Heavy Metals and Polycyclic Aromatic Hydrocarbons in Roadside Soil Samples: A Review

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***Abstract*—**Diverse contaminants released into the environment through progress of urbanization and industrialization adversely affect human health. Among various sources of contaminants, especially, in big cities, automobiles play a significant role in aggravating the pollution. Various pollutants *viz.,* heavy metals (Pb, Mn, Ni, Zn, As, Hg, Cd) and Polyaromatic hydrocarbons (Benzo-a-pyrene, fluoranthene, pyrene, benzo-b-anthracene, benzo-b-fluoranthene, acenaphthylene, fluorine, phenantherene, anthracene, chrysene, benzo-k-fluoranthene, benzo-e-pyrene, indenol-1,2,3-cd-pyrene, dibenzo-a,h-anthracene, benzo-ghi-perylene) are released by vehicles. Further, these pollutants are expected to cause severe mutagenic, genotoxic and carcinogenic effects. Considering this, many authors monitored the levels of pollution in roadside soil, water and plants. The present review focuses upon the analysis and effects of heavy metals and polycyclic aromatic hydrocarbons from the roadside samples.

***Keywords*—**Automobiles, Carcinogenicity, Atomic Absorption Spectrophotometer, Gas Chromatography – Mass Spectroscopy, Soil pollution.

I. Introduction

THE environment has been contaminated with different pollutants such as pesticides [1]-[11], inorganic fertilizers [12]-[15], heavy metals [16]-[23] and polycyclic aromatic hydrocarbons [24]-[26] for the past decades. These pollutants are derived from different sources *viz.,* industries [27]-[31], agriculture [32]-[34], domestic [35]-[37], commercial and vehicular emissions [18], [38]-[43].

Anthropogenic activities like energy production, construction, waste disposal, coal and fuel combustion are the other major sources of soil pollution. Although in many urban areas, industries were moved away from residential areas, bus terminals and railway stations still continued to be major source of soil pollution [44]-[46]. The vehicle repairs also release heavy metals to air that ultimately get deposited on the soil. Lagerwerff [47] reported that the Fe, Cu, Zn were essential component of alloy, pipe, wire and tyre in motor vehicles and these metals were released into soil by either mechanical abrasion or normal wear and tear.

The pollutants present in soil not only affect the micro flora and fauna of soil ecosystem but also contaminate fruits and vegetables. Last but not the least, they result in formation of leachates that ultimately contaminate the ground water passing through the soil profiles or by directly entering the surface water system through run offs. The consumption of the contaminated food and water causes severe health problems in human beings. Rapid motorization has resulted in release of deleterious mutagens/genotoxins/carcinogens to all components of environment. The direct DNA damaging effects of these pollutants further result in long term effects such as carcinogenicity [48]. The exposure to automobile emissions was reported to cause various respiratory diseases and lung cancer [49]-[50]. Some authors documented the adverse effects of toxic metal like lead that is released from vehicular emissions [51]-[52] while some authors reported the accumulation of other metals in plants [53] and rivers [54].

The pollutants emitted from vehicles get dispersed by wind or rainfall, yet, they reach the soil ecosystem after setting down. The surface soil thus seems to be the promising material for analysis of vehicular pollution. Moreover, it is easy to obtain the adequate soil samples for both biological and chemical analysis. Considering the need to address the awareness for exposure of human population to the vehicular emissions, the review is focused on estimation of heavy metals (Table I) and polycyclic aromatic hydrocarbons (Table II) from roadside soil.

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A. Heavy Metals

The determination of heavy metals in environmental samples is very important because these heavy metals pose toxic effects such as blood enzyme changes, anemia, hyperactivity and neurological disorders. Flora [54] reported the uptake of heavy metals in edible plants. Nordberg [55] emphasized that excessive exposure of heavy metals such as Cd caused harmful effects in renal, pulmonary, hepatic, skeletal and reproductive systems.

Among various heavy metals, lead is considered as the primary carcinogen. This metal is of great interest because of its alarming increase in air and soil ecosystems through vehicular emissions. Moreover, it is also used as alkyl lead compounds for antiknocking and antifreezing purposes in fuel [56]-[58]. Pb has been reported to be particularly toxic to the brain, kidneys, reproductive system, cardiovascular system as a result of chronic and acute exposure as well as repeated exposure of Pb stored in the body tissues. During pregnancy, lead has tendency to cross the placental barrier and can cause intrauterine death or premature births [59].

Lead being the primary carcinogen, has been analyzed by various scientists using different analytical methods [18], [41], [50], [60]. The content of lead was estimated in water and soil samples around Lake Victoria, Kisumu, Kenya using Atomic Absorption Spectrophotometer (AAS) and was found in the range of 140 to 260, 140 to 600µl/L and 0.3 to 3.9µg/g in tap water, surface water and soil samples, respectively. The authors correlated presence of lead in soil and water samples to that of emissions from vehicles [50].

Al-Chalabi [41] studied the distribution of lead in the roadside soils collected from three sites *viz.,* south east freeway, Logan road and Ipswich road of urban area of Brisbane, Australia. The total content of lead was determined by Flameless AAS and the mean concentration of lead (µg/g) was found to be 2990 (south east freeway), 1950 (Logan road) and 3800 (Ipswich road). Vehicular emissions were considered as one of the major sources of lead in roadside soils by the authors.

Some authors have estimated heavy metals in plants along with the soil samples to explore the heavy metals pollutants in roadside soil. Akbar [18] estimated heavy metal contamination of roadside soils of northern England. The roadside soils often get contaminated from operations like combustion, component wear, fluid leakage, corrosion of metals etc. of road transport. The soil samples from 35 different sites of northern England were estimated for four different heavy metals *viz.*, cadmium, copper, lead and zinc using Atomic Absorption Spectrophotometer. The samples included both roadside and non roadside samples. Among four heavy metals studied, it was observed that concentration of lead was maximum in all samples and it ranged from 25 to 1198 µg/g. However, concentration of zinc, copper and cadmium ranged from 56.7 to 480 µg/g, 15.5 to 240 µg/g and 0.3 to 3.8µg/g, respectively. The roadside soil showed high metals content as compared to non roadside soil.

Mashi [60] reported the accumulation of lead in surface soils and a plant species *Balenites aegyptica* of Katsina urban area, Nigeria. The concentration of Pb in the high, medium, low and zero traffic density areas were 75, 53, 35 and 12µg/g, respectively in the fruit pulp, 16, 13, 8 and 6µg/g, respectively in fruit kernel, 138, 97, 64 and 18µg/g, respectively in tree barks and 44, 28, 17 and 9µg/g, respectively in leaves. For soil analysis, under-tree-canopy soil samples had 99, 74, 44 and 17µg/g, respectively while outside-canopy soil samples had 113, 91, 50 and 18µg/g, respectively of lead content for various classes of vehicular traffic density. The authors indicated that traffic density strongly influenced the emission of Pb in surrounding atmosphere.

