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Heavy Metal Pollution of Soils Along Three Major Highways in Bangladesh

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A study was carried out to investigate the heavy metal pollution of roadside soils by vehicles along three major highways in Bangladesh: Dhaka-Aricha, Dhaka-Chittagong and Dhaka-Mymensingh highways. Total contents of Co, Cr, Cu, Ni, Pb, Sr and Zn were determined by the HF-HNO_3-$HClO_4$ acid treatment. Accumulation of Pb, Ni, Cr, Cu and Zn in roadside soils along Dhaka-Mymensingh highway was observed, possibly due to the intensive traffic of vehicles. In addition, sporadic high Zn accumulation was noticed in soils along three highways which was ascribed to the industrial discharge.

INTRODUCTION

Pollution is now a global concern. With advancement of civilization, our beloved world becomes more and more polluted by various sources, rendering itself more and more hazardous for our life. Although extent of pollution is greater in developed countries, the condition of developing countries is not so safe. Rapid urbanization, industrialization, and motorization in many parts of Tropical Asia have considerably increased the risks of heavy metal pollution.

Bangladesh is an agro-based country; still there are some industries in and around the city area. Major cities are connected by roads and highways among themselves and with each corner of the country. The intensity of traffic in these roads specially near the cities is very high. Consequently, the possibility of soil pollution in nearby fields becomes large from the emission of fuel burning and addition from vehicle parts and tires. Such type of pollution has already been reported by many scientists (Page and Ganje, 1970; Tiller et al., 1987; Wheeler and Rolfe, 1979).

Research work on the heavy metal pollution of soils is highly limited in Bangladesh. Among the two major pollution sources, industries and vehicles, the present work was focused on the latter. To investigate heavy metal pollution by vehicles, soil samples from the vicinity of three major highways, which connect the capital Dhaka city with most parts of the country and have a very high intensity of buses, mini-buses, trucks etc., were collected and analyzed for heavy metals.

MATERIALS AND METHODS

Soils used

Ten soil samples were collected from each of Dhaka-Aricha (between Hemaetpur and

Savar), Dhaka-Chittagong (between Kanchpur and Meghna) and Dhaka-Mymensingh (between Tongi and Joydevpur) highways. Of them, eight samples were taken from the roadside of the highway, while two were from the sites 1 km away from it, to be used as control samples. The sampling depth was 0–10 cm. Brief description of soil samples is given in Table 1. Increase in the sample number in each highway indicates increase in the distance away from Dhaka city for Dhaka-Aricha highway, and the reverse for Dhaka-Chittagong and Dhaka-Mymensingh highways.

The soil samples of each highway are not identical in physiography except for Dhaka-Mymensingh highway, where all soil samples were taken from Madhupur Tract. In case of Dhaka-Aricha highway, seven soil samples were taken from Brahmaputra Floodplain while

Table 1. Brief description of soil samples.

Sample No	Soil series	Physiography	Land use
		Dhaka-Aricha highway	
1	Brahmaputra Silty Alluvium	Brahmaputra Floodplain	Boro-Fallow
2	Melandaha	Brahmaputra Floodplain	Rabi vegetables-Sesbania-Fallow
3	Dhamrai	Brahmaputra Floodplain	Boro-Jute-T. Aman
4	Dhamrai	Brahmaputra Floodplain	Boro-Fallow
5	Melandaha	Brahmaputra Floodplain	Rabi vegetables-Jute-Fallow
6	Noadda	Madhupur Tract	Fallow
7	Belabo	Madhupur Tract	Fallow
8*	Melandaha	Brahmaputra Floodplain	Fallow
9	Belabo	Madhupur Tract	Fallow
10*	Melandaha	Brahmaputra Floodplain	Lentil-Jute-T. Aman
		Dhaka-Chittagong highway	
11	Sonatala	Brahmaputra Floodplain	Rabi crops-Jute/B. Aman-Fallow
12	Sonatala	Brahmaputra Floodplain	Boro-Fallow
13	Jalkundi	Meghna Estuarine Floodplain	Mustard-Jute-Fallow
14	Jalkundi	Meghna Estuarine Floodplain	Mustard-Boro-Fallow
15	Jalkundi	Meghna Estuarine Floodplain	Mustard-Jute-Fallow
16*	Jalkundi	Meghna Estuarine Floodplain	Mustard-Boro-Fallow
17	Silmandi	Brahmaputra Floodplain	Mustard-Sesbania-Fallow
18	Silmandi	Brahmaputra Floodplain	Fallow
19*	Silmandi	Brahmaputra Floodplain	Mustard-Sesbania-Fallow
20	Jalkundi	Meghna Estuarine Floodplain	Fallow
		Dhaka-Mymensingh highway	
21	Demra	Madhupur Tract	Boro-Fallow-T. Aman
22*	Chhiata	Madhupur Tract	Fallow-T. Aus-T. Aman
23	Demra	Madhupur Tract	Fallow
24	Demra	Madhupur Tract	Fallow
25*	Chhiata	Madhupur Tract	Fallow-T. Aus-T. Aman
26	Demra	Madhupur Tract	Fallow
27	Khilgaon	Madhupur Tract	Fallow-T. Aman
28	Demra	Madhupur Tract	Fallow
29	Khilgaon	Madhupur Tract	Boro-T. Aman
30	Kalma	Madhupur Tract	Boro-Fallow-T. Aman

