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Accumulation of Lead in Soil, Water and Plants due to Automobile Emission in Coimbatore Suburbans

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Studies were conducted on the accumulation of lead in soil, water and plants due to automobile emission in suburban environments of Coimbatore City, Tamil Nadu, India. The soil samples collected along the road sides of Coimbatore suburban showed higher concentration of pH and EC with an unusual elevated level of lead (Pb). As high as 276 mg kg^{-1} of Pb was recorded from Tadagam Road II location that was near a marble-stones selling unit. Water samples of suburban also showed higher values of pH and EC. An EC of 3 dSm^{-1} was recorded at Tadagam Road IV location, which was a residential suburban drinking water sample. Increased concentrations of Pb have also been recorded in these samples. The samples also exceeded the maximum permissible levels of Pb in drinking water. Of the 10 plants from suburban areas, the desert-horse purslane, coral creeper and castor plants had accumulated higher levels of Pb (60-100 mg kg^{-1}). It is concluded, in general, that the soil, water and plants of Coimbatore suburban are polluted by the lead emitted by automobiles on road.

Key words: Lead pollution, soil, water, plants

Environmental pollution is a 'by product' of human developments. Of several causes, air pollution is most deleterious to the living beings on this biosphere. Automobile emission is the prime reason for air pollution now-a-days. Lead, a toxic heavy metal, is introduced into the environment mostly from petrol driven vehicles. The increasing use of lead in petrol is responsible for the alarming and threatening exposure to this toxic pollutant, globally. Lead comes in the category of those trace elements which is known to be toxic even when present in traces. It is one of the softest and heaviest metals available. Lead in the tetraethyl $[CH_3CH_2)_4Pb]$ form is used as an antiknock additive to gasoline to increase its octane number. The lead containing gasoline fumes from automobile exhaust constitute the chief and widespread source of lead contamination in the urban environment (Pratapa Mowli and Venkata Subbaya, 1989). Thus lead contamination in soil, water and plants becomes inevitable from the automobile exhaust. The inappropriate use of lead and its compounds has resulted in sporadic and silent outbreak of lead poisoning in the environment including human beings (Seema George, 2003). Hence, the present investigation was carried out to estimate the amount of vehicular lead in the suburban environments of Coimbatore city to determine the quantum of lead deposition in soil, water and plants ecosystems.

Materials and Methods

A study was undertaken to examine the lead pollution due to automobile emission in Coimbatore suburban environments. The details of the materials used and methodology adopted are described here. Coimbatore, strategically located at the Coromandel coast, is at 10ºN 77ºE and 426.72 m.s.l and is the second largest industrial centre in Tamil Nadu. It enjoys a salubrious climate as it is exposed to the Palghat gap of the Western Ghats. This has attracted a large number of textile mills to the region and Coimbatore is rightly called "The Manchester of South India". The region is also well known for

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the manufacture of varied goods which has earned it the title “The Detroit of the South”. The minimum and maximum temperatures prevails between 21ºC and 34ºC. It receives an annual rainfall of 714 mm.

Collection and processing of samples

Soil

The soil samples were collected during June-July 2007 at different locations over a length of 12 kilometers along the State Highways of Coimbatore city suburban roads from GCT Campus i.e. *Thadagam* Road to *Kanuvai.* The locations of the sampling sites are presented in Table 1. The samples were collected from 10 locations at a distance approximately 1-2 km. Replicate samples were collected from each location at 0-15 cm depth. The soil samples were air dried for 2 to 3 days at 25ºC and after grinding, passed through a 2 mm nylon sieve. The homogenized soils were stored in polythene bags until further analysis.

Water

The water samples were collected from ponds, stagnated surface water bodies, running waters, wells, bore wells or drinking water source of the mentioned suburban road-sides during June-July 2007. The samples were collected in new one litre polythene containers, which were previously rinsed with sampling water before taking the samples. After measuring the pH and EC, the water samples were acidified with concentrated HNO_3 (2 ml L^{-1}) to a pH around 3.0 to stabilize the original valence state of Pb. The samples were stored at 4ºC and analyzed within a week.

Plant

The plant samples were collected from the above mentioned suburban road-sides (adjacent to soil collection) during June-July 2007 (Table 2). The plant samples were collected from selected location and gently washed with 1% HCl, and dried in hot air oven at 70ºC for 8 hours and ground to pass a 0.425 mm screen using a stainless steel Wiley Mill. The samples were stored in plastic containers until further analysis.

Chemical analysis

pH and electrical conductivity

The pH and electrical conductivity (EC) of soil were measured in H_2O (1:2.5) after one hour equilibration using ELTOP digital pH meter (3020) and Deluxe Conductivity meter-601 E, respectively. The pH and EC were directly measured in water samples immediately after collection.

