^{-1} when the permissible level is only 10 mg kg^{-1}. Wide variations were noted within sites. There was no significant difference between crops in the content of cadmium.

Table 5.29. Soil cadmium content (mg kg^{-1}) in agricultural areas

Agriculture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	20.1^{a}±3.15*	0.48	64.20	28.2^{a}±8.00	0.92	201.40
Vegetables	19.3^{a}±4.56	0.87	90.00	16.5^{a}±3.24	0.23	39.60
Banana	28.6^{a}±10.67	1.30	192.00	18.8^{a}±3.7	0.20	64.00
Mixed crop	28.9^{a}±2.76	0.23	127.60	26.5^{a}±2.6	0.28	140.20
Rubber	25.2^{a}±6.38	0.22	174.00	25.9^{a}±5.1	0.38	125.80

*similar alphabets in superscript denote insignificant difference

Cadmium content was found to be comparatively higher in GOI press compound, KINFRA and NGIL areas when the surface soil was taken into account (Table 5.30). In the sub surface soil cadmium was present beyond permissible levels in all the sites except CUMI, which had much lesser content of cadmium especially in the surface soil.

Table 5.30. Soil cadmium content (mg kg^{-1}) in industrial areas

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	29.7^{a}±8.12*	2.48	106.40	28.2^{a}±5.57	9.80	30.10
KINFRA	29.7^{a}±7.31	6.42	51.20	23.5^{a}±12.93	4.00	73.80
VAIGAI	15.5^{a}±2.41	0.20	24.60	36.2^{a}±16.41	0.20	73.60
CUMI	4.5^{a}±2.79	0.28	18.00	11.5^{a}±8.60	2.20	213.40
INFO Park	11.1^{a}±2.10	4.20	15.96	29.3^{a}±9.34	0.31	53.80
NGIL	25.16^{a}±1.54	12.80	32.70	20.6^{a}±1.3	10.80	58.90

*similar alphabets in superscript denote insignificant difference

Cadmium content in surface soil as shown by the graph is seen to vary between landuses with higher values in GOI Press, KINFRA, rubber, mixed crops, banana and NGIL sites (Fig. 5.15). Much lower values were obtained in CUMI followed by Infopark and Vaigai threads. Significant difference could not be noted between landuses.

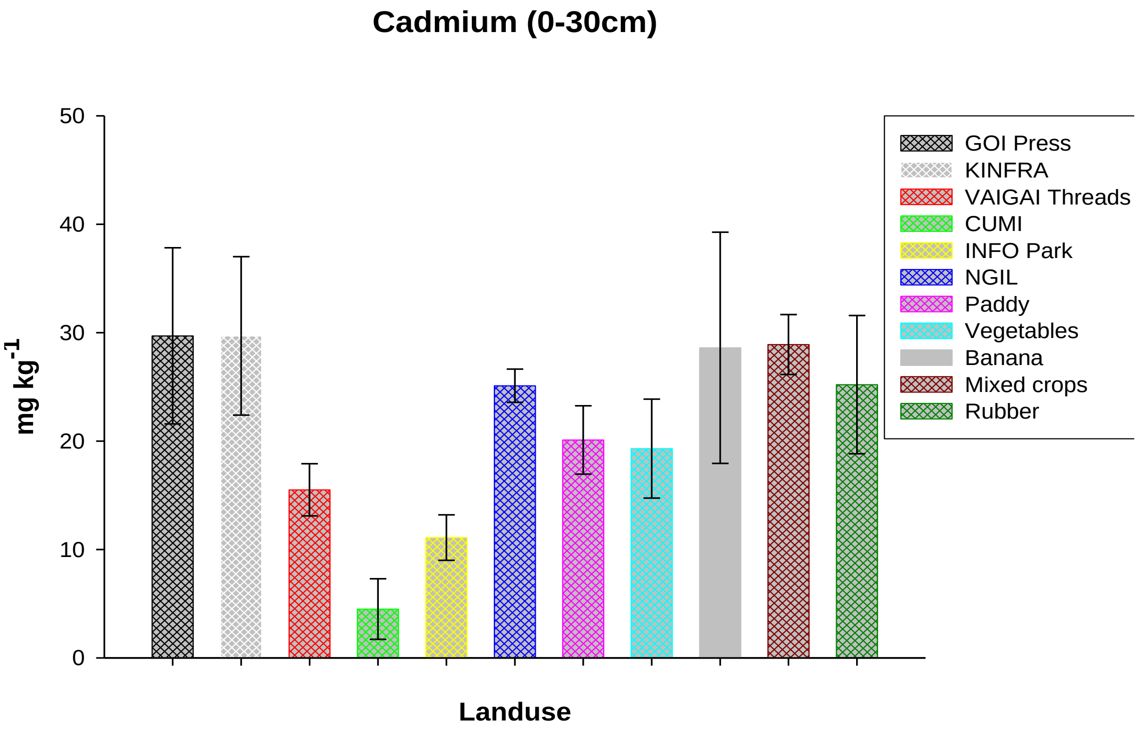


Figure 5.15. Variation in cadmium of surface soil with different landuses

In the sub surface soil, cadmium was highest in Vaigai threads followed by Infopark, paddy, mixed crop, rubber and GOI press compound. Lowest value was recorded in CUMI area (Fig. 5.16).

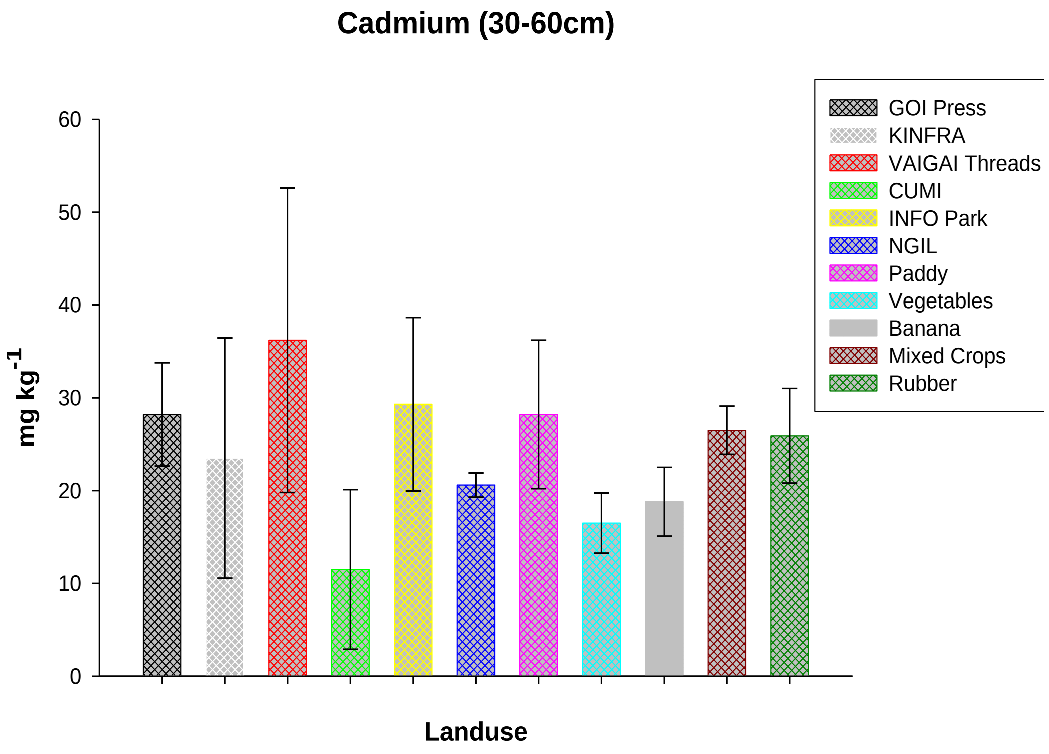
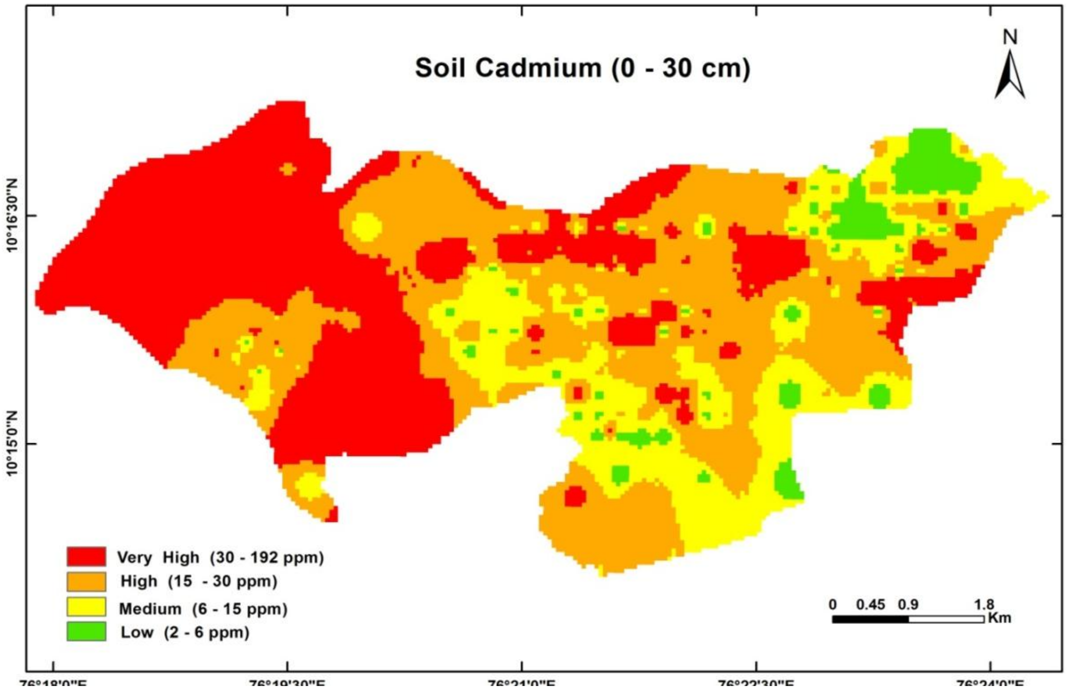


Figure 5.16. Variation in cadmium of sub surface soil with different landuses

Soil Cadmium

Cadmium was found to be present at levels exceeding the desirable value of 10 mg kg^{-1} in most of the area (Map 5.16). The upper classes of 15-30 and 30-192 occupy almost equal area of 38.65 per cent and 37.17 per cent respectively. The class 6 to 15 mg kg^{-1} also contain higher than permissible levels of cadmium in part. Thus cadmium is a soil pollutant in the region. Highest level of 30-192 mg kg^{-1} is mostly seen in the western low lying area where chances of accumulation from upper reaches as well as the contribution from high input paddy cultivation are possible.

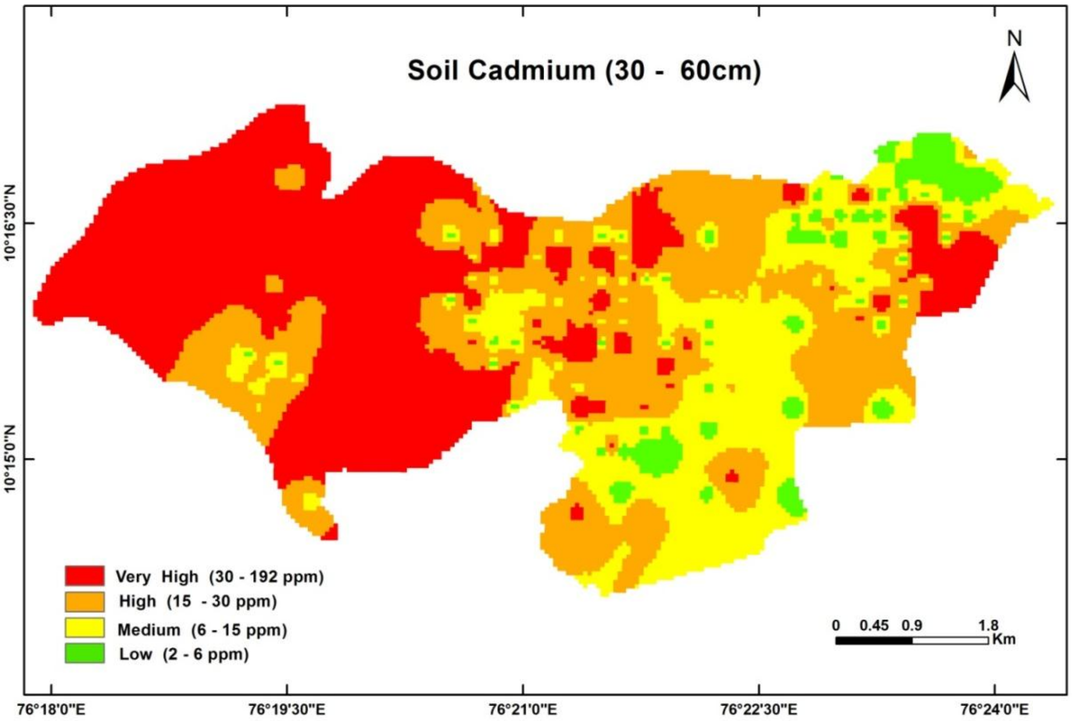


Map 5.16. Distribution of soil Cadmium in 0-30 cm

Table 5.31. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
2-6	168.25	4.69
6-15	698.00	19.48
15-30	1385.25	38.65
30-192	1332.25	37.17
Total	**3583.75**	**100**

The pattern of cadmium distribution in the sub surface soil was only slightly different from the surface soil with more area in the higher classes; 73 per cent of the land had cadmium content of more than 15 mg kg^{-1} (Fig. 5.17). The lower classes were of less than 15 mg kg^{-1} were seen restricted to the central and eastern portions in pockets. Higher levels were mostly noted in the western region, reasons mentioned in the surface soil being applicable here also. Presence of cadmium in such levels in the soil is of concern, especially so considering the acidic nature of the soil that can increase its solubility and availability and thus lead to easy absorbtion by the flora and fauna and thus contribute to biomagnifications in the food chain. Cadmium is known to affect kidney in higher animals including humans.



Map 5.17. Distribution of soil cadmium in 30-60 cm

Table 5.32. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
2-6	169.00	4.72
6-15	797.80	22.26
15-30	1154.00	32.19
30-192	1463.00	40.82
Total	**3583.75**	**100**

Soil Lead

Content of soil lead in various crops was found to be much beyond permissible levels (Table 5.33). Surface soils had around 300 mg kg^{-1} lead. Paddy with the highest lead content had 377.8 mg kg^{-1} of lead which was followed by vegetables, rubber, mixed crop and banana. No significant difference was observed between sites.

Table 5.33. Soil lead content (mg kg^{-1}) in agricultural areas

Agriculture	0-30cm			30-60cm		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	377.8^{a}±92.41*	34.0	460.0	285.4^{bcd}±28.85	46.0	596.0
Vegetables	312^{a}±30.23	132.0	530.0	282.7^{bcd}±26.98	138.0	556.0
Banana	273.4^{a}±43.63	2.0	620.0	331.8^{bcd}±34.39	22.0	508.0
Mixed crop	293.9^{a}±10.07	42.0	574.0	289.8^{bcd}±10.37	18.0	568.0
Rubber	301.9^{a}±24.48	76.0	530.0	269.8^{abc}±25.28	22.0	506.0

*similar alphabets in superscript denote insignificant difference

Industrial areas also reported high levels of lead with highest values observed around GOI press compound, Vaigai threads and NGIL sites (Table 5.34). Sub surface soils did not differ much from the surface soil as far as lead was considered. Significant difference was noted in KINFRA and NGIL sub surface soil. Wide variation was noted within sites.

Table 5.34. Soil lead content (mg kg^{-1}) in industrial areas

Industrial Area	0-30cm			30-60cm		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	304.2^{a}±34.08*	234.0	498.0	317.6^{bcd}±37.88	278.00	463.0
KINFRA	216^{a}±55.07	118.0	472.0	170.8^{a}±36.74	38.00	500.0
VAIGAI	371.8^{a}±39.37	6.0	314.0	365.7^{cd}±34.86	34.00	240.0
CUMI	247.6^{a}±21.77	162.0	650.0	236.3^{ab}±15.34	148.00	484.0
INFO Park	237.6^{a}±32.96	190.0	340.0	293.2^{bcd}±37.56	184.00	298.0
NGIL	364.2^{a}±18.49	160.0	358.0	391.8^{d}±12.10	218.00	416.0

*similar alphabets in superscript denote insignificant difference

The content of lead in surface soil as seen in the figure 5.17 below indicates comparatively lower levels in KINFRA, CUMI and Infopark sites. Other landuses do not differ much between themselves though slightly higher values are seen in paddy, Vaigai threads and NGIL sites.

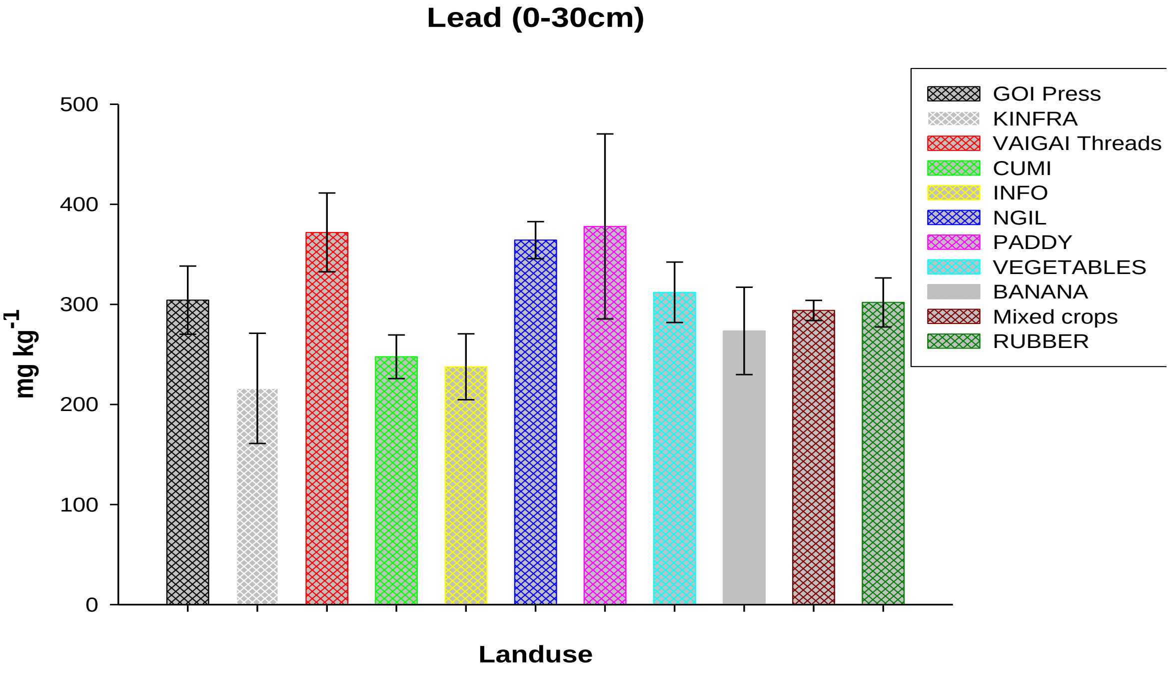


Figure 5.17. Variation in lead of surface soil with different landuses

The trend in lead content of sub surface soil resembled that of surface soil with KINFRA and CUMI having comparatively lower levels as compared to the other sites (Fig. 5.18). Higher values were noted in NGIL and Vaigai thread sites.

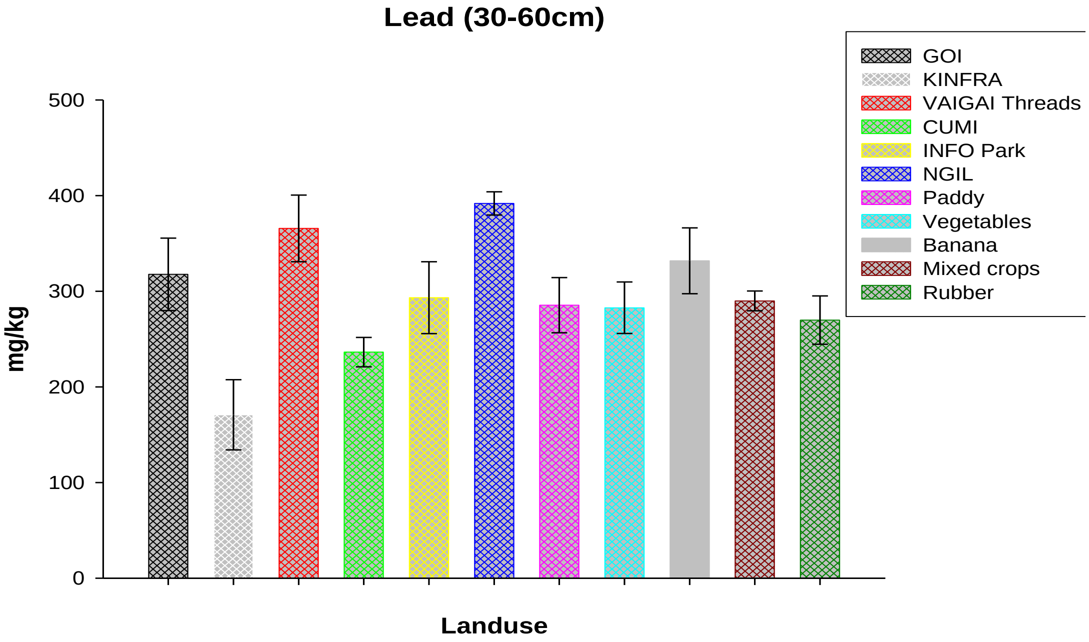
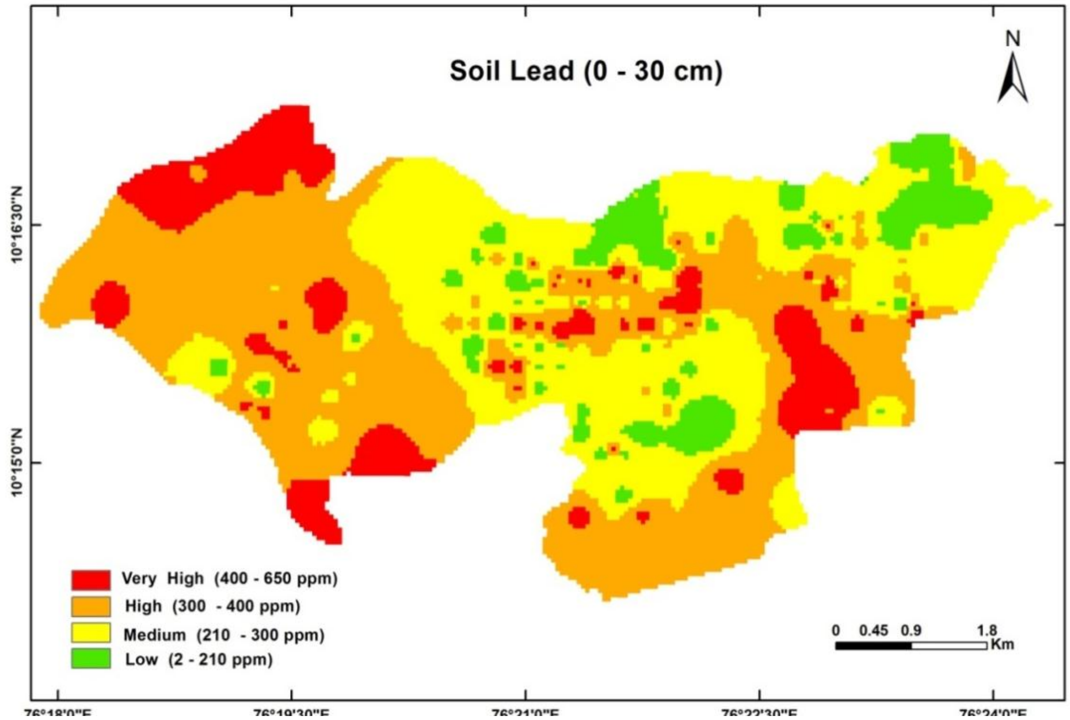


Figure 5.18. Variation in lead of sub surface soil with different landuses

Lead was present at levels much higher than the permissible range of 70 mg kg^{-1}; only a handful of locations out of 283 sample sites had less than 70 mg kg^{-1} of lead (Map 5.18). All the other areas were high in lead the severity of which was graded into 4 classes as shown in the table above. The map makes it clear that areas with more than 210 mg kg^{-1} occupy 91.36 per cent of the land area. The different classes are distributed all over the region, the highest concentration seen towards the western part and the lowest towards the eastern part.

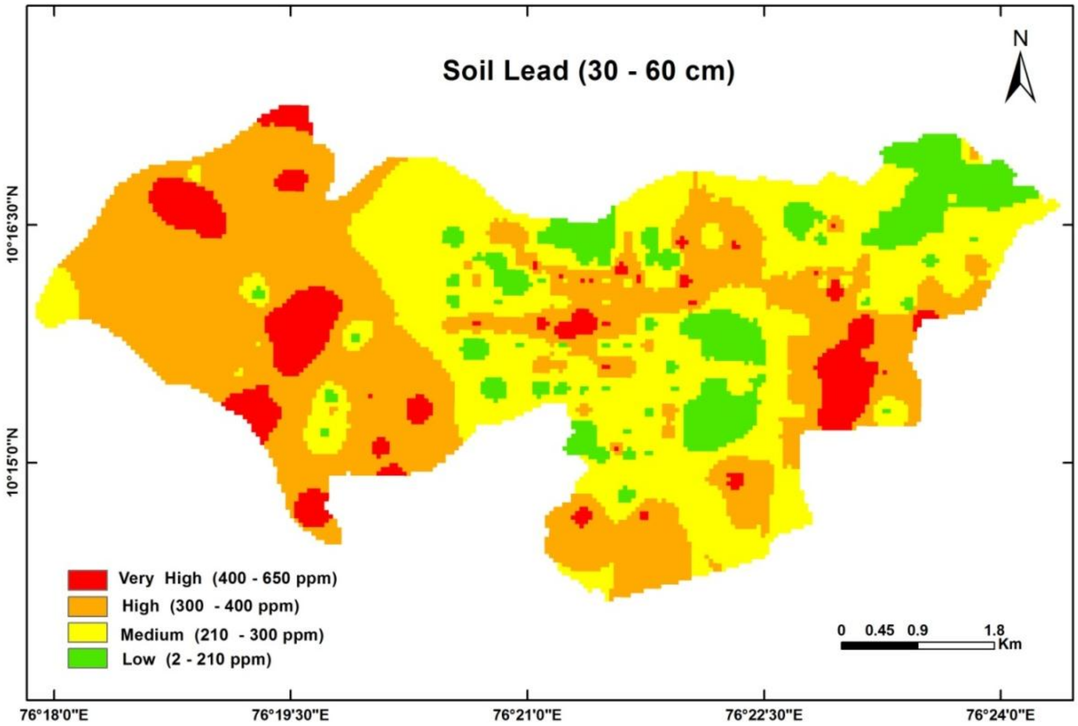


Map 5.18. Distribution of soil lead in 0-30 cm

Table 5.35. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
<210	379.50	10.59
210-300	1311.00	36.57
300-400	1609.00	44.88
400-650	285.30	7.96
Total	**3583.75**	**100**

The distribution of lead in the sub surface soil of 30-60 cm as shown in the map 5.19 indicates slightly different pattern with a shift in area towards the lower classes. The table shows that there was a decrease in the uppermost class of 400-650 mg kg^{-1} and an increase in the lower classes. Though such a pattern indicating slight decrease in the lead concentration is present, the area with more than 210 mg kg^{-1} remains almost the same with around 90 per cent. Thus lead remains a matter of grave concern being very toxic affecting the neuro and muscular system.



Map 5.19. Distribution of soil lead in 30-60 cm

Table 5.36. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
<210	379.50	10.59
210-300	1311.00	36.57
300-400	1609.00	44.88
400-650	285.30	7.96
Total	**3583.75**	**100**

Soil Nickel

Nickel content in the soils of different agricultural crops were found to be very high with values exceeding 150 mg kg^{-1} when the permissible range is hardly 70 mg kg^{-1} (Table 5.37). Paddy soils had the highest levels of more than 300 mg kg^{-1} which was followed by banana, vegetables, rubber and mixed crop. Surface and sub surface soil did not differ much in nickel content. Significant differences were also absent between crops.

Table 5.37. Soil nickel content (mg kg^{-1}) in agricultural areas

Agriculture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	316.6^{bc}±92.41*	62.60	556.60	309.65^{c}±34.68	79.00	551.80
Vegetables	236.9^{abc}±30.23	65.30	605.20	244.9^{bc}±33.72	19.80	515.80
Banana	244.1^{abc}±10.07	55.20	2030.20	226.9^{abc}±11.30	12.50	632.40
Mixed crop	156.8^{ab}±43.63	42.80	394.80	163.9^{ab}±21.45	57.00	329.40
Rubber	224.3^{abc}±24.48	62.20	528.40	221.30^{abc}±29.01	2.00	748.20

*similar alphabets in superscript denote insignificant difference

Industrial sites also contained higher than permissible levels of nickel with values ranging from 140 to 440 mg kg^{-1} when both surface and sub surface soil was taken into account (Table 5.38). Comparatively lower levels of nickel were noted in CUMI and NGIL sites which were significantly different from other sites.

Table 5.38. Soil nickel content (mg kg^{-1}) in industrial areas

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	302.8^{bc}±34.08*	159.80	529.20	296.2^{c}±20.95	56.90	343.50
KINFRA	282.3^{abc}±55.07	220.80	347.00	298.5^{c}±36.82	202.40	449.60
VAIGAI	351.5^{c}±39.37	217.20	661.80	440.8^{d}±51.79	214.20	494.80
CUMI	139.9^{a}±21.77	27.20	249.20	150.2^{ab}±42.41	125.60	804.40
INFO Park	360.4^{c}±32.96	263.20	440.20	303.12^{c}±42.63	12.40	505.20
NGIL	126.9^{a}±18.49	89.30	176.80	107.6^{a}±6.09	103.60	410.20

*similar alphabets in superscript denote insignificant difference

The figure given below (Fig. 5.19) depicting nickel content in surface soil of different landuses shows that among the industrial sites only CUMI and NGIL had comparatively lesser nickel levels and among the agricultural sites only banana had lower levels. Highest level of nickel was noted in Infopark, Vaigai threads and paddy.

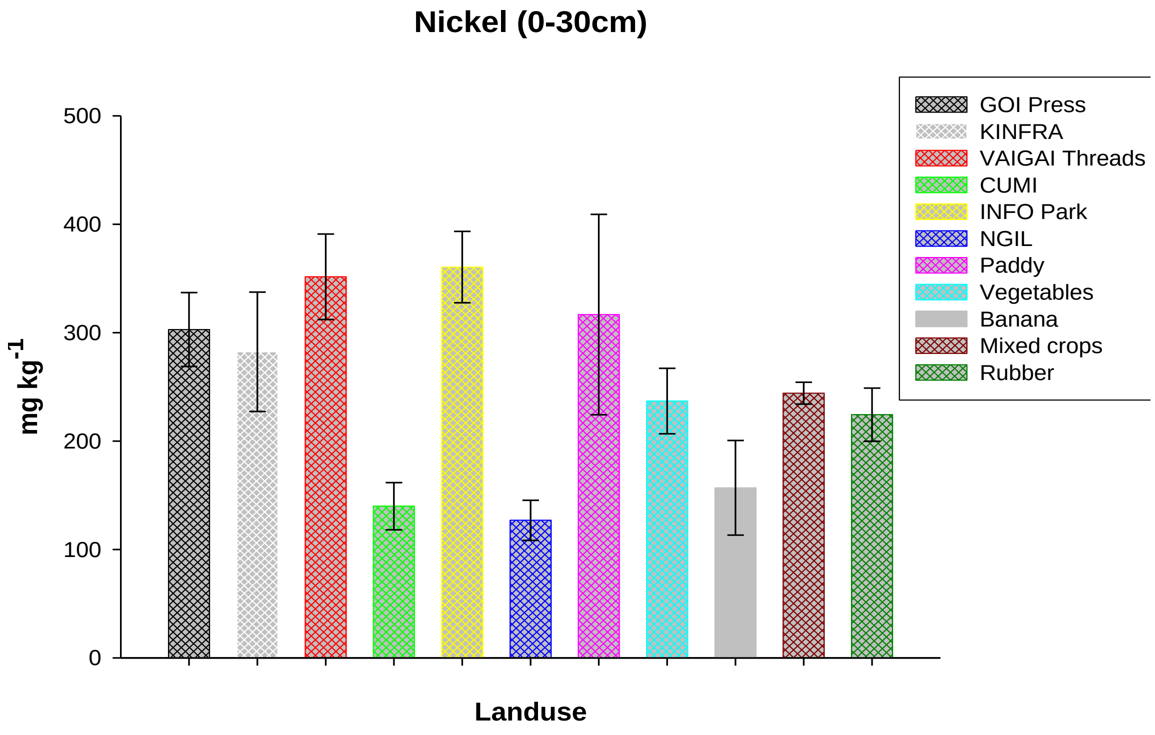


Figure 5.19. Variation in nickel of surface soil with different landuses

Nickel content in sub surface soils as given belowin figure 5.20 shows that NGIL, CUMI and banana sites had comparatively lower levels while Vaigai threads had the highest level of nickel.

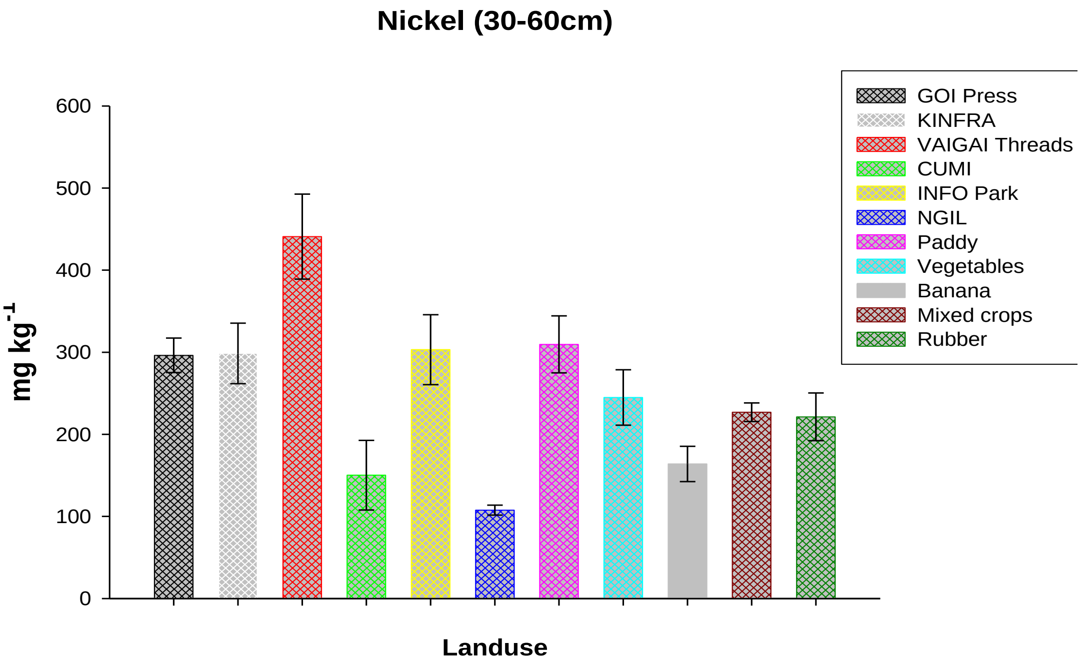
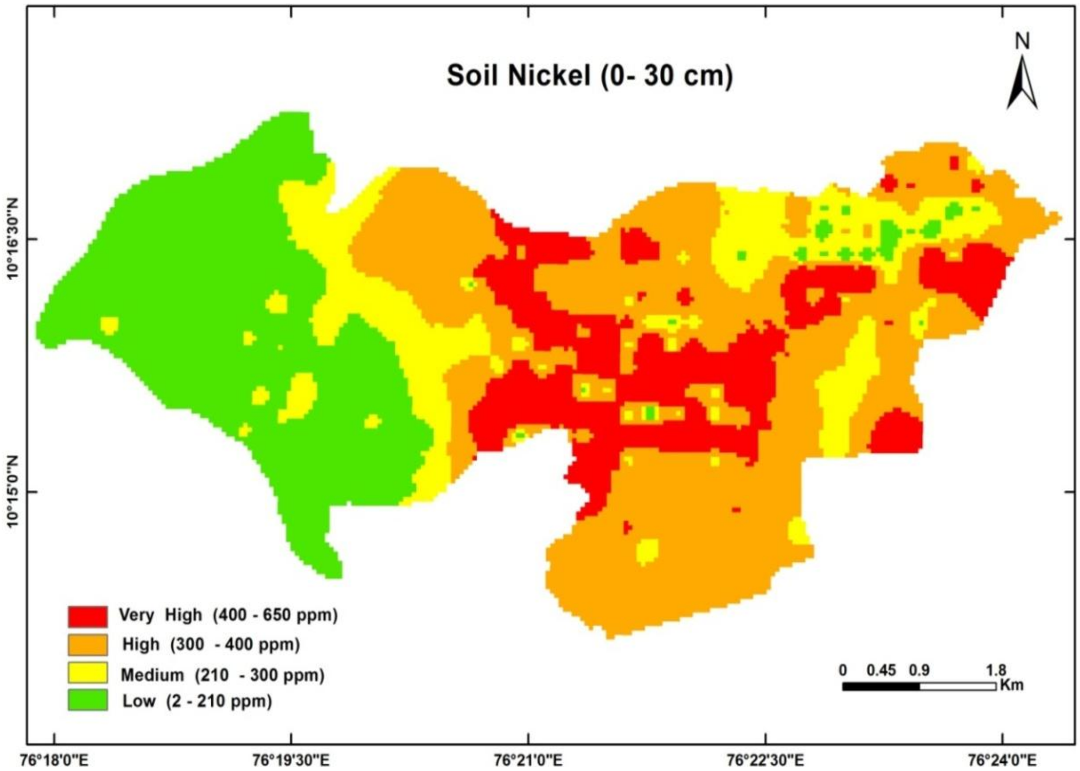


Figure 5.20. Variation in nickel of sub surface soil with different landuses

Nickel distribution in the region as given in the map 5.20 shows that the higher levels are found to be present in the central and eastern portions and the lower levels in the western part, though the lower levels also exceed the permissible range of 70 mg kg^{-1} in majority of the samples; only 14 samples out of 283 had values less than 70 mg kg^{-1}. Areas with >210 mg kg^{-1} cover almost 71 per cent of the land. Thus it can be seen that nickel is present in extremely high levels almost parallel to lead.

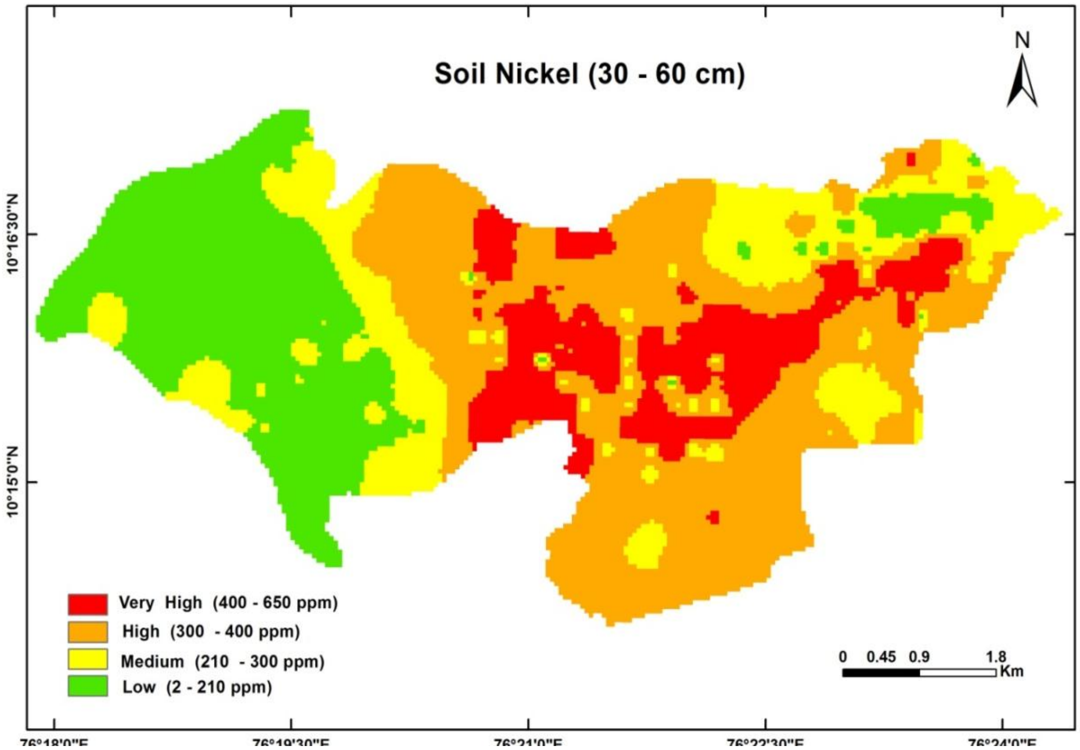


Map 5.20. Distribution of soil nickel in 0-30 cm

Table 5.39. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
<210	1028.00	28.69
210-300	561.75	15.67
300-400	1405.75	39.23
400-650	588.25	16.41
Total	**3583.75**	**100**

The map 5.21 and the table 5.40 shows the distribution of nickel in four selected classes in the 30-60 cm layer of the soil. There was slight decrease in the area under the highest class of 400-650 mg kg^{-1} and appreciable increase in the less than 210 mg kg^{-1} class. The higher classes together constitute 73.24 per cent of the area which is similar to the content in the surface soil. The fact that only 15 samples out of 283 has less than 70 mg kg^{-1} of nickel which is the desirable level points to the seriousness of nickel pollution in the region.



Map 5.21. Distribution of soil nickel in 30-60 cm

Table 5.40. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
<210	959.00	26.76
210-300	690.50	19.27
300-400	1407.00	39.26
400-650	527.30	14.71
Total	**3583.75**	**100**

Soil Chromium

Chromium content in surface soil of agricultural landuse were seen to be slightly above the permissible range of 60 mg kg^{-1} in all the sites (Table 5.41). Significant differences did not occur between crops. There was no remarkable difference in the subsoil in chromium content. Significant difference occurred only between paddy and banana in the sub surface soil.

Table 5.41. Soil chromium content (mg kg^{-1}) in agricultural areas

Agriculture	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
Paddy	78.2^{abc}±4.45*	32.10	137.00	72.5^{c}±5.62	58.10	118.0
Vegetables	68.8^{ab}±10.11	2.00	176.00	61.3^{bc}±10.71	38.80	92.2
Banana	83.9^{abc}±8.10	14.00	122.10	84.6^{ab}±22.45	55.00	119.3
Mixed crop	87.3^{abc}±3.93	12.00	218.00	83.9^{abc}±4.30	72.00	102.8
Rubber	72.9^{ab}±7.29	22.10	202.00	59.3^{abc}±7.01	45.00	84.1

*similar alphabets in superscript denote insignificant difference

Chromium content exceeded permissible level in all the industrial sites except CUMI (56.5 mg kg^{-1}) when the surface soil was considered (Table 5.42). Significant difference was noted between CUMI, Vaigai Threads, GOI press and Info park sites. Sub surface soil did not differ much from the surface soil though its content increased in most of the sites. Significant difference occurred between most of the industrial sites.

Table 5.42. Soil chromium content (mg kg^{-1}) in industrial area

Industrial Area	**0-30cm**			**30-60cm**		
	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.
GOI Press	115.4^{c}±9.18*	52.70	122.90	138.2^{c}±34.5	95.2	192.1
KINFRA	82.3^{abc}±7.21	64.60	172.60	96.5^{c}±20.2	50.4	117.2
VAIGAI	113^{c}±18.18	65.20	131.20	141.8^{d}±28.7	90.9	186.6
CUMI	56.5^{a}±10.79	32.40	197.40	55.2^{ab}±32.41	18.2	108.5
INFO Park	108.2^{bc}±12.5	24.40	120.80	111.12^{c}±31.63	57.2	166.9
NGIL	80.6^{abc}±4.90	77.40	151.20	73.6^{a}±3.09	65.80	99.20

*similar alphabets in superscript denote insignificant difference

The figure 5.21 below shows that chromium content was highest in GOI press, Vaigai threads and Infopark and least in CUMI. Other sites did not differ much between themselves.

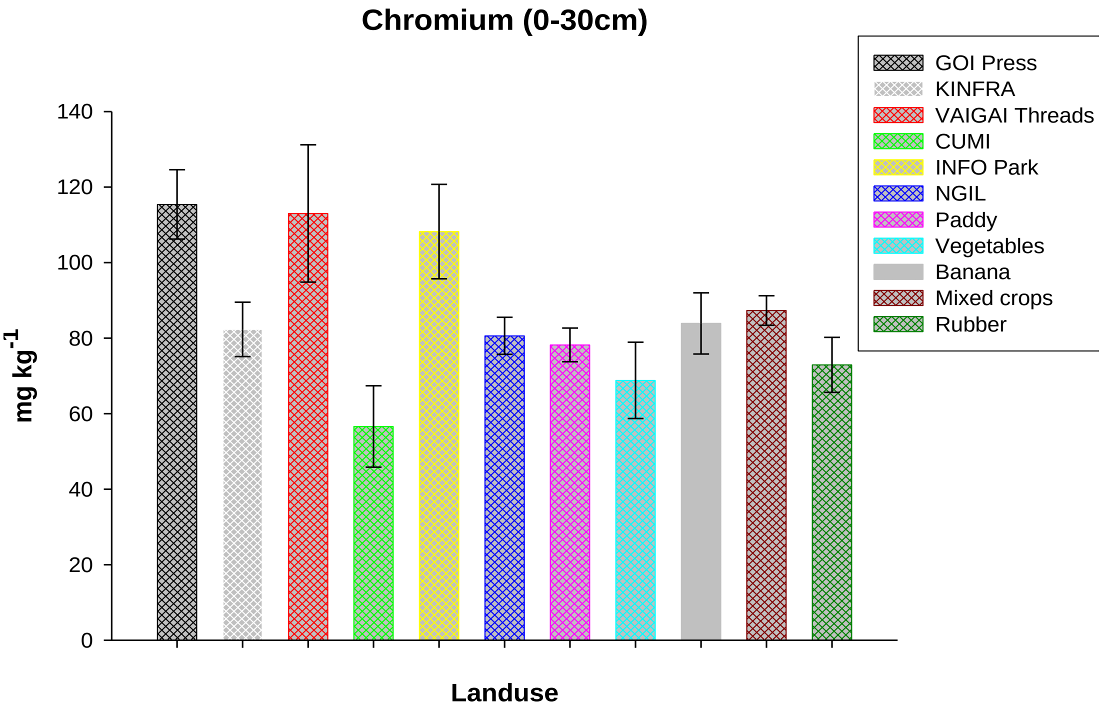


Figure 5.21. Variation in chromium of surface soil with different landuses

It can be seen from the figure 5.22 that GOI press, Vaigai threads and Info Park had maximum chromium content in the sub surface soil also. Other sites had lower levels with CUMI recording the least amount.

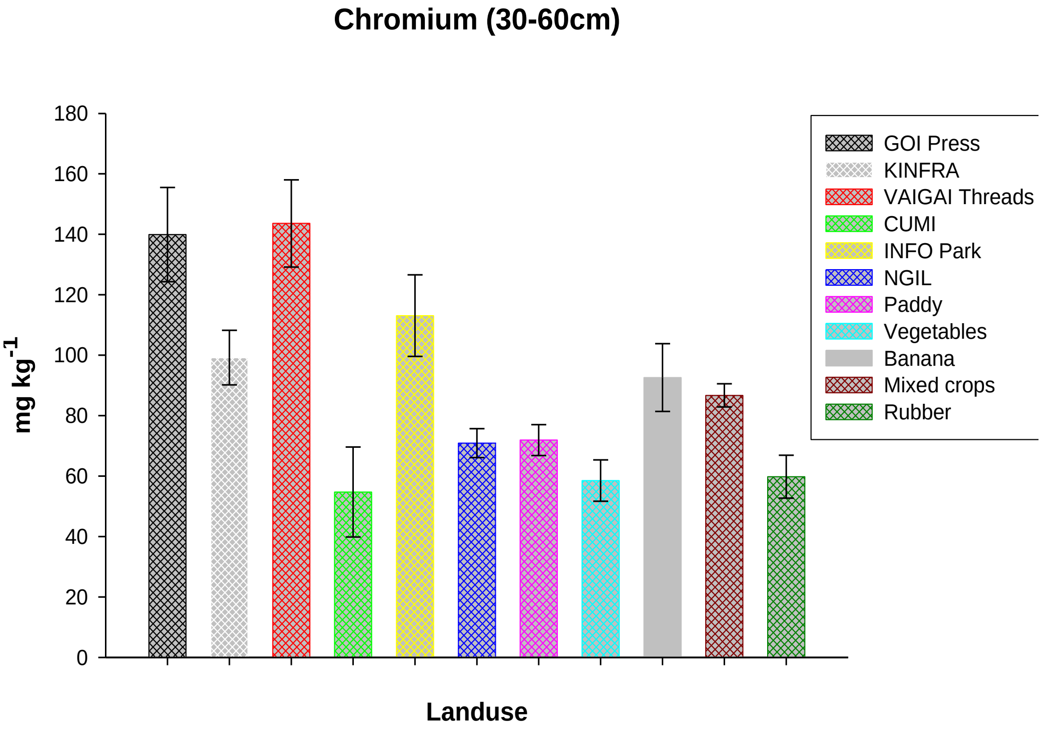
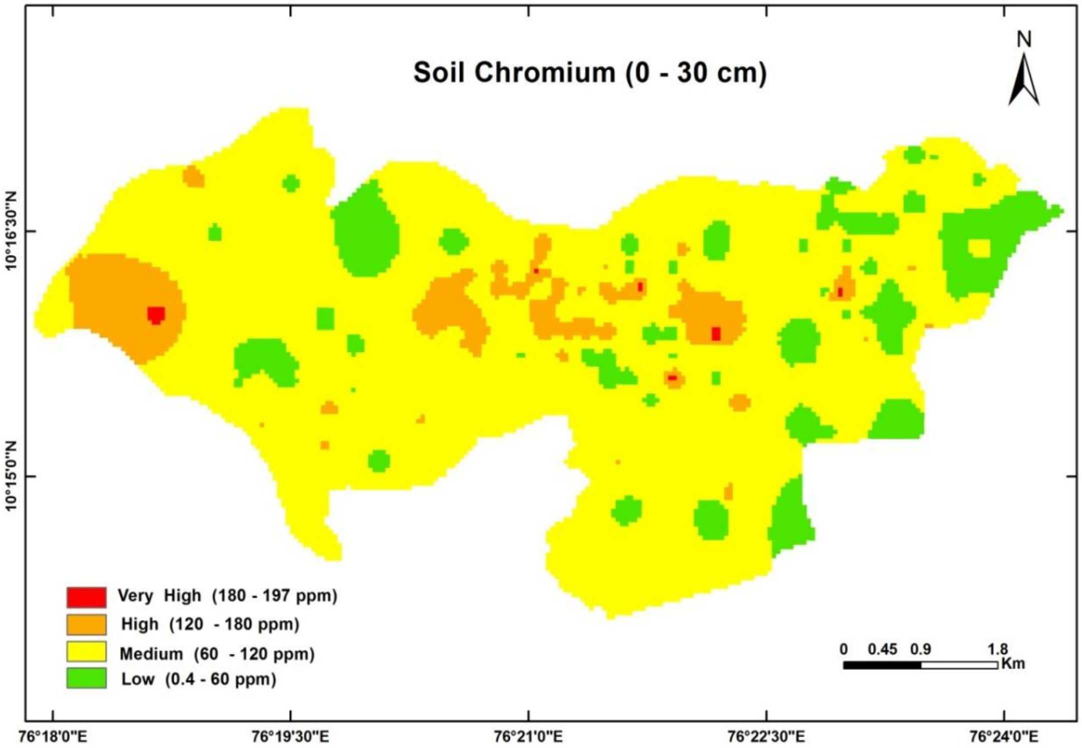


Figure 5.22. Variation in chromium of sub surface soil with different landuses

Chromium in the surface soil is being presented in the map 5.22 and the table 5.43 after grouping into four classes. It can be seen that 79 per cent of the area falls in the 60-120 mg kg^{-1} class and only 12.45 per cent area has safe levels of chromium. Areas with more than 120 mg kg^{-1} is very less and in pockets scattered in the central region and the western part.

