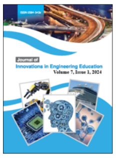

Journal of Innovations in Engineering Education
JIEE 2024, Vol. 7, Issue 1.

https://doi.org/10.3126/jiee.v7i1.61659

THAPATHALI CAMPUS
Institute of Engineering
Tribhuvan University

Analysis of the concentration of heavy metals and their vehicle emission in urban road dust of Kathmandu valley

Bikram Kumar Das[a], Ram Kumar Sharma[a], Madhav Narayan Shrestha [b] and Basant Lekhak[a,c,d,*]

[a]*Department of Civil Engineering, Pulchowk Campus, Institute of Engineering Tribhuvan University, Lalitpur 44700, Nepal*
[b]*Environment and Water Resource Specialist, Nepal*
[c]*Department of Civil Engineering, Thapathali Campus, Institute of Engineering, Tribhuvan University, Kathmandu 44600, Nepal*
[d]*Department of Civil Engineering, Nepal College of Information Technology, Pokhara University, Lalitpur 44700, Nepal*

ARTICLE INFO

Article history:

Received 19 August 2024
Revised in 21 September 2024
Accepted 5 October 2024

Keywords:

Heavy metals
Urban road dust
Particulate matters
Vehicle emission
Air Quality Index

Abstract

Greater environmental harm and health risks are associated with fine urban dust than with coarser urban dust. This study aims to analyze the heavy metal (Cu, Zn, and Cd) concentration of heavy traffic road sections and compares it with medium traffic road sections with the same starting and end point for a study of how heavy metals from vehicles contribute to road dust (size $< 150\,\mu$m). Twenty-seven dust samples of spatial and temporal variation were collected from the study area and were analyzed by Atomic Absorption Spectrophotometer with acetylene flame for zinc, copper, and cadmium. Cadmium is not detected (<0.5 mg/kg) in any of the samples. The decreasing order of average concentration of zinc and copper in street dust is found from high traffic road to medium traffic roads and low traffic roads. The ANOVA combined with IBM SPSS statistics software results at a significance level ($\alpha = 0.05$) suggest that the mean average concentration of Zinc (Zn) of different road groups classified are notably different ($F_{3,402} = 5.75$ and $p < (\alpha = 0.05)$). The ANOVA results at the significance level ($\alpha = 0.05$) of Copper (Cu) of the three road groups classified are not found to be notably different ($F_{3,402} = 2.446$ and $p > (\alpha = 0.05)$). Therefore, it can be said that vehicle volume has a direct effect on the contribution of zinc in roadside dust, but the copper concentration seems to be influenced by some other contributors like construction activities, burning of coal.

1. Introduction

Social and economic development of any place is dependent on the road; a well-connected road enhances society development but exposes the population to various pollutant sources. Dust is the most common pollutant in developing area ever-present and in the end gather on a different surface of the earth. Road traffic-related dust may account for 33% of all air pollution [1]. Atmospheric deposition, sedimentation, impaction, and interception are the process by which road surface stores various amount of heavy metal. [2]insight on the fact; "Top soil and roadway dust in urban cities is sign of heavy metal pollution due to deposition in atmosphere."

Heavy metals is omnipresent in the natural environment like soil, water, air, etc. among which few are essential for life, they can be hazardous when appears in amount higher then specified in the national air quality guidliness. The five basic needs for human survival are air, water, food, heat, and light (Pancha Tatwa), with air being the most crucial component [3]. Gradual progress in development continuously releases heavy metals which possess a threat to the health of exposed population.

Heavy metals major sources are considered to be automobiles. Zinc, copper, and lead is heavy metals that are most commonly exhibits from road travel. About one-half of zinc and copper released in terrestrial environment is because of the automobile, as zinc is released because of tire abrasion and copper is released because of brake abrasion. Motor oil is also another path for

*Corresponding author:
basant.lekhak@pcampus.edu.np (B. Lekhak)

the release of heavy metals. It is broadly assumed that the issue of heavy metal pollution is associated with the intensive industrial areas, but according to [4] road and vehicle traffic are regarded as one of the major sources of heavy metals. Heavy metals can be carried far away from sources by wind, depending on which form they are present i.e. gaseous form or particulate matter. Traffic and domestic emissions, construction activities, abrasion of pavement surface, etc., are sources of heavy metals in urban roadside dust due to anthropogenic activities.