Lead in soil

About one gram soil was digested with 10-15 ml freshly prepared aqua-regia (HCl : HNO_3 at 3:1) at 110ºC for 2 hours in a hot plate and made up to 50 ml using double distilled water. After filtration (using Whatman No.42) and centrifugation (at 8000 rpm; 10 min), total Pb concentration was measured using an Atomic Absorption Spectrometer (Varian Spectra AA-200) with air-acetylene flame. The wavelength at 358 nm was used with a spectral slit width of 0.2 nm. Moisture factor was applied to express the results on oven dry weight basis.

Lead in water

The water soluble (or solution phase) Pb fraction was determined in the water samples after filtration through Whatman No.2 filter paper. To determine the total Pb content, the water samples were digested using aqua-regia at 1:2 ratio at 110ºC for about 2 hours, since the results of Mahimairaja *et al.* (1997) showed that the determination of heavy metals in undigested and filtered water samples recorded reduction in the recovery of total metal content. Acid digestion recovers metals both in solution and in colloidal particles. Therefore water samples were subjected to acid digestion. After filtration and appropriate dilution, Pb was determined by using Atomic Absorption Spectrometer (AAS).

Lead in plant

About 0.5 to 1.0 g of dried sample was digested with 15-20 ml aqua-regia at 110º for 2 hours, and made up to 50 ml after filtration (using Whatman No.6) the Pb content was determined in the extract using an Atomic Absorption Spectrometer. Collected data were statistically analyzed for coefficient of variance.

Results

Soil

The soil pH of suburban samples of Coimbatore ranged from 8.11 to 8.56 (Table 3) and the variation among the samples seems to be minimum. The lowest pH was recorded at Tadagam Road IV representing a residential area in suburban and the highest at Kanuvai I representing an area near marble stone-cutting unit.

The EC of suburban soil samples ranged from 0.04 to 0.67 dSm^{-1} (Table 3). The lowest being recorded at Tadagam Road II and followed by Tadagam Road I but highest was recorded at Goundampalayam II representing a residential area.

The concentration of Pb in suburban soil samples ranged from 115.4 to 276 mg kg^{-1} (Table 3). The lead deposition on soils was very higher in these suburban locations contrary to the urban location. Very high levels of Pb were recorded at Kanuvai I (238), Kanuvai II (250), Tadagam Road II (276), Tadagam Road V (180) and Tadagam Road VI (175.6).

Water

The water samples collected at ten locations of suburban Coimbatore city had a mean pH of 8.04 and the values ranged from 7.52 to 8.58 (Table 3). Higher levels of pH from 8.21 to 8.58 were noticed at Kanuvai I, & II and Tadagam Road I, II, IV and VI.

A mean EC level of 1.31 dSm^{-1} was recorded among ten locations of suburban localities in Coimbatore city with a range of 0.04 to 3.00 dSm^{-1} (Table 3). EC less than one dSm^{-1} were recorded at Tadagam Road I, Tadagam Road II, Tadagam Road III and Tadagam Road VI. Very high level (3 dSm^{-1}) of EC was noticed at Tadagam Road IV.

The concentration of Pb in water samples ranged from 0.29 to 2.65 mg l^{-1} (Table 3). The Pb concentration exceeded the maximum permissible limit permitted by WHO (0.1 mg l^{-1}) and USEPA (0.05 mg l^{-1}).

Plant

The Pb concentration recorded in plants of suburban areas of Coimbatore ranged from 1.3 to 102.2 mg kg^{-1} (Table 4). The curry leaves plant had low levels of Pb (1.30). But higher concentrations of Pb were recorded from *Antigonan leptopus* (a common fence-creeper)

Table 1. Soil, water and plant sampling locations and landmarks on the road sides of suburban areas of Coimbatore

Sample No.	Road location	Landmarks of sampling
1.	Goundampalayam I*	Cultivated Field
2.	Goundampalayam II	Balaji Nagar**
3.	Kanuvai I	Panchayat Union School
4.	Kanuvai II	Residential Area**
5.	Thadagam Road I	Kertiman Matriculation School
6.	Thadagam Road II	Maruti Marbles
7.	Thadagam Road III	Cultivated land
8.	Thadagam Road IV	TVS Nagar
9.	Thadagam Road V	Velandipalayam Bus Stop**
10.	Thadagam Road VI	Venkitapuram Amman Koil

* The roman letters I, II… are used to denote the exact location from where the samples were drawn on the sides of suburban roads (State Highways Road)

** Water samples of these locations were collected from ditches and other samples were drinking / bore well waters.

with 102.2 mg kg^{-1} and *Portulaca* sp (a common weed in road sides) with 80.4 mg kg^{-1}. The castor, *Ricinus communis* also had registered Pb @ 62.1 mg kg^{-1} location in this study.