Pirzada [61] estimated lead content in plants (*Derbergia sisso* and *Cannabis sativa*) and soil samples from 10 locations along Islamabad Highway, Pakistan. The strong correlation was observed for concentration of lead in soil and plant *i.e.* both highest and lowest values of lead concentration in both soil and plants were found to be from same site. Apart from this, the concentration of lead in soil decreased with increasing distance from roadside. Authors reported that the traffic was the key source of lead in soil and plants of that area.

Sharma [53] reported the accumulation of lead and cadmium in soil and vegetable crops along major highways in Agra (India). Soil and vegetable samples collected along highway from the 10 sites in Agra district (India) were analyzed for heavy metals using flame atomic absorption spectrophotometer (F-AAS). The higher levels of metals were found in soil and vegetation samples collected at distance 0 - 0.5m as compared to the soil and vegetation samples collected at distance 5-15m. This study revealed that high traffic intensity along the major highway greatly influenced the roadside plant and soil samples.

Although lead is primary environmental pollutant released from vehicular emissions, various other heavy metals including As, Sb, Hg, Cd, Cu, Zn etc. were also reported in soil, water and plant samples along the roadside [19], [21], [23], [62]. Ozaki [23] estimated the arsenic (As), antimony (Sb) and mercury (Hg) distribution in the roadside soil and dust at four different stations *viz.,* Kamikochi bus terminal, Kama Tunnel, Matsumoto Interchange and east exit of Matsumoto station, Japan. All four sites showed high concentrations of heavy metals which indicated that the sites were strongly affected by presence of automobiles. The release of heavy metals from the combustion of fossil fuel has also been documented by others authors [63]-[64]. According to Petroleum statistics 1995, about 3 billions tons gasoline was produced per year which was also considered as one of the major source of Hg pollution in soils [62]. Liang [62] further reported that about 0.2-3.3ng/g of Hg was present in different types of gasoline.

Onder [19] determined heavy metal pollution in grass and soils of green areas of Konya, Turkey. The samples of grass (*Lolium perenne* L.) and soils were taken from eight different sites *viz.,* Alaeddin Hill Park, Anit Place, Cement Factory Garden, Selcuk University Campus, Chrome-Magnesite Factory Garden, Karatay Industry Park, Meram Region and Sugar Factory Garden and studied for presence of various heavy metals by using Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES). This study compared the heavy metals pollution of year 2003-2004 and revealed that both grass and soil samples showed high contents of heavy metals in 2004 as compared to 2003.

Abechi [21] evaluated the contents of heavy metals (Pb, Zn, Mn, Cu, Ni, Cd, Co and Fe) in roadside soils of major streets in Jos metropolis, Nigeria using Atomic Absorption Spectrophotometer (AAS). The order of the total metal content for the studied samples was Fe > Zn > Mn > Pb > Cd > Cu. Correlation analysis between metals and the traffic volume was found to be significantly positive at $p < 0.05$. The study also emphasized that metal pollution in soil was mostly originated from vehicular emissions.

Ramakrishnaiah [22] analyzed heavy metal contamination of roadside soil and their mobility in relations to pH and organic carbon. The concentrations of Pb, Zn, Cd, Ni, Cu, Cr and Mn were determined using Atomic Absorption Spectrophotometer (AAS). The study was planned to assess the impacts of automobiles on heavy metal contamination of roadside soil. Soil samples from four polluted sites and one non polluted site were collected at a depth of 0, 2, 5, 10, 15, 20, 30cm. Pb levels in polluted sites varied from 70 to 280.5µg/g and it rapidly decreased with depth whereas mean concentrations of Zn, Cd, Ni, Cu, Cr, and Mn were significantly higher at polluted sites and followed a decreasing trend with the increased depth. Correlation coefficients between all heavy metals and traffic density were found to be positively significant except for nickel. It was observed that Pb, Zn, Cd, Cu and Mn were largely concentrated in the top 5 cm.

Odiyo [65] studied the trace and platinum group metals in Thohoyandou, South Africa. Soil, vegetation, sewage and river waters were analyzed for heavy metals. The soil and vegetation samples were analyzed by atomic absorption spectrophotometer while water samples were analyzed by inductively coupled plasma atomic emission spectrometry. Study revealed that there was a positive correlation between soil and vegetation for concentration of metals. The author observed that there was a reduction of metals concentration in soil and vegetation with increasing distance from the road traffic. The order of concentration of metals was found as Pb> Zn > Cr > Cu > Cd in soils, Pb > Zn > Cd > Cr > Cu in vegetation and Fe > Zn > Pt > Cu > Pd in sewage water.

Massadeh [66] reported lead and cadmium contamination of roadside soils in Irbid city, Jordan. For evaluation of amount and distribution of lead and cadmium, 260 samples were analyzed using Graphite Furnace Atomic Absorption Spectrophotometer. The concentration of lead ranged from 325 to 431µg/g while concentration of cadmium ranged from 1.142 to 1.135µg/g. The concentration of lead and cadmium were directly correlated with traffic intensity. Shi [67] analyzed about 273 soil and dust samples collected from Shanghai, China for the toxic metal contamination. It was concluded that Pb, Zn and Cu mainly originated from traffic contaminants, Cd from industrial emissions whereas Cr and Ni from natural atmospheric deposition.

Jaradat [44] analyzed heavy metals contamination (Cu, Pb, Cd, and Zn) of roadside soil, plants and air for samples collected from the southern part of the Jordan. Concentration of Cu, Cd, Pb, and Zn in soil samples were 29.7, 0.75, 188.8 and 121.7µg/g, respectively. Concentrations of these heavy metals in plants were 31.3, 7.3 and 98.7µg/m^3 for Cu, Pb and Zn, respectively while for air, their concentration were 0.40, 0.94 and 0.26µg/m^3, respectively. Thus, roadside soil, plant and air had significant concentrations of heavy metals through at automobiles emissions.

Kadi [38] correlated the chemical composition and automobiles traffic of roadside soil of Jeddah city, Saudi Arabia. The soil samples were collected from the areas having heavy and light traffic intensity and were analyzed for K, As, Co, Cr, Ni, Pb, Sb, V and Zn. The content of lead and zinc were found to be high in the samples that were collected from the areas of heavy traffic intensity. The content of lead ranged from 0.3 - 104.8±0.003 mg/kg for the samples of high traffic intensity while the content of lead was 0.3±0.00 for the samples of no traffic intensity. The zinc content was found to be in range of 56.59±0.003 to 456.93±0.06 mg/g.