2. Purpose of the study

The major purpose of this study is to analyze the heavy metal (Cu, Zn, and Cd) concentration of heavy traffic road sections and compare it with medium traffic road sections with same starting and end points to analyze the vehicular contribution of heavy metals concentration in roadside dust (size <150µm).

3. Study area

Chandragiri municipality is selected as the study area, in the Kathmandu District of Nepal's Bagmati Province. According to the 2021 Nepal Census, Chandragiri municipality has a total population of 136,928 people. Its total area is 43.9 km^2, and its population density is 3118 people per km^2. For present study 3 major location Kalanki-Satungal-Nagdhunga (9.25 km) (Heavy Traffic Road), Kalanki-Balambu-Nagdhunga (8.9 km) (Medium Traffic Road) and vicinity of Dahachowk park (Undisturbed site) was selected and classified on the basis of average daily traffic of the road as shown in the Figure 1.

4. Methodology

A total of twenty-seven road dust samples were taken from the roadways. The detailed description of the sampling site is given in Table 2. Both the left and right sides of the road were used to collect dust samples. May 2022, a dry month, was used for sampling. A plastic dustpan and brush were used to gather the dust samples. Approximately 200-300 grams of dust were collected at every 1 km and kept in self-sealing plastic bag. Dust samples were collected from the site and kept in an oven for twenty-four hours at hundred degrees Celsius to completely remove moisture. They were then sieved through 2.36 mm sieves to remove tinny pebbles and other unwanted material, and again through 150 micron sieves. Finally, 1-2 g of the dried dust samples was subjected to acid digestion following EPA method 3050B. The prepared sample using the EPA method 3050B is then subjected to be measured using a flame atomic absorption spectrometer (Analytik Jena GmbH - novAA 350) to determine the concentration of Cu, Zn, and Cd. 1ppm, 2ppm and 4ppm standard solution were used to validate the analytical method. The instrumental parameters were those recommended by the manufacturer. In the experiments, duplicate samples, standard samples, and reagent blanks were all evaluated concurrently to provide quality control.

After examining the heavy metal content in each of the twenty-seven samples of the designated road that were collected; we have to design a hypothesis to observe the contribution of vehicle for heavy metals in terrestrial environment. Our research is structured so that we may draw the conclusion that vehicle mass influences the amount of heavy metals present in road dust that is smaller than 150 microns. Before doing any meaningful hypothesis test, we must first identify the null hypothesis and alternative hypothesis.

The null hypothesis is defined as:

H_0: Vehicular movement has no significant effect on concentration of heavy metal (Zn, Cu, and Cd); i.e. $\mu_1 = \mu_2 = \cdots = \mu_k$

Against the alternative hypothesis:

H_1: Vehicular movement has a significant effect on concentration of heavy metal (Zn, Cu, and Cd); i.e. $\mu_i \neq \mu_k$

Because the data are categorized based on a single component (i.e. Vehicular movement), hypothesis testing is carried out using the single-factor ANOVA test in IBM SPSS Statistics. MS-Excel is also used to calculate all other statistics, including mean, standard deviation, and others.

5. Result and discussion

A sample of road dust from three distinct sites in the Chandragiri Municipality-high traffic road, medium traffic road, and low traffic road was examined for the concentration of heavy metals like zinc (Zn), copper (Cu), and cadmium (Cd). This section discusses and visually illustrates the impact analysis due to vehicle in heavy metal concentration.