Discussion

In normal soils, the concentration of Pb in general is below 10 mg kg^{-1}. But the maximum allowable concentration of Pb in agricultural soil is 100 mg kg^{-1}. But this study showed that the suburban road side soils were polluted to high levels of Pb which is more than 100 mg kg^{-1} and also with highest record of up to 276 mg kg^{-1}. The reason for higher level of Pb may be due to the fact that the lorries and heavy load vehicles passing this suburban road were more than the urban roads in this study. Due to traffic congestion, the heavy vehicles were diverted in this suburban area. Also, more number of schools in this location attracts more amount of vehicle movement leading to heavy automobile exhaust vis-à-vis more deposition of Pb in the suburban soils. Such accumulation of Pb in soil is attributed mainly due to the automobile exhaust (Brown, 1986; Seema George, 1999, Seema George, 2003). However, the soils differed considerably in their Pb contents. This differential accumulation of Pb is related to traffic density, mode of vehicle operation, wind direction, rainfall, distance from the road, and characteristics of soil. Lead dominates the roadside environment because of its common usage in gasoline as an additive as lead tetraethyl. The deposition of particulate Pb from automobile exhaust was influenced by the weather factors. Schrinding *et al* (1998) and Ki-Hyun Kim (1997) who observed maximum concentration of soil-Pb during winter and minimum during summer. But, Mooniaruck *et al* (1996) inferred that concentration of suspended particulate Pb in traffic dense area was higher during summer than winter. The soils at high usage vehicular road recorded more Pb compared to low vehicular road. It is also evidenced in this study that the suburban road in this case was a high vehicular road which had higher levels of Pb in soil samples than urban road. Interestingly, Seema George (1999) stated that Pb concentrations were higher during winter in soils of National Highways, while the concentrations were higher during summer in soils of State Highways.

The dynamics in the soil properties play important role in the accumulation of Pb in soil. Accordingly, Alloway (1995) stated that the

Table 2. Plant samples collected from suburban areas of Coimbatore

S. No.	Common Name	Botanical Name	Family
1.	Curry leaf	*Murraya koenigii* (L.) Sprengel	Rutaceae
2.	Green amaranth	*Amaranthus viridis* L.	Amaranthaceae
3.	Desert horse purslane	*Trianthema portulacastrum* L.	Aizoceae
4.	Indian Doab	*Cynodon dactylon (*L.) Pers.	Poaceae
5.	Castor	*Ricinus communis* L.	Euphorbiaceae
6.	Coral vine	*Antigonon leptopus* Hook Arn.	Polygonaceae
7.	Bitter weed	*Parthenium hysterophorus* L.	Asteraceae
8.	Thorn apple	*Datura stramonium* L.	Solanaceae
9.	Indian copper leaf	*Acalypha indica* L.	Euphorbiaceae
10.	Paper flower	*Bougainvillea spectabilis* L.	Nyctaginaceae

Table 3. pH, EC and Pb contents in soil and water samples along the road sides of suburban area in Coimbatore

Sample No.	Location	Soil			Water		
		pH	EC (dSm^{-1})	Pb (mg kg^{-1})	pH	EC (dSm^{-1})	Pb (mg kg^{-1})
1.	Goundampalayam I	8.21	0.26	118.0	7.52	1.20	1.28
2.	Goundampalayam II	8.31	0.67	115.4	7.94	1.94	2.54
3.	Kanuvai I	8.56	0.12	238.0	8.35	1.46	1.24
4.	Kanuvai II	8.47	0.30	250.0	8.21	1.02	2.54
5.	Thadagam Road I	8.16	0.07	142.0	8.58	0.04	0.29
6.	Thadagam Road II	8.27	0.04	276.0	8.26	0.42	0.74
7.	Thadagam Road III	8.35	0.31	124.0	7.59	0.84	0.48
8.	Thadagam Road IV	8.11	0.38	106.2	8.19	3.00	1.50
9.	Thadagam Road V	8.13	0.35	180.0	7.52	2.31	2.65
10.	Thadagam Road VI	8.27	0.15	175.6	8.24	0.82	0.32
	Mean	**8.28**	**0.27**	**172.52**	**8.04**	**1.31**	**1.36**
	S Ed	**0.15**	**0.19**	**62.35**	**0.38**	**0.90**	**0.94**
	CV (%)	**65.26**	**70.11**	**36.14**	**4.69**	**68.72**	**68.88**

retention of added heavy metals to soils was often correlated with the soil organic matter. The distribution of Pb in various fractions of soils in Coimbatore urban environment showed that Pb is mostly present in organic plus iron oxide bound fraction as extracted in EDTA (Seema George, 1999).

