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Contamination of Heavy Metal in Soil Due to Industrial Activity

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Abstract Due to rapid urbanization and scarcity of land, most of the urban parks and recreational areas in Bhopal are built close to major roads or industrial areas, where they are subject to many potential pollution sources, including vehicle exhaust and industrial emissions. An extensive soil survey was conducted in different areas of Bhopal to study the current conditions of heavy metals contamination in soils. Soil samples and associated street dusts were collected from within the industrial area of Govindpura and Mandideep, Bhopal. The total concentrations of heavy metals, pH value of soil, conductivity, moisture content and major elements in the samples were determined. The results of minerals and heavy metal concentrations obtained are also compared with ICAR, IARI manual.

Keywords: *heavy metal contamination, industrial areas, Govindpura and Mandideep*

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1. Introduction

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition [1,2]. Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) [3]. Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation [4], and their total concentration in soils persists for a long time after their introduction [5]. Changes in their chemical forms (speciation) and bioavailability are, however, possible. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants [6]. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems [7,8,9].

The adequate protection and restoration of soil ecosystems contaminated by heavy metals require their characterization and remediation. Contemporary legislation respecting environmental protection and public health, at both national and international levels, are based on data that characterize chemical properties of environmental phenomena, especially those that reside in our food chain [10]. While soil characterization would provide an insight into heavy metal speciation and bioavailability, attempt at remediation of heavy metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, and environmental and associated health effects (risks) of these heavy metals. Risk assessment is an effective scientific tool which enables decision makers to manage sites so contaminated in a cost-effective manner while preserving public and ecosystem health

With a population of over 2 million and an area of only 2772.40 sq km, Bhopal is densely populated. The rapid urbanization and continuous demand for land for housing and infrastructural development have put great pressure on the local environment. Due to the scarcity of land, most of the parks in Hong Kong are built close to busy roads or near industrial areas, where they are subject to potential pollution from various sources. Heavy metals may come from many different sources in urbanized areas, including vehicle emissions, industrial discharges and other. Atmospheric pollution is one of the major sources of heavy metal contamination. Heavy metals can accumulate in topsoil from atmospheric deposition by sedimentation, impaction and interception. The persistence of heavy

metals in soils is a long process. Top soils and roadside dusts in urban area are indicators of heavy metal contamination from atmospheric deposition.

2. Methodology

a) Sampling Points and Sample Collection

The main objective of this study is to examine the potential risk area for a soil contamination with heavy metals, within the industrial area of Govindpura and Mandideep, Bhopal. Govindpura is an area in the BHEL Township in the city of Bhopal, India. Mandideep is a town with municipality in Goharganj sub-district of Raisen district in the Indian state of Madhya Pradesh. Mandideep is 23 km from Bhopal and is basically an Industrial township which came into existence in late 1970s.

A total 20 samples were collected from above sampling points (Ten samples each from Govindpura and Mandideep). The soil sample are collected at 15cm depth around the sample area; it will thoroughly mixed and transferred into clean and labelled polythene bag for onward analysis in the laboratory.

b) Sample Preparation

Soil samples were also collected from each designated points, all the samples were collected at 0 to 15 cm depth using a soil auger, the samples from the designated points were made into a composite sample. Each composite sample was stored in a tight polythene bag and labelled SD1-SD19 and SW1-SW19 for dry and wet seasons respectively [5]. The samples were oven dried at 105°C, crushed in a porcelain mortar and pestle, sieved through a 2-mm sieve. 1 g of the sieved sample was weighed and transferred into a 100 cm^3 beaker, 5 cm^3 of HCl and 15 cm^3 and Nitric acid were added to the sample and boiled gently on a hot plate until the volume reduced to about 5 cm^3. Deionized water was added and boiled gently again till the volume was approximately 10 cm^3. The suspension was cooled, filtered through a Whatman No. 540 filter paper. The beaker and filter paper were washed with small amount of water until a volume of about 25 cm^3 was obtained. The filtrate was transferred into a 50 cm^3 volumetric flask and was made up to the mark with deionized water and stored in a 100 cm3 polythene bottles for elemental analysis using Atomic Absorption Spectrophotometer [6].