5.1. Heavy metals concentration in road dust

Each average concentration of heavy metals (mg/kg) in road dust and the concentrations at three distinct locations are shown in Table 3 and Table 4. Cd is not detected in any of the samples. Among different site studied higher concentration of both zinc and copper is found to be higher in H7 among all sample with 129.037 mg/kg of zinc which is around six times greater than

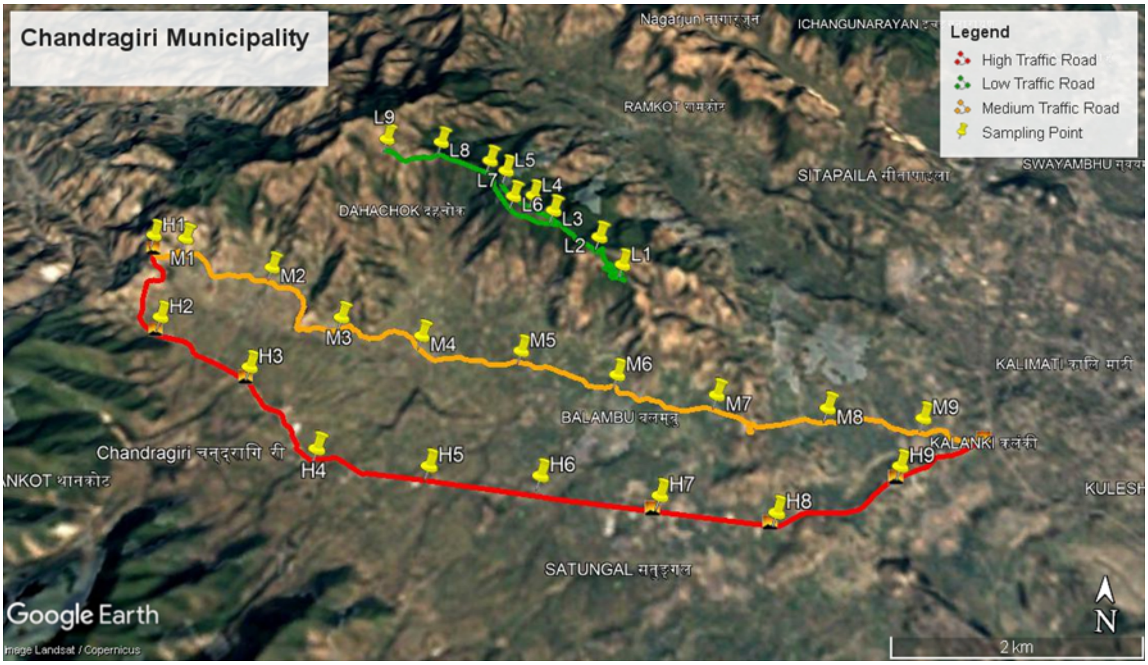

Figure 1: Study area with selected road sections for study

Indian natural soil background value of zinc (i.e. 22.1 mg/kg) and also thrice than the average value of undisturbed site (i.e. 41.7 mg/kg) and 136.310 mg/kg of copper which is more than twice the value of Indian natural soil background value of copper (i.e. 56.5mg/kg). Average concentration of dust sample of three different sites is shown in Table 4 and its bar graph is shown in Figure 2 and 3. The decreasing order of zinc and copper average concentration in street dust of all the sites is from high traffic roads to medium traffic roads and then low traffic roads.

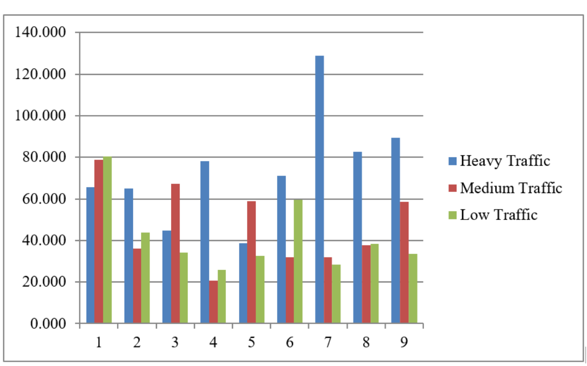

Figure 2: Zinc concentration (mg/kg) in study area

Figure 2 shows the concentration of zinc in road dust of heavy traffic, medium traffic respectively. The highest concentration of zinc is found to be in the sampling

