Chapter I

Introduction

1.1. The Problem Investigated

Heavy metal pollution and its impact on the vegetation along a 110 km stretch on the Main Central Road (MC road) and Kottayam Kumily road (KK road), in Kottayam District, Kerala was the major theme of the current investigation. Phytosociological details of the vegetation (Density, Frequency, Abundance and Relative Abundance of all species) occupying these polluted roadsides were determined in the monsoon and summer seasons for two years. The very common and highly tolerant species of these roadside floras were found out on the basis of phytosociological analysis. Specific amount of heavy metals in the roots and shoots of some of the most common species in relation to the amount of metals in the soils of these roadsides were also assessed. Statistical comparisons and correlations were carried out to identify the seasonal, regional and roadwise tendencies of the vegetation, heavy metal pollution in the soils as well as the accumulation of the four different heavy metals, Pb, Zn, Cu and Ni in the common plants.

1.2. The Hypothesis

Roads are continuously increasing at a fast rate and roadsides occupy a very broad area of most countries (Ross, 1986). Road ecology is one of the great frontiers of research and knowledge awaiting science and society (Spellerberg, 1998; Forman and Deblinger, 2000). Roadsides provide enormous opportunity for new thinking and approaches in ecological investigations; however, few recognize the significance of road ecology (Forman and Alexander, 1998). Roads influence the natural environment to a very high degree (Poszyler-Adamska and Czerniak, 2007). The role of roads as major line sources of pollution contaminating roadside air, water and soil with different toxic materials including heavy metals is well documented all over the world (Sinha, 1993; Singh et al. 1997; Turer et al. 2001; Turer and Maynard, 2002; Dongarra et al. 2003; Cicek and Koparal 2003; Ghose et.al.
Precipitation influences the quantity of heavy metals in roadside soils and plants (Ho and Tai, 1979; Ward et al. 1979; Piron-Frenet et al. 1994). Roadside plants show various biological responses to roadside pollution and are bio-indicators of pollution levels (Joshi and Shrivastava, 2003). These were the basic theories upon which the assumptions of the current research are conceived. Kerala is one of the fast urbanizing states of India and the KK and MC roads are some of the busiest roads of the state, polluted by heavy metals at a rapid rate for quite long time. Therefore, an investigation into the degree of contamination caused by heavy metals, the types of resilient species and the nature of accumulations of the four different common heavy metals into these roadside plants was very relevant. Moreover, in Kerala, situated in the southern Western Ghats, one of the biological hotspots of the world abounding in diverse kinds of flora and fauna, the roadside vegetation also is expected to be much rich in resilient plant species.

1.3. The Major Assumptions

1. Heavy metal contamination is common on busy roadsides of Kerala, one of the fast urbanizing State of India.

2. Heavy metal pollutants such as Pb, Zn, Cu and Ni are in excess in these roadsides.

3. Quantities of these metals on roadsides are in direct proportion to traffic density.

4. In wet tropical states like Kerala, monsoons affect the quantity of metals on roadsides.

5. Disturbed roadsides have vegetations of high species richness in Kerala.

6. Phytosociological methods can reveal the differences in the degree of tolerance of roadside species of Kottayam District, Kerala.

7. Roadside species growing in heavy metal contaminated soils accumulate an excess of metals in their tissues.
8. All the different resistant species accumulate heavy metals in different quantities.

9. Plants accumulate more heavy metals in roots than in shoots.

In order to explain the rationale of these investigations, the importance of different aspects of these studies such as problems of roadside pollution, heavy metal accumulation in roadside environment, species composition of heavy metal contaminated roadsides, accumulation pattern of different metals on roadsides and the applications of the information in phytoremediations are discussed one by one on the basis of some of the most significant recent research reports.