Morcelli [68] examined the distribution pattern of platinum group elements *viz.,* platinum (Pt), palladium (Pd) and rhodium (Rh) and other metals like Zn and Cu in the roadside soil of major road in Sao Paulo, Brazil. The samples were collected from four heavy polluted sites and analyzed by High-resolution inductively coupled plasma mass spectrometry (HR-ICP-MS). The content of platinum group element ranged from 0.3 to17ng/g for Pt, 1.1 to 58ng/g for Pd and 0.07 and 8.2ng/g for Rh.

Jian-Hua [20] studied the distribution of heavy metals such as Ni, Pb, Cr, Zn, Cu, and Cd from the roadside soil of Zhengzhou-Putian Section of Longxi-Haizhou Railroad, China. The soil samples were collected at distance of 0, 10, 20, 30, 50, 100, 200, 300 and 500m from the railroad edge. The contents of Pb and Cd were estimated by graphite furnace atomic absorption spectrometry (GF-AAS) while contents of Cu, Zn, Cr and Ni were estimated by flame atomic absorption spectrometry (F-AAS). The maximum concentrations of the metals were found at distance 10–30m from the railroad and the content of these metals was found in order of Cr > Cd > Pb > Zn > Ni > Cu.

Mbah [42] analyzed variations in heavy metal contents on roadside soils along a major express way in south east Nigeria. 15 surface soil samples were collected at the distance of 50 cm – 1 m and 15 samples from 100 m away from the roadside. The soil samples were analyzed using Atomic Absorption spectrophotometer. The mean values of Fe, Cu, Zn, Pb and Cd were 5205.11, 247.97, 74.11, 100.19 and 18.8 mg/kg, respectively at depth of 50 cm – 1 m whereas means values at 100 m away from the roadside were 4890, 217.86, 64.08, 87.13 and 3.05 mg/kg, respectively.

Haal [69] described that most of the pollution in roadside soils and groundwater was mainly due to vehicular emissions. The various heavy metals (Pb, Cd, Ni, Zn, Cu, Co) were analyzed from the roadside soils in Talinn during 2001-2007. It was observed that heavy metals pollution was lower in autumn as compared to spring reason.

Hamurcu [70] determined the mineral and heavy metal levels of some fruits grown at the roadsides in Turkey by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). The levels of Pb and Se were found to be very high in the fruit samples. The results showed that the average level of Cu ranged between 0.27 mg/kg and 0.05 mg/kg, Cr as 0.32 mg/kg and 0.18 mg/kg, Ni as 0.68 mg/kg and 0.26 mg/kg, Pb as 2.86 mg/kg and 1.54 mg/kg and Se as 12.96 mg/kg and 5.42 mg/kg. The levels of Cu, Cd and Cr in samples were found to be below pollution levels.

Malkoc [71] studied the levels of heavy metal pollution in roadside soils of Eskisehir, Turkey. 15 soil samples were taken from three different lines: only - tramway lines, only - traffic lines, and both traffic and tramway lines and analyzed for different heavy metals *viz*., Cd, Cu, Cr, Fe, Hg, Mn, Ni, Pb, and Zn. The level of pollution in soil was estimated based on the geoaccumulation index (Igeo), enrichment factor (EF), pollution index and integrated pollution index (IPI). The values for the integrated pollution index (IPI) were found to be in the order of Pb > Zn > Cu > Fe > Mn > Ni > Cr > Cd.

Bakirdere [72] determined the lead, cadmium and copper in roadside soil and plants in Elazig, Turkey. The soil samples were collected at distances of 0, 25 and 50 m from the roadside soil and the concentrations of lead, cadmium and copper were measured using Flame Atomic Absorption Spectrophotometer (FAAS). To increase the sensitivity of Pb, Cd and Cu, the Slotted Tube Atom Trap (STAT) was used.

Lead concentrations in soil samples varied from 1.3 to 45 mg/kg while mean lead levels in plants ranged from 120 ng/g to 866 ng/g. The level of Cd in soil samples ranged from 78 to 527 ng/g while Cd concentration in different vegetation samples varied from 1.3 to 45 mg/kg. Concentrations of Cu in soil and plant samples were found to be in the range of 11.1 – 27.9 mg/kg for soil and 0.8 – 5.6 mg/kg for plants.

Grigalaviciene [73] estimated the concentrations of Pb, Cu and Cd in 81 topsoil samples collected from three similar sites located near the Vilnius-Klaipeda Highway, Lithuania. The soluble and total content of heavy metals were determined by using atomic absorption spectrophotometer. The maximum concentration of heavy metals was found at distance 5 m from the road.

Mmolawa [74] assessed heavy metals *viz.,* Al, Co, Cu, Fe, Pb, Mn, Ni and Zn along the major roadside soils of Botswana, using enrichment factor ratios (EF), contamination factor (CF), pollution load index (PLI) and geoaccumulation index (*I*geo) methods. The studied sites were divided into five zones as FN (Francistown- Nata), NM (Nata-Maun), MG (Maun-Ghanzi), GK (Ghanzi-Kang) and TS (Tshabong-Sekoma). The zones FN, NM and MG showed high load of metal pollution as compared to GK and TS zones**.**

Christoforidis [75] studied heavy metals in about 96 street dusts and 96 roadside soils that were collected from three different localities (urban, industrial, peripheral) of Kavala city, Greece. They analyzed samples for Pb, Cu, Zn, Ni, Cr, Cd, As and Hg using the atomic absorption spectrophotometer. The results have shown that dust and soil samples from the urban and industrial area had significantly high levels of the metals as compared to those from the control site. The mean values for Pb, Cu, Zn, Ni, Cr, Cd, As and Hg in street dust were 300.9, 123.9, 271.6, 57.5, 196.0, 0.2, 16.7 and 0.1 µg/g, respectively while for roadside soil the values were 359.4, 42.7, 137.8, 58.2, 193.2, 0.2, 62.3 and 0.1 µg/g, respectively.

Kim [76] calculated the long-term behavior of particulate matters at urban roadside and background locations in Seoul, Korea. The concentrations of particulate matter, $PM_{2.5}$, PM_{10} and TSP at an urban roadside and an urban background station were analyzed. Data collected over a 10 year period was analyzed. The concentrations of the particulates measured at the urban site were systematically larger than at the background station. Mean PM values at the former also exhibited a slight fall over the decade unlike those at the background station.

