Chapter 1
INTRODUCTION

Increasing number of vehicles, haphazard locations of different kind of industries and varied social activities of the people have rendered the atmosphere extremely vulnerable. Industrial activities of man have increased in manifold in recent years for advancement in technology. Much of the chemical products and waste products of modern society are released into the environment either during production, storage, transport, use or ultimate disposal and these released materials participate in natural cycles and frequently lead to interference and disturbance of natural balance. Today cities are fast running into gas chambers with the advent of more and more of technological innovation. The vehicles, municipal solid waste, slum cluster, industrial units have together just thrown the environmental health of city out of control. Today what we have achieved technologically has been at the cost of our environment. Thus the need for environmental quality monitoring at a global level grows and increases exponentially as water, land and soil use intensifies. Environmental analyses often involve wide variety of matrices, ranging from air to sewage water to polluted soil samples (Khan et al., 2005; Igwe et al., 2008; Shah et al., 2009).

1.1 Background of the study

Guwahati city is not only the heart of Assam but also for the other North Eastern states for A to Z factors. Daily from all over the country more than 1 lakh
people enter the Guwahati city and more than 1 lakh people leave for Guwahati city. Besides the city’s vehicles a large number of outsider vehicles ply on the roads of Guwahati city. So for the increasing population, vehicles and other necessities—a large number of construction work and industrialization has been going on in order to meet the demand of shelter, hassle free transportation and work for unemployed. For better transportation system a large number of flyover construction and road widening has been going on in the entire city specially in Jalukbari, Jorabat and Khanapara area for more than five to six years. Traffic jam is common in the entire city for the such undergoing construction work from the beginning of the work. Ultimately such undue traffic jams increasing the amount of vehicular emissions than as usual. Thus these emissions definitely have major role in contaminating the gross environment of the Guwahati city besides urbanization and industrialization. Thus the environment has tremendous impact on living organisms as well as on non living material such as stone, metals, mortar, wood, paint, electrical wiring, rubber, paper, leather, textile materials and foods.

1.2 Importance of the study

Soil contamination can be problematic on several levels. Risks from soil contamination include plants absorbing contaminants through the soil; groundwater becoming contaminated as it interacts with and flows beneath the soil; and bioaccumulation, occurring when livestock or humans ingest contaminants from vegetation growing in compromised soil (Rosen, 2002). Urban roadside top soils are the “recipients” of large amounts of pollutants from a variety of sources including industrial wastes, vehicle emissions, coal burning waste as well as other activities. Accordingly, roadside top soils have become an increasingly important environmental
sampling medium for assessing anthropogenic pollutant levels in the urban environment (Manta DS et al., 2002, Wang XS et al., 2005). Besides the inhalation of dust, urban soils could also be transferred to humans through hand-to-mouth ingestion or dermal contact, especially children, due to outdoor activities (Bright et al., 2006). However, under these conditions, the amount of soil involuntarily ingested depends on the adherence of soil to the skin. Finer soil particles tend to adhere more efficiently to human hands (Yamamoto et al., 2006). It is thought that such particles should have a fineness of <100 mm, especially <50 mm (Sheppard and Evenden, 1994; Yamamoto et al., 2006; Siciliano et al., 2009). Furthermore, very fine clay particles (<2 mm) could be incorporated into the surface of the skin (through dermal absorption), because they are of the same scale of roughness as the surface of the skin, and become resistant to cleaning (Sheppard and Evenden, 1994).

Geographic focus of resource consumption and emissions of large amount of chemicals of various composition have been taking place in cities as the industrial and economic activities are much more concentrated in urban areas. Soil contributes directly or indirectly to the normal quality of life to the residents of urban localities as soil is an important component of urban ecosystems. Soil is responsible for biochemical transformations, cycling of various nutritious elements, water filtration including plant support. It is well established that due to anthropogenic activities urban soils differ from natural soils. An understanding of the properties, processes and ecosystem services of intensively disturbed urban soils has important implications for a large urban population (Vegter, 2007). Thus, in the last three or four decades, the study of urban soils has emerged as an important frontier in environmental research (Wong D et al., 2006 and Heinrich Almut, 2008). However, road construction has also
resulted in heavy environmental pollution (Bai et al., 2008). When rain falls, the runoff washes pollutants off the streets, parking lots, construction sides, industrial storage yards and other built-up areas, and lawns. The urbanization has also impacted on the runoff with respect to both quantity and quality (Gromaire, 1999 and Allen et al., 2002). Urban runoff carries a mixture of pollutants from these places as well as the construction sides, and also a variety of chemicals like pesticides used in households and commercial places (Southerland, 2000). Due to increasing urbanization, built up area has multiplied and water can hardly penetrate underground and this has resulted in an increased volume of runoff which often creates water logging problems in the towns and cities. The rapid urbanization and increasing population brings in proportional amount of car emissions, municipal wastes, car maintenance wastes, pesticides and household hazardous chemicals which can enter into the runoff water that flows into the nearby water bodies. Suspended solids, oxygen demanding substances, toxic metals and trace elements, organic contaminants, pathogenic bacteria and nutrients are the common pollutants found in runoff water that flows into the nearby water bodies. According to MELP, (1992) other constituents and characteristics which may affect the behavior and fate of the pollutants in urban runoff include major ions such as sodium, chloride, calcium, magnesium, potassium, alkalinity, pH and salinity of the runoff water. Nabizadeh et al., (2005) have reported that polluted urban runoff can be a major source of water quality problems in receiving waters.

Heavy metal contamination in the soil–water–plant ecosystem is of great concern because of possible influence on food chain. In the soil system, pollution by toxic metals is due to both natural processes, such as weathering of minerals and
anthropogenic activities, related to vehicular emissions, industry, agriculture, burning of fossil fuels, mining and metallurgical processes and their waste disposal (Mmolawa et al., 2010).

According to EPA (1986) 60% of the key pollutants have been detected in urban storm runoff. Considering risk factors, routine urban soil and road runoff water survey with a comprehensive assessment of soil-water quality is needed for the control and management of urban pollution. The present study is aimed to check the contamination status of city roads with high traffic intensity and commercial activities by selected physico-chemical parameters with special emphasis on toxic trace elements. Rapid urbanization and growing population is a global phenomenon. Now world’s more than half population lives in urban areas and it is expected that it would be raised to almost 70% by 2050 according to the United Nations report. So the study of urban environments is very much important with regard to human health and its related matter.

1.3 Soil pollution

1.3.1 Introduction

Productive soils are necessary for agriculture to supply the world with sufficient food. An ideal soil contains equivalent portions of sand, silt, clay, and organic matter. Soil is basically made up from porous, unconsolidated material consisting of weathered bed rock or of allochthonous sediments. The Soil Science Society of America (1995) defined soil as the capacity of a specific kind of soil function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human
health habitation. Soil is the thin layer of organic and inorganic materials that covers the earth's rocky surface. Soil is characterized by intense activity of plant roots, fungi, bacteria, soil macro fauna etc. in top few decimeters of soil. The organic portion of soil is derived from the decayed remains of plants and animals and is concentrated in the dark uppermost topsoil. The inorganic portion is made up of rock fragments and was formed over thousands of years by physical and chemical weathering of bedrock.

In general, most plants grow by absorbing nutrients from the soil. Their ability to do this depends on the nature of the soil. Depending on its location, soil contains some combination of sand, silt, clay, and organic matter. The makeup of a soil and its acidity determine the extent to which nutrients are available to plants. Clay and organic soils hold nutrients and water much better than sandy soils. As water drains from sandy soils, it often carries nutrients with it. These nutrients are then no longer available to plants. Nitrogen, phosphorus, potassium, calcium, magnesium and sulphur are considered as macronutrients of soil while boron, copper, chloride, iron, manganese, molybdenum and zinc are considered as micronutrients. Macronutrients tend to be less available in soils with low pH and micronutrients tend to be less available in soils with high pH. In the pH range of 6.0-6.5, soil nutrients are more readily available to plants, and microbial populations in the soil increases. Microbes convert nitrogen and sulphur to forms that plants can use. Most of the nitrogen taken up by plants is from the soil in the forms of nitrate (NO$_3^-$). Nitrogen is found in organic and inorganic forms in soils. Over 90 percent of soil nitrogen is associated with soil organic matter. Conversion of nitrogen depend on soil moisture conditions, soil acidity, temperature, and microbial activity. Globally, about 40% of total N$_2$O emissions come from human activities (EPA, 2010). N$_2$O emissions is projected to
increase by 5% between 2005 and 2020, which may be due to increases in emissions from agricultural activities (U.S. Department of State, 2007). Important source of emissions of NH$_3$ is decomposition of manure. Atmospheric depositions of nitrogen mainly take place due to release of NOx from agriculture, transportation, and industry activities. Application of phosphorus fertilizer is the prime external source of phosphorus in soil. Soil pH and organic matter content determine the availability of the phosphorus. Heterotrophic bacteria convert inorganic phosphate into organic phosphate which is less associated with large humus polymer (Whitehead, 2000). Phosphorus availability decreases in soil due to its high affinity for iron, aluminium and calcium. The key role of potassium is the regulation of water use in the plant (osmoregulation). The largest soil component of potassium, 90 to 98%, is the soil minerals such as feldspar and mica. Potassium deficiency can have a dramatic affect on the plants ability to survive and function during stress periods such as high temperatures, drought and wear. Factors which can lead to potassium deficiency include: leaching in sandy soils or soils with low CEC values, sides being irrigated with water that is high in sodium and where high rates of calcium and magnesium are added through the irrigation water or through the fertilization programme. Human activities have changed the character and quality of our soils over time. Natural and synthetic materials that can adversely affect the physical, chemical and biological properties of soil and seriously affect the productivity of soil are called soil pollutants. And soil pollution is the contamination of soil with harmful substances that can adversely affect the quality of the soil and the health of those living on it and is the presence of toxic chemicals in soil in high enough concentrations to be of risk to human health and/or ecosystem. When the levels of contaminants in soil are not of
risk, soil pollution may occur simply due to the fact that the levels of the contaminants in soil exceed the levels that are naturally present in soil. Compaction is the process by which soil particles are forced closer together reducing soil porosity. This is caused by heavy machinery traffic. Soil pollution has become an important factor of environmental degradation. Soil pollution occurs due to automobile exhausts, municipality wastes, biological agents, depositions of chemical species on the surface soil through precipitations released by industries or from burning of fossil fuels, coals and wood etc. The amount of pollutant in soil is expressed in terms of its mass per volume concentration using the unit milligram per kilogram.