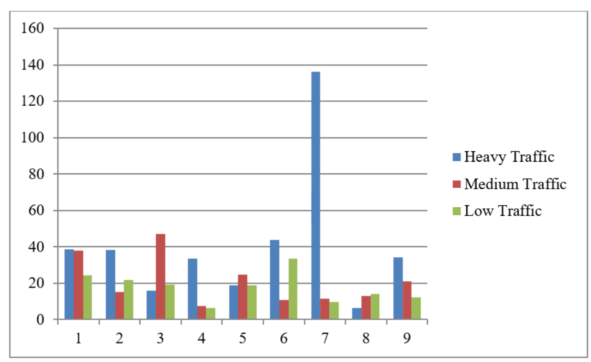

Figure 3: Copper concentration (mg/kg) in study area

point H7 (129.037 mg/kg) which falls in the region of heavy traffic road and also the sampling point of the road is valley curve which may be the reason of deposition of great of amount of zinc there. Also we can observe in the graph that the concentration of road along the high traffic road and medium traffic road is not consistent which may be because of the landscape of the road section follows various summit and valley curve. Like sampling point H4 have low concentration in comparison to other sampling point in heavy traffic road which may be because it has a 10 m elevation downhill in just 150 meter towards sampling point H5; which possess concentration equivalent to the average concentration of heavy traffic road. Similarly sampling point M1 bears greater concentration among the sampling

Table 1: Sampling point Co-ordinate

Road Classification	**Sampling Point**	**Latitude**	**Longitude**	**Landmark**
Heavy Traffic Road	H1	27°42’26.28"N	85°12’18.43"E	Nagdhunga police checkpost
	H2	27°42’0.31"N	85°12’25.99"E	Way to Lag lage pakha park
	H3	27°41’45.74"N	85°12’57.61"E	Mt. Chandragiri School
	H4	27°41’22.59"N	85°13’22.45"E	Tribhuvan Park
	H5	27°41’19.01"N	85°13’57.03"E	Panchakanya Mandir (Gujurdhara)
	H6	27°41’17.41"N	85°14’31.05"E	Vehicle Academy and Research Centre (Gujurdhara)
	H7	27°41’13.04"N	85°15’7.36"E	Satungal Complex
	H8	27°41’9.51"N	85°15’42.48"E	Way to Serenity Nepal
	H9	27°41’23.73"N	85°16’21.65"E	Way to Balkhu Khola corridor
Medium Traffic Road	M1	27°42’25.65"N	85°12’28.99"E	Panchakanya Devi Temple Nagdhunga
	M2	27°42’17.60"N	85°12’58.97"E	Agricultural area (Nagdhunga)
	M3	27°42’2.61"N	85°13’23.92"E	Nagdhunga Tunnel east portal
	M4	27°41’57.72"N	85°13’50.59"E	Agricultural Land (Dahachowk)
	M5	27°41’54.05"N	85°14’23.00"E	Mega Bank (Dahachowk Branch)
	M6	27°41’47.58"N	85°14’54.00"E	Purano Satungal
	M7	27°41’42.42"N	85°15’25.56"E	Basanta Tole Samaj
	M8	27°41’39.74"N	85°16’0.54"E	Melissa Marga
	M9	27°41’37.81"N	85°16’30.59"E	Melissa Marga (Kalanki)
Low Traffic Road	L1	27°42’18.96"N	85°14’54.99"E	Dahachowk Park
	L2	27°42’26.33"N	85°14’47.22"E	
	L3	27°42’34.38"N	85°14’31.90"E	
	L4	27°42’38.48"N	85°14’25.04"E	
	L5	27°42’46.44"N	85°14’15.59"E	
	L6	27°42’38.42"N	85°14’18.49"E	
	L7	27°42’50.75"N	85°14’9.77"E	
	L8	27°42’56.64"N	85°13’52.77"E	
	L9	27°42’56.42"N	85°13’34.50"E	

Table 2: Sampling Site Information

No.	Name of Sampling Site	Site Description	Average Daily Traffic
1	Kalanki- Satungal- Nagdhunga	Most used highway for exit of Kathmandu valley, heavy traffic, commercial area and motor workshop, densely populated	13,662
2	Kalanki- Balambu- Nagdhunga	Mostly Residential area, agricultural land, medium traffic volume and densely populated	4,836
3	Dahachowk Park	Low traffic road, sparse residential and undisturbed area	Not observed

point of medium traffic road which may be because sampling point is just 1 km away from the sampling point H1 at elevation difference of 20 m downhill. Also in low traffic road sampling point L1 bears a quite greater concentration but not that much in comparison to two road classified before which may be because the sampling point have few residential area in the surrounding Therefore we can say that sampling points that falls in valley curve or in downhill possess greater concentration.

