Poll Res. 39 (1) : 104-108 (2020)

ISSN 0257–8050

A STUDY ON COMPARATIVE ANALYSIS OF HEAVY METALS CONCENTRATION IN ROAD DUST – A CASE STUDY OF VADODARA CITY, INDIA

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(Received 13 July, 2019; accepted 25 October, 2019)

ABSTRACT

Concentration of heavy metals such as Zn, Cu, Ni and Fe in road dust was analysed from different category of roads in and around Vadodara city. Road dusts were collected from random spots on both sides of the roads and following mixing for composition in equal proportion from each category road. The samples were analysed following digestion and as methods suggested in "Standard Methods". The determined concentrations were also compared with category of road, average traffic volume count and pavement material. The highest degree of contamination was identified on highway/expressway with high speed vehicles and concrete pavement. The higher values of contamination factor for zinc on urban roads and highways with more traffic volume count revealed the significant contribution of automobile tyres. Further, no significant variation of iron was observed in road dust of various categories of roads with background soil during the study.

KEY WORDS: Atomic Absorption Spectrophotometer, Heavy metals, Road dust

INTRODUCTION

Particles of dust which are deposited from the atmosphere and accumulate along road are called road dust (Faiz *et al.,* 2009). Road dust remains deposited for short time. It is simply re-suspended back into the atmosphere, where they contribute significant amount of heavy metals (Ferreira *et al.,* 2005). It may perhaps chemically or physically interact with the natural compounds which change their form of presence in the environment. Generally, they may react with particular species, change oxidation state and precipitate (Dube *et al.,* 2001). Trace metals in road dust may come from several human activities, such as industrial and energy production, construction, vehicle exhaust, waste disposal, as well as coal and fuel combustion.

Heavy metals discharged from stationary and mobile sources enter into water, air and soil and can even enter plants, animals and human bodies. Public health is affected by release of heavy metals in the atmosphere. Outdoor settled dusts comprising heavy metals are a significant source of experience for people, particularly children and other vulnerable persons. Breathing, dust consumption, and dermal contact are mutual paths by which toxic heavy metals can enter the body. Through breathing, airborne dust particles pose significant health dangers, such as diverse respiratory illnesses, decreased lung function, and cardiovascular diseases (Turner *et al.,* 2010). Dust is consumed in human body via food chain and also by direct and indirect contact with polluted matters. For example, Ni is categorised as a skin sensitizer and it can cause sensitive contact dermatitis (Mazinanian *et al.,* 2013). Road dust with its high heavy metal substances has a high opportunity of causing cough/breathing in both children and adults for the period of inhalation.

The main objectives of the current study are (1) to examine the spatial variation of heavy metals in road dust in and around Vadodara city, (2) to compare concentration of heavy metals with various site features for e.g. road width, pavement material, traffic volume count and such others and (3) comparison of its outcome with different other studies carried out in different locations of India.

MATERIALS AND METHODS

Study area and Sampling Method

Samples were collected from Village road, Urban road (locations such as Old Padra road, Panigate road, Karelibaug, Dandiya bazar road), Highway and Expressway (Concrete and Asphalt pavement portions) and Industrial road of Vadodara city. Sampling was done along the each road separately.

Road dust samples were collected during the dry weather to avoid possible wash away or leaching of the heavy metals if collected in the rainy season and were also collected in two consecutive days to minimise temporal changes (Abechi *et al.,* 2010). To have one representative sample for each location, the road dust was collected from two locations of single road of two opposite lanes each on two consecutive days i.e. eight samples in equal quantities are mixed for each road dust sample