1.4. Roadsides as Line Sources of Pollutants

Pollution from automobile exhausts is a serious cause of environmental quality deterioration in developing countries, which is a potential threat to natural ecosystems (Lenz et al. 2004). Emissions from vehicle exhausts are a major problem in the busy city centers (Pearson et al. 2000; Ghose et al. 2005; El – Hasen, 2007). In India the level of pollutants especially that of heavy metals is increasing in the urban environment, a major share of which comes from automobile exhausts (Joshi and Shrivastava, 2003). Motor vehicles have been regarded as the primary cause of pollution in the urban areas and accounts for 60-70% of the pollution found in the urban environment (Singh et al. 1995). Chronic emission of trace metals such as Pb, a major toxin in roadside emissions from vehicles, and the degree and nature of environmental contamination that these toxins cause must be adequately examined (Ona et al. 2006). In populous developing countries like China, India, and Indonesia, gasoline with Pb additive concentrations up to 0.45 g l$^{-1}$ is still continuing (Sutherland et al. 2003) and more than 70 % of added Pb in gasoline is released with exhaust (Davis, 1973). Automobile release of Pb onto roadsides may be up to 80 mg km$^{-1}$ in average roads (Smith, 1975). About 90% of all Pb emissions in the atmosphere in India are from leaded gasoline (Kamavisdar et al. 2005). Common heavy metals found on contaminated roadsides include Pb, Cd, Cu and Zn (Hemphill et al. 1974;
Harris, 1979; Harrison et al. 1981; Harrison and Johnston, 1985; Nyangababo and Hamya, 1986; Harrison et al. 2003; Hashisho and El-Fadel, 2004; Plesnicar and Zupancic, 2005; Juknevicius et al. 2007) and these have different traffic sources (Li et al. 2004).

Metallic elements having specific gravity greater than 4.0 and a relative density of approximately 5g/cm$^3$ are referred to as heavy metals (Clijsters et al. 1999). These elements become toxic to humans, when their concentration exceeds the limit in the environment. Excess release of heavy metals into environment is called heavy metal contamination. Environmental pollution from heavy metal is a global phenomenon receiving high attention today because of the recent knowledge that heavy metals in environment may enter food chains from soils and result in health hazards (Mashi et al. 2005). Automobiles are the primary source of heavy metal accumulation in roadside vegetation of urban areas and the amount of Pb, Cd, and Ni in the urban environment forms an index to the degree of pollution (Burton and John, 1977). Since the first report of Warren and Delavault (1962) on contamination of vegetation and soils near highways, there have been numerous investigations, which reveal that the distribution of heavy metals from an automobile source is related to traffic volume and distance from the road (Cannon and Bowles, 1962; Motto et al. 1970; Page et al. 1971; Haney et al. 1974; Tam et al. 1987; Caselles, 1998; Bhatia and Ghosh, 1999; Jaradat and Momani, 1999; Yun et al. 2000; Onianwa, 2001; Sayaka et al. 2002; Turkoglu et al. 2003; Tuzen 2003; Birch and Scollen, 2003; Ideriah et al. 2004; Wang et al. 2006; Al-Khashman, 2007; Yetimoglu, et al. 2007). In the absence of proper monitoring, heavy metal contamination of urban soils from automobile exhausts may exceed the tolerable limits in the near future (Kumar et al. 1993).

Heavy metal accumulation on roadsides is quite a serious environmental issue (Ozaki et al. 2004a). High levels of contamination by heavy metals in roadside soils, grasses, and other vegetations in relation to urbanization with heavy traffic are well known (Ward et al. 1975; Ward et al. 1977; Ho and Tai, 1988). Pollution from non-vehicle sources such as
pavement wear and road maintenance may exceed significantly that from automobile exhausts (Hall et al. 2008). Heavy metals reach roadsides from automobile exhausts, tyre and break pads, anti wear substances added to lubricants and depend on the type of fuels used (Carlosetena et al. 1988; Monaci and Bargagli, 1997; Adekola et al. 2002; El-Hasan et al. 2006; Suzuki et al. 2009). Tyre is a significant source of pollutants, especially a source of Zn in urban environment (Adachi and Tainosho, 2004). Gasoline related sources are major contributors to the elevated levels of Pb, Cd, Cu, Zn and Ni in top soil of roadsides (Fakayode and Olu-Owolabi, 2003). One of the chief toxins in roadside dust is Pb (Krishnayya and Bedi, 1986; Fergusson, 1987), which has deleterious environmental impacts (Kumar et al. 2005) and the major source of Pb on roadside is automobile exhausts (Lu et al. 2003). Quantity of heavy metals such as Pb in soils is a good indicator of automobile pollution (Momani, 2006). Pb on roadsides usually increases with the increase in traffic volume (Wheeler and Rolfe, 1979; Gratani et al. 1992; Hakan and Murat, 2004).