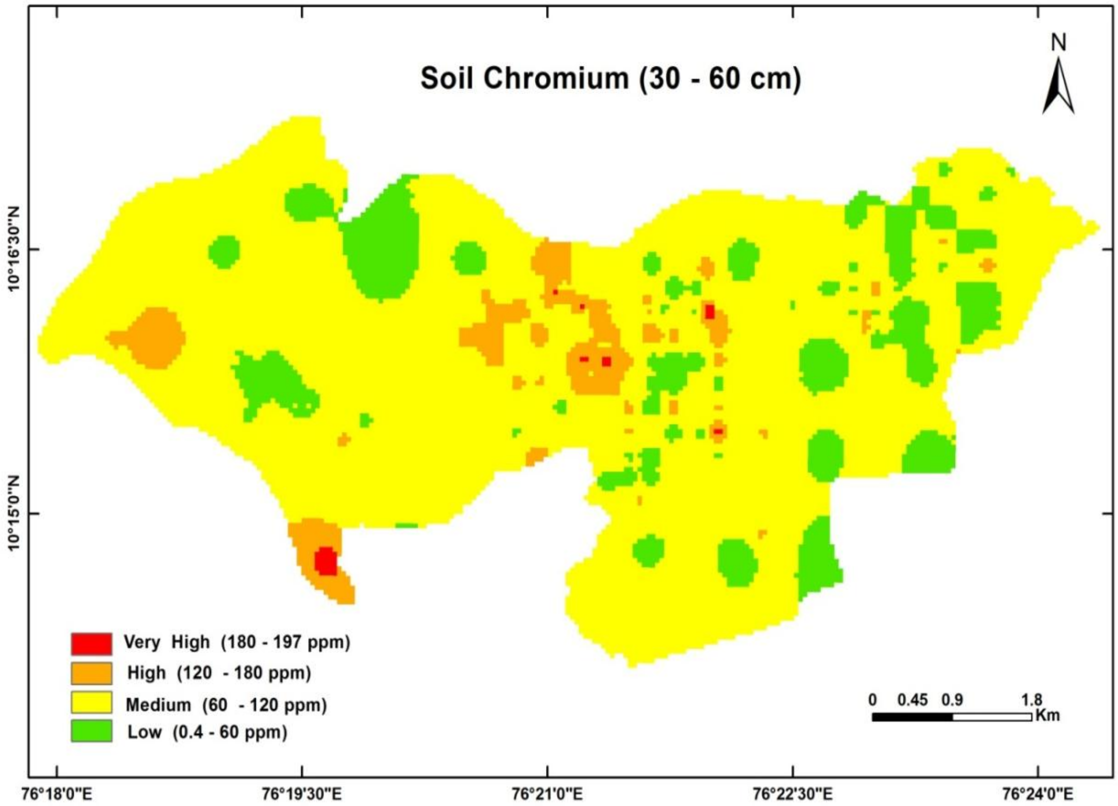


Map 5.22. Distribution of soil chromium in 0-30 cm

Table 5.43. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
<60	446.25	12.45
60-120	2828.50	78.93
120-180	302.25	8.43
180-197	6.75	0.19
Total	**3583.75**	**100**

The distribution of chromium in sub surface soil of 30-60 cm almost remains the same (Map 5.23) with 80 per cent falling in 60-120 class and 13.67 per cent in the safe range of less than 60 mg kg^{-1}. The upper classes with more than 120 mg kg^{-1} is less and scattered mostly in the central and western region. Chromium also is of concern since it is present at higher levels than permissible in most of the region.



Map 5.23. Distribution of soil chromium in 30-60 cm

Table 5.44. Extent of area under different classes

Class (mg kg^{-1})	**Area (ha)**	**Percentage**
<60	490.00	13.67
60-120	2865.00	79.95
120-180	217.80	6.08
180-197	10.75	0.30
Total	**3583.75**	**100**

5.3.2 IMPACT OF LANDUSE ON SOIL QUALITY

Soil quality is likely to be influenced by the type of landuse. Crops and cropping pattern modifies the soil. Industrial wastes also contaminate the soil. Impact of different landuse on soil quality is explained by combining all parameters giving appropriate weightage and presenting through map. Fractions of heavy metals in the soil were also determined to reveal the level of enrichment, contamination and mobility of these elements.

Agricultural landuse

Soil properties and heavy metal contents in the soils (0-60 cm) of various agricultural ecosystems given in tables 5.45 and 5.46 is discussed below. Soil pH in the agricultural areas ranged from 4.68 to 4.96 indicating very acidic soil. Mixed crop and rubber recorded significantly higher pH value compared to other agricultural landuses though even these pH values were much less than what is desirable (6-7). Crops of paddy, vegetables and banana were seen to decrease the soil pH. The cultural practices in these crops, especially the high inputs of agro chemicals mainly fertilizers are known to increase soil acidity (McLaughlin, et.al 1996). Electrical conductivity was found to range from 0.016 to 0.096 dS/m in the agricultural soils with no significance difference between the landuses. These values are extremely low and of no consequence. Organic carbon values in the soil ranged from 1.3 to 1.89 per cent indicating adequate content of organic carbon in the sites; the desirable level is more than 0.75 g kg^{-1}. Banana based landuse recorded comparatively lower organic carbon content. Addition of organic manures including farmyard manure, green manure and compost as a basal dressing is a common practice that helps in maintaining high OC in these soils.

Table 5.45. Soil properties in agricultural areas

Landuse	pH	EC	OC
Paddy	4.73^{b} (0.06)	0.017^{a} (0.001)	1.83^{ab} (0.15)
Vegetables	4.68^{b} (0.09)	0.016^{a} (0.002)	1.73^{ab} (0.16)
Banana	4.75^{b} (0.1)	0.025^{a} (0.002)	1.37^{a} (0.12)
Mixed crop	4.89^{bc} (0.03)	0.085^{a} (2.16)	1.67^{ab} (0.05)
Rubber	4.96^{bc} (0.04)	0.095^{a} (4.73)	1.89^{ab} (0.13)
Desirable	6-7	<4	>0.75

Iron content of the soil in agricultural areas ranged from 85.47 to 131.67 mg kg^{-1}. Higher iron content was observed in banana, mixed crops and rubber which are cultivated in the upland areas while in the low land where paddy and vegetables are cultivated the value lie within the desirable levels of less than 100 mg kg^{-1}. The upland soils are highly weathered soils with preponderance of sesqoxides while the low land soils are comparatively fine textured with proportionately higher contents of silt and clay. Manganese content in the soil was found to vary from 181 to 244.69 mg kg^{-1} in different agricultural landuses; all the values exceeded the desirable level of 100 mg kg^{-1}. Zinc content was low in all the agricultural sites except rubber, where the values were slightly higher than the desirable levels of less than 50 mg kg^{-1}. The values ranged from 38 to 57.4 mg kg^{-1}. Copper concentration ranged from 48.07 to 66.63 mg kg^{-1} in the soils of various agricultural crops. All the crops except paddy and rubber had acceptable copper levels of <60 mg kg^{-1}. Paddy and rubber recorded slightly higher values which can be due to the application of copper sulphate as a fungicide in these crops. Cadmium exceeded the permissible limit of <10 mg kg^{-1} in all the agricultural landuses. The values ranged from 17.9 to 27.7 mg kg^{-1}. Cadmium reaches the soil from several sources including fertilizers and poultry manure. Cadmium content in phosphatic fertilizers varies from 0.14 mg kg^{-1} to 50.9 mg kg^{-1} depending on the concentration in the phosphate rock used in the manufacture of the fertizer (Zapata and Roy, 2004; Lugon-Moulin *et al.*, 2006).

Phosphate rock also contain other hazardous metals such as lead, mercury, chromium, selenium, arsenic and uranium, the concentration of which depend on the geographical location of the rock. Such metals also find their way into fertilizers during recycling of waste and sewage sludge (Ivan Fernandez, 2002; Wilson, 1997). Lead concentration was also very high in all the agricultural soils, values ranging 285.9 to 331.6 mg kg^{-1} where as the permissible level is only upto <70 mg kg^{-1}. Enrichment of lead to such high levels in all the landuses can be due to contamination from burning of fossil fuels. Pollution from traffic release Pb, Zn and Cu to environment (Shi *et al.,* 2008).

There was no significant difference among crops innickel content. It exceeded the permissible limit of 70 mg kg^{-1} in all the agricultural areas with values ranging from 160.3 to 313.13 mg kg^{-1}. Nickel is known to be present in certain fertilizers, the application of which might have led to such high values. There was no significant difference between the crops. Chromium content in the agricultural soils ranged from 63.67 to 88.29 mg kg^{-1}. All the values exceeded desirable levels in the soil.

Heavy metals bioaccumulate within an organism when they are consumed and stored faster than they are being excreted (Banerjee, 2003; Shi *et al.,* 2008). Though all the heavy metals are harmful to animals and man, cadmium is comparatively more persistent. Even low levels of cadmium cause serious diseases especially in humans since the body is unable to get rid of Cd as fast as other heavy metals. Cadmium is also known to displace zinc and cause its deficiency also. Zinc deficiency on the other hand aggravates cadmium toxicity resulting in renal dysfunction, kidney stones, weak bones, cancer, pulmonary disease, hypertension, and the weakening of the immune system (Ivan Fernandez, 2002).

Table 5.46. Heavy metal content in soils of agricultural areas

Landuse	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Cu mg kg^{-1}	Cd mg kg	Pb mg kg^{-1}	Ni mg kg^{-1}	Cr mg kg^{-1}
Paddy	85.47^{b} (5.4)	244.69^{bc} (19.37)	40.9^{b} (3.02)	66.09^{ab} (4.77)	24.17^{a} (4.29)	331.6^{bcd} (48.36)	313.13^{cde} (25.005)	75.09^{ab} (3.39)
Vegetables	87.95^{bc} (6.6)	205.54^{b} (17.36)	50.2^{bc} (4.09)	62.6^{a} (5.01)	17.93^{a} (2.77)	297.47^{bcd} (20.13)	240.9^{bcd} (23.96)	63.67^{ab} (6.08)
Banana	131.67^{bcd} (5.3)	181^{ab} (16.06)	38.0^{b} (3.4)	48.07^{a} (3.52)	23.79^{a} (5.6)	302.58^{bcd} (27.82)	160.35^{ab} (15.73)	88.29^{bc} (6.84)
Mixed crop	106.44^{bcd} (2.5)	221.1^{bc} (38.24)	45.9^{bc} (1.4)	61.56^{a} (2.41)	27.74^{a} (1.91)	291.9^{abcd} (7.21)	235.49^{bcd} (10.58)	87.04^{bc} (2.74)
Rubber	115.13^{d} (5.7)	224.45^{b} (15.88)	57.4^{c} (3.2)	66.63^{ab} (4.89)	25.59^{a} (4.07)	285.9^{abcd} (17.57)	222.84^{bc} (18.03)	66.4^{ab} (5.12)
Desirable	<100	<100	<50	<60	<10	<70	<70	<60

Industrial landuse

Soil properties in the 0-60 cm layer as influenced by landuse, especially industries is described below in tables 5.47 and 5.48. It was seen that the soil was highly acidic in all the sites with pH values ranging from 4.08 to 5.1 in different landuses. Significantly lower values were observed in the soils near Carborandum Universal. Electrical conductivity ranged from 0.02 to 0.09 dS/m. It was extremely low and of no impact as regards the soil and its characteristics. Organic carbon was found to range from 1.74 to 2.49 per cent. These values are very high indicating ample supply of organic matter. Significantly higher values were observed in the soils around Carborandum Universal and lower values around Nitta Gelatin areas.

Table 5.47. Soil properties in industrial areas

Landuse	pH	EC	OC
GOI Press	5.06^{bc} (0.09)	0.09^{a} (3.33)	1.74^{ab} (0.14)
KINFRA	4.86^{bc} (0.09)	0.022^{a} (0.01)	1.75^{ab} (0.25)
VAIGAI	5.00^{bc} (0.1)	0.09^{a} (4.93)	1.83^{ab} (0.093)
CUMI	4.08^{a} (0.07)	0.006^{a} (0.002)	2.49^{c} (0.42)
INFO Park	4.96^{bc} (0.1)	0.006^{a} (0.002)	2.06^{bc} (0.43)
NGIL	5.12^{c} (0.11)	0.04^{a} (0.004)	1.28^{a} (0.07)
Desirable	6-7	<4	>0.75

Iron content in soil was found to exceed desirable limits in all the sites. Values were found to range from 114 to 144 mg kg^{-1}. Manganese also exceeded desirable limits of 100 mg kg^{-1}; values ranged from 115 to 409 mg kg^{-1} in the industrial sites with significant variation between sites. The content of zinc was found to vary from 21 to 80 mg kg^{-1} in the sites. All the sites had zinc concentrations within accepted limits except Carborandum Universal site which had 80 mg kg^{-1} of zinc. Copper content exceeded desirable levels in soils around Vaigai threads, Carborandum Universal and Nitta Gelatin sites. The values ranged from 42 to 91 mg kg^{-1} in these industrial sites.

Carborandum Universal that manufactures precision abrasives of silicon carbide by combining silica with carbon releases sulphurdioxide into the atmosphere in the process. Similarly Nitta Gelatin India Ltd., that produce ossein from animal bones employ huge quantity of hydrochloric acid in the process, the fumes of which pollute the air around the industry. Both these industries thus cause acidification of the environment including the soil. GOI Press and Vaigai Threads utilizing dyes are bound to release heavy metals especially chromium. KINFRA with multitude of different industries also create wastes of several kinds while INFO Park generates e-waste in their functioning.

Table 5.48. Heavy metal content in soils of industrial areas

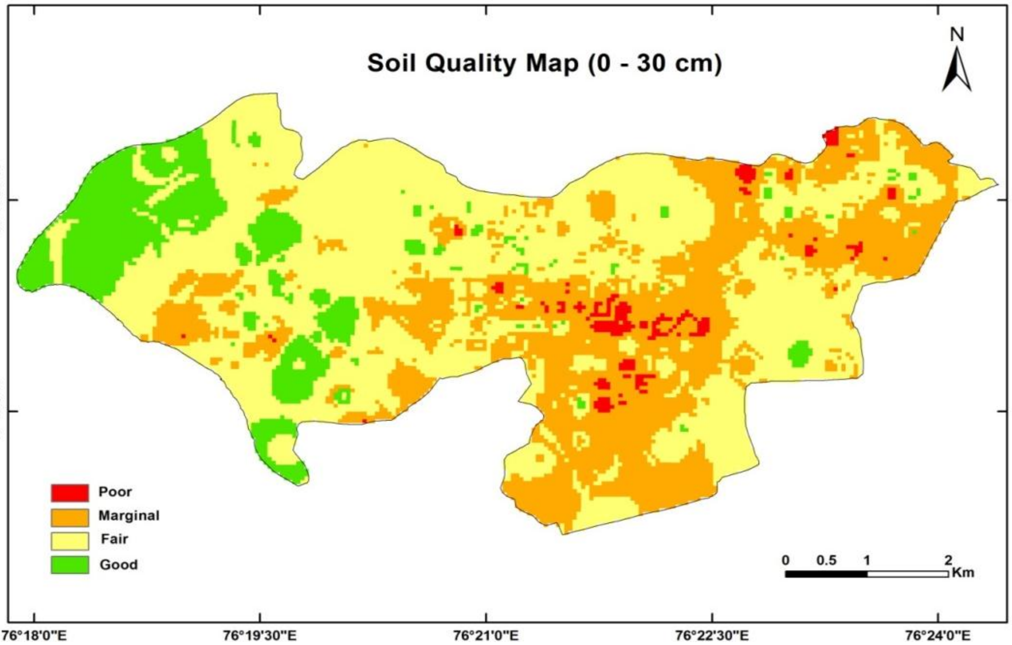
Landuse	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Cu mg kg^{-1}	Cd mg kg^{-1}	Pb mg kg^{-1}	Ni mg kg^{-1}	Cr mg kg^{-1}
GOI Press	144.96^{a} (4.4)	396.5^{d} (35.01)	51.1^{bc} (5.1)	42.5^{a} (2.43)	28.9^{b} (4.8)	310.9^{bcd} (25.06)	299.5^{cd} (15.78)	127.7^{d} (9.17)
KINFRA	131.53^{a} (2.6)	409.9^{d} (41.6)	22.3^{a} (3.8)	47.5^{a} (2.18)	26.6^{ab} (7.08)	193.4^{a} (32.09)	290.46^{cd} (20.83)	90.82^{bc} (6.13)
VAIGAI Threads	128.96^{cd} (7.3)	224.44^{bc} (30.18)	50.7^{bc} (6.5)	91.0^{c} (14.29)	25.8^{ab} (8.39)	368.7^{cd} (25.72)	396.16^{e} (31.68)	128.3^{d} (11.79)
CUMI	114.94^{a} (4.2)	266^{bc} (36.39)	80.5^{d} (5.9)	87.2^{bc} (4.04)	8.02^{a} (4.43)	242^{ab} (12.81)	145.1^{ab} (25.85)	55.61^{a} (8.77)
INFO Park	157.46^{a} (4.1)	301.2^{c} (59.38)	21.3^{a} (5.01)	59.8^{a} (10.12)	20.24^{ab} (5.43)	265.4^{abc} (25.31)	331.8^{de} (26.23)	110.66^{cd} (8.74)
NITTA Gelatin	118.72^{bc} (4.7)	115.9^{a} (5.95)	42.1^{b} (1.5)	65.17^{ab} (2.72)	22.91^{ab} (1.07)	378.03^{d} (11.16)	117.33^{a} (4.82)	75.8^{ab} (3.48)
Desirable	20-100	<100	<50	<60	<10	<70	<70	<60

Cadmium content was found to be high in all the industrial sites except Carborandum Universal area. The values ranged from 8-28 mg kg^{-1}. Significant difference was noted in GOI press and CUMI sites. Lead concentration was very high in all the industrial sites. The values ranged from 193-378 mg kg^{-1}. Significant difference was observed between KINFRA and Nitta Gelatin areas. Nickel content exceeded the permissible limits in all the industrial areas and the values ranged from 117 to 396 mg kg^{-1}. Significant difference was observed in Vaigai threads and Nitta Gelatin areas. Chromium values ranged from 55.6 to 127 mg kg^{-1} in the industrial soils. Carborandum universal area alone was found to have significantly lower concentrations of 55.6 mg kg^{-1}.

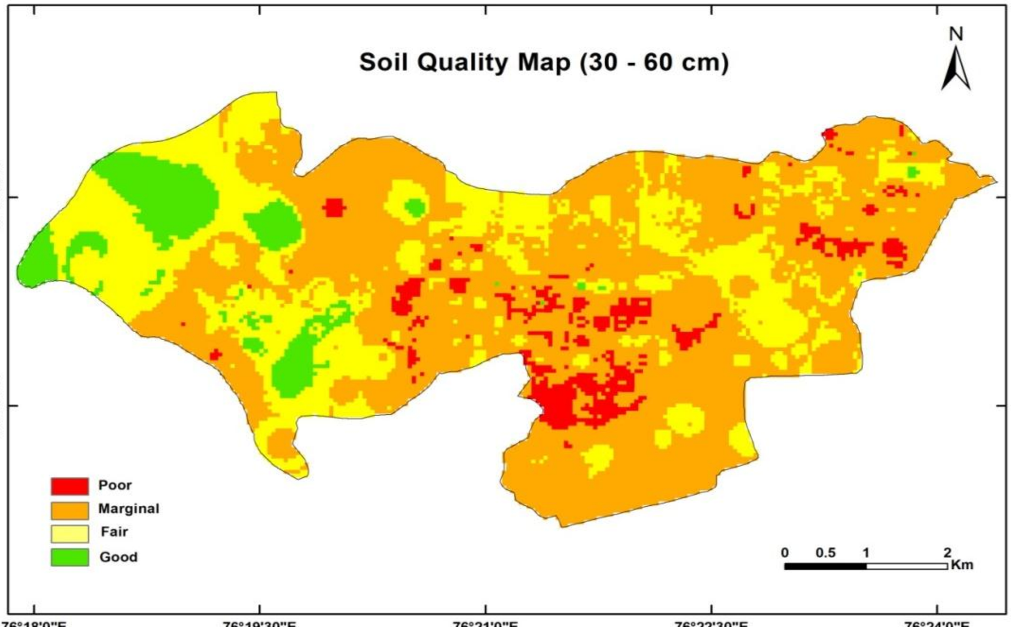
Soil quality map of surface and sub surface depth

Soil quality maps were prepared by combining all the parameters in surface soils. Soil quality was ascertained as an integration of properties studied with appropriate weightage given to each property and by employing raster calculator. Interpolation is the technique used in merging the map.

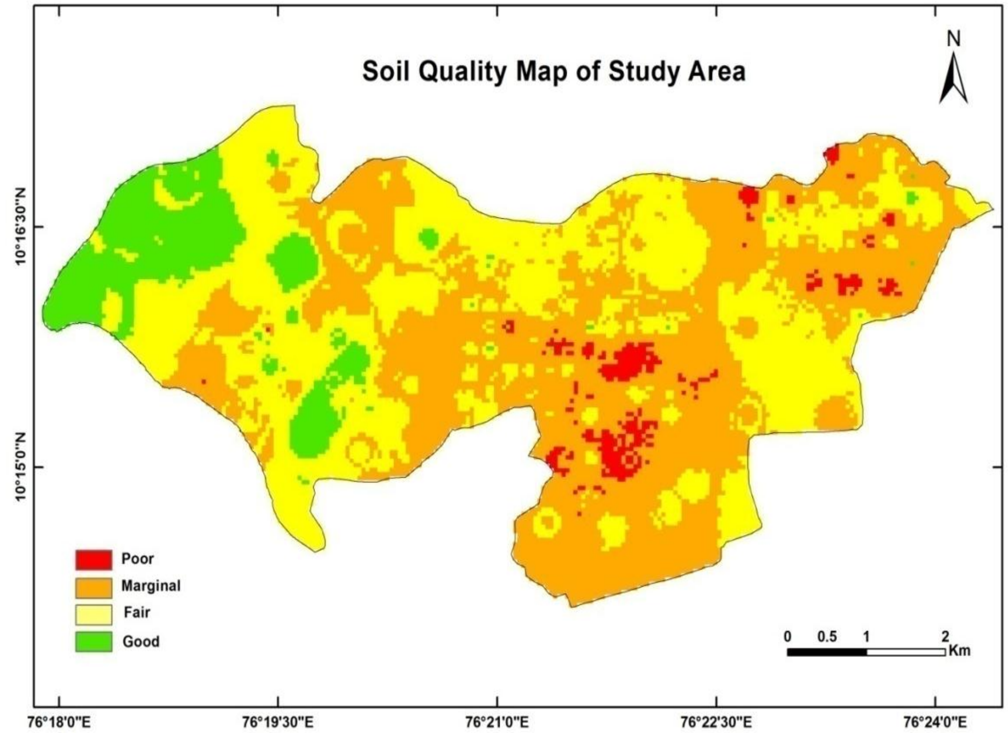
It can be observed from maps 5.24 to 5.26 that soils of the study area were degraded to varying levels when all the properties were considered together. The level of degradation was further graded into high, medium, low and very low categories. Quality deterioration was found to be more in the surface soil compared to the sub soil. High levels of degradation were present in the central and north eastern parts. A pocket of high degradation can be seen in the southwest region also. It can be assumed to be due to the combined effect of industrial and agricultural pollution in these sites. The national highway and railway that cuts through the central Koratty region also might have contributed its share towards pollution of the area. Medium and low levels of degradation are seen interspersed throughout the rest of the region. Very low levels are restricted to a few pockets only. Thus it can be seen that the soils of Koratty region are degraded and contaminated by heavy metals to levels that warrant attention. Map 5.26 gives the consolidated picture of 0 – 60 cm depth considered together. It can be seen that the pattern remains similar to the earlier figures with the high levels of degradation in the central and northeastern regions; a small pocket is seen in the south west portion. These regions are impacted more by the presence of large and small industries as also the national highway and the railways. Urban waste adds to the soil contamination in these sites. The south western portions are low lands with comparatively lower population density.



Map 5.24. Soil quality map of surface soil



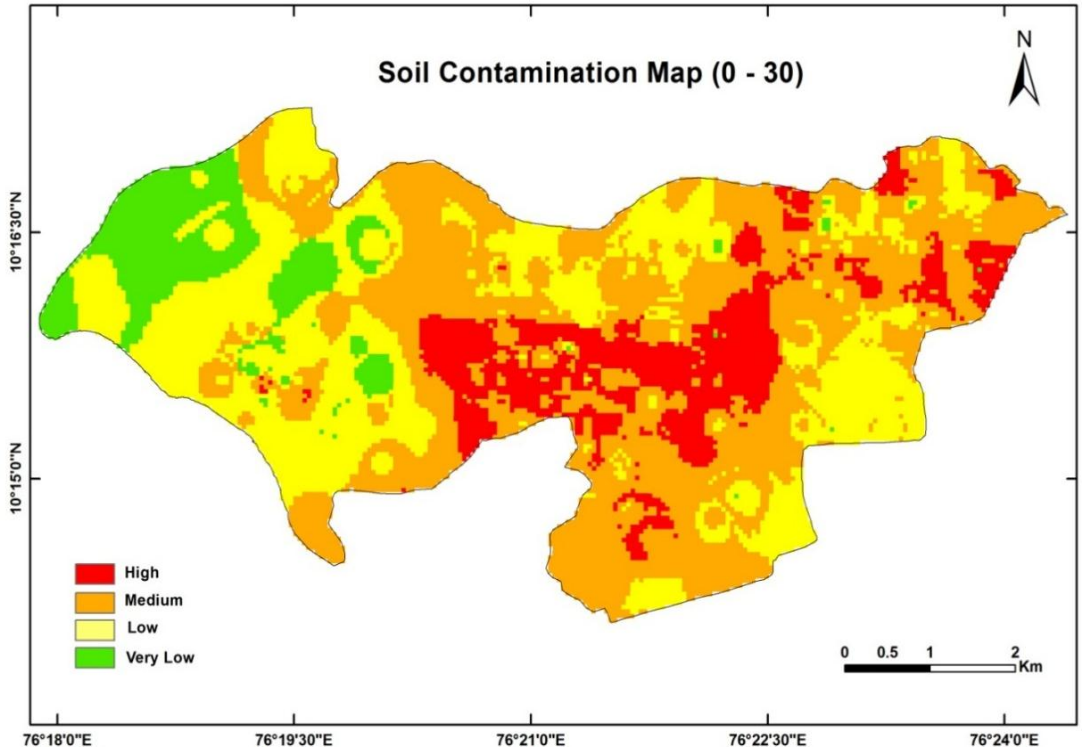
Map 5.25. Soil quality map of subsurface soil



Map 5.26. Soil quality map of 0-60 cm

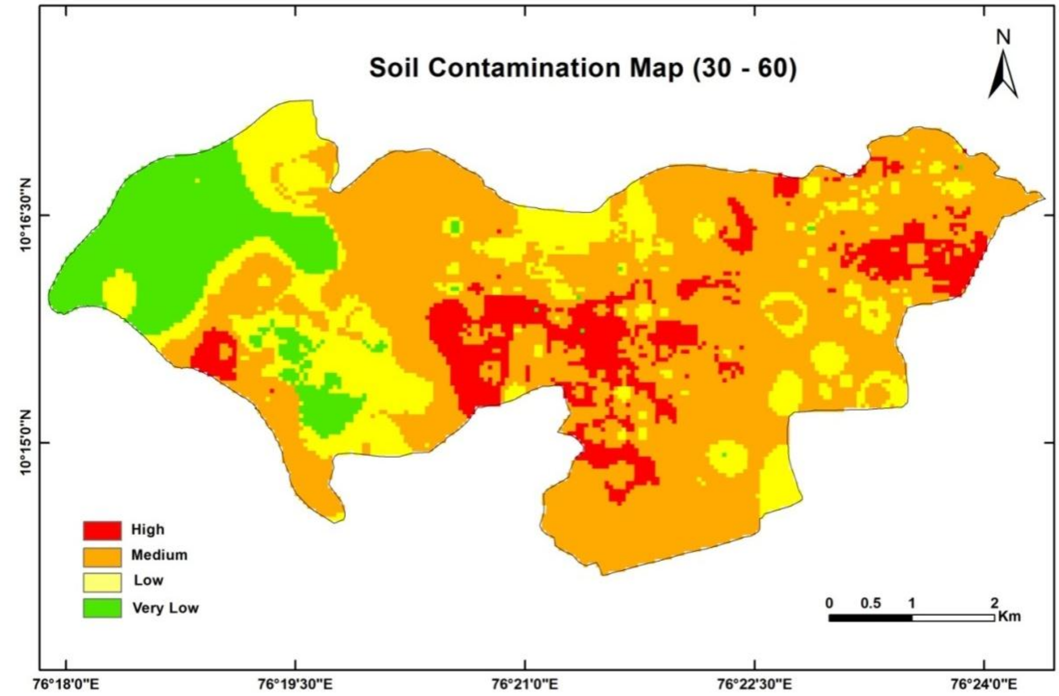
Soil Contamination

Soil contamination maps were prepared by combining all the parameters in surface and subsurface soils (Map 5.27 to 5.29). Soil contamination was ascertained as an integration of contaminants studied with appropriate weightage given to each property and by employing raster calculator. Interpolation is the technique used in merging the map. By using Arc GIS software the final soil contamination map were prepared to identify the major contaminated areas in the Koratty region.



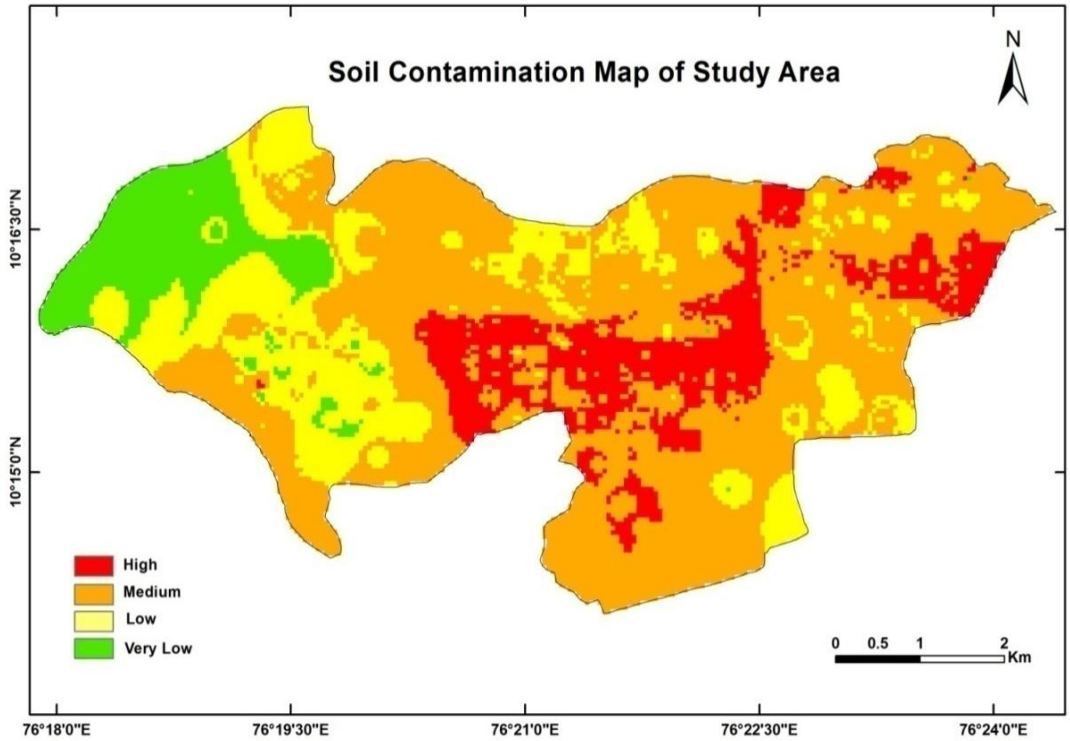
Map 5.27. Soil contamination map of 0-30 cm

Contamination of surface soil shown in the map 5.27 indicates comparatively high levels of contamination due to heavy metals in the central region as also in the north eastern part. Pockets of such levels can also be seen in a small region in the south west part. The major industries are situated in this region. Government of India press, KINFRA, INFO Park, and Vaigai Threads are situated in the central part while CUMI is located in the north east region. The central belt is also heavily impacted by the national highway and railway. Medium to low levels of contamination are present in most of the area. Low to very low contamination is mostly found in the south western part except for the pockets around NGIL Ltd.



Map 5.28. Soil contamination map of 30-60 cm

Soil contamination of subsurface soil indicates that contamination is lesser in the central and northeastern regions as compared to the surface soil; there is a decrease in the area that has high levels of contamination. On the other hand the small pockets of contamination in the south west part is seen to have intensified in the subsoil as compared to the surface soil with a slight shift in position towards west. It seems that polluting substances in this part are more mobile moving down the soil as also downslope. An increase in the area of medium levels of contamination is also evident in the map. The extent of very low contamination remains more or less same.



Map 5.29. Soil contamination map of 0-60 cm

An attempt was also made to reveal the picture of contamination when the 0-60 cm depth was considered as a whole. The map 5.29 given above resembles the suface soil contamination map more with high contamination in the central belt seen spreading to the northeast region. The high pollution area in the southwest also resembles the pattern in the surface soil. Medium to low contamination is seen spread across the landscape while the very low contaminatin area is restricted to the western part. Reasons mentioned in the first section holds good in the second and third part also.

Heavy metal fractions

Speciation of heavy metals has been worked out to understand the fate of heavy metals in the soil. Different fractions estimated give a picture of the likely impact of heavy metals in the soil on the environment. Geo accumulation index has also been worked out to rule out the contribution of heavy metals from the parent rock.

Geoaccumulation Index

Samples of soil collected from various sites with both industrial and agricultural landuses were analysed for geo accumulation index (Igeo) of heavy metals. It can be seen from the table 5.49 that all the heavy metals had negative Igeo values indicating no contamination from natural sources.

Table 5.49. Geoaccumulation index of Heavy metals

Site	Cd	Cu	Fe	Mn	Ni	Pb	Zn
Industry	-1.495	-0.485	-0.53	-0.015	-0.541	-0.532	-0.298
Agriculture	-0.585	-0.585	-0.471	-0.096	-0.054	-0.532	-0.386

Heavy metal fractions

Fractions of heavy metals namely exchangeable fraction, iron and manganese fractions, organic matter fractions and residual fraction were estimated in the sites with different industries as well as different agricultural crops. Industries that were considered include Government of India press, KINFRA, Vaigai Threads, INFOPark, CUMI and NGIL. Major agricultural crops were grouped separately into high input and low input agriculture. Paddy, banana and vegetables were included together in high input group while rubber and mixed crop were considered as low input agriculture. The heavy metal fractions in these sites are given below in tables 5.50 to 5.57.

Table 5.50. Speciation of Cadmium in different landuses

Landuse	Exchangeable fraction (mg kg^{-1})	Fe & Mn fraction (mg kg^{-1})	Organic matter fraction (mg kg^{-1})	Residual fraction (mg kg^{-1})	Total (mg kg^{-1})
GOI Press	1.09	1.32	1.66	2.31	6.39
KINFRA	1.74	1.73	1.58	1.67	6.72
VAIGAI	1.62	1.7	1.52	1.84	6.68
CUMI	1.53	1.46	1.68	1.75	6.42
INFO Park	1.87	1.87	0.52	1.72	7.34
NGIL	1.38	1.94	1.67	1.95	6.94
High-Agri	1.92	2.10	1.33	1.47	6.82
Low-Agri	1.95	1.84	1.93	1.31	7.03

Table 5.51. Speciation of Copper in different landuses

Landuse	Exchangeable fraction (mg kg^{-1})	Fe & Mn fraction (mg kg^{-1})	Organic matter fraction (mg kg^{-1})	Residual fraction (mg kg^{-1})	Total (mg kg^{-1})
GOI Press	0.69	2.80	3.13	14.22	20.84
KINFRA	0.74	1.96	3.58	16.17	22.45
VAIGAI	0.84	2.32	3.45	16.34	22.95
CUMI	1.25	1.92	4.26	18.54	25.97
INFO Park	0.45	2.87	4.12	20.45	27.90
NGIL	0.73	1.89	3.56	15.15	21.33
High-Agri	1.36	1.71	3.11	15.04	21.22
Low-Agri	1.28	1.85	4.57	21.48	29.18

Table 5.52. Speciation of Iron in different landuses

Landuse	Exchangeable fraction (mg kg^{-1})	Fe & Mn fraction (mg kg^{-1})	Organic matter fraction (mg kg^{-1})	Residual fraction (mg kg^{-1})	Total (mg kg^{-1})
GOI Press	178.80	925.60	321.81	39216.50	40642.50
KINFRA	170.43	904.06	319.04	40432.64	41826.17
VAIGAI	180.68	835.26	274.74	48527.24	49817.92
CUMI	167.88	983.47	315.54	41354.62	42821.51
INFO Park	173.50	751.75	260.50	49427.50	50612.50
NGIL	278.43	745.36	284.37	50543.74	51851.9
High-Agri	281.80	776.65	296.87	35799.00	37154.10
Low-Agri	294.36	810.23	353.23	42676.13	44133.95

Table 5.53. Speciation of Manganese in different landuses

Landuse	Exchangeable fraction (mg kg^{-1})	Fe & Mn fraction (mg kg^{-1})	Organic matter fraction (mg kg^{-1})	Residual fraction (mg kg^{-1})	Total (mg kg^{-1})
GOI Press	54.82	106.02	6.74	50.10	435.34
KINFRA	52.43	102.06	6.87	51.52	212.88
VAIGAI	46.34	120.47	4.07	45.34	216.22
CUMI	40.79	85.32	5.47	46.35	177.93
INFO Park	49.62	88.87	3.55	43.80	185.85
NGIL	55.62	112.37	3.86	40.37	212.22
High-Agri	15.54	116.34	5.29	43.99	181.16
Low-Agri	54.38	94.67	6.38	45.06	200.49

Table 5.54. Speciation of Nickel in different landuses

Landuse	Exchangeable fraction (mg kg^{-1})	Fe & Mn fraction (mg kg^{-1})	Organic matter fraction (mg kg^{-1})	Residual fraction (mg kg^{-1})	Total (mg kg^{-1})
GOI Press	3.80	12.14	13.70	30.70	60.35
KINFRA	3.78	12.14	12.89	28.76	57.57
VAIGAI	3.42	8.78	20.76	34.57	67.53
CUMI	3.75	10.34	25.76	40.27	80.12
INFO Park	3.37	9.45	23.60	36.85	73.27
NGIL	3.84	12.15	24.37	36.51	76.87
High-Agri	12.79	7.31	40.39	207.60	268.09
Low-Agri	5.67	5.02	25.32	54.37	90.38

Table 5.55. Speciation of Lead in different landuses

Landuse	Exchangeable fraction (mg kg^{-1})	Fe & Mn fraction (mg kg^{-1})	Organic matter fraction (mg kg^{-1})	Residual fraction (mg kg^{-1})	Total (mg kg^{-1})
GOI Press	17.25	30.69	21.75	20.56	101.81
KINFRA	16.94	30.52	20.76	20.67	88.89
VAIGAI	25.87	44.54	28.32	42.36	141.09
CUMI	18.63	38.74	24.57	31.28	113.22
INFO Park	23.75	40.50	18.50	36.25	119.00
NGIL	18.96	34.67	25.48	30.52	109.63
High-Agri	5.12	32.37	37.00	15.12	89.62
Low-Agri	12.04	20.45	15.64	16.14	64.27

Table 5.56. Speciation of Zinc in different landuses

Landuse	Exchangeable fraction (mg kg^{-1})	Fe & Mn fraction (mg kg^{-1})	Organic matter fraction (mg kg^{-1})	Residual fraction (mg kg^{-1})	Total (mg kg^{-1})
GOI Press	2.38	2.43	1.88	11.66	18.37
KINFRA	2.45	2.45	2.08	10.89	17.87
VAIGAI	2.26	1.89	2.05	7.65	13.85
CUMI	2.46	2.04	1.89	8.32	14.71
INFO Park	2.23	1.36	1.02	8.51	13.12
NGIL	2.64	1.96	2.78	8.46	15.84
High-Agri	2.17	1.68	3.08	13.88	20.81
Low-Agri	2.12	1.46	2.23	7.45	13.26

Cadmium

Cadmium content was highest in the residual fraction in most of the sites followed by exchangeable or Fe & Mn fractions except in GOI Press and NGIL sites where organic matter fraction was also high.

The fractions of cadmium in high input agriculture areas followed the trend of decreasing levels of Fe and Mn fractions, exchangeable fraction, residual fraction and organic matter fraction. In low input agriculture the pattern of different fractions was exchangeable fraction followed by organic matter fraction, Fe & Mn fraction and residual fraction. The total of these fractions did not differ much between high input and low input agriculture.

Copper

Copper content was present mostly in the residual fraction with lesser amounts in the organic matter, Fe & Mn and exchangeable fractions. This pattern was similar in all the landuses. The total of all the fractions did not vary between landuses. Copper content in the soil did not differ much in the industrial sites. It was comparatively more in the low input agricultural sites as compared to the high input agricultural areas. It is low in mobility and hence accumulates at the site of application. Similar results were reported by Krishna *et.al*, 2004.

Iron

Residual fraction of iron was extremely high with about 100-200 times of other fractions. Fe & Mn fraction came next which was followed by the organic matter fraction and the exchangeable fraction. This pattern was exhibited in all the landuses irrespective of industrial or agricultural use. The total fraction was only slightly more than the residual fraction and did not differ much between the sites. Soils in the humid tropics are usually rich in sesquioxides (Baranowski *et al.*, 2002) which is the case here also and chances of iron pollution are thus more.

Manganese

Manganese was found to be more in the Fe and Mn fraction in all the landuses. This was followed by exchangeable, residual and organic matter fractions in all the sites except the high input agricultural sites where exchangeable fraction followed the Fe & Mn fraction with exchangeable and organic matter fractions following it. The total fraction was more in the GOI press compound and similar in other industrial as well as agricultural sites.

Nickel

In the case of Nickel, it was seen that most of it occurred in the residual fraction which was followed by the organic matter, Fe & Mn and exchangeable fractions in all the industrial sites. In the agricultural area also the residual fraction was the highest but the order of decrease was organic matter, exchangeable and Fe and Mn fractions. The total fraction of Ni was similar in all the industrial sites but it was almost 4 times in the high input agricultural area.

Lead

The fractions of lead in the soil followed a different pattern. In the GOI press and KINFRA site, it was highest in Fe & Mn bound fraction which was followed by the organic matter, residual and exchangeable fractions. In the case of Infopark site, Fe and Mn fraction was followed by the residual, organic matter and exchangeable fractions. In the Infopark site Fe & Mn bound fraction was followed by residual, exchangeable and organic matter fractions. CUMI and NGIL were similar to Vaigai threads with the residual, organic matter and exchangeable fractions following the Fe & Mn bound fractions.

In high input agricultural area it was the organic matter fraction that was highest which was followed by Fe & Mn fraction, residual fraction and exchangeable fractions. In the case of low input agriculture the pattern was Fe & Mn fraction, residual, organic matter and exchangeable fractions in decreasing order.

When all the fractions were considered together it was observed that industrial areas had comparatively higher lead levels. The content of lead was comparatively more in high input agricultural areas as compared to low input agriculture.

Zinc

The residual fraction of Zinc was greater than the other fractions in all the landuses. It was followed by Fe & Mn, exchangeable and organic matter fractions in the GOI site while the pattern of distribution was in the order of the residual fraction followed by the exchangeable, Fe & Mn and organic matter fractions in the KINFRA compound. In the Vaigai threads site residual fraction was followed by exchangeable, organic matter and Fe & Mn fractions. Infopark and CUMI were similar to KINFRA in zinc fractions. In the case of NGIL residual fraction was followed by organic matter, exchangeable and Fe and Mn fractions. Similar was the pattern in both high input and low input agriculture areas.

Enrichment Factor

Enrichment factor of heavy metals calculated using the continental crust average with Fe as reference element for normalization indicated that Cadmium, Nickel and lead have accumulated beyond the normal excepted levels in the soil in all the sites (Table 5.58). Lead values of around 4 to 5 did not vary much between sites. Nickel enrichment values were slightly less than the lead values with around 2 to 3 except the high input agriculture area recording a value of 13.26. Cadmium enrichment was high in all the landuses, the highest value of 6.47 being obtained in high input agriculture. All the other heavy metals studied had only minimum enrichment factor.

Table 5.58. Enrichment factor of heavy metals

Site	Cd	Cu	Fe	Mn	Ni	Pb	Zn
GOI Press	5.62	0.71	1.00	0.17	2.6	4.38	0.22
Infopark	4.25	0.77	1.00	0.11	2.54	4.09	0.13
Vaigai Threads	5.32	0.81	1.00	0.15	2.71	4.84	0.23
CUMI	4.53	0.78	1.00	0.14	2.52	4.12	0.14
Nitta Gelatin	5.48	0.82	1.00	0.24	2.64	4.66	0.22
KINFRA	5.53	0.73	1.00	0.18	2.58	4.23	0.24
High-Agri	6.47	0.80	1.00	0.32	13.26	4.22	0.21
Low-Agri	4.23	0.75	1.00	0.22	2.34	4.28	0.25

The moderately high enrichment factor of lead is a potential source of bioaccumulation due to its mobility in the exchangeable fraction (Fig. 5.23). Cadmium on the other hand has low mobility in all the fractions and hence chances of pollution of ground water is minimum. The enrichment factor for cadmium was more than three in all the sites with negligible Igeo values indicating anthropogenic factors in increasing Cadmium contamination in these sites. The high enrichment factor of nickel especially in the agricultural land is also a matter of concern due to its mobility and carcinogenic effect.

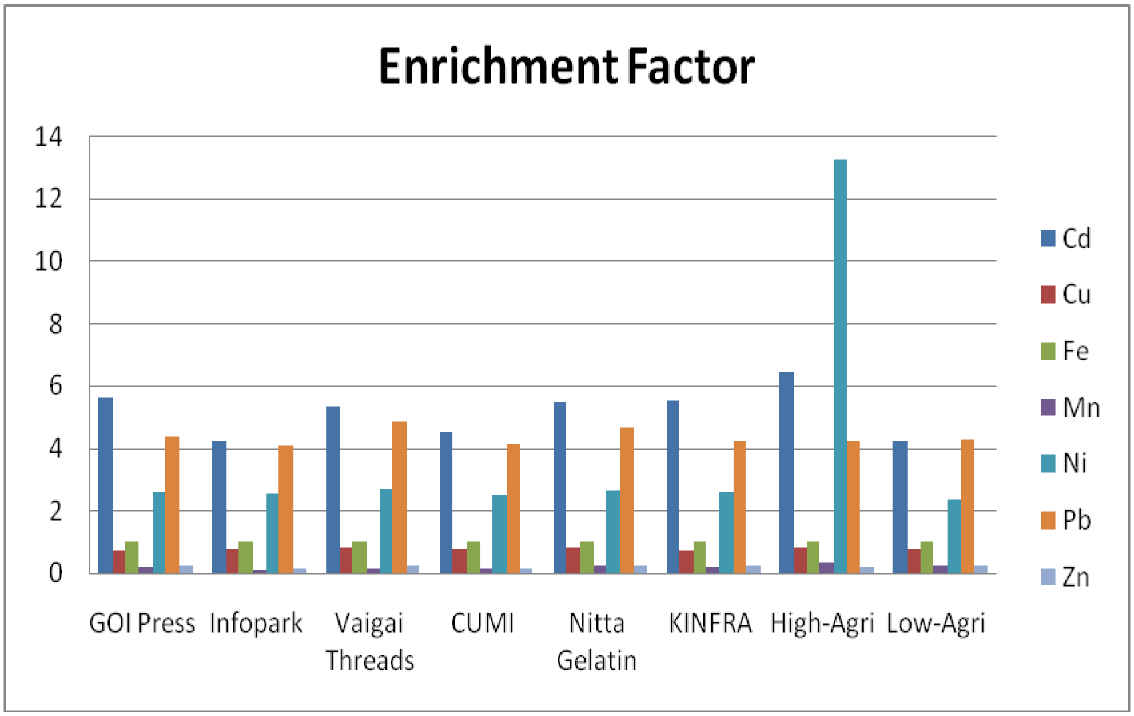


Figure 5. 23. Enrichment factor of different elements in the three sites

Contamination Factor

Contamination factor which gives an idea of concentration of the element in relation to background concentration is shown in table 5.59.

Table 5.59. Contamination factor of heavy metals

Site	Cd	Cu	Fe	Mn	Ni	Pb	Zn
GOI Press	6.52	0.83	1.16	0.19	3.02	5.09	0.26
Infopark	6.12	1.11	1.44	0.17	3.66	5.95	0.18
Vaigai Threads	5.45	1.04	1.39	0.18	3.54	5.06	0.20
CUMI	5.24	0.98	1.24	0.15	3.78	4.84	0.19
Nitta Gelatin	6.64	1.14	1.18	0.14	3.04	5.02	0.25
KINFRA	6.51	0.95	1.24	0.20	3.14	5.24	0.23
High-Agri	6.95	0.85	1.46	0.16	13.40	4.48	0.29
Low-Agri	5.42	0.91	1.20	0.15	3.26	5.24	0.22

It can be seen that all the sites had moderate to high contamination of Cadmium, Nickel and Lead (Fig. 5.24). Fe, Mn, Cu and Zn were low to moderate with respect to the contamination factor. Higher contamination levels of Cd, Ni and Pb in these sites can be due to fertilizers, industrial effluents and vehicular traffic as well. The high concentration of Ni in the agricultural soil is probably due to phosphatic fertilizers and also sewage disposal.

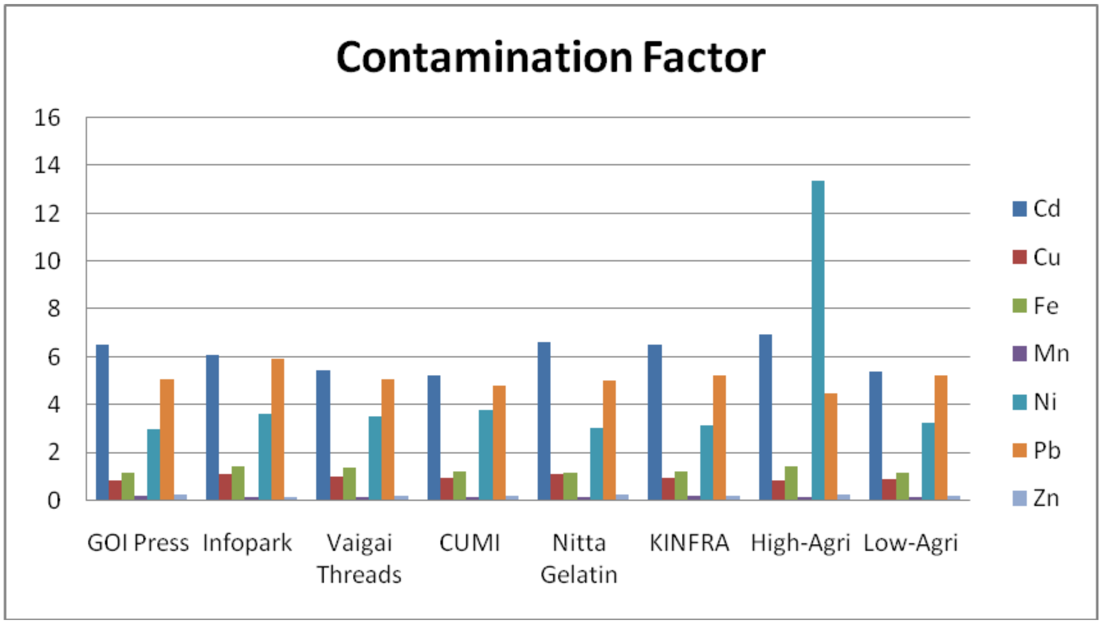


Figure 5.24. Contamination factor of different elements in the three sites

Mobility

Mobility of different heavy metals in soils of the study sites are given in table 5.60 and figure 5.25 below and discussed along with.