1.3.2 Road side surface soil contamination and its sources

A soil pollutant is any factor which deteriorates the quality, texture and mineral content of the soil or which disturbs the biological balance of the organisms in the soil. Pollution in soil has adverse effect on plant growth. One of the key issue is the degradation and pollution of urban soils in many parts of the world. Urban soils are subjected to continuous accumulation of contaminants from either localized or diffuse sources. Both natural and man-made soil pollutants include a large variety of contaminants or organic and inorganic chemicals. The most common chemicals involved are solvents, pesticides, lead, and other heavy metals. Human activities such as accidental leaks and spills, dumping, manufacturing processes, etc are the reasons of the accumulation of chemicals in soil at levels of health risk. Soil pollution can result from contaminated water absorbing into the soil. Soil contamination is caused by the presence of man made chemicals or other alteration in the natural soil environment. It is typically caused by vehicular emissions, industrial activity,
agricultural chemicals, or improper disposal of waste. Motor vehicles contaminate not
only the air but also the soil environments by emitting the exhaust gases. The soil
adjacent to major roads is thus polluted with heavy metals (Williamsom et al., 1972).
Construction sides are important source of soil pollution in urban area due to their
almost ubiquitous nature and the chemical used at construction sides may pollute the
soil. The most common chemicals involved are petroleum hydrocarbons, solvents,
pesticides, lead and other heavy metals.

Typical contaminants include persistent toxic substances (PTSs), such as trace
metals (Nriagu Jozef et al., 2011; Ajmone-Marsan et al., 2010) and persistent organic
pollutants (POPs) (Fabietti et al., 2010). The main sources of the persistent toxic
substances pollutants (such as trace metals) and persistent organic pollutants are may
be due to traffic emissions, industrial discharges, chemical and metallic pollutants and
wastes from municipal activities. Soils may become contaminated by the
accumulation of heavy metals and metalloids through emissions from the vehicular
emissions, rapidly expanding industrial areas, mine tailings, disposal of high metal
wastes, leaded gasoline and paints, land application of fertilizers, animal manures,
sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of
petrochemicals, and atmospheric deposition (Khan et al., 2008, Zhang et al., 2010).
The movement of soil pollutants is determined by factors like climate, nature of the
pollutants and physico-chemical properties of the soil. The adsorption properties of
soil determine the concentration load of pollutants in the soil and the soil adsorption
capacities are primarily determined by soil organic matter. Soil pollutants are
transported by runoff water, leaching, soil microorganism, plants and atmospheric
volatilization. Heavy metals constitute an ill-defined group of inorganic chemical
hazards, and those most commonly found at contaminated sides are lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), copper (Cu), iron (Fe) and nickel (Ni). The most frequently reported heavy metals with regards to potential hazards and occurrence in soils are Al, Co, Cu, Fe, Pb, Mn, Ni, Zn and accumulation of these metals in top soils are greatly influenced by traffic volume (Mmolawa et al., 2010). Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation (Kirpichtchikova et al., 2006), and their total concentration in soils persists for a long time after their introduction (Adriano et al., 2003). Changes in their chemical forms (speciation) and bioavailability are, however, possible. Traffic again should be considered as an important source because Mn organic compounds are added as an anti-knocking agent to gasoline, and during combustion they are emitted into the environment (Ozaki et al., 2004). Corrosion processes of galvanized-metal structures and the abrasion of all Cd-bearing alloys and tire rubbers are among the main sources of Cd emissions (Ozaki et al., 2004; Charlesworth et al., 2011).

The metal Zn in road side soil is assumed to be due to sources such as tire rubber of motor vehicles and/or lubricating oils, to which Zn compounds are added for the quality improvement. What is more, diesels are also doped with Zn or ZnSO₄ (Katterman et al., 2007; Charlesworth et al., 2011). Ferguson et al. (1991), Akhter et al. (1993) and Al-Shayep et al. (2001) reported that the source of Ni and Cr in street dust is believed to be corrosion of cars and chrome plating of some motor vehicle parts respectively. Substantial medical waste is generated every day which is disposed
off along with domestic waste increasing the chance of life threatening infection. Many pollutants can remain in urban soils for a long time, which may act as a source of further pollution in urban environments, and pose a potential threat to human health and ecological systems. The higher risk comes from those chemicals that may travel easier through air (as fine particulate matter) and which are resistant to degradation and bioaccumulate in living organisms such as PAHs.

1.3.3 Vehicular growth in the city and release of pollutants from vehicles

As per the report released by district transport office, Kamrup, the vehicular growth in the Guwahati city is abruptly high in last four years. The total number of vehicles registered in the city went up from 28,201 in 2007-08 to 64,815 in 2011-12. The average daily registration of vehicles was 80 in 2008-09, which increased to 119 in 2009-10, 157 in 2010-11 and 178 in 2011-12. It has been observed that the registered vehicle in Kamrup DTO in the recent year 2011–2012 is 2.29 times higher in comparison to the registered vehicle in 2007–2008. Out of the total increase in the number of vehicles, 50 percent are two wheelers, while 28.8 percent are cars and 0.5 percent buses. Type of registered non transport vehicles include Scooter, Moped, Motorbike, Station Wagan, Trailor, Tractor, Crane, Govt. Vehicle, FireBrigade, Ambulance etc. and transport vehicles include Trucks (Multiaxle Vehicle, Articulated Vehicle, Medium, Heavy), L.C.V Goods (Four Wheelers, Three Wheelers), Buses (Contract/Stage Carriage, Omni Buses, Mini Buses, School Buses) and Taxi (A.A.T.O.V, Motor Cabs, Maxi Cabs, Other Taxi, Passenger three wheeler Autorickshaw). The vehicular growth including transport and non transport vehicle in the city for last four years is given in
Table 1.1 and the diagrammatic representation of the vehicular growth is exhibited in Fig. 1.1

**Table 1.1: The vehicular growth of transport and non transport vehicle**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Year</th>
<th>Total number of registered vehicle</th>
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<tbody>
<tr>
<td>1.</td>
<td>2007-2008</td>
<td>28201</td>
</tr>
<tr>
<td>2.</td>
<td>2008-2009</td>
<td>29200</td>
</tr>
<tr>
<td>3.</td>
<td>2009-2010</td>
<td>43435</td>
</tr>
<tr>
<td>4.</td>
<td>2011-2012</td>
<td>64815</td>
</tr>
</tbody>
</table>

**Fig.1.1: Vehicular Growth of Guwahati City for four years (2008–2012)**

Vehicles release the pollutants at ground level and contaminate the gross environment. Pollutants released from vehicles may either be emitted into the atmosphere and then transported to varying distances covering local, regional and global scales before being deposided to the earth’s surface or may be deposided directly onto the street dust, roadside soil and shrubs etc. Some of the pollutants get deposided directly on the roadside dust and others come to road dust from the atmosphere through dry and wet precipitation processes (Golomb et al., 1997). The contaminant input to roadside environment involves numerous potential sources and broadly categorized as:-

- Vehicle associated components
- Coach and road construction materials
• Road surface erosion
• Animal waste and vegetable debris

**Petrol driven vehicle:**

The main gaseous emission from gasoline engine include hydrocarbon (HC), CO, NO\textsubscript{x}, CO\textsubscript{2}, SO\textsubscript{2}, and water vapour. The particles are mostly carbonaceous spherical sub micrometer agglomerates particles (Concawe Report, 1998) ranging from 0.01 to 0.08 μm, consisting of carbon core with various associated organic compounds. From investigations of the elemental composition of particles emitted by a gasoline engine, Ristovski et al. (1999) reported the presence of boron, calcium, titanium, chromium, manganese, iron, cobalt, nickel, copper, zinc, cadmium, barium and lead. Iron particles were observed in very small size of < 0.02 μm. Calcium and zinc were the most abundant elements besides iron and their sizes were much larger (~ 0.1μm), these metals have their origin in the additives of lubricating oil (Lidia et al., 2002).

**Diesel driven vehicles:**

Diesel exhaust is emitted from a broad range of diesel engines; the on-road diesel engines of trucks, buses, and cars and the non road diesel engines that include locomotives, marine vessels, and heavy duty equipment (USEPA, 2002). Diesel vehicle emits key pollutants like nitrogen oxides; sulphur dioxide and particulate matter while it offers a reduction in the key pollutant carbon mono oxide. The sizes of diesel particulates, which are of greatest health concern, are in the categories of fine, ultra fine, and nano particles. The mixture of these fine, ultra fine, and nano particles is composed mainly of elemental carbon with adsorbed compounds such as organic carbon, sulphate, nitrate, metals, and other trace elements (Kleeman et al., 2000).
Diesel engine has no carburetor and the fuel is directly injected into the cylinder and thus it has higher compression ratio than the gasoline engine and hence it can be run on a lean mixture of air/fuel. The high compression ratio creates high temperature, which results more NOx from diesel engine (Mohan et al., 1996). The generally high acidity of urban soil can be attributed to nitrate and nitrite emissions from diesel engines (Spangler et al., 1990). The combustion system itself leads to high emission of soot and particles. Diesel exhaust particles are mostly sub micrometer agglomerates of carbonaceous spherical particles containing up to 4000 individual spherical particles clustered as agglomerates up to 30 μm (Kittelson et al., 1978).

