CHAPTER 7

LEAD IN VEHICULAR EMISSIONS: ITS OCCURRENCE IN SOILS ALONG HIGHWAYS

- EFFECTS ON HUMAN HEALTH
- VEHICULAR DEMOGRAPHY
- IMPACT ON ENVIRONMENT
- STUDY OF LEAD DEPOSITION IN SOILS ALONG HIGHWAYS
- LEAD UPTAKE BY GRASS AND VEGETABLE
7.1 VEHICULAR EMISSIONS: THEIR EFFECT ON HUMAN HEALTH

Automobiles affect the environment through a number of channels. Hence their impact on human and animal life, trees and vegetations are unavoidable. The emissions from automobiles contain mainly carbon mono-oxide, unburnt and oxidised hydrocarbons, oxides of nitrogen, particulate matter and sulphur dioxide. Carbon mono-oxide is a highly poisonous gas. The haemoglobin of human blood, on exposure to CO, is transformed to carboxyhaemoglobin. The haemoglobin which is a carrier of oxygen, is essential for the survival of life. The haemoglobin has an affinity for carbon mono-oxide which is 240 times higher than that for oxygen. The depletion of oxygen level in human body causes a very high effect on central nervous system. The larger presence of CO in atmospheric air results in weakening of nervous system, weakening of eye-sight and ailments of respiratory system (1).

The hydrocarbons cause inflammation of eyes and throat, are odorous, and cancerous. The oxides of nitrogen cause coughs and respiratory problems. The hydrocarbons and oxides of nitrogen under the effect of light, produce photochemical smog. Sulphur dioxide and the particulate matter also promote smog formation. The metals present in particulate matter are toxic and carcinogenic. They also cause silicosis disease. The inorganic lead present in the emitted particles affect liver, kidney and is injurious to the brain of infants. Out of the total lead entering into human body, 60% is retained permanently in the body itself. The lead contents in saleable petrol in Delhi, Mumbai, Madras and Calcutta are (mg/l) 180, 155, 290, 100 respectively (1):

The air pollution arising through automobiles affects animal life, plants,
vegetations, open lands, building structures and the solar light, besides the adverse
effects on human life. The SO$_2$, hydrocarbons and smog cause yellowing of the
plant leaves. The emitted smoke results in blackish deposition on wall-surfaces and
clothings. The sulphur contents in petrol are in the range of 0.05 - 0.1%. The
acidic contents of the emissions have damaging effects on buildings, clothings,
their colour shades, and electric equipments (1).

The automobiles also produce noise pollution, which has diverse effect on
normal human functions. The noise limit for the human beings is 60 decibel. The
fast moving small car produces a noise level of 40 decibel. The noise level of a
car horn 5 m away is 100 decibel.

A petrol driven automobile on consuming 1000 kilolitres of fuel is estimated to produce 240 kg of gaseous products and 1 kg of solid particulate matter. While a diesel-driven vehicle on consuming the same quantity of the fuel will produce 40 kg of gaseous products and 10 kg of solid particulate matter (1).

7.2 AUTOMOBILE I.C. ENGINES AS PRIMARY POLLUTORS: A SURVEY.

Informations gathered in USA show that internal combustion engine is a
primary pollutor in terms of carbon mono-oxide, unburnt hydrocarbons and
nitrogen oxides in comparison to the contribution of factories (2). Petrol, the chief
fuel of I.C. engines, is composed of a number of different hydrocarbons derived
from hydrogen and carbon in various arrangements. This mixture of hydrocarbons
is often simplified in description to the equivalent of a single average component
octene C$_4$H$_8$. During refining, various additives are mixed with the petrol, the
principal one being tetraethyl lead (TEL). This is an antidetonating compound which prevents the fuel from spontaneously exploding before it is ignited by the spark plug. The TEL burns to lead oxide with the air, and to lead chloride and bromide with the scavenger. On an average, from 2/3 rd to 3/4 th of the lead originally in the TEL is discharged in the gases leaving the exhaust system to enter the atmosphere (3).