Table 5.60. Mobility of different heavy metals

Site	Cd	Cu	Fe	Mn	Ni	Pb	Zn
GOI Press	1.095	0.695	178.8	54.825	3.805	17.25	2.385
Infopark	1.875	0.45	173.5	49.625	3.375	23.75	2.23
Vaigai Threads	1.460	0.624	165.3	52.734	3.250	22.54	2.42
CUMI	1.940	0.732	185.6	55.430	3.925	23.06	2.50
Nitta Gelatin	1.962	0.740	210.5	60.320	3.864	20.35	2.32
KINFRA	1.363	0.520	170.4	45.25	3.04	18.37	2.35
High-Agri	1.92	1.365	281.8	15.54	12.79	5.125	2.17
Low-Agri	1.08	0.70	170.3	40.20	3.45	17.40	2.10

Among the heavy metal elements studied, Fe was the most mobile which was followed by Mn, Pb, Ni and others in order. Though the mobility of lead, nickel, cadmium and others are low, they are still of concern being very toxic even at low concentrations.

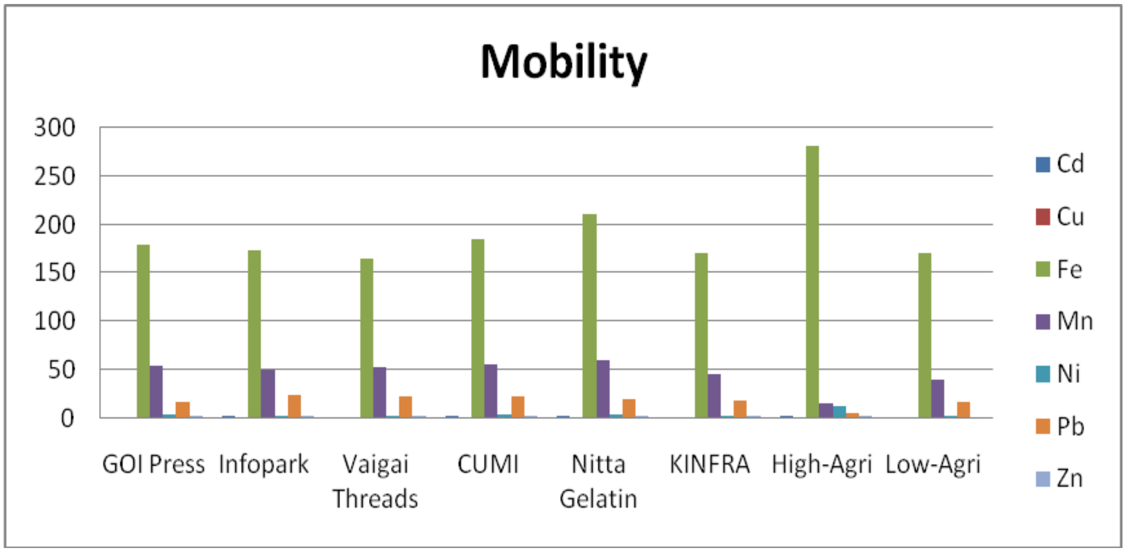


Figure 5.25. Mobility of different elements

The speciation of heavy metals in Koratty region revealed different patterns with respect to the elements studied namely copper, iron, manganese, zinc, nickel, lead and cadmium. Copper and iron were mostly restricted to the residual fraction in both industrial and agricultural areas with slightly higher values in the industrial sites. Cu accumulates at the site of addition since it is not a mobile element while iron is comparatively mobile and hence easily transported through the soil. The Fe and Mn fraction contained maximum amount of Mn in both industrial and agricultural sites. Zinc was found to be more in the residual fraction in industrial as well as agricultural areas. Zinc is being enriched from fertilizers, hazardous waste, municipal sludge etc. Electroplating industries making use of electro galvanizing also release considerable amount of zinc into the surroundings. Being mobile it is easily translocated with percolating water and can lead to pollution when higher amounts are added to the soil.

The residual fraction contained maximum nickel in all the sites irrespective of industrial or agricultural use. The total nickel content in the agricultural soil was much higher than the industrial sites. Fertilizers especially phosphates are a source of nickel in soil. More important is the application of waste disposal including sewage sludge. Predominantly high residual fractions of Ni has been reported by others also. Nickel may be increasingly bound to organic matter, a part of which forms easily soluble chelates. The solubility and mobility of nickel increases with decreasing pH. Many nickel compounds are soluble at a pH less than 6.5 (Kabata-Pendias and Mukherjee, 2007; McGrath, 1995; Tye *et al.,* 2004; IPCS, 1991) and hence nickel contamination is a cause of concern.

Cadmium was found to be more in the residual and exchangeable fractions in the industrial sites while it was more in Fe and Mn fractions in the agricultural area. Cadmium content was low in most of the sampled sites except the agricultural areas where its values were high which is of concern due to chances of bioaccumulation in the cultivated crops since a preference for Cd is reported among plants (Amoo *et al.,* 2005).

The pattern of speciation of lead was different from the above elements. It was highest in the Fe and Mn fractions in the industrial sites while the agricultural areas recorded more nickel in the organic matter fraction. Lead pollution is expected from printing industry which is reflected in the data also. Vehicular traffic is another major source of Pb through automobile emissions. Paint, plumbing materials, battery etc., also contribute to Pb contamination of the soil. The negative values of Igeo index indicates that enrichment of Pb was not from natural sources. In cultivated soils it was seen that Pb is largely held by organic matter restricting its availability to the crops. But the acidic soils present in the area may increase the solubility and leaching of Pb to the ground water. Increase in mobility of lead with decreasing pH was also reported by Baranowski *et al.,* 2002.

The results show that Cd, Ni & Pb can be major pollutants. Fe is the most mobile & Cd the least mobile. Cu, Mn & Zn were found to be low in the area.

5.4. SUMMARY

Soil quality was found to be degraded to varying levels in Koratty region. Acidity has increased significantly to levels of pH less than 5 in most of the lands. Extremely acidic soils have been located near two prominent industries namely CUMI and NGIL which are consuming large quantities of sulphuric acid and hydro chloric acid, the fumes of which spread over the area. Most of the agriculture soil were found to have pH in the range of 4.4-4.9 in the surface and 4.6-5.0 in the sub surface soil on an average. The respective figures in industrial sites were pH 4.0-5.2 and 4.1-5.0. Electrical conductivity was too low to be of any consequence. EC values were less than 0.03 dS/m in all the areas. Organic carbon was high in most of the sites including agriculture and industrial areas. It was found to be around 0.7-1.2% in the surface soil of agricultural areas and 0.7-1.5 in the industrial sites. The subsurface soil had 0.2-0.9 and 0.3-0.8% respectively.

Heavy metals studied including Fe, Mn, Zn, Cu, Cd, Pb, Ni and Cr were present in all the localities to varying levels. Fe was found to be present at levels of 88-142 mg kg^{-1} and 93-151 mg kg^{-1} in the surface and subsurface of agricultural soils while the corresponding figures in the industrial sites were 118-150 and 110-144 mg kg^{-1} respectively. Mn was present at levels of 169-265 mg kg^{-1} in the surface soil, 192-225 mg kg^{-1} in the subsurface soil and agricultural area. The respective figures in the industrial sites were 201-298 and 205-280 mg kg^{-1} respectively. Cu and Zn were present within the permissible levels. Values of Zn were in the range of 37-52 mg kg^{-1} and 38-57 mg kg^{-1} in the two depths of agriculture areas. The corresponding values in industrial sites were 18-81 and 15-79 mg kg^{-1} respectively. Cu was present in the range of 48-67 mg kg^{-1} and 41-88 mg kg^{-1} in the surface soil of agriculture and industry. In the subsoil it was present at 47-66 mg kg^{-1} in agriculture lands and 43-85 mg kg^{-1} in industrial areas. Pb, Ni, Cd and Cr were all present in quantities exceeding desirable levels. Pb was present in extremely high levels irrespective of landuse. It was present at 273-377 mg kg^{-1} in agriculture surface soil and at 262-371 mg kg^{-1} in industrial surface soil. In the subsoil the levels were 269-331 and 172-391 mg kg^{-1} in the two landuses. Ni and Cd were present at higher levels mostly in agricultural areas as compared to the industrial sites. Ni was present in the range of 156-316 mg kg^{-1} and 163-309 mg kg^{-1} in the surface and subsurface soil of agricultural landuse. The respective figures in industrial sites were 139-360 and 107-440 mg kg^{-1} respectively. Cd was present at levels of 19.32 – 28.9 mg kg^{-1} and 16.5-28.2 mg kg^{-1} in the surface and subsurface soil of agricultural area while respective figures in industrial sites were 4.5-29.7 and 11.5-36 mg kg^{-1} respectively. Cr was present at high levels in both industrial and agriculture landuses. It was present at levels of 68-87 mg kg^{-1} and 163-310 mg kg^{-1} in the surface soil of agriculture and industrial sites. In the subsurface soil the levels were 56-115 mg kg^{-1} and 107-440 mg kg^{-1} in the two respective sites.

Thus soil quality was found to be badly affected by both agriculture and industries. The national highway and railway cutting through the central region of Koratty is an important source of pollution from fossil fuel burning. The degree of contamination by heavy metals explored by studying different fractions of these elements in the soil revealed that lead, nickel and cadmium are serious soil contaminants in the region.

CHAPTER 6

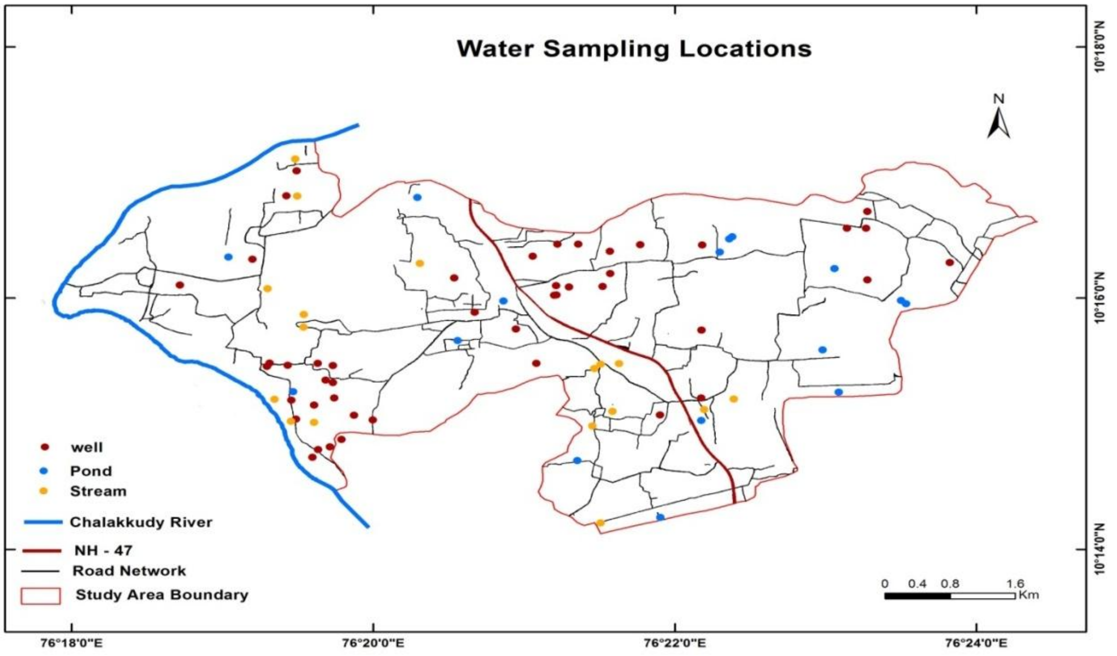
WATER QUALITY AS INFLUENCED BY LANDUSE

6.1 INTRODUCTION

Land use and its modifications directly affect the quality of water that drains from the watershed. Developmental activities including high input agriculture, industries and vehicular traffic realease many pollutants that ultimately reach the water bodies and contaminate it.

6.2 METHODOLOGY

A detailed survey was conducted to identify the water bodies in Koratty region. The water samples were collected during pre monsoon and post monsoon periods. Surface water such as streams, water courses and ponds as also wells and bore wells were sampled for assessing water quality.



Map 6.1. Water sampling locations

Site selection for surface water samples

The selection of sampling site was decided by the various uses of water and by their location, relative magnitude and importance.

Wells, ponds and water courses were selected throughout the region based on different stresses imposed on the system by different activities. The factors, which were considered during the site selection were urban and domestic waste, agricultural residues and industrial pollution.

Sample collection

The sampling was carried out manually using a water sampler. The collected samples were transferred to transparent polyethylene bottles, which were thoroughly cleaned and rinsed with the sampled water. Information regarding the source and the conditions at the time of sampling was recorded andthe container tagged noting the sample number, source of sample and sampling location. While taking the sample from open well the bucket was lowered at least two to three meters below the surface and sample collected preferably from the centre of the well.

Parameters measured in the field

Water quality parameters including pH, conductivity and temperature were measured at the sampling site immediately after the collection of water sample. Fixing of sample for estimation of DO and BOD was done at the site itself. Samples for biological parameters were collected in sterile Tarsons bottles to avoid contamination (APHA, 2005).

Physical parameters

Physical parameters listed below were determined following procedures given in APHA (2005) and CPCB (2008).

Temperature (^oC)

Temperature was measured at the sampling station itself, using centigrade thermometer.

Total Dissolved Solids (mgL^{-1})

It was determined as the residue left after evaporation of the filtered sample.

Total Suspended Solids (mgL^{-1})

Total suspended solids included insoluble matter in water.

Chemical parameters

Chemical parameters listed below were determined following procedures given in APHA (2005) and CPCB (2008).

pH

pH of the samples was measured using Systronics digital pH meter. The instrument was calibrated using pH 4 and 9.2 buffer solutions.

Electrical Conductivity (EC)

Conductivity becomes an indicator of dissolved ions present in any water sample. EC was measured using ELICO conductivity meter.

Sulphate

Sulphate ion was precipitated in an acid medium with barium chloride in such a manner as to form barium sulphate crystals of uniform size. Nephelo turbidity meter measured the absorbance of barium sulphate suspension and the sulphate ion concentration was determined by comparison of the reading with a standard curve.

Phosphate

Ammonium molybdate was made to react with Phosphate-P in the water sample to form molybdophosphoric acid, which was reduced by the addition of stannous chloride to obtain blue colour and estimated at 690nm.

Nitrate

Nitrate nitrogen was estimated by the cadmium reduction technique with the help of spectrophotometer. The estimation of dye was made at 543nm using UV Visible spectrophotometer (Hitachi, U-2800)

Fluoride

Fluoride was estimated using UV-Visible spectrophotometer.

Turbidity (mgL^{-1})

Turbidity was measured with the help of Nephelometer (Turbidity meter) and expressed as Nephelometric Turbidity Units (mgL^{-1}).

Phenolic compounds

Phenolic compounds were estimated using spectrophotometer

Dissolved Oxygen (DO) (mgL^{-1})

Dissolved oxygen was estimated by Winkler's Iodometric method.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) was estimated by incubation of the sample at 20^0C for a period of time 5 days so that microorganisms can act up on the biodegradable matter. After 5 days the DO content was determined. The difference between the initial and final DO gives BOD.

Chemical Oxygen Demand (COD) (mgL^{-1})

Chemical oxygen demand (COD) was estimated using open reflux method by oxidizing the organic matter with potassium dichromate in the presence of sulphuric acid (H_2SO_4).

Oil and Grease

Oil and grease content in water sample was estimated by the Gravimetric method. A volume of 250 ml of sample was acidified to pH 2 by dropwise addition of 50% sulphuric acid and 20 ml hexane. The mixture was shaken well for 10 minutes and kept for layer separation. The aqueous layer was collected in a beaker. The organic layer was transferred to a previously weighed evaporating dish from the separating funnel. Again 15 ml hexane was added to the aqueous layer and shaken well for 10 minutes. Then the aqueous layer was discarded and the organic layer was transferred from the separating funnel to evaporating dish. The oil was collected in the evaporating dish and kept in the oven and allowed to dry.

Heavy metals

Iron (mg kg^{-1})

Iron usually exists in natural water both in ferric and ferrous forms. It is converted into ferrous state by boiling with hydrochloric acid and hydroxylamine. The reduced iron chelates with 1, 10 - phenonthroline at pH 3.2 to 3.3 to form a complex of orange-red colour. The intensity of this color is proportional to the concentration of iron and follows Beer's law, and therefore, can be determined using spectrophotometer.

Cadmium (mg kg^{-1})

Anodic stripping voltammetric method was used.

Zinc (mg kg^{-1})

Zinc was determined by Zincon method.

Manganese, lead, copper, nickel and cadmium were determined using Atomic Absorption Spectrometer according to APHA (2005).

Total Coliform MPN Procedure:

Aseptically transferred 10, 1, 0.1 ml aliquots of the sample in sterilized dilution water to MacConkey fermentation tubes. Incubated the inoculated tubes at 37 + 0.5°C. After 48+3hours, swirled each tube and examined for gas production. Recorded the presence or absence of growth and gas. Presence of both gas and growth constitutes a positive presumption test. Noted the number of positive tubes for each dilution and compared with the MPN index chart to get the Most Probable Number (MPN)/100ml of total coliforms.

Faecal Coliform MPN Procedure

Gently shook the previous positive tubes and transferred three loopful to a fermentation tube containing BGLB. Incubated the inoculated tubes at 44.5^{0}C, and checked for gas production within 24+3 hours. Count was determined using MPN index.

Detection of E.coli

Gently shook the previous positive tubes to re-suspend the growth and with a sterile loop, transferred three loopful to a fermentation tube containing peptone water. Incubate the inoculated tubes at 44.5^{0}C for 24+3 hours. After the incubation added 2-3 drops of Kovac's reagent. Formation of a violet ring indicates the presence of *E.coli.*

Pesticide Residues

Pesticide residues were estimated using GCMS.

6.3 RESULTS AND DISCUSSION

6.3.1 Water quality

6.3.1.1 Well Water Quality in Koratty Region

Data obtained on water quality of 50 wells in Koratty region sampled during both pre and post monsoon seasons is provided in table 6.1.

It was found that the pH of well water was 5.45 on an average during pre-monsoon and 5.3 during post-monsoon season. These values indicate acidity of well water irrespective of seasons. There were wells with pH less than 4 also though restricted to 3 or 4 sites. Electrical conductivity (EC), an index of salt concentration, was low in all the wells. The EC values on an average was found to be 105 dS/m during pre monsoon season and 148.5 dS/m during post monsoon seasons. Slight increase was noted during post monsoon as compared to the pre monsoon. Total Dissolved Solids (TDS) was found to be more than the WHO limits (25 mgL^{-1}) at all sites both during the pre-monsoon (73.5 mgL^{-1}) and the post-monsoon (104 mgL^{-1}). Comparatively higher values were observed during post monsoon season.

Table 6.1. Physico-chemical properties of well water in Koratty

Parameters	Values		Permissible Limits
	Pre monsoon	Post monsoon	
pH	5.45±1.2	5.3±0.145	6.5-8.5
EC (dS/m)	105±19.5	148.5±44	500
TDS (mgL^{-1})	73.5±12	104±10.5	25
Sulphate (mgL^{-1})	3.45±1.45	2.5±1.45	200
Phosphate (mgL^{-1})	0.035±0.01	0.04±0.035	0.05
Nitrate (mgL^{-1})	1.605±2	1.82±1.175	2
Fluoride (mgL^{-1})	0.2±0.1	0.13±0.025	1
Oil and grease (mgL^{-1})	12.5±3.3	36.5±20	10
Phenoliccompounds (mgL^{-1})	1.25±0.75	0.51±0.01	0.002

The concentration of Nitrate, Phosphate, Sulphate and Fluoride was found to be low in both pre-monsoon and the post-monsoon period. It indicates that there is no contamination from these anions. Nitrate was found to be within the permissible limits (2 mgL^{-1}) at all sites both during the pre-monsoon (1.605 mgL^{-1}) and the post-monsoon period (1.82 mgL^{-1}). Phosphate concentration was found to be 0.035 mgL^{-1} in pre monsoon and 0.04 mgL^{-1}in post monsoon seasons. Sulphate was found to be present at 3.45 mgL^{-1} during the pre-monsoon season; values around 2.5 mgL^{-1} were recorded in the post-monsoon period. Fluoride was also found to be within the permissible limits (1 mgL^{-1}) at all sites both during the pre-monsoon (0.2 mgL^{-1}) and the post-monsoon period (0.13 mgL^{-1}).

Oil and grease as well as Phenolic compounds were present in quantities higher than permissible limits in all the wells. Oil and grease was observed to be present at an average concentration of 36.5 mgL^{-1} in the post monsoon season with wide variations between wells. Contamination by oil and grease was found to be less during pre monsoon as compared with the post monsoon season with12.5 mgL^{-1}. Phenolic compounds also contaminated wells in the region with average concentration of 1.25 mgL^{-1} and 0.51 mgL^{-1} respectively during the pre and post monsoons.

pH of well water

Seasonal variations in pH of well water is shown in figure 6.1 below. Wells in the region were all acidic with pH values less than 6 which was below the permissible limit of 6.5 to 8.5. They also differed widely in their pH value. It can be seen from Figure 6.1 below that wells from 1 to 25 were all within the pH range of 5 to 6; these wells were located on the eastern side of the National Highway. Wells from 26 to 38 can be seen to be located on the south western part of the study area and all of them had extremely low pH ranging from 3.7 to 5 indicating serious levels of acidity. Most of these were located around NGIL. Wells from 40 to 50 were having a pH range of 5 to 6 except 2 wells numbered 42 and 45. Acidity of well water in general was more during pre monsoon season as compared to the post monsoon.

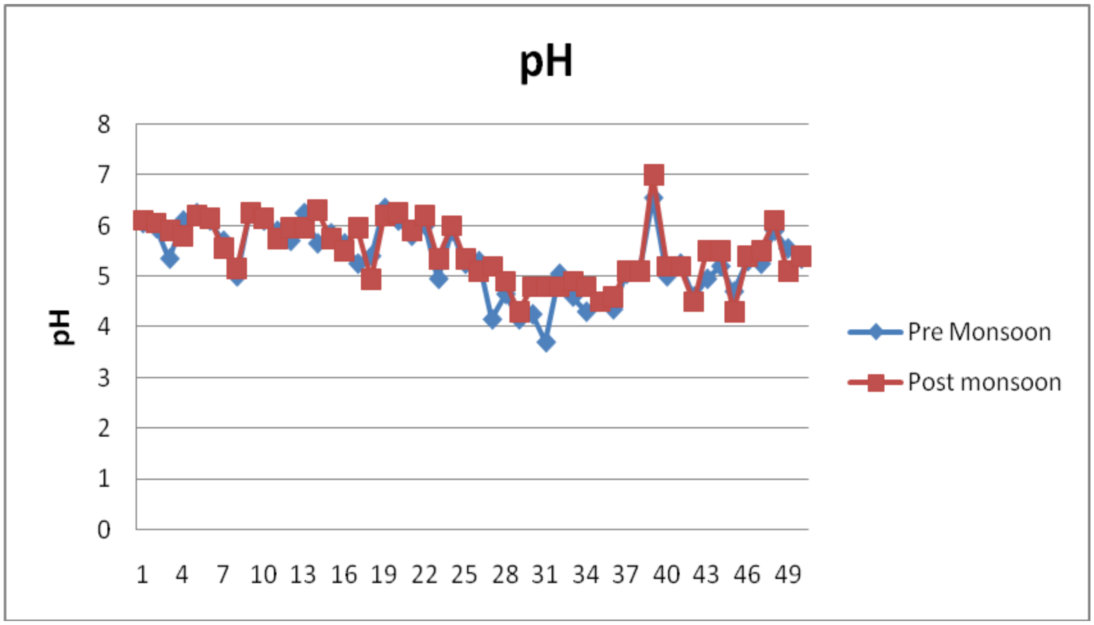


Figure 6.1. Seasonal variation in pH of well water across sites

EC of well water

Electrical conductivity of wells given in the Figure 6.2 shows that almost all the wells had very low EC values of less than 200 dS/m except well number 31 which had exceptionally high conductivity of 1550 dS/m in pre monsoon and well number 48 with 650 dS/m in post monsoon.

Other exceptions were well number 39 and 40 with slightly more than 200 dS/m of EC values. It can be seen that the pattern of EC in well water resembled the trend of pH in the fact that the wells upto 29 did not show much variation and were all having EC values less than 200 dS/m. Variation is noted from well number 30 onwards, all of which occur in the south western part of the study area in the vicinity of NGIL.

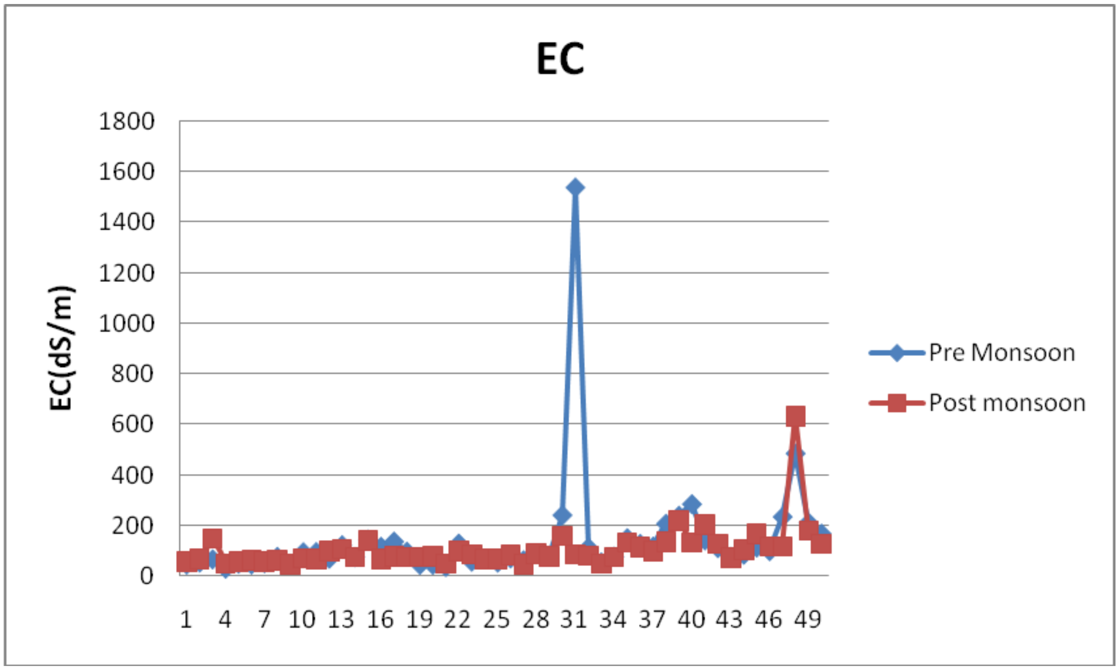


Figure 6.2. Seasonal variation in EC of well water across sites

TDS in well water

Total dissolved solids in well water (Fig. 6.3) followed the exact trend of EC. All the wells upto the 29th were similar in TDS with values less than 100 mgL^{-1} and these wells upto 25 were in Koratty area. Differences in TDS started from well number 30 onwards falling in south western region with well number 31 near NGIL exhibiting exceptionally high TDS of 1100 mgL^{-1}. Higher TDS value was observed in well number 48 also. The high value of well number 31 was in pre monsoon season while that in the 48th well was obtained during post monsoon season. Most of the wells had higher total dissolved solids exceeding the permissible level of 25 mgL^{-1} of water

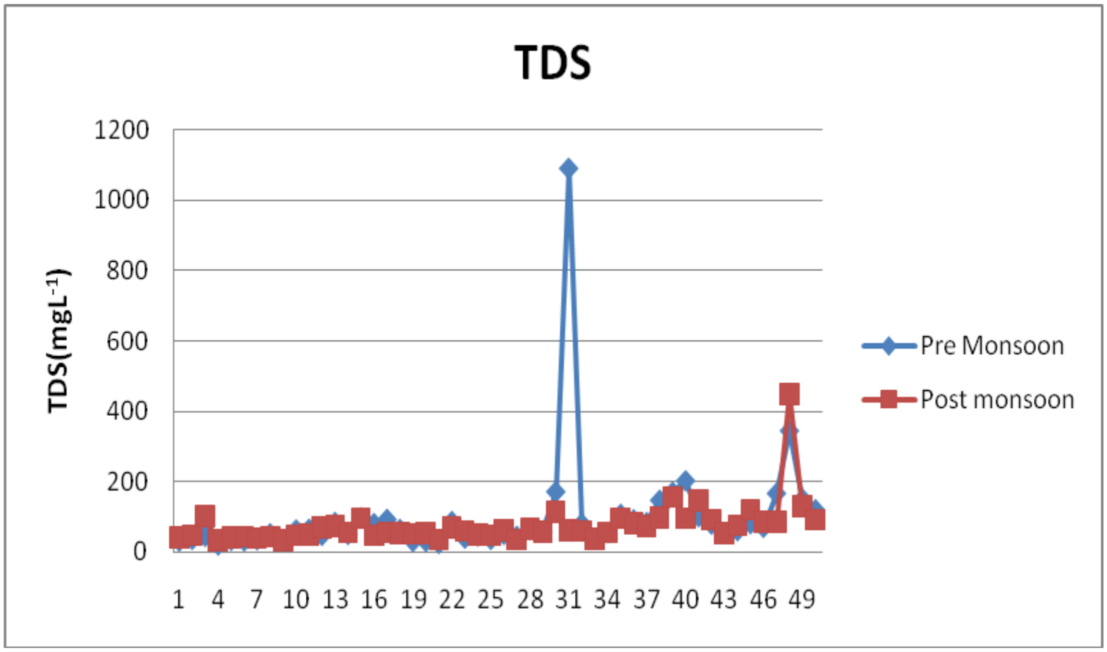


Figure 6.3. Seasonal variation in TDS of well water across sites

Sulphate in well water

The content of sulphate was low upto the 25th well with values less than 4 mgL^{-1} except well number 10 which had slightly more than 12 mgL^{-1} of sulphate present in the premonsoon season (Fig. 6.4). Higher sulphate contents of 2 to 11 mgL^{-1} with wide fluctuations during both pre and post monsoons were observed from 26th well onwards all of which occur in south western region. Sulphate content was more in post monsoon in all the wells except the 10th well which is situated behind KINFRA. All the values were within the permissible levels of 200 mgL^{-1} of water.

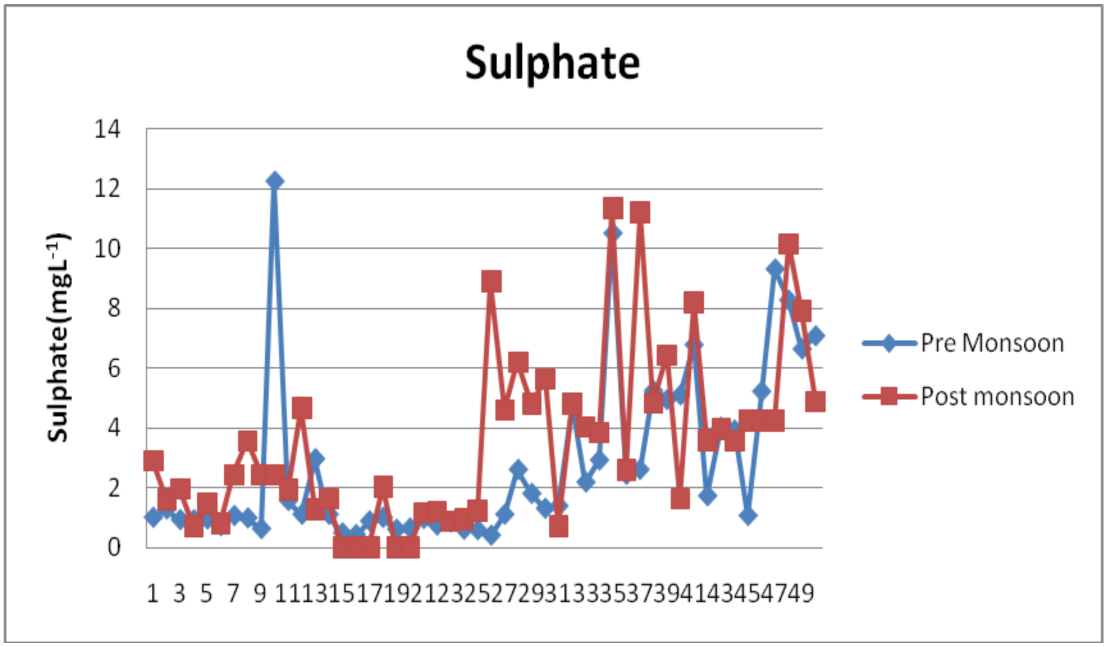


Figure 6.4. Seasonal variation of sulphate in well water across sites

Phosphate in well water

The content of phosphate showed wide variations between wells throughout the region (Fig. 6.5) with values ranging from 0 to 0.13 mgL^{-1}. Most of the wells had values less than 0.06 mgL^{-1} of phosphate. The content of phosphate was higher in post monsoon in general though differences were also observed in a few wells; well number 4 situated in front of KINFRA was exceptional with the highest value during pre monsoon season. The permissible level of phosphate is 0.05 mgL^{-1} of water.

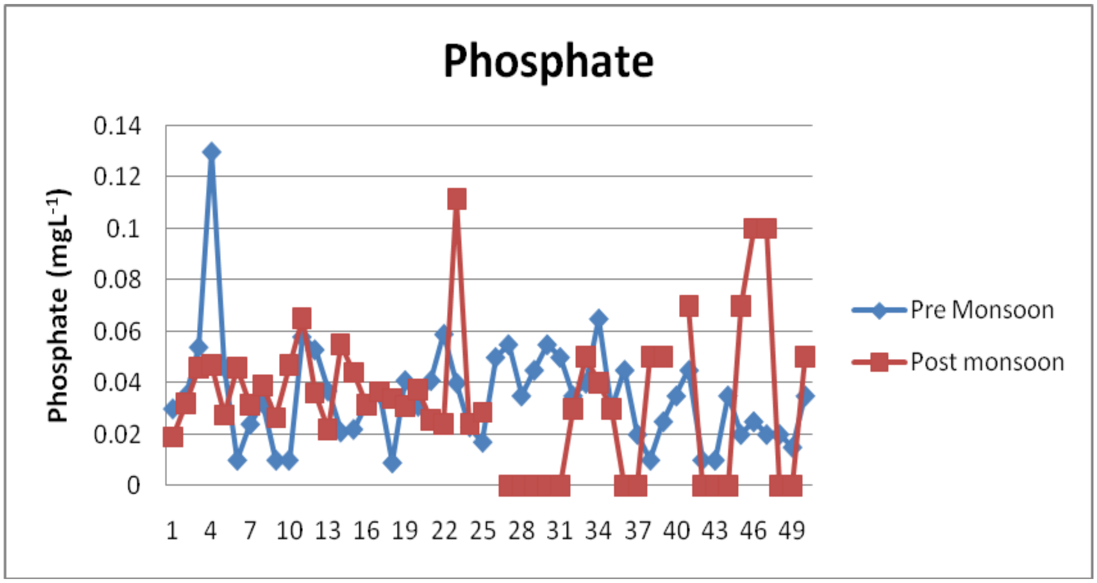


Figure 6.5. Seasonal variation of phosphate in well water across sites

Nitrate in well water

Nitrate content in well water was very low in almost all the wells (Fig. 6.6) with values less than 2 mgL^{-1} irrespective of locational differences. A few wells had higher nitrate levels during pre monsoon with well number 15 exhibiting the highest value of 9 mgL^{-1} in pre monsoon season. The values were all within the permissible level of 20 mgL^{-1} of water.

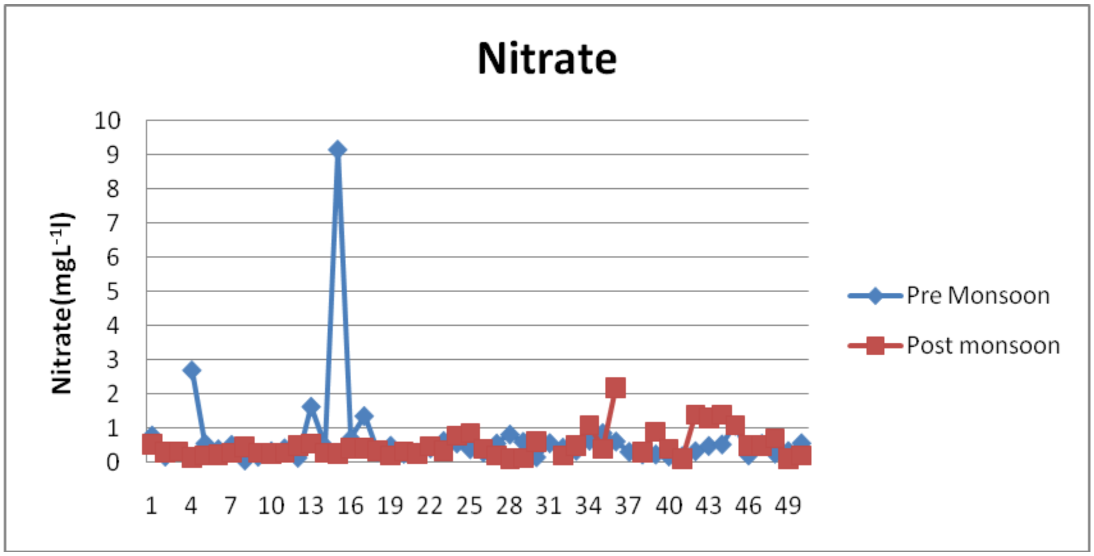


Figure 6.6. Seasonal variation of nitrate in well water across sites

Fluoride in well water

Wide variations in fluoride were noted in all the wells between pre and post monsoons (Fig. 6.7). Concentration of fluoride was less than 0.4 mgL^{-1} and the pre monsoon had higher levels in most of the wells. These were within the permissible limit of 1 mgL^{-1}.

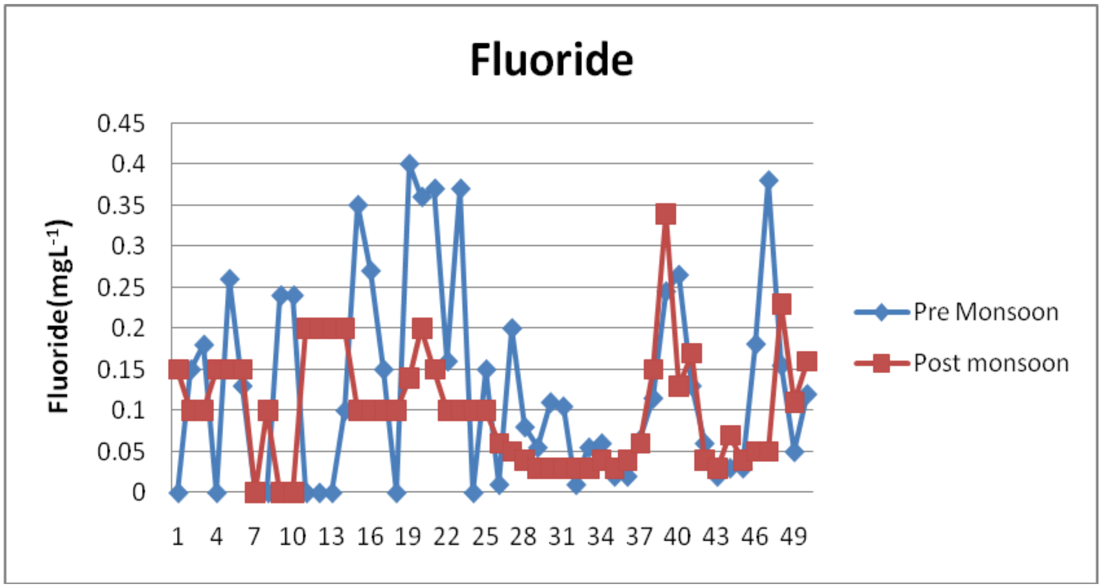


Figure 6.7. Seasonal variation of fluoride in well water across site

Oil and Grease in well water

Oil and grease was present in higher levels in many of the wells (Fig. 6.8). Wells upto the 10th in post monsoon and 22nd in pre monsoon had only negligible quantity of oil and grease but most of the other wells had high contents during post monsoon and slightly lesser amount in pre monsoon season. The highest value of 150 mgL^{-1} was recorded in well number 11 during post monsoon. The permissible level of 10 mgL^{-1} of oil and grease was seen to be exceeded in many wells.

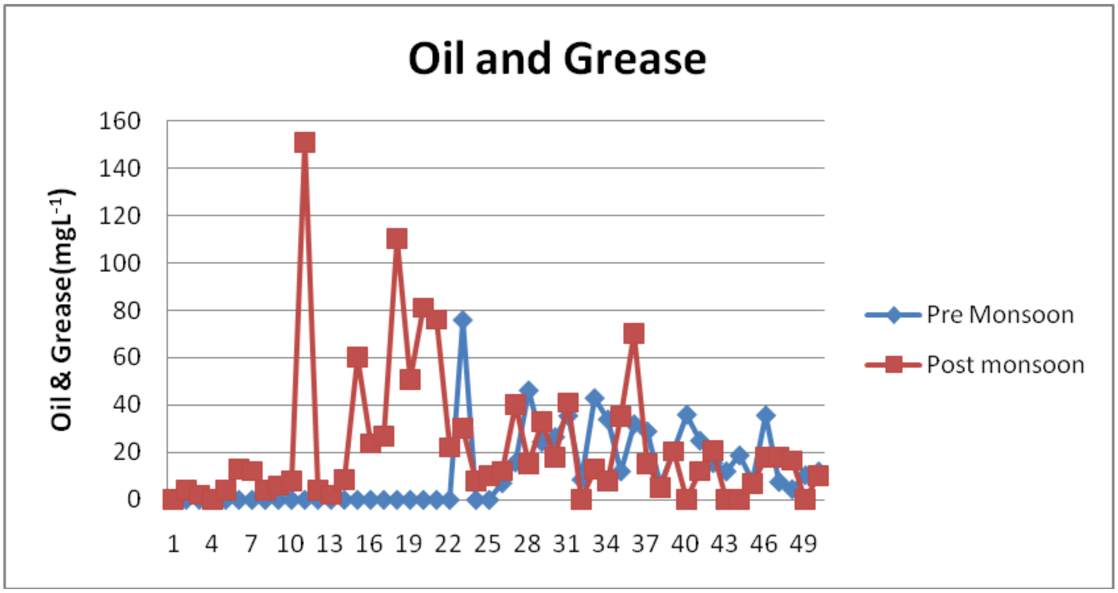


Figure 6.8.Seasonal variation of oil and grease in well water across sites

Phenolic compounds in well water

Phenolic compounds were either absent or negligible in all the wells (Fig. 6.9) except well number 7 near KINFRA and 12 near CUMI recording 12 mgL^{-1} and 16 mgL^{-1} of phenolic compounds respectively during post monsoon season. The permissible level is 0.002 mgL^{-1} of water.

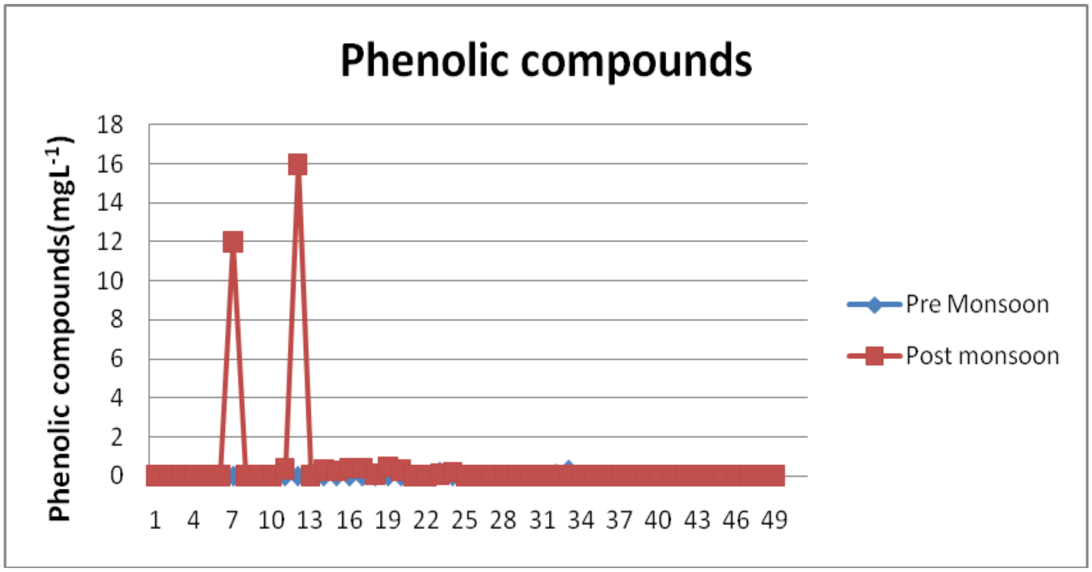


Figure 6.9. Seasonal variation of phenolic compounds in well water across sites

Biochemical properties of well water

Biochemical properties of well water is shown in Table 6.2 given below. Mean values of DO were found to be 5.5 mgL^{-1} in pre monsoon and 5.4 mgL^{-1} in post monsoon. BOD was more in post monsoon with values around 5.2 mgL^{-1} as compared to 3.9 mgL^{-1} in pre monsoon. COD on the other hand was higher in pre monsoon with 12 mgL^{-1} as compared to 6.9 mgL^{-1} in post monsoon. DO was less than what is required and BOD and COD were higher than what is acceptable when all the wells were considered together.

Table 6.2. Biochemical properties of well water in Koratty

Parameters	Values		Permissible limits
	Pre monsoon	Post monsoon	
DO (mgL^{-1})	5.4 ±0.18	5.5 ±0.16	>6
BOD (mgL^{-1})	5.2 ±0.6	3.9±0.3	<2
COD (mgL^{-1})	12 ±2	6.9 ±3.8	<7

Dissolved Oxygen in well water

Dissolved oxygen values in wells were found to lie between 4 and 7 mgL^{-1} in most of the wells (Fig. 6.10). Wells upto the 25th had DO values around 5 to 6 mgL^{-1}, the only exception being well number 3 with the lowest DO value of 3 mgL^{-1} in pre monsoon season. Wider fluctuations of DO were noted from well number 26 onwards falling in south western region. DO values were comparatively lower in pre monsoon though there were exceptions to this also. Dissolved oxygen levels of >6 mgL^{-1} is considered safe for drinking.

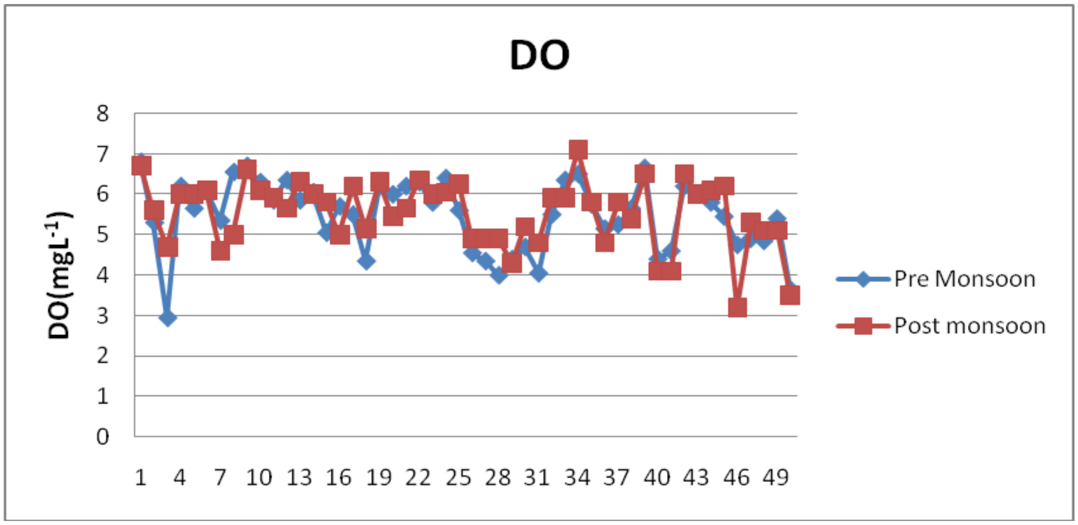


Figure 6.10. Seasonal variation of Dissolved oxygen in well water across sites

Biochemical Oxygen Demand in well water

Biochemical oxygen demand showed wide variations in wells (Fig. 6.11) upto the 25th especially during the pre monsoon season; values ranged from 2 to15 mgL^{-1} during this season. Wells from 26th onwards recorded values within a narrow range of 2 to 6 mgL^{-1} with less variation. BOD was more during premonsoon season as compared to the post monsoon. BOD values greater than 2mgL^{-1} indicate contamination of water. Almost all the wells exceeded BOD limits.

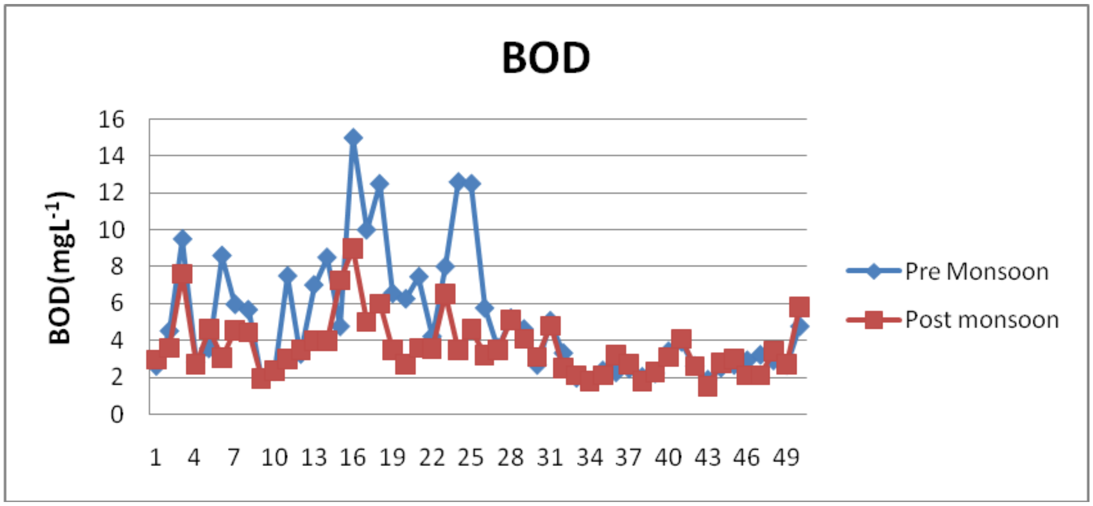


Figure 6.11. Seasonal variation of Biochemical oxygen demand in well water across sites

Chemical oxygen demand in well water

Chemical oxygen demand was found to exhibit wide variations with values ranging from 10 to around 100 mgL^{-1} during the pre monsoon season; variations were more in wells from the 25th onwards (Fig. 6.12). Post monsoon values were less than 20 mgL^{-1} upto the 25th well after which COD values fluctuated between 0 to 40 mgL^{-1}. COD was higher during pre monsoon season except a few wells in Kadukutty area. The permissible limits of COD is 7 mgL^{-1} of water.