The roadside topsoil concentrations of heavy metals *viz.,* Pb, Zn, Cd, Cu, Cr, Co and Ni in Ibadan, Nigeria was also documented [77]. The soil samples were collected from 45 different locations all over the city. The flame atomic absorption spectrophotometer (F-AAS) was used to estimate the content of heavy metals. The average concentration of Pb, Zn, Cd, Cu, Cr, Co and Ni were 81, 8, 0.55, 17, 22.1, 7.9 and 10.5 ppm, respectively.

Khan [78] estimated lead and cadmium contamination of different roadside soils and plants in Peshawar City, Pakistan. The different soil and plants (*Eucalyptus camaldulensis, Ficus elastica, Dalbergia sissoo and Alstonia scholaris*) samples were collected and analyzed for Pb and Cd metals by Atomic Absorption Spectrophotometer. The mean content of Pb and Cd was 53.9 and 6.0 mg/kg, respectively in soils and 49.1 and 10.9 mg/kg, respectively in plants. The order of metal accumulation index (MAI) in different plant species were found to be *E. camaldulensis* > *F. elastic* > *D. sissoo* > *A. scholaris*.

Faiz [79] estimated ccumulation of Cd, Cu, Ni, Pb and Zn along Islamabad Expressway, Pakistan from the dust and soil samples. The samples were analyzed for five heavy metals using FAAS (flame atomic absorption spectrometry). The average concentration of Cd, Cu, Ni, Pb and Zn were found to be 5, 52, 23, 104 and 116 mg/kg, respectively. The pollution level was estimated based on the geoaccumulation index (Igeo), the pollution index (PI) and the integrated pollution index (IPI). The values of IPI were in the order of Cu > Pb > Zn > Cd > Ni.

Aslam [80] studied the heavy metals contamination in roadside soil near different traffic signals in Dubai. The roadside soil samples were collected from three different locations *viz.* roads having more than two traffic signals, roads having only one traffic signal and roads having no traffic signals. They analyzed Cd, Pb, Cu, Ni, Fe, Mn and Zn by Atomic Absorption Spectroscopy (AAS). The range of the metals observed in soil having more than two traffic signals were Cd (0.17 – 1.01), Pb (259.66 – 2784.45), Cu (15.51 – 65.90), Ni (13.31 – 98.13), Fe (325.64 – 5136.37), Mn (57.95 – 166.43), and Zn (91.34 – 166.43) mg/kg while the range of metals analyzed in samples collected from the roadside having only one traffic signal were Cd (nd – 0.80), Pb (145.95 – 308.09), Cu (0.82 – 18.04), Ni (18.29 – 59.36), Fe (88.51 – 3649.42), Mn (25.88 – 147.34) and Zn (8.97 – 106.11 mg/kg). However, the range of metals at roads having no traffic signals were Cd (0.0 – 0.57), Pb (8.34 – 58.20), Cu (2.88 – 5.81), Ni (3.34 – 73.80), Fe (55.34 –332.81), Mn (2.98 – 98.73) and Zn (1.23 – 46.6 mg/kg). Cd, Cu, Ni, Fe, Mn and Zn in soil were present within the normal range of background levels whereas lead was reported in high concentration.

The seasonal variation in the concentration of heavy metals in roadside soil in Yauri, Nigeria using atomic absorption spectrophotometer were examined [81]. The soil samples were collected in dry and rainy season. It was observed that the range of As, Cd, Cr, Cu, Fe, Ni, Pb and Zn were 1.15 - 3.14, 0.14 - 7.0,1.64 - 22.36, 4.86 - 29.30, 2001 - 8091, 351.6 - 843.3, 35.9 - 306.7, and 79.6 - 202.4 µg/g for dry season and ND – 13.04 µg/g, ND - 7.02, ND - 13.79, 0.99 - 23.72, 748 - 6000, 201.13 - 507.10, 24.00 - 316.14 and 33.84 - 131.06 µg/g for wet season, respectively. The higher heavy metal concentrations were found in the roadside soil during the dry season than in wet season. The results indicated that in both wet and dry seasons, most of the heavy metals were above the natural heavy metals concentrations of surface soil.

Wang [82] analyzed the antimony in urban roadside surface soils of Xuzhou (China). In order to assess the magnitude of contamination and to identify the possible contamination sources, 21 top soils samples were collected. It was observed that Sb in urban surface soils was 0.96 mg/kg. The Sb in the Xuzhou top soils was mainly due to the inputs of coal combustion. Cal-Prieto [83] stated that about 0.2-1.0 mg/kg Sb naturally occurred in the earth's crust, but the various anthropogenic activities in many areas were responsible for significant increased of Sb in soil. It was found that up to 3.5 tones/year were emitted to the atmosphere from human activities and up to 18000 and 26000 tones/year were estimated as inputs to the aquatic ecosystems and soils, respectively.

Addo [84] analyzed the various heavy metals *viz.,* As, Cr, Cu, Mn, Ni, Pb and Zn from the dust deposited roadside soil samples collected from the Ketu-South District, Volta Region in Ghana. About 50 samples were analyzed for various heavy metals using Energy Dispersive X-Ray Fluorescence (ED-XRF). The concentration of heavy metals studied ranged from 0.4-18.2 µg/g for As; 284-9106 µg/g for Cr; 18.4-144.1 µg/g for Cu; 233-1240 µg/g for Mn; 12.3-493.2 for Ni; 3.1-67.8 µg/g for Pb; and 18.2-406.5 µg/g for Zn.

Naser [85] examined lead, cadmium and nickel in roadside soils and vegetables along a major highway in Gazipur, Bangladesh. The soil samples were collected at various distances *viz.,* 0, 50, 100 and 1000 m (meter) from the road. Both soil and plant samples were analyzed for heavy metals using atomic absorption spectrometry. It was observed that there were significant differences in the concentrations of lead, cadmium and nickel for different plant species and soil sample at various distances. The order of accumulation of heavy metals was found to be nickel > lead > cadmium.

Masoudi [86] observed the distribution of lead, cadmium, copper and zinc in roadside soil of Sari-Ghaemshahr road, Iran. The soil samples were collected at the distances of 4, 8, 16, 32, 64 and 100 m from the road edge of both sides of the road and analyzed for various heavy metals *viz.,* Pb, Cd, Cu and Zn using flame atomic absorption. Three heavy metals excluding Cd were significantly different ($p < 0.01$) in the distance of 4 m. The concentration of Pb was found to be 2.95 mg/kg at 4 m, 1.76 mg/kg at 64 m. The concentration of Cu at 4 m of road was found to be 1.91 mg/kg which was decreased at 16 m distance (1.48 mg/kg) and then increased at 32 m (2.02 mg/kg) distance and 100 m (1.25 mg/kg). The concentration of Zn at 4, 8, 16, 32, 64 and 100 m distance from the road were found to be 3.66 mg/kg, 2.23 mg/kg, 1.37 mg/kg, 1.31 mg/kg 0.81 mg/kg and 1.13 mg/kg 100 m, respectively.