In a diesel engine, the temperature of air after compression is about 650 °C compared to 350 °C in a petrol engine. The average diesel fuel hydrocarbon is dodecane \( \text{C}_{12}\text{H}_{26} \), and the mixture does not contain any man-made additives. The only important additional component in terms of air pollution is sulphur, which occurs in concentration 5-20 times that in petrol. Like the petrol engine, diesel engines also produce some unburnt hydrocarbons.

In addition to the above mentioned contribution of automobiles to environmental pollution, the following channels of environmental pollution have also to be considered: (i) the oil refuge discarded by the road vehicles which contain a suspension of metallic and alloy particles in thick oil media, and (ii) the effluent discharged by automobile service station which contain oil and grease in addition to other components.

7.3 VEHICULAR DEMOGRAPHY AS A BASE FACTOR FOR THE ASSESSMENT OF VEHICULAR POLLUTION

An assessment of vehicular pollution in metropolitan cities has shown that the quantum of pollutants emitted by vehicles is obviously directly proportional to the number of vehicles plying in the city. The number of vehicles in turn depend
upon the population. There are also contributory factors which aggravate the vehicular pollution. These factors are unplanned development of central business areas of the cities, inadequate and ill-maintained roads, lack of discipline in driving, ill-maintained vehicles and unscientific traffic management. Moreover, the high rise buildings tend to interfere with dispersion of pollutants. The assessment has also shown that petrol driven vehicles 2, 3 and 4 - wheelers are the major contributors of the total vehicular pollution in all the metropolitan cities. The assessment has further shown that the quantum of vehicular pollutants emitted is highest at present in Delhi followed by Bombay, Bangalore, Calcutta and Ahmedabad (4).

The assessment of vehicular pollution, applying the emission factors laid down by the World Health Organisation (WHO) based on kilogram of pollutants emitted per thousand kilometers running of different categories of vehicles within the municipal limit of metropolitan city, has shown the particulate emission factor as follows (kg) : light duty gasoline powered - 0.33, light duty diesel powered - 0.44, heavy duty diesel powered 0.75, motor cycles - 0.20 (4).

The vehicular demography (All India Basis) compiled through a survey has shown that during 1971-81 there has been nearly 3-fold rise in the total number of vehicles registered in the country (4). Assuming the trend to follow, the extrapolated value for 1991 has been estimated as 15 millions. The same trend projected up to 1996 has been shown in Fig 7-1. From the data (Fig. 7-1) it can be seen that the 2-wheelers are the major contributors to vehicular air pollution followed by 4-wheelers (i.e car, jeep, taxi etc.), trucks and buses in decreasing order of magnitude, and their numbers are expected to be (in million) 15.2, 2.8, 1.6, 1.19 respectively by the year 1996. The assessment report has further shown
Fig. 7-1 VEHICULAR POPULATION GROWTH IN INDIA
that the vehicles in metropolitan cities (i.e. those with population over 10 lakhs) constitute about 35% of total vehicular population in the country, which was expected to rise to 39.5% in 1991 (4).

Out of the country’s total vehicular population, approximately 58.6% is the contribution of 2-wheelers, and 16.5% that of 4-wheelers. The projected figures for the 2-wheelers and 4-wheelers for 1990-91 were 63.3% and 13.2% respectively. The estimated petrol consumption (in kL/year) in four top metropolitan towns are as follows: Calcutta -3,60,379, Bombay - 9,59,220, Delhi - 8,87,349, Madras - 2,38,937 (1986-87 figures). The estimated diesel consumption of vehicles for the same duration for the above mentioned cities are Calcutta - 4,10,362, Bombay - 1,72,492, Delhi - 2,54,159, Madras - 1,04,452. The estimated particulate emission load in metropolitan cities (in tonnes/day) as on 31-3-1987 has been reported as follows: Delhi - 8.58, Bombay - 4.66, Bangalore - 2.18, Calcutta - 2.71, Ahmedabad - 2.46, Pune - 1.99, Madras - 1.95, Hyderabad - 1.62, Jaipur - 0.98, Lucknow - 0.95, Kanpur - 0.88, Nagpur - 0.46 (4).

