Bull. Environ. Contam. Toxicol. (1989) 42:743–748

Bulletin of Environmental Contamination and Toxicology

Preliminary Evaluation of Metal Pollution from Wear of Auto Tires

Muhammad Sadiq, Ibrahim Alam, Aarif El-Mubarek, and H. M. Al-Mohdhar

Water Resources and Environment Division, Research Institute, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia

The impact of traffic on environmental quality in urban areas has been widely investigated (Elwood 1983; Elwood and Gallacher 1984; Mcclellan 1986; Wheeler and Rolfe 1979) with major emphasis placed on air pollution and associated human health hazards from auto emissions (Chamberlain 1983; Elwood 1986; Schroeder et al 1987). However, auto emissions are not the only source of metal pollution of the surrounding environments. Auto tires could be an important source of environmental pollution.

As a result of wear, tire particles are scattered into the ambient environment and can contaminate it if these particles contain metals. Contributions to environmental pollution from auto tires will depend upon the rate of wear and the concentrations of potential pollutants in them. Information on metal concentrations in auto tires and tire wear coefficient under various road conditions are lacking in the literature. The objectives of this study are to determine metal concentrations in various auto tires and to evaluate metal pollution from auto tires.

MATERIALS AND METHODS

The most commonly used auto tires were considered for this study. A total of 58 pieces of car tires (10x10 cm) was cut from 29 tires of different brands and sizes. The manufacturing country and company, and size of each tire sample were recorded.

All the tire samples were first washed with detergent and then with distilled water several times to remove extraneous materials. The tires were cut into small pieces to remove iron wires. Then the samples were

Send reprint requests to Muhammad Sadiq on the above address

dried at 60 ^{o}C to constant weight and crushed to near-powder conditions. Triplicate samples of one g of pulverized tire was taken into digestion tubes. Ten ml of ultrex grade nitric acid and 5 ml of perchloric acid were added to each digestion tube. The content of the tubes were digested for three hours in a block digestor at 120 ^{o}C. After cooling, the aliquots were filtered and the volume was increased to 50 ml using double distilled water. Concentrations of metals in the filtrates were determined using an inductively coupled argon plasma analyzer (ICAP).

Surface soil samples (upper 2 cm layer) were collected from two location on the Riyadh-Dhahran highway at a distance of 2, 20, 50, 100 and 200 meters from the highways. Location 1 was in the desert, about 30 km from Dhahran, and location 2 was in Dhahran, behind Petromin offices. The soil samples were sieved and dried at 60 ^{o}C. Triplicate soil samples of one g were taken in digestion tubes containing 10 ml ultrex nitric acid and 2 ml perchloric acid. These samples were digested and filtered as described above.

Special attention was paid to quality control of the analytical data. Reference material of citrus leaves from the United States Bureau of Standards (USNBS) was included in the analysis.

RESULTS AND DISCUSSION

Concentrations of various metals in different brands of auto tires are given in Table 1. Because zinc compounds are used as a filler in all auto tires, its concentrations were found to be several percents and these data are not included in Table 1. The auto tires varied significantly ($P < 0.05$) in aluminum concentrations. Uniroyal contained the highest aluminum concentrations (2714-3823 ug/g) followed by Goodyear (584-1212 ug/g). Depending upon the tire brand and traffic volume, it seems that wear of auto tires could be an important source of aluminum contamination along highways. Aluminum concentration within the same brand of tire varied significantly ($P < 0.05$) suggesting that aluminum, and perhaps other metals too, was not distributed uniformly in the tires.