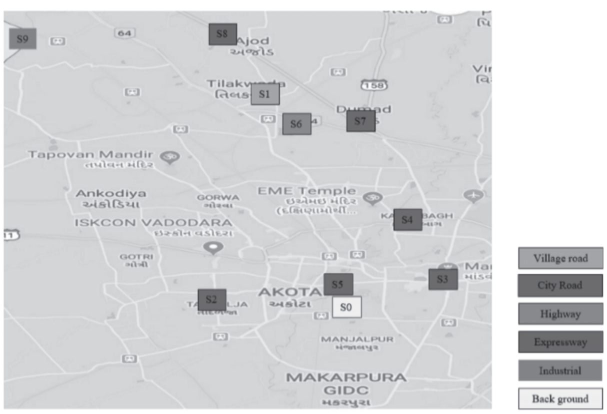

Fig. 1. Map of Sampling Sites in Vadodara

(Qasem *et al.,* 1999). The samples collected were collected in clean polythene bags to minimize sample contamination and labelled immediately at the point of collection for proper identification (Baba *et al.,* 2014). The dust samples were screened to remove any visible hairs, stones, and grit. The samples were then oven-dried at 103 ^{o}C-105 ^{o}C for 1 hour and normalised using a mortar and pestle. The samples were sieved through 150µm mesh sieve.

Sample digestion

All experiments were performed with analytical reagent grade chemicals. All laboratory glassware and plastic containers were initially cleaned with distilled water. For digestion of soil samples transfer a measured volume of well-mixed (5g), acid-preserved sample appropriate for the expected metals concentrations to a flask. Add 5 ml concentrated HNO_3 and add few glass beads and bring to a slow boil and evaporate on a hot plate to the lowest volume possible. Continue heating and add 15 mL (1+1) HCl and evaporate until digestion was completed. Cool it to room temperature, filter it and make up with distilled water up to mark. Calibration standards were prepared from the stock solution of the elements to be determined by serial dilution. The digested samples were then analysed for heavy metal using Atomic Absorption Spectrophotometer and Spectrophotometer (APHA *et al.*, 2012).

RESULTS AND DISCUSSION

The Zinc, Copper, Nickel and Iron concentrations were measured as reported in Table 2 for three consecutive months of winter and summer each.

The concentration of zinc in road dust was due to the tyre abrasion in vehicle because Zn is used as vulcanization agent in tyres and lubricating oil

Table 1. Detailed features of different sampling locations covered under study

Sampling Location	Average no. of vehicles/hr.	Site description
Village Road (Asphalt pavement)	400	Low traffic with Agriculture & mixed use areas in surrounding
Urban Road (Asphalt pavement)	3000	Heavy traffic comprising mostly 2, 3 wheelers & passenger cars
Highway and Expressway road (Asphalt and Concrete pavement)	4000	High traffic with more heavy vehicles with single & multi axle vehicles
Industrial Road (Asphalt pavement)	1500	Medium traffic, similar to urban road surrounded with small industrial units (mostly small scale & non chemical industries)

contain zinc as additive (Bhattacharya *et al.*, 2011). The concentration of nickel in road dust was due to corrosion of metallic parts and spillage of lubricants in vehicles. The concentration of copper in road dust gives less concentration which is due to combustion of diesel fuel.

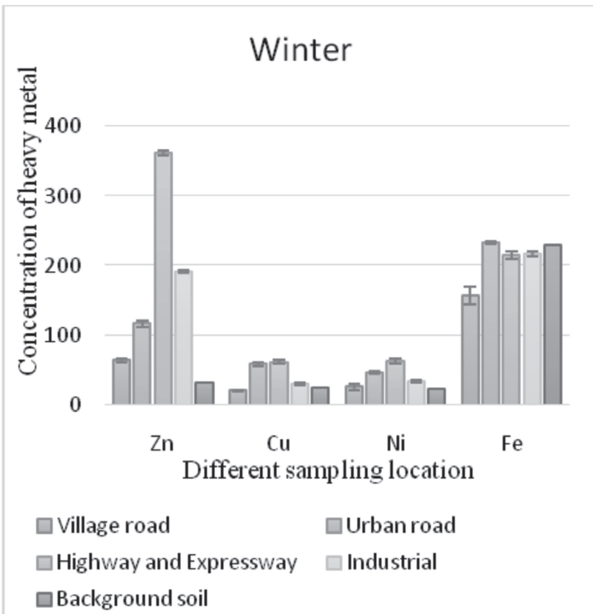

Fig. 2. Concentration of heavy metal in winter in mg/kg

Contamination Evaluation

The Contamination factor and Degree of Contamination advised by Hakanson *et al.*, 1980 is found useful in order to assess the overall contamination of road dust by heavy metals.