7.4 IMPACTS OF AUTOMOBILES ON ENVIRONMENT: A SURVEY

The effluents of automobile service stations have been reported to contain oil and grease in the range 15 - 34 mg/l (5), in addition to other undesirable species. Lead in the form of alkyl lead compounds is added to improve the anti-knock quality of motor spirit. These compounds of lead are subjected to elevated temperature and pressure of combustion, and are converted to lead oxide. The lead oxide reacts with other additives in the fuel, and leave the engine
through exhaust pipe as particles of lead salts. The sedimentation of the emitted lead contaminates the surface soils as well as road side vegetations. Lead in the plants is mostly found as surface deposition. Most of the studies with plants have shown a strong inverse correlation between plant lead level and sampling distance from the road sides, and less strong but direct correlation between lead deposition on plants and the traffic volume (6). An earlier study carried out along the side of national highway for a length of 30 km between Raipur and Bhilai has shown that average concentration of lead on the leaves of Ipomea is 29.7 ppm in comparison to 18 ppm for the same species in a contamination-free area. The concentration of lead in the deposited dust was found to be 50 ppm in the case of leaves of cassia cyamea at the side of the highway, in comparison to 20 ppm in case of the same species in the contamination-free area. Lead deposition on the leaves of plants is dependent on the distance of the plant from the road and also the plant height. In the case of cassia cyamea, the effect of greater height was compensated by the close proximity of the plants in comparison to Ipomea which were smaller in height, but situated 50-100 ft. away from the road. Further, the lead level was found to be higher at those sampling sites where the traffic densities were higher (5). As far as the particulate emissions are concerned, diesel and two stroke engines have been reported as predominant contributors (7). However, the damage due to the particulates is somewhat less severe. Among the gaseous components, oxides of nitrogen and the nitrated organics generated due to them are considered to be most hazardous. The nitrated compounds are also involved in the generation of extremely fine particulates which enhance creation of photo-chemical smog. For this reason, oxides of nitrogen and oxidants are considered to be the most dreaded air pollutants in USA (8). A detailed study of some toxic metals in the oil refuge of vehicles has shown the presence of a number of toxic metals (Cu, Pb, Zn, Cr
and Ni) in the refuge. The metals found to be prominently present in the oil refuge were as follows: Cu in the oil of motor cycles, Pb in oil of trucks and cars, Zn in the oil of jeeps, Mo in the oil of cars, and Cr and Ni in oils of trucks (5). The environment is susceptible to contamination if the oil-refuge is discharged into surroundings without an appropriate treatment. Sahu and co-worker have reported the toxicity of petroleum pollutants to plankton and fish (9). Sarkar and Banerjee (10) have reported acceleration of peroxidase and catalase activities in leaves of wild dicotyledonous plants as an indication of automobile exhaust pollution. Thakre and Rao have reported bio-monitoring of autoexhaust pollutants with special reference to lead by analysing washed and unwashed leaves of plants from traffic areas (11) for lead presence. Krishnayya and Bedi have reported the effect of automobile lead pollution on some road side trees (12). Sahu and Warrier (13) have reported lead, cadmium and copper contamination of soil and vegetation due to vehicular emission along Powai road in North Bombay. Anbazhagan and co-workers studied the effect of autoexhaust pollution on growth, pigment levels and lead content of Calotropis procera L., and found that the entry of lead into the plant system close to highway could be through stomata and roots (14). Salgare and Rawal (15) studied the effect of autoexhaust pollution at Andheri (west). Bombay on the anatomy of some cultivated plants, and found inhibition of several parameters of the plants Salgare and Thorat (16) studied the effect of autoexhaust pollution at Andheri (west). Bombay on the micro-morphology of some trees, and found inhibition of length and breadth of stomata of the trees. Veerbhadra Swamy and co-worker (17) have noticed that the leaves take more lead of the exhaust emissions than stem, roots or seed. Also, the uptake of lead by the oil-seed plants was found to be higher than other vegetations studied by them. Rastogi and co-workers (18) have noticed higher prevalence of respiratory
impairment in traffic policeman exposed to automobile exhaust. Gupta and co-worker (19) have reported the effect of vehicular pollution on visible vigilance and vision-fitness on traffic police staff. Satyanarayan and co-workers (20) have studied morphological trait changes of plants growing in automobile polluted areas. Sadasivam and co-workers have studied atmospheric lead concentrations in urban areas of India, and have found auto-exhaust as an important source of lead in atmospheric air (21). Veerbhadra Swamy and co-worker (22) have reported the penetration of lead upto a depth of 15 cm along low and high traffic density roads. Joshi and co-workers (23) have studied the impact of heavy metals accumulation on leaves, and surface micro-organisms of sub-tropical pine.