Figure 3 shows the graph for concentration of copper in heavy traffic road, medium traffic road and low traffic road respectively. The highest concentration of copper among all the sample was also found to be in sampling point H7 (136.31 mg/kg) which falls in the region of heavy traffic road and also the sampling point of the

Table 3: Heavy metal concentration (mg/kg) in each sample of collected road dust

Road Type	Location	Zn (mg/kg)	Cu (mg/kg)	Cd (mg/kg)
High Traffic	H1	65.532	38.5	<0.5 (ND)
	H2	64.898	38.21	<0.5 (ND)
	H3	44.899	16.03	<0.5 (ND)
	H4	78.1	33.5	<0.5 (ND)
	H5	38.770	18.850	<0.5 (ND)
	H6	71.247	43.630	<0.5 (ND)
	H7	129.037	136.310	<0.5 (ND)
	H8	82.519	6.500	<0.5 (ND)
	H9	89.26	34.27	<0.5 (ND)
Medium Traffic	M1	78.67	38.02	<0.5 (ND)
	M2	35.972	15.07	<0.5 (ND)
	M3	67.348	47.23	<0.5 (ND)
	M4	20.542	7.42	<0.5 (ND)
	M5	58.92	24.82	<0.5 (ND)
	M6	31.840	10.78	<0.5 (ND)
	M7	32.039	11.4	<0.5 (ND)
	M8	37.613	12.84	<0.5 (ND)
	M9	58.52	21.15	<0.5 (ND)
Low Traffic	L1	80.33	24.24	<0.5 (ND)
	L2	43.832	21.917	<0.5 (ND)
	L3	34.2	19.297	<0.5 (ND)
	L4	25.97	6.41	<0.5 (ND)
	L5	32.543	18.824	<0.5 (ND)
	L6	59.62	33.56	<0.5 (ND)
	L7	28.322	9.509	<0.5 (ND)
	L8	38.23	14.23	<0.5 (ND)
	L9	33.545	12.076	<0.5 (ND)

Table 4: Metals average concentration (mg/kg dry wt.) in road dust of Chandragiri municipality (Mean ±SD)

Sampling Site	Number of Samples	Zn (µg/g)	Cu (µg/g)
High Traffic Road	9	73.807 ± 26.459	40.644 ± 37.930
Medium Traffic Road	9	46.829 ± 19.542	20.970 ± 13.579
Low Traffic Road	9	41.843 ± 17.546	17.785 ± 8.322

road is valley curve which may be the reason of deposition of great of amount of copper there. Also, we can observe in the graph that the concentration of road along the high traffic road and medium traffic road is not consistent which may be because of the landscape of the road section follows various summit and valley curve. Sample point M3 is close to the Nagdhunga East Portal construction site. Therefore, it can be said that contribution of construction activities in release of copper is high. Also there is decrease in the sampling point M4 it may be because the reason falls in agricultural area. Hence, it can be said that copper concentration is more at the place with construction activities and at the sampling point of valley curve and less concentration was observed at agricultural area.

The Figure 4 displays the typical level of heavy metals in road dust. Although the mean concentration of heavy metals on roads with heavy traffic is higher than that on roads with medium traffic, which is higher than that on roads with low traffic, it can be seen that the distribution of heavy metals on the road is uneven. Concentration of each sample is shown in Table 3, the highest concentration of both copper and zinc is found to be in sampling point H7 of heavy traffic road, which may be because the sampling point H7 is road nearby the petrol pump and according to [2]; Because they are found in gasoline, automobile parts, and oil lubricants, heavy metals including Zn, Cu, Pb, and Hg are excellent markers of