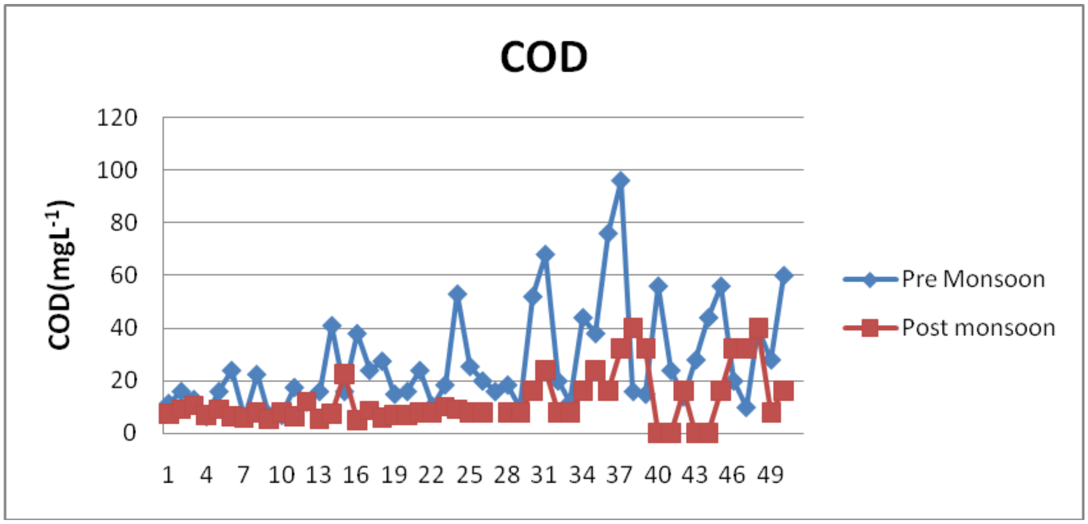


Figure 6.12. Seasonal variation of chemical oxygen demand in well water across sites

Dissolved Oxygen (DO) concentration was 5.5 mgL^{-1} during the premonsoon and 5.4 mgL^{-1} during the post-monsoon season on an average. These values were near desirable levels of good quality potable water. Biochemical Oxygen Demand (BOD) varied from 3.9 mgL^{-1} in the pre-monsoon to 5.2 mgL^{-1} in the post-monsoon season. These values indicate greater demand on dissolved oxygen by biochemical reactions. BOD was more in post monsoon when compared to premonsoon values. It exceeded the permissible limits in both the seasons. Chemical Oxygen Demand (COD) was also found to be greater than permissible limit during pre monsoon season (12 mgL^{-1}) and within limits (6.9 mgL^{-1}) in post-monsoon period on an average indicating remarkable contamination by chemicals during premonsoon season.

Heavy metals in well water

Heavy metal concentrations (mgL^{-1}) in wells in the region are given below in Table 6.3 and described with figures in the succeeding section. Heavy metals, Fe, Mn, Ni, Pb, Cu, Cr and Zn were present during premonsoon season in some of the wells. Fe, Mn and Cu were within permissible limits. The presence of Ni, Pb, Cr and Zn that are not permitted in potable water is of concern. Post monsoon samples were better in quality though Zn was present in a few wells; Fe and Mn were within acceptable limits.

Table 6.3. Heavy metal concentration in well water of Koratty

Parameters	Values		Permissible limits
	Pre monsoon	Post monsoon	
Fe (mgL^{-1})	0.08±0.004	0.01±0.004	0.3
Mn (mgL^{-1})	0.025±0.015	0.1±0.01	0.1
Ni (mgL^{-1})	0.01±0.002	ND	Not permissible
Pb (mgL^{-1})	0.01±0.002	ND	Not permissible
Cu (mgL^{-1})	0.02±0.002	ND	1
Cr (mgL^{-1})	0.01±0.02	ND	Not permissible
Cd (mgL^{-1})	ND	ND	Not permissible
Hg (mgL^{-1})	ND	ND	Not permissible
Zn (mgL^{-1})	0.035±0.0012	0.06±0.04	Not permissible
As (mgL^{-1})	ND	ND	Not permissible

ND=Not Detected

Iron in well water

The content of iron was within the permissible limits of 0.3 mgL^{-1} in both pre and post monsoon as can be seen from the Figure 6.13. Extremely low levels were observed in post monsoon season. Pre monsoon season exhibited slightly higher values though most wells were having only less than 0.05 mgL^{-1}; the greatest value of 0.4 was observed in well number 30 in the south western region.

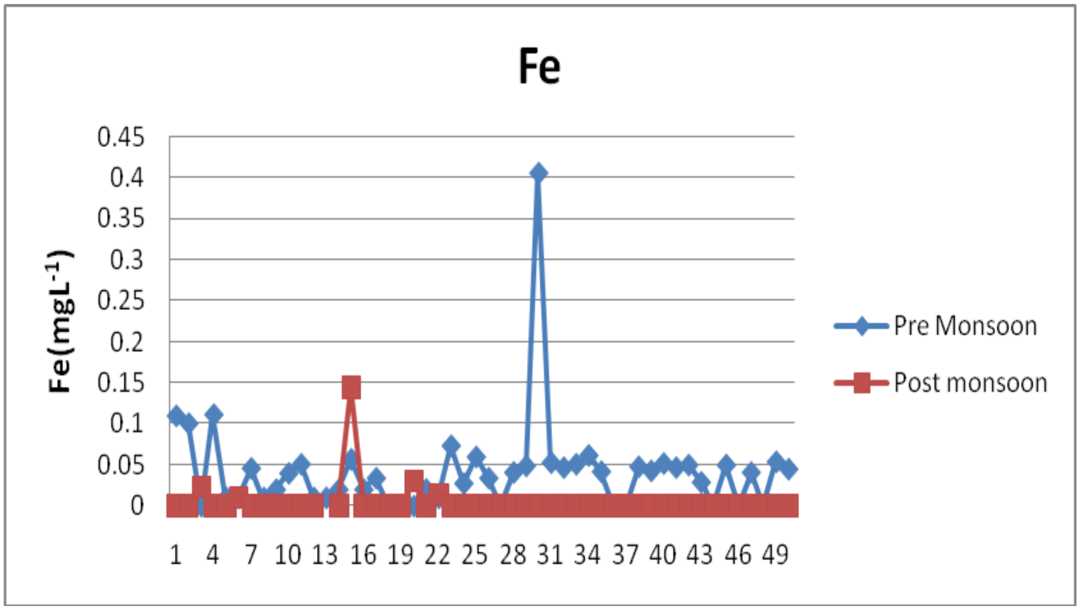


Figure 6.13. Seasonal variation of iron content in well water across sites

Manganese in well water

Manganese concentration in well water was negligible (Fig.6.14) during post monsoon in almost all the wells with one or two exceptions. Higher levels were observed to be present in pre monsoon especially after the 20th well with the highest value of 0.6 mgL^{-1} recorded in well number 38 situated in the south western region. The permissible level is 0.1 mgL^{-1} of water.

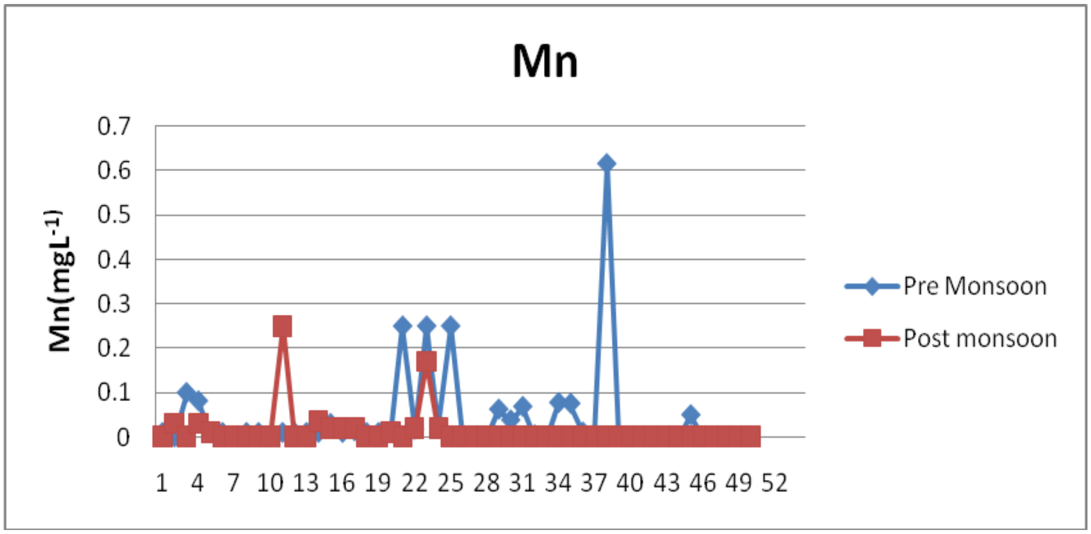


Figure 6.14. Seasonal variation of manganese in well water across sites

Zinc in well water

The content of zinc in well water (Fig.6.15) was also similar to the previous elements in post monsoon with negligible contents except well number 3 which had around 0.32 mgL^{-1} of zinc. Pre monsoon season exhibited variations with values going upto 0.17 mgL^{-1}. The presence of zinc is not permitted in potable water.

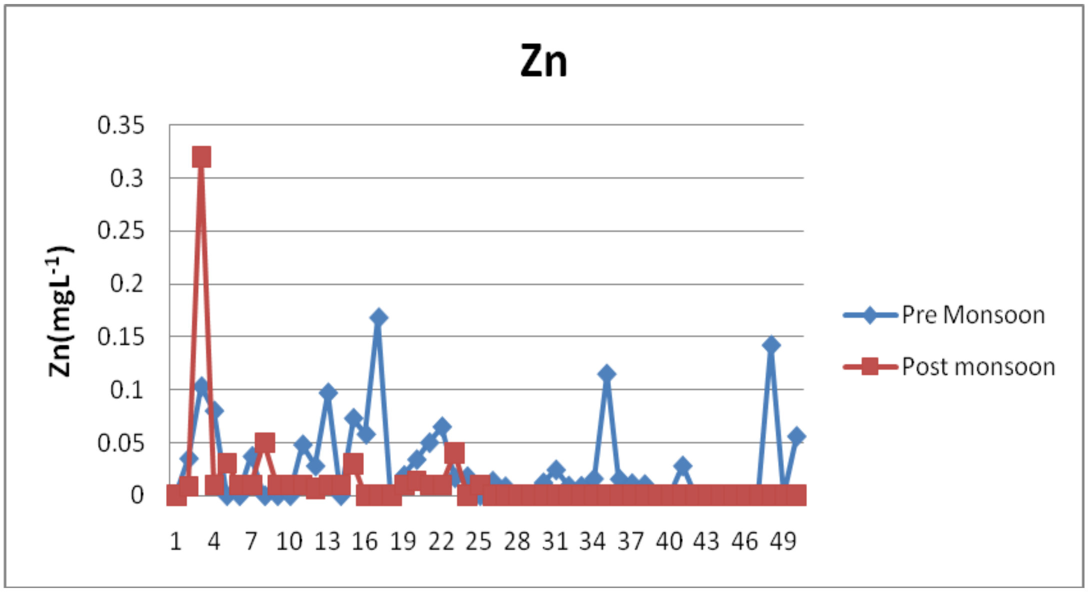


Figure 6.15. Seasonal variation of zinc in well water across sites

The concentration of iron, manganese and copper were found to be low during both the pre-monsoon and post monsoon periods. Their values were within the permissible limits. Heavy metal such as nickel, chromium and lead were present in a few wells only and that too in pre monsoon season. Zinc was present in both pre monsoon and post monsoon seasons. These heavy metals are highly toxic to humans and hence are not at all permissible in drinking water. Cadmium, mercury and arsenic were absent in the water samples.

Coliforms in well water of Koratty

Coliforms were present in most of the wells of Koratty region (Table 6.4), presence of which is not permitted. Total coliforms on an average was 1646 cfu 100 ml^{-1} in premonsoon and 941.5 cfu 100 ml^{-1} in post monsoon. E.coli was also present at levels of 59 cfu 100 ml^{-1} and 62.5 cfu 100 ml^{-1} during pre and post monsoons. Feacal coliforms were more in the pre monsoon season with around 250 cfu 100 ml^{-1} and during post monsoon its level was 62.5 cfu 100 ml^{-1}. Dilution through recharge during monsoons is expected to reduce the concentration of coliforms as is obtained in the study. But the presence of such levels even in the post monsoon is to be considered seriously.

Table 6.4. Coliforms in well water

Parameters	Values		Permissible limits
	Pre monsoon	Post monsoon	
TotalColiforms (cfu 100ml^{-1})	1646 ±354	941.5 ±242	Not Permissible
E-Coli (cfu 100ml^{-1})	59 ±27	62.5 ±31	Not Permissible
Fecal Coliforms (cfu 100ml^{-1})	250 ±130	62.5 ±60	Not Permissible

Out of 50 wells sampled bimonthly for two years it was seen that E-coli was present in seven wells in the central region while Fecal coliform was present in 14 wells all of which were situated in the western most low lying region. All other wells were safe in this respect.

Variations of Total coliforms in well water

Total coliforms exhibited remarkable variations between wells in both pre and post monsoon (Fig.6.16). Higher coliform content was present during post monsoon. Values were mostly less than 2000 cfu 100 ml^{-1} in most of the wells, though higher values of upto 12000 were noted in a few wells. Well number 17 had around 10000 cfu 100ml^{-1} in pre monsoon while well number 19 recorded the highest value of 12000 cfu 100ml^{-1} in post monsoon.

Most of the samples were found to be bacteriologically contaminated. Total coliforms, E.coli and Fecal coliforms were present in remarkably high numbers, which is not at all permitted in the drinking water.

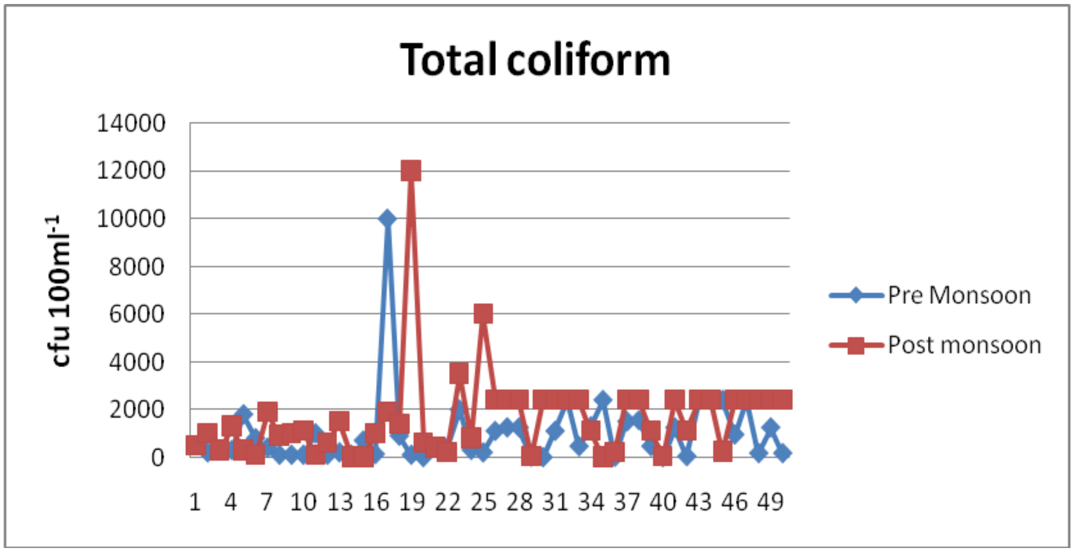


Figure 6.16. Seasonal variation of total coliforms in well water across sites

Pesticide Residues in well water of Koratty

Results of pesticide residue analysis given in Table 6.5 showed the presence of organochlorine pesticides in some of the samples; most of the wells were free of pesticides and its residues. Aldrin, Dieldrin and DDD were detected in few of the water samples. These are highly toxic substances which are not permissible in potable water.

Table 6.5. Pesticide Residues in well water

Parameters	Values		Permissible limits
	Pre monsoon	Post monsoon	
Aldrin (μg/l)	0.002	0.001	Not Permissible
Dieldrin (μg/l)	0.001	0.001	Not Permissible
DDD (μg/l)	0.001	0.001	Not Permissible

6.3.1.2 Pond water Quality in Koratty Region

Water quality of 18 ponds in Koratty region sampled during both pre and post monsoon seasons is provided below in Table 6.6

Water in ponds were acidic with pH of 5.9 on an average during both pre and post monsoons. Electrical conductivity (EC), an index of ionic concentration, was low in ponds. In pond water EC value on an average was found to be 87 dS/m during pre monsoon season and 82.6 dS/m during post monsoon season. Slight increase was noted during pre monsoon as compared to the post monsoon in ponds.

Total Dissolved Solids (TDS) was found to be within the WHO limits (500 mgL^{-1}) in ponds. In pond water the TDS during the pre-monsoon was 59 mgL^{-1} and it was only 56.6 mgL^{-1} during post-monsoon. Slightly higher values were observed during pre monsoon season.

Sulphate concentrations were very low in the ponds of Koratty region. The permissible limits were 400 mgL^{-1} in non potable water. In pond water sulphate value on an average was found to be 0.5 mgL^{-1}during pre monsoon season and 0.4 mgL^{-1} during post monsoon seasons.

Phosphate concentration on an average was found to be within permissible limits of 0.05 mgL^{-1} in both seasons.

Table 6.6. Physico-chemical properties of water in ponds

Parameters	**Pond**		Permissible Limits
	Pre monsoon	Post monsoon	
pH	5.9 ±0.1	5.9 ±0.1	6.5 – 8.5
EC (dS/m)	87 ±10	82.6 ±7.3	2000
TDS (mgL^{-1})	59 ±6	56.6 ±5.3	500
Sulphate (mgL^{-1})	0.5 ±0.3	0.4 ±0.2	400
Phosphate (mgL^{-1})	0.03 ±0.01	0.05 ±0.02	0.05
Nitrate (mgL^{-1})	0.04 ±0.01	0.3 ±0.2	10
Fluoride (mgL^{-1})	0.11 ±0.01	0.2 ±0.08	1.5
Oilandgrease (mgL^{-1})	98.2 ±49	103.9±31	10
Phenolic compounds (mgL^{-1})	0.1±0.01	0.2±0.02	0.002

The concentration of nitrate and fluoride in ponds was found to be low in both pre-monsoon and the post-monsoon period. It indicates that there is no contamination from these anions. Nitrate was found to be within the permissible limits of 10 mgL^{-1} in all the ponds during both seasons. In the pre-monsoon season nitrate concentration was only 0.04 mgL^{-1} while the concentration during the post monsoon was hardly 0.03 mg per litre.

Fluoride was also found to be within the permissible limits (1.5 mgL^{-1}) in all the ponds irrespective of seasons. The values were 0.11 mgL^{-1} in pre monsoon and 0.2 mgL^{-1} in post monsoon season.

Oil and grease were present in higher than permissible limits in ponds. The average concentration was 98.2 mgL^{-1} in pre monsoon and 103.9 mgL^{-1} in post monsoon. WHO permissible limit is only 10 mg per litre of water. The values show that there is severe oil and grease contamination in pond water. Greater values were recorded during the post monsoon season in ponds.

Phenolic compounds were also found to contaminate ponds in the region. Average concentration of phenolic compounds was found to be 0.1 mgL^{-1} and 0.2 mgL^{-1} respectively during the pre and post monsoons. The permissible limits of phenolic compounds in non potable water is only 0.002 mgL^{-1}. The results show that phenolic compound contamination is high in ponds.

pH of pond water

Ponds in Koratty region were all acidic with pH values less than 6.5 which was below the permissible range of 6.5 to 8.5; few ponds had slightly higher pH values (Fig. 6.17). Pond numbers 7 to 11 are located in the eastern part of Koratty with hilly terrain while all the others are located towards the south western part in low lying areas. The trends in these areas are similar with no distinct pattern between pre and post monsoons. The pond number 7 is the only one with neutral pH of 7 reasons being that it is treated with lime and other chemicals for the purpose of drinking water supply.

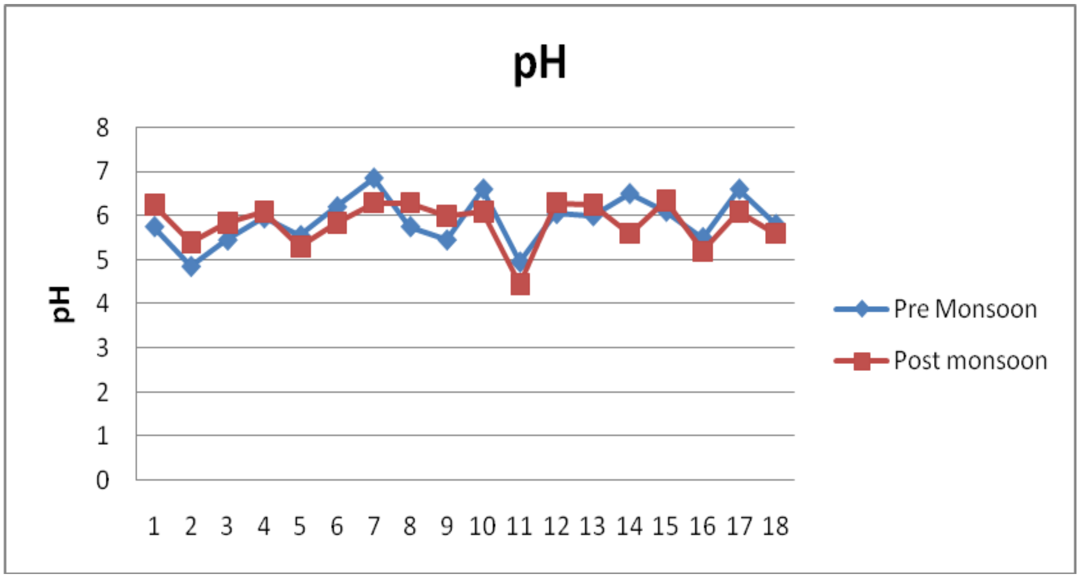


Figure 6.17. Seasonal variation in pH of pond water across sites

EC of Pond Water

Electrical conductivity of water in all the ponds were found to be within permissible limits. Wider fluctuations were seen in the low lying western half of the study area as can be seen from the figure 6.18 given below.

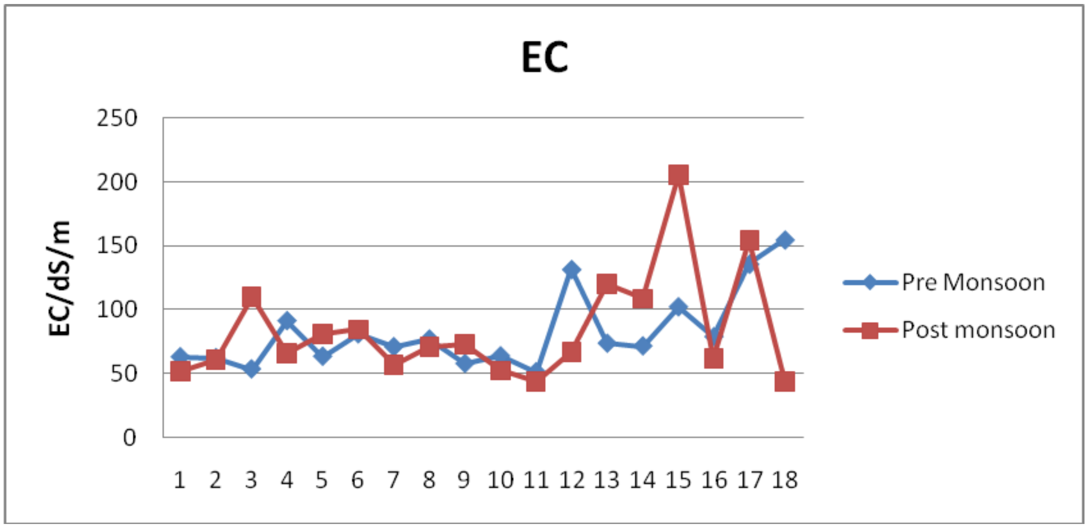


Figure 6.18. Seasonal variation in EC of pond water across sites

TDS in pond water

Total dissolved solids (Fig. 6.19) were also within the permissible level of 500 mgL^{-1} in all the ponds. Wider variations during both seasons occurred in ponds situated in the lower reaches of the study area.

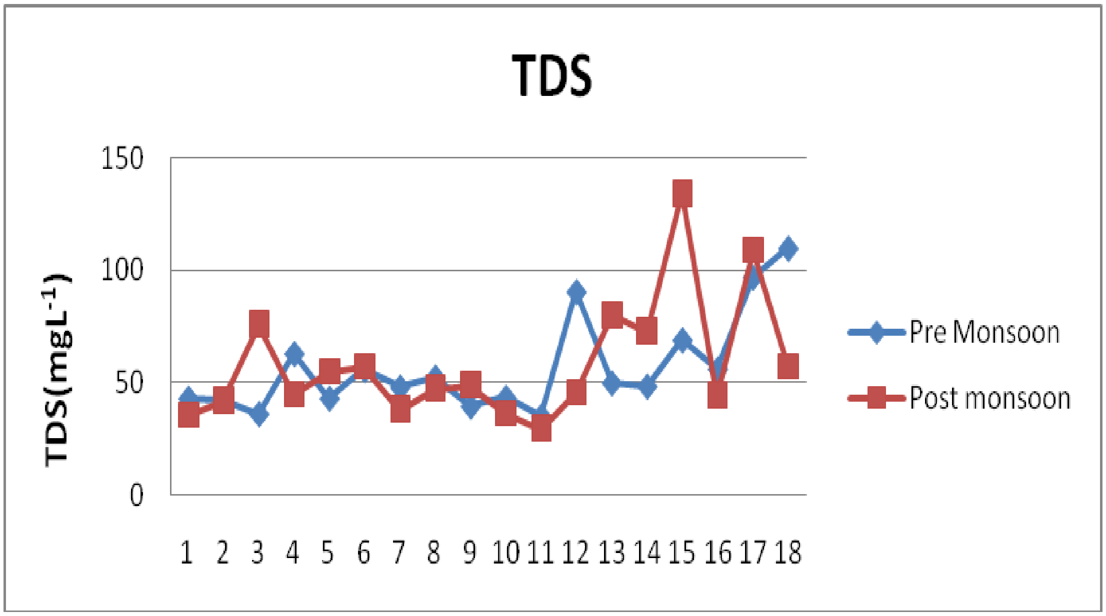


Figure 6.19. Seasonal variation of TDS in pond water across sites

Phosphate in pond water

Phosphate content in ponds were found to be within the permissible limit of 0.05 mgL^{-1} during both monsoon seasons (Fig.6.20). It was very high with 0.37 mgL^{-1} in pond number 2 during pre monsoon. This particular pond is being used for washing clothes and bathing both of which release phosphate from the soaps and detergents, the impact of which was only pronounced during the pre monsoon season when both recharge and overflow were meagre.

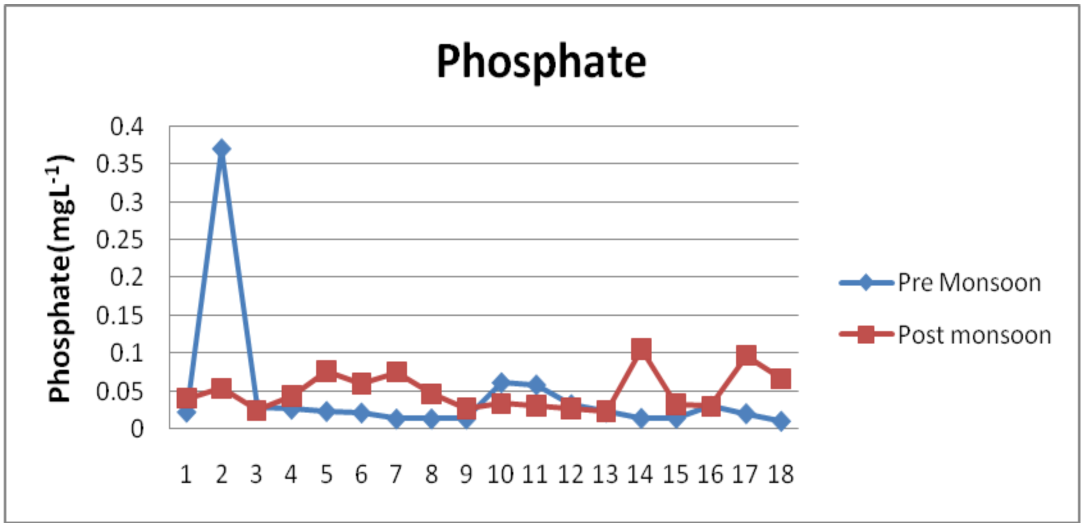


Figure 6.20. Seasonal variation of phosphate in pond water across sites

Nitrate in pond water

Nitrate ions were very less in all the ponds; comparatively higher values were recorded in pre monsoon samples (Fig. 6.21). Variation between ponds is less, the only exceptional value of 3.2 mgL^{-1} obtained in pre monsoon in pond number 18 which was situated on the lowest valley on the western side with chances of accumulation from all around.

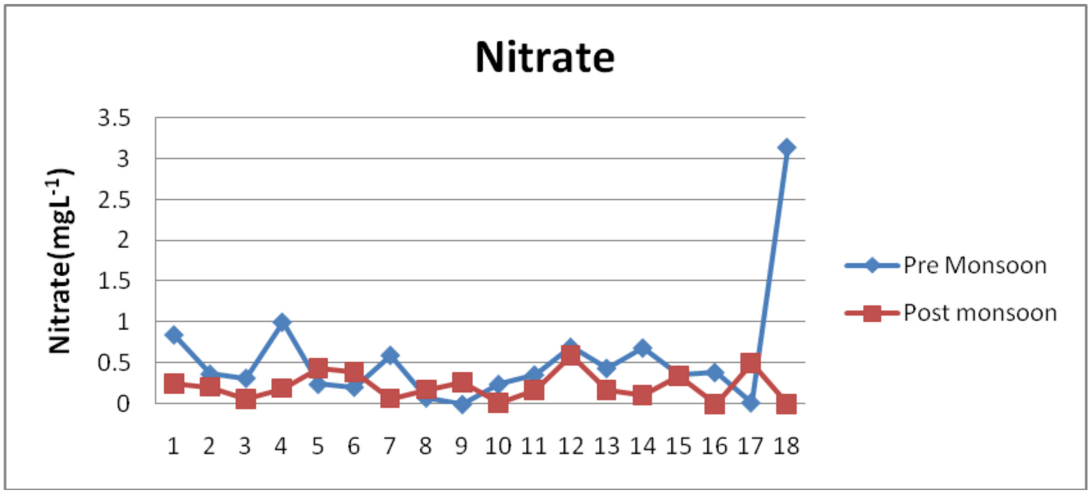


Figure 6.21. Seasonal variation of nitrate in pond water across sites

Fluoride in pond water

Water in ponds were within acceptable limits (1.5 mgL^{-1}) of fluoride content as can be seen from the figure 6.22 given below. Most of the ponds had less than 0.2 mgL^{-1} of fluoride only. Higher values were noted during pre monsoon as compared to post monsoon season.

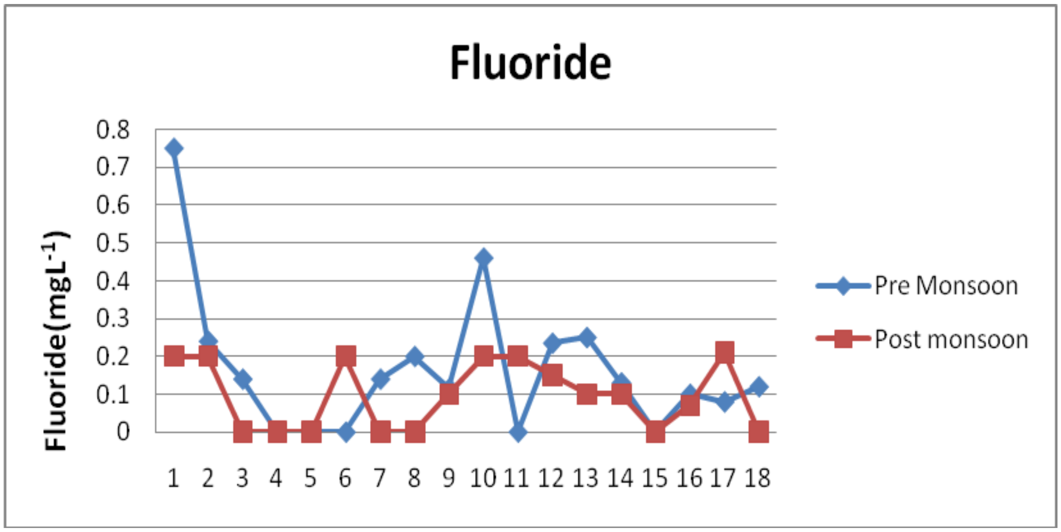


Figure 6.22. Seasonal variation of fluoride in pond water across sites

Oil and Grease in pond water

Oil and grease were found to be present beyond acceptable levels in most of the ponds in Koratty with remarkable variations between ponds (Fig.6.23). The permissible maximum is only 10 mgL^{-1}. No definite trend could be observed between pre and post monsoons. Extremely high values were obtained in the 8th pond during post monsoon and 11th pond during pre monsoon both of which are situated in the upper eastern region.

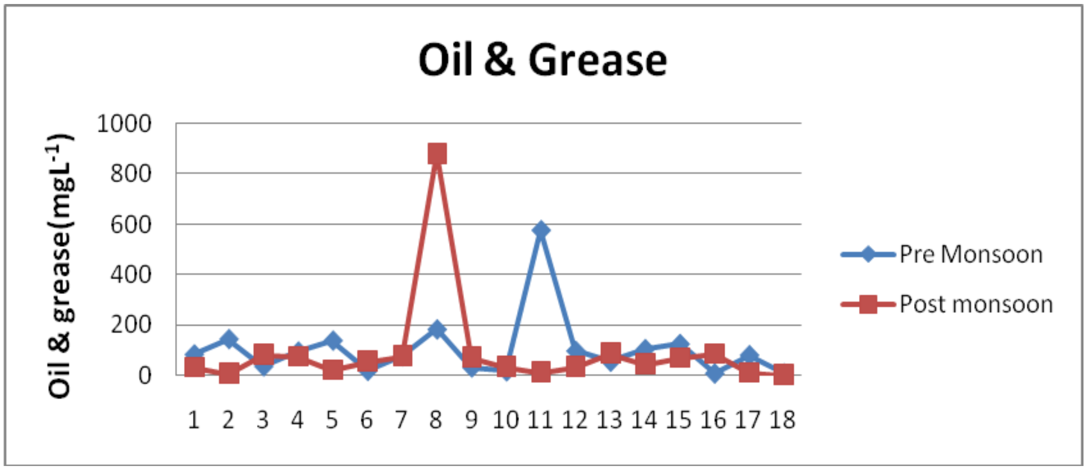


Figure 6.23. Seasonal variation of oil and grease in pond water across sites

Phenolic compounds in pond water

Almost all the ponds in Koratty region had extremely high levels of phenolic compounds exceeding the permissible limit of 0.002 mgL^{-1} (Fig. 6.24). Phenolic compounds were more during post monsoon season as compared to the pre monsoon the only exception being 3rd and 4th ponds with highest value of 0.55 and 0.45 mgL^{-1} respectively. Negligible values were obtained in ponds 16, 17 and 18 which were situated on the lowest western part.

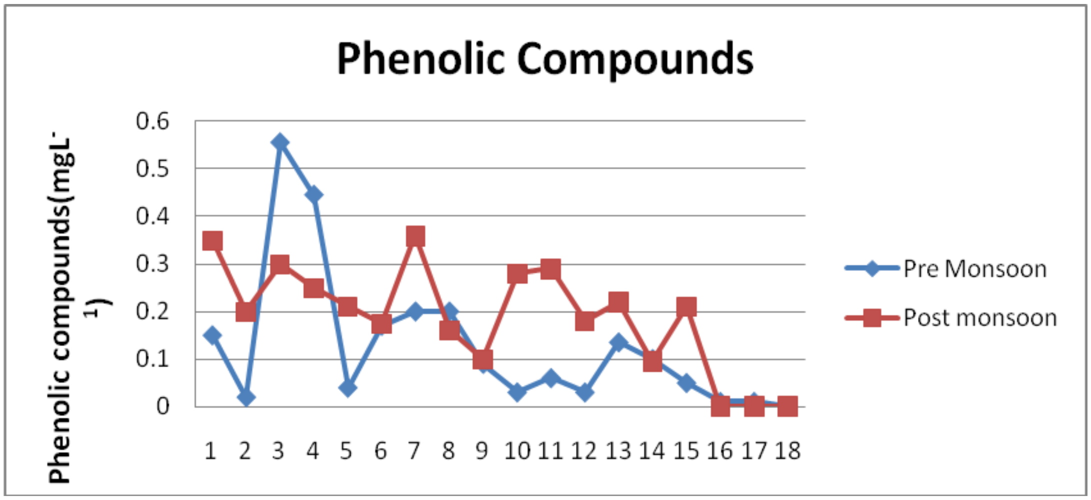


Figure 6.24. Seasonal variation of phenolic compounds in pond water across sites

Biochemical properties of ponds in Koratty

Ponds in Koratty in general were found to have poor water quality with respect to biochemical properties (Table 6.7). Dissolved oxygen levels were below the desirable limits in both pre and post monsoon periods, post monsoon having slightly better values than the premonsoon. Biochemical oxygen demand and chemical oxygen demand were both found to exceed the permissible limits in both the seasons. Post monsoon levels were slightly better than premonsoon levels as was the case with dissolved oxygen.

Table 6.7. Biochemical properties of ponds in Koratty

Parameters	**Pond**		Permissible Limits
	Pre monsoon	Post monsoon	
DO (mgL^{-1})	5.4±0.5	5.5±0.5	>6
BOD (mgL^{-1})	8.2±1	5.9±1	<3
COD (mgL^{-1})	23.5±2	11.6±3.6	<7

Dissolved oxygen in pond water

Dissolved oxygen levels in ponds were seen to be less than desirable levels of 6 mgL^{-1} in most of the ponds (Fig. 6.25). Slightly higher values were obtained during post monsoon season. Lower levels of DO with values less than 5 were obtained in ponds 1,2, 11, 17 and 18 all of which are located in wet land areas.

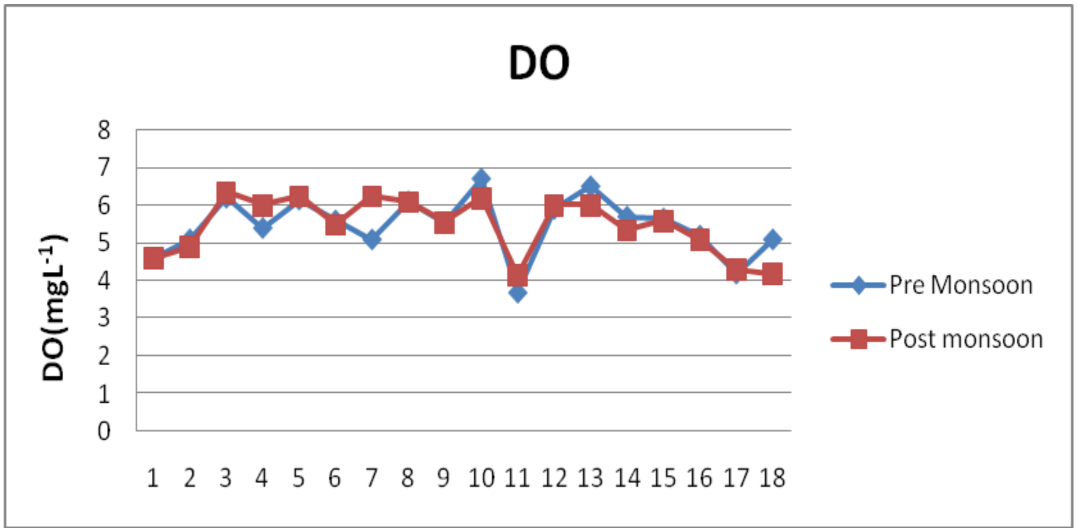


Figure 6.25. Seasonal variation of dissolved oxygen in pond water across sites

Biochemical oxygen demand in pond water

Biochemical oxygen demand of ponds in Koratty showed different trends with some of them having higher values in pre monsoon and some others in post monsoon season (Fig. 6.26). All the ponds had higher than permissible (<3 mgL^{-1}) levels of BOD except 16, 17 and 18 located in the low lying western part.

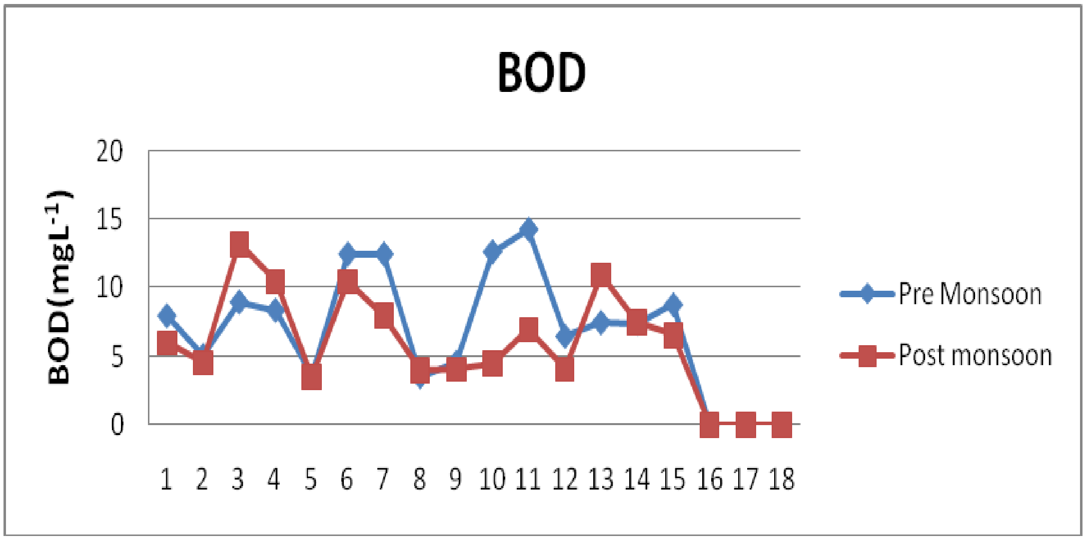


Figure 6.26. Seasonal variation of biochemical oxygen demand in pond water across sites

Chemical oxygen demand in pond water

All the ponds except 16 and 18 had higher COD levels than the permissible range of <7 mgL^{-1} and pre monsoon values were almost always higher than post monsoon (Fig. 6.27). Extremely high values of more than 20 mgL^{-1} was obtained in 13 out of the 18 ponds in pre monsoon.

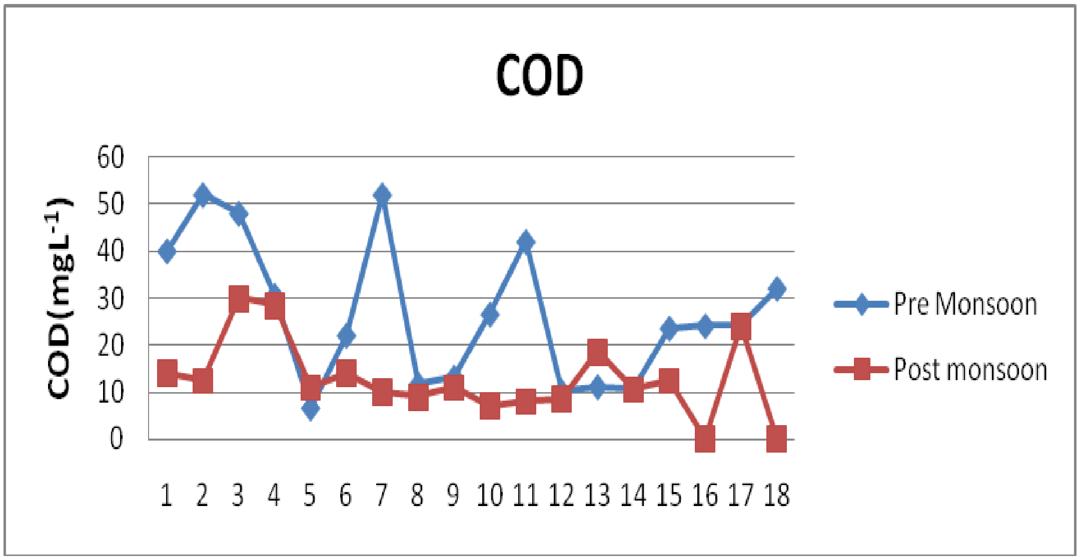


Figure 6.27. Seasonal variation of chemical oxygen demand in pond water across sites

Heavy Metals in Pond water

Among the heavy metals included in the study, iron, manganese, copper and zinc were present in pond water at levels that were within permissible limits in both pre and post monsoon seasons (Table 6.8). Nickel and lead were present in quantities exceeding permissible limits during post monsoon season. The content of nickel was 0.011 mgL^{-1} in premonsoon which was with in limits but values were higher (0.074 mgL^{-1}) in post monsoon, the permissible level being 0.02 mgL^{-1}. Lead whose presence is not permitted was seen to occur at 0.011 mgL^{-1} in pond water.

Table 6.8. Heavy metals in pond water

Parameters	**Pond**		Permissible Limits
	Pre monsoon	Post monsoon	
Fe (mgL^{-1})	0.13±0.0	0.13±0.0	1.0
Mn (mgL^{-1})	0.07±0.0	0.06 ±0.0	0.5
Ni (mgL^{-1})	0.011±0.0	0.074±0.0	0.02
Pb (mgL^{-1})	ND	0.011±0.0	Nil
Cu (mgL^{-1})	ND	0.01±0.0	3.0
Cr (mgL^{-1})	ND	ND	0.01
Cd (mgL^{-1})	ND	ND	0.005
Hg (mgL^{-1})	ND	ND	0.0001
Zn (mgL^{-1})	0.01±0.0	0.005±0.0	1.0
As (mgL^{-1})	ND	ND	0.05

ND: Not Detected

Heavy metals, iron, manganese, nickel and zinc were present in small amounts in the ponds during pre monsoon season. In the post monsoon, iron, manganese, nickel, lead, copper and zinc were detected of which the presence of lead is not permitted. It seems that monsoon rains wash down these elements into the ponds from the surrounding though the levels are of no significance.

Manganese in pond water

Manganese was very low in all the ponds and with negligible quantity in most of the sites (Fig. 6.28). Comparatively higher values were obtained in pond numbers 3 and 7 only during pre and post monsoon respectively.

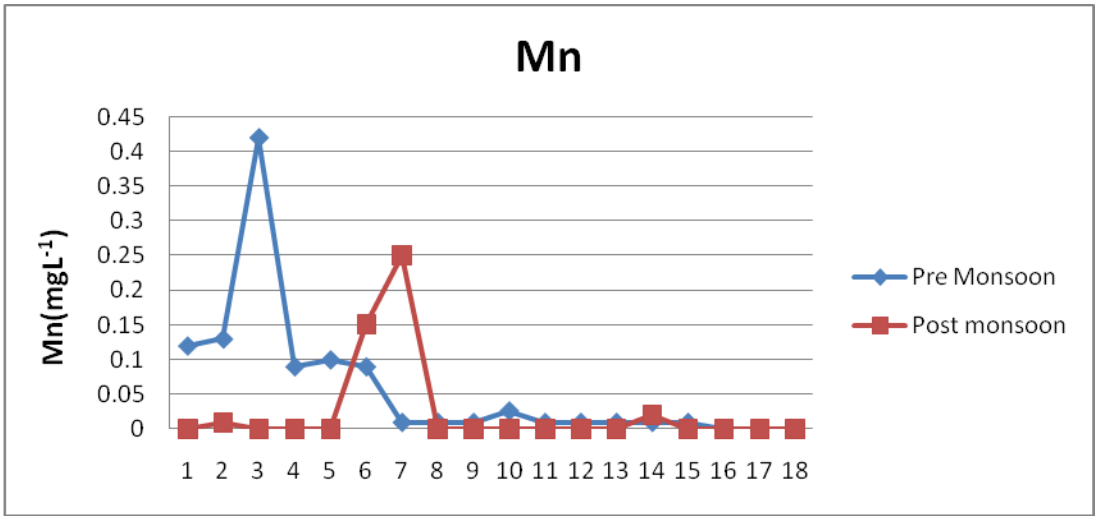


Figure 6.28. Seasonal variation of manganese in pond water across sites

Iron in pond water

Presence of iron in ponds was detected mainly in the pre monsoon season only (Fig. 6.29). It was present in acceptable levels only with remarkable variation between sites. Post monsoon samples were free of iron except pond 4, 11 and 15.

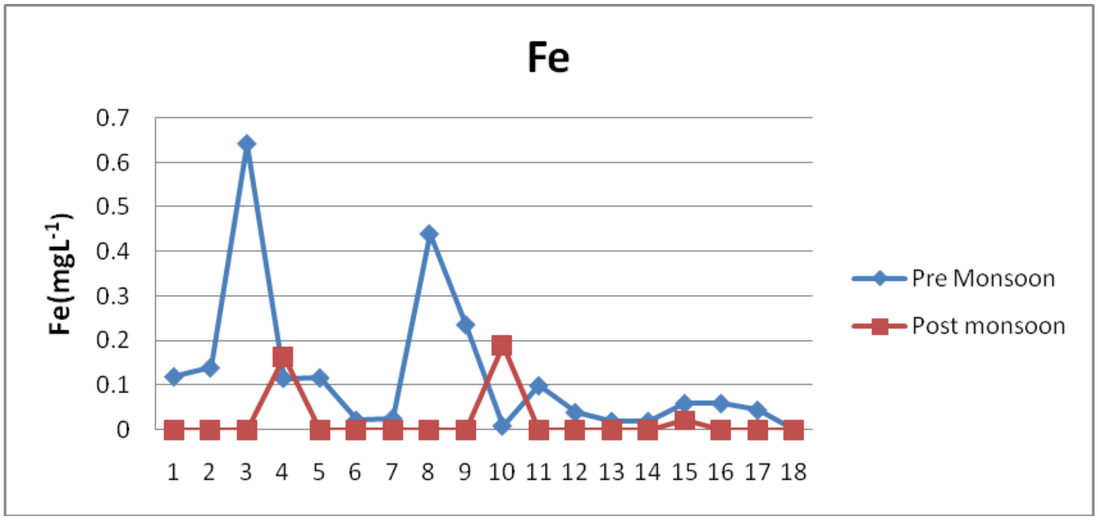


Figure 6.29. Seasonal variation of iron content in pond water across sites

Nickel in pond water

Most of the ponds had less than 0.02 mgL^{-1} of nickel which is the acceptable limit (Fig. 6.30). Pond numbers 3 and 4 along with 7 had slightly higher nickel content in the post monsoon season.