7.5 EXHAUST-EMITTED LEAD: STUDY OF DEPOSITION ON SURFACE SOILS AND UPTAKE BY GRASS ALONG A HIGHWAY

INTRODUCTION

Production of gasoline antiknock additives, specially tetraethyl lead (TEL) accounts for about 20% of the total lead consumed in United States. Nearly all gasolines sold in the United States and elsewhere until recently contained lead-alkyl compounds added to improve the antiknock quality of the fuel. Average concentrations of lead in gasoline has risen from 2.32 g/gal in 1963 to 2.59 g/gal in 1970 (24). Based on this average, an automobile travelling at 60 mph and consuming 1 gallon of fuel every 15 miles may exhaust in excess of 2000 µg of lead every second (25). Approximately, $13.6 \times 10^4$ tonnes of lead were emitted to the atmosphere in automotive exhaust in 1970.

When gasoline containing lead antiknock fluids is burned in an engine, the
alkyl lead compounds decompose at the high temperature and pressure, and then react to form the materials that are carried into the exhaust system. These inorganic lead exhaust products are primarily lead halide, PbClBr, along with two forms e.g. NH₄Cl. 2PbClBr and 2NH₄Cl.PbClBr. Once the lead halides of the exhaust reach the atmosphere, they probably undergo photolysis and eventually form PbO or other lead oxides (26). A study carried out by Mueller et al (27) shows a median diameter of 0.24 micron for lead-containing exhaust particulates. This value is verified by the median diameter of approximately 0.25 micron found by Robinson et al (28). More than 40% of the lead particles (by weight) are smaller than 0.3 micron, and 95% are less than 0.5 micron. A much higher median diameter value was found by Habibi (29) in a study which included the large lead particulates which settle out within a short distance from a car.

Studies of the lead particulates leaving the tail pipe have shown that from 70 - 80% of the metallic lead used by a vehicle will eventually be exhausted from the tail pipe (30). The balance remains in the engine itself, in the lubricating oil, oil filter and the vehicle exhaust system which is released into the environment at some other point of time. According to a report, the transfer of gasoline from one container to another in the United States accounted for a release of 40 tonnes of lead into the air in 1968 (24). It is expected that the atmospheric lead levels near service stations are very high, specially if the attendants tend to spill gasoline on the ground.

Soil, dust fall and rainfall are potential sources of lead uptake by plants (31). The lead content of food has been largely influenced by environmental contaminations. That may have been through surface contamination as well as
plant tissue incorporation of lead that was deposited on soils or crops grown in areas near the highways or lead-smelters (32). When such crops are used as forage for farm animals, the lead was found transported into milk or meat (32, 33). It was found that horses which have marked tendency of pulling grass along with the roots and soils would digest far greater quantities of lead than would be estimated from the analysis of forage alone (34). Cedar trees in Missouri on a road side, contaminated with lead ore dust, contained as much as 20000 ppm in ash (35), and Spanish moss near heavily travelled roads contained as much as 15000 ppm in ash (36).