Heavy metals usually accumulate on the surface layers of soils close to the roadsides and there is a low vertical and horizontal mobility of metals (Garcia-Miragaya et al. 1981; Ferretti et al. 1995; Hafen and Brinkmann, 1996; Turer and Maynard, 2002; Bretzel and Calderisi, 2006; Biasioli et al. 2007). Roadside pollutants are usually found concentrated at about 5-10 cm depth of roadside soils (Gratani et al. 1992). This human induced accumulation of heavy metals in nature is toxic to plants, animals and humans (Abul-Kashem and Singh, 1999). Since the density of automobiles is higher in the urban environment, heavy metal pollution is comparatively higher in the cities than in the rural environment (Tahir et al. 2007). Traffic related heavy metal contamination of soils has its impact on adjacent water bodies as well (Sansalone and Buchberger, 1997; Revitt and Ellis, 1980). Hence evaluation of the degree of heavy metal pollution on roadsides is very essential (Hall et al. 2008).

In India, urbanization is rapidly growing. But studies and surveys regarding heavy metal pollution on roadsides are partially unrecognized and
the non-availability of the data is a barrier to the prevention of toxic hazards. Therefore, any efforts to generate data in this context will be helpful in reducing further contamination. Moreover, absorption of heavy metals in the soil by agriculturally and otherwise useful plants can be avoided. Otherwise, plant accumulation of heavy metals in the long run will cause health hazard to humans and domestic animals (Dutta and Mookerjee, 1980). With the continuing population growth and rapid economic development in Kerala, the percentage of population living in cities is increasing tremendously. Consequently, the importance of environmental quality of urban soils is becoming more and more significant with regard to human health. However, very little information is available about heavy metal contamination of soils in this State. Therefore, the present estimation of heavy metals such as Pb, Cu, Zn and Ni on roadside surface soils (0-5 cm) close to the tar-edge of busy roadsides is highly relevant. Further, the significance of the estimation of heavy metals in roadside plants in relation to the amount of such contaminants in soils needs detailed explanation.

1.5. Plant Accumulation of Heavy Metals

Pb contamination of top soil and the consequent acummulation of Pb in vegetation, food crops and humans living along the highway and high traffic locations in several urban cities have been well reported from 1970s onwards (Chow, 1970; Page et al.1971; Davies and Holmes, 1972; Haney et al. 1974; Ward et al. 1975; Flangan et al. 1980; Agrawal et al. 1981; Ndiokwere, 1984; Fakayode and Onianwa, 2002; Caselles et al. 2002; Fakadyode and Olu-Owolabi, 2003). Vegetation may be used to monitor environment changes (Naszradi et al. 2004; Okonkwo and Maribi, 2004). Global studies on the presence of metals in plants and soils in relation to traffics are many (Stanford et al. 1975; Rodriguez-Flores and Rodriguez-Castellon, 1982; Ratcliffe and Beeby, 1984; Albasel and Cottenie, 1985; Sitole et al. 1993; Xiong, 1998; Sayaka, et al. 2002; Amusan et al. 2003; Odiyo et al. 2005; Okunola et al. 2007). From developing countries like India also, there are several reports of heavy metal contamination of soils and plants in relation to road traffic (Krishnayya and Bedi, 1986; Madany, 1990; Ylaranta, 1994; Fatoki, 1997;
Elemental concentrations of grasses in pastures are well correlated with traffic density (Ward et al. 1977). A field experiment revealed accumulation of relatively high levels of heavy metals in the shoots and roots of *Cynodon dactylon* (Wong and Chui, 1990; Wen-sheng et al. 2004). *Eleusine indica* and *Cynodon dactylon* are the dominant and well known tolerant species on roadsides (Wong and Lau, 1985; Wong, 1987). Heavy metal contamination has received much attention with regard to uptake by plants and contamination of aquatic environments (Li and Shuman, 1996). Pb accumulation in plants on roadsides is a potential threat to human survival (Finster et al. 2004). Pb levels of roadside vegetation decrease with distance from roadside and Pb content in the roadside grass increases with the increase in traffic density (Lam et al. 1999). Therefore, monitoring of toxic metals in the soils close to roads in relation to the accumulation of the chemicals in plants growing in contaminated soils becomes a task of high priority and significance in environmental research and protection. However, the importance of this enquiry is more significant, especially, when the general details of studies on roadside vegetation is also well examined. The reasons to include the analysis of roadside vegetation in the current investigative study are many.