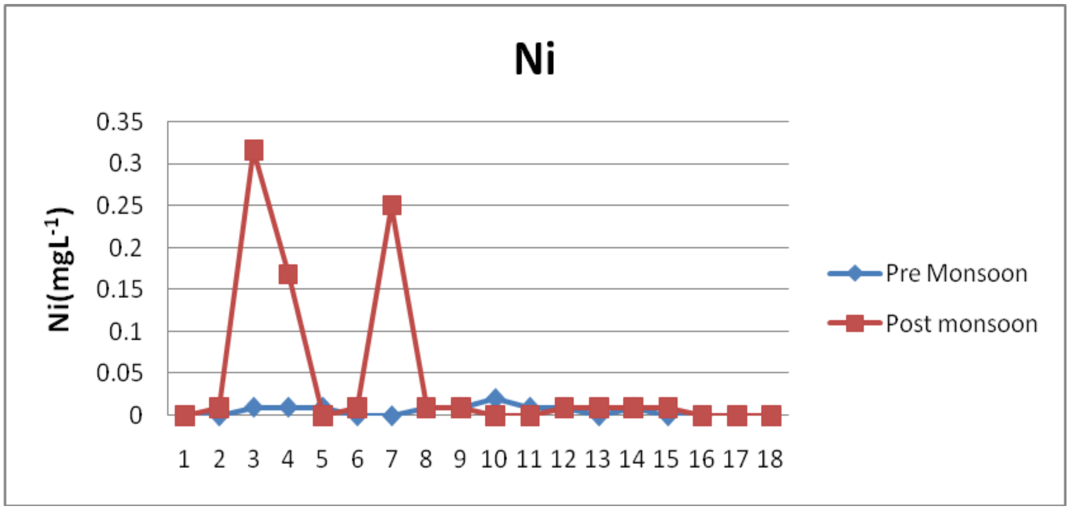


Figure 6.30. Seasonal variation of nickel in pond water across sites

Lead in pond water

Lead was present in the ponds during post monsoon though in negligible quantities (Fig. 6.31). Its presence is of concern because of its toxicity. Most of the ponds had only 0.01 mgL^{-1} of lead while ponds 8,9,10 and 13 had 0.02 mgL^{-1} of lead.

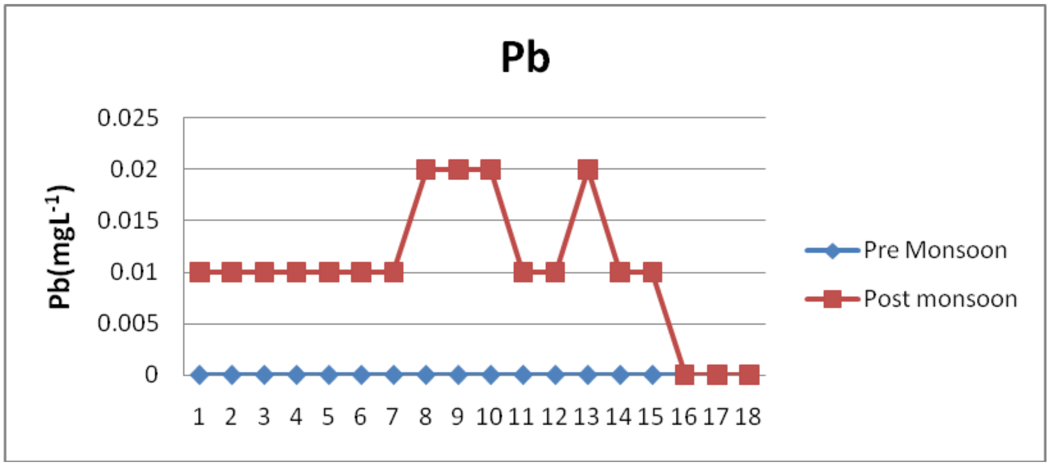


Figure 6.31. Seasonal variation of lead in pond water across sites

Copper in pond water

Copper content in water of ponds was observed to be in very low quantities much below the permissible levels of 3 mgL^{-1} (Fig. 6.32). Most of the ponds had only 0.01 mgL^{-1} of copper and that too in the post monsoon season.

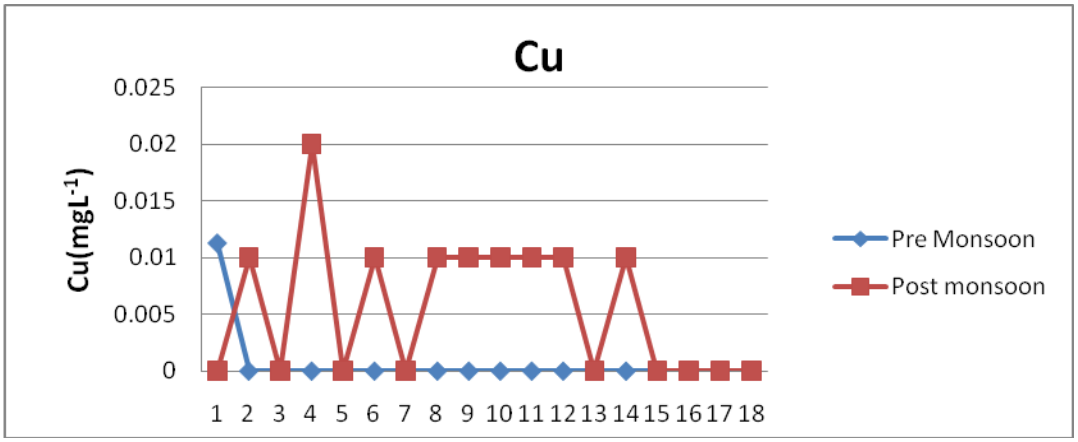


Figure 6.32. Seasonal variation of copper in pond water across sites

Zinc in pond water

Zinc also was present in very low quantities in pond water (Fig. 6.33). Values were higher in pre monsoon as compared to the post monsoon. The highest value was 0.07 mgL^{-1} in the 1 pond 16 situated in the western part.

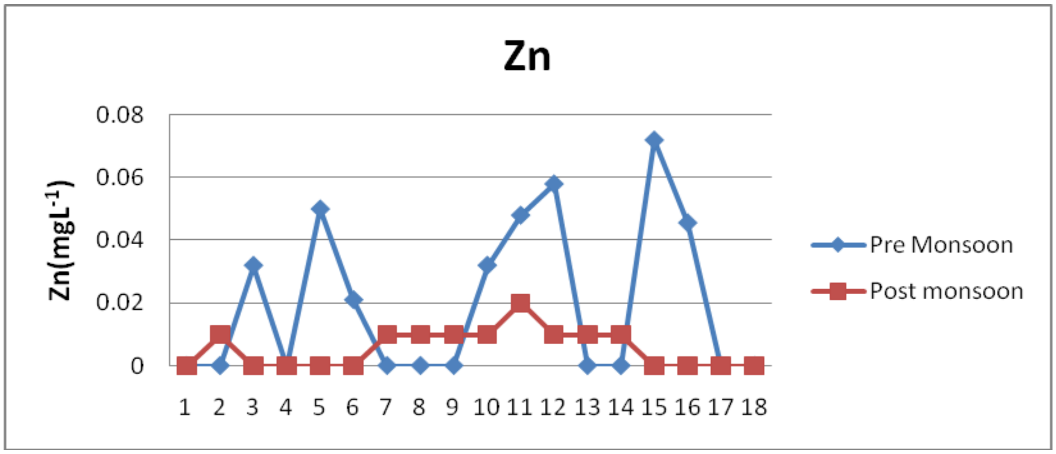


Figure 6.33. Seasonal variation of zinc in pond water across sites

Coliforms in pond water

Pond water was found to be contaminated with coliforms in quantities higher than permissible levels in at least one of the seasons (Table 6.9). Total coliforms were very high (>2000 cfu 100 ml^{-1}) in number in both pre and post monsoons though values were higher in post monsoon. E-coli was present in levels higher than acceptable limits only during post monsoon. Feacal coliforms were on the other hand higher in pre monsoon season.

Table 6.9. Coliforms in pond water

Parameters	**Pond**		Permissible Limits
	Pre monsoon	Post monsoon	
Total Coliforms (cfu 100ml^{-1})	3577±1450	2021±616	Less than 50
E-Coli (cfu 100ml^{-1})	122±44	29±16	Less than 50
Fecal Coliforms (cfu 100ml^{-1})	91 ±68.6	4.2 ±4.3	Less than 50

Total coliforms in Pond water

Variations in total coliforms between ponds as given in figure 6.34 below indicates that there is remarkable variation upto the 11th pond. Ponds from 12 to 18 did not differ much and also during the two seasons. Total coliforms were comparatively more in pre monsoon.

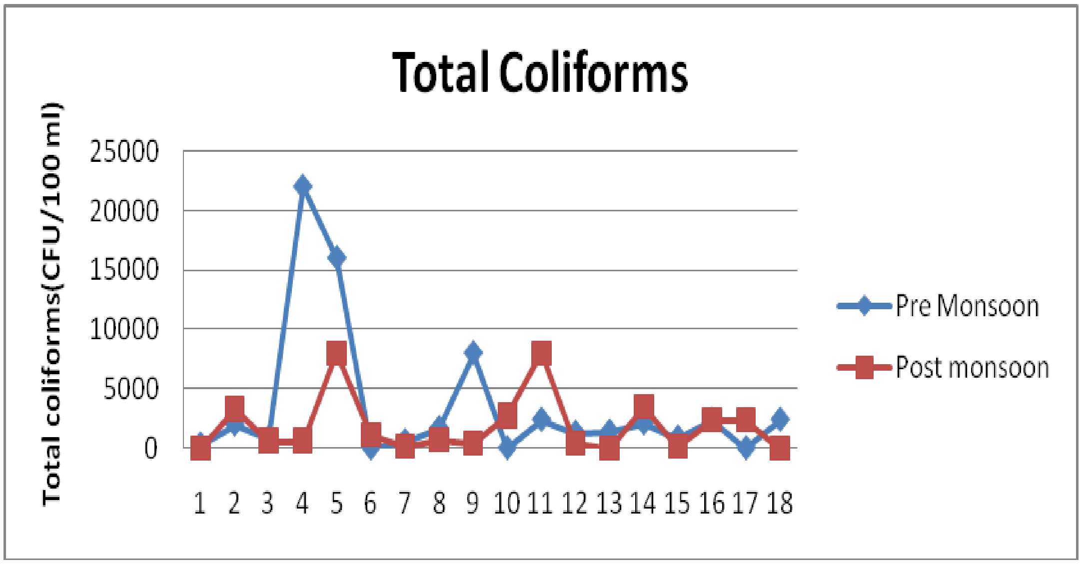


Figure 6.34. Seasonal variation of total coliforms in pond water across sites

E-Coli in pond water

E-coli was present in a few sites only and they were found to be in high quantities during pre monsoon except ponds 3 and 4 which had higher number of E-coli in post monsoon season alsoFigure 6.35.

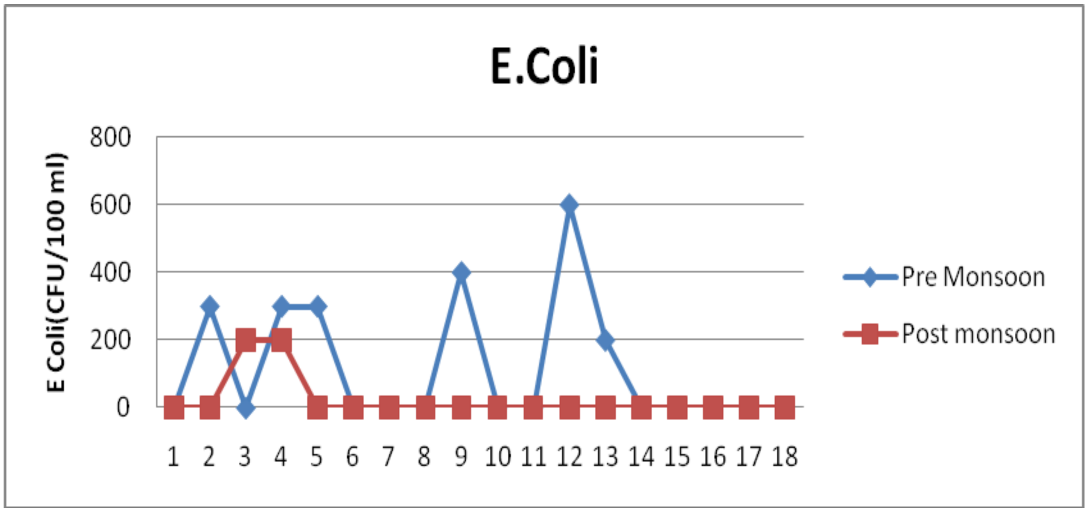


Figure 6.35. Seasonal variation of E-coli in pond water across sites

6.3.1.3 Quality of water in water courses of Koratty Region

Water quality of 14 water courses in Koratty region sampled during both pre and post monsoon seasons of 2011 and 2012 is provided below in table 6.10.

Table 6.10. Physico chemical properties of water courses

Parameters	Water courses		Permissible Limits
	Pre monsoon	Post monsoon	
pH	5.6 ±0.1	5.7 ±0.07	6.5 – 8.5
EC (dS/cm)	75±6	90±14	2000
TDS (mgL^{-1})	52±9	62±4.8	500
Sulphate (mgL^{-1})	1.6 ±0.6	1 ±0.4	400
Phosphate (mgL^{-1})	0.03±0.01	0.04±0.002	0.05
Nitrate (mgL^{-1})	0.25±0.03	0.29 ±0.04	10
Fluoride (mgL^{-1})	0.19±0.04	0.13±0.04	1.5
Oilandgrease (mgL^{-1})	82 ±21	42±8	10
Phenolic compounds (mgL^{-1})	0.16±0.05	0.2±0.07	0.002

It can be seen that the pH of water courses on an average was 5.6 in pre monsoon and 5.7 in post monsoon seasons. These values are below the desirable range of 6.5 to 8.5

Electrical conductivity (EC), an index of salt concentration, was low in the water courses. Water courses shows an average EC of 75 ds/m during pre monsoon season and 90 during post monsoon seasons.Slight increase was noted during post monsoon as compared to the pre monsoon season in the water courses.

Total dissolved solids (TDS) was found to be within the WHO limits (500 mgL^{-1}) in all the water courses. In pre monsoon season the TDS value was 52 mgL^{-1} and it was 62 mgL^{-1} duringpost mosoon season.

Sulphate concentrations were very low in the Water courses of Koratty region. The permissible limits were 400 mgL^{-1} in non potable water. In Water courses sulphate value on an average was found to be 1.6 mgL^{-1} during pre monsoon season and 1 mgL^{-1} during post monsoon seasons.

Phosphate concentrations werewithin the permissible level of 0.05 mgL^{-1} in pre monsoon (0.03 mgL^{-1}) and in post monsoon the value was found to increase to 0.04 mgL^{-1}.

The concentration of nitrate in water courses were found to be low in both pre-monsoon and the post-monsoon period. It indicates that there is no contamination from this anion. In water courses the values were with in the permissible limits. During the pre-monsoon the values were 0.25 $mgL^{-1}$and during the post-monsoon period 0.29 mgL^{-1}.

Fluoride was also found to be within the permissible limits (1.5 mgL^{-1}) in all the water courses. The values were 0.19 mgL^{-1} in the pre-monsoon and 0.13 mgL^{-1} in the post-monsoon period

Oil and grease were present in higher than permissible limits in all the water courses. WHO permissible limit is 10 mgL^{-1}. In water courses the concentration was very high with values around 82 mgL^{-1} and 42 mgL^{-1} in pre monsoon in the post-monsoon period.

Phenolic compounds were also found to contaminate the water courses in the region. The permissible limits of phenolic compounds in non potable water is 0.002 mgL^{-1}. In water courses the values exceeded the permissible limits in both pre and post monsoon with 0.16 mgL^{-1} and 0.2 mgL^{-1} respectively.

pH in water courses

Wide variations in pH were observed between water courses in the region (Fig.6.36). Values ranged from 5.2 to 6.2 and the pH was comparatively less in post monsoon season. The trend was similar in water courses 4 to

11 and dissimilar in others when seasons were compared. Lowest pH was be noted in water courses 5 to 7 and 13.

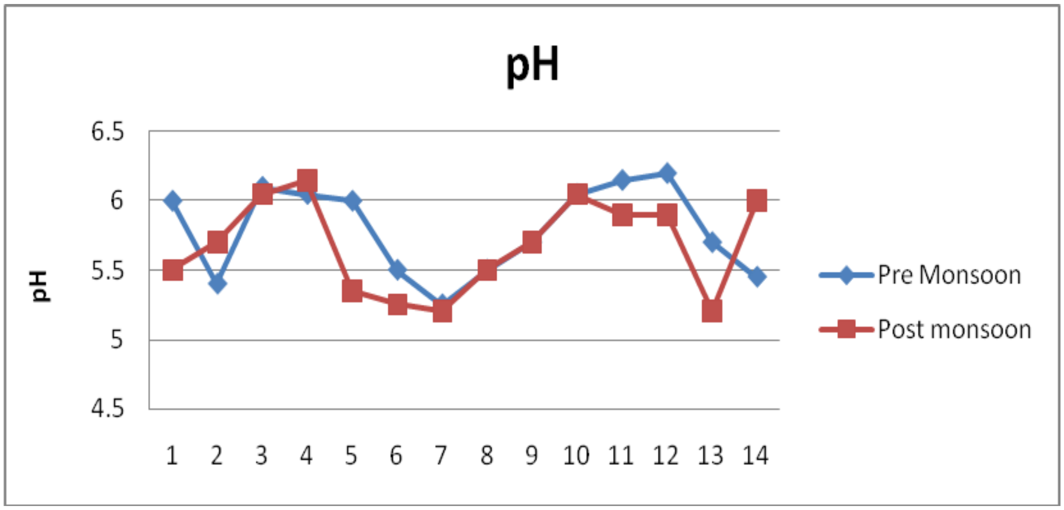


Figure 6.36. Seasonal variation in pH of water courses across sites

EC in water courses

Conductivity of water courses (Fig.6.37) was much low in all the water courses (50 to 150 dS/m) except water course 7 which had a value of 270 dS/m; the upper permissible level is 2000 dS/m. Values were always higher in post monsoon.

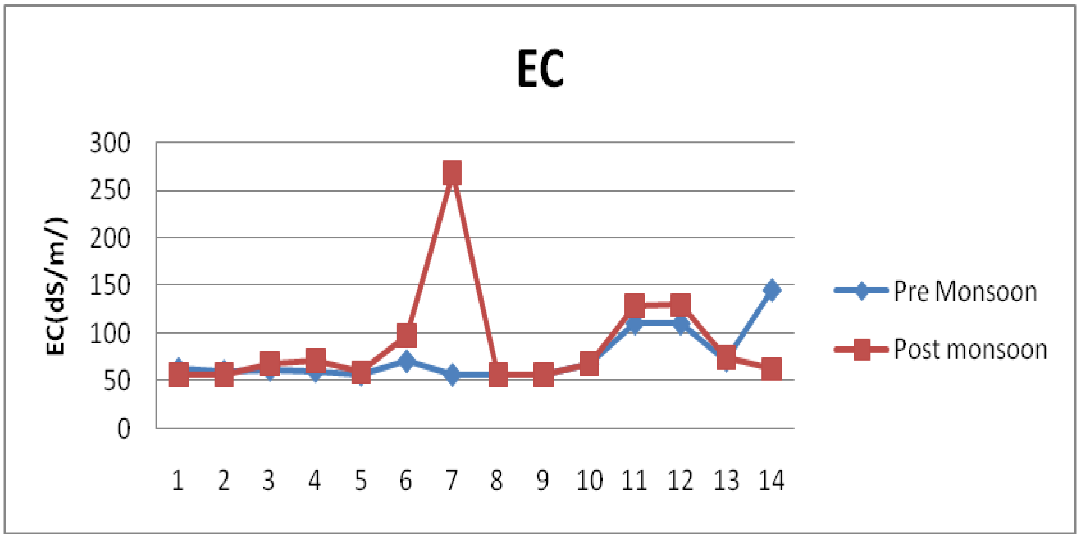


Figure 6.37. Seasonal variation in EC of water courses across sites

TDS in water courses

Total dissolved solids were present within permissible levels (<500 mgL^{-1}) only (Fig.6.38) with most water courses falling in the range of less than 100 mgL^{-1}; water courses number 7 alone had TDS values of 180 mgL^{-1}. TDS values were slightly more in post monsoon season.

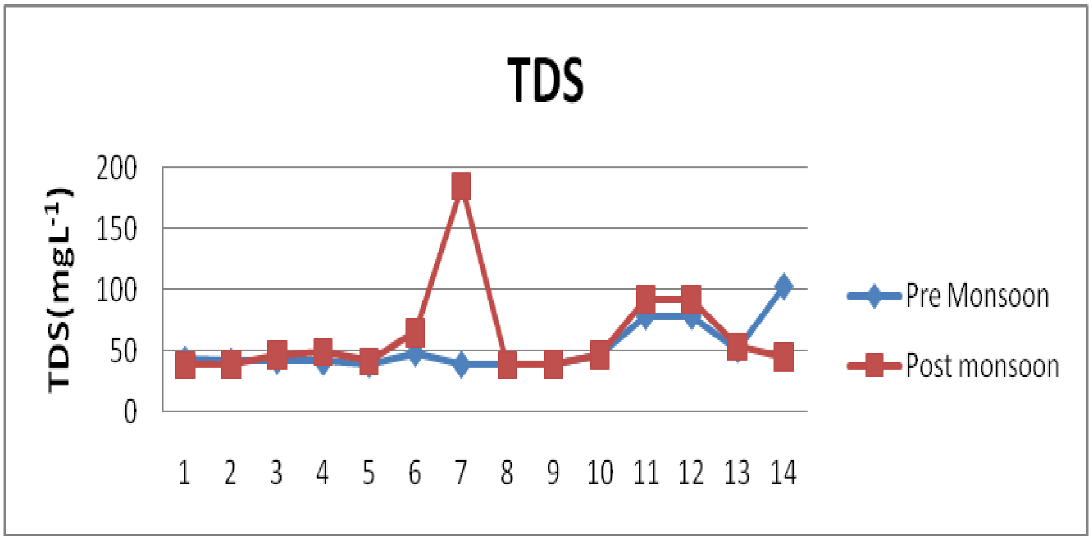


Figure 6.38. Seasonal variation of TDS in water courses across sites

Phosphate in water courses

There was wide variation in the content of phosphate between water courses (Fig.6.39). During pre monsoon season the phosphate content was lower than the desirable level of 0.05 mgL^{-1} with all the values below 0.035 mgL^{-1}. But phosphate content was at or above 0.05 mgL^{-1} in 4 water courses out of the 14 Water courses namely water courses number 4,6,13 and 14. In general, phosphate ions were more in the post monsoon season in the water courses exceptions being 11th and 12th water courses which had negligible phosphate during the post monsoon.

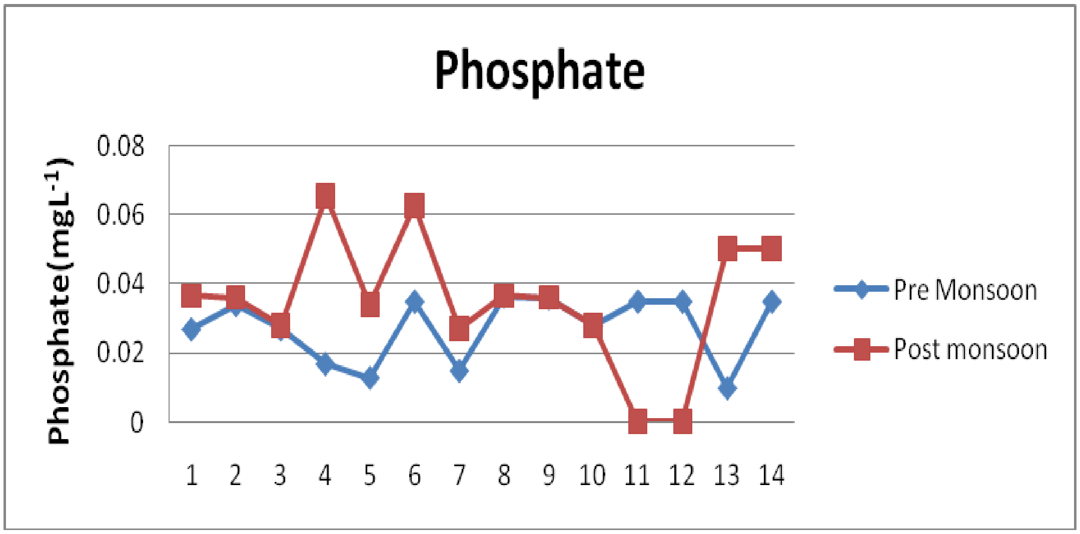


Figure 6.39. Seasonal variation of phosphate in water courses across sites

Nitrate in water courses

Nitrate content (Fig.6.40) was much lower than the permissible level (10mgL^{-1}) in all the water courses; its content was below 0.3mgL^{-1}. No definite trend could be observed between pre and post monsoons among the water courses, though wide variations between water courses was present.

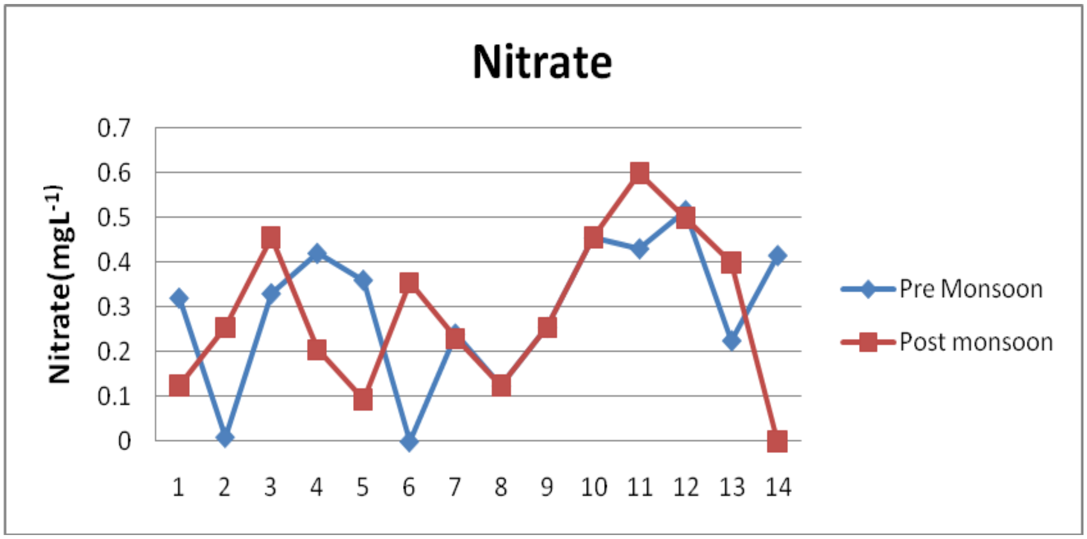


Figure 6.40. Seasonal variation of nitrate in water courses across sites

Fluoride in water courses

Fluoride content (Fig.6.41) was also low in water courses in the region with much lower values of less than 0.2 mgL^{-1} when the acceptable level is 1.5 mgL^{-1}. There was remarkable variation between water courses in pre monsoon unlike post monsoon when there was no much variations between the water courses.

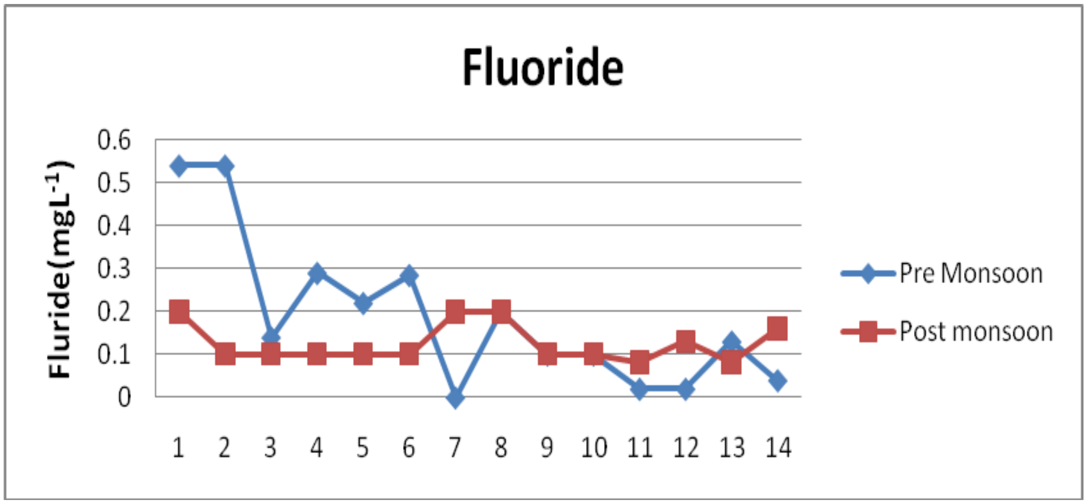


Figure 6.41. Seasonal variation of fluoride in water courses across sites

Oil and grease in water courses

The content of oil and grease was much higher than the desirable levels of 10mgL^{-1} in all the water courses during both the seasons except water course number 13 and 14 with negligible quantity in post monsoon (Fig.6.42). Values were always higher in pre monsoon season especially so in the case of water courses 4 and 7 with 300 mgL^{-1} and 250 mgL^{-1} of oil and grease respectively.

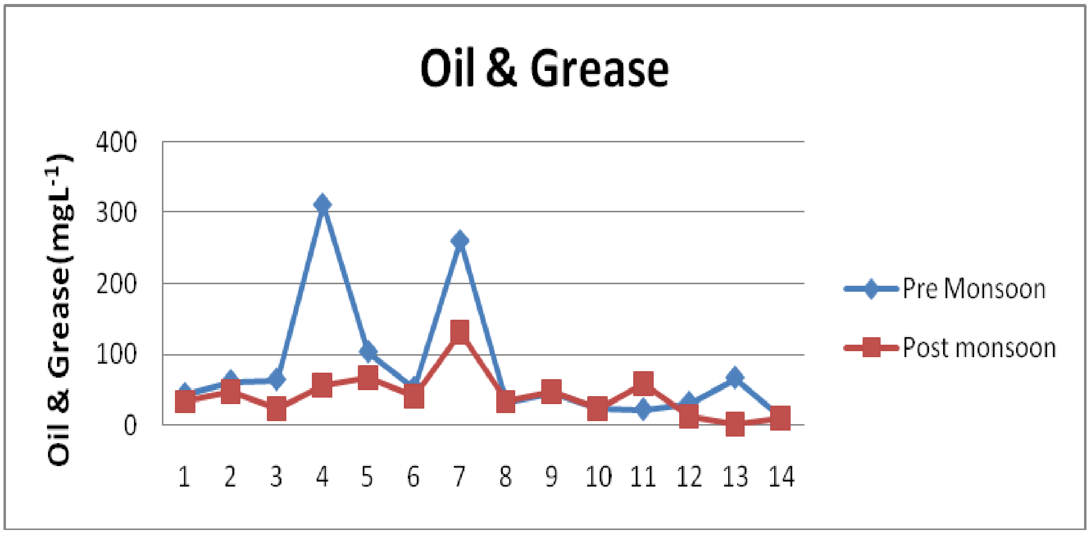


Figure 6.42. Seasonal variation of oil and grease in water courses across sites

Phenolic compounds in water courses

Phenolic compounds (Fig.6.43) were present in much higher than acceptable levels of 0.002 mgL^{-1} in most of the water courses in both seasons. Small variations were noted between water courses and between seasons. Highest levels were noted in the third water course only.

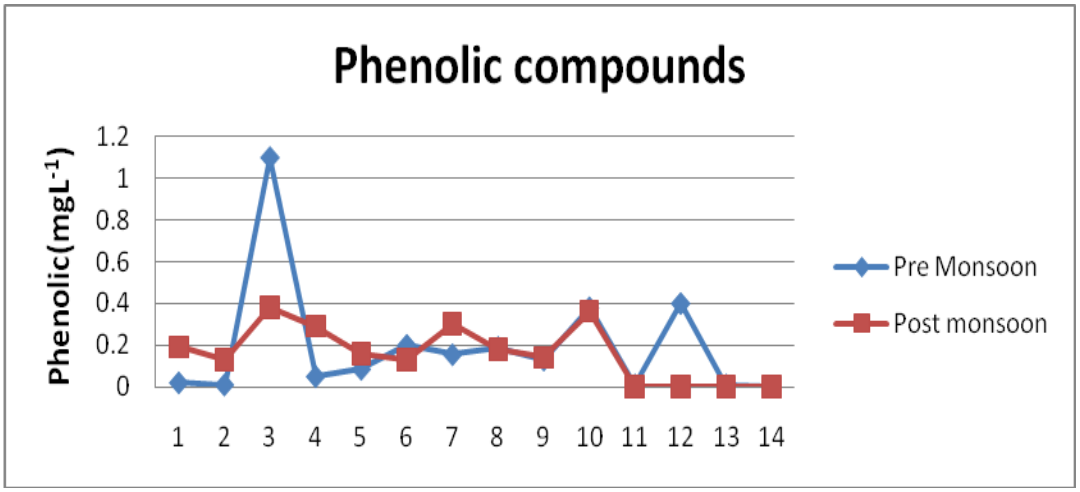


Figure 6.43. Seasonal variation of phenolic compounds in water courses across sites

Biological properties of water courses

Stream water quality considering all the water courses in the region together was found to be degraded with respect to its biological properties (Table 6.11). Dissolved oxygen (DO) levels were 3.4 mgL^{-1} in pre monsoon season and 3.6 mgL^{-1} in post monsoon season which was much below the desirable level of 6mgL^{-1}. Biochemical oxygen demand (BOD) of 4.5 mgL^{-1} was also higher than what is desirable (<3 mgL^{-1}) level. Chemical oxygen demand (COD) was also beyond acceptable limits (<7 mgL^{-1}) with values of 30 and 10 mgL^{-1} in pre and post monsoon respectively.

Table 6.11. Biological properties of water courses

Parameters	Water courses		Permissible Limits
	Pre monsoon	Post monsoon	
DO (mgL^{-1})	3.4 ±0.5	3.6 ±0.5	>6
BOD (mgL^{-1})	4.5 ±0.7	4.5 ±1	<3
COD (mgL^{-1}))	30 ±15	10±5.2	<7

Dissolved oxygen (DO) in water courses

Dissolved oxygen varied only slightly between streams as also seasons (Fig.6.44). All the streams were low in dissolved oxygen considering the desirable range of 6 mgL^{-1}.

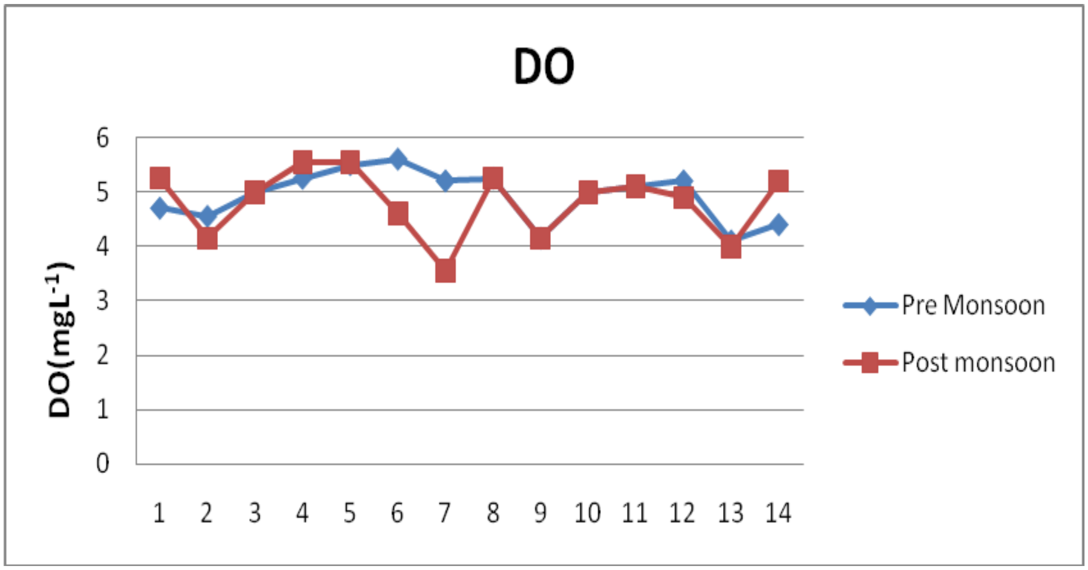


Figure 6.44. Seasonal variation of Dissolved oxygen in water courses across sites

Biochemical oxygen demand in water courses

Biochemical oxygen demand was found to vary with season in the first 4 streams; other streams did not vary much (Fig.6.45). All the streams had higher values than what is permissible.

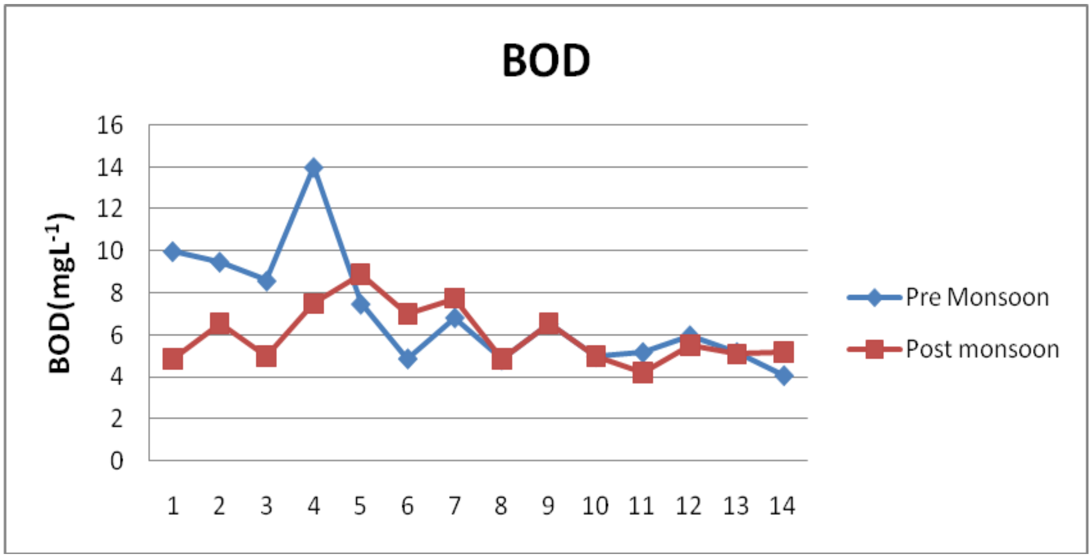


Figure 6.45. Seasonal variation of biochemical oxygen demand in water courses across sites

Chemical oxygen demand in water courses

The demand for oxygen in water by chemicals was higher than desirable range of less than 7 mgL^{-1} in all the water courses; stream 12 and 13 during post monsoon was the only exception (Fig.6.46). COD was found to be much high in pre monsoon with values going up as high as 75 mgL^{-1} in water courses 4 and with wide variations between water courses. Post monsoon values did not vary much and were around 10 mgL^{-1} in most of the water courses.

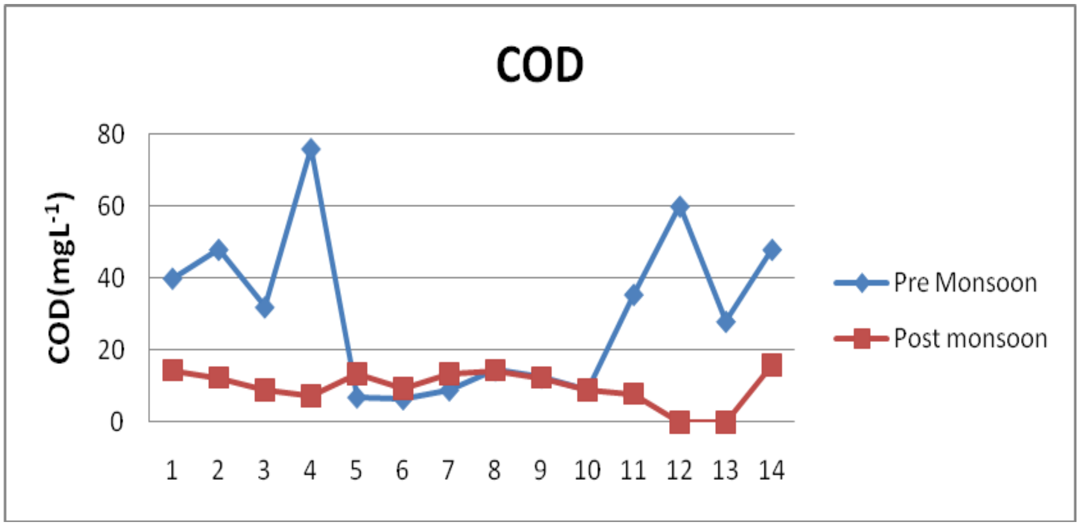


Figure 6.46. Seasonal variation of chemical oxygen demand in water courses across sites

Heavy Metals in water courses

Heavy metals Fe, Mn, Ni and Pb were present in water courses during pre monsoon season of which only Pb is of concern; others were within acceptable levels (Table 6.12). More elements were detected in the post monsoon season which included Fe, Mn, Ni, Cu, Cr and Zn. Pb was absent in post monsoon.

Table 6.12. Heavy Metals in water courses

Parameters	Water courses		Permissible Limits
	Pre monsoon	Post monsoon	
Fe (mgL^{-1})	0.10±0.025	0.05±0.01	1.0
Mn (mgL^{-1})	0.1±0.01	0.02 ±0.01	0.5
Ni (mgL^{-1})	0.02±0.002	0.01 ±0.002	0.02
Pb (mgL^{-1})	0.01 ±0.002	ND	Nil
Cu (mgL^{-1})	ND	0.01 ±0.007	3.0
Cr (mgL^{-1})	ND	0.01±0.003	0.01
Cd (mgL^{-1})	ND	ND	0.005
Hg (mgL^{-1})	ND	ND	0.0001
Zn (mgL^{-1})	ND	0.03±0.003	1.0
As (mgL^{-1})	ND	ND	0.05

Manganese in water courses

Manganese was present at very low concentration of less than 0.16 mgL^{-1} compared to the acceptable level of < 0.5 mgL^{-1} (Fig.6.47). Pre monsoon water had slightly higher values of Mn as compared to the post monsoon season which had negligible quantity only in most of the water courses.

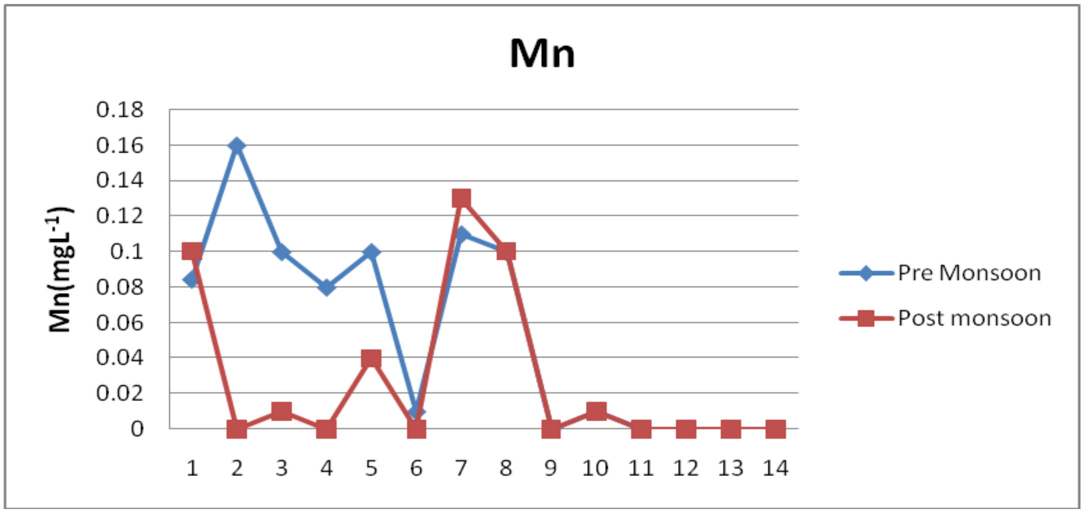


Figure 6.47. Seasonal variation of manganese in water courses across sites

Iron in water courses

All the water courses in the region had very low levels of iron with most values less than 0.15 mgL^{-1}; the desirable level is 1.0 mgL^{-1} (Fig.6.48). Variations between water courses is evident from the graph as is the difference in pattern between pre and post monsoon. Most of the post monsoon values were negligible.

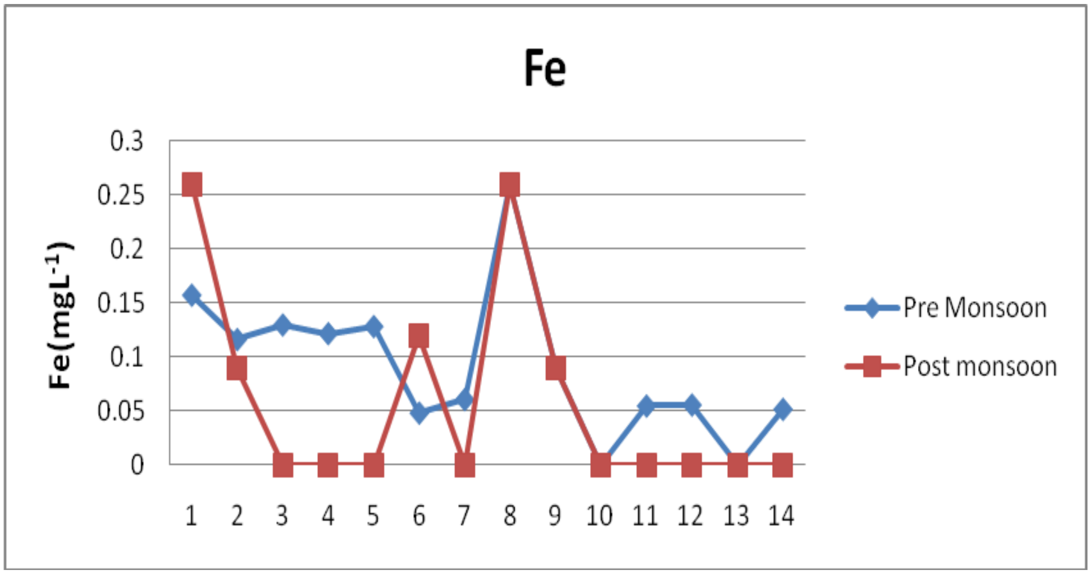


Figure 6.48. Seasonal variation of iron content in water courses across sites

Nickel in Water courses

Nickel concentration in water differed between water courses as also between seasons (Fig.6.49). Post monsoon season had comparatively higher levels than the pre monsoon. All the water courses had nickel levels at or below the desirable level of 0.02 mgL^{-1}.

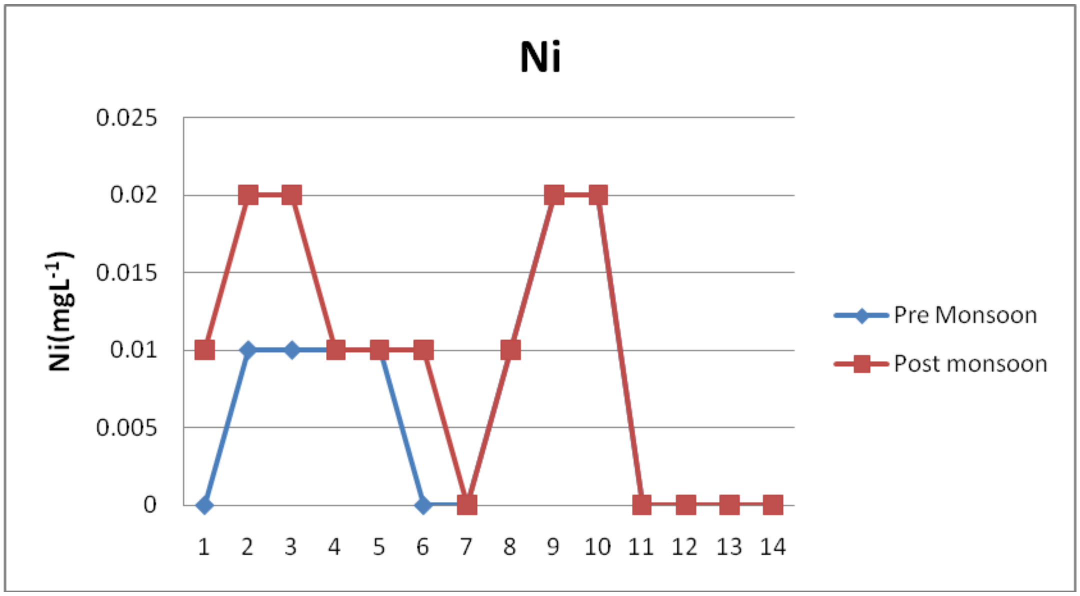


Figure 6.49. Seasonal variation of nickel in water courses across sites

Lead in water courses

Lead was found to be present in concentrations less than 0.02 mgL^{-1} with most sites having negligible quantities (Fig.6.50). It is not at all permitted to be present in water and hence its presence though in pre monsoon only is of concern.

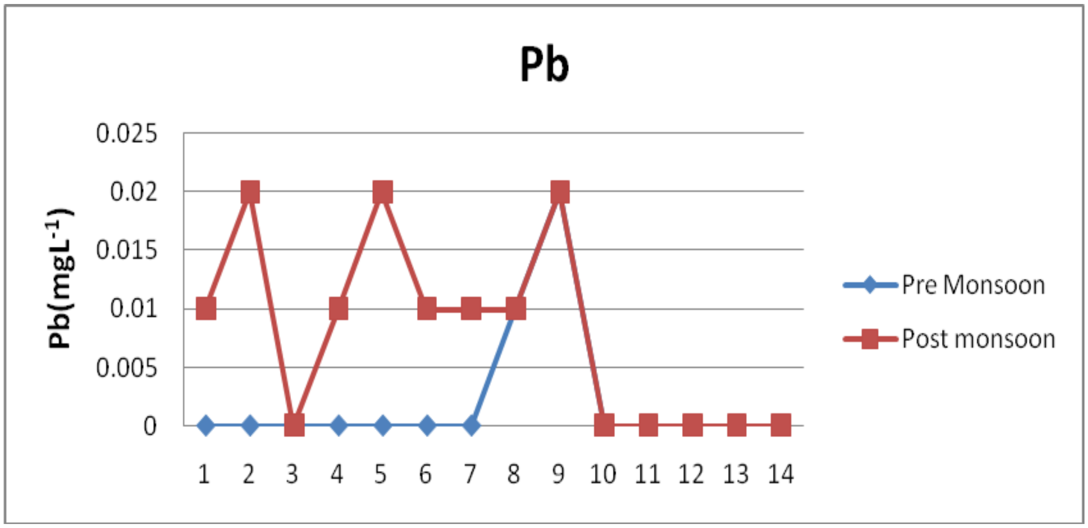


Figure 6.50. Seasonal variation of lead in water courses across sites

Copper in water courses

Copper was difficultly detectable in water courses (Fig.6.51) with few water courses having less than 0.01 mgL^{-1} and one water course (No.1) with 0.1 mgL^{-1} copper in the pre monsoon season. The acceptable limit of copper is upto 3 mgL^{-1}.