In the background of the above-stated observations, it was found useful to assess the lead presence in surface soils along a highly travelled road in Raipur town, and also to examine the uptake of lead by the grass grown in the contaminated soils.

**MATERIALS AND METHODS**

**Sample Collection**: A stretch, 12 km long along National Highway No. 6, within the city limits of Raipur was selected for the studies. This stretch is used for the usual highway vehicular traffic, and also for the localised traffic of the city. As there is a traffic restriction for the entry of heavy vehicles which are mostly diesel-driven, most of the vehicles plying on this stretch are 2, 3 and 4-wheeler petrol-driven vehicles. Nine sites were identified for the sample collection. Out of these, 8 sites were at the highway side. One sampling site was at the side of an inner road in a colony situated close to the National Highway. Another eight samples of soils were also collected from the same places, but the
sampling sites in each case were about 50 ft away from the National Highway. The locations of the sample collections have been described in Table 7-1, and shown in Fig. 7-2. The soil samples were collected by digging holes (dia. 4 cm, depth 15 cm) at each site. The samples were powdered, sieved and representative quantities (200 g each) were dried in oven (105 °C) for 3 hours. Samples of green grass (50 g each) were collected from the same sites from which the soil samples were collected. All grass samples were collected with their roots intact. All grass samples were washed with distilled water to remove adhering impurities. Each unit of the grass was broken into roots and shoots, which were later kept in oven at 110 °C till they were completely dry, and assumed constant weight.

Procedure

Weighed quantities (0.5 g each) of the samples were treated in a teflon digestion bomb using 10 ml acid mixture of HCl, HF and HNO₃, and placing in an oven at 180 °C for three hours (37). Sample solutions for lead determination were made in a medium of 0.1 M EDTA (disod. salt) to suppress the interference of phosphate and fluoride (38). For the AAS determinations, the standard solution of lead was prepared by dissolving 1 g of the metal wire in nitric acid (1:1), and diluting the solution to 1 litre (1 ml = 1000 µg Pb). The analysis was carried out by using an Atomic Absorption Spectrophotometer (Varian-Model BQ-20). The operating conditions of the instrument were as follows: wave length - 217.0 nm, spectral band pass -1.0 nm, fuel - C₂H₂, support - Air, flame stoichiometry oxidising, optimum working range 5 - 20 µg/ml. During calibration, the standard solution of lead was suitably diluted to match the concentrations of the sample solutions within the measurement sensitivity (39). The physical properties of the
FIG. 7-2 LOCATION OF SAMPLING SITES
### TABLE 7.1 ANALYSIS DATA OF LEAD IN SOILS AND GRASS ALONG A HIGHWAY STRETCH

<table>
<thead>
<tr>
<th>Sampling sites (Fig. 7.2)</th>
<th>Lead in soils (ppm)</th>
<th>lead in grass (ppm)</th>
<th>Grass shoots**</th>
<th>Grass shoots**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At Highway side</td>
<td>At 50 ft. away</td>
<td>At Highway side</td>
<td>At 50 ft. away</td>
</tr>
<tr>
<td>1. Tatibandh Chowk*</td>
<td>137.8</td>
<td>11.0</td>
<td>14.0</td>
<td>6.8</td>
</tr>
<tr>
<td>2. Colony Road (Tatibandh)</td>
<td>104.0</td>
<td>92.0</td>
<td>6.7</td>
<td>2.8</td>
</tr>
<tr>
<td>3. University gate</td>
<td>126.0</td>
<td>112.8</td>
<td>4.0</td>
<td>16.7</td>
</tr>
<tr>
<td>4. Ashram</td>
<td>142.0</td>
<td>115.2</td>
<td>16.6</td>
<td>6.7</td>
</tr>
<tr>
<td>5. Azad Chowk*</td>
<td>152.0</td>
<td>117.6</td>
<td>19.0</td>
<td>12.3</td>
</tr>
<tr>
<td>6. Jalalabad Chowk*</td>
<td>190.0</td>
<td>67.3</td>
<td>18.0</td>
<td>9.8</td>
</tr>
<tr>
<td>7. Shastri Chowk*</td>
<td>164.0</td>
<td>6.6</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>8. Shankar Nagar Chowk*</td>
<td>180.0</td>
<td>12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Telibandha</td>
<td>128.0</td>
<td>15.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Road junction sites
** Results on dry basis