1.3.4 Distribution of trace metals in soil

Metals are a unique class of toxicants since they cannot be broken down to non-toxic forms and thus the concentration and distribution pattern of metals within the ecosystem is especially important. Many of the toxic metals from the earth’s crust come to the environment due to rapid developments and anthropogenic activities. Once the ecosystem is contaminated by trace metals, they remain a potential threat for many years. This has substantially raised the chances of exposure to these metals in excess of their natural levels through ingestion, inhalation or skin contact. Complex soil functions are beneficial to man and other living organisms. Soil acts as a filter, storage and transformation system and thus protects the global ecosystem against the adverse effects of environmental pollutions. These soil functions can be of best performed only if the normal soil properties are preserved and the natural balance is not unduly distributed.
1.3.5 Road side soil and human health

Soil contamination typically arises from the rupture of underground storage links, application of pesticides, automobile emissions, percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. Human health is directly affected by contaminated soil through direct contact with soil or via inhalation of soil contaminants, which have vaporized. In general potentially greater threats are posed by the infiltration of soil contamination into ground water aquifers used for human consumption. Health consequences from exposure to soil contamination vary greatly depending on pollutant type, pathway of attack and vulnerability of the exposed population. The effects of soil pollution reach across the spectrum from water and air to vegetation, and to human health and society as well. Soil pollution effects may vary based on age, general health status and other factors. According to The Environmental Protection Agency, soil pollution for kids always involves higher risks than for adults. While the specific effects depend on the pollutant, in general they include further environmental contamination as the polluted soil washes into water or is kicked up into the air. Many chlorinated solvents induce liver changes, kidney changes and depression of the central nervous system. There is an entire spectrum of further health effects such as headache, nausea, fatigue, eye irritation and skin rash for the above cited and other chemicals. At sufficient dosages a large number of soil contaminants can cause death by exposure via direct contact, inhalation or ingestion of contaminants in groundwater contaminated through soil (Xu, 2007). Chronic exposure to chromium, lead and other metals, petroleum, solvents, and many pesticide and herbicide formulations can be carcinogenic, can cause congenital disorders, or
can cause other chronic health conditions. Industrial or man-made concentrations of naturally occurring substances, such as nitrate and ammonia associated with livestock manure from agricultural operations, have also been identified as health hazards in soil and groundwater (http://yosemite.epa.gov/water/owrcCatalog.nsf).

Table 1.2: Heavy metal in the surface of soil of the world (Athar et al., 1995)

<table>
<thead>
<tr>
<th>Meatal/Metalloids</th>
<th>Concentration (mg/kg)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Al</td>
<td>71,000</td>
</tr>
<tr>
<td>As</td>
<td>8</td>
</tr>
<tr>
<td>Be</td>
<td>0.3</td>
</tr>
<tr>
<td>Cd</td>
<td>0.5</td>
</tr>
<tr>
<td>Cr</td>
<td>60</td>
</tr>
<tr>
<td>Co</td>
<td>8</td>
</tr>
<tr>
<td>Cu</td>
<td>23</td>
</tr>
<tr>
<td>Pb</td>
<td>30</td>
</tr>
<tr>
<td>Mn</td>
<td>550</td>
</tr>
<tr>
<td>Hg</td>
<td>0.11</td>
</tr>
<tr>
<td>Ni</td>
<td>20</td>
</tr>
<tr>
<td>Se</td>
<td>0.4</td>
</tr>
<tr>
<td>Ag</td>
<td>0.005</td>
</tr>
<tr>
<td>Sn</td>
<td>4</td>
</tr>
<tr>
<td>U</td>
<td>2</td>
</tr>
<tr>
<td>V</td>
<td>87</td>
</tr>
<tr>
<td>Zn</td>
<td>60</td>
</tr>
</tbody>
</table>


Mashi et al. (2005) reported that release of heavy metals is one of the most significant environmental problems caused by the anthropogenic activities. Recently, there has been an increased concern regarding the occurrence of the heavy metals because of their toxicity. Due to high concentration in the environment, these metals may not only pollute the environment but also enter the food chain from soils. Roy et al. (1993) reported that exposure to the metal ions in sufficient quantities can have serious impacts on human health. Nickel and zinc are some of the metals, which are
essential at very low concentrations for life because they have important roles in metabolic processes taking place in living cells. Cadmium and lead on the other hand are non essential metals, which are known to cause severe damage in living organisms even at low concentrations (Gadd et al., 1993). The presence of these metal ions at elevated levels in the environment is often toxic to living organisms (Hustchison et al., 1973). Reddy et al. (1990) reported that the metal toxicity has a direct effect on various physiological and biochemical processes such as photosynthesis, chlorophyll content and reduction in plant growth. Chirika et al. (2011) reported that if large quantities of metal ions are present in soil then the metal ions bind strongly to soil particles and some of these dissolve in water causing metal pollution, hence they accumulate in the bodies of water and soil organisms; they can interrupt the activity in soils, as they negatively influence the activity of soil microorganisms and earthworms and thus the breakdown of organic matter in the soil may seriously slow down because of this. Chirika et al. (2011) also reported that on zinc-rich soils only a limited number of plants have a chance of survival. Gadd et al. (1978) reported that the water soluble zinc that is located in soils can contaminate groundwater. Zinc ions may also increase the acidity of water.

Markus et al. (1996) and Wilcke et al. (1998) reported that the source of key heavy metals Pb, Cu, Zn and Cd in street dust is believed to be from leaded gasoline, car components, tyre abrasion, lubricants, industrial and incinerator emissions.

The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants (Maslin et al., 2000). Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through the direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal...
human) and contaminated ground water. Disturbed ecosystem reduces food quality (safety and marketability) via phytotoxicity, reduces land usability for agricultural production causing food insecurity and land tenure problems (McLaughlin et al., 2000; McLaughlin et al., 2000; Ling et al., 2007). Dust particles function as a carrier of other pollutants which is largely dependent on the particulate composition in terms of the nature of different minerals and organic compounds and their proportions (McBride, 1994).

The presence of heavy metals in and around urban areas has been a subject of great concern due to their non-biodegradable nature and long biological half-lives within the human body, when consumed. For example, Co, Cd and Ni inhibit stomatal activity and decrease photosynthesis (Prasad, 1995). On the other hand, Cd, Cr, Zn and Mn cause neurosis and chlorosis (Delgado et al., 1993) while Cu, Cd, Mn, Co, Zn and Pb impaired seed sprouting and interfere with hormonal balance (Rauser and Dumbroff, 1981).

1.4 Road runoff water
1.4.1 Introduction
Fresh water is a very valuable resource and getting more valuable daily. Increasing populations and technological growth have put the ecosystem under stress and thus the availability of fresh water is at a very high risk (UN, 2002). Consequently people need to utilise every source of water including surface water, groundwater, oasis water, rain water, etc. to meet their demand.

Rain is liquid precipitation that is the condensation of atmospheric water vapour that is pulled down by gravity into drops of water heavy enough to fall and
deposited on the earth surface (Robert, 2002). Surface runoff on the other hand is the water flow which occurs when soil is infiltrate to full capacity and excess water from rain flows over the land. Precipitation can occur via collision with other rain droplets within a cloud while heavy precipitation occur in mountainous areas where upslope flow is maximized within windward sides of the terrain at elevation (Waziri et al., 2012).

Urban surface storm water runoff can be divided in three main types:

- partly sealed surfaces (such as overgrown soil in backyards, urban green spaces and porous paving),
- impermeable roof surfaces and
- impermeable road surfaces.

The level of contamination in rainwater runoffs has become an increasing concern in rainwater utilization. Nonpoint pollution resulting from urban surface runoff was recognized as one of the major causes of quality deterioration in receiving water bodies (Gnecco et al., 2005; Li et al., 2007a; Lijklema et al., 1993). Urbanisation, development and populating of an area create different pollutants, which are carried by road runoff water to receiving waters, such as rivers and lakes, and deteriorate their quality and endanger their ecosystems. Urban rain water, once was recognized as a major source of pollutants, is now considered as a valuable resource for non-drinking purposes in cities. Storm water runoff from urban areas is a significant source of pollution to inland water bodies such as streams, rivers, and lakes (Thomas and Reese, 1995). Despite existing systems of urban runoff collection and disposal, limited consideration has been given to the quality of rain water runoff. Not only water flows into the river but also rubbish, animal droppings, chemicals, fertilizers,
oils, soil and anything that is placed in or washes into street gutters can end up in the river, and polluting the environment (Allison et al., 1998). Urban rain water is harmful to the environment due to its effects on quality and quantity of receiving waters (Lubliner, 2007). As urbanization increases and the amount of permeable land cover decreases, the ability for rainwater to dissipate into the ground through deep infiltration and shallow infiltration considerably decreases (USEPA 2009; Mallin et al., 2009). Numerous dissolved contaminants from both point and non-point sources in urban runoff dramatically increases receiving stream water conductivity and contamination (USEPA, 2009). High concentrations of conductive substances in runoff may shock organisms in the receiving waters (NRC, 2008; Glick, 1979; Rasmussen et al., 2009).