Higher levels of Pb deposition were noticed in the water samples of suburban Coimbatore. But Pb contents of ditch water sample were very high than the drinking water samples. The reason for higher Pb content in ditch water might be due to accumulation of Pb from various sources, like soil, rain water, home and hospital waste water, etc. Surface runoff and leaching also might have contributed for high levels of Pb in ditch water. Seema George (1999) reported that the water Pb was low during summer and higher during winter. The reason being probably due to adsorption of Pb in soil or soil particles as it was found to be an important mechanism for reducing the heavy metal concentration in solution. Water samples from National Highways recorded higher concentration of Pb than from State Highways. This demonstrates that Pb poisons the soil and water environments and makes it unsuitable for either cultivation of agricultural crops or consumption of water by human beings or irrigation of such Pb polluted water for agricultural purposes too. Seema George (1999) reported higher concentration of Pb in water samples and attributed mainly due to deposition of atmospheric aerosols containing Pb particulates emitted from automobile exhaust.

The safer limit for Pb in drinking water fixed by Ministry of Health, Government of India (1971) is 0.1 mg l^{-1}. In the present investigation, all the samples of suburban showed higher concentration of Pb content in drinking water. Also, the ditch water samples had very high levels (up to 4 mg l^{-1}). It is alarming that the Coimbatore urban and suburban drinking water

Table 4. Lead contents of plants naturally grown along the road sides of suburban area in Coimbatore

Sample No.	Location	Plant species		Pb(mg kg $^{-1}$)
1.	Goundampalayam I	Paper flower		10.3
2.	Goundampalayam II	Castor oil plant		62.1
3.	Kanuvai I	Indian Doab		32.0
4.	Kanuvai II	Desert horse purslane		80.4
5.	Thadagam Road I	Green amaranth		28.2
6.	Thadagam Road II	Thorn apple		18.0
7.	Thadagam Road III	Indian copper leaf		20.2
8.	Thadagam Road IV	Coral creeper		102.2
9.	Thadagam Road V	Bitter weed		39.4
10.	Thadagam Road VI	Curry leaf tree		1.3
			Mean	**39.41**
			S Ed	**32.40**
			CV (%)	**82.20**

samples exceeded the maximum permissible limit of Pb prescribed for drinking purpose too. Of course this drinking water might influence the higher animals including human.

Plants in the ecosystem play important role in recycling of organic and inorganic elements. In this study, curry leaves, green amaranth, desert horse purslane, India Doab, castor oil plant, coral creeper, bitter weed, thorn apple, Indian copper leaf, and paper flower were studied for Pb accumulation. The plants namely *Saranai* (in Tamil Vernacular): Desert-horse purslane, *Trianthema portulacastrum* had accumulated more amounts of Pb followed by castor, coral creeper, green amaranthus and Indian Doab. Of the 10 plants, curry leaves had very low concentration of Pb. The reason for higher accumulation in some of the plant species may be attributed to their broad leaved nature, accumulating efficiency and absorption from the soil and also to some unknown physiological reasons. Seema George (1999; 2003) stated that the Indian Doab, *Cynodon dactylon* recorded higher Pb. Saxena *et al.,* Seema George (1999) and Czuba and Hutchinson (1980) evidenced that leafy crops especially lettuce (*Lactuca sativa* L) and celery (*Apium graveolens*) accumulated higher Pb levels in the foliage when compared with levels in root crops. Saxena *et al* (1991) reported that Pb accumulation was more in the leaves and shoots than in roots of sorghum, maize and wheat cultivated adjacent to a state highways, possibily due to aerial deposition of Pb on shoot surfaces. Lindbery and Haris (1981) demonstrated that Pb is absorbed internally by leaves or irreversibly adsorbed onto leaves. According to Thakre and Vitall (1985), the accumulation of Pb in vegetation through aerial deposition near highways varies with vehicular traffic density and distance from road. Lord *et al*. (1979) stated that the Pb enters the plants mostly through stomata.

It is summarized from the forgoing results that the automobile exhaust resulted in severe contamination of Pb in soil, water and plants in the suburban environments of Coimbatore. There is no doubt that the Pb will find its way to higher animals including human through soil, water and plants since their existence is in close proximity into them. Reports of Pb accumulation in human body have very well been documented elsewhere. This study also supports the Pb accumulation from automobile exhaust to soil-water-plant system and its carry over to higher animals including human.

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