The contamination factor (C_f) is calculated as:

$C_f = C_m / C_b$

Where,

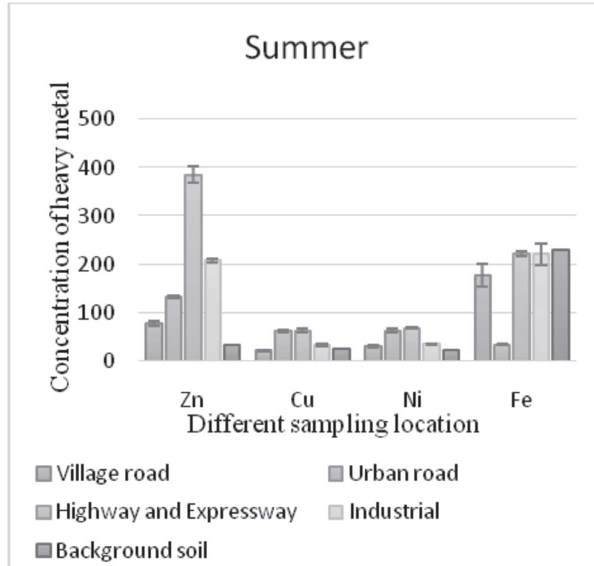

Fig. 3. Concentration of heavy metal in summer in mg/kg

C_m is the mean concentration of metal and

C_b is the concentration of each individual metal at control site

The degree of contamination (C_d) is the summation of contamination factors for all of the heavy metals considered under case study.

$$C_d = \sum_{i=0}^{n} Cfi$$

Table 3. Classes of Contamination level using C_f and C_d

Contamination level	C_f value	C_d value
Low Contamination	$C_f < 1$	$C_d < 8$
Moderate Contamination	$1 < C_f < 3$	$8 < C_d < 16$
Considerable Contamination	$3 < C_f < 6$	$16 < C_d < 32$
Very high Contamination	$C_f > 6$	$C_d > 32$

For a case study area C_f and C_d for different locations were calculated and reported as in Table 4.

Table 2. Concentration of heavy metals at different locations in mg/kg of road dust

Concentration of different heavy metals (mg/kg)		Winter				Summer				Background soil
		Village road	Urban road	Highway & Expressway	Industrial road	Village road	Urban road	Highway & Expressway	Industrial road	
Zinc	Mean	64	116.18	361.33	190.75	77	133.6	385	208.25	32
	S.D.	2.92	5.22	3.70	1.75	5.87	3.01	17.40	3.75	
	Peak	68	123.5	364.33	192.5	84	136.8	414	212	
Copper	Mean	20.8	58.27	61.68	30.1	21.8	62.21	63.02	33.7	25.3
	S.D.	0.90	2.20	2.40	2.1	0.87	1.61	3.27	2.7	
	Peak	22.80	60.43	65.07	32.2	22.8	64.65	66.3	36.4	
Nickel	Mean	25.47	46.3	62.89	33.87	30.25	52	68.07	35.3	22
	S.D.	4.55	1.67	3.63	2.23	3.31	3.29	1	1.6	
	Peak	31.8	47.8	67	36.1	33.8	55	69.37	36.9	
Iron	Mean	157.12	233.43	214.65	216.4	177.15	236.6	222.77	221.5	230.2
	S.D.	12.08	2.26	5.58	4.1	24.25	0.8	5	22.35	
	Peak	169.2	235.75	220.23	220.5	201.4	237.4	227.77	243.5	