Rain water washes dusts away from the atmosphere and the impervious urban surfaces and, in the form of storm runoff, carries off dissolved, colloidal and solids constituents in a heterogeneous mixture which includes organic and inorganic compounds, nutrients, oils, greases and heavy metals (Gnecco et al., 2004). The associated pollutant load is mainly produced by vehicular traffic and other human activities. The wash off process from road surfaces has been pointed out as an important source of pollutants. High concentrations of heavy metals in dissolved form such as Zn, Cd, Cu and Pb are easily removed in the form of soluble corrosion products of metal surfaces that are commonly used as roofing or gutter materials (Chang and Crowley, 1993; Förster, 1996; Gromaire-Mertz et al., 1999; He et al., 2001). The level of contaminates in rain water runoffs has become an increasing concern in rain water utilization. And one of the best counter measures against a water shortage in urban areas, rain water utilization plays a very important role. It can
overcome a shortage of water supply and in the mean while is very effective for runoff control (Kim R.H., 2001; Wang J.Z. et al., 2004a; Wang J.Z. et al., 2006).

Populations in most parts of the developing world, areas where water is a scarce commodity rely on rain water as the primary source of fresh water, providing suitable environment for diverse ecosystems and crop irrigation. However, human activities such as agriculture, urbanization and the rate of increase of land transformation are alarming. Humans are therefore capable of altering and affecting each part of the hydrologic cycle chemically, physically or biologically. Some impacts may be minor and barely perceptible; others have affected human, degraded rivers, lakes, ground water and rain water to enormous degrees (Ayodele and Abubakar, 1998; Ojolo et al., 2007).

1.4.2 Pollutants in road runoff water and their sources

As urbanization increases and the amount of permeable land cover decreases, the ability for rainwater to dissipate into the ground through deep infiltration and shallow infiltration considerably decreases. Among particulate pollutants on urban road surfaces, fine solids form the dominant fraction and exert a significant influence on road runoff water due to ease of mobility (Deletic et al., 2006; Herngren et al., 2006; Goonetilleke et al., 2009). Furthermore, fine solids particles on road surfaces are also a significant source of air pollution in urban areas (Thorpe and Harrison, 2008; Amato et al., 2009, 2011) and ultimately mixed up with runoff water. It is commonly known that particles accumulated on urban road surfaces carry toxic pollutants such as heavy metals (Rogge et al., 1993; Gunawardana et al., 2011). Winter time salting and sanding practices may leave concentrations of chloride;
sodium and calcium on the roadway surface. Ordinary operations and the wear and tear of motor vehicles also result in oil, grease, rust, hydrocarbons, rubber particles, and other solid materials dropping onto the highway surface.

The associated pollutant load is mainly produced by vehicular traffic and other human activities. The wash off process from roof surfaces has been pointed out as an important source of pollutants. High concerns of heavy metals in dissolved from such as Cu and Pb are easily removed in the form of soluble corrosion products of metal surfaces that are commonly used as roofing or gutter materials (Allison R.A et al., 1998; Chang M et al., 1993; Forster, 1996; Gromaire-Mertz et al., 1999). Heavy metals Pb and Cu are readily soluble salts in runoff, are regarded as hazardous to water (He et al., 2001). So the most common pollutants in road way runoff are heavy metals, inorganic salts, aromatic hydrocarbons and suspended solids which accumulate on the road surface as a result of regular highway operation and maintenance activities. These materials are often washed off the highway during rain or snow storm events. Table 1.2 presents a summary of the typical pollutants that can be found in road runoff and their associated sources.
Table 1.3: Typical pollutants found in runoff from roads

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulates</td>
<td>Pavement wear, vehicles, the atmosphere and maintenance activities, snow/ice abrasiveness and sediment disturbance</td>
</tr>
<tr>
<td>Rubber</td>
<td>Tire wear</td>
</tr>
<tr>
<td>Asbestos</td>
<td>Clutch and brake lining wear</td>
</tr>
<tr>
<td>Nitrogen and Phosphorus</td>
<td>Atmosphere, roadside fertilizer application and sediments</td>
</tr>
<tr>
<td>Lead</td>
<td>Leaded gasoline from auto exhaust, tire wear, lubricating oil and grease, bearing wear and atmospheric fallout</td>
</tr>
<tr>
<td>Zinc</td>
<td>Tire wear, motor oil and grease</td>
</tr>
<tr>
<td>Iron</td>
<td>Auto body rust, steel highway structures such as bridges and guardrails and moving engine parts</td>
</tr>
<tr>
<td>Copper</td>
<td>Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Tire wear and insecticide application</td>
</tr>
<tr>
<td>Chromium</td>
<td>Metal plating, moving engine parts and brake lining wear</td>
</tr>
<tr>
<td>Nickel</td>
<td>Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear and asphalt paving.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Moving engine parts</td>
</tr>
<tr>
<td>Cyanide</td>
<td>Anti-caking compounds used to keep deicing salt granula</td>
</tr>
<tr>
<td>Sodium and Calcium</td>
<td>Deicing salts and grease</td>
</tr>
<tr>
<td>Sulphate</td>
<td>Roadway beds, fuel and deicing salts</td>
</tr>
<tr>
<td>Chloride</td>
<td>Deicing salts</td>
</tr>
<tr>
<td>Bromide</td>
<td>Exhaust</td>
</tr>
<tr>
<td>Petroleum</td>
<td>Spills, leaks, antifreeze and hydraulic fluids, asphalt surface leachate and blow-by motor lubricants</td>
</tr>
<tr>
<td>PCBs and Pesticides</td>
<td>Spraying of highway right-of-ways, atmospheric deposition and PCB catalyst in synthetic tires</td>
</tr>
<tr>
<td>Pathogenic Bacteria</td>
<td>Soil litter, bird droppings and trucks hauling livestock/stockyard waste</td>
</tr>
</tbody>
</table>

**Sources:**
1. U.S. Environmental Protection Agency.
1.4.3 Road runoff water quality effects on receiving waters

Water quality of storm-water runoff was soon identified as being a concern as important as water quantity. Urban rain water is harmful to the environment because of the effects, it has on the water quality and water quantity of receiving waters (Lubliner et al., 2007). EPA (1986) estimates that 77 out of the 127 key pollutants have been detected in urban storm runoff. Rain water pollution is a non-point source of pollution. The porous natural landscapes like forests, grasslands and wet lands can trap rainwater and allow it filter into the ground slowly while runoff tend to reach receiving water gradually. However, non porous landscapes like buildings, roads, parking lots etc do not allow slow percolation of runoff into the ground. Therefore, during heavy rainfall, the runoff that is not absorbed into the ground washes pollutants such as grease, bacteria, animal waste, pesticides, salts, heavy metals etc into nearby water ways without any treatment where it can degrade water sheds. As a result, fish and aquatic species are harmed as well as recreational areas become unsafe due to increase in contaminants (Chang et al., 2004; Simmons et al., 2001; Dinrifo et al., 2010). Urban storm water runoff contains pollutants which can impact the quality of surface water, seepage water and ground water. Heavy metals, e.g. lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), polycyclic aromatic hydrocarbons (PAH), mineral oil hydrocarbons (MOH) and readily soluble salts in runoff, are partly regarded as hazardous to water (Pitt et al., 1994). The distribution or concentration of these pollutants depends on the characteristics of the surface, and the dry and wet atmospheric depositions (Förster, 1996b, 1999). Particulates or sediment suspended in the runoff may contain relatively insoluble substances like heavy metals adhere to
them. These substances are then transported to receiving waters where they may create a threat to aquatic life. The "sink effect" of heavy metal bioaccumulation in stream and lake sediments has been revealed by many studies. Likewise, aquatic life near a road will, also, show increases in heavy metals. Fertilizers containing nitrates and phosphates may stimulate the growth of algae blooms in receiving waters and deplete levels of dissolved oxygen necessary for supporting aquatic life causing eutrophication. Airborne particulate matter may be fall to earth where it will become a component of highway runoff during periods of precipitation. Nutrients from road runoff may also pose hazard to groundwater resources.

1.5 Toxicity of trace elements under study

1.5.1 Toxicity of trace elements

Soil particles and water molecules are important carriers of metals, certain of which possess toxic properties and are present in excess of natural levels. Environment Protection Agency has listed eight common heavy metals as pollutants, viz., As, Cd, Cr, Cu, Hg, Ni, Pb and Zn. Thus regarding health effects, much focus is on smaller particles (size 10 micron and less), which are respirable. It has been reported that children could ingest heavy metals including dusts via their hands or mouths (Watt et al., 1993). If this inhalable dust has higher concentration of trace metals like Pb, Cd, Cr, Ni, Zn etc, then it may cause serious health effects as follows:

**Lead (Pb):** Lead is toxic and its hazardous effects due to industrial exposure are well documented. Tiredness, run down feeling, nervousness, depression, lack of mind concentration, frequent cold and other infections, mild psychoneuroses results from lead poisoning. Most of lead is accumulated from the diet, air and water. Rate of accumulation of lead is about 200-300 μg per day per person. Biochemical signs of
toxicity are seen from disturbances to prophyrin metabolism. Clinical signs of toxicity are most often seen at blood lead levels above 4 \( \mu \text{mol.lit}^{-1} \).

Lead is accumulated in bones and soft tissues, particularly in brain leading to depressed functioning. It causes structural damage to mitochondria of kidney and it is responsible for the loss of amino acids, glucose and phosphate in urine. It is also responsible for increased dental caries as it is poorly excreted. It damages liver, kidney and gastrointestinal tract and causes anorexia, muscle pains, weakness, joint pain, tremor, anaemia. It also causes abnormalities in fertility and pregnancy.

Lead is a cumulative polytrophic poison acting mainly on the central and peripheral nervous system. There is substantial evidence that high Pb level in the environment could effect blood Pb level, intelligence and behaviour.