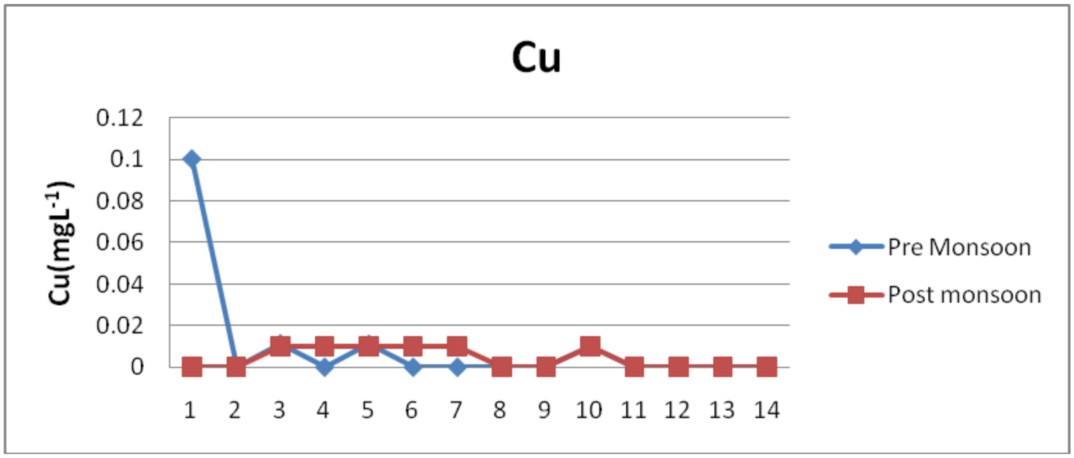


Figure 6.51. Seasonal variation of copper in water courses across sites

Zinc in water courses

Zinc was also present only in negligible levels of less than 0.05 mgL^{-1} in all the water courses (Fig.6.52) except water course number 1 with 0.35 mgL^{-1} of Zn in pre monsoon season. The acceptable level of Zn is 1 mgL^{-1}.

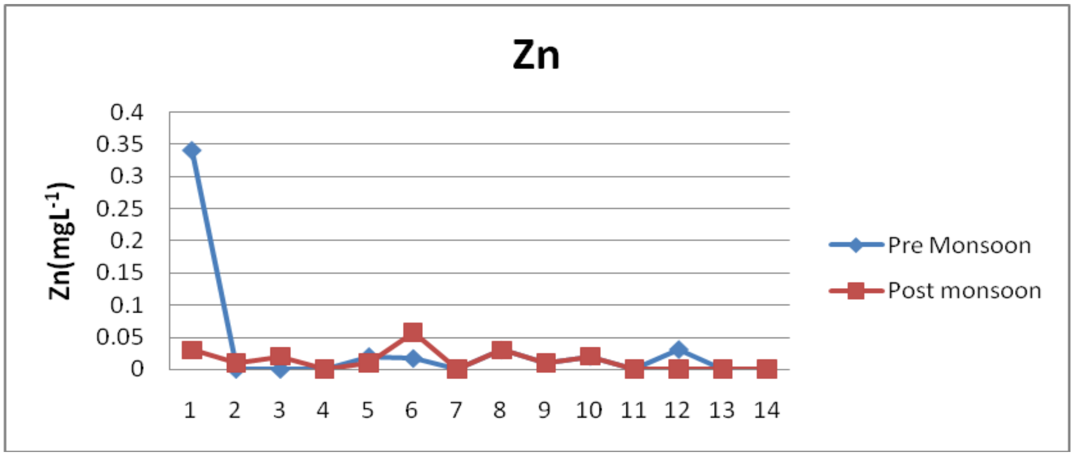


Figure 6.52. Seasonal variation of zinc in water courses across sites

Coliforms

Water courses in general were contaminated with coliforms in pre and post monsoon seasons (Table 6.13). Total coliforms were found to be 5657 and 4266 cfu 100ml^{-1} on an average in pre and post monsoon respectively. The figures for E.coli were 640 and 733 cfu 100ml^{-1} and that for feacal coliforms 156 and 1210 cfu 100ml^{-1} respectively in pre and post monsoons.

Table 6.13. Coliforms

Parameters	Water courses		Permissible Limits
	Pre monsoon	Post monsoon	
TotalColiforms (cfu 100ml^{-1})	5657 ±831	4266.6 ±1540	Less than 50
E-Coli (cfu 100ml^{-1})	640 ±126	733.3 ±143	Less than 50
Feacal Coliforms	156.3 ±155	1210.5 ±29	Less than 50

Coliforms were present in extremely high numbers in most of the water courses. Total coliforms decreased in post monsoon though wider variations were seen in post monsoon as compared to pre monsoon. E-coli and Feacal coliforms increased in the post monsoon season.

Total Coliforms in water courses

Total coliforms were present in higher levels than permissible (<50 cfu 100ml^{-1}) in most of the water courses (Fig. 6.53). Values were higher in pre monsoon in general with as high as 22000 cfu 100ml^{-1} obtained in the 4th water course.

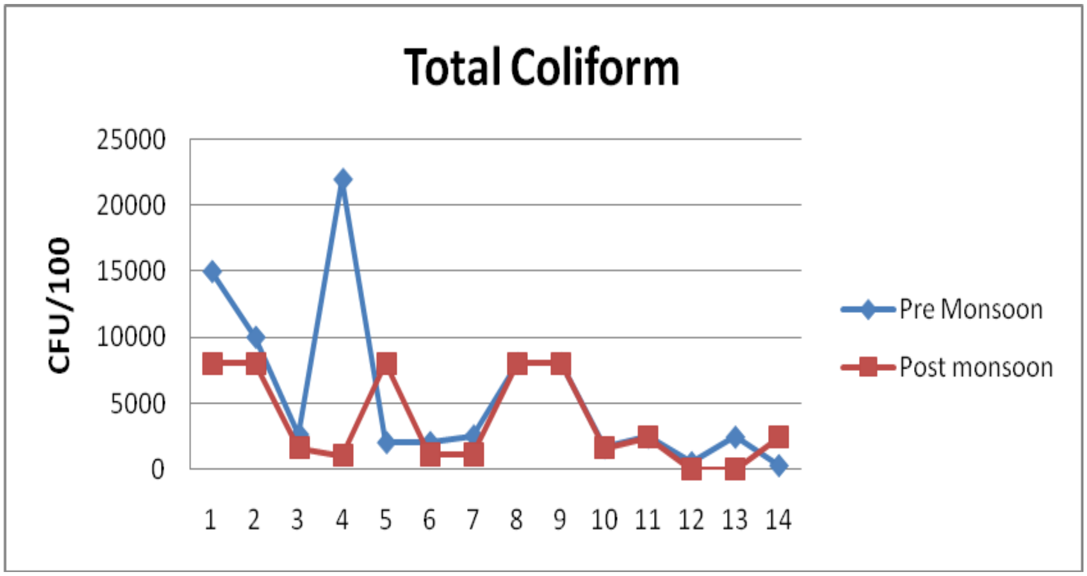


Figure 6.53. Seasonal variation of total coliforms in water courses across sites

E.coli in water courses

E-coli was also found to be present in higher than permissible levels in half of the water courses; the other half had negligible concentrations of E.coli only (Fig.6.54). As with the case of total coliforms, E.coli was also higher in the pre monsoon season.

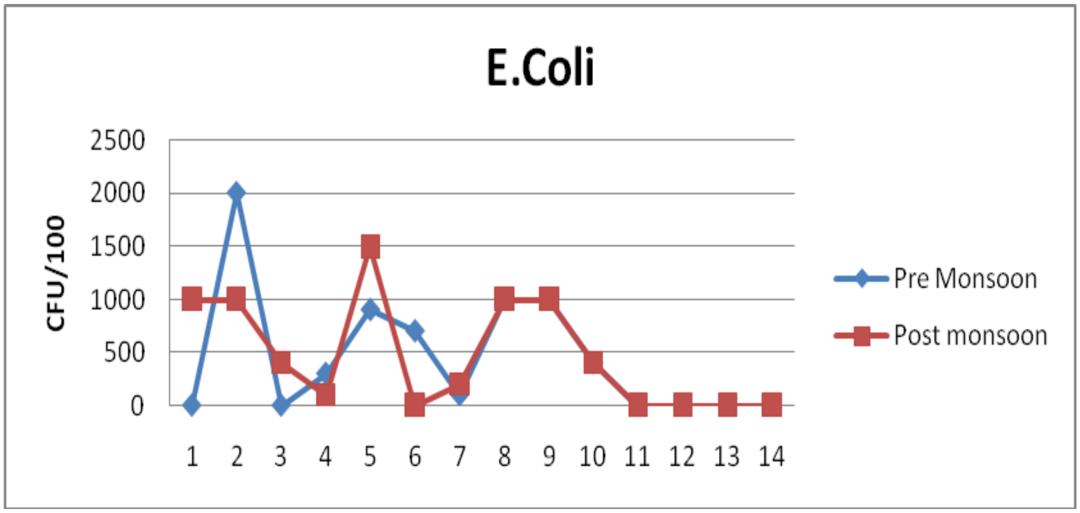
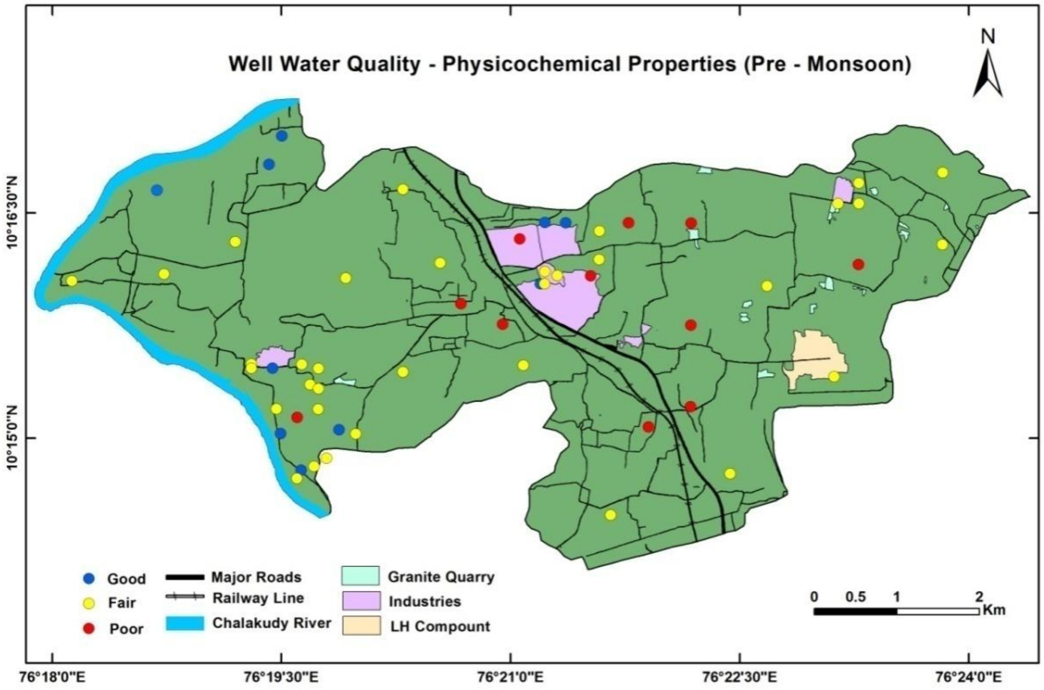


Figure 6.54. Seasonal variation of E.coli in water courses across sites

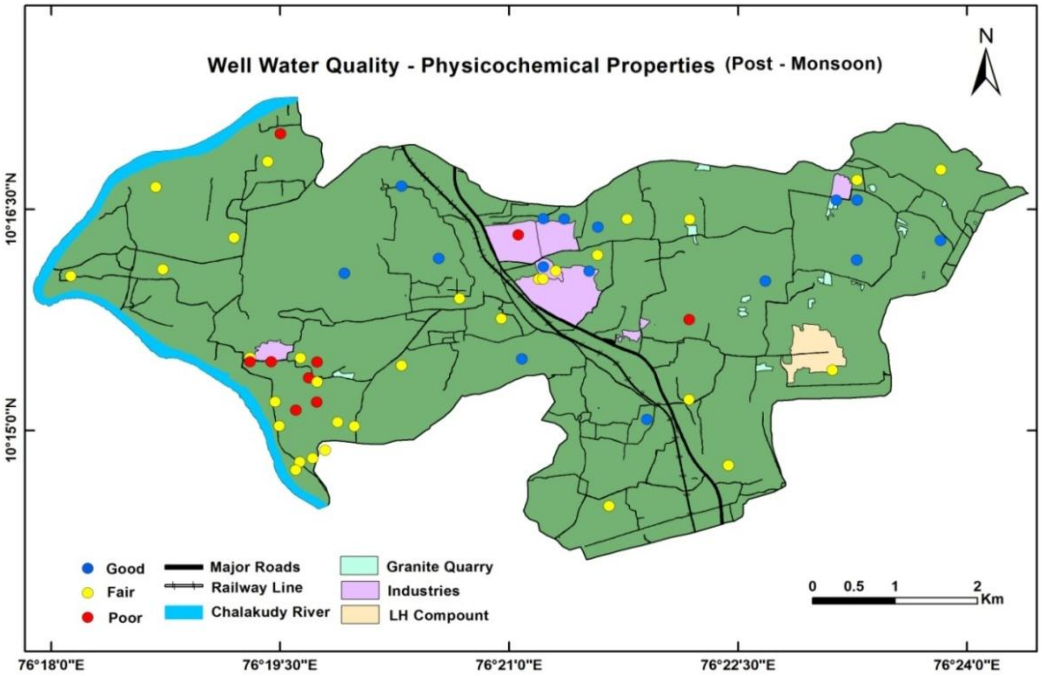
6.3.2 IMPACT OF LANDUSE ON WATER QUALITY

The quality of water in wells were assessed based on physico chemical properties and grouped into three major qualities as good, fair and poor by utilizing the GIS technique employing raster calculator and interpolation technique and by giving appropriate weightage to each property so that the overall water quality is brought out. It can be seen from the Map 6.2 below that during the pre monsoon season maximum number of wells had water of fair quality. Poor quality wells came next in number and good quality wells were a few. Wells with fair water was distributed throughout the region. Good water was present in some of the wells in the northern and north western part. Poor quality wells can be seen to be restricted to the middle part of Koratty region. Good quality water was present in 9 wells out of 50, fair quality in 30 wells and 11 wells had poor quality water.



Map.6.2. Distribution of wells with differing water quality- Physico-chemical properties (pre monsoon)

In post monsoon season, the pattern got changed (Map 6.3) with more number of good wells (15 Nos.) and least number of poor wells (9 Nos). Water quality in wells improved in the post monsoon season probably due to dilution resulting from the monsoon water. Fair quality wells were distributed all over the region as was the case in pre monsoon season. A clustering of bad wells in the vicinity of NGIL can also be observed.



Map 6.3. Distribution of wells with differing water quality-Physico-chemical Properties (post monsoon)

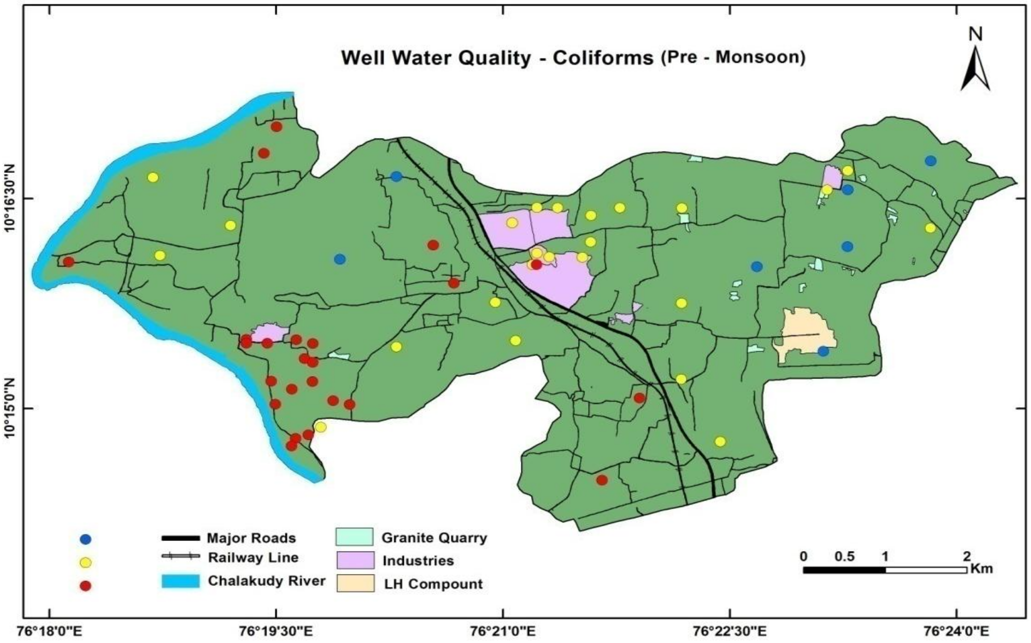
The poor quality wells were seen near the N.H and around the industrial belt of Government of India press, KINFRA, CUMI and Info park during pre monsoon season. During the post monsoon season poor quality wells were seen shifted to the western part near NGIL. The slope of the watershed towards Chalakudy river in the western part could have caused such a change.

Quality of well water with respect to the physico chemical properties was impaired by several factors including anions such as sulphate, phosphate, nitrate and fluoride as well as oil and grease and phenolic compounds the combined action of which was seen reflected in the pH, EC and TDS values. Agro chemicals and other chemicals released from industries and wastes of several kinds are expected to supply ions and organic chemicals in water (Regunath 1987; Rajaguru and Subburam 2000; Sonoda *et al*, 2001, Woli *et al.*, 2004; Rakesh *et al.*, 2005; Lee *et al.*, 2009; Wan *et al.*, 2014) Serious acidity (pH 4) of well water was noticed around NGIL industry which can be due to leaching of chloride ions to the ground water. High levels of phenolic compounds were obtained in only two wells one near KINFRA and another near CUMI during the post monsoon season. Phenolic compounds result from decomposition of organic matter which percolates down during the monsoon rains (Cornish and Mensahh, 1999).

Dissolved oxygen was much below the desirable level (>6 mgL^{-1}) and biochemical oxygen demand exceeded the desirable level (<2 mgL^{-1}) in most of the wells. Chemical oxygen demand was also higher than the permissible limit of 7 mgL^{-1}. BOD and COD values were found to be more during the pre monsoon season. Heavy metals and pesticide residues were also present in some of the wells especially during the pre monsoon season. Demand on oxygen by organisms and chemicals are reflected in the BOD and COD respectively and these two are inversely related to the DO values. Contamination of water in wells of Koratty is reflected in its physico chemical properties though most of the wells in the region have fair to good quality water. Water quality deterioration is restricted mainly to pockets of intense developmental activities.

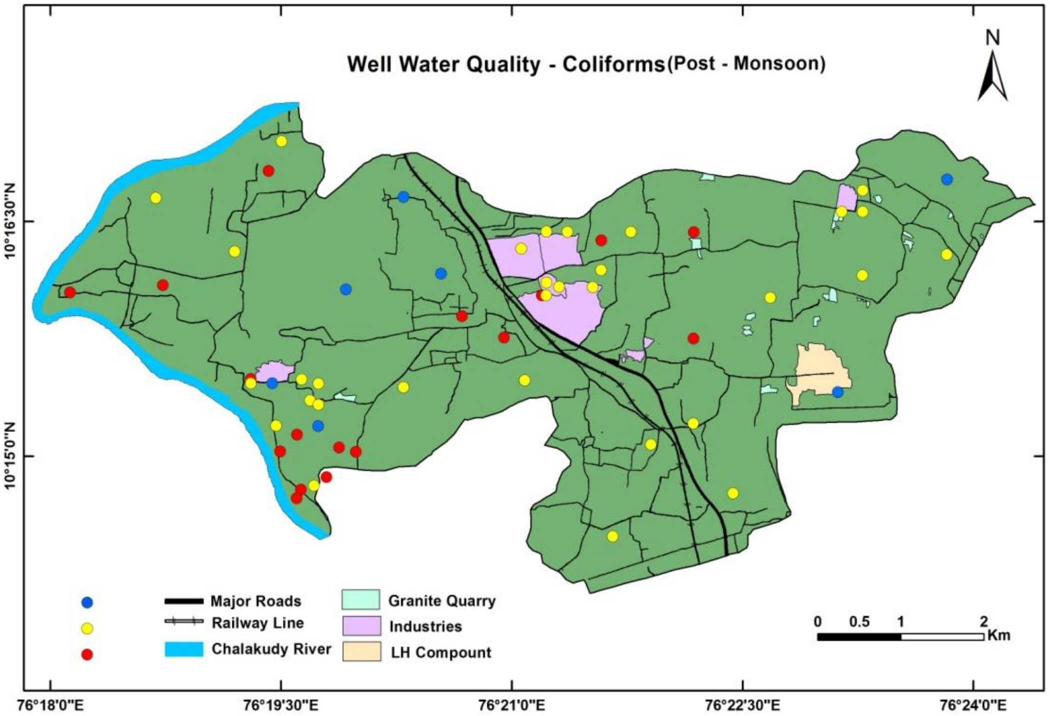
Coliforms - well water

Water quality in wells based on the content of coliform bacteria (Map 6.4) indicates that most of the wells were either poor or fair during the pre monsoon season. Few wells had good quality water and these wells were found in the eastern part mostly. Fair wells were located along the central part of the region while poor quality wells were seen clustered in the low lying south western part, though a few of them are also seen scattered in the central and western parts.



Map 6.4. Distribution of wells with differing water quality- Coliforms (pre monsoon)

During the post monsoon season the pattern of distribution was seen to be different from the pre monsoon season (Map 6.5). The wells with fair and poor quality is seen to be distributed all over the region while the number of good quality wells remained almost the same though there was some shift in their location. Poor quality wells were more towards the low lying western region.



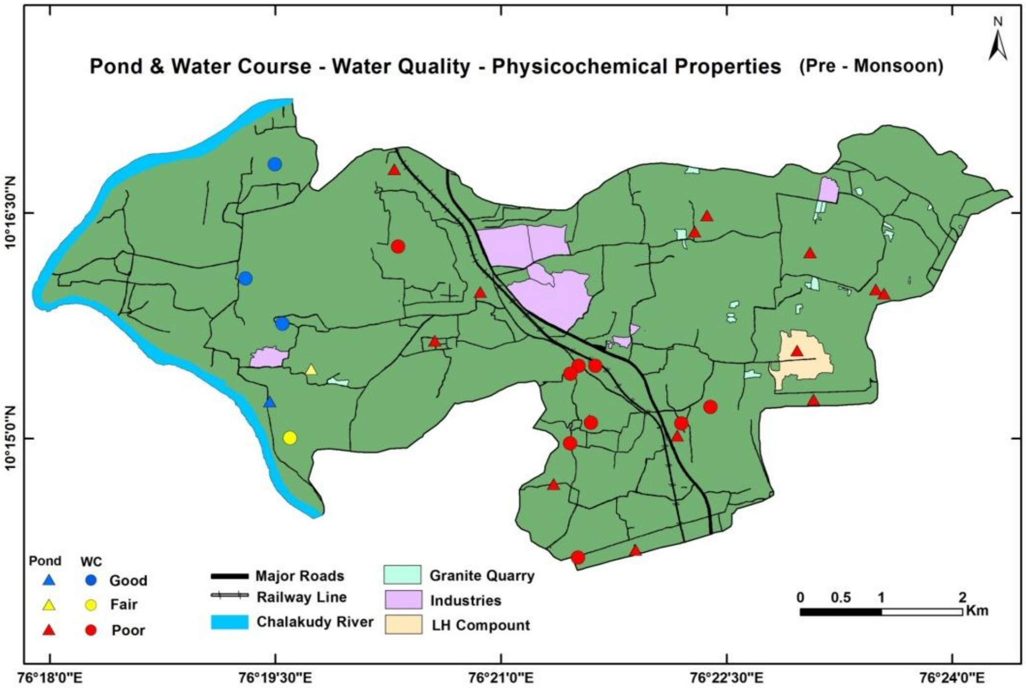
Map 6.5. Distribution of wells with differing water quality- Coliforms (post Monsoon)

Physico-chemical properties of water in ponds & water courses

Water quality of ponds and water courses in the region is depicted below in Map 6.6. It can be seen that most of the ponds and water courses had poor quality water during the pre monsoon season. They are all located in the middle and eastern region. Good and fair quality water was restricted to the western part.

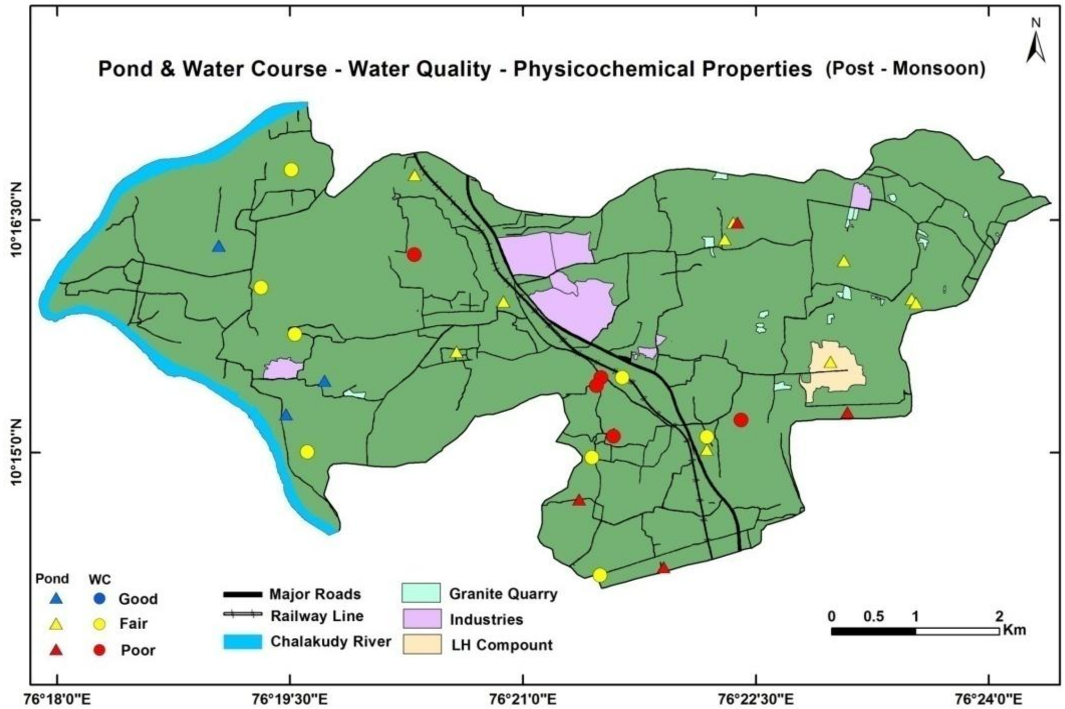
Ponds in Koratty were acidic and contaminated by oil and grease and phenolic compounds both of which exceeded the permissible limits. Other physico chemical properties of water in the ponds such as TDS, sulphate, phosphate, fluoride are all within the desirable level. DO levels were less than what is desirable and BOD and COD exceeded the permissible levels. Ponds having stagnant water have the chance of accumulating organic debris which demands oxygen for its decomposition. This combined with the demand by organisms (BOD) cause a reduction in DO levels. Oil and grease that reach the ponds mainly from vehicles add to the contamination. Organic substances such as carbohydrates, proteins, fats, lignin, tannin etc., are biodegradable and are quickly decomposed by microbes (DANIDA, 1998; Lamb, 1985) which consume dissolved oxygen in the water for respiration. Easily biodegradable wastes thus cause rapid depletion in DO levels. Demand on oxygen by decomposing organisms (BOD) and that by chemicals (COD) were seen to exceed desirable levels in ponds in the region. Heavy metals though present mostly in post monsoon season were of no consequence since their values were all within acceptable levels.

Water courses in the region were not much different from ponds as regards its properties. Water was acidic with pH less than 6.0. Oil and grease and phenolic compounds were present beyond the permissible limits. EC, TDS, sulphate, phosphate, nitrate and fluoride were within desirable levels. Contamination by oil and grease was high in all the water courses during both seasons, though pre monsoon season registered slightly higher values. Phenolic compounds exceeded acceptable levels in most of the water courses in both the seasons. Water quality of streams was degraded as regards its biological properties also. DO levels were less and BOD and COD levels high when compared with permissible level. Values were comparatively higher in the pre monsoon season. Heavy metals, though present, were within the permissible level.



Map 6.6. Distribution of ponds and water courses with differing water quality-physico chemical properties (pre monsoon)

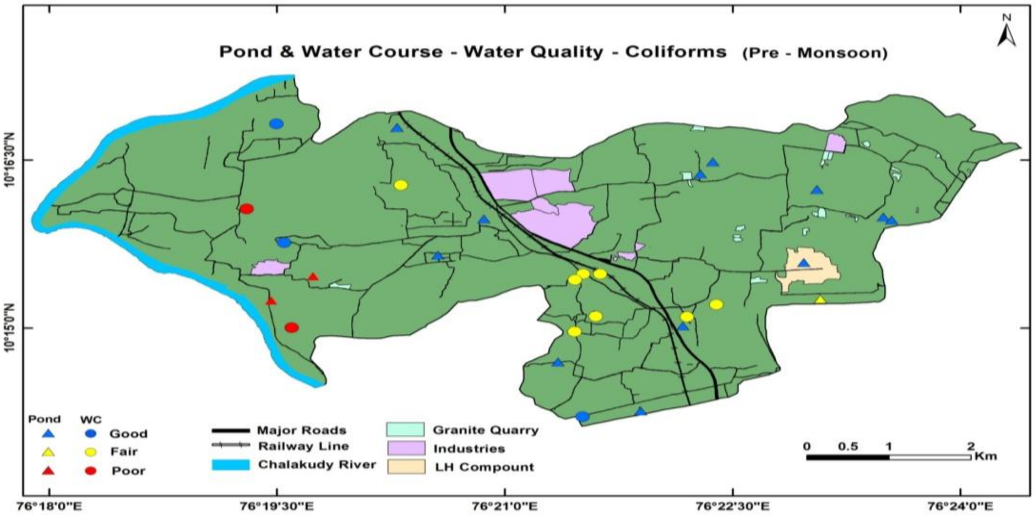
Post monsoon season can be seen to bring a perceptible change in the quality of water of ponds and water courses; there was overall improvement in water quality with a reduction in the number of poor quality ponds and water courses. Good quality water was absent in water courses but present in a few ponds in the western part. The shift was mainly to fair quality in the case of both ponds and water courses.



Map 6.7. Distribution of ponds and water courses with differing water quality- Physico chemical properties (post monsoon)

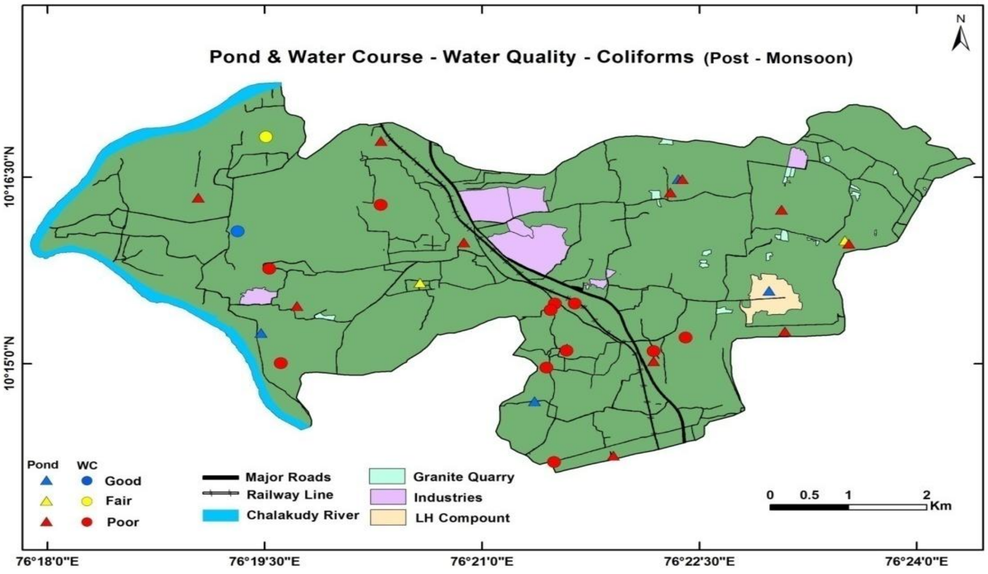
Coliforms in ponds and water courses

Water quality of ponds and water courses with particular reference to coliform contamination is shown in the following maps 6.8 and 6.9. It can be seen that almost all the ponds and water courses had good and fair quality water in the pre monsoon season; poor quality was seen restricted to the south western low lying area.



Map 6.8. Distribution of ponds and water courses with differing water quality- Coliforms (pre monsoon)

It can be seen that there was a drastic shift in water quality of ponds and water courses towards poor quality in the post monsoon period. Almost all the ponds and water courses were seen to be contaminated with coliforms. Fair or good quality water was seen restricted to the western part with one or two ponds and water courses.



Map 6.9. Distribution of ponds and water courses with differing water quality- Coliforms (post monsoon)

Total coliforms were present in ponds beyond permissible level during both pre monsoon (3577 cfu 100 ml^{-1}) and post monsoon (2021 cfu100 ml^{-1}) seasons values of which were much above the permissible limits of less than 50 cfu100 ml^{-1}. E. coli and Fecal coliforms were also present beyond permissible levels in the pre monsoon season. Contamination of coliform bacteria was restricted to the south western region during pre monsoon season probably due to the drainage pattern of the landscape that is towards the western region. In the post monsoon season, on the other hand, the contamination can be observed to spread across the whole landscape since the water table has come up permitting easy dispersal of bacteria across surface soil that was not possible during pre monsoon season with deep water table and quick drainage from the uplands. The pattern of residence with households in close vicinity seems to have further aggravated the situation. Pollution of household wells by pathogenic bacteria was described by Reghunath (1987) while Citizen's Report (1982) stated that 70% of water bodies in the country are polluted and various reasons including domestic, agricultural, commercial, industrial were ascribed to the degradation (Vimal and Talashikar, 1985; Allan, 2004). Total coliform, E. coli and Fecal coliforms were present at much higher levels than desirable limits in most of the water courses.

6.4. SUMMARY

Water quality in wells

The quality of water in wells of Koratty were acidic on an average with pH less than 5.5, which is much below the permissible pH range of 6.5-8.5 for potable water. Acidity was more in premonsoon in most of the wells. The distribution of wells with higher acidity was more in the south western region with a few wells near NGIL recording values below pH 4.0 even indicating serious acidity.

Electrical conductivity was insignificantly low with values much below the permissible level of 500 dS/m. Variations in EC values were noted only in the western region with one well having EC of 1550 dS/m. Total dissoleved solids, on the contrary, exceeded permissible limits of 25 mgL^{-1} with mean value of 73.5 mgL^{-1} in premonsoon and 104 mgL^{-1} in post monsoon on an average. Variations in TDS was higher in the western part and the well with EC of 1550 dS/m located near NGIL recorded a TDS value of 1100 mgL^{-1} much above the desirable level.

Content of anions nitrate, phosphate, sulphate and fluoride were low and within permissible limits. Nitrate was less than 2.0 mgL^{-1} on an average (permissible level 20 mgL^{-1}) and variations between wells was minimum, though a single well recorded higher levels of 9 mgL^{-1} which was also within the permissible level. Phosphate was less than 0.04 (permissible level 0.05 mgL^{-1}) and wide variations were seen between wells as also between seasons and a few wells were found to exceed the permissiblelimits mostly in post monsoon. Sulphate was less than 4 mgL^{-1} (permissible 200 mgL^{-1}) and its content varied widely among wells in the western part that had higher levels compared to the eastern region. The content of fluoride was less than 0.2 mgL^{-1} (permissible 1.0 mgL^{-1}) it also was found to exhibit wide variations among wells with wider ranges in the pre monsoon season.

Wells were observed to be contaminated with oil and grease with average values of 36.5 mgL^{-1} in pre monsoon and 12.5 mgL^{-1} in post monsoon when the permissible level was only 10 mgL^{-1} for potable water. Much higher values than the mean values mentioned were recorded in many wells. Wells in the eastern half were found to have permissible contents of oil and grease in the pre monsoon season but the levels were seen to exceed in the post monsoon. Wide variations in values were recorded in wells in the western region in both seasons. Percolation of oil and grease in rainy season would have resulted in the higher levels in post monsoon in the upper eastern half while higher water table in the western low lying region can be the reason for the pattern exhibited there.

Phenolic compounds were also present at much higher levelsthan what is permissible (0.002 mgL^{-1}) with 12.5 mgL^{-1} in pre monsoon and 0.51 mgL^{-1} in the post monsoon season. The high contents of phenolic compounds in pre monsoon could be attributed to higher litterfall and decomposition during this period and less volume of water in wells. During post monsoon, dilution is expected due to additional recharge of water from the monsoons.

Dissolved oxygen (DO) levels were less than what is desirable (>6 mgL^{-1}) on an average though some of the wells recorded desirable levels especially during the post monsoon season. Biochemical oxygen demand (BOD) exceeded acceptable limits of < 2 mgL^{-1} in both seasons though higher values were observed in the post monsoon season. It was also noted that higher BOD was present in wells situated in the eastern half especially in pre monsoon with wide fluctuation between wells. Chemical oxygen demand (COD) was also more in pre monsoon as was BOD but wider variations were seen in the western half. Post monsoon values were within the acceptable limit of <7 mgL^{-1} in most of the wells. Decrease of BOD and COD with increase in water levels in wells after rains is as expected. Decrease in DO is directly related to increase in BOD and COD of water.

Heavy metals iron, manganese and zinc were present in most of the wells in both seasons of which iron and manganese were within limits; zinc is not permitted to be present in potable water and hence its presence is of serious concern. Copper, lead, nickel and chromium were detected in a few wells in minute quantities and in pre monsoon season only. Arsenic, cadmium and mercury were not detected in any of the wells.

Coliforms that are not at all permitted in drinking water was recorded at very high levels in many of the wells. E.coli was seen to occur in 7 wells in the central region while fecal coliforms were recorded in 14 wells situated in the western region. Pesticide residues were detected in very few wells only.

Water quality in ponds

Water in ponds were acidic with pH less than 6.0 on an average with no difference in seasonal values. Total dissolved solids that on ionization increase conductivity was low with values less than 60 mgL^{-1} which was reflected in the low EC values of less than 100 dS/m. Wider fluctuations in both TDS and EC was observed in the low lying western region. Nitrate, phosphate, sulphate and fluoride were present but within permissible limits in both seasons. Oil and grease as well as phenolic compounds were high in both seasons with slight variations between sites and seasons.

Dissolved oxygen was found to be less than what is desirable. BOD and COD values exceeded permissible limits in both seasons with comparatively higher values in pre monsoon.

Heavy metals Fe, Mn, Ni and Zn were present in some of the ponds in the pre monsoon season though within limits only. In the post monsoon, Pb and Cu were also present in addition to the above of which Pb is not at all permitted even in pond water.

Coliforms were present at high levels in ponds. The counts of total coliforms, E.coli and fecal coliforms were more in pre monsoon as compared to the post monsoon season. E coli was absent in most of the ponds and fecal coliforms were within permissible limits in the post monsoon season.

Water quality in water courses

Water was found to be acidic with mean pH of 5.6 in the pre monsoon and 5.7 in the post monsoon season in the water courses also as was the case with wells and ponds. The desirable level is 6.5-8.5 in stream water. TDS and EC of < 100 mgL^{-1} were much within the desirable levels of < 2000 mgL^{-1} and 500 mgL^{-1} respectively; the values are extremely low to be of any consequence.

Nitrate with < 0.3 mgL^{-1}, phosphate at <0.04 mgL^{-1}, sulphate at <2 mgL^{-1} and fluoride at < 0.2 mgL^{-1} were all within the permissible limits of 10 mgL^{-1}, 0.05 mgL^{-1}, 400 mgL^{-1} and 1.5 mgL^{-1} respectively. None of these anions were a cause of concern as regards the quality of water in water courses.

Oil and grease and phenolic compounds were present at levels far exceeding the permissible limits. Oil and grease was present at 82mgL^{-1} in pre monsoon and 42 mgL^{-1} in post monsoon on an average when the permissible limit is only 10 mgL^{-1} of water. Similarly phenolic compounds were found to be present at very high levels of 0.1 mgL^{-1} and 0.2 mgL^{-1} in pre and post monsoons respectively; the permissible level is only 0.002 mgL^{-1}. Oil and grease was more in pre monsoon while phenolic compounds were higher in post monsoon. Oil and grease is expected to reach water courses at almost constant rate year round but the increase in volume of water after rains could have diluted it. Phenolic compounds mostly from decayinglitter might be reaching the water courses along with runoff during rains through drainage from the catchment resulting in the increase in its content in the post monsoon season.

DO levels were much below the acceptable limits of >6 $mgL^{-1}$with mean pre monsoon values of 3.4 mgL^{-1} and 4.5 mgL^{-1} in the two seasons. BOD exceeded permissible levels of < 3 mgL^{-1} with values around 4.5 mgL^{-1} in both seasons. COD also was found to cross the acceptable levels of < 7

mgL^{-1}; it was very high in pre monsoon with $30mgL^{-1}$ and slightly less in post monsoon with 10 mgL^{-1} on an average. These levels of DO, BOD and COD indicate pollution of the water courses.

Heavy metals Fe, Mn, Ni, Cu, Cr and Zn were present in water courses in post monsoon season but all of them were within acceptable limits only. In the pre monsoon season, Fe, Mn, Ni and Pb alone were detected of which the presence of Pb though in small levels of 0.01 mgL^{-1} is of concern since it is not permitted in any of the water bodies including water courses.

Coliforms were present at alarming levels in most of the water courses. The counts of total coliforms was 5657, that of E.coli 640 and fecal coliforms 156 cfu $100ml^{-1}$ in the pre monsoon season. The respective figures in post monsoon were 4266, 733 and 1210 cfu $100ml^{-1}$. These values are much above the permissible value of 50 cfu $100ml^{-1}$common for all types of coliforms.

CONCLUSIONS

Land in Koratty region is mainly used for agriculture with 89.2% of the land utilized in this way. Mixed crops in homesteads occupy maximum area of 48.6% of the agricultural land followed by paddy, rubber, coconut, vegetables and banana in decreasing acreage. Major industries in the region are Government of India Press, Kinfra Park, Info Park, Vaigai threads, CUMI and NGIL which together occupy 3.2% of the land. Small industries of different kinds also are spread over the landscape. Roads including the national highway, railway, irrigation canals, water bodies including wells ponds and watercourses and built up area occupy rest of the area.

Soils in both agricultural lands and industrial sites were found to be highly acidic with pH less than 5.0 on an average. Lowest pH was recorded near CUMI and NGIL. Electrical conductivity values were less than 0.03 dS/m in most areas which was too low to be any significance. Organic carbon content of surface soil was high with values in the range of 0.7% to 1.5% in both agricultural and industrial sites.

Iron and manganese content in soils were much above the desirable levels. Zinc was less in most landuses except rubber. Copper exceeded permissible levels in paddy, rubber, CUMI, Vaigai Threads and NGIL areas. Cadmium, lead, nickel and chromium were present at high levels in all the landuses.

Mobility of heavy metals in the soil was found to be in the order Fe> Mn > Pb > Ni > Zn > Cd > Cr. Contamination factor of heavy metals indicated that contamination in agricultural areas was in the order Ni> Cd > Pb > Fe > Zn > Cu > Mn. Contamination factor in industrial areas followed the order Cd> Pb > Ni > Fe > Cu > Zn > Mn. Enrichment factor revealed that Cd, Pb and Ni were highly enriched in the soils.

Water quality in wells of Koratty were found to be affected at different levels due to landuse. Water was acidic in all the wells with pH less than 5.5 on an average which is much below the desirable level of 6.5-8.5 and acidity was observed to be more in premonsoon season. Lowest pH values of around 4.0 were recorded in a few wells near NGIL.

Electrical conductivity of well water was insignificantly low in all the wells with less than 200 dS/m much lower than the permissible level of 500 dS/m. Total dissolved solids (TDS) exceded the permissible limits of 25mgL^{-1} with mean values of 73.5 mgL^{-1} in premonsoon and 104mgL^{-1} in post monsoon. Variation was higher in wells in the western region.

Nitrate, phosphate, sulphate and fluoride ions were present in well water but only with in the permissible limits.

Most of the wells were contaminated with oil and grease at concentrations of 36.5 mgL^{-1} in premonsoon that got diluted to a level of 12.5 mgL^{-1} in the post monsoon season; the permissible limit is 10 mgL^{-1} for potable water. Wells in the eastern part of the study area were found to have oil and grease within limits in premonsoon but beyond limits in post monsoon indicating percolation and enrichment during rains. The western low lying regions on the other hand had higher water table year round and exhibited wide variations in oil and grease content. Phenolic compounds were also present in much higher levels than the permissible level of 0.002 mgL^{-1}. The levels were higher in premonsoon with mean values around 1.25 mgL^{-1} and slightly lesser values of 0.51 mgL^{-1} in post monsoon season.

Dissolved oxygen (DO) were slightly less than the desirable level of 6.0 mgL^{-1} in most of the wells though some of the wells had desirable levels especially in the post monsoon season. Biochemical oxygen demand

(BOD) exceeded acceptable limits of <2 mgL^{-1} in most of the wells and higher BOD values were recorded in post monsoon. BOD was higher in wells on the easteren half of the study area especially during pre monsoon and with wide variations between wells. Chemical oxygen demand (COD) was found to exceed the permissible limit of < 7 mgL^{-1} in most of the wells in pre monsoon only; it was within limits in post monsoon. Wider variations were observed in wells in the western region.

Heavy metals iron, manganese and zinc were present in most of the wells in both seasons of which iron and manganese did not exceed permissible levels. Zinc is not permitted to be present in potable water and hence its presence in well water is of concern. Copper, lead, nickel and chromium were detected in a few wells in minute quantities and in premonsoon only. Arsenic, cadmium and mercury were not detected in any of the wells.

Some of the wells in the region were found to be heavily polluted with coliforms; coliforms are not permitted to be present in drinking water. E.coli was seen in 7 wells in the central region while fecal coliforms were recorded in 14 wells situated in the south western region. Pesticide residues were detected in few wells.

Water in ponds were acidic with pH less than 6.0 on an average with no seasonal differences. Total dissolved solids (TDS) that on ionization increase the electrical conductivity was low (<60 mgL^{-1}) that was reflected in the low EC values of < 100 dS/m. Wide fluctuation in both TDS and EC were observed in the low lying western region. Nitrate, phosphate, sulphate and fluoride were present within permissible limits in both seasons. Oil and grease as well as phenolic compounds were high in both seasons with slight variations between sites and seasons.

Dissolved oxygen (DO) was found to be less than what is desirable in ponds.BOD and COD values exceeded permissible limits in both seasons with comparatively higher values in the premonsoon season.

Heavy metals Fe, Mn, Ni and Zn were present in some of the ponds in premonsoon but within permitted levels only. In the post monsoon season, Pb and Cu were also present in addition to the above of which Pb is not permitted even in pond water.

Coliforms were present at high levels in ponds. Total coliforms, E.coli and Fecal coliforms were more in premonsoon as compared to post monsoon. In post monsoon E. coli was absent in most of the ponds and fecal coliforms were within permissible limits only.

Water quality in water courses were also found to deteriorated in the region. Water was found to be acidic with average pH of 5.6 in premonsoon and 5.7 in post monsoon season much below the desirable range of 6.5-8.5 in streams. EC with values <100 dS/m and TDS with values < 100 dS/m were well within the permissible limits of 2000 dS/m and 500 dS/m respectively; the values are extremely small and hence of significance. Nitrate, phosphate, sulphate and fluoride were all within the permissible limits. None of these anions were a cause of concern in the water courses.

Oil and grease and phenolic compounds, on the contrary, were present at levels far exceeding permissible levels. Oil and grease was present at 82 mgL^{-1} in premonsoon and 42 mgL^{-1} in post monsoon on an average when the permissible limit is only 10 mgL^{-1} of water. Phenolic compounds also were found to be present at mean levels of 0.1 mgL^{-1} and 0.2 mgL^{-1} in pre and post monsoon respectively.

DO levels were much below the acceptable range of > 6 mgL^{-1} with pre monsoon values of 3.4 mgL^{-1} and post monsoon values of 3.6 mgL^{-1} on an average. BOD exceeded permissible value of < 3 mgL^{-1} with mean values of 4.5 mgL^{-1} in both seasons. COD also exceeded desirable levels of <7 mgL^{-1}; it was very high in pre monsoon with 30 mgL^{-1} and slightly less in post monsoon with 10 mgL^{-1} on an average. The values of DO, BOD and COD indicate considerable levels of pollution in water courses in the region from chemicals.

Heavy metals Fe, Mn, Ni, Cu, Cr and Zn were present in water courses in the post monsoon but all of them were within acceptable levels only. In the pre monsoon season, Fe, Mn, Ni and Pb alone were detected of which the presence of Pb is of concern though negligible at 0.01 mgL^{-1}.

Coliforms were present at alarming levels in most of the water courses. The counts for total coliforms was 5657 cfu $100ml^{-1}$, that of E.coli 640 and fecal coliforms 156 cfu 100 ml^{-1} in pre monsoon. The respective figures in post monsoon were 4266, 733 and 1210 cfu $100ml^{-1}$. The permissible level is only 50 cfu 100 ml^{-1} for all the forms.

Thus soil quality was found to be badly affected by both agriculture and industries. The national highway and railway cutting through the central region of Koratty is another important source of pollution from fossil fuel burning. Cadmium followed by nickel were the major soil contaminants in industrial areas while nickel followed by cadmium was the major pollutant in agricultural areas. Lead was present in high levels in the soil throughout the study area. The degree of contamination by heavy metals explored by studying different fractions of these elements in the soil revealed that lead, nickel and cadmium are serious soil contaminants in the region.

Well water quality in the area was fair to good in most cases. Water quality problems of Koratty region are mainly associated with phenolic compounds, oil and grease, DO, BOD and COD. Nitrate, phosphate, sulphate and fluoride content were found to be within the desirable limits. Heavy metals such as nickel, lead, chromium and zinc are present in some of the samples. Bacteriological contamination by coliforms was present in some of the wells. Pesticide residues were found in few wells only. Quality deterioration was more during premonsoon season as compared to post monsoon season. Water quality in ponds and water courses were also seen to be degraded by the presence of high levels of oil and grease, phenolic compounds and coliforms. The pH was below desirable levels, DO was less while BOD and COD were high in these water bodies. Nitrates, phosphates, sulphates, fluorides and heavy metals were also present but in small amounts only. Deterioration in water quality could not be assigned to any particular landuse except near NGIL industry were many wells were found to have severe acidity.

SUGGESTIONS

Air quality monitoring seems to be important as soil and water quality monitoring, since much of the pollutants come through the air. The present study could not accommodate this aspect.

Contamination of soil and water has been brought out in the study. Bioaccumulation and biomagnification needs further attention.

Shift from inorganic to organic agriculture and strict adherence to guidelines and restrictions by industries is warranted. Industries may contain some of the air pollution by establishing green belts around. Recycling/ reuse of waste water also needs attention.

Remedial measures utilizing both flora and fauna needs to be researched. Phytoremediation as also microbial biofilters deserves special mention in this regard.

LITERATURE CITED

Abbasi, A.H., Jarvie, H.P., Neal, C., Tappin, A.D., Burton, J.D., Hill, L., Neal, M., Harrow, M., Hopkins, R., Watts, C., Wickham, H. 1996. Riverine inputs of major ions and trace elements to the tidal reaches of the River Tweed, UK. *The Science of the Total Environment*, 251/ 252: 55 - 81

Acosta, J.A., Faz, A., Martínez-Martínez, S., Zornoza, R., Carmona, D.M., Kabas, S. 2011. Multivariate statistical and GIS-based approach to evaluate heavy metals behavior in mine sites for future reclamation. *Journal of Geochemical Exploration*, 109: 8–17

Adamowski, J., Prokoph, A. 2013. Assessing the impacts of the urban heat island effect on stream flow patterns in Ottawa, Canada. *Journal of Hydrology*, Vol. 496: 225–237

Adeel, Z., Safriel, U., Niemeijer, D., White, R., 2005. Millennium Ecosystem assessment, Ecosystems and Human Well-being: Desertification Synthesis. World Resources Institute, Washington, DC.

Adriano, D.C. 2001. Trace elements in terrestrial environments: Biochemistry, bioavailability and risks of metals. - Springer Verlag.