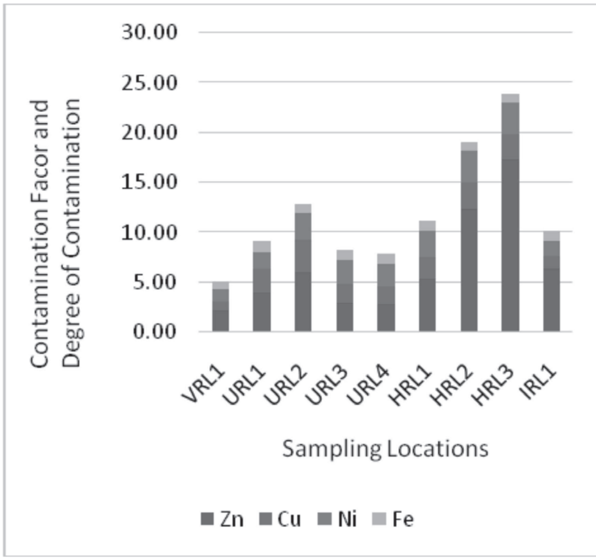

Fig. 4. Contamination Factor and Degree of contamination for Different Locations

As suggested by Hakanson, contamination levels can be classified into four classes, as follows:

The road dust of Highway and Expressway was found considerably contaminated, whereas road dust of urban roads was found moderately contaminated.

Comparison with other studies in India

The heavy metals concentration in road dust of urban roads of Vadodara city is compared with data stated for other cities in the India (Table 4). The concentration of Zinc in the road dust of Vadodara city is almost similar to other cities of India except significant high concentration found in Bhillai and Navi Mumbai. The average concentration of Copper and Nickel in road dust of urban roads in Vadodara city is also similar as of other case studies, except Nickel concentration found in Navi Mumbai.

CONCLUSION

The movement of heavy vehicles, high speed of automobiles, pavement surface and tyre abrasion were possible reasons for contributing high concentration of zinc in road dust of highway/ expressway.

Higher concentration of copper in the road dust of urban roads and highway/expressways compare to village road and industrial road with less traffic revealed significant contribution of traffic volume count. It may also be concluded that variation in speed of vehicles, types of vehicles and type of pavement are not significantly contributing copper concentration in road dust.

Table 4. Contamination Factor and Degree of contamination for Different Locations

Sampling Locations		Contamination Factor (C_f)				Degree of contamination
		Zn	Cu	Ni	Fe	
Village Road	(VRL1)	2.2	0.8	1.3	0.7	5
Urban road	URL1	3.9	2.3	1.7	1.2	9.1
	URL2	6.0	3.3	2.6	0.9	12.8
	URL3	2.9	1.9	2.3	1.1	8.2
	URL4	2.7	1.9	2.2	1.0	7.8
Highway & Expressway	HRL1	5.3	2.2	2.7	0.98	11.2
	HRL2	12.4	2.7	3.2	0.9	19.2
	HRL3	17.3	2.6	3.1	0.9	23.9
Industrial Road	(IRL1)	6.3	1.3	1.5	1.0	10.1

Table 5. A comparison of the mean heavy metal concentrations (mg/kg) in Road dust of Vadodara and other cities in India

City	Ni mg/kg	Cu mg/kg	Zn mg/kg	Fe mg/kg
Anand (Gujarat) (Bhattacharya, 2011).	56.90-75.81	51.66-129.98	43.64-92.79	-
Surat (Gujarat) (Krishna, 2007).	79	137.5	139	-
Delhi (Banerjee, 2003).	100-989	50-1350	120-180	-
Calcutta (west Bengal) (Chaterjee, 1999).	42	44	159	-
Bhillai (Chhattisgarh) (Ambade, 2012).	45.3	126.4	813.2	-
Navi Mumbai (Maharashtra) (Amit, 2016).	15.17	136.54	938.80	119.53
Vadodara (Gujarat) only Urban Roads	49.15	60.24	124.8	235.41

Relatively higher concentration of nickel in road dust were observed on highway/expressway compared to other roads. This may signifies importance of the movement of heavy vehicles and high speed for leaching high Nickel into road dust.

There were no significant high or low concentration of iron were observed in road dust of different categories of roads.

The contamination factor and degree of contamination were observed higher due to zinc on concrete pavement of expressway.

There were no significant variations observed in concentration of heavy metals into road dust due to the change in ambient air temperatures of winter and summer.

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