**Cadmium (Cd):** Cadmium is not an essential element for human body. It is a toxic metal. Intake of cadmium occurs mainly through the food chain by about 40 mg per day. Exposure to metallic dust or fume during industrial operations causes hypertension and cardiovascular problems, which finally lead to acute damage to the workers lung. It is the cause of proteinuria, glycosuria, carcinomas, edematons along with proliferative and fibrogenic effects on lungs. Zinc appears to give some protection against the toxic effects of cadmium. The reported hypertensive effect of cadmium in man has been associated with a high cadmium/zinc ratio in the kidney. Cadmium depresses growth and reduces the digestion of protein and fat. Enzyme bound cadmium accumulates in kidney, liver and reproductive organs. The kidney is the main target of attack by cadmium. Renal damage takes place when a critical level of 200\( \mu \text{g} \) of cadmium per gram is exceeded. It is the excess cadmium thioein that is
the toxic factor here. The affected kidney is unable to retain plasma proteins and other substances including calcium and phosphorus. These substances are excreted in excess, leading to renal stone formation and bone damage in severe cases.

A specific disease, known as itai-itai, broke out in Japan, was attributed to cadmium poisoning. Itai-itai shows painful symptoms of multiple fractures arising from ostomalacia. It is largely confined to post-menopausal women with initial signs of lumber pains and myalgia in the legs. Skeletal formation takes place at the later stages, with marked decrease body weight, proteinuria and glaucoma. Cadmium is a very poisonous metal even at extremely low concentration. It is known to accumulate in human kidney and liver.

**Chromium (Cr):** Air borne Cr compounds and chromic acid mists particularly, the hexavalent chromates, appear to produce irritation of the skin and respiratory tract, dermatitis, perforation of the nasal septum, ulcers and cancer of the respiratory tract.

**Nickel (Ni):** It is an essential trace element. Nickel dust or nickel containing asbestos powder inhaled on occupational exposure, may produce bronchial cancer in man. It causes dermatitis, respiratory disorders, reduces activities of cytochrome c oxidase, isocitrate dehydrogenase of liver and maleic dehydrogenase of kidney \( \text{LD}_{50} \) (dog) = 0.8g/kg. The most common adverse health effect of Ni in human is an allergic reaction. Nickel acts as an initiator and promoter of cancer.

**Zinc (Zn):** Acute zinc poisoning is characterized by metallic taste, substernal and abdominal pain, vomiting, purging, convulsions, collapse and death. Chronic zinc poisoning usually occurs among the workers of zinc smelters. Zinc pollution due to inhalation of industrial smoke causes severe respiratory irritation and cyanosis, called
zinc fume fever. Chronic over ingestion of zinc causes dyspepsia, colic, diarrhoea, anorexia, peripheral neuritis leading to paralysis. Zinc is an essential element for humans. Too little Zn can cause health problems, but too much Zn is also harmful. Excess amount of zinc can cause stomach cramps, nausea, vomiting, central nervous system disturbances.

Copper (Cu): Although copper in trace amounts is essential for life due to its role in metalloenzymes, viz., cytochrome c oxidase, superoxide dismutase, blue copper proteins, ascorbic acid oxidase, ceruloplasmin, hemocyanin, etc. but even in moderately low concentrations copper salts may cause vomiting and considerable gastrointestinal irritation.

In patients, suffering from Wilson’s disease, the copper level control mechanisms are damaged. Absorption of copper is increased since excretion cannot keep pace with the intake. So copper accumulates in various organs, such as liver, kidney and brain. Such absorption of copper severely damages central nervous system, leads to tremor, rigidity, metal subnormality, etc. accumulation of copper also leads to cirrhosis of liver, which ultimately causes a painful death. Cu poisoning leads to renal damage, CNS irritation and depression, disruption of kidney function, etc.

Manganese (Mn): It is an essential nutrient for animals and plants. But airborne manganese is responsible for an increased incidence of manganic pneumonia in populations living in industrial areas. Toxicity due to manganese is responsible for “Parkinson’s syndrome”. Chronic manganese poisoning through ingestion progressive deterioration in the central nervous system, resulting in cramps, tremors, hallucinations and lethargy. It causes renal degeneration. Manganese deficiency in
human induces transient dermatitis, changes in human hair colour and growth, hypocholesterolemia and skeletal abnormalities.

**Iron (Fe):** Anemia results from insufficient oxygen supply, often because of a decrease in hemoglobin (Hb) blood levels. Approximately 65 to 70% of total body iron resides in hemoglobin. Acute iron poisoning results in corrosion of the gastrointestinal tract. Excess iron digestion causes chronic iron poisoning or hemochromatosis. The chelating agent of choice for iron toxicity is the siderophore desferrioxamine, a polypeptide having a very high affinity for Fe (III) but not for other metals.

**Cobalt (Co):** Cobalt is an essential element. Liver, kidney, heart and muscles contain higher amounts of cobalt than other components of the body. Cobalt itself is the etiological of hard metal disease. It is very toxic to mammals if injected intravenously. Fatal poisoning has been cost by drinks containing 1.2-1.5 mg. Lit\(^1\) of cobalt. Ingestion of higher doses of cobalt over a period of some days affects hemoglobin content and produces polycythaemia and hyperlipemia. Cobalt is considered goitrogenic agent. The principal symptoms of poisoning are cardiac insufficiency and myocardial failure. Cobalt and its compound lead to lung fibrosis. Cobalt causes chitis, asthma and emphysema. Disease of the heart muscle, cardiomyopathies are caused by cobalt.

**1.6 Literature Survey**

**1.6.1 Literature survey of road side surface soil**

Rapid urbanization is a worldwide phenomenon. According to World Urbanization Prospects, over half of the world's 6.9 billion people now live in urban areas, likely rising to 68.7% by 2050 (UN,2010). Urban environments thus become
supremely important with regard to human health and wellbeing (Davydova, 2005). Industry and economic activities are more concentrated in urban areas, and cities have become the geographic focus of resource consumption and chemical emissions, which may cause many environmental problems. Soil is a crucial component of urban ecosystems, contributing directly or indirectly to the general quality of life for city residents. Soil plays a principal role in biochemical transformations, the cycling of elements, filtration of water, supporting plants and infrastructure, and many recreational activities (Stroganov et al., 1997).

Contaminated urban soils may pose significant risks to human health through the ingestion of soil particles, dermal contact, inhalation of dust and the consumption of vegetable crops (Markus and McBratney, 2001; Filippelli et al., 2005; Kachenko and Singh, 2006; Nabulo et al., 2010; Hamzeh et al., 2011; Luo et al., 2011). Urban soils differ greatly from natural ones as they are more strongly influenced by anthropogenic activities (Bullock and Gregory, 1991). The accumulation of heavy metals in topsoil is greatly influenced by traffic volume and vehicles, which introduce a number of toxic metals into the atmosphere (Wixson and Davies, 1994). An understanding of the properties, processes, and ecosystem services of intensively disturbed urban soils has important implications for a large urban population (Vegter, 2007).

It is reported that in the last three or four decades, the study of urban soils has emerged as an important frontier in environmental research (Wong et al., 2006; Heinrich and Morel, 2008). One of the key issues is the degradation and pollution of urban soils in many parts of the world. Urban soils are subject to continuous accumulation of contaminants from either localized or diffuse sources (Nriagu and...
Pacyna, 1988; Ajmone-Marsan and Biasioli, 2010 and Fabietti et al., 2010). Heavy metal contamination of soil pollution is a serious problem in comparison to air or water pollution as organic components bind the heavy metals by the organic components in the surface layers of the soil tightly and consequently the soil is an important geochemical sink which accumulates heavy metals quickly and usually depletes them very slowly by bio accumulating into plants or by leaching effect into groundwater aquifers (Infotox, 2000). However, plant toxicity can occur at soil Pb concentrations ranging from 100 to 500 mg kg\(^{-1}\), depending on the plants and the physico-chemical properties of soils (Kabata-Pendias and Pendias, 2001). Typical contaminants include persistent toxic substances (PTSs), such as trace metals and persistent organic pollutants (POPs). The main sources of these pollutants are industrial discharges, traffic emissions, and wastes from municipal activities. Many pollutants can remain in urban soils for a long time, which may act as a source of further pollution in urban environments, and pose a potential threat to human health and ecological systems (Wong et al., 2006).

Most of the heavy metals in small amounts enter the human body via drinking water, food, and air. Some heavy metals like iron, cobalt, copper, manganese, and zinc are nutritionally essential for human health for normal growth but the excessive levels is harmful to the organisms. Some of these heavy metals are referred as the trace elements and some form of them are commonly found in synthetic multivitamin products, fruits, and vegetables. So heavy metals are the metallic elements having a relative high density and toxicity at low concentrations. Street dusts and top roadside soils in urban area are indicators of heavy metal contamination from atmospheric deposition. Key heavy metals are thereby Pb from leaded gasoline, Cu, Zn, and Cd.
from car components, tyre abrasion, lubricants, industrial and incinerator emissions (Markus et al., 1996 and Wilcke et al., 1998). The source of Ni and Cr in street dust is believed to be corrosion of cars (Ferguson et al., 1991 and Akhter et al., 1993) and chrome plating of some motor vehicle parts (Al-Shayep et al., 2001) respectively.

Heavy metals are natural constituents of the earth’s crust. Heavy metals are stable and persistent environmental contaminants since they can not be degraded or destroyed easily. So the heavy metals have tendency to accumulate in the soil, freshwater, sediments and sea waters. They are persistent in all parts of the environment because of their non biodegradable nature. Metals may be found in solution of soil as complexed form of organic or inorganic constituents or free ions. Metals in both of these forms may be taken up by plants, retained on mineral surfaces, natural organic matter and microbes, transported through the soil profile into ground water via leaching, precipitated as solid phase and diffused in porous media such as solids. Translocation of heavy metals through the environment by erosion of the soil particles to which they are adsorbed or bound takes place very quickly and re-deposited somewhere else. Many researchers have reported about the contamination of soil from various anthropogenic sources such as automobile emission (Lagerweff and Specht, 1970; Fergusson et al., 1980; Garcia-Miragaya, 1984), mining activity (Davies and Ginnever, 1979; Culboard and Johnson, 1984), and agricultural practices (Colbourn and Thornton, 1978).