### 1.6. Importance of Natural Vegetations on Roadsides

Roadside communities are ecologically unique owing to the influence of roads on general land systems (National Research Council, 1997). Pollutants from roads directly affect roadside plants (Mandal and Mukherji, 2001) and vegetation on roadsides clearly reflect the nature and degree of such pollutions (Angold, 1997). There are several reports on Pb and various other pollutants accumulating in plants on sides of roads with high traffic density (Motto, 1970; Lagerwerff, 1970; Duggan and Williams, 1977; Dutta, 1981; Atkins, 1982; Wong and Lau, 1985; Tumi et al. 1990; Singh et al. 1995; Singh et al. 1997; Fatoki, 2003) and roadside plant species can be used as reliable monitors of roadside pollutants (Singh, 1995; Aksoy and Ozturk, 1997; Abdulla and Latiff, 1988; Aksoy and Sahin, 1999; Aksoy et al. 1999; Aksoy et
al. 2000; Swaileh et al. 2004; Raina and Bindu, 2004; Kumar et al. 2005; AL-Khlaifat and Al-Khashman, 2007). Hence studies on floristic details of roadside are significant to reveal information of potential metal accumulating species in nature. Moreover, roadside community is mostly native vegetation with relatively high plant species richness (Bennett, 1991) and since vegetations on roadsides are subjected to trampling of people and crushing by vehicles (Forman and Alexander, 1998), roadside vegetation analysis is good to identify species resistant to such disturbances. Knowledge of species tolerant to pollution and disturbance has high ecological uses.

Roadside communities in relation to environmental gradients such as altitude and other climatic features are well known (Lausi and Nimis, 1985; Wilson et al. 1992; Ullmann et al. 1995; Arevalo et al. 2005). Most studies of roadsides mainly include survey of species diversity and vegetation characteristics (Frenkel, 1970; Wester and Juvik, 1983; Holzapfel et al. 1990; Heindal and Ullmann, 1991; Sykora et al. 2002; Ahmad et al. 2004), which are either with a concern for conserving wild species occupying the area (Allem, 1997) or examining the dangers of roadsides as a route of invasive exotics (Rentch et al. 2005). Disturbance is widely recognized as a primary influence on plant community composition and is frequently implicated in the spread of invasive exotic plants (Larson, 2003). Moreover, roadside communities are usually described as synanthropic systems (Cilliers and Bredenkamp, 2000; Wrobel, 2006) and roadsides are ecotones or edge habitats that provide specialized species. Road margins in general provide some of the exciting opportunities for research on plant communities (Way, 1977).

Roadside plants play a key role in the movement of heavy metals into animals and humans through food chains and hence the study of the nature of roadside vegetation is highly relevant (Gupta et al. 1996; Singh et al. 1997; Tarnath et al. 2005). The discovery of scores of new plant species from roadsides over recent decades has shown that plants can survive successfully under conditions far distant the ideal, often through their use of adaptive mechanisms (Allem, 1997). Apart from information on resilient species through floristic analysis, phytosociological investigations of
Vegetations can provide the relative importance of each of them. Knowledge of the relative importance of individual species on disturbed sites enables proper understanding of the economical and ecological relevance of each. Relatively little research on roadside vegetation has been done in India and especially in the biodiversity-rich state of Kerala and the present investigation really filled the gap. The importance of vegetation analysis on roadsides may be further understood, especially in relation to the possible utilities as sources of economically and ecologically useful species are explained in detail.