* Control samples.

the rest three from Madhupur Tract; in case of Dhaka-Chittagong highway, five from Brahmaputra Floodplain, and other five from Meghna Estuarine Floodplain (Table 1).

Collection and description of soil samples was performed by the staffs of Soil Resources Development Institute (SRDI), Krishi Khamar Sarak, Dhaka, *as per* request made by the authors. The soil samples, immediately after collection, were brought to Japan by air. They were then air-dried, gently crushed, passed through a 2-mm sieve and kept in polyethylene bags for subsequent analysis.

Analytical method

Soil samples were digested with the HF-HNO_3-$HClO_4$ acid treatment (Committee of Soil Standard Methods for Analyses and Measurements, 1986) to determine the total

Table 2. Total contents of heavy metals in roadside soils.

Sample No	Co	Cr	Cu	Ni	Pb	Sr	Zn
	(mg kg^{-1})						
	Dhaka-Aricha highway						
1	16	92	47	53	27	147	125
2	17	88	39	48	26	150	112
3	17	93	43	45	28	140	80
4	17	92	39	48	27	142	80
5	16	80	34	40	23	160	144
6	21	102	25	42	26	34	52
7	13	71	16	23	20	34	51
8*	22	91	33	37	32	138	501
9	14	80	16	24	20	34	70
10*	16	77	33	41	22	157	73
	Dhaka-Chittagong highway						
11	12	67	28	28	29	105	60
12	15	90	36	44	27	126	74
13	14	89	34	36	27	118	74
14	16	94	37	44	28	114	85
15	16	94	33	43	26	140	84
16*	16	94	31	45	23	141	85
17	15	88	29	42	25	137	80
18	15	86	30	36	26	138	74
19*	17	110	48	61	31	137	108
20	15	91	36	47	29	120	90
	Dhaka-Mymensingh highway						
21	14	85	27	31	24	50	72
22*	11	65	16	20	17	46	27
23	11	57	17	17	18	42	25
24	12	70	25	22	23	76	88
25*	11	61	17	19	19	68	155
26	16	94	54	43	42	67	871
27	22	126	38	54	33	44	73
28	11	72	22	26	23	71	41
29	20	109	35	54	29	61	59
30	13	70	30	27	28	81	152

* Control samples.

contents of heavy metals. For this purpose, 1 g of powdered soil sample was weighed into a teflon beaker and placed on a hot plate. Five mL of $HClO_4$ and 5 mL of HNO_3 were added to the soil. The beaker was covered, heated for 2–3 h at 120 °C, and then heated without cover until dryness at 200 °C. After cooling and addition of 5 mL $HClO_4$ and 10 mL HF in this sequence, the beaker was heated at 80 °C for 15 min. It was cooled and again heated until dryness at 200 °C after addition of another 10 mL of HF. The beaker was cooled, 5 mL of 6M HCl and 1 mL of HNO_3 were added, and it was heated with cover at 100 °C for about 1 h. The beaker was then filled-up to its two-thirds with deionized water, covered and heated at 80 °C for 2 h. The solution was transferred into a 50 mL volumetric flask and made up to the mark with deionized water after cooling. The solution was quickly transferred into a plastic bottle and analyzed for Cu and Pb by atomic absorption spectrophotometer (AAS), and for Co, Cr, Ni, Sr and Zn by inductively coupled plasma-atomic absorption spectrophotometer (ICP-AAS). The analytical results are shown in Table 2.

RESULTS

Dhaka-Aricha highway

Samples 6, 7 and 9 were taken from Madhupur Tract while others from Brahmaputra Floodplain, of which samples 8 and 10 are control samples.

Among the seven elements analyzed, total Cu and Sr contents showed a variation with physiography; soils of Brahmaputra Floodplain had higher values than did Madhupur Tract soils. Total Ni also showed the similar trend except for sample 6. Total Pb, Cr and Co contents showed apparently no variation within ten samples. Only Zn gave an indication of soil pollution. Namely, sample 8 contained 501 mg kg^{-1} of total Zn which was much higher than the contents of other samples and even higher than the common range (10 to 300 mg kg^{-1}) for soils as reported by Lindsay (1979). But, the cause of this

Table 3. The contents of various elements in the lithosphere and soils.