Release of heavy metals is one of the most significant environmental problems caused by the anthropogenic activities. Recently, there has been an increased concern regarding the occurrence of the heavy metals because of their toxicity. Due to high concentration in the environment, these metals may not only
pollute the environment but also enter the food chain from soils (Mashi et al., 2005). Industrial wastes as on one of the prime anthropogenic source of heavy metals in nature (Haines and Pocock, 1980; Parry et al., 1981; Culboard et al., 1983 and Gibson – Farmer, 1983). Atmospheric deposition is the main source of metal input to soils. Trace metals such as Cu, Pb, and Zn are transported in particulate phases (Adriano, 2001 and Adriano et al., 2005). Civilization was founded upon the metals of antiquity, gold, copper, silver, lead, tin, iron and mercury (Sparks, 2005)

Natural and consumer materials contain small concentrations of different heavy metals as reported by ATSDR (1999). Heavy metals are essential in building materials, vehicles, appliances, tool and computers and other electronic goods components. Heavy metals also get its essential application in the field of infrastructure including highways, bridges, railroads, airports, electrical utilities and food production and distribution (Spark, 2010). The petrol driven (two stroke) vehicles release gaseous exhaust with carbon monoxide (3%), hydrocarbon hexane (500 ppm) and oxide of nitrogen (1500 ppm) while the four stroke petrol driven vehicle release 3.4% CO, 850 ppm hexane and 1000 ppm oxide of nitrogen respectively (Bhardadwaj, 1990). Since potassium permanganate gets its use as an oxidizing and disinfectant in water purification and in waste-treatment plants, so it is also used in metal cleaning, bleaching and as a preservative for fresh flowers and fruits. Manganese compounds are used in manufacturing of products such as batteries, steel and unleaded petrol. In the production of dry cell batteries, matches, fireworks, porcelain and glass-bonding materials, manganese dioxide is commonly used. Metal manganese is also used as the starting material for the production of other manganese compounds such as manganese chloride is a precursor of other manganese
compounds. Mn is used as a catalyst in the chlorination of organic compounds, in animal feed to supply essential trace minerals and in dry cell batteries. Manganese sulphate is used as a fertilizer, livestock nutritional supplement and in ceramics (US EPA, 1984). Nickel is found in milk, coins and kitchen utensils and Chromium in fresh foods, copy machine toner. Cadmium is mainly used in batteries, plastics. Cadmium is also found in cigarette smoke, in shellfish and vegetables. Cadmium is used industrially as an anti-friction agent, as a rust-proofer, in plastics manufacture, in alloys and in alkaline storage batteries.

Copper is essential to all living organisms and has a wide range of effects depending on concentration and chemical formulation. Copper is used in chemical catalyst, in the electrical industry, in alloys such as brass, in equipments, in petrol, toys, paint etc. Use of lead is found in batteries, electronic equipments, toys, paint and in petrol. Although lead has been used as fuel additives for several years but now this practice has stopped because of the health implications of lead. Currently methylcyclopentadienyl manganese tricarbonyl (MMT) is the most popular lead replacement compound due to its lower production costs (Chevron, 2002 and Graboski, 2003). The manganese based additive is added in smaller amounts than TEL (Tetraethyl lead), with a maximum concentration of 18mg/L (Chevron, 2002; DEAT and DME, 2003; Goosen, 2003).

The growth of plants is effected by the trace elements. Saline soils are entirely free of plant and animal life as is the case of Dead Sea or great salt lakes (Brenchly W.E., 1943). The metals and their compounds can accumulate in the tissues, bones or nerves of the human body and can cross the placenta causing harm to an unborn child.
in pregnant women. He also reported that children are the most susceptible to health problems caused by heavy metals, because their bodies are smaller and still developing (Fergusson, 1991 and Thomson, 2007). Exposure to the metal ions in sufficient quantities can have serious impacts on human health. Nickel and zinc are some of the metals, which are essential at very low concentrations for life because they have important roles in metabolic processes taking place in living cells (Roy et al., 1993). The degradation of soil quality associated with the constant dumping of non-biodegradable metal/metalloid pollutants has drawn focus of scientists working in this area and one of the study revealed that, the soil adjacent within 100 ft of the edge of the road to major roads is found polluted with heavy metals particularly lead given out along with gases from the automobile engine (Williamson et al., 1972). The metal toxicity has a direct effect on various physiological and biochemical processes such as photosynthesis, chlorophyll content and reduction in plant growth (Hustchison et al., 1973 and Reddy et al., 1990). If large quantities of metal ions are present in soil then the metal ions bind strongly to soil particles and some of these dissolve in water causing metal pollution, hence they accumulate in the bodies of water and soil organisms; they can interrupt the activity in soils, as they negatively influence the activity of soil microorganisms and earthworms and thus the breakdown of organic matter in the soil may seriously slow down because of this (Chirika et al., 2011). The pollution of soils by heavy metals from automobile sources is a serious environmental issue. These metals are released during different operations of the road transport such as combustion, component wear, fluid leakage and corrosion of metals. Lead, cadmium, copper, and zinc are the major metal pollutants of the roadside environments and are released from fuel burning, wear out of tyres, leakage of oils, and
corrosion of batteries and metallic parts such as radiators etc. (Dolan et al., 2006). The soil pollutants of the surface soil can move to the ground water through the medium of unsaturated zone which is inhabited by myriads of soil organisms (Yaron B et al., 1984). On zinc-rich soils only a limited number of plants have a chance of survival (Chirika et al., 2011). The Water soluble zinc that is located in soils can contaminate groundwater and Zinc ions may also increase the acidity of water (Gadd et al., 1978).

The major pollutants emitted by vehicles include oxides of nitrogen, sulphur dioxide, carbon monoxide, SPM and lead (Parida M et al., 1990). Cadmium and lead on the other side are nonessential metals, which are known to cause severe damage in living organisms even at low concentrations. The presence of these metals ions at elevated levels in the environment is often toxic to living organisms (Gadd et al., 1993). Anthropogenic source is the major source of heavy metal pollution in urban areas and which also include the combustion the fossil fuel and coal (SCOPE, 1987). The extent of the pollution of a soil can be measured with respect to a particular toxic element by determining its concentrations and comparing this with unpolluted soil values. Also distribution profile of toxic elements provides an insight into their behavior during weathering and availability to plants (Alloway B.J., 1990). Pb in roadside soil was found upto a distance of 50 meters (Goldsmith et al., 1976). The Lead has a cumulative polytropic poisonous action mainly on the central and peripheral nervous system (Kehoe R.A., 1969). That soil pH and conductivity increases while porosity and water holding capacity of the soil decreases when soil was incorporated with fly ash (Kumawat D.M., 1988). A relationship was found between the distribution of roadside soil and vegetation with the daily traffic volume (Wheeler G.L et al., 1979). Accumulations of these metals in top soils are greatly influenced
by traffic volume. Lead, in particular, is a pollutant of concern because of the use of alkyl lead compounds as antiknock and freezing additives in fuel. Other heavy metals associated with vehicular emissions are Cu and Zn (Al-Kashman et al., 2009). Lead compounds predominate in the small particles, with a mass median equivalent diameter (unit density sphere) of approximately 6.12 μm in the atmosphere near auto traffic zones and remains airborne for long periods of time and settles slowly on plane surface and can also be inhaled by human being into their respiratory tract (Robinson et al., 1963).

The majority of the heavy metals are toxic to the living organisms and even those considered as essential can be toxic if present in excess. The heavy metals can impair important biochemical processes posing a threat to human health, plant growth and animal life (Jarup, 2003; Michalke, 2003; Silva et al., 2005). Beaton et al. (1992) have found the median hydrocarbons emission as 1,100 ppm measured as propane equivalent, while the emission comes from 12% of the fleet with more than 4,000 ppm propane equivalent in this exhaust when they assessed the emission characteristics of Mexico City vehicles. Studies have shown that such pollutants can be harmful to the roadside vegetation, wildlife, and the neighbouring human settlements (Muskett and Jones, 1980; Khan and Frankland, 1983; Ndiokwere, 1984; Iqbal et al., 1994; Ferretti et al., 1995; Caselles, 1998; Turer and Maynard, 2003). The distribution of these metals in the roadside soils is strongly but inversely correlated with the increase in the distance from road (Warren and Birch, 1987; Bhatia and Choudhri, 1991; Aksoy, 1996). Khandekar R.N et al. (1984) reported elevated levels of heavy metals in soil, vegetation and ambient air urban areas along with particulate and gaseous pollutants, due to burning of fossil fuels and industrial emissions. The
most frequently reported heavy metals with regards to potential hazards and occurrence in soils are Al, Co, Cu, Fe, Pb, Mn, Ni and Zn (Mmolawa, K.B. et al., 2009). The contamination of road side by Zn and Pb metal was found high (Albasel et al., 1985). The presence of heavy metals in and around urban areas have been a subject of great concern due to their non-biodegradable nature and long biological half-lives within the human body, when consumed (Prasad, 1995). 264 surface soil samples were studied by Klein D. in 1972, and found Cu, Cd, Cr, Ni, Pb, Zn were more concentrated in soil from industrial areas in comparison to residential and agricultural areas. On an average a car discharges 0.5 to 105 of pollutants during a day's driving depending on the condition of the car. Vehicular exhaust accounts for more than 50% of the total pollution from all source put together in all the big cities of India (Mathur H.b., 1992). Cobalt, Cadmium and nickel inhibit stomatal activity and decrease photosynthesis. On the other hand, Cadmium, Chromium, zinc and Manganese cause neurosis and chlorosis (Delgado et al., 1993). It was found that Cu, Cd, Mn, Co and Zn impair seed sprouting and Cd, Cu, Ni and Pb interfere with hormonal balance (Rauser and Dumboff, 1981). About 52% of total cadmium pollution comes from the incineration of disposal Cd bearing product such as automobile tyres, motor oils, fungicides, plastics and coal (Rao C.S., 1994).