Zhang [87] studied the influence of traffic activity on heavy metal concentrations of roadside farmland soil in mountainous areas of Trishuli city and Kathmandu, Nepal. About 342 topsoil samples from the depth of 0–5 cm were collected under dry weather and analyzed for various heavy metals *viz.,* Pb, Cd, Cu and Zn by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

B. Polycyclic Aromatic Hydrocarbons

Apart from heavy metals, polycyclic aromatic hydrocarbons (PAHs) are the second major contaminant from vehicular emissions. Many authors reported the accumulation of PAH in roadside soil, plants and water system [26], [88]-[90]. Creosotes are the complex mixture of polycyclic aromatic hydrocarbons as well as phelonic and aromatic sulphur and nitrogen compounds. It is extracted by fractional distillation of crude coal tar and contains about 30 different types of PAHs [26], [91]. Chemical composition of creosote depends upon the origin of coal and nature of distillation process. However, phenanthrene is most abundant PAH in creosote followed by naphthalene and fluoranthene [92]-[93]. Moret [26] estimated the content of polycyclic aromatic hydrocarbon (PAH) from the soil and olives collected in areas contaminated with creosote released from old railway ties and concluded that very high content of PAH (114.7 to 2157.2 µg/g for dry weight of total light PAH and 167.3 to 3121.8 µg/g for dry weight of heavy PAH) were found in soil sample up to 1 m from the source of contamination.

Wang [94] studied the concentrations, sources and spatial distribution of polycyclic aromatic hydrocarbons in soils from Beijing, Tianjin and surrounding areas, North China. 40 samples were collected from industrial areas, roadsides and other pollution sources and across a range of soil types in remote, rural villages and urban areas. The total concentrations of 16 PAHs ranged from 31.6 to 1475.0 ng/g. The maximum PAH concentrations were measured in urban soils, followed by rural village soils and soils from remote locations.

Liu [88] studied the polycyclic aromatic hydrocarbons in urban soils of different land uses in Beijing, China. 127 surface soil samples were collected from Beijing's urban district and were analyzed for 16 polycyclic aromatic hydrocarbons (PAHs) *viz.,* (naphthalene (Nap), acenaphthylene (Any), acenaphthene (Ane), fluorene (Fle), phenanthrene (Phe), anthracene (Ant), fluoranthene (Fla), pyrene (Pyr), benz[a]anthracene (Baa), chrysene (Chy), benzo[k]fluoranthene (Bkf), benzo[b]fluoranthene (Bbf), benzo[a]pyrene (Bap), indeno[1,2,3-cd]pyrene (I1p), dibenz[a,h]anthracene (Daa), benzo[ghi]perylene (Bgp) by using gas chromatography- mass spectrometry (GC/MS). The various physicochemical characteristics of soil *viz.,* pH, clay content, cation exchange capacity (CEC), total organic carbon (TOC) and black carbon (BC) were also determined. The means concentrations of individual PAH was found in order of I1p (14.7%) > Bkf (14.6%) > Bgp (11.8%) > Chy (9.3%) > Fla (9.0%) > Bap (8.5%) > Phe (7.6%) > Baa (7.0%) > Pyr (6.2%) > Bbf (4.9%) > Daa (3.8%) > Ant (1.6%) > Fle (0.6%) > Any (0.2%) > Nap (0.05%) > Ane (0.02%).

Hassanien [95] examined the road dust samples in Greater Cairo, Egypt for presence of polycyclic aromatic hydrocarbons (PAHs). 12 different PAHs were identified using HPLC spectroscopy. The result indicated that PAHs ranged from 0.045 to 2.6 mg/kg. Pyrene (1.031 1.028 mg/kg) and phenanthrene (1.028 mg/kg) were found to be maximum while benzo(a)pyrene (0.0001 mg/kg) was found to be minimum.

Many reports indicated that oil spills around petroleum exploration and refinery areas in Nigeria were the major sources of PAH pollution [24], [96]. Onianwa [24] studied petroleum hydrocarbon pollution of urban topsoil in Ibadan city, Nigeria. The samples were collected from 7 different zones *viz.,* railway tracks, petrol stations, refuse dumps, residential areas, high traffic density areas, auto-mechanic workshops and control zones. The significant amount of petroleum hydrocarbons was present around petrol stations (1440-2560 mg/kg) and mechanical workshops (710-1250 mg/kg). The order of hydrocarbon levels at different sampling sites was petrol station > mechanical workshop > refuse dumps > high traffic > traffic areas > railway tracks > control zones residential areas.

Kumar [89] reported the distribution of polycyclic aromatic hydrocarbons in roadside soil at traffic intercepts. The concentration of polycyclic aromatic hydrocarbons (PAHs) was determined at 10 different locations of Jalandhar city, Punjab (India) at 1, 2 and 3 m distances from roadside in soil covering all the major traffic intercepts within city. The study was conducted during autumn and winter season to determine the contamination levels and their distribution in soil. The samples were analyzed using Gas Chromatography-Flame Ionization Detector (GC-FID). The average concentration was found to be 4.04 μg/g and 16.38 μg/g during winter and autumn, respectively. The diBenzo(ah)Anthracene and Benzo(a)Pyrene were found in highest concentration at all the intercepts ranging between 0.008 to 28.4 μg/g during winter and 0.01 to 252.55 μg/g during autumn. The average concentration of non-carcinogenic and carcinogenic polycyclic aromatic hydrocarbons during winter was 2.1 and 6.4 μg/g and autumn was 4.74 and 35.08 μg/g, respectively.

Guo [97] predicted occurrences and sources of polycyclic aromatic hydrocarbons and *n*-alkanes in $PM_{2.5}$ in the roadside environment of a major city in China. 36 $PM_{2.5}$ samples were collected from the road with heavy traffic in Qingdao, (North China) from March, 2004 to January, 2005 for detailed characterization of 16 priority polycyclic aromatic hydrocarbons (PAHs) proposed by the USEPA and *n*-alkanes. Average PAH levels were reported to be 32.3, 11.5, 48.9 and 263 ng/m^3 for spring, summer, autumn and winter, respectively whereas the average concentrations of *n*-alkane in $PM_{2.5}$ at ground level were 232, 121, 309 and 369 ng/m^3 in spring, summer, autumn and winter, respectively.