1.7. Roadside Vegetations: Sources of indicator and metal accumulator plants

Some species of plants accumulate heavy metals in high concentration against the concentration gradient of the disturbed soils where they grow (Nikhil, 2006). Such plants are potential hyper accumulators. Hyper-accumulator plants have high ecological uses such as phytoremediation and phytomining. Higher plants are well known for bio accumulative properties of heavy metals (Al-Shayeb et al. 1995; Aksoy and Ozturk, 1997; Altaf, 1997; Aksoy and Sahin, 1999; Aksoy et al. 1999; Tomasevic et al. 2004; Swaileh et al. 2004; Celik et al. 2005; Taranath et al. 2005; Anoliefo et al. 2006; Ano et al. 2007; Okunola et al. 2007; Bakirdere and Yaman, 2008), which suggests that the pollution resistant plant communities on contaminated roadsides may be important sources of hyper accumulator species. Such plants that preferentially accumulate some elements in higher proportion are useful in biogeochemical prospecting (Nagaraju and Karimulla, 2002).

Fast growing urbanization in developing countries is causing increasing roadside pollution, which is associated with environmental impacts. Vegetation and soils near roadsides are important sinks for roadside pollutants. Therefore, phytosociological analysis of the so far unknown roadside vegetations of Kerala, especially the heavy metal accumulation in them in relation to the contaminants in the soils is highly significant. Since Kerala is one of the well known biological ‘hot spots’ in India, which is rich in biodiversity, a scientific study of contaminated roadsides here is highly
important to the discovery of some hitherto unknown pollution tolerant species from this region. Preliminary knowledge of metal accumulation tendencies in resilient species is important to further experimentation with them for the discovery of new hyper metal accumulator species useful in phytoremediation. The potentials of the applications of the present findings can be detailed further with the explanations of phytoremediation and phytoextraction as significant newly emerging soil cleaning and resource recovery technologies.

1.8. Significance in Phytoremediation

Contamination of environment with toxic metal has become a world wide problem, affecting crop yield, soil biomass and fertility, contributing to bioaccumulation in the food chain (Gratao et al. 2005). Remediation of soils contaminated with toxic metals is a real challenge, because heavy metals are long term contaminants with the ability to accumulate in soils and plants; there is no easy way to remove those metals (White et al. 2002). Plants used in phytoremediation are either naturally occurring or genetically engineered species (Cunningham et al. 1997). Phytoremediation is the eco-technology that is a safe and also a cheap method of removal contaminants from the environment.

There are different kinds of phytoremediation. The process of using metal accumulator species for removing organic or inorganic contaminants from soil is called Phytoextraction. If plants are used to absorb and convert the toxins into non toxic forms, the process is Phytovolatilization; and if plants are used for stabilization of an inorganic into a less soluble form, the process is Phytostabilization. Since the cost of implementation is cheap and the environmental benefits are many, this technology is widely accepted as one of the best technologies of environment cleaning. These are more acceptable to the public than other traditional methods of cleaning of soils and waters polluted with difficult toxins such as heavy metals (Suresh and Ravishankar, 2004). However, the development and progress of this technology depends on the knowledge of hyper tolerant and hyper accumulator species. Hyper accumulator species are hyper tolerant species (Baker and Brooks, 1989). Usually the metal accumulator species found in nature are used in
phytoremediation processes (Chaney et al. 1997). Over four hundred hyper-accumulator flowering plant species are known in the world (Prasad and Freitas, 2003) and some of them are patented for their specific metal accumulation potentials. Hyper accumulators are herbaceous or woody plants that accumulate about 100 times or greater metal concentration in shoots than those non accumulators usually found in nature and they tolerate toxins without visible symptoms of damage (Barcelo and Poschenrieder, 2003). Plants with high metal uptake capacity and a high biomass production are useful to extract metals from soils within a reasonable time frame (Ebbs and Kochian, 1997). The ideal plant species to remediate a heavy metal contaminated site would be a rapidly growing high biomass crop with an extensive root system that can both tolerate and accumulate contaminants of interest (Ghosh and Singh, 2003b; Odjegba and Fasidi, 2004). Baker (1987) studied the major developments in the field of heavy metal tolerance in plants over the last 15 years. Hyper accumulating plant species in general have tolerance to extremely hostile edaphic environments that would kill many other species (Bondada and Ma, 2003).