Sample was not obtainable at these sites.
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samples and standards were matched closely to avoid matrix effect (39).

The results obtained have been shown in Table 7-1.

The metal and the chemical reagents used were of spectroscopic grade. The water used was distilled and deionised. The glasswares used were superior quality borosilicate.

RESULTS AND DISCUSSION

The data obtained (Table 7-1) have provided the following informations.

i) The 12 km stretch of the National Highway passing through the centre of Raipur city, which was selected for the studies here gave clear evidence of lead depositions along its sides and also at places situated 50 ft away from it. The lead occurrence along the side of the highway was found in the range 104.0 - 190.0 ppm, while that at places 50 ft away was in the range 92.0-120.4 ppm. The lead occurrence in the surface soils along the highway was found much larger than the normal occurrence of the metal in the common types of soils of the Chhattisgarh region which is reported to be in the 57.0 - 85.0 ppm range (40). Even at places 50 ft away from the highway, the surface soils was found to contain lead at higher levels compared to that in normal soils of the area. The lead occurrence found in soils along the Highway and also in those 50 ft away from it was found to be much higher than that found in the 52 samples of surface soils which were collected from most parts of the country and analysed for lead and other metals (Table 2-2).
ii) Out of the 9 sampling sites, 5 sites were situated at road junctions which naturally had higher traffic densities. The higher vehicular movement at these sites is reflected by the higher occurrence of lead in soils collected from these sites compared to those collected from other sampling sites.

iii) The soil along a colony road connected with the highway, but situated away from it, which had a low traffic volume, showed the lowest presence of lead (104.0 ppm) compared to the soils collected from all other sampling sites.

iv) The grass samples which were collected at sampling sites along with the soil samples have all shown measurable presence of lead in roots as well as in shoots. The lead presence in roots has been found to be higher compared to that in shoots in all the collected samples. Although no rigid linearity between the lead occurrence in soils and that in roots and shoots was noticed, a higher presence of lead in roots and shoots was observable with higher occurrence of lead in soil. Although the lead occurrence in the shoots was nearly half of that found in roots, a uniform relationship between the two was not observable.

In conclusion, it was found that lead contamination in surface soils along heavily travelled roads is an unavoidable outcome of vehicular traffic, and it will continue to happen so long as the exhaust emissions contained lead-bearing particulates. The data also suggest a high probability of the uptake of this toxic metal by crops, vegetations and grass, grown in areas which are exposed to vehicular emissions. To assess the extent of lead uptake and its entry into food chain, the lead uptake by a commonly grown vegetable (Bhindi) has been studied in detail, and described in the next section.
INTRODUCTION