Concentrations of cobalt in the tire samples ranged between 10 to 997 ug/g dry weight. Analysis of variance of the data revealed that cobalt concentrations between various brands of tires and within the same brand were significantly different ($P < 0.05$). However, some general conclusion can be drawn from these results. Yokahoma, Goodyear, Goodrich, Marchal, Mightyorb, and

Table 1 Concentrations (ug/g dry weight) of metals in auto tires

Tire type,Size,Country	Al	Co	Cu	Fe	Mn	Pb	Ni	P	Ti
Bridgestone,155/13,Japan	354	23.9	5.7	80.1	5.2	37.3	11.4	246.1	6.5
Bridgestone,175/14,Japan	275	59.6	3.5	72.9	11.0	24.0	11.2	195.6	9.0
Bridgestone,650/14,Japan	227	290.2	8.6	82.1	2.9	18.6	3.8	75.0	25.8
Bridgestone,195/7HR14,Japan	121	10.0	45.9	9.1	7.4	2.1	17.9	18.9	1.3
Yokahoma,8.25/16,Japan	981	259.0	2.3	88.1	3.5	19.3	2.5	208.5	20.3
Yokahoma,165/13,Japan	482	552.2	1.9	55.6	2.9	24.3	2.4	172.2	22.5
Yokahoma,P 225/75R15,Japan	401	760.8	9.3	96.6	1.7	53.1	4.4	147.2	2.3
Smitomo,G 78/15,Japan	229	56.3	1.1	60.3	10.9	15.9	3.9	235.5	2.0
Toyo,RG 78/15,Japan	73	75.5	1.8	43.9	1.9	24.5	3.5	247.0	1.9
Toyo,195/60HR14,Japan	484	398.6	4.9	165.1	6.0	34.0	3.3	253.2	19.5
Goodyear,G 78/15,Japan	997	308.4	1.3	153.2	3.0	55.5	3.2	245.3	27.9
Goodyear,7.50/16,Japan	997	553.7	3.2	163.1	3.4	8.4	6.9	97.6	8.9
Goodyear,P 205/78R15,Japan	584	630.4	2.9	123.9	5.1	19.7	0.0	88.1	51.3
Firestone,650/14,Spain	142	210.8	12.0	75.9	1.6	31.2	2.8	177.9	2.2
Firestone,195/15,Spain	217	134.0	4.6	114.3	5.0	21.5	2.6	228.2	3.4
Uniroyal,225/75,USA	2738	53.3	1.9	251.5	6.0	23.6	3.9	272.7	17.1
Uniroyal,P205/75R15,USA	3823	136.7	2.4	318.0	3.5	6.5	4.6	243.4	19.3
Uniroyal,P205/75R15,USA	2714	267.5	2.0	258.5	3.1	5.3	3.8	161.7	92.6
Goodrich,P205/75A15,USA	89	881.5	2.9	69.9	5.2	154.6	3.6	160.4	3.2
Michelin,P235/75R15,Canada	197	675.0	2.4	164.5	3.3	36.4	3.8	164.9	21.8
Samyoung,175/15,Korea	69	212.0	3.3	72.5	11.7	235.6	3.3	156.8	0.8
Marchal,600/14,Korea	143	361.8	9.0	179.5	4.3	518.6	3.4	96.7	3.2
Marchal,175/14,Korea	154	554.2	4.1	778.1	3.6	3.4	9.6	305.1	4.1
Hankook,850/14,Korea	193	48.6	2.4	164.6	5.2	39.2	6.1	133.3	1.9
Hankook,600/14,Korea	196	10.0	18.1	163.1	6.3	29.5	2.6	215.5	2.0
Avror,175/14,Korea	317	147.6	2.9	275.0	8.1	42.4	3.1	285.7	1.3
Mightyorb,600/14,Korea	168	721.8	17.3	142.4	3.5	27.9	3.6	144.8	3.8
Mightyorb,600/14,Korea	201	960.5	12.7	102.1	3.1	58.6	3.5	142.7	3.6
Dunlop,85/5R14,France	64	997.1	4.1	67.9	6.1	85.3	3.1	210.1	1.1

Dunlop contained significantly ($P < 0.05$) higher concentrations of cobalt than other tires. The data of this study suggest that tire wear could be an important source of cobalt contamination along the roadside.

Although there were some higher values, in general the concentrations of copper, nickel and manganese in the tire samples were below 10 ug/g tire. It seems that wear of auto tires would not make appreciable contributions to copper, nickel, and manganese contamination of the ambient environment.