It was reported that in terrestrial ecosystems, soils are the major recipient of metal contaminants, while in aquatic systems sediments are the major sink for metals. He also reported that a number of biogeochemical processes take place at the heterogeneous interface between the rock, soil, water, air and living organisms and these processes or interactions in turn control the solubility, mobility, bioavailability and toxicity of metals (Spark, 2005). The heavy metals are extremely toxic to flora
and fauna and being peagonally added to environment due to pollution (Autonovics T et al., 1971). Humans are always exposed to the natural levels of trace elements and under normal conditions the body is able to control some of these elements. He also reported that continuous exposure to elevated levels of metals could cause serious illness or death (Okonkwo, 2005; Rollin et al., 2005 and Moja, 2005). The health hazards presented by heavy metals depend on the level and the length of exposure (Thomson, 2005).

1.6.2 Literature survey of road runoff water

Rain water runoff is the rain that runs off streets, rooftops, parking lots, lawns and otherland surfaces and eventually runs into our streams. Rain water also picks up pollutants as it flows across land surfaces. Pollutants include sediment, pesticides, fertilizers, bacteria and disease causing organisms from pet waste and failing septic systems; petroleum products such as oil and grease; salt used on roads and sidewalks; and even auto wear and exhaust. Sometimes pollutants (e.g., used oil, paint thinners, etc.) are illegally dumped directly into storm drains and waterways. The road runoff is the principal source of non point water pollution (Marsalek et al., 1997).

Urban storm water discharge during wet-weather flows is a major contributor to the pollution of many receiving waters (Lee et al., 2004 and Nordeid et al., 2004). Adverse impacts on receiving waters associated with rain water discharges have been discussed by EPA (1995b) in terms of three general classes as:-
a) Short-term changes in water quality during and after storm events including temporary increases in the concentration of one or more pollutants, toxics or bacteria levels.

b) Long-term water quality impacts caused by the cumulative effects associated with repeated storm water discharges from a number of sources.

c) Physical impacts due to erosion, scour, and deposition associated with increased frequency and volume of runoff that alters aquatic habitat.

The expansion of urban areas is creating more impervious surfaces, such as roofs, roads, and parking lots, which collect pathogens, metals, sediment, and chemical pollutants and quickly transmit them to receiving waters during rain. This non-point source pollution is one of the major threats to water quality and is linked to chronic and acute illnesses from exposure through drinking water, seafood, and contact recreation.

Impervious surfaces have long been implicated in the decline of watershed integrity in urban and urbanizing areas (Banneman et al., 1993; Brattebo and Booth, 2003). The chemical composition of urban runoff is influenced by watershed characteristics such as land use, traffic volume, and percent impervious cover. Heavy metals are of particular interest in rain water runoff due to their toxicity, ubiquitousness, and to the fact that they do not degrade in the environment. Impervious surfaces also lead to pooling of rain water, increasing potential breeding areas for mosquitoes, the disease vectors for dengue hemorrhagic fever, West Nile virus, and other infectious diseases. Urban road runoff water once was recognized as a major source of pollutants, is now considered as a valuable resource for non-drinking purposes in cities. Urban road runoff water non-pollutant source pollutants are
recognized as a major cause of receiving waters quality deterioration. Urbanization, development and populating of an area create different pollutants. Storm water runoff from urban areas is a significant source of pollution to inland water bodies such as streams, rivers and lakes (Thomas N.D., 1995). Non potent pollution resulting from urban surface runoff was recognized as one of the major cause of quality deterioration in receiving water bodies (Feng P et al., 2006; Gnecco T, 2005; Lijklema L et al., 1993).

Storm water runoff not only flows into the river but also rubbish, animal droppings, chemicals, fertilizers, oils soil and anything that is placed in or washes into street gutters can end up in the river and polluting the environment (Li LQ et al., 2007a). Rain water washes dusts away from the atmosphere and the impervious urban surfaces and in the form of storm runoff, carries of dissolved colloidal solids constituents in a heterogeneous mixture which includes organic and inorganic compounds, nutrients, oil, greases and heavy metals. Runoff from road surfaces is thought to be a significant source of nonpoint pollution to surface and ground waters (Gupta and others, 1981). “Most aquatic biota is sensitive to pH variations,” and “fish kills and reduction and change of other species result when the pH is altered outside their tolerance limits.” Most pH impacts in urban waters are caused by runoff of rainwater with low pH levels i.e. acid precipitation (Novotny and Olem, 1994). The importance of suspended solids and pH in regulating the toxicity of trace metals. An increasing pH in suspended solids reduced the toxicity of metals and hydrocarbons, while decreasing pH (from 8 to 5) increased the toxicity of metals (Hall and Anderson, 1988). It is well recognised that hardness (or salinity) is an important factor
in metal bioavailability through its influence on metal speciation (Markich, 1994; Bervoets, 1996).

Increasing salinity which decreases the free ion activity of trace metal has been found to correlate with decreasing bioavailability (Bervoets, 1996). Freshwater systems are contaminated due to runoff and drainage via sediments or disposal, while ground water is impacted through leaching or transport via mobile colloids (Adriano, 2001). Highway runoff as a potential source of pollution has been recognized by numerous investigators (Sartor and Boyd, 1972; Shaheen, 1975; Novotny and Chesters, 1981; Gupta and others, 1981). The major component of street-surface contaminants is particulate matter. Non particulate soluble and suspendable matter also is present on street surfaces (oils and salts). Chemical constituents associated with highway runoff include heavy metals, nutrients, and complex organic compounds. Heavy metals include cadmium, chromium, copper, iron, lead, zinc, aluminum, and nickel. Nutrients include nitrogen and phosphorus species. Organic compounds include oil and grease and poly aromatic hydrocarbons (Donna M. Schiffer, 1989). The magnitude of constituents on highways is dependent on many side-specific variables, such as traffic characteristics (speed, volume of traffic, and amount of braking), climatic conditions (frequency, intensity, and duration of precipitation, and wind), percentage of pervious and impervious areas contributing runoff to the roadway, age and condition of automobiles on the road, regulations in the area governing emissions and littering, highway maintenance policies (street sweeping, mowing adjacent to highways, and deicing), and the types and amounts of vegetation on the road right-of-way (Gupta et al., 1981).
In the process of recirculation of water in nature, all the airborne pollutants are returned to Earth's surface, where they contribute to the worsening of the quality of water and changes in the chemical composition of soils (Polkowska Ż. et al., 2010). Traffic and road transportation in general are responsible for manufacturing and subsequently introducing into the environment a huge number of toxic substances, including tar and oil products, dioxines, oxygen compounds, halogenofenols, metals and even salts used for de-icing roads in winter (Maltaby L et al., 1995). The compounds present in the runoff from the arterial roads originate not only from the process of burning gas and diesel oil, but also as a result of the usual wear and tear of car parts. Lube oils and fuels are responsible for hydrocarbon emissions (Polkowska Ż. et al., 2010). Incomplete combustion of fuels introduces to the environment such compounds as CO, NO\textsubscript{2}, ketones, alehydes and polycyclic aromatic hydrocarbons (PAHs), consumption of the oil in the crankcase contributes to the emission of aromatic hydrocarbons (fluoranthene, pyrene, fenanthrene and naphtalene). Composition of the exhaust gases depends on the type and use of the engine. CO and hydrocarbon emissions maxima are usually observed during braking and idle run, while nitrogen oxides are chiefly produced during cruise and acceleration periods. In addition to the petroleum hydrocarbons, traffic pollutes the environment with heavy metals. Consumption of tires is a source of zinc and cadmium, while use of brake shoes creates lead, chromium, cadmium and magnesium. Engines and oil leaks brings about such metals such as aluminium, cobalt, nickel and chromium, and consumption of wheels creates iron, aluminium, chromium, and zinc (Maltaby L et al., 1995). He also found that other hazardous pollutants produced by motor vehicles are dusts, asbestos dust originating from the brake lining and dust from the abrasion of tires.
The monitoring of the composition of wet-deposition (e.g., rain, sleet, snow) on urban highways and its effects on urban pollution has been an important part of environmental studies in many countries (Mangani et al., 2005; Backstrom et al., 2003). Physiochemical characteristics of water can influence the bioavailability and hence toxicity of road runoff samples. Physico-chemical states of metals in water, sediments and soil greatly influence the transport, cycling, fate, bioavailability and toxicity of heavy metals in the environment. Globally, the concentration, transport and fate of some of these pollutants are usually difficult to generalise on especially in most runoff studies (Grenato and Smith, 1999) because rainfall occur not at fixed and definite times, but randomly with varying intensity, resultant volume and quality of the runoff (Marsalek et al., 1997; Luke and Barrie, 2001). Nevertheless, persistent efforts directed at monitoring these pollutants have shown that Zinc, Lead, Copper, Cadmium and Nickel along with some other heavy metals could all be found in urban and highway runoffs (Marsalek et al., 1997; Luke and Barrie, 2001; Mangani et al., 2005). Other pollutants that could be found in highway runoff include hydrocarbons (Barret et al., 1993), along side pollution-indicator indices such as total solids, total suspended solids, (Perdikaki and Mason, 1999; Hvitved-Jacobson and Yousef, 1991). Heavy metals such as copper, cadmium, chromium, lead and zinc among others are constantly being studied and monitored in highway runoffs because of their probable mobilization to useable water systems such as the beaches and underground water, where at elevated concentration levels could cause public health risks (Dwight et al., 2002). As these heavy metals and other pollutants are continuously mobilized to such water bodies and exposed land mass, they ultimately lead to soil and water pollution (Perdikaki and Mason, 1999). Though, the level of the pollution
depends on the nature of civil works on the highway, the duration of the Antecedent Dry Period (ADP) before the rainfall, size of the rainfall, volume of traffic per day of the study side and nature of land use of the adjoining area (Driscoll et al., 1990), various studies have emphasized on the importance of the first flush phenomenon, which are basically samples collected within the first few minutes of the commencement of rainfall, as being a suitable marker towards identifying the upper limits of these pollutants (Barret et al., 1993; Soller et al., 2004; Mangani et al., 2005). According to (Pitt et al., 1995). Pollution from non-point sources such as highway runoff has continued to be a major source of concern for environmental regulatory bodies and other stakeholders the world over as they contribute to the pollutant load of the receiving environment, in most cases the water bodies and farmlands. This results in a gradual degradation of the receiving water quality and an eventual impairment of the beneficial uses of such receiving environment wide range of pollutants have been shown to be present in highway runoff with about 75% (by dry weight) of these pollutants derived directly or indirectly from vehicles, road surface degradation, atmospheric sources and road maintenance (Ellis and Revitt, 1994). The primary sources of metals in urban storm water are industry and automobiles. Davis et al. (2001) reported that the sources of heavy metals in urban storm water runoff are numerous and the release of metals into the environment is governed by several complex mechanisms.