c) Instrumentation

Along with a 4 kW X-ray generator, a Philips PW-2440 fully automatic, microprocessor- controlled, 168-position automatic PW 2540 vrc sample changer X-ray Spectrometer was used for the determination of major and trace metals (S, P, Mn, Fe, Cd, Cu, Ni, Pb, Zn, Cr, Hg) in soil samples. Suitable software “Super Q” was used to define dead-time correction and inter element matrix-effects. Reference samples from the US Geological Survey, Canadian Geological Survey, International Working Group France, and NGRI India were used to prepare calibration curves for major oxides and trace metals.

d) Heavy metal determination

1g of the oven dried sample ground sample was weighed using a top loading balance and placed in a 250ml beaker which has been previously washed with nitric acid and distilled water. The sample was reacted with sample was reacted with 5ml of HNO_3, 15ml of concentrated $H_2SO_4$and 0.3ml of $HClO_4$ using dropping pipette. The mixture was digested in a fume cupboard, heating continued until a dense white fume appeared which was then ingested for 15minutes, set aside to cool and diluted with distilled water. The mixture was filtered through acid washed Whattman No.44 filter paper into a 50ml volumetric flask and diluted to mark volume. The sample solution was then aspirated into the Atomic Absorption Spectroscopic machine at intervals .

3. Results and Discusion

3.1. Analysis of Minerals and Heavy Metal in Soils of Govindpura

The results of concentration of minerals and heavy metals in soil sample collected at Govindpura, Bhopal are presented in Table 1.

Table 1. Concentration of minerals and heavy metals in soil (mg/Kg)

Location	S	P	Mn	Fe	Cd	Cu	Ni	Pb	Zn	Cr	Hg
1	17.10	52.79	73.06	1811.25	0.08	11.88	2.91	0.65	17.92	2.92	0.16
2	14.33	43.76	46.114	1383.69	8.25	5.58	2.83	1	7.81	3.14	0.28
3	5.75	27.51	49.74	1541.14	3.05	5.96	3.7	0.94	5.77	3.36	0.12
4	8.31	29.44	36.64	1368	0.04	3.01	6.3	0.8	25.21	3.39	0.30
5	5.23	29.06	58.82	1370.54	11.02	3.14	3.88	1.05	6.45	3.23	0.24
6	26.65	21.72	58.14	2251.13	0.14	8.07	2.39	2.73	306.95	3.51	0.12
7	22.25	63.14	53.42	1359.9	0.06	4.78	3.53	1.02	13.92	3.58	0.16
8	83.39	48.74	40.29	1144.98	7.34	9.37	1.72	2.48	20.4	1.73	0.15
9	4.06	30.75	44.78	1432.64	0.05	3.37	3.7	0.98	5.41	3.54	ND*
10	15.17	39.66	59.22	1628	3.25	11.01	2.95	1.22	10.59	3.79	ND*
Min.	4.06	21.72	36.64	1144.98	0.04	3.01	1.72	0.65	5.41	1.73	0.12
Max.	83.39	63.14	73.06	2251.13	11.02	11.88	6.3	2.73	306.95	3.79	0.3
Mean	20.22	38.65	52.02	1529.12	3.328	6.617	3.39	1.28	42.04	3.21	0.19
SD	23.43	13.24	10.78	310.65	4.116	3.286	1.22	0.71	93.32	0.57	0.07

ND*= Not detected.

The mean value of Fe is higher among all heavy metals and was found to be (1529.12 ± 310.65) mg/Kg. The mean value of Hg was the minimum among all minerals and heavy metals and was found to be (0.19 ± 0.07) mg/Kg. The mean concentration of minerals and heavy metals in soil were in the following order of Fe>Mn>Zn>P>S>Cu>Ni>Cd>Cr> Pb>Hg.

3.2. Analysis of Minerals and Heavy Metal in Soils of Mandideep, Bhopal

The results of concentration of minerals and heavy metals in soil sample collected at Mandideep, Bhopal are presented in Table 2.