Ray [98] studied the effects of jet turbine exhaust in the peripheral soil of the International Airport in Delhi, India. 3 sampling sites were selected in the area surrounding the airport while one background site was chosen in a remote area. Site-I (LP) was selected near the landing point of the airport, site-II (T/I) was located near the taxi/idle point and Site-III (T-O) was situated near the take-off point of the airport. About 12 polycyclic aromatic hydrocarbons (PAHs) were analyzed in the <2 mm surface soil by using high performance liquid chromatography (HPLC). The sum of 12 PAHs ranged from 0.39 μg/g to 7.53 μg/g. Among the three sampling sites selected around the International Airport, maximum concentration of PAHs was found to be at the site near landing point, while minimum concentration was observed at the site near take-off point.

Essumang [99] estimated the level, distribution and source of Polycyclic Aromatic Hydrocarbons (PAHs) in roadside soil of Esbjerg, Denmark. 24 soil samples were collected from the 9 different locations and the level of PAHs were determined using GC/MS/MS with ion trap detector (TCD). The fluoranthene, benzo(b)fluoranthene andbenzo(a)pyrene were found in higher concentration.

Bhupander [90] evaluated the distribution, composition profiles and sources of polycyclic aromatic hydrocarbons (PAHs) in the roadside soil collected from Dehli, India. The soil samples were collected from fourteen roadside urban locations and examined by using high performance liquid chromatography with Ultraviolet-Diode Array Detector (HPLC-UV-DAD). The average concentration of all PAHs was 6838.6 ± 3528.4 μg/kg. The concentration of carcinogenic PAHs was found to be 67.4% out of total PAHs estimated.

Ortiz [100] determined the presence of Polycyclic Aromatic Hydrocarbons in the top soils collected from 2 semi-rural terrains *viz.,* Tlahuac and Milpa Altaduring during 2008–2009 in Mexico city. The determination of PAH was carried out by using gas chromatography with a flame ionization detector. The concentrations of PAH in Tlahuac were 9.13 mg/kg (dry season) and 11.22 mg/kg (wet season) and in Milpa Alta were 11.43 mg/kg (dry season) and 35.77 mg/kg (wet season). The variation of total PAH concentrations were correlated with environmental and anthropogenic conditions in Mexico City by authors.

TABLE I
SUMMARY OF LITERATURE ON HEAVY METALS POLLUTION IN ROADSIDE SOIL SAMPLES

S. No.	Site description	Heavy metals analyzed	Methods/instrument used	Results	References
1.	Roadside soil, Northern England	Cd, Cu, Pb and Zn	Perkin Elmer 1100 Atomic Absorption Spectrophotometer	Pb (25.0 to 1198.0µg/g), Zn (56.7 to 480.0 µg/g), Cu (15.5 to 240.0 g/g) and Cd (0.3 to 3.8 µg/g)	Akbar [18]
2.	Grass and Soil, Konya, Turkey	Pb, Cu, Zn, Co, Cr, V, Cd and Ni	Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)	High contents of lead were found in roadside soil and grass.	Onder [19]
3.	Roadside soil railroad side, Zhengzhou-Putian Section of Longxi-Haizhou Railroad, China	Ni, Pb, Cr, Zn, Cu, and Cd	Pb and Cd by graphite furnace atomic absorption spectrometry (GF-AAS) while Cu, Zn, Cr and Ni by flame atomic absorption spectrometry (F-AAS)	Content of metals were found in order: Cr > Cd > Pb > Zn > Ni > Cu.	Jian-Hua [20]
4.	Roadside Soils of Major streets, Jos metropolis, Nigeria	Pb, Zn, Mn, Cu, Ni, Cd, Co and Fe	Atomic Absorption Spectrophotometer	Order of heavy metals found: Fe > Zn > Mn > Pb > Cd > Cu	Abechi [21]
5.	Roadside soil, Banglore, India	Pb, Zn, Cd, Ni, Cu, Cr and Mn	Atomic Absorption Spectrophotometer	Pb (70 to 280.5µg/g), Zn (101.9 to 192.2), Cd (4.5 to 22.62µg/g), Ni (7 to 30µg/g), Cu (14.2 to 60µg/g), Cr (22.2 to 72.5µg/g) and Mn (104.3 to 252.3µg/g)	Ramakrishnaiah [22]
6.	Roadside soil and Dust, Kamikochi, Chubu Sangaku National Park, Japan	As, Sb, and Hg	Atomic Absorption Spectrophotometer	High concentration of heavy metals due to high intensity of automobiles	Ozaki [23]
7.	Soil sample, Bursa plain, Turkey	Cd, Cu, Pb, Mn, Ni and Zn	Atomic Absorption Spectrophotometer	Mn and Zn were quite high and Cd was found to be very low	Aydinalp [33]
8.	Roadside soil of Jeddah city, Saudi Arabia	K, As, Co, Cr, Ni, Pb, Sb, V and Zn	inductively coupled plasma-optical emission spectrometer (ICP-OES) and ICP-mass spectrometry (ICP-MS)	Lead and Zinc was found in high contents and ranged from 0.3-104.8±0.003mg/kg of 56.59± 0.003 to 456.93±0.06mg/g, respectively.	Kadi [38]
9.	Roadside soils, Brisbane, Australia	Pb	Flameless Atomic Absorption Spectrophotometer	Pb (1950 ± 300 to 3800 ± 300 µg/g)	Al-Chalabi [41]
10.	Roadside soils along a major express way, south east Nigeria	Fe, Cu, Zn, Pb, and Cd	Atomic Absorption spectrophotometer.	**At distance 50cm – 1m away from roadside**: Fe (5205.11mg/kg), Cu (247.97mg/kg), Zn (74.11mg/kg), Pb (100.19mg/kg), and Cd (18.8 mg/kg) **At 100 m away from the roadside**: Fe (4890), Cu (217.86mg/kg), Zn (64.08mg/kg), Pb (87.13 mg/kg) and Cd (3.05mg/kg)	Mbah [42]
11.	Roadside soil, plants and air, southern part of the Jordan	Cu, Cd, Pb and Zn	Flameless Atomic Absorption Spectrophotometer	Soil: Cu (29.7µg/g), Cd (0.75µg/g), Pb (188.8 µg/g) and Zn (121.7µg/g) Plants: Cu (31.3µg/m^3), Pb (7.3µg/m^3) and Zn (98.7 µg/m^3) Air: Cu (0.40µg/m^3), Pb (0.94µg/m^3) and Zn (0.26µg/m^3)	Jaradat [44]
12.	Tap water, Surface water, Vegetables and Soil samples, Kismu, Kenya	Pb	Shimadzu Atomic Absorption Spectrophotometer	Tap water (140 to 260µl/L), surface water (140 to 600µl/L), Vegetables (0.0-3.3µg/g) and soil (0.2-3.9µg/g)	Mokokha [50]
13.	Soil and vegetable samples along highway, Agra, India	Cd and Pb	Flame atomic absorption spectrophotometer	High level of Cd and Pb was found at distance of 0-5m of roadside	Sharma [53]
14.	Roadside soil and components of *Balenites aegyptica* Plant, Katsina urban area, Nigeria	Pb	atomic absorption spectrophotometry	Pb in the high, medium, low and zero traffic density areas was 75, 53, 35, and 12µg/g respectively in the fruit pulp, 16, 13, 8, and 6 µg/g respectively in fruit kernel and 44, 28, 17, and 9µg/g respectively in sleaves. For tree barks, the values are 138, 97, 64, and 18µg/g respectively while for under-tree-canopy soil samples the mean values are 99, 74, 44, and 17 µg/g.	Mashi [60]
15.	Roadside Soil and Plants, Rawalpindi, Pakistan	Pb	Atomic Absorption Spectrophotometer	Plants: Pb (1.0518-3.9253 mg/Kg) Soils: Pb (2.2884-4.9946 mg/Kg)	Pirzada [64]
16.	Soils, vegetation, sewage and river waters samples, Thohoyandou, South, Africa.	Pb, Zn, Cr, Cu, Cd, Fe and Pt	Soils and vegetation samples were analyzed by atomic absorption spectrophotometer and water samples were analyzed by inductively coupled plasma atomic emission spectrometry	Order of heavy metals: Pb > Zn > Cr > Cu > Cd (soil), Pb > Zn > Cd > Cr > Cu (Vegetation), Fe > Zn > Pt > Cu > Pd (water)	Odiyo [65]
17.	Roadside soils, Irbid city, Jordan	Pb and Cd	Graphite Furnace Atomic Absorption Spectrophotometer	Pb (325 to 431 µg/g) and Cd (1.142 to 1.135 µg/g)	Massadeh. [66]
18.	Roadside soil of major road, Sao Paulo, Brazil	platinum (Pt), palladium (Pd) and rhodium (Rh) Zinc (Zn) and copper (Cu)	High-resolution inductively coupled plasma mass spectrometry (HR-ICP-MS)	Pt (0.3 to17 ng/g), Pd (1.1 to 58 ng/g) and Rh (0.07 and 8.2 ng/g)	Morcelli [68]
19.	Fruits grown at the roadsides, Turkey	Pb, Cd, Se, Ni, Cr, Cu	Inductively Coupled Plasma Atomic Emission Spectrometry	Cu (0.27mg/kg and 0.05mg/kg), Cr(0.32 mg/kg and 0.18 mg/kg), Ni (0.68 mg/kg and	Hamurcu [70]