Various pollutants are commonly found in urban and suburban storm water. Runoff from roofs, roads, and parking lots can contain significant concentrations of copper, zinc, and lead, which can have toxic effects in humans. Insecticides are frequently found in fish at levels considered harmful to wildlife, raising concerns
about carcinogenic effects and disruption of hormonal systems in humans. Pollutants from increased traffic volume in recent decades has resulted in higher concentrations of polyaromatic hydrocarbons, known for human carcinogens and in urban lake sediments, these concentrations are commonly exceeding levels set to protect aquatic ecosystems. Metals in urban storm water have the potential to impact water supply and cause acute or chronic toxic impacts for aquatic life. Vehicles contribute a number of pollutants to urban storm water in addition to metals and nitrogen. Engine coolants and antifreeze containing ethylene glycol and propylene glycol can be toxic and contribute to water quality impairments. Oil, grease, and other hydrocarbons related to vehicle use and maintenance also pollute urban runoff. They come from disposal of used oil and other fluids on the ground or into storm drains, spills of gasoline or oil, and leaks of oil and other fluids from vehicles. In addition, hydraulic oil is ubiquitous at industrial sides and is difficult for facilities to control at the source, contributing these hydrocarbons to stormwater. Runoff from residential car washing also contributes oil and grease to the stormwater system. The vehicle exhaust that is deposited on roads also contributes dioxins, highly toxic chemicals that persist in the environment. The heavy metals are dominated by discharges from impervious areas such as highways, road surfaces, and roofs (Nelson and Booth, 2002; Van Metre and Mahler, 2003; Chang et al., 2004; Nordeid et al., 2004). These metals are either dissolved in the storm water or are bound to particulates; the degree of binding is a function of pH, average pavement residence time and the nature and quantity of solids present (Sansalone and Buchberger, 1997).

The partition between the solid and aqueous phase has a major effect on the occurrence, transport, fate, and biological effects of heavy metals in aquatic systems.
Heavy metals accumulated in sediments have the potential to produce toxic effects in benthic invertebrates and aquatic microorganisms, both in wetlands as well as ponds (Wood and Shelley, 1999; Karouna-Renier and Sparling, 2001). A significant portion of the heavy metals in storm water is associated with suspended particulate materials that vary from coarse (>75 µm) and fine particulates (<75 to 1 µm), to colloids (<1µm) (Sansalone, 2003). Research investigations on storm water runoff increasingly focus on evaluating storm water runoff quality and the effectiveness of adopting storm water best management practices to minimize pollutant input to receiving waters. Most pollutants in urban runoff, including heavy metals, are in particulate form, or, are bound to particulates and tend to settle out of the water column and accumulate in sediments (Campbell, 1994). Sedimentation is believed to be the primary means by which vegetated control facilities and other BMPs improve runoff quality (Mazer et al., 2001). Oregon Environmental Council also reported that the effects of metals on human and aquatic health can be far reaching. Lead, which is often used as an indicator for other toxic pollutants in storm water, can be harmful or deadly for human and aquatic life. Zinc, although not harmful to humans at concentrations normally found in storm water, can be deadly for aquatic life. Cadmium can bio accumulates in an ecosystem, soil microorganisms are especially sensitive to it, and it is harmful to human health. Chromium damages fish gills, causes birth defects in animals, and is also dangerous to human health. Mercury is a neurotoxin that bio accumulates and has led to fish consumption advisories in Oregon rivers. Recent research demonstrates that low levels of copper inhibit the olfactory systems of salmonid fish, decreasing their ability to hide in response to warning signals. Some metals bind to soils and organic matter and are transported in
sediment, while other metals dissolve in water. Rainwater is naturally slightly acidic, which increases its ability to dissolve heavy metals and compounds the health and environmental effects of storm water runoff from urban areas. The transportation system is a primary source of metals in storm water runoff to urban streams and groundwater. Cadmium, copper, cobalt, iron, nickel, lead and zinc are deposited into the environment by vehicle exhaust, brake linings, and tire and engine wear. They accumulate on roads, waiting to be washed into storm drains with the next rainfall. Pollutant concentrations in roadway runoff are positively correlated with traffic volume. All cars, even the cleanest vehicles, shed small amounts of metals, fluids, and other pollutants. Galvanized metal rooftops, gutters and down spouts, and moss killer are also a source of zinc in storm water. Some copper comes from architectural uses and treated wood, and a primary source is brake pads. Outdoor storage of scrap metal can also contribute to metal pollution. Excessive nutrient levels in waterways stimulate the growth of plants and algae, which can reduce dissolved oxygen levels and harm the entire aquatic ecosystem. The primary nutrients are phosphorous and nitrogen. Phosphates and nitrates enter storm water from fertilizers applied to lawns and golf courses, decomposition of natural rock and soils, air deposition from vehicle exhaust, detergents used to wash cars on the street, and pet waste.

Heavy metals entering into the runoff from a large variety of non-point sources are likely to cause further impairment of water quality of the receiving waters through increasing urbanization and road construction activities (Garcia-Criado et al., 1999). Polluted runoff can be a major source of water quality problems in receiving waters and so the aquatic life can be adversely affected due to change in water chemistry and habitat loss. The metals and other organics carried by road runoff water
are toxic to fish and other forms of aquatic life (Nabizadeh et al., 2005). Understanding of the characteristics of urban runoff pollution is beneficial to develop urban stormwater management effectively (Zhang et al., 2013).
1.8 Objectives of the study

The present study has been formulated the following objectives for the study on the quality of road side surface soil and road runoff water in Guwahati City, Assam.

(i) To characterize the road side surface soil and road runoff water quality in Guwahati City, Assam with respect to physico-chemical parameters.

(ii) Fraction of various particle size of the road side surface soil and distribution of metal content in fraction of three particle size.

(iii) Heavy metal content in road side surface soil and road runoff water with respect to Pb, Cd, Zn, Cr, Cu, Fe, Mn, Ni, Al, and Co.

1.9 Significance of the study

Guwahati is the principal city of the entire north eastern India and is a major commercial and educational centre of eastern India. Guwahati city is the gateway of northeast India and thus is an important hub for transportation in the entire north east region and plays a major role for cultural and sports activities. Unfortunately the environmental quality of the city is degraded due to over population, rapid urbanization, increased automobiles, local soil erosion, inadequate soil-water use management, and intensive deforestation. Further release of contaminants including trace metals from man made sources have contributed to increased pollution to the environment of the Guwahati city. Heavy metals and other chemical pollutants pose potential risks to the ecosystem once they accumulated in soil or sediment due to their non biodegradable and persistent nature leading to the changes in the composition of atmosphere, soil and water resources. Although there has been enormous amount of
environmental research work at national and global level but the monitoring of environmental quality is not accelerated in Assam as well as in North-East part of India. Guwahati city with rapid infrastructural developmental work, concentrated population, large energy consumption, heavy transport and industrial activities display the worst environmental pollution problem. Moreover the urbanized region of Assam bears the highest pressure on the natural environment. The spreading of pollutants in the environment depends on its physico-chemical characteristic and on the soil’s retention ability along with transport rate of air and water by which the pollutants get transported. Heavy metals are well established to be detrimental to human health and environment. Thus monitoring of soil, water and systematic collection of information on heavy metal levels are an essential component of any pollution control system. Urban expansion transforms local environments and in the context of effective urban resource planning and management, the recognition of the impacts of urbanization on the water environment is among the most crucial. The significance stems from the fact that water environments are greatly valued in urban areas as environmental, aesthetic and recreational resources and hence are important community assets. Accurate environmental assessment can be an actual management tool also and helps to detect the problem before it becomes severe. Knowledge of the concentration pattern of trace metals in road runoff water can play an important role in estimating the sources of runoff water pollution, especially in the heavy traffic areas of Greater Guwahati which is the largest urban area of Assam, India. One of the aims of the study is to present a statistically meaningful road runoff rain-water quality database on trace metal contamination with special reference to copper, zinc, manganese, iron, cadmium, lead, chromium, cobalt, and nickel so that purpose-orientated water
assessments and predictions can be made in the study area. Finally, the present research is undertaken with a specific view to strengthen the national and local urban road side surface soil and road runoff water quality database and is a humble attempt to understand the impact by investigating the quality of road side surface soil as well as road runoff water along the city’s roads for the development of appropriate pollution mitigation strategies.