According to a report (41), 761 out of 912 samples of a variety of plants from throughout the United State contained from, 1 to 7000 ppm lead in ash. Cedar trees in Missouri on a road side contaminated with lead ore dust contained as much as 20000 ppm in ash (35), and the spanish moss near heavily travelled roads contained as much as 50000 ppm in ash (36). Many studies on lead contaminated vegetations have been made since the report of Cannon and Bowles (42) on lead in grasses along highways was published. Warren (43) concluded that since food supplies come from a wide variety of sources, it seems reasonable to assume that under normal conditions humans must anticipate ingesting some 400 µg of Pb daily, of which some 20 - 40 µg will be absorbed. Uptake of lead from the soil through the roots is a significant source of Pb to plants (44). Dedolph et al (45) concluded that half of the lead content in rye grass and radish leaves is of soil-origin. Baumhardt showed that high soil-acidity favours plant uptake of lead (46). Distribution of lead within the plant organism is variable with the species. Motto et al (44) showed the lead content to be generally higher in leaves and roots than in fruit, grain and tuber. They also showed that the lead in leaves increases with increasing soil-concentration. In a study of plants grown in British Columbia on soils of different lead - contaminations, Warren et al (43) showed approximately a 2-fold variation in lead in the edible portions of 14 vegetables, but in any given species there was little correlation between lead content in the edible portions and soil-lead. Goodman and Roberts have shown soil as an important contributor of lead to plants (47). It is reported that metal uptake and toxicities vary with plant species, soil characteristics and
concentrations of metals present in the soil. Bhargava (48) reported the uptake of zinc by zinc amended soils by the crops of *Vicia faba* (L). Dev and co-workers (49) have reported the heavy metals accumulation by wheat on application of sewage sludge to wheat crops. Dubey and co-worker (50) reported the adverse effects of Co, Cd, Ni, Zn and Mn on the growth parameters of soyabean. Barman and Lal (51) have reported the bio-accumulation of Zn, Cu, Cd and Pb in cultivated vegetables and wheat grown in industrially polluted fields. Sahoo and co-workers (52) observed the accumulation of heavy metals in *Spinacia oleracea* along railway track.

In the work being described here, the accumulation of lead in the roots, stems, leaves and fruits of *Abelmoscus esculantus* (Bhindi) on exposure of high levels of lead concentrations to the soil has been studied.

**MATERIALS AND METHODS**

**Sample Collection**: The soil used was paddy growing (Kanhar type). The characteristics of the soil used here were studied and described under Results and Discussion. The seeds used of *Abelmoscus esculantus* were obtained from a local seed shop.

**Study of Growth Parameters**: 10 kg of the paddy soil was placed separately in each of the five porcelain pots (size 10 litres each), and kept flooded. One pot was used for control and the other 4 pots for the study of the lead effect. Lead ions were incorporated in the soil in the other four pots through the application of a solution of lead nitrate so as to produce a concentration of 100 mg/kg of lead in
soil. The pots were irrigated and kept for two days for equilibration before sowing the seeds.

Five seeds were initially sown in each pot, and the seedlings were thinned after seven days to have only two per pot. The moisture status of soil in pots was maintained by irrigation whenever necessary with deionised water. The growth parameters (germination percentage and the seedling heights) were recorded during the maturity period of the plants. The observations have been shown under Results and Discussion.

The plants from all the pots were removed on the 70th day after the sowing of the seeds, and washed with water to remove adhering impurities. All the plants (control as well as lead polluted) were then divided partwise as roots, stems, leaves and fruits. All parts were dried at 105 °C till all moisture was removed, and the weights assumed constant values.

Procedure

Weighed quantities (1 g each) of the roots, stems, leaves and fruits were crushed and treated with HNO₃ and HClO₄ mixture (1:1). Lead in each sample was determined using an atomic absorption spectrophotometer (Varian Model BQ-20) following the recommended condition of operation as described earlier (Section 7.5) (38).

Three replicate determinations for each sample were made, and the mean values have been shown in Table 7-2.
TABLE 7-2 LEAD UPTAKE BY ABELMOSCUS ESCULANTUS

<table>
<thead>
<tr>
<th>Parts</th>
<th>Control* (ppm)</th>
<th>Polluted* (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Root</td>
<td>12.8</td>
<td>60.0</td>
</tr>
<tr>
<td>2. Stem</td>
<td>9.6</td>
<td>38.0</td>
</tr>
<tr>
<td>3. Leaves</td>
<td>5.2</td>
<td>32.0</td>
</tr>
<tr>
<td>4. Fruit</td>
<td>2.4</td>
<td>26.0</td>
</tr>
</tbody>
</table>

* On dry basis, mean values of three replicate determinations.