Afshin, Q., Farid, M., Giti, F. 2009. Characterization of metal pollution in soils under two landuse patterns in the Angouran region, NW Iran: a study based on multivariate data analysis. *Journal of Hazardous Materials*, 172: 374–384

Aggergaard, S., Jensen, F.B. 2001. Cardiovascular changes and physiological response during nitrite exposure in rainbow trout. *Journal of Fish Biology*, 59: 13 - 27

Ahearn, D.S., Sheibley, R.S., Dahlgren, R.A., Anderson, M., Jonson, J., Tate, K.W. 2005. Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California. *Journal of Hydrology*, 313: 234–247

Allan, J. D., 2004. Landscapes and River scapes: The influence of land use on stream ecosystems. Annual Review of Ecology, Evolution and Systematics, 35: 257–284

Alloway, B. J., Ure, A. M. 1990. Methods of analysis of heavy metals in soils, p. 40–80.1389–414

Ambasht, M. 1990. Alterations in the hematological parameters of rainbow trout, Oncorhynchusmykiss, exposed to cypermethrin at low temperature in soft water. *Canadian Journal of Fisheries and Aquatic Sciences*, 49: 1189 - 1197

Amoo, I.A., Adebayo, O.T., Lateef, A.J. 2005. Evaluation of heavy metals in fishes, water and sediments of Lake Kainji, Nigeria. *Journal of Food Agriculture and Environment*, 3(1): 209-212

APHA, 2005. Standard methods for examination of water and waste water, 21st edition. American Public Health Association, Washington DC, USA, 1368p.

Ashutosh, G., Joshi, V. P., Sati, O.P. 1993. Physico-chemical characteristics of sewage and its impact on water quality of Alakanda at Srinagar. *Transactions of the Ammerical Fisheries Society*, 76: 322 - 334

Bailey, S.E., Olin, T.J., Bricka, R.M., Adrian, D.D. 1999 A review of potentially low-cost sorbents for heavy metals. *Water Research*, 33(11):2469–2479

Baker, A., 2003. Land use and water quality. *Hydrological Process*, 17: 2499–2501

Balakrishnan, M., Arul Antony, S., Gunasekaran, S., Natarajan, R. 2008. Impact of dyeing industrial effluents on the ground water quality in Kancheepuram, India. *Indian Journal of Science and Technology*, 1(7): 1-8

Banerjee, A.D.K. 2003. Heavy metal levels and solid phase speciation in street dusts of Delhi, India. *Environmental Pollution,*123: 95–105

Baranowski, R., Rybak, A., Baranowski, I. 2002. Speciation analysis of elements in soil samples by XRF, *Polish Journal of Environmental Studies*, 11: 473-482

Barton, N.H., Turelli, M.1990. Evolutionary quantitative genetics: How little do we know? Annual Review of Genetics, 23: 337–370

Baruah, C.P., Van der Oost, R., Beyer, J. Vermeulen, N.P.E. 2003. Fish bioaccumulation and biomarkers in environmental risk assessment: Annual Review of Environmental Toxicology and Pharmacology,13: 57 - 149

Beckwith, P. R., Ellis, J. B., Revitt, D. M., Oldfield, F. 1986. Heavy metal and magnetic relationships for urban source sediments. Physical Earth Planet International, 42: 67–75

Benovic, A., Lucic, D., Onofri, V. 2000. Does change in an Adriatic Hydromedusan fauna indicate an early phase of marine ecosystem destruction? *Marine Ecology*, 21: 221 - 231

Binkley, F., Brown, M. 1993. Toxic effects of cadmium chloride on the haematology of fish, Tilapia mossambica. Zoological Society of Pakistan, 13: 141 - 154

Blundell, A., Hannam, J. A., Dearing, J. A. Boyle, J. F.2009. Detecting atmospheric pollution in surface soilsusing magnetic measurements: A reappraisal using an England and Wales database. *Environmental Pollution*, 157: 2878–2890

Boruvka, L., Vacek, O., Jehlicka, J. 2005. Principal component analysis as a tool to indicate the origin of potentially toxic elements in soils. *Geoderma*, 128 (3): 289–300

Brinkmann, R.1994. Lead pollution in soils adjacent to homes in Tampa, Florida. *Environmental Geochemistry and Health*, 16 (2): 59-64

Brown, L.R., Flavin, C., French, H. 1997. States of the world - 1997. W.W. Norton and Company, New York.

Buck, O., Niyogi, D. K., Townsend, C. R. 2004. Scale-dependence of land use effects on water quality of streams in agricultural catchments. *Environmental Pollution*, 130: 287–299

Bryan, G.W., Langston, R.J. 1992. Bioavailability, accumulation and effects of heavy metals in sediments, with special reference to United Kingdom estuaries: a review. *Environmental Pollution*, 76: 89-131

Camargo, J., Alonso, A. 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment. *Environment*. Int. 32: 831–849

Canbay, M., Aydin, A., Kurtulus, C. 2010. Magnetic susceptibility and heavy-metal contamination in top soils along the Izmit Gulf coastal area and IZAYTAS (Turkey). *Journal of Applied Geophysics*, 70: 46–57

Chartzoulakis, K., Klapaki, G. 2000. Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. Scientific Horticulture, 86(3): 247–260

Chen, T. B., Wong, J. W. C., Zhou, H. Y., Wong, M. H. 1997. Assessment of trace metal distribution and contamination in surface soils of Hong Kong. *Environmental Pollution*, 96: 61–68

Chen, X., Xia, X.H., Zhao, Y., Zhang, P. 2010. Heavy metal concentrations in roadside soils and correlation with urban traffic in Beijing, China. *Journal of Hazardous Materials*, 181: 640–646

Chino, M. 1981. In: Kitagishi, K. & Yamane, I. Eds: Heavy metal pollution in soils of Japan, Japan Science Congress Proceedings.

Chu, H.J., Lin, Y.P., Jang, C.S., Chang, T.K. 2010. Delineating the hazard zone of multiple soil pollutants by multivariate indicator kriging and conditioned Latin hypercube sampling. *Geoderma*, 158:242–251

Citizens Report. 1982. The State of India’s Environment. Centre for Science and Environment, New Delhi, India.

Clark John.1977.Water Supply and pollution control, An Arbour Science Publishers Inc., MICH.

Cognetti, G. 1994. Colonization of brackish waters. Marine Pollution Bulletin, 28: 583 - 586

Cognetti, G. 1999. Conservation strategies in the Mediterranean. Aquatic Conservation and Marine Fresh Water Ecosystems,9: 509 - 515

Cognetti, G., Maltagliati, F. 2000. Biodiversity and adaptive mechanisms in brackish water fauna. Marine Pollution Bulletin, 40: 7 - 14

Cornish, G., Mensahh, A. 1999. Water quality and peri-urban irrigation. Report OD/TN95 HR Wallingford, Wallingford, UK.

CPCB, 2008. Guidelines for water quality monitoring. MINARS/27/2007-08, Central Pollution Control Board, Parivesh Bhavan, East Arjun Nagar, New Delhi, 35p.

Cressie, N.1988. Spatial prediction and ordinary kriging. Mathematical Geology, 20(4): 405–421

Cui, Y., Zhu, Y., Zhai, R., Chen, D., Huang, Y., Qiu, Y. 2004. Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China. Environment International, 30: 785–791

Daily, G.C., Alexander, C.S., Erlich, P.R., Goulder, L.Z., Goulder, J., Matson, P.A., Mooney, H.A., Postal, S., Schneider, S.H., Tilman, D., Woodwell, G.M.1997. Ecosystem services; benefits supplied to human societies by natural ecosystems. Ecological Society of America; Issues in Ecology - Vol. 2. Washington, D.C.

DANIDA.1998. Environmental Profile of Mwanza Municipality, Mwanza Municipal Council. CBEM Kampsax

Das, M.H., Sinha, M.S. 1993. Statistical significance versus fit: Estimating the importance of individual factors in ecological analysis of variance. Oikos, 93: 505 - 516

DeFries, R., Asner, G., Houghoton, R. 2004. Ecosystem and Land Use Change. American Geophysical Union, Geophysical Monograph Series, Washington, DC

Degetto, S., Schintu, M., Contu, A., Sbrignadello, G. 1997. Active urea transport and an unusual basolateral membrane composition in the gills of a marine elasmobranches. *American Journal of Physiology*, 280: 16 – 24

Devi, S.K., Venugopal, P., Ramani, K.N., Lalitha S., Unnithan, R.V. 1979. Hydrographic features and water quality of Cochin backwaters in relation to industrial Pollution. *Indian Journal of Marine Science*, 8: 141-145

Dufresne, F., Bourget, E., Bernatchez, L. 2002. Differential patterns of spatial divergence in microsatellite and allozyme alleles: further evidence for locus specific selection in the acorn barnacle, Semibalanusbalanoides. Molecular Ecology, 11: 113 - 123

Evans, C.R., Galindo-Bect, M.S., Glenn, E.P., Page, H.M., Galindo-Bect, L.A., HernaHndez-AyoHn, J.M., Petty, R.L., GarcmHa-HernaHndez, J. 1999. Analysis of the Penaeid shrimp catch in the Northern Gulf of California in relation to Colorado River discharge. Fishery Bulletin.

FAO. 1998. Terms and definitions. FAO, Forest Resources Assessment Programme, Working Paper 1(FRA 2000), 17 p.

Facchinelli, A., Sacchi, E., Mallen, L. 2001. Multivariate statistical and GIS-based approach to identify heavy metal sources in soils, *Environmental Pollution*, 114: 313–324

Fayiga, A.O., Ma, L.Q., Cao, X., Rathinasabapathi, B.2004. Effects of heavy metals on growth and arsenic accumulation in the arsenic hyper accumulator PterisvittataL. *Environmental Pollution*, 132(2): 289–296

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Stephen, R.C.F., Chapin,S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A.,Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyderl, P.K.2005. Global consequences of land use. Science, 309: 570–574

Galbraith, L. M., Burns, C. W. 2007. Linking land-use, water body type and water quality in southern New Zealand.*Landscape Ecology*, 22: 231–241

Ghatak, P.Y., Kumar, G.F. 1992. Dissolved trace metal distributions in Port Jackson estuary (Sydney Harbour), Australia. Marine Pollution Bulletin, 46: 719 - 730

Giller, K.E., Witter, E., Mcgrath, S.P.1998. Toxicity of heavy metals to microorganisms and microbial processes in agricultural soils: a review. *Soil Biology and Biochemistry*,30(10): 1389-1414

Goovaerts, P., Webster, R., Dubois, J.P.1997. Assessing the risk of soil contamination in the Swiss Jura using indicator geostatistics. *Environmental Ecology Statistics*, 4(1): 49–64

Gregorio, G.B., Senadhira, D. 1993. Genetic analysis of salinity tolerance in rice (Oryza sativa L.). Theoritical and Applied Genetics, 86(2-3): 333–338

Gyanath, O.P. 2000. CensoNacional de Poblacio´n, Hogares y viviendas. Result adosprovisionales. Volumen 1, Total del paý´s. Republica Argentina – InstitutoNacionaldeEstadý´stica y Censos, Buenos Aires.

Haidary, A., Amiri, B. J., Adamowski, J., Fohrer, N., Nakane, K. 2013. Assessing the impacts of four land use types on the water quality of wetlands in Japan. *Water Resource Management*, 27: 2217–2229

Hall, R. 1994. Gold and Green. Institute for Southern Studies. Southern Exposure, 4 - 6.

Hayes, A.W and Kruger, C.L. 2000. Hayes' Principles and Methods of Toxicology, sixth edition. CRC Press, London

Haque, N., Peralta-Videa, J.R., Jones, G.L., Gill, T.E., Gardea-Torresdey, J.L. 2008. Screening the phytoremediation potential of desert broom (BaccharissarothroidesGray) growing on mine tailings in Arizona, USA. Environmental Pollution, 153: 362–368

Heberer, T. 2002. Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: a review of recent research data. Toxicology Letter, 131(1): 5–17

Hoelzel, A.R. 1998. Molecular Genetic Analysis of Populations. Oxford University Press, Oxford.

Hoffmann, A. A., Parsons, P. A. 1991. Respiratory responses to hypoxia in fish. American Zoology, 13: 475 - 489.

Huertas, M., Gisbert, E., Rodryguez, A., Cardona, L., Williot, P., CastelloOrvay, F. 2002. Acute exposure of Siberian sturgeon (Acipenserbaeri, Brandt.) yearlings to nitrite: median-lethal concentration (LC50) determination, hematological changes and nitrite accumulation in selected tissues. Aquatic Toxicology, 57: 257 - 266

Hussain, M. A. 1976. Preliminary observations of pollution of Lake Hussainsagar caused by industrial effluents. *International Journal of Environmental Health*, 18: 227 - 236

IPCS, 1991. Environmental health criteria 108, Nickel, International programme on chemical safety, WHO, Geneva.

Islam, M.S., Ahmed, M.K., Al-Mamun, M.H., Hoque, M.F. 2014a. Preliminary assessment of heavy metal contamination in surface sediments from a river in Bangladesh. Environment Earth Science. http://dx.doi.org/10.1007/s12665-014-3538-5.

Islam, M.S., Han, S., Ahmed, M.K., Masunaga, S. 2014b. Assessment of trace metal contamination in water and sediment of some rivers in Bangladesh. *Journal of Water Environment Technology*, 12: 109–121

Ivan Fernandez, 2002. Cadmium in Fertilizers: To Catch a Killer. Frost & Sullivan Market Insight. http://www.frost.com/prod/servlet/market-insight-print.pag?docid=JEVS-5N2GU5

Jameson, K.L., Rana, R.F. 1996. Identification of freshwater and anadromous inconnu in the Mackenzie River system by analysis of otolith strontium. *Transactions of the American Fisheries Society*, 130: 725 - 741

Jaya, D.S., Lekshmi, K. 2007. Studies on the distillery effluent characteristics and its impact on Vembanadlake in the industrial area of Varanadu in Alappuzha. *Journal of Industrial Pollution Control*, 23(2): 271-277

Jayapalan, A.P., Sasidharan, K.M., Nair, V.A. 1976. Some aspects of the physiochemical and biological variations in Periyar water due to the effluent discharge from FACT, Bulletin from Department of Fisheries, Kerala. 1, 1976, 47-59

Jackson, M.L., 1973. Soil chemical analysis. Prentice Hall, INC, Englewood cliff, NJ.1958

Jensen, F.B. 2003. Nitrite disrupts multiple physiological functions in aquatic animals. *Comparative Biochemical Physiology*, 135A: 9 - 24

Johnson, L. B., Richards, C., Host, G. E., Arthur, J. W. 1997. Landscape influences on water chemistry in Midwestern stream ecosystems. *Freshwater Biology*, 37(1): 193–208

Joseph, K.J., Nambisan, P.N.K., Shynamma, C.G., Lakshmanan, P.T. 1984. Studies on phytoplankton in polluted waters. *Journal of Marine Biology Association of India*, 26: 42 - 46

Joy, C.M. 1989. Growth response of phytoplankton exposed to industrial effluents in river Periyar. Ph.D. Thesis. Cochin University, Kerala.

Juang, K. W., Chen, Y. S., Lee, D. Y. 2004. Using sequential indicator simulation to assess the uncertainty of delineating heavy-metal contaminated soils. *Environment Pollution*, 127: 229–238

Juang, K. W., Liao, W.J., Liu, T. L., Tsui, L., Lee, D.Y. 2008. Additional sampling based on regulation threshold and kriging variance to reduce the probability of false delineation in a contaminated site. *Science Total Environment*, 389: 20–28

Kabata-pendias, A., Mukherjee, A.B. 2007. Trace elements from soil to humans, Berlin, *Springer Verlag*.

Karim, Z., Qureshi, B.A., Mumtaz, M., Qureshi, S. 2014. Heavy metal content in urban soils as an indicator of anthropogenic and natural influences on landscape of Karachi- A multivariate spatio-temporal analysis. *Ecological Indicators*, 42: 20–31

Karl, E.R., Knudsen, and P.K. Jensen, F.B. 1997. Recovery from nitrite-induced methaemoglobinaemia and potassium balance disturbances in carp. *Fish Physiology*. Biochemistry, 16: 1-10

Karr, H., Chu, V. 1999. Particulate trace metal and major element distributions over consecutive tidal cycles in Port Jackson Estuary, Australia. *Environmental Geology*, 4: 231-239

Karr, J.R., Chu, E. W. 1995. Ecological integrity: Reclaiming lost connections. *In*: Perspectives on Ecological Integrity, Karr (Ed.). Klunia, Dordrecht, Netherlands. p. 34-48

Khaleel, R., Reddy, K.R., Overcash, M.R.1981. Changes in soil physical properties due to organic waste applications: a review. *Journal of Environment Quality*, 10(2): 133–141

Khan S, Cao Q, Zheng YM, Huang YZ, Zhu, Y.G. 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution*, 152(3): 686–692

Krishna, A.K., Satyanarayanan, M., Govil, P.K. 2004. Assessment of heavy metal pollution in water using multivariate statistical techniques in an industrial area: A case study from Patancheru, Medak District, Andhra Pradesh, India. *Journal of Hazardous Materials*, 167: 366-373

Lamb, J.C. 1985. Water Quality and its control. John Wiley & sons, New York.

Lathrop, R. G., Zampella, R. A., Procopio, N. A. 2007. Relationship of land use and cover patterns and surface-water quality in the Mullica River basin? *Journal of the American Water Resources Association*, 43(3): 594–604

Lee, J.J., Jang, C.S., Wang, S.W., Liu, C.W. 2007. Evaluation of potential health risk of arsenic affected groundwater using indicator kriging and dose response model. Science of the Environment, 384: 151–162

Lee, S. W., Hwang, S. J., Lee, S. B., Hwang, H. S., Sung, H. C. 2009. Land scape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics. Landscape and Urban Planning, 92(2): 80–89

Leonard, P.L. 2002. Factors affecting brain cholinesterase activity in bluegill (Lepomismacrochirus). Water Air Soil Pollution, 135: 249-264

Li, J.H., Lu, Y., Yin, W., Gan, H.H., Zhang, C., Deng, X.L., Lian, J. 2009. Distribution of heavy metals in agricultural soils near a petrochemical complex in Guangzhou, China. Environmental Monitoring and Assessment, 153: 365–375

Li, S., Gu, S., Tan, X., Zhang, Q., 2009. Water quality in the upper Han River basin, China: the impacts of land use/land cover in riparian buffer zone. *Journal of Hazardous Materials*, 165: 317–324

Li, S., Xia, X., Tan, X., Zhang, Q. 2013. Effects of catchment and riparian landscape setting on water chemistry and seasonal evolution of water quality in the Upper Han River Basin, China. PLoS One, 8(1), e53163

Li, Y., Wang, S., Cui, X. 2011. The different land-use types characteristics of heavy metals pollution in China's northeastern old industrial base. *Environment Science Management*, 36(3): 118–22

Lim, H.S., Lee, J.S., Chon, H.T., Sager, M. 2008. Heavy metal contamination and health risk assessment in the vicinity of the abandoned Songcheon Au–Ag mine in Korea. *Journal of Geochemical Exploration*, 96: 223–230

Lin, Y., Hong, M., Han, G., Zhao, M., Bai, Y., Chang, S.X. 2010. Grazing intensity affected spatial patterns of vegetation and soil fertility in a desert steppe. *Agriculture, Ecosystems and Environment*, 138: 282–292

Liu, P., Zhao, H.,Wang, L., Liu, Z., Wei, J.,Wang, Y., Jiang, L., Dong, L., Zhang, Y. 2011. Analysis of heavy metal sources for vegetable soils from Shandong Province, China. *Agricultural Science of China*, 10: 109–119

Liu, W., Zhang, Q., & Liu, G. 2012. Influences of watershed landscape composition and configuration on lake-water quality in the Yangtze River basin of China. *Hydrological Process*, 26: 570–578

Liu, Z., Li, Y., Li, Z. 2009. Surface water quality and land use in Wisconsin, USA GIS approach. *Journal of Integrative Environmental Sciences*, 6(1): 69-89

Lombi, E., Zhao, F.J., Zhang, G., Sun, B., Fitz, W., Zhang, H., McGrath, S.P.2002. In situ fixation of metals in soils using bauxite residue: chemical assessment. *Environmental Pollution*, 118(3): 435–443

Lu, S. G., Bai, S. Q., Cai, J. B., Xu, C. 2005. Magnetic properties and heavy metal contents of automobile emission particulates. *Journal of Zhejiang University of Science*, 6: 731–735

Lu, S. G., Bai, S. Q., Fu, L. X. 2008. Magnetic properties as indicators of Cu and Zn contamination in soils. *Pedosphere*, 18: 479–485

Lugon-Moulin, N., Ryan, L., Donini, P., Rossi, L. 2006. Cadmium content of phosphate fertilizers used for tobacco production (PDF). *Agronomic Sustainability and Development*, 26: 151–155. doi:10.1051/agro:2006010. Retrieved27 June 2014

Luo, W., Lu, Y., Gisey, J.P., Wang, T., Shi, Y., Wang, G., Xing, Y. 2007. Effects of land use on concentrations of metals in surface soils and ecological risk around Guanting Reservoir, China. *Environment and Geochemical Health* 29: 459–471

Mathur, D.S. 1965. Toxicity of Aldrin to certain fish. *Science and Culture*, 35: 418-419

Matson, P.A., Parton, W.J., Power, A.G., Swift, M.J., 1997. Agricultural intensification and ecosystem properties. *Science*, 277: 504–509

McGrath, S.P. 1995. Nickel. *In*: Heavy metals in soils (2nd edn.)(ed. Alloway, B.J), Blackie Academic and Professional, London.

McLaughlin, M. J., Tiller, K. G., Naidu, R., Stevens, D. P. 1996. Review: the behaviour and environmental impact of contaminants in fertilizers. *Soil Research*. 34: 1–54. Doi:10.1071/sr9960001

Mdamo, A. 2001. Accumulation of Nutrients and Heavy Metals in plants at Kagondo natural Wetland (Draft Paper).

Michael, M.I., Hilmy, A.M., El-Domiaty, N.A., Wershana, K. 1987. Serum transaminases activity and histopathological changes in Clariuslazera chronically exposed to nitrite. Compendium of Biochemical Physiology, 86C: 255 - 262

Mico, C., Recatala, L., Peris, M., Sanchez, J. 2006. Assessing heavy metal sources in agricultural soils of an European Mediterranean area by multivariate analysis, *Chemosphere*, 65: 863–872

Morgan, R. 2013. Soil, heavy metals, and human health. *In*: Brevik, E.C. & Burgess, L.C. (eds) Soils and human health. Boca Raton. FL: CRC Press, 59-80

Morrice, J.A., Danz, N.P., Regal, R.R., Kelly, J.R., Niemi, G.J., Reavie, E.D., Hollenhorst, T., Axler, R.P., Trebitz, A.S., Cotter, A.M., Peterson, G.S. 2008. Human influences on water quality in Great Lakes coastal wetlands. *Environment Management*, 41(3): 347-357

Mosley, L., Sarabjeet S. and Aalbersberg, B. 2004. Water quality monitoring in Pacific Island countries. Handbook for water quality managers & laboratories, Public Health officers, water engineers and suppliers, Environmental Protection Agencies and all those organizations involved in water quality monitoring (1st Edition). 43 p; 30 cm, ISSN: 1605-4377: SOPAC, The University of the South Pacific. Suva - Fiji Islands.

Nadia, M. A. 2006. Study on effluents from selected sugar mills in Pakistan: Potential environmental, health, and economic consequences of an excessive pollution load: Sustainable Development Policy Institute. Islamabad, Pakistan.

Ngoye, E., Machiwa, J.F. 2004. The influence of land use patterns in the Ruvu river watershed on water quality in the river system. *Physical Chemistry of Earth*, 29: 1161–1166

Nguyen, H.L., Leermakers, M., Kurunczi, S., Bozo, L., Baeyens, W. 2005. Mercury distribution and speciation in lake Balaton, Hungary. *Science Total Environment*, 340: 231–246

Nicholson, F,A., Smith, S.R., Alloway, B.J., Carlton-Smith, C., Chambers, B.J.2003. An inventory of heavy metals inputs to agricultural soils in England and Wales. *Science Total Environment*, 311(1): 205–219

Ozkan, K. 2011. Climate change effects on nitrogen loading from cultivated catchments in Europe: implications for nitrogen retention, ecological state of lakes and adaptation *Hydrobiologia*, 663: 1–21

Papa, S., Bartoli, G., Pellegrino, A., Fioretto, A. 2010. Microbial activities and trace element contents in an urban soil. *Environment Monitoring and Assessment*, 165: 193–203

Patz, J.A., Daszak, P., Tabor, G.M., Aguirre, A.A., Pearl, M., Epstein, J.2004. Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence. *Environment Health Perspective*, 112: 1092–1099

Paul, A.C. and Pillai, K.C. 1986. Geochemical transport of trace metals in Periyar River. Proceedings of Seminar on Status of Environmental Studies in India.p. 357 - 362

Paul, A.C., Pillai, K.C. 1978. Pollution profile of a river. *Water, Air and Soil Pollution*, 10: 133 - 146

Pielke, R. A.2005. Land use and climate change. *Science*, 310: 1625–6

Piper, C. S. 1966. Soil and plant analysis. Hans publishers, Bombay, 368 p.

Pourrut, B., Shahid, M., Dumat, C., Winterton, P., Pinelli, E. 2011. Lead uptake, toxicity, and detoxification in plants. *Environment Contamination and Toxicology*, 213: 113–136

Pratt, B., Chang, H. 2012. Effects of land cover, topography, and built structure on seasonal water quality at multiple spatial scales. *Journal of Hazardous Materials*, 209–210: 48–58

Pretty, J. 2008. Agricultural sustainability: concepts, principles and evidence. Philosophical Transactions of the Royal Society of Biological Science, 363: 447-465

Rajaguru, P., Subburam, V. 2000. Ground water quality in Tirupur, Proceedings of the Symposium and Workshop on Environmental Awareness on Quality Management of Irrigation Water. Bharathiar University, Coimbatore, 69p.

Rakesh Kumar., R.D. Singh., K.D. Sharma. 2005. Water resources of India. *Current Science*, 89: 794-811

Rashed, M.N. 2010. Monitoring of contaminated toxic and heavy metals, from mine tailings through age accumulation, in soil and some wild plants at Southeast Egypt. *Journal of Hazardous Materials* 178: 739–746

Reghunath, 1987. Ground water Hydrology, 2nd Edition, John Wiley and Sons Inc., NY, 563p.

Ribolzi, O., Cuny, J., Sengsoulichanh, P. 2011. Land use and water quality along a Mekong tributary in northern Lao P.D.R. *Environmental Management*, 47 (2): 291 -302

Rimer, A. E., Nissen, J. A., Reynolds, D. E. 1978. Characterization and impact of storm water runoff from various land cover types. *Journal of Water Pollution Control Federation*, 50(2): 252–264

Romic, M., Romic, D. 2003. Heavy metals distribution in agricultural top soils in urban area. *Environmental Geology*, 43(7): 795–805

Sahu, M.J., Philip, G.H., Rajasree, B.H. 1994. Action of cypermethrin on tissue transamination during nitrogen metabolism in Cyprinus carpio.*Ecotoxicology and Environment Safety*, 34: 174 - 179

Salem, H. M., Eweida, A., Azza, F. 2000. Heavy metals in drinking water and their environmental impact on human health, Centre for Environmental Hazards Mitigation, p: 542- 556

Salequzzaman, M., Tariqul, I. S. M., Tasnuva, A., Kashem, M. A. and Mahedi Al Masud, M. 2008. Environmental impact of sugar industry - a case study on Kushtia Sugar Mills in Bangladesh: Khulna: Green World Foundation.

Sankaranarayanan, V.N., Gopalakrishnan, T.C., Balasubramanian, T. B., Lalithambika, D., Krishnankutty, M. 1989. Environmental conditions of some paddy cum prawn culture fields of Cochin backwaters; south west coast of India. *Indian Journal of Marine Science*, 17: 24 - 30

Savvides, C., Papadopoulos, A., Haralambous, K.J., Loizidou, M. 1995. Sea sediments contaminated with heavy metals: Metal speciation and removal. *Water Science Technology*, 32: 65 – 73

Scheffer, M., Carpenter, S., Foley, J. A., Folke, C., Walker, B. 2001. "Catastrophic shifts in ecosystems". *Nature*, 413: 591–596

Senesi, G.S., Baldassarre, G., Senesi, N., Radina, B. 1999. Trace element inputs by anthropogenic Megacity of Lagos. A Poster Presented at the Diffuse Pollution Conference, Dublin 2003.

Sheppard, S.C.1998. Geophagy: Who eats soil and where do possible contaminants go? *Environmental Geology*, 33: 109-114

Shi, G., Chen, Z., Xu, S., Zhang, J., Wang, L., Bi, C., Teng, J. 2008. Potentially toxic metal contamination of urban soils and roadside dust in Shanghai, China. *Environmental Pollution,* 156: 251–260

Silas, E.G., Pillai, V.K. 1976. Water pollution and fish mortality in the Cochin backwater. National Seminar on Environmental Pollution Souvenir, Cochin.

Silva, L.F.O., Oliveira, M.L.S., Neace, E.R., O'Keefe, J.M.K., Henke, K.R., Hower, J.C. 2011. Nanominerals and ultrafine particles in sublimates from the Ruth Mullins coal fire, Perry County, Eastern Kentucky, USA. *International Journal of Coal Geology*, 85: 237–245

Silva, L.F.O., Sampaio, C.H., Guedes, A., Fdez-Ortiz de Vallejuelo, S., Madariaga, J.M. 2012. Multi analytical approaches to the characterisation of minerals associated with coals and the diagnosis of their potential risk by using combined instrumental micro spectroscopic techniques and thermodynamic speciation. Fuel, 94: 52–63

Smith, J.L., Halvorson, J.J., Papendick, R.I. 1993. Using multiple-variable indicator kriging for evaluating soil quality. *Soil Science Society of America Journal*, 57(3): 743–749

Sonoda, K., Yeakley, J. A., Walker, C. E. 2001. Near-stream land use effects on stream water nutrient distribution in an urbanizing watershed. *Journal of the American Water Resources Association*, 37(6): 1517–1532

Spijker, J., Mol, G., Posthuma, L.2011. Regional ecotoxicological hazards associated with anthropogenic enrichment of heavy metals. *Environment and Geochemical Health*, 2011: 1-18

Stormer, J., Jensen, F.B., Rankin, J.C. 1996. Uptake of nitrite, nitrate and bromide in rainbow trout, Oncorhynchusmykiss: effects on ion balance. *Canadian Journal of Fish Aquatic Science*, 53: 1943 - 1950

Sun, R., Wang, Z., Chen, L., Wang, W. 2013. Assessment of surface water quality at large watershed scale: Land-use, anthropogenic, and administrative impacts. *Journal of the American Water Resources Association*, 49(4): 741–752

Sun, Y.B., Zhou, Q.X., Xie, X.K., Liu, R. 2010. Spatial, sources and risk assessment of heavy metal contamination of urban soils in typical regions of Shenyang, China. *Journal of Hazardous Materials*, 174: 455–462

Szefer, P., Geldon, J., Ahmed Ali, A., Paezosuna, F., Ruiz-Fernandes, A.C., Guerro-Gaivan, S.R. 1998. *Environmental International*, 24 (3): 359-374

Tamer, A., Elbana,G., Malak, A., Hesham, M., Mohamed, H., Bahnassy.C., FawzyKishk, M., Selim, H.M. 2013. Heavy metals accumulation and spatial distribution in long term wastewater irrigated soils. *Journal of Environmental Chemical Engineering*, 1: 925–933

Tariq, M., Ali, M., Shah, Z. 2006. Characteristics of industrial effluents and their possible impacts on quality of underground water; Soil Science Society of Pakistan Department of Soil & Environmental Sciences, NWFP Agricultural University, Peshawar.

Tavares, M.T., Sousa, A.J., Abreu, M.M. 2008. Ordinary kriging and indicator kriging in the cartography of trace elements contamination in São Domingos mining site (Alentejo,Portugal). *Journal of Geochemical Exploration*, 98: 43–56

Thornton, J.A., Nduku, W.K. 1982. Lake McIlwaine: the eutrophication and recovery of a tropical African Lake. Dr. W. Junk Publishers, The Hague, The Netherlands.

Thuy, H.T.T., Tobschall, H.J., An, P.V. 2000. Distribution of heavy metals in urban soils – a case study of Danang-Hoian Area (Vietnam). *Environmental Geology*, 39 (6): 603-610

Tipping, E., Rieuwerts, J., Pan, G., Ashmore, M.R., Lofts, S., Hill, M.T.R., Thornton, I. 2003. The solid solution partitioning of heavy metals (Cu, Zn, Cd, Pb) in upland soils of England and Wales. *Environmental Pollution*, 125(2): 213–225

Tong, S.T.Y., Chen, W. 2002. Modeling the relationship between land use and surface water quality. *Journal of Environmental Management*, 66: 377-393

Trivedi, R. K., Goel, P.K. 1984. River pollution in India. Ashish Publication House, New Delhi.

Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I., Thies, C. 2005. Land scape perspectives on agricultural intensification and biodiversity ecosystem service management. Ecology Letters, 8: 857–874

Tu, J.2011. Spatially varying relationships between land use and water quality across an urbanization gradient explored by geographically weighted regression. *Applied Geography*, 31: 376–392

Tu, J. 2013. Spatial variations in the relationships between land use and water quality across an urbanization gradient in the watersheds of Northern Georgia, USA. *Environmental Management*, 51(1): 1–17

Tye, A.M., Young S., Crout, N.M.J., Zhang, H., Preston, S., Zhao F.J., McGrath, S.P. 2004. Speciation and solubility of Cu, Ni and Pb in contaminated soils, *European Journal of Soil Science,* 55: 579–590

UNDTCD.1991. Criteria for and Approaches to Water Quality Management in Developing Countries: Natural Resources Water Series No.20, United Nations, New York.

UNESCO, WHO and UNEP.1996. Water quality assessments - A guide to use of biota, sediments and water in environmental monitoring - Second Edition. Chapman & Hall, London

Ure, A.M., Quevauviller, P.H., Muntau, H., Griepink, B. 1992. B. EUR report. CEC Brussels, 14763: 1992:85

USEPA (U.S.Environmental Protection Agency). 1996. Liquid assets- a summer time perspective on the importance of clean water to the nation's economy. Office of the Water Report No.800- R-96-002, Washington.

Van Meirvenne M., Meklit, T.2010. Geostatistical simulation for the assessment of regional soil pollution. *Geographic Analysis*, 42: 121–135

Verma, S.R., Shukla, G.R. 1969. Pollution in a perennial stream Khala by the sugar factory effluent near Lakshar, district Saharanpur, *Indian Journal of Environmental Health*, 11: 145 –147

Verma, S.R., Tyagi, A.P., Dalela, R.C. 1978. Pollution studies of the rivers of Western India with special reference to biological indices. Proceedings of the Indian Association of Sciences, 87: 123- 131

Vimal, O.P., Talashikar, S.G. 1985. Recycling of sewage waste in agriculture, problems. *Journal of Science Research*, 44: 126 - 142

Walker, T.R., Crittenden, P.D., Dauvalter, V.A., Jones, V., Kuhry, P., Loskutova, O., Mikkola, K., Nikula, A., Patova, E., Ponomarev, V.I., Pystina, T., Rätti, O., Solovieva, N., Stenina, A., Virtanen, T., Young, S.D. 2009. Multiple indicators of human impacts on the environment in the Pechora Basin, north-eastern European Russia. *Ecological Indicators*, 9: 765–779

Walkley, A., Black, I. A. 1934. An examination of degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37: 29-37

Walters, D. 2007. Designing Community, Charrettes, Master plans and Form-based Codes, Oxford, UK.

Wan, R., Cai, S., Li, H., Yang, G., Li, Z., Nie, X. 2014. Inferring land use and land cover impact on stream water quality using a Bayesian hierarchical modeling approaching the Xitiaoxi River Watershed, China. *Journal of Environmental Management*, 133: 1–11

Wang, Q., Yamabe, K., Narita, J., Morishita, M., Ohsumi, Y., Kusano, K., Shirai, Y., Ogawa H.I. 2001. Suppression of growth of putrefactive and food poisoning bacteria by lactic acid fermentation of kitchen waste process. *Biochemistry*, 37: 351–357

Wang, G., Yinglan, A., Jiang, H., Fu, Q., Zheng, B. 2014. Modelling the source contribution of heavy metals in surficial sediment and analysis of their historical changes in the vertical sediments of a drinking water reservoir. *Journal of Hydrology* doi: http://dx.doi.org/10.1016/j.jhydrol. 2014.11 .034

Wei, B.G., Yang, L.S. 2010. A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Micro chemical Journal*, 94: 99–107

White, C. S. 1976. Factors influencing natural water quality and changes resulting from land-use practices. Water, Air and Soil Pollution, 6(1): 53–69

White, M.D., Greer, K.A. 2006. The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Penasquitos Creek, California. Land- scape and Urban Planning, 74: 125–138

Wilson, D.1997. Business Fear In The Fields – How Hazardous Wastes Become Fertilizer – Spreading heavy metals on farmland is perfectly legal, but little research has been done to find out whether it's safe. Seattle Times Newspaper, 3rd July 1997

Woli, K.P., Nagumo, T., Kuramochi, K., Hatano, R. 2004. Evaluating river water quality through land use analysis and N budget approaches in livestock farming areas. *Science Total Environment*, 329: 61–74

Wuana, R. A. and Okieimen, F. E. 2011. Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation.*ISRN Ecology*. Article ID402647, 20 pages,http://dx.doi.org/10.5402/2011/402647

Wu B., Wang G., Wu J., Fu Q., Liu C. 2014. Sources of heavy metals in surface sediments and an ecological risk assessment from two adjacent plateau reservoirs. *PLoS ONE*, 9(7): e102101. doi:10.1371/journal.pone.0102101

Xu, J., Sharma, R., Fang, J., Xu, Y. 2008. Critical linkages between land-use transition and human health in the Himalayan region. *Environmental Indicators*, 34: 239–247

Yang, C., Wu, Z., Zhang, H., Guo, R., Wu, Y.2009. Risk assessment and distribution of soil Pb in Guangdong, China. Environment Monitoring and Assessment, 159: 381–391

Yu, J., Huang, Z., Chen, T., Qin, D., Zeng, X., Huang, Y. 2012. Evaluation of ecological risk and source of heavy metals in vegetable-growing soils in Fujian province, China. *Environment Earth Science*, 65: 29–37

Yuan, G.L., Sun, T.H., Han, P., Li, J., Lang, X.X. 2014. Source identification and ecological risk assessment of heavy metals in top soil using environmental geochemical mapping: typical urban renewal area in Beijing, China. *Journal of Geochemical Explore*, 136: 40–67

Zapata, F., Roy, R.N. 2004.Use of Phosphate Rocks for Sustainable Agriculture: Secondary nutrients, micronutrients, liming effect and hazardous elements associated with phosphate rock use. www.fao.org. FAO. Retrieved 27 June 2014

Zeng, G., Liang, J., Guo, S., Shi, L., Xiang, L., Li, X. 2009. Spatial analysis of human health risk associated with ingesting manganese in Huangxing Town, Middle China. *Chemosphere*, 77: 368–375

Zhao, Y., Xu, X., Sun, W., Huang, B., Darilek, J., Shi, X.2008. Uncertainty assessment of mapping mercury contaminated soils of a rapidly industrializing city in the Yangtze River Delta of China using sequential indicator co-simulation. *Environment Monitoring and Assessment*, 138: 343–355

Zukowska, J., Biziuk, M.2008. Methodological evaluation of method for dietary heavy metal intake. *Journal of Food Science*, 73: 21–29

LIST OF PUBLISHED PAPERS

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Sreejesh K.K., Thomas T.P., Rugmini P., Prasanth K.M. and Kripa P.K. 2013. Carbon Sequestration Potential of Teak (Tectona grandis) Plantations in Kerala. *Research Journal of Recent Sciences*, 2: 167-170

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Heavy Metals and its Fractions in Soils of Koratty Region, Kerala

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Abstract

Heavy metal pollution of the environment is a universal problem and the soil often forms a repository of these elements. The developmental activities especially industrialization and high input agriculture contribute to accumulation of heavy metals to toxic levels in the soils. An attempt has been made to estimate the accumulation of heavy metals like iron, zinc, copper, cadmium, lead, nickel and manganese in the soil of Koratty region in central Kerala which has a history of industrialization. The various fractions of these heavy metals namely, exchangeable, reducible, oxidizable and residual fractions were determined to reveal the fate of these metals in soil. The fractionation was done following the BCR process suggested by European Community Bureau of Reference. Iron seemed to be the easily mobilized element, while cadmium and copper were least mobile. The order of mobility in the exchangeable fractions was Fe>Mn>Pb>Ni>Zn>Cu=Cd. The degree of contamination, enrichment factor, and index of geoaccumulation revealed that cadmium, nickel and lead are pollutants in Koratty region of Kerala.

Keywords: Heavy metal fractions, soil, environment, Koratty.

Introduction

Heavy metals in the environment has increased beyond acceptable levels due to human intervention through developmental activities including industries and agriculture. These heavy metals become toxic and they accumulate in soft tissues of animals when they enter body through food, water, air or the skin[1-4]. Heavy metal toxicity can cause several diseases affecting almost all the vital organs and functions[5-9]. Unlike organic pollutants, heavy metals do not decay and hence persist in the environment. They have the potential of bioaccumulation and biomagnification also[10]. Soil often forms a repository of these elements because soil particles such as clay and humus have charges that help the metal cations to bind themselves with the soil, and thus prevent their release, though temporarily. The soluble forms of heavy metals are more dangerous because they are readily available to plants and animals[11].

Sequential extraction of different forms of heavy metals helps in quantifying the fractions in different phases. The commonly used procedure is the BCR [Community Bureau of Reference of the European Commission] now referred as standards, measuring and testing programme. Different fractions determined following this procedure are exchangeable, reducible, oxidisable and residual fractions. The BCR procedure has been tested for sediments[12] and soils[13]. Pollution of the environment, particularly the soil is ascertained by calculating the enrichment factor, the contamination factor and the degree of contamination[14,15]**.** Index of geoaccumulation (Igeo) is also widely used in the assessment of contamination by heavy metals in terrestrial, aquatic and marine environment[16,17]**.**

Koratty region in central Kerala has an early history of industrialization and high input agriculture. Several industries such as the Government of India Press and Madurai Coats were established long ago followed by latest additions such as Carborandum Universal (CUMI), KINFRA and Infopark along with a multitude of small and medium industries. Heavy metal accumulation in the soils of this region thus assumes significance and hence this study to evaluate the heavy metals and their speciation.

Study Area: The study was conducted in Koratty in Thrissur district of Kerala, India situated between 10° 19' and 10° 32' N latitudes and 76° 29' and 76° 44' E longitudes. The region has a history of industrialization and major industries like Government of India Press and Madurai coats were established in 100 acre each though land was scarce even in those days. Modern agriculture was also encouraged in the region with hybrid varieties and high inputs of irrigation, fertilizers and pesticides. The impacts of these are expected to leave their imprints on the environment, especially soil. The soils in the area belong to the Koratty series which is lateritic with high content of sesquioxides. The climate is tropical with bimodal monsoons providing about 300cm of annual precipitation. The atmosphere is warm humid in most of the months.

Methodology

Soil samples to a depth of 40cm were collected from different regions in the study site and composite samples obtained representing each area. The samples were air dried, sieved through 2mm sieve and analysed for heavy metals. Extraction was done following hydrogen peroxide digestion and estimation using Varian

Atomic Absorption Spectrophotometer (AAS). The fractions of heavy metals were determined following the BCR (European Community Bureau of Reference) procedure. Degree of contamination was calculated using the formula $C_{deg=}\sum C^{i}_{f}$ where contamination factors of all the elements are taken into account. Contamination factor of each element was calculated using the formula $C^{i}_{f}= C^{i}_{0\text{-}1}/C^{i}_{n}$. Enrichment factor which gives an indication of heavy metals added to the environment other than from natural sources was determined using the formula, $EF_X=[X_S/E_S\ (ref)]/[X_c/E_c\ (ref)]$. Igeo which gives an assessment of contamination with reference to background levels was calculated using the formula Igeo = Log Cmetal/1.5 Cmetal (control).

Results and Discussion

Heavy metal contamination by cadmium, copper, iron, manganese, nickel, lead and zinc in the soils of Koratty region namely Government of India Press compound, Infopark compound and agricultural land is presented below.

Geoaccumulation index of heavy metals: Geoaccumulation index (Igeo) of heavy metals in the study sites is shown in table 1. It can be seen that all the elements studied had negative Igeo values. These negative values indicate that contamination of heavy metals by natural sources is almost absent at these sites.

Heavy metals and its fractions in different sites: Two of the bigger sites which hosted important industries in the region, namely the Government of India Press compound and the Infopark compound were studied along with the adjacent agricultural lands to find out the differences, if any, between the two types of land use. The heavy metal contents and its speciation are discussed below separately.

Site 1. GOI Press Compound: Heavy metals fractionated in different soil components in the compound of the Government of India Press is given in table 2 below.

Cadmium: Cadmium was found to be more in the residual fraction which was followed by organic matter fraction, Fe andMn fractions and exchangeable fraction in soils of GOI press site. But in the Infopark site the exchangeable, Fe andMn and residual fractions were almost equal; the organic matter fraction had the least amount of Cd. The pattern was different in the agricultural area with Fe and Mn fractions dominating which was followed by exchangeable, residual and organic matter fractions in order. There was not much difference between these sites in total fractions of Cd. The content of Cd in the above sites was also low except the agricultural sites which recorded higher Cd values.

Copper: Copper was present mostly in the residual fraction with lesser amounts in the organic matter, Fe and Mn and exchangeable fractions. This pattern was similar in all the 3 sites. The total fraction was not much different in the three sites. Copper was comparatively more in the industrial sites as compared to the agricultural areas. It is low in mobility and hence accumulates at the site of application.

Site 2. Infopark Compound: The different fractions of heavy metals in the soils of Infopark compound are presented in the table 3 below.

Table-1
Geoaccumulation index of heavy metals

Site	Cd	Cu	Fe	Mn	Ni	Pb	Zn
GOI Press	- 1.495	- 0.485	- 0.53	- 0.015	- 0.541	- 0.532	- 0.298
Infopark	- 1.128	- 0.048	- 0.159	- 0.22	- 0.436	- 0.047	- 1.014
Agriculture	- 0.585	- 0.585	- 0.471	- 0.096	- 0.054	- 0.532	- 0.386

Table-2
Heavy metal speciation in GOI press compound

Elements	Exchangeable ($mg\ kg^{-1}$)	Fe and Mn ($mg\ kg^{-1}$)	Organic matter ($mg\ kg^{-1}$)	Residual ($mg\ kg^{-1}$)	Total ($mg\ kg^{-1}$)
Cd	1.09	1.32	1.66	2.31	6.39
Cu	0.69	2.80	3.13	14.22	20.84
Fe	178.80	925.60	321.81	39216.50	40642.50
Mn	54.82	106.02	6.74	50.10	435.34
Ni	3.80	12.14	13.70	30.70	60.35
Pb	17.25	30.69	21.75	20.56	101.81
Zn	2.38	2.43	1.88	11.66	18.37

Table-3
Heavy metal speciation in Infopark compound

Elements	Exchangeable (mg kg^{-1})	Fe and Mn (mg kg^{-1})	Organic matter (mg kg^{-1})	Residual (mg kg^{-1})	Total (mg kg^{-1})
Cd	1.87	1.87	0.52	1.72	7.34
Cu	0.45	2.87	4.12	20.45	27.90
Fe	173.50	751.75	260.50	49427.50	50612.50
Mn	49.62	88.87	3.55	43.80	185.85
Ni	3.37	9.45	23.60	36.85	73.27
Pb	23.75	40.50	18.50	36.25	119.00
Zn	2.23	1.36	1.02	8.51	13.12

Table-4
Heavy metal speciation in the Agricultural lands

Elements	Exchangeable (mg kg^{-1})	Fe and Mn (mg kg^{-1})	Organic matter (mg kg^{-1})	Residual (mg kg^{-1})	Total (mg kg^{-1})
Cd	1.92	2.10	1.33	1.47	6.82
Cu	1.36	1.71	3.11	15.04	21.22
Fe	281.80	776.65	296.87	35799.00	37154.10
Mn	15.54	116.34	5.29	43.99	181.16
Ni	12.79	7.31	40.39	207.60	268.09
Pb	5.12	32.37	37.00	15.12	89.62
Zn	2.17	1.68	3.08	13.88	20.81

Iron: Residual fraction of iron was extremely high, Fe and Mn fraction came next which was followed by the organic matter fraction and the exchangeable fraction. This pattern was exhibited in all the 3 sites. The total fraction was only slightly more than the residual fractions and did not differ much between the 3 sites. Soils in the humid tropics are usually rich in sesquioxides which is the case here also and chances of iron pollution are thus more.

Manganese: Manganese was found to be more in the Fe andMn fraction in all the 3 sites. In the GOI site, this was followed by the exchangeable, residual and organic matter fractions. In the Infopark site the Fe and Mn fraction was followed by exchangeable, residual and organic matter fractions while in the agricultural area the pattern was Fe and Mn fraction followed by residual, exchangeable and organic matter fractions. The total fraction was more in the GOI press site but similar in the other two sites.

Site 3. Agricultural Area: Heavy metals present in different fractions of the soil in the agricultural landscape is provided in table 4 below.

Nickel: Most of the nickel occurred in the residual fraction which was followed by the organic matter, Fe and Mn and exchangeable fractions. This pattern existed in both GOI press and Infopark sites. In the agricultural area the residual fraction was the highest as was the case with the other 2 sites but the order of decrease was organic matter, exchangeable and Fe and Mn fractions. The total fraction of Ni was similar in the two industrial sites but was much higher in the agricultural area.

Lead: The fractions of lead in the soil followed a different pattern in the 3 sites. In the GOI press site, it was highest in Fe andMn fraction which was followed by the organic matter, residual and exchangeable fractions. In the case of Infopark site, Fe and Mn fraction was followed by the residual, exchangeable and organic matter fractions. On the other hand in the agricultural site, the organic matter fraction was highest which was followed by Fe and Mn fraction, residual fraction and exchangeable fractions. The total fraction was lesser in the agricultural area as compared to the industrial sites both of which had similar values.

Zinc: The residual fraction of Zn was greater than the other fractions in all the 3 sites. It was followed by Fe and Mn, exchangeable and organic matter fractions in the GOI press site while the pattern of distribution in the Infopark site was in the order of the residual fraction followed by the exchangeable, Fe and Mn and organic matter fraction. In the agricultural area, the organic matter fraction came next to the residual one which was followed by the exchangeable and Fe and Mn fractions.

Discussion: The results obtained was interpreted by calculating the enrichment factor and the contamination factor of heavy metals in the soils of the three sites and is discussed below.

Table-5
Enrichment factor of heavy metals

Site	Cd	Cu	Fe	Mn	Ni	Pb	Zn
GOI Press	5.62	0.71	1.00	0.17	2.6	4.38	0.22
Infopark	4.25	0.77	1.00	0.11	2.54	4.09	0.13
Agriculture	6.47	0.80	1.00	0.32	13.26	4.22	0.20

Table-6
Contamination factor of heavy metals

Site	Cd	Cu	Fe	Mn	Ni	Pb	Zn
GOI	6.52	0.83	1.16	0.19	3.02	5.09	0.26
Infopark	6.12	1.11	1.44	0.17	3.66	5.95	0.18
Agriculture	6.95	0.85	1.06	0.16	13.40	4.48	0.29

Enrichment Factor: Enrichment factor of heavy metals calculated using the continental crust average with Fe as reference element for normalization indicated that Cd, Ni and Pb have accumulated beyond the normal expected levels in the crust in all the three sites. Enrichment factor of Pb was moderate with values slightly less than 5 in all the three sites but that of Ni was moderate in the industrial sites and significantly high in the agricultural areas. Cd enrichment was significant in GOI press site and agricultural areas while moderate in the Infopark area. All the other heavy metals studied had only minimum enrichment factor table 5 and figure 1.