Lead concentrations in the auto tires samples varied significantly ($P < 0.05$), with a range of 2.1 to 518.6 ug/g tire. The data of this study suggest that, depending on the tire brand and traffic load, the wear of auto tires can contribute substantially to lead contamination along the roadside. This source of lead pollution will gain further significance when lead in auto missions is decreased to a minimum in future. Similar conclusions can be drawn regarding the contribution of auto tires to environmental pollution of phosphorus, titanium and iron although these elements already exist in appreciable amounts in soils (Lindsay 1979).

To further verify the contribution of auto tires to metal pollution, soil samples were collected from two locations along the Dhahran-Riyadh highway and analyzed for metal concentrations. These results are summarized in Table 2. As mentioned above, all the auto tires contain several percents of zinc compound as filler. An increase in zinc concentrations in the soil surrounding a road can be attributed to tire wear and traffic volume. Concentrations of zinc in the soil samples ranged between 23125 to 55398 ug/g. Zinc concentrations in the soil samples increased several hundredfold as compared with the average zinc levels in uncontaminated soils in the area (5-30 ug/g soil). These results suggest a significant contribution to soil zinc from auto tires.

As expected, lead concentrations decreased with distance. The soil samples from location 2 contained severalfold higher lead concentrations than location 1. This could be attributed to substantially higher traffic volume at this location. Similar trend was exhibited in barium concentrations in the soil samples. Distribution of all other metals did not follow a particular trend. Comparing the results of soil analysis of this study with the average concentrations of these metals in uncontaminated soils in the area, it may be concluded that zinc, lead, barium and nickel were higher in the soil samples.

Table 2 Metal concentrations in the soil samples

Distance from road(m)	Concentration, ug/g										
	Ba	Cr	Cu	Fe	Mn	Ni	P	Pb	Sr	Ti	V	Zn
Location 1												
2	123.0	14.0	1.6	1476	58.8	23.9	533	80.8	4.4	11.9	0.00	23125
20	42.8	11.0	2.3	2675	72.5	27.3	524	64.6	5.5	24.2	2.62	24084
50	16.7	9.9	1.5	2287	61.8	6.6	560	51.8	5.0	54.3	0.82	32009
100	25.4	15.9	13.3	3375	92.0	6.9	480	67.6	3.6	62.6	0.55	30331
200	41.1	14.0	2.5	3025	77.5	10.4	602	40.7	3.0	5.2	5.18	31465
Location 2												
10	405.0	11.3	4.3	2650	62.6	9.1	249	1335.9	11.4	8.1	3.86	42157
50	669.2	9.5	4.0	2050	51.5	9.2	410	616.6	12.7	2.2	0.52	55398
100	37.5	9.3	3.5	2937	61.6	11.1	480	106.1	26.7	63.5	1.39	47918
200	32.3	10.0	3.9	3200	73.3	6.3	566	53.2	43.8	8.5	2.19	45156

Ba = barium Cr = chromium Cu = copper Fe = iron Mn = manganese
Ni = nickel P = phosphorus Pb = lead Ti = titanium
V = vanadium Zn = zinc Sr = strontium

Acknowledgment The authors wish to acknowledge the support of the Research Institute of King Fahd University of Petroleum and Minerals in carrying out this study.

REFERENCES

Chamberlain AC (1983) Effect of airborne lead on blood lead. Atmos Environ 17:677-692

Elwood PC (1986) The sources of lead in blood. Sci Total Environ 52:1-23

Elwood PC (1983) Blood lead and petrol lead. Br Med J 286:1515

Elwood PC and Gallacher JEJ (1984) Lead in petrol and levels of lead in blood: scientific evidence and social policy. J Epidemiol and Community Health 38:315-318

Lindsay WL (1979) Chemical Equilibria in Soils. Jhon Wiley Interscience, New York

Mcclellan RO (1986) Health effects of diesel exhaust: A case study in risk assessment. Am Ind Hyg Assoc J 47:1-13

Schroeder WH, Dobson M, Kane DM and Johnson ND (1987) Toxic trace elements associated with airborne particulate matter: A review. JAPCA 37:1267-1285.

Wheeler GL and Rolfe GL (1979) The relationship between daily traffic volume and the distribution of lead in roadside soil and vegetation. Environ Pollut 18:265-274

Received July 12, 1988; accepted September 15, 1988.