Element	Content in lithosphere (mg kg^{-1})	Common range for soils (mg kg^{-1})	Selected average for soils (mg kg^{-1})			
Co	40	1–40	8	9.1	58	56
Cr	200	1–1000	100	54	133	136
Cu	70	2–100	30	25	27	33
Ni	100	5–500	40	19	22	22
Pb	16	2–200	10	19	–	–
Sr	150	50–1000	200	240	66	108
Zn	80	10–300	50	60	68	66
Reference	1	2	3	4	5	6

1, 2 and 3: Lindsay (1979); 4: Sposito (1989); 5: Domingo and Kyuma(1983) for Bangladesh paddy soils; and 6: Domingo and Kyuma (1983) for tropical Asian paddy soils.

pollution is not considered to be due to vehicles, because the sample itself is a control one, collected 1 km away from the highway. Possible source of Zn pollution of sample 8 is discharge from some factories or industries nearby the sampling location. Samples 1, 2 and 5 also contained the clearly high amounts of total Zn in comparison to the control sample (sample 10). The pollution in these soils again might be from some factories or industries.

Dhaka-Chittagong highway

Samples 11, 12 and 17 through 19 were taken from Brahmaputra Floodplain, while others from Meghna Estuarine Floodplain; samples 16 and 19 are control samples.

No variation according to physiography was noticed. Except for sample 19, the contents of different elements did not vary with the sample. Total Zn, Cr, Ni and Cu contents in sample 19 were higher than those in other samples. However, the reason is not due to the effects of vehicles as this sample is a control.

Dhaka-Mymensingh highway

All samples were collected from the same physiography of Madhupur Tract; samples 22 and 25 are control samples. Total Co and Sr contents did not vary among the samples. But other elements showed variation leading to possible trends of pollution.

According to Tiller (1989), Pb dominates the roadside environment because of its common use in a gasoline additive, lead tetraethyl. Other metals, especially Cd, Zn, Cr and Ni, also accumulate near roads because of wear of vehicle parts and tires and use as fuel additives. From this viewpoint, Pb, Zn, Cr and Ni can be related to the pollution due to vehicles in our determination. Lead, Cr and Ni contents of samples 22 and 25, the control, were lower by 30 to 45% than those of seven samples (samples 21, 24 and 26 through 30), except for sample 23, collected from the roadside. Copper also showed the same tendency as Pb, Cr and Ni. These results probably indicate the Pb, Cr, Ni and Cu pollution of soils by vehicles along Dhaka-Mymensingh highway. Pollution of Zn by vehicles was also suggested, because total Zn content of sample 22 was lower than those of samples 21, 24 and 26 through 30. In addition to the pollution by vehicles, the extraordinarily high total Zn contents of samples 25, 26 and 30 indicate another source of pollution, probably discharge from some factories or industries. The Zn pollution by industrial discharge was most intensive for sample 26. The high total Pb and Cu contents of this sample compared to the other samples may be partially contributed by the industrial discharge.

DISCUSSION

Comparing the data of the present study with reported values listed in Table 3, it is obvious that although total Zn, Pb, Cu, Ni and Cr contents of soil samples were found to be higher than those of control samples, only Zn content in two samples (samples 8 and 26) was higher than the reported common range. This two soils can be termed as "polluted by Zn". Both soils were taken from fallow land (Table 1). It is also obvious from the present study that some other samples are accumulating Zn, Pb, Cu, Ni and Cr. Although these soils may not be termed as "polluted" at present, but may be so in near

future. The reason for heavy metal accumulation, especially Zn, is apparently not the high density of vehicles; rather the effect of factories or industries around the sampling sites. However, for other metals as well as Zn in Dhaka-Mymensingh highway, vehicles can be considered as a reason.

It is not clear why the effect of traffic density on accumulation of heavy metals in nearby soils was not found in Dhaka-Aricha and Dhaka-Chittagong highways. One reason may be that the intensity of vehicles in these highways is lower than that of Dhaka-Mymensingh highway; but apparently this is not true. Main contaminant from vehicles is Pb which is emitted mostly in fine particles and dispersed throughout large area (Tiller, 1989). This may be one possibility and sampling distance be another factor. Wheeler and Rolfe (1979) found that Pb in soil and vegetation decreased quickly with increasing distance from highway. The sampling distances from the road may be shorter in case of Dhaka-Mymensingh highway than those for the other two highways. Sampling depth also may be a factor. Further study should be done by reducing the sampling depth from 0–10 cm to 0–5 or 0–1 cm and by taking sampling distance from the road as a variable.

CONCLUSION

Heavy metal pollution by factories and/or by vehicles was observed for soils along the three major highways in Bangladesh. Pollution of Pb, Ni, Cr, Cu and Zn by vehicles was smaller in extent but prevailing in soils along the roadside in Dhaka-Mymensingh highway. Heavy metal pollution by factories or industries was mainly due to Zn and greater in extent but was site-specific.

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