Table 2. Concentration of minerals and heavy metals in soil (mg/Kg)

Location	S	P	Mn	Fe	Cd	Cu	Ni	Pb	Zn	Cr	Hg
1	22.21	50.88	67.85	1506.66	0.06	5.67	3.31	1.72	10.61	3.65	0.18
2	20.18	66.92	48.37	1376.37	0.05	6.01	3.02	2.18	11.18	2.65	0.23
3	30.07	44.38	26.61	1381.52	0.11	9.31	2.57	17.5	96.8	2.81	0.09
4	20.64	66.33	51.91	846.76	4.03	6.67	2.82	0.49	4.41	2.08	0.12
5	6.54	20.27	40.07	1203	0.03	2.11	2.17	1.09	4.69	2.72	0.26
6	6.81	18.41	45.78	1358.74	0.03	1.92	1.35	1.1	2.19	2.37	0.12
7	6.99	15.98	21.52	850.26	6.02	1.4	0.88	0.87	3.6	1.47	0.11
8	9.97	28.17	48.92	1282.29	0.04	5.27	4.69	1.25	6.95	2.71	0.08
9	9.01	28.43	40.54	1285.25	8.04	4.8	2.24	0.91	4.89	2.47	0.15
10	7.39	34.35	43.7	1236.86	0.03	2.52	2.89	0.81	4.51	2.68	0.18
Min.	6.54	15.98	21.52	846.76	0.03	1.4	0.88	0.49	2.19	1.47	0.08
Max.	30.07	66.92	67.85	1506.66	8.04	9.31	4.69	17.5	96.8	3.65	0.26
Mean	13.98	37.41	43.52	1232.77	1.84	4.56	2.59	2.79	14.98	2.56	0.15
SD	8.49	18.93	12.95	219.86	3.03	2.53	1.05	5.19	28.89	0.55	0.05

The mean value of Fe is higher among all heavy metals and was found to be (1232.77 ± 219.86) mg/Kg. The mean value of Hg was the minimum among all minerals and heavy metals and was found to be (0.15 ± 0.05) mg/Kg. The mean concentration of minerals and heavy metals in soil were in the following order of Fe>Mn>PZn>S> Cu >Pb>Ni>Cr>Cd>Hg.

3.3. Comparison of Minerals and Heavy Metal in Soils with Standards

For each heavy metal, the mean for each food item was compared with the WHO/FAO permissible level as test value using a one-sample t test at 99% confidence interval of the difference.

Table 3. Results of comparison of minerals and heavy metal concentrations forGovindpura with ICAR, IARI manual

Heavy metals	S	P	Mn	Fe	Cd	Cu	Ni	Pb	Zn	Cr	Hg
Mean	13.98	37.41*	43.52*	1232.7*	1.84	4.56	2.59*	2.79*	14.98*	2.56*	0.15
t	1.38	-4.14	-864.3	15.05	-1.28	3.48	-120.5	-437.7	-32.46	-255.9	1.62
df	9	9	9	9	9	9	9	9	9	9	9
p	0.201	0.03	0.00	0.00	0.231	0.07	0.00	0.00	0.00	0.00	0.14

From the above table following conclusion can be obtained:

- In case of Sulphur, no significant difference was recorded between control limit and sample. Therefore, difference is insignificant at t=1.38 and p=0.201.
- In case of phosphorus, significant difference was recorded between control limit and sample. Therefore, difference is significant at t=- 4.14 and p=0.03.
- In case of manganese, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 8.64.3 and p=0.00.
- In case of iron, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = 15.05 and p=0.00.
- In case of cadmium, no significant difference was recorded between control limit and sample. Therefore, difference is insignificant at t = -1.28 and p = 0.231.
- In case of nickel, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = -120.5 and p = 0.00.
- In case of lead, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = -437.7 and p = 0.00.
- In case of zinc, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 32.46 and p = 0.00.
- In case of chromium, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 255.9 and p = 0.00.
- In case of mercury, no significant difference was recorded between control limit and sample. Therefore, difference is insignificant at t = 1.62 and p = 0.14.

Table 4. Results of comparison of minerals and heavy metal concentrations forMandideep with ICAR, IARI manual

Location	S	P	Mn	Fe	Cd	Cu	Ni	Pb	Zn	Cr	Hg
Mean	13.98	37.41*	43.52*	1232.7*	1.84*	4.56	2.59*	2.79*	14.98*	2.56*	0.15
t	1.482	-3.104	-721.5	17.012	-3.28	1.95	-142.0	-59.2	-107.7	-269.7	0.106
df	9	9	9	9	9	9	9	9	9	9	9
p	0.172	0.013	0.00	0.00	0.009	0.08	0.00	0.00	0.00	0.00	.918

From the above table following conclusion can be obtained:

- In case of Sulphur, no significant difference was recorded between control limit and sample. Therefore, difference is insignificant at t=1.482 and p=0.172.
- In case of phosphorus, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 3.104 and p=0.013.
- In case of manganese, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 721.5 and p=0.00.
- In case of iron, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = 17.01 and p=0.00.
- In case of cadmium, no significant difference was recorded between control limit and sample. Therefore, difference is insignificant at t = -3.28 and p = 0.009.
- In case of nickel, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = -142 and p = 0.00.
- In case of lead, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 59.2 and p = 0.00.
- In case of zinc, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 107.7 and p = 0.00.
- In case of chromium, significant difference was recorded between control limit and sample. Therefore, difference is significant at t = - 269.7 and p = 0.00.
- In case of mercury, no significant difference was recorded between control limit and sample. Therefore, difference is insignificant at t = 0.106 and p = 0.918.

3.4. Soil Property

The results of pH in soil sample collected from Govindpura and Mandideep, Bhopal is shownbelow.

Table 5. Results of pH value of soil at Govindpura and Mandideep, Bhopal

Sampling site	Govindpura	Mandideep	Requirements
1	8.07	8.11	6.5-7.5
2	8.91	8.41	
3	8.71	7.83	
4	8.48	7.51	
5	8.76	8.54	
6	8.35	6.93	
7	8.44	8.01	
8	8.53	8.52	
9	8.68	8.37	
10	8.44	9	

The pH of the soil is an important parameter that directly influences mineral mobility. The pH of the soil samples analyzed were ranged from 8.07 to 8.91 for Govindpura and 7.51 to 9 for Mandideep showing that the soil in the area covered in this study is slightly alkaline in nature. The pH values obtained in this study were found to be slightly higher than values reported by requirements.

The results of conductivity in soil sample collected from Govindpura and Mandideep, Bhopalis shown below.

Table 6. Results of conductivity of soil at Govindpura and Mandideep, Bhopal

Sampling site	Govindpura	Mandideep	Requirements
1	0.63	0.51	4 ms/cm
2	0.21	0.32	
3	1.62	0.4	
4	0.24	1.12	
5	1.95	1.73	
6	0.53	1.74	
7	0.49	1.7	
8	0.54	0.33	
9	0.22	0.26	
10	0.96	0.45	

The electrical conductivity (EC) obtained in this study have ranged from 0.21 to 1.95 ms/cm of soil from Govindpura while 0.26 to 1.74 ms/cm from Mandideep. The electrical conductivity obtained in this study were found to be smaller than values reported by requirements.

The results of moisture content in soil sample collected from Govindpura and Mandideep, Bhopal is shown below.

Table 7. Results of moisture content in soil at Govindpura and Mandideep, Bhopal

Sampling site	Govindpura	Mandideep	Requirements
1	1.38	1.98	(15-25)%
2	2.34	2.86	
3	1.28	2.39	
4	1.96	2.49	
5	2.26	1.36	
6	1.19	2.2	
7	1.28	2.06	
8	1.26	1.36	
9	2.46	1.48	
10	2.48	2.13	

The moisture content obtained in this study have ranged from 1.19 to 2.48 % of soil from Govindpura while 1.36 to 2.86 % from Mandideep. The moisture content obtained in this study were found to be smaller than values reported by requirements.

4. Conclusion

1. The mean concentration of heavy metal “Fe” in soil is highest at both the places i.eMandideep and GovindPura area.

2. The mean concentration of heavy metal “Hg” in soil is lowest at both the places i.emandideep and govindpura area.
3. The mean concentration of minerals and heavy metals in soil at GovindPurawere in the following order of Fe>Mn>Zn >P >S >Cu >Ni >Cd >Cr >Pb >Hg.
4. The mean concentration of minerals and heavy metals in soil at mandideep were in the following order of Fe >Mn >P >Zn>S>Cu>Pb>Ni>Cr>Cd>Hg.
5. The pH of the soil samples analyzed were ranged from 8.07 to 8.91 for Govindpura and 7.51 to 9 for Mandideep showing that the soil in the area covered in this study is slightlyalkaline in nature.
6. The electrical conductivity of the soil samples of Govindpura and Mandideep were found to be smaller than values reported by requirements.
7. The moisture content obtained in this study have ranged from 1.19 to 2.48 % of soil from Govindpura while 1.36 to 2.86 % from Mandideep. The moisture content obtained in this study were found to be smaller than values reported by requirements.

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