S. No.	Site description	Heavy metals analyzed	Methods/instrument used	Results	References
				0.26 mg/kg), Pb (2.86 mg/kg and 1.54 mg/kg) and (Se 12.96 mg/kg and 5.42 mg/kg)	
20.	Roadside soils of Eskisehir, Turkey	Cd, Cu, Cr, Fe, Hg, Mn, Ni, Pb, and Zn	Inductively coupled plasma-optic emission spectrometer	The content of heavy metals was in order: Pb > Zn > Cu > Fe > Mn > Ni > Cr > Cd	Malkoc [71]
21.	Roadside soil and plant, Elazig, Turkey	Pb, Cd and Cu	Flame Atomic Absorption Spectrophotometer	**In soil**: Pb (1.3 to 45 mg/kg), Cd (1.3 to 45 mg/kg), Cu (11.1–27.9 mg/kg) **In vegetation**: Pb (120 ng/g to 866 ng/g), Cd (1.3 to 45 mg/kg) and Cu (0.8–5.6 mg/kg)	Bakirdere [72]
22.	Vilnius-Klaipeda highway	Pb, Cu and Cd	atomic absorption spectrophotometer	High levels found at distance 5 m from roadside	Grigalaviciene.[73]
23.	Dust and soil, Kavala city, Greece	Pb, Cu, Zn, Ni, Cr, Cd, As and Hg	atomic absorption spectrophotometer	**In street dust:** Pb (300.9 μg/g), Cu (123.9 μg/g), Zn (271.6 μg/g), Ni (57.5 μg/g), Cr (196.0 μg/g), Cd (0.2 μg/g), As (16.7 μg/g) and Hg (0.1 μg/g) **In roadside soil:** Pb (359.4 μg/g), Cu (42.7 μg/g), Zn (137.8 μg/g), Ni (58.2 μg/g), Cr (193.2 μg/g), Cd (0.2 μg/g), As (62.3 μg/g) and As (0. μg/g)	Mmolawa [74]
24.	Roadside soil, Ibadan, Nigeria	Pb, Zn, Cd, Cu, Cr, Co and Ni	flame atomic absorption spectrophotometer	Pb (81 ± 140 ppm), Zn (8 ± 37 ppm), Cd (0.55 ± 0.49 ppm), Cu (17 ± 17 ppm), Cr (22.1 ± 9.6 ppm), Co (7.9 ± 3.8 ppm) and Ni (10.5 ± 9.7 ppm)	Onianma [77]
25.	Soils and plants, Peshawar City, Pakistan	Pb and Cd	Atomic Absorption Spectrophotometer	**In soils**: Pb (53.9 mg/kg) and Cd (6.0 mg/kg) **In plants**: Pb (49.1 mg/kg) and (10.9 mg/kg)	Khan [78]
26.	Dust and soil, Islamabad Expressway, Pakistan	Cd, Cu, Ni, Pb and Zn	flame atomic absorption spectrometry	Cd (5 ± 1 mg/kg), Cu (52 ± 18 mg/kg), Ni (23 ± 6 mg/kg), Pb (104 ± 29 mg/kg) and Zn (116 ± 35 mg/kg)	Faiz [79]
27.	Roadside soil near different traffic signals *viz.*, near one traffic signal, near more than two traffic signal and near zero traffic signal, Dubai.	Cd, Pb, Cu, Ni, Fe, Mn and Zn	Atomic Absorption Spectroscopy (AAS)	**At more than two traffic signal**: Cd (0.17–1.01 mg/kg), Pb (259.66–2784.45 mg/kg), Cu (15.51–65.90 mg/kg), Ni (13.31–98.13 mg/kg), Fe (325.64–5136.37 mg/kg), Mn (57.95–166.43 mg/kg) and Zn (91.34–166.43 mg/kg) **At one traffic signal**: Cd (nd–0.80 mg/kg), Pb (145.95–308.09 mg/kg), Cu (0.82–18.04 mg/kg), Ni (18.29–59.36 mg/kg), Fe (88.51–3649.42 mg/kg), Mn (25.88–147.34 mg/kg) and Zn (8.97– 106.11 mg/kg) **At no traffic signal**: Cd (0.0–0.57 mg/kg), Pb (8.34–58.20 mg/kg), Cu (2.88–5.81 mg/kg), Ni (3.34–73.80 mg/kg), Fe (55.34–332.81 mg/kg), Mn (2.98–98.73 mg/kg) and Zn (1.23–46.6 mg/kg)	Aslam [80]
28.	Urban roadside surface soils of Xuzhou, China	Sb	Inductively Coupled Plasma Mass Spectrometry	0.96 mg/kg	Wang [82]
29.	Roadside soil sample, Ketu-South District, Volta Region, Ghana	As, Cr, Cu, Mn, Ni, Pb and Zn	Energy-dispersive. X-ray fluorescence (ED-XRF)	0.4-18.2 μg/g for As, 284-9106 μg/g for Cr, 18.4-144.1 μg/g for Cu, 233-1240 μg/g for Mn, 12.3-493.2 for Ni, 3.1-67.8 μg/g for Pb and 18.2-406.5 μg/g for Zn	Addo [84]
30.	Roadside soils and vegetables, Gazipur, Bangladesh	Pb, Ni, Cd and	Atomic Absorption Spectrophotometer (AAS)	The content of heavy metals was in order: Ni > Pb > Cd	Naser [85]
31.	Roadside soil, Sari-Ghaemshahr road in Iran	Pb, Cd, Cu and Zn	Flame Atomic Absorption	**North road:** Pb (2.95 ± 0.05 to 2.75 ± 0.03), Cd (0.11 ± 0.01 to 0.13 ± 0.02), Cu (1.91 ± 0.07 to 1.25 ± 0.04) and Zn (3.66 ± 0.05 to 1.13 ± 0.03) at 4 m to 100 m distance from road **South road:** Pb **(**7.83 ± 0.05 to 2.03 ± 0.01), Cd (0.16 ± 0 to 0.19 ± 0.01), Cu (3.59 ± 0.01 to 1.65 ± 0.11) and (3.55 ± 0.01 to 2.16 ± 0.01) at 4 m to 100 m distance from road	Masoudi [86]
32.	Soil, Kathmandu, Nepal	Cu, Zn, Cd and Pb	Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)	Cu (19.99 mg/kg), Zn (76.30 mg/kg), Cd (0.36 mg/kg) and Pb (22.57 mg/kg)	Zhang [87]