Plants suitable for Phytoremediation should possess the ability to accumulate the target metal in the above ground parts and to tolerate the metal contamination that is to be accumulated (Karenlampi et al. 2000). Metal hyper accumulator plants have been found in a wide range of families of vascular plants (Reeves and Baker, 2000; Prasad and Freitas, 2003). Experimental studies have shown that the Poaceae family members have better absorptive abilities of heavy metals (Jankaite and Vasarevicius, 2007). No plants have been proved to able to phyto extract Pb with high efficiency (Zhuang et al. 2007). Pb contaminated roadsides are the best places to search them out, because evidences indicate that tolerant plants on contaminated soils have the genetic potential to accumulate toxic metals (Wen-sheng et al. 2002)

Identification of metal hyper accumulator species has been an impetus for Phytoremediation research (Lasat et al. 2002). Governments world wide are encouraging research and demonstration programmes to use the potential
of Phytoremediation. Environment Canada’s has developed a data base (PHYTOREM) of 775 plants with capabilities to accumulate or hyper accumulate one or several of 19 key metallic elements (McIntyre, 2003). A potentially emerging environmental application of hyper accumulator plant is “Phytomining”, which is a process to remove precious metals or other industrially important metals from naturally occurring locations where conventional mining would not be economically feasible (Prasad, 2003). Possibilities are always there to identify metal tolerant plant species from natural vegetation in sites that are contaminated with various heavy metals (Yoon et al. 2006)

Most of the studies related to hyper accumulator species have been done in developed countries and the knowledge of indigenous hyper accumulator plants of our country suitable for phytoremediation is particularly limited. Commercial application of phytoremediation of soil, heavy metals, or organic compounds is still in its earlier phase. Therefore, explorations of the flora of all contaminated sites in our country, especially the roadsides, are highly necessary for discovering newer and better hyper accumulator species.

1.9. The Major Aims and Objectives

1. Examine the extent of heavy metal contamination (Pb, Zn, Cu and Ni) on roadsides in Kottayam District of Kerala.

2. Collect the species composition of flora on busy roadsides in this District of Kerala.

3. Analyze the relative significance of different roadside species in this region through phytosociological analysis.

4. Learn whether some indicator or hyper tolerant species are common to the contaminated roadsides throughout the road length in the District.

5. Assess the accumulation pattern of Pb, Zn, Cu and Ni in the roots or shoots of the common plant species on roadsides in relation to the amount of each of them in soils.
1.10. The Major Achievements

Kerala, situated in the Southern Western Ghats, one of the biodiversity hotspots in the world, was found to be a suitable place for searching out metal accumulator species, especially when literature describing the characteristics of roadside vegetation in Kerala was quite unavailable. Kerala being a less industrialized and fast urbanizing region of India, inventory of pollution resistant species of the busy roadsides of the state was highly significant. The current thorough floristic investigation of two busy roads in the state has shown that roadsides in Kerala are truly species rich places. The phytosociological analyses enabled to identify tolerant and metal accumulator species among these roadside communities. The amounts of heavy metal contaminants (Pb, Zn, Cu and Ni) on these roadsides were found to be very much above that of national/international standards for natural soils. The nature of accumulation of these different heavy metals in roots and shoots of some of the very many common roadside species were also found out. These findings enabled to focus on the hyper accumulation potentials of 19 of the most tolerant roadside species and the possible applications of them based on further research, in the cleaning of contaminated environments.