The moderately high enrichment factor of Pb is a potential source of bioaccumulation due to its mobility in the exchangeable fraction. Cd on the other hand has low mobility in all the fractions and hence chances of pollution of ground water is minimum. The enrichment factor for cadmium was more than three in all the sites with negligible Igeo values indicating anthropogenic factors in increasing Cd contamination in these sites. The high enrichment factor of nickel especially in the agricultural land is also a matter of concern due to its mobility and carcinogenic effect.

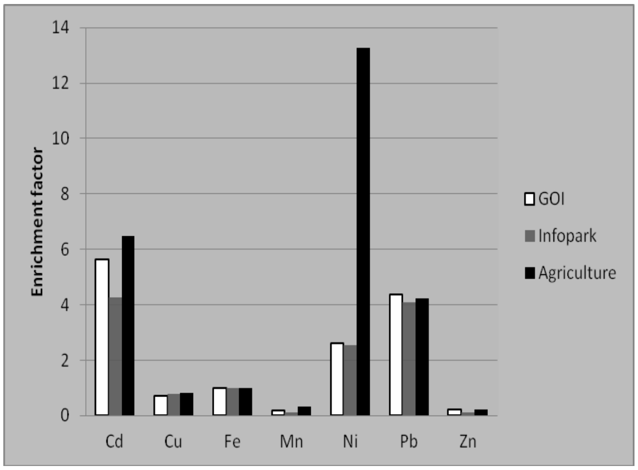

Figure-1
Enrichment factor of different elements in the three sites

Contamination Factor: Contamination factor which gives an idea of concentration of the element in relation to background concentration is shown in table 6 and figure 2.

It can be seen that all the three sites namely GOI press compound, Infopark compound and Agricultural area had moderate to high contamination of cadmium, nickel and lead. Iron, manganese, copper and zinc were low to moderate with respect to the contamination factor. Higher contamination levels of Cd, Ni and Pb in the three sites can be due to fertilizers, industrial effluents and vehicular traffic as well. The high concentration of Ni in the agricultural soil is probably due to phosphatic fertilizers, contaminated irrigation water or sewage water.

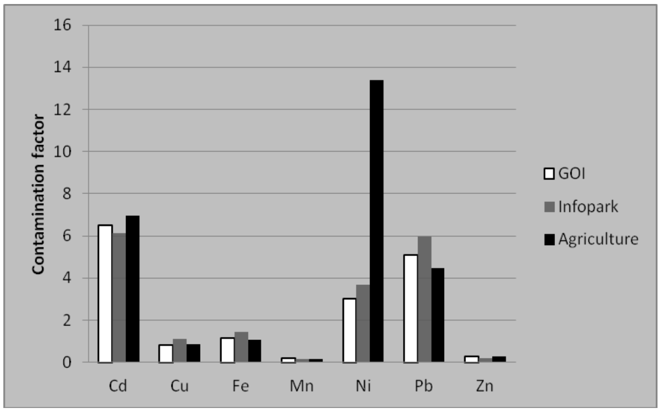

Figure-2
Contamination factor of different elements in the three sites

The speciation of heavy metals in Koratty region revealed different patterns with respect to the elements studied namely copper, iron, manganese, zinc, nickel, lead and cadmium. Copper and iron were mostly restricted to the residual fraction in both industrial and agricultural areas with slightly higher values in the industrial sites. Cu accumulates at the site of addition since it is not a mobile element while iron is comparatively mobile and hence easily transported through the soil. The Fe and Mn fraction contained maximum amount of Mn in both industrial and agricultural sites. Zinc was found to be more in the residual fraction in industrial as well as agricultural areas. Zinc is being enriched from fertilizers, hazardous waste, municipal sludge etc. Electroplating industries making use of electro galvanizing also release considerable amount of zinc into the surroundings. Being mobile, it is easily translocated with percolating water and can lead to pollution when higher amounts are added to the soil.

The residual fraction contained maximum nickel in all the sites irrespective of industrial or agricultural use. The total nickel content in the agricultural soil was much higher than the industrial sites. Fertilizers especially phosphates are a source of nickel in soil. More important is the application of waste disposal including sewage sludge. Predominantly high residual fractions of Ni has been reported by others also[18-21]**.** Nickel may be increasingly bound to organic matter, a part of which forms easily soluble chelates. The solubility and mobility of nickel increases with decreasing pH. Many nickel compounds are soluble at pH less than 6.5 and hence nickel contamination is a cause of concern.

Cadmium was found to be more in the residual and exchangeable fractions in the industrial sites while it was more in Fe and Mn fractions in the agricultural area. Cadmium content was low in most of the sampled sites except the agricultural areas where its values were high which is of concern due to chances of bioaccumulation in the cultivated crops since a preference for Cd is reported among plants[22]**.**

The pattern of speciation of lead was different from the above elements. It was highest in the Fe and Mn fractions in the industrial sites while the agricultural areas recorded more nickel in the organic matter fraction. Lead pollution is expected from printing industry which is reflected in the data also. Vehicular traffic is another major source of Pb through automobile emissions. Paint, plumbing materials, battery etc., also contribute to Pb contamination of the soil. The negative values of Igeo index indicates that enrichment of Pb was not from natural sources. In cultivated soils it was seen that Pb is largely held by organic matter, restricting its availability to the crops. But the acidic soils present in the area may increase the solubility and leaching of Pb to the ground water. Increase in mobility of lead with decreasing pH was also reported by Baranowski *et al*., 2002 [23]**.**

The results show that Cd, Ni andPb are pollutants in the study sites. Fe is the most mobile and Cd the least mobile among the elements and Cu, Mn and Zn contents were found to be low in the area.

Conclusion

Fractions of heavy metals determined using BCR sequencing extraction method showed that the order of mobility of metals was Fe>Mn>Pb>Ni>Zn>Cd>Cu. Contamination factors determined in the study gives an indication of site specific pollution. It was seen that the industrial sites were contaminated by Cd, Pb, Ni, Fe, Cu, Zn and Mn in decreasing order. The agricultural sites were contaminated by Ni, Cd, Pb, Fe, Zn, Cu and Mn in the same order. Enrichment factors reveal that the accumulated Cd, Pb and Ni are due to anthropogenic activities rather than from natural sources. The results show that Cd, Ni and Pb are pollutants in the area.

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References

1. Murhekar Gopalkrushna Haribhau, Trace metal contamination of surface water samples in and around Akot city, Maharashtra, India, *Res.J.Recent Sci.,***1(7),** 5-9 **(2012)**

2. Nwajei G.E., Obi-Iyeke G.E. and Okwagi P., Distribution of selected trace metals in fish parts from the River Nigeria, *Res.J.Recent Sci.,***1(1),** 81-84 **(2012)**

3. Sharma Pramila, Fulekar M.H. and Pathak Bhawana, E-Waste – A challenge for tomorrow, *Res.J.Recent Sci.,* **1(3),** 86-93 **(2012)**

4. Choudhary Ranjeeta , Heavy Metal Analysis of Water of Kaliasote Dam of Bhopal, MP, India, *Res.J.Recent Sci.,* **1 (ISC-2011),** 352-353 **(2012)**

5. Menc M., Didier V., Loffler M., Gomez A.and Masson P., A mimicked in-situ remediation study of metal contaminated soils with emphasis on cadmium and lead. J.Environ.Qual, **23,** 58-63 **(1994)**

6. Chirenje T., Ma L., Reeves M. and Szulczewski M., Lead distribution in near surface soils of two Florida cities: Gainesville and Miami, Geoderma, **119**, 113-120 **(2004)**

7. Biqing Shi, Zhaoyu and Lu zhenhua, Environmental pollution and human health, China Environ. Press, **(2008)**

8. Young R.A., Toxicity profiles: Toxicity summary for cadmium risk assessment information system, University of Tennessee **(2005)**

9. Goyer R.A and Clarkson T.W., Toxic effects of metals in Casarett and Doullis, In: Toxicology-The basic science of poisons, 6th edition, Macgraw-Hill, New York, 811-867 **(2001)**

10. Fagbote Emmanuel Olubunmi and Olanipekun Edward Olorunsola, Evaluation of the status of heavy metal pollution of soil and plant of Agbabi bitumen deposit area, Nigeria.Am-Euras, J,Sci.Res., **5(4)**, 241-248 **(2010)**

11. Srivastava K.P. and Singh Vikash Kumar, Impact of air pollution on pH of soil of Saran, Bihar, India, *Res. J. Recent Sci*., *Res.J.Recent Sci.*, **1(4),** 9-13 **(2012)**

12. Thomas R.P., Ure A.M., Davidson C.M and Little John D., Three –stage sequential extraction procedure for the determination of metals in river sediments, *Analytica Chimica Acta*, **286**, 423-429 **(1994)**

13. Davidson C.M, Duncan A.L, Little John D., Ure A.M and Garden L.M., A critical evaluation of the three stage BCR sequential extraction procedure to assess the potential mobility and toxicity of heavy metals in industrially contaminated land, *Analytica Chimica Acta,* **363**, 45-55 **(1998)**

14. Huu H.H., Rudy S., and Damme A.V., Distribution and contamination status of heavy metals in estuarine sediments near Cau Ong harbor, Ha Long Bay, Vietnam. *Geol. Belgica.,* **13(1-2)**, 37-47 **(2010)**

15. Rastmanesh F., Moore F., Kopaei M.K., Keshavarzi B. and Behrouz M. Heavy metal enrichment of soil in Sarcheshmeh copper complex, Kerman Iran, *Environ. Earth Sci.,* **62,** 329-336 **(2010)**

16. Muller G., Index of geoaccumulation in sediments of the Rhine river, *J. Geol,* 108-118 **(1969)**

17. Tijiani M.N and Onodera S., Hydro geochemical assessment of metal contamination in an urban drainage system: A case study of Osogbo township, SW Nigeria, *J. Water resources Prot.,* **3 (2009)**

18. Kabata-pendias A. and Mukherjee A.B. Trace elements from soil to human, Berlin, Springer Verlag **(2007)**

19. McGrath S.P., Nickel, In: Heavy metals in soils (2nd edn.) (ed. Alloway, B.J), London, Blackie Academic and Professional **(1995)**

20. Tye A.M., Young S., Crout N.M.J., Zhang H., Preston S., Zhao F.J., and McGrath S.P., Speciation and solubility of Cu, Ni and Pb in contaminated soils, *European J. Soil Sci.,* **55**, 579–590 **(2004)**

21. IPCS, Environmental health criteria 108, Nickel, International programme on chemical safety, WHO, Geneva **(1991)**

22. Alloway B.J., Cadmium In: Heavy metals in soils, second edition (Alloway, B.J ed.). Blackie, New York, 122-151 **(1995)**

23. Baranowski R., Rybak A. and Baranowska I. Speciation analysis of elements in soil samples by XRF, *Polish J. Environ. Studies,* **11**, 473-482 **(2002)**

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Aquatic Macroinvertebrates as Bioindicators of Stream Water Quality- A Case Study in Koratty, Kerala, India

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Abstract

The paper discusses the results of an attempt to test the suitability of aquatic macroinvertebrates as bioindicators of stream water quality in a natural water course locally referred as Koratty chal that runs through the length of agricultural lands in Koratty region. Rapid bioassessment protocol recommended by Environmental Protection Agency (EPA) was followed utilizing Kicknet and D'net of 500µm mesh size to sample the macroinvertebrates. Family Biotic Index (FBI) calculated using the tolerance value of different taxa showed that there was remarkable variation in water quality along the stream. FBI values were around 4.1-5.0 in upstream reaches indicating good water quality. Deterioration of water quality downstream was evidenced in the FBI value of 5.3-5.5 in the mid reaches and 6.0-6.5 in the lower reaches. These values were also found to be in conformity with the water quality as assessed at the biomonitoring sites. It is thus concluded that biomonitoring is feasible in such streams in the region to obtain a quick assessment of water quality.

Keywords: Aquatic macroinvertebrates, bioindicators, stream water quality, Koratty.

Introduction

Human intervention in the name of development has adversely affected many natural ecosystems all over the world, the cumulative impact of which is now threatening the very existence of man through global warming and climate change. Air, water and soil, the most important primary natural resources have become polluted beyond tolerable limits[1]. Fresh air and good quality potable water have become commodities. Natural forests which are capable of buffering the adverse effects to a great degree have been constantly suffering large scale conversions and degradation adding to the magnitude of the problem.

Industries and vehicular traffic release various toxic gases into the atmosphere including carbon dioxide, sulphur dioxide, nitrous oxide, chlorine etc., all of which contaminate the air, soil and water[2]. Modern farming with an eye on quick profits employs the use of synthetic fertilizers, pesticides, weedicides and hormones. Urbanisation and its consequent demands on space and facilities is yet another factor contributing to pollution of the environment.

Pollutants have an influence on the organisms and exposure of organisms to sub-lethal doses of stress (e.g. a pollutant chemical) over a long time period results in many interactions[3, 4, 5]. Initially these interactions may occur at the level of biochemical and cellular processes and lead to physiological effects such as disruption of respiratory, excretory, locomotary, feeding, circulatory, reproductive and neural phenomena in animals and photosynthetic, transpiratory, respiratory, growth and reproductive processes in plants and microorganisms. The structure of the DNA and chromosomes in the organism may be affected leading to modification and eventual evolution of organisms which are capable of withstanding the stresses. This pattern of evolution of resistance or tolerance to the stress factors also occurs in entire communities, for example, shifts in the composition of plant communities in the vicinity of polluted sites which could result in the evolution of plant species that accumulate metals[6].

Nature has its own way of indicating the health of the environment through indicator species of plants and animals, generally termed as bio indicators. Most ecological and environmental bio indicators have strong relationship with some characteristic of their environment[7, 8, 9]. Any deviation from the normal habitat conditions is reflected in alteration of their health, population and distribution.

A bio indicator can be defined as "a species or group of species that readily reflects the abiotic or biotic state of an environment, represents the impact of environmental change on a habitat, community or ecosystem, or is indicative of the diversity of a subset of taxa, or the whole diversity, within an area. Such organisms are monitored for changes (biochemical, physiological or behavioral) that may indicate a problem within their ecosystem. Bio indicators can tell us about the cumulative effects of different pollutants in the ecosystem.

Aquatic macro invertebrates are an integral part of the food chain in lotic environments and they are sensitive to changes in the environment though degrees of sensitivity differ among various groups. Communities of organisms integrate the impact of different stressors and thus provide a broad measure of their aggregate impact. Macro invertebrates have limited migration and their assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances and thus are particularly suited for assessing site specific impacts. They are most frequently used in bio monitoring since many of them are sensitive to pollution and integrate short term and long term effects of environmental stressors[10,11,12,13]. Different taxa have different habitat preferences and pollution tolerances. Absence of sensitive species and presence of tolerant ones indicate water quality deterioration. Various indices based on these criteria such as Hilsenhoff's Biotic Index (HBI), Invertebrate Community Index (ICI), Biological Monitoring Working Party Score (BMWP), Macro invertebrate Water Quality Index (MWQI), Average score per taxon, percent model affinity and EPT richness index have been used to evaluate water quality.

Study Area: Koratty region lies between 10° 19' and 10° 32' N latitudes and 76° 29' and 76°44' E longitudes and is situated in the central part of Kerala State. The landscape is a mixed mosaic of level to rolling land with low lying paddy fields interspersed in between. Mixed crops of coconut, are canut, banana, vegetables and cash crops such as nutmeg cover most of the land, though rubber plantations are on the increase and paddy fields on the decline. High input farming using fertilizers and pesticides is being followed by most farmers to obtain quick returns. Koratty region is also blessed with a multitude of industries. These units while supporting the development of the area also adds to the pollution of the environment due to their effluents. *Koratty chal* drains through the length of Koratty and hence the impact of various activities in the watershed is expected in the *Koratty chal*.

Methodology

Rapid Bio assessment Protocol developed by United States Environment Protection Agency[14] was followed for estimating the Family Biotic Index (FBI) by assigning specific tolerance values for different families of macro invertebrates in stream water. For sampling these macro invertebrates, a length of 100m stream reach was considered as a unit and the macro invertebrates sampled using D-frame net as also kicks net both of which were of 500µm mesh size. The kick net was placed downstream and the stream bottom substrates 1m above kicked to dislodge invertebrates clinging to debris and stones into the kick net. The contents in the net were emptied into bucket and invertebrates collected. The D frame net was employed to trap specimens clinging to vegetation, root mats etc., along the boundary. Riffles and pools were sampled separately to account for sub habitat variations. The collected specimens were preserved in jars containing either 70% ethanol. They were identified using a microscope with the help of standard keys and the Family Biotic Index calculated.

For standardizing the sampling intensity we went for various sampling trials and by plotting the family accumulation curve concluded that 26 composite samplings were enough to get representative data from 100m stream reach is represented in figure-1.

Water quality parameters such as pH, DO, temperature and flow velocity were recorded onsite and water samples collected and analysed for various other parameters in table-3. Family Biotic Index was calculated using modified Hielsenhoff's formula[15] and Water Quality Index using the CCME WQI method[16]. Wilcoxon Signed Rank statistic[17]. which is a non parametric statistic preferred over the Student's 't' test when comparing populations which are not normally distributed was utilized in the present study to test the null hypothesis of no significant difference between the three sites.

Results and Discussion

The stream, *Koratty Chal* has been studied with respect to the quality of water in three sections along its flow viz., upstream, midstream and downstream to ascertain variations in properties as also to test the feasibility of utilizing bioindicators of pollution in monitoring the deterioration in the quality of water. Family Biotic Index values given in table-1 and figure-2 clearly demonstrate that there existed a gradual decrease in water quality downstream with midstream recording intermediate values.

The Wilcoxon Signed Rank Test used to test the null hypothesis of no statistical difference in total taxa between the three sites revealed that the midstream section was not significantly different while the downstream portion was significantly different from the upstream section. These FBI values were found to be in conformity with the WQI values calculated based on analysis of water samples. Qualitatively, it was seen that the upstream reach of the *Koratty chal* had fair water, the midstream reach had water of marginal quality and the downstream reach recorded poor water quality.

The families of organisms identified are given in table 2. It can be seen that Ephemeroptera (may flies) were represented by five families, Plecoptera by two, Trichoptera (caddisflies) by three, Odonata (anisoptera and zygoptera) by seven, Coleoptera by three, Hemiptera by two and Diptera by five families, Decapoda, Hirudinea and Aquatic oligochaeta were also present which could not be identified upto family level.

Water quality as evidenced in various parameters on samples collected during pre and post monsoon periods of 2010 are given below in table-3. Samples were collected simultaneously from the same sections that were sampled for macro invertebrates and water was analyzed with respect to physico-chemical and biological properties. It could be seen that the water was acidic with some amount of salts as reflected in the electrical conductivity. Both these properties did not show any appreciable differences or notable trend along the length of the *Koratty chal*. On the other hand, DO, BOD, COD, TDS, nitrate, phosphate, fluoride, oil and grease and phenolic compounds were found to register a progressive increase as we move down the stream. Post monsoon values were higher as compared to the pre monsoon samples.

The land use in Koratty region with a predominantly agrarian economy is influenced more by market forces and thus a shift from traditional coconut - paddy cultivation to money spinning cash crops is evidenced. Rubber and nutmeg as well as banana and vegetables are gaining importance. Most of these crops necessitate higher inputs through fertilizers and pesticides to fetch quick profits. The impacts of such practices are evident in the values of nitrates, phosphates, pesticide residues and some of the heavy metals in Koratty chal. Industries and municipal waste along with vehicular traffic also would have contributed to some of these pollution seen downstream of the *Koratty chal*.

Heavy metals such as iron, manganese, nickel, lead, copper and zinc were not present in detectable quantities during the pre monsoon season though their presence was detected during the post monsoon season. Presence of heavy metals in detectable quantities in stream water is a cause of concern as is other properties. They may bio-accumulate in the organisms, enter the food chain and affect them in various ways by disrupting their physiology. These toxic materials bio magnify in the food chain and eventually reach human beings causing several serious diseases. Similarly pesticide residues lindane and DDD were present during the post monsoon period. Total Coliforms and *E.coli* were present throughout the stream and their counts increased downstream. Post monsoon counts were higher than pre monsoon counts in this case too.

Water Quality Index of the three sampling sites is given below in table-4 and figure-3. It can be seen that the upstream water was fair in quality , the midstream marginal and the downstream poor in quality and this status remained similar in both pre and post monsoon periods along the stream course.

The organic pollutants such as oil and grease as well as phenolic compounds detected in the water samples indicate that the stream is being contaminated by organic wastes as it runs down the terrain. Organic wastes whether urban or rural from sewage or farm lands affect the quality of water. Increased turbidity in the water will reduce light penetration that in turn will reduce the volume of water capable of supporting growth of photosynthesizing plants that can provide oxygen. Particulate matter on settling will flocculate small floating animals and plants. As these floccules settle, sludge blankets are formed on the stream bed and many of the areas that formerly could have been inhabited by benthic organisms become covered and uninhabitable except by chironomid larvae, oligochaete worms and other sludge loving organisms[18]. Organic materials consume much of the dissolved oxygen in water during its decomposition depleting its levels in water. The COD values obtained in the study indicate that oxygen consumption by this process is on the increase downstream. Bacteria also consume lot of oxygen which is reflected in the BOD values which also is seen to increase as we move down the stream. The number of coliform bacteria which is seen to increase downstream could have influenced the BOD in water.

Aquatic insects are more easily constrained by a decrease in oxygen than any other water quality attribute because of their evolution from their ancestors on land with well developed tracheal respiratory system adapted to an atmosphere rich in oxygen. Aquatic invertebrates that utilize dissolved oxygen face serious limitations with its decreasing levels. Several factors such as temperature, salinity, turbulence, pollution etc., determine the amount of oxygen in water. Several adaptations to counter these environmental constraints have been developed by aquatic insects. Some have developed high tolerance while others remain sensitive. Respiratory adaptations in aquatic macroinvertebrates include air tubes, cutaneous and gill respiration, extraction of air from plants, haemoglobin pigments, air bubbles and plastrons. Air bubbles are seen in Hemiptera (Nepidae, Belostomatidae) and Diptera (Ptychopteridae, Culicidae, Syrphidae). Cutaneous and gill respiration is common in the immature stages of most insect orders. Most of them need oxygenated water for their survival though certain species of Chironominae are capable of surviving oxygen depletion using haemoglobin pigments that help in the transfer of oxygen. Coleoptera and Hemiptera adults make use of an air bubble and certain species within this group have evolved a system of micro-hairs or papillae that hold an air film called plastron which enables them to stay submerged for longer periods. Most of the Ephemeroptera, Plecoptera and Trichoptera species are sensitive to pollution due to low levels of adaptive mechanisms. On the other hand families such as chironomids with long cylindrical body have larger body surface area for diffusion of oxygen. These are also blessed with the respiratory pigment haemoglobin that releases oxygen at low external O_2 pressures. When chironomid larvae undulate their bodies in their mud burrows to get more O_2, their haemoglobin gets O_2 saturated which is released when necessary.

Thus the organisms that can tolerate pollution increase and sensitive groups decrease as the level of contamination increase downstream. Such an effect was evident in the composition of aquatic macroinvertebrates present in the upstream, midstream and downstream stretches of *Koratty chal.* Deterioration in water quality was reflected in both water quality index calculated based on different properties of water as well as family biotic index calculated based on the tolerance of organisms. These two indices gave similar estimates of water quality.

Conclusion

The Family Biotic Index utilized in the present study was found applicable in monitoring stream water quality in Koratty region.

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References

1. Murhekar Gopalkrushna Haribhau, Trace metal contamination of surface water samples in and around Akot city, Maharastra, India, *Res. J. Recent Sci.,* **1(7),** 5-9**(2012)**
2. Srivastava K.P. and Singh Vikash Kumar, Impact of air pollution on pH of soil of Saran, Bihar, India Res. J. Recent Sci., *Res .J. Recent Sci.,* **1(4),** 9-13**(2012)**
3. Nwajei G.E., Obi-Iyeke G.E. and Okwagi P., Distribution of selected trace metals in fish parts from the River Nigeria, *Res.J.Recent Sci.,* **1(1),** 81-84**(2012)**
4. Sharma Pramila, Fulekar M.H. and Pathak Bhawana, E-Waste–A challenge for tomorrow, *Res. J Recent Sci.,* **1(3),** 86-93**(2012)**
5. Choudhary Ranjeeta, Heavy Metal Analysis of Water of Kaliasote Dam of Bhopal, MP, India, *Res. J. Recent Sci.,* **1 (ISC-2011),** 352-353 **(2012)**
6. Mhatre G.N. and Panthurst C.E., Bio indicators to detect contamination of soils with special reference to heavy metals, In Pankhurst, C.E., Double, B.M., Gupta, V. V. S. R (eds), Biological indicators of soil health, CAB Intl, pp, 349 – 369 (**1997**)
7. Kitching R.L., Orr A.G., Thalib L., Mitchell H., Hopkins, M.S. and Graham A.W., Moth assemblages as indicators of environmental quality in remnants of upland Australian rain forest, *J. Appl. Ecol*., **37**, 284-297 (**2000**)
8. Davis A.J., Holloway, J. D., Huijbegts H., Krikken I., Ashley H., Spriggs K. and Sutton S.L., Dung beetles as indicators of change in the forests of northern Borneo, *J. Appl. Ecol*., **38**, 593-616 (**2001**)
9. McGeoch M. A., The selection, testing and application of terrestrial insects as bio indicators, *Biol. Rev. Cambridge Phil. Soc*., **73**, 181-201 (**1998**)
10. Sharma C. and Rawat J.S., Monitoring of aquatic macro invertebrates as bio indicator for assessing the health of wetlands, A case study in the central Himalayas, India, *Ecol. Indicators,* **9,** 118-128 (**2009**)
11. Thorne R. St. J. and Williams W.P., The response of benthic invertebrates to pollution in developing countries, A multi metric system of bio assessment, *Freshwater Biol*., **37,** 671-686 (**1997**)
12. Kazanci, N. and Dugel M., Ordination and classification of macro invertebrates and environmental data of stream in Turkey, *Water Sci. Technol*., **47**, 7-8 (**2000**)
13. Mason W.T., Jr. A rapid procedure for assessment of surface mining impact to aquatic life, In: Coal conference and Expo V (Symposium proceedings). October **23-25,** 310-323 (**1979**)
14. Plafkin J.L., Barbour M.T., Porter K.D, Gross. S.K. and Hughes R.M, Rapid bio assessment protocols for use in streams and rivers, benthic macro invertebrates and fish, U.S Environmental Protection Agency, Office of Water Regulations and Standards, Washington DC, EPA 440-4-89-001(**1989**)
15. Hielsenhoff W.L., Rapid field assessment of organic pollution with a family- level biotic index, *J. North Am. Benthol Soc*., **7,** 65-68 **(1988)**
16. CCME, Canadian environmental quality guidelines for the protection of aquatic life, CCME water quality index, Technical Report 1 (**2001**)
17. Wilcoxon F., Individual comparisons by ranking methods, Biometrics Bulletin, **1(6)**, 80-83 (**1945**)
18. Kenneth M.M., Biological effects of industrial pollution, *J. Wildlife Diseases*, **6,** 343-346 (**1970**)

Table -1
FBI values and its interpretation during pre and post monsoon periods

Stream reach	**FBI and its interpretation**						
	Pre-monsoon		**Post-monsoon**		**Wilcoxon Signed Rank of taxa**	**Impact**	**Agreement with WQ**
	Value	Status	Value	Status			
Upstream	4.1	V. Good	4.95	Good			Yes
Midstream	5.3	Fair	5.5	Fair	NS	No	Yes
Downstream	6.0	Fairly poor	6.5	Fairly poor	S	Yes	Yes

NS - Non Significant; S - Significant p=0.05

Table -2
Organisms identified from the collected samples

Ephemeroptera	**Lestidae**
Baetidae	Coenagrionidae
Ephemerellidae	Decapoda
Caenidae	Coleoptera
Heptageniidae	Detiscidae
Potamanthidae	Carabidae
Tricorythidae	Sialidae
Plecoptera	Gerridae
Perlidae	Elmidae
Trichoptera	Hemiptera
Hydropsychidae	Corixidae
Limnephilidae	Balostomatidae
Glossosomatidae	Hirudineae
Polycentropodidae	Aquatic oligochaetae
Odonata	Diptera
Libellulidae	Chironomidae
Cordullidae	Simulidae
Gomphidae	Tipulidae
Platycnemidae	Athericidae
Calopterygidae	Culicidae
Chlorocyphidae	Nymphomidae
Macromiidae	Ceratopogonidae

Table-3
Variation in Water Quality along *Koratty Chal* during pre and post monsoon

Parameters	**Pre-monsoon 2010**			**Post-monsoon 2010**		
	Up	**Mid**	**Down**	**Up**	**Mid**	**Down**
P^H	6.2	6.1	6.2	6.4	6.2	5.9
EC (µs/cm)	58.50	63.40	68.60	56.00	68.00	72.43
DO	7.021	6.742	4.85	6.6	6.3	4.2
BOD	2.830	3.050	4.332	2.818	3.2	4.03
COD (mg/l)	18.0	20.0	34.2	19.00	25.24	37.00
TDS (mg/l)	37.44	40.58	52.36	39.00	42.45	56.00
Phosphate-P (mg/l)	0.043	0.052	0.12	0.030	0.060	0.080
Nitrate-N (mg/l)	0.12	0.35	0.54	0.13	0.34	0.46
Fluoride (mg/l)	00	00	00	0.05	0.10	0.20
Oil and grease (mg/l)	2.0	6.80	8.45	65.60	84.20	87.60
Phenolic compounds (mg/l)	00	0.01	0.12	0.10	0.20	0.25
Iron (mg/l)	00	00	00	0.09	0.24	0.26
Manganese (mg/l)	00	00	00	00	0.01	0.01
Nickel (mg/l)	00	00	00	0.001	0.01	0.020
Lead (mg/l)	00	00	00	0.001	0.01	0.024
Copper (mg/l)	00	00	00	00	0.01	0.01
Zinc (mg/l)	00	0.049	0.062	0.009	0.01	0.03
Lindane (µg/l)	00	00	00	00	0.001	0.001
DDD (µg/l)	00	00	00	00	0.001	0.001
Total coliform (CFU/100 ml)	4000	8000	10000	6000	12000	14000
E.Coli (CFU/100 ml)	500	800	1200	1000	1200	1400

Table - 4
Water Quality Index

Stream Reach	**WQI**			
	Pre-monsoon		**Post-monsoon**	
	Value	**Status**	**Value**	**Status**
Upstream	75	Fair	72	Fair
Midstream	58	Marginal	55	Marginal
Downstream	37	Poor	32	Poor

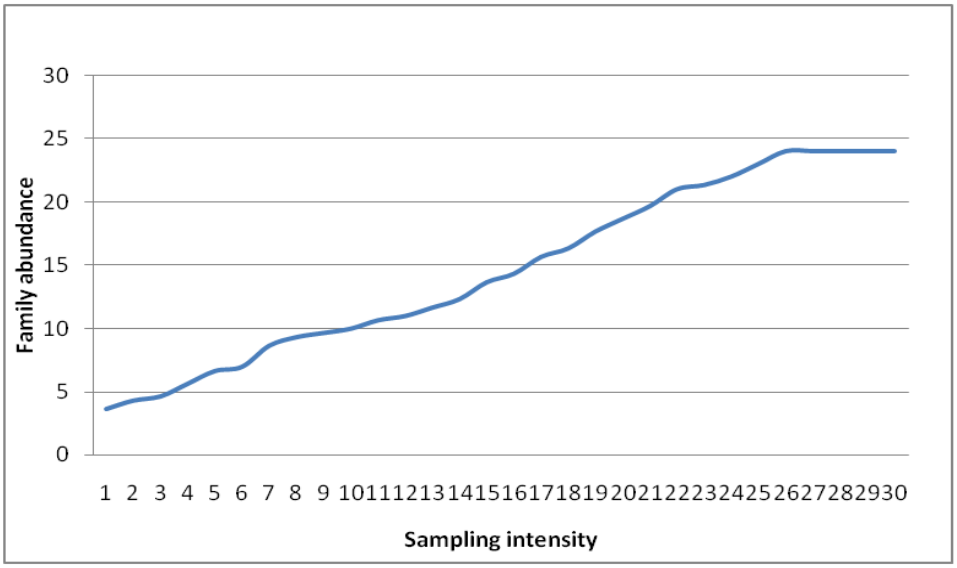

Figure-1
Family accumulation curve

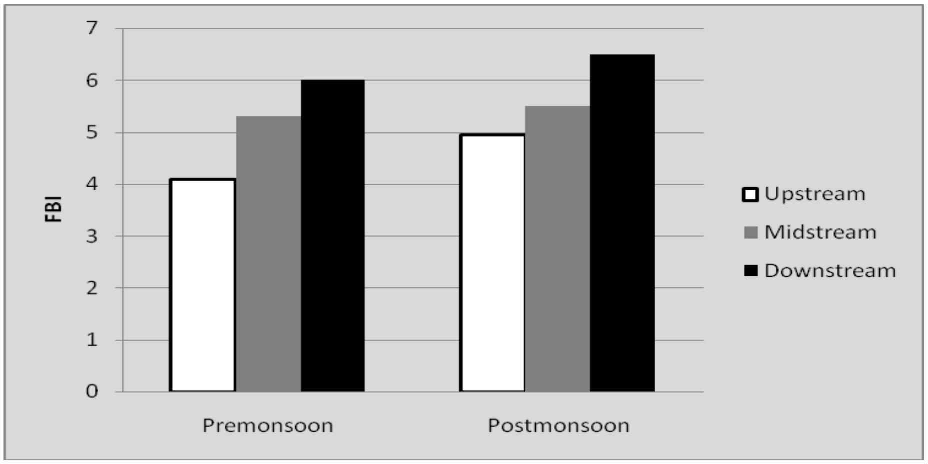

Figure-2
Variation in FBI along *Koratty chal* in the two seasons

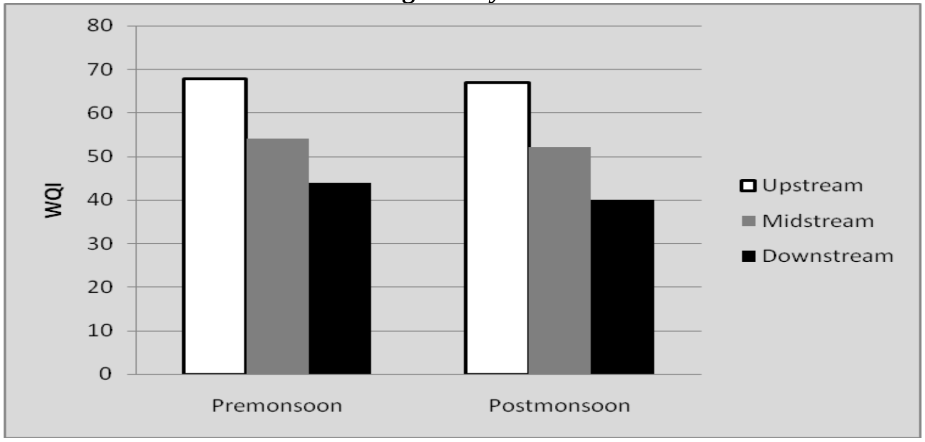

Figure-3
Graph showing Variation in Water Quality Index along *Koratty Chal*

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Carbon Sequestration Potential of Teak (*Tectona grandis*) Plantations in Kerala

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Abstract

Teak (Tectona grandis) is the most important forest plantation species and it occupies the major area under forest plantations in Kerala. In addition to its value as an ideal timber, it also plays an important role in storing carbon. The silviculture of teak necessitates felling at regular intervals of 5, 10, 20, 30, 40 and 50 years of age. The present study was carried out to estimate the carbon storage in different compartments of teak in each of these felling periods to arrive at an estimate of its carbon sequestration potential. Carbon content of teak biomass was estimated using CHNS analyser. There was slight variation in carbon content between age groups and considerable difference between various parts of the tree. The wood contained around 46%, bark around 32%, branches around 40% and the roots around 45% of carbon. Regression equations were developed to predict the total tree carbon storage from tree measurements. It was found that around 181 ton carbon per hectare is stored by a teak plantation in Kerala during its life time of 50 years by yielding biomass at different stages of thinning operations and at final felling stage.

Key words: Teak, carbon sequestration, Kerala.

Introduction

Teak (*Tectona grandis* Linn. F) is a valuable timber yielding species in the tropics especially India, Indonesia, Malaysia, Myanmar, northern Thailand, and northwestern Laos. The first teak plantation in the world was raised in Nilambur, Kerala, India in the year 1840. The Kerala Forest Department now has about 56510 ha under teak, out of which approximately 64 per cent is in the first rotation and the remaining 36 percent in the second and third rotation stages and about 1000 ha is being felled and replanted every year[1,2].

Global warming due to increased concentration of green house gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and sulphur hexa fluoride (SF6) in the earth's atmosphere is one of the most important concerns of mankind today[3]. United Nations Framework Convention on Climate Change (UNFCCC) created during the Rio Earth Summit in 1992 to stabilize GHG concentration in the atmosphere came into force in March 1994. The 3rd conference of parties (CoP 3) which met in Japan in 1997 decided on certain protocols which came to be known as Kyoto protocol. The Kyoto protocol legally binds 39 developed countries to reduce their GHG emissions by an average of 5.2% relative to 1990 levels by the period 2008-2012, referred as the first commitment period. The Kyoto protocol permits the developed countries to reach their targets through several mechanisms. They are emission trading, joint implementation and clean development mechanism (CDM). CDM allows developed nations to achieve reduction obligation through projects in developing countries that reduce emissions or sequester CO_2 from the atmosphere[4,5]. The CoP 7 of UNFCCC that met in Bonn (Germany) in July 2001 decided to include Afforestation and Reforestation (A/R) as an effective way to reduce atmospheric carbon by building up terrestrial carbon stocks and to produce Certified Emission Reductions (CERs).

It has been suggested that improved land management could result in sequestration of substantial amount of soil carbon and can be an option to reduce atmospheric CO_2 concentration [6,7,8]. Forest management such as rotation length is seen as an activity that countries may apply under the Kyoto Protocol to help them meet the commitments for reduction of green house gas emissions[9]. However, the benefits can get reversed through disturbances and harmful practices during harvest which would release the carbon back to the atmosphere. Individual trees and stands of trees sequester carbon within their main stem wood, bark, branches, foliage and roots. Carbon sequestered by the main stem wood results in longer sequestration while other components sequester and release carbon on shorter intervals due to natural pruning and decomposition[10].

Carbon sequestration potential of tree species becomes relevant in this respect. It varies with species, climate, soil and management. Forest plantations have significant impact as a global carbon sink[11,12]. Young plantations can sequester relatively larger quantities of carbon while a mature plantation can act as a reservoir. Long rotation species such as teak (*Tectona grandis*) has long carbon locking period compared to short duration species and has the added advantage that most of the teak wood is used indoors extending the locking period further.

Material and Methods

Teak plantations in different thinning regimes and at final felling were surveyed in Nilambur forest division, Kerala and seven sites corresponding to the prescribed felling schedule and on comparable site quality selected for the study. Measurements of fifty standing trees as regards height and GBH were taken while the ten felled trees were measured as logs. Fifty trees closest to transects taken at right angles to each other were considered for the purpose of height and GBH measurements. Samples of wood from ten felled trees in each of the sites were collected by slicing thin discs from the cut portions of logs. Samples of wood were also collected from different branches of each felled tree. Root systems of the selected ten trees in each site were excavated manually by starting at the stump and following the roots to possible limits. The stump along with the exposed roots were pulled out with the help of tractor. Estimation of fine roots was done by taking pits around each tree from which all soil was removed to isolate fine roots to possible extent. They were weighed in the field itself and samples collected from different parts of the root system to estimate dry mass.

The schedule of felling operations presently followed by the Kerala Forest Department in teak plantations is the first mechanical thinning at the age of 5 years by removing every alternate row to facilitate space for growth which is followed by selective silvicultural thinnings at 10, 15, 20, 30, and 40 years when 1739, 318, 126, 103, 40 and 19 trees respectively are removed from a hectare. The plantations are clear felled at 50 years when hardly 155 trees remain.

Carbon storage was worked out at two levels *viz.*, tree level and plantation level. Above ground and below ground biomass of teak was estimated by destructive sampling. Biomass of trees that are removed from the site through felling at each stage including the final felling stage was only considered for estimating carbon sequestration.

Various regression equations were fitted for each age class using DBH as an independent variable and total tree carbon storage (wood + branches + root + bark) as dependent variables using data from 10 trees/age class. Data were transformed to log to the base 10 as is commonly done to linearize data of this type. The statistical analyses were conducted using SPSS soft ware package.

Results and Discussion

Biomass of teak trees of different ages: Data on biomass of teak at different felling cycles is given compartment wise as wood, bark, branches and root (table 1). Above ground biomass represent mean of 50 trees and below ground biomass represent 10 trees. It can be seen that at the 5th year mechanical thinning wood biomass amounted to 50.56 kg/tree on an average, bark constituted 8.92kg/tree while the contribution of root was 8.33kg/tree. Wood constituted 75%, bark 13% and root 12% of the total biomass. At the age of 10 year the wood biomass was estimated to be around 91.5kg, the bark around 14.89kg, branches 26.91kg and root around 21.28kg per tree. Wood constituted 59%, bark 10%, branches 17% and root 14% of the total biomass.

At the second silvicultural thinning of fifteenth year, wood constituted 121.5kg, bark 16.76kg, branches 27kg and root 38.67kg per tree. The contribution of wood was found to be 50%, bark 8%, branches 25% and root 17% of the total biomass. At the age of 20 years the respective figures were 142.28kg of wood, 19.4kg of bark, 27.53kg of branches and 48.51kg of roots per tree. Wood constituted 60%, bark 8%, branches 12% and root 20% of the total biomass.

At the 30th year of fourth silvicultural thinning, wood was found to yield 254.34kg, while the bark constituted around 28.26kg per tree. The contribution of branches was 38.38kg and that of root 87.60kg per tree towards the tree biomass. Wood constituted 62%, bark 7%, branches 9% and root 21% of the total biomass. The wood biomass at the 5th silvicultural thinning at the age of 40 years was found to be around 480.48kg, bark biomass around 44.63kg while the branches were found to weigh about 95.93kg per tree and the root portion contributed 131.28kg of biomass. Wood constituted 64%, bark 6%, branches 13% and root 17 percent of the total biomass. Biomass partitioning at the age of 50 years was found to be in the order of 635.85kg wood, 59.07kg bark, 183.55kg branches and 173.73kg of roots per tree. Wood constituted 66%, bark 6% and branches and root 17% each of the total biomass.

Table-1
Biomass distribution in various compartments at different thinning stages

	Mean biomass (kg/tree) ± SD						
Compartments	5 year	10 year	15 year	20 year	30 year	40 year	50 year
Wood	50.56 ±3.00	91.50 ±8.55	112.15 ±18.47	142.28 ±54.00	254.34 ±94.50	480.48 ±67.55	635.85 ±155.45
Bark	8.92 ± 0.06	14.89 ±2.03	16.76 ±4.56	19.40 ±4.37	28.26 ±9.24	44.63 ±10.30	59.07 ±12.50
Branches	-	26.91 ±11.53	27.00 ±18.62	27.53 ±22.14	38.38 ±25.34	95.93 ±23.65	183.55 ±64.53
Root	8.33 ±0.50	21.28 ±3.24	38.67 ±4.32	48.51 ±15.00	87.60 ±20.40	131.28 ±25.00	173.73 ±46.53
Total	67.81	154.59	223.14	237.72	408.57	752.32	1052.20

SD - Standard Deviation

Table-2
Mean carbon content in different compartments at various stages of growth

Compartments	**Mean carbon content (kg/tree) ± SD**						
	5 year	**10 year**	**15 year**	**20 year**	**30 year**	**40 year**	**50 year**
Wood	23.26 ±1.50	42.09 ±4.21	51.59 ±7.70	65.45 ±24.25	116.99 ±24.40	221.02 ±21.24	292.49 ±102.50
Bark	2.86 ±0.30	4.77 ±0.45	5.36 ±1.20	6.21 ±2.06	9.04 ±3.22	14.28 ±2.36	18.90 ±6.04
Branches	-	11.30 ±3.23	11.42 ±5.24	11.56 ±7.24	16.12 ±11.76	40.29 ±12.30	77.09 ±20.20
Root	3.33 ±0.15	8.94 ± 1.65	16.63 ±2.22	20.86 ±6.00	38.55 ±9.35	57.76 ±8.54	76.44 ±18.36

SD - standard deviation

Table-3
Regression equations for predicting per tree total carbon content

Plantation	**Regression**	**Adjusted R^2**	**t-value for slope coefficient**
5 Year	Log (Y) = 1.301 + 0.197 log (DBH)	0.875	7.992**
10 Year	Log (Y) = 0.429 +1.201 log (DBH)	0.909	9.542**
15 Year	Log (Y) = 0.381 +1.293 log (DBH)	0.840	6.957**
20 Year	Log (Y) = 0.261 +1.344 log (DBH)	0.944	12.395**
30 Year	Log (Y) = -0.412 +1.818 log (DBH)	0.981	21.509**
40 Year	Log (Y) = -0.282 +1.743 log (DBH)	0.953	13.507**
50 Year	Log (Y) = 0.268 +1.461 log (DBH)	0.883	8.292**

** significant at p = 0.01

Carbon content of teak trees of different ages: Carbon content of teak partitioned in the wood, bark, branches and root is given in Table 2. It can be seen that at the age of 5 years, the wood portion of the tree contained 23.26 kg carbon, the bark 2.86 kg and the root 3.33 kg carbon per tree. At the first silvicultural thinning of 10th year, carbon content in wood was found to be 42.09 kg, that in bark around 4.77kg, branches around 11.3kg and the roots contained around 8.94kg carbon per tree. At 15 year of age, wood portion of the tree on an average was found to contain 51.59kg carbon while the bark contained 5.36kg, the branches 11.42kg and the roots 16.63kg carbon.

Carbon content of wood was found to be 65.45kg, that of bark 6.21kg, branches 11.56kg and the root 20.86kg on an average per tree at the time of third silvicultural thinning at 20 years of age. At thirty year age when the fourth silvicultural thinning is carried out the average carbon content per tree was found to be 116.99kg in wood portion, 9.04kg in bark, 16.12kg in branches and 38.55kg in the roots. At the fifth silvicultural thinning at the 40th year carbon content in wood was about 221.02kg, that in bark around 14.28kg, while the branches contained about 40.29kg and the root 57.76kg per tree. Carbon content of wood portion was found to be around 292.49kg, bark around 18.99kg, branches around 77.09kg while the roots contained 76.44kg carbon per tree at the age of 50 years.

Carbon content in compartments of different aged teak trees is shown in Fig 1. It can be seen that most of the carbon was stored in the wood portion which was followed by root, branches and bark, the trend becoming more pronounced in the latter years.

Development of prediction equations of carbon storage: Various regression equations were fitted for each component of carbon storage to develop non destructive predictors and are given in table 3. The ‘t’ values of regression coefficients of the equations were also highly significant in all cases.

Linear regression equations of log DBH versus per tree total carbon content show that these relationships are strong yielding coefficients of determination (R^2) of 0.840 to 0.981 in various thinning regimes which means that the variation in total carbon content could be well explained by DBH of trees in all the plantations.

Estimation of carbon storage potential of teak plantations in Kerala: Carbon storage potential of teak plantations in Kerala was calculated based on the number of trees removed at each felling cycle and is given in table 4. The carbon storage potential was found to be 51.20 t/ha at the first mechanical thinning of 5 year growth, followed by 21.34, 12.21, 10.72, 7.23 and 6.33 t/ha during the first, second, third, fourth and fifth silvicultural thinning at 10, 15, 20, 30 and 40 years of age respectively and 72.1t/ha at the time of final felling.

Table-4
Plantation level carbon sequestration (Tons per hectare)

Felling regime	No. of trees removed	Carbon (t/ha)
5	1739	51.2
10	318	21.34
15	126	12.21
20	103	10.72
30	40	7.23
40	19	6.33
50	155	72.1
Total	2500	181.13

Conclusion

It can be concluded within the limitations of the present study that 181.13 ton carbon per hectare could be stored by a teak plantation in Kerala during its life time of 50 years by yielding biomass at different stages of thinning operations and at final felling stage.

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References

1. Balagopalan M., Rugmini P. and Chacko K.C., Soil conditions and growth of teak in successive rotations in Kerala State, India. *In*: Bhat K. M., Nair K.K.N., Bhat K.V., Muralidharan E.M., and Sharma J.K. (*eds.*) Quality timber products of teak from sustainable forest management, Proceedings of the international conference on quality timber products of teak from sustainable forest management, Peechi, India, 2-5 December 2003, 173-178 (**2005**)
2. Nagesh Prabhu, Teak in Kerala State, India: Past, Present and Future. *In*: Bhat, K. M., Nair K.K.N., Bhat K.V., Muralidharan E.M., and Sharma, J.K. (*eds*) Quality timber products of teak from sustainable forest management, Proceedings of the international conference on quality timber products of teak from sustainable forest management. Peechi, India, 2-5 December 2003, pp. 54-56 (**2005**)
3. Komalirani1 Y., and Sharma R., CO2 Emission Reduction potential through improvements in technology from Civil Aviation Sector in India - A Case of Delhi-Mumbai air route, *Res.J.Recent.Sci.*, **1(ISC-2011),** 134-144 **(2012)**
4. Reddy R.N. and Suvikram Y.V.N.S., CO2 Emission Reduction potential through improvements in technology from Civil Aviation Sector in India - A Case of Delhi-Mumbai air route, *Res.J.Recent.Sci.* **1(ISC-2011),** 388-397 **(2012)**
5. Metting F.B., Smith J.L and Amthor J.S., Science needs and new technology for soil: Science, monitoring and beyond. *In*: Proceedings of the St. Michaels workshop, Battelle press, Columbus, Ohio, USA, December 1998 (**1999**)
6. Pastian K., Six J., Elliott E.T and Hunt H.W., Management options for reducing CO_2 emissions from agriculture soils, *Biogeochem.*, **48,** 147-163 (**2000**)
7. Post W.M., Peng T.H., Emanuel W.R., King A.W., Dale V.H and De Angels D.L., The global carbon cycle, *Am. Sci.*, **78,** 310-326 (**1990**)
8. Yadav R., Soil organic carbon and soil microbial biomass as affected by restoration measures after 26 years of restoration in mined areas of Doon Valley, *Int. J. Env. Sci.* **2(3),** 1380-1385 **(2012)**
9. IPCC, Additional human-induced activities. Article 3.4 *In*: Watson R.T., Noble I.R., Bolin, B., Ravindranath N. H., Verardo D.J., Dokken D.J. (*eds.*) Land use, land use change and forestry. A special report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 189-217 (**2000**)
10. Montagmini F. and Porras C., Evaluating the role of plantations as carbon sinks: An example of an integrative approach from the humid tropics, *Environ. And M,* **22,** 459-470 (**1998**)
11. Teerawong L., Pornchai U., Usa K., Charlie N., Chetpong B., Jay H.S. and David L.S., Carbon sequestration and offset, The pilot project of carbon credit through forest sector for Thailand, *Int. J. Env. Sci.*, **3(1),** 126-133 **(2012)**
12. Rahman M.H, Bahauddin M, Khan M.A.S.A, Islam M.J and Uddin M.B., Assessment of soil physical properties under plantation and deforested sites in a biodiversity conservation area of north-eastern Bangladesh, *Int. J. Envt. Sci.*, **3(3)**, 1079-1088 **(2012)**