TABLE II
SUMMARY OF LITERATURE ON POLYCYCLIC AROMATIC HYDROCARBONS IN ROADSIDE SOILS

S. No.	Site description	PAH analyzed	Methods/instrument used	Results	References
1.	Soil and olives, old railway tiles, Italy.	Polycyclic aromatic hydrocarbons	Reversed - Phase High Performance Liquid Chromatography (HPLC)	Total light PAH: 114.7 to 2157.2 µg/g and total heavy PAH: 167.3 to 3121.8 µg/g	Moret [26]
2.	Urban soils of different land uses, Beijing, China	Polycyclic aromatic hydrocarbons (naphthalene (Nap), acenaphthylene (Any), acenaphthene (Ane), fluorene (Fle), phenanthrene (Phe), anthracene (Ant), fluoranthene (Fla), pyrene (Pyr), benz[a]anthracene (Baa), chrysene (Chy), benzo[k]fluoranthene (Bkf), benzo[b]fluoranthene (Bbf), benzo[a]pyrene (Bap), indeno[1,2,3-cd]pyrene (I1p), dibenz[a,h]anthracene (Daa), benzo[ghi]perylene (Bgp)	Gas chromatography-mass spectrometry (GC/MS)	I1p (14.7 %) > Bkf (14.6 %) > Bgp (11.8 %) > Chy (9.3 %) > Fla (9.0 %) > Bap (8.5 %) > Phe (7.6 %) > Baa (7.0 %) > Pyr (6.2 %) > Bbf (4.9 %) > Daa (3.8 %) > Ant (1.6 %) > Fle (0.6 %) > Any (0.2 %) > Nap (0.05 %) > Ane (0.02 %).	Liu [88]
3.	Roadside soils, Jalandhar city, Punjab, India	polycyclic aromatic hydrocarbons	Gas chromatography- flame ionization detector (GC-FID)	DiBenzo (ah) Anthracene (0.008 to 28.4 µg/g) and Benzo (a) Pyrene (0.01 to 252.55 µg/g) were found in highest concentration.	Kumar [89]
4.	Roadside soils, Delhi, India	Polycyclic Aromatic Hydrocarbons	High Performance Liquid Chromatography with Ultraviolet-Diode array detector (HPLC-UV-DAD)	6838.6 ± 3528.4 µg/kg	Bhupander [90]
5.	Road dust samples, Greater Cairo, Egypt	Polycyclic Aromatic Hydrocarbons	HPLC spectroscopy	Pyrene (1.031 1.028 mg/kg) and phenanthrene (1.028 mg/kg) were found in highest concentrations while benzo(a)pyrene (0.0001 mg/kg) was found in lower concentration.	Hassanien [95]
6.	Roadside soil, Qingdao, North China	Polycyclic aromatic hydrocarbons and *n*-alkanes	Gas chromatography–mass spectrometry	**PAH**: spring (32.3 ng/m^3), summer (11.5 ng/m^3), autumn (48.9 ng/m^3) and winter (263 ng/m^3) ***n*-alkane**: spring (232 ng/m^3), summer (121 ng/m^3), autumn (309 ng/m^3) and winter (369 ng/m^3)	Guo [97]
7.	Peripheral soil, international airport, Delhi, India	Polycyclic Aromatic Hydrocarbons	High-performance liquid chromatography	2.39 µg/g to 7.53 µg/g	Ray [98]
8.	Topsoils, Mexico City	Polycyclic Aromatic Hydrocarbons	Gas Chromatography with a flame ionization detector	**Site – I (Tlahuac):** 9.13 mg/kg in dry season and 11.22 mg/kg (wet season) **Site – II (Milpa Alta):** 11.43 mg/kg (dry season) and 35.77 mg/kg (wet season)	Ortiz [100]

II. SUMMARY

Several studies on the pollution of soils along the highways and railway tracks indicated the presence of carcinogenic heavy metals and polycyclic aromatic hydrocarbons (PAHs). The maximum concentration of both heavy metals and polycyclic aromatic hydrocarbons were found to be at 10 – 30 m distance from road/ railway track. As both these pollutants are well known carcinogens, their regular monitoring is mandatory. Although the reports presented in present review article discloses the load of heavy metals and polycyclic aromatic hydrocarbons on soil ecosystems via vehicular emissions, yet, the literature is scanty from many parts of the world. Considering the harmful consequences of pollutants released from vehicular emissions, the strict guidelines should be laid and followed in order to reduce the pollution load.

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