RESULTS AND DISCUSSION

The physico-chemical characteristics of the soil used in the pot culture were as follows: the soil used was paddy growing (Kanhar type), brown to black in colour, clayey in texture, very sticky and plastic in consistence with abundant lime concretions and about 17% available water, pH - 7.50, Organic carbon - 3.5%, N - 441 ppm, P - 16.0 ppm, potash - 795 ppm, cation exchange capacity 38.50 meq/100g, SiO₂ - 68.10%, Fe₂O₃ - 11.0%, Al₂O₃ - 14.0%, Pb - 60 ppm.

The impact of the lead presence in soils was observed as described below:

i) On the 8th day of the observation after the sowing of the seeds when there was 100% germination in the control pot, 70% germination was observed in the lead contaminated pots.

ii) On the 31st day of the observation while the average seedling height in the
control pot was 30 cm, it was only 14 cm in the lead-contaminated cases.

iii) While the flowering was observed in control plants after 52 days, the same could be observed in lead-polluted plants after a period of 60 days.

iv) While fruiting was found to commence in the control plants on the 59th day (at normal plant height of 36 cm), it was observed in lead-polluted plants on the 68th day with 30 cm average height of the plants.

v) Lead was found to be present in the root, stem, leaves and fruits of the control plants, and this lead uptake was from the background presence of lead which was at a level of 60 ppm. The lead occurrence in case of the control plants was found to be in the following order: roots > stems > leaves > fruits.

vi) In the lead-contaminated soils, several-fold accumulation of lead was observed in comparison to the control plants. The increase was found as follows: root - about 5-fold, stem - about 4-fold, leaves - about 6-fold, fruit - 11-fold. It is of utmost hygienic concern to find that the largest accumulation of lead was in the fruit-part which is the most commonly used vegetable in most parts of the country.

It is concluded that the surface soil requires to be protected from any external contribution of lead arising through the human agencies.
SUMMARY

This chapter was devoted mainly to study of lead contamination of soil. This was studied with special reference to the lead contributions arising through automobile emissions. In this context, the nature and composition of the automobile emissions, their genesis in I.C. engines and their adverse effects on the environment and the human health were described through a literature survey. The role of tetraethyl lead which is used as an additive in petrol, and the emission of lead containing particles was explained. Taking automobiles as the prime source of pollution, along the highways, the populations and the growth rates of automobiles in cosmopolitan cities of the country were studied. The contamination of soil resulting from the depositions of the lead emitted by vehicles was given particular emphasis in the studies. The lead uptake by plants grown along the highways was explained citing examples. The accumulation of lead in the various parts of the vegetable plants grown in polluted soils was studied through a literature survey.

The lead occurrence in soil and its uptake by grass along a 12 km stretch of a highway was experimentally determined. The lead occurrences along a highway side were found in the range of 104.0 - 190.0 ppm, while those at places situated 50 ft. away from the highway were in the range of 92.0 - 120.4 ppm. This was found to be much higher as compared to the natural occurrence of lead which was reported in the range of 57.0 - 85.0 ppm. The sites at the road junctions indicated much higher occurrence of lead in the soil. The grass samples collected along the side of the highway and also those collected from 50 ft. away from the highway indicated significant uptake of lead. The occurrence of lead in the roots was found to be 2-fold compared to that in the shoots of the grass.
The uptake of lead by a plant *Abelmoschus esculentus*, which is most commonly used as a vegetable diet, was studied in detail. For this purpose, a pot culture study using normal soil and lead polluted soil was carried out. It was found that the lead accumulation in the root was about 5-fold, in stem 4-fold, in leaves 6-fold and in fruit 11-fold compared to the lead levels in these parts of the plant grown in the normal soil. The studies revealed high probabilities of lead entering into food chain, through the use of vegetables grown in lead polluted soils.
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