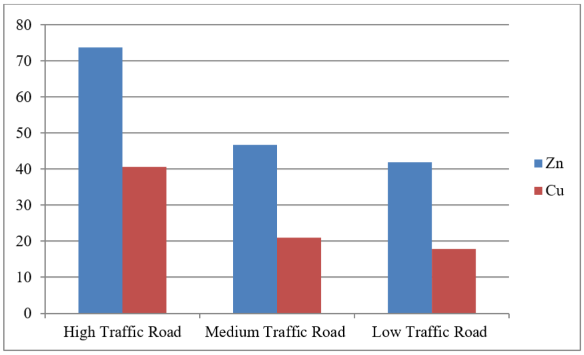

Figure 4: Average concentration (mg/kg) of heavy metal (Zn and Cu) in Road dust

pollution in street dust. The lowest concentration among the entire sample is found to be in M4 of medium traffic road which is a section of medium traffic road. Few of the background sample L1 and L6 tends to meet the concentration of high volume traffic road which may be due to the deposition by wind at certain point; as road dust of fine size can be carried out by wind which result in the contamination of site with low anthropogenic activities.

Large levels of Zn and Cu are constantly present in road dust, while Cd is not found in any of the examined samples. Zinc concentration range from 20.542 mg/kg to 129.037 mg/kg. The main source of zinc in the terrestrial environment according to [1] is vehicle as "The most likely source, originating from the attrition of motor vehicle tire rubber made worse by bad road surfaces, was zinc, which is employed as a vulcanization agent in tires. Particularly, the abrasion of car tires rises in hot temperature environments". Also copper concentration range from 6.41 mg/kg to 136.21 mg/kg. [5] have mentioned "The main sources of copper in street dust may include lubricant spills, engine wear and tear, bearing metals, and corrosion of metallic automotive parts."

Table 5 demonstrates the average Zn, Cu, and Cd concentrations in various cities throughout the world. Comparing the average value of zinc of our study with other cities we can see that the zinc concentration of our study is 73.81 mg/kg but other cities bear greater concentration which is because of the population density. Our study area have less population density in comparison to other cities like Calcutta , Beijing, etc. but comparing the copper concentration value it seems considerably less concentration, which therefore indicates that the copper release in terrestrial environment is comparatively less and is independent of population.

5.2. Testing of hypothesis

Hypothesis testing using one way ANOVA is done for testing the statistically significance of concentration of heavy metals within the sampling site. The result of one way ANOVA is further used to make the decision whether to reject or accept null hypothesis.

The hypothesis test if the vehicular movement effects the concentration of heavy metal zinc in road side dust. Road were classified into three groups based on the volume of vehicular movement (Group1: Heavy Traffic Road, Group 2: Medium Traffic Road and Group 3: Low Traffic Road).

5.2.1. Hypothesis testing for zinc

The ANOVA results at significance level ($\alpha = 0.05$) suggest that the mean average concentration of Zinc (Zn) of different road groups classified are significantly different ($F_{3,402} = 5.75$ and $p < \alpha = 0.05$). One-way ANOVA test was carried out using IBM SPSS statistics software. An ANOVA table (Table 6) presents the outcomes of the calculations that result in the F-statistic.

The equal variance was presumed because Levene's statistics are not significant. Using the Bonferroni, Sidak, and Scheffe approach, post hoc comparison was evaluated to look for individual differences across groups. All the test indicates that the mean scores for high traffic road (M = 73.807, S.D = 26.46) was significantly different form medium traffic road (M = 46.829, S.D = 19.542). Low traffic road (M = 41.843, S.D = 17.546) was significantly different from high traffic road (M = 73.807, S.D = 26.46). However, no significant different was found between medium traffic road and low traffic road. Table 7 and Table 8 shows the test statistics of homogeneity test and post hoc comparison test. As ANOVA test justify the significant difference in the mean score of road group classified according to the volume of vehicle movement. According to [9] "Tire wear releases zinc, whereas brakes release copper". Hence tires abrasion may be the major contributor of Zinc in urban road as heavy loaded vehicle have access only for the high traffic road and tire abrasion is excess in heavily loaded vehicle; Also according to [2] "Because they appear in gasoline and oil lubricants, which may be the secondary cause of Zinc release in urban road dust, heavy metals like Zn, Pb, and Hg are excellent markers of contamination in street dust."

5.2.2. Hypothesis testing for copper

The ANOVA results at significance level ($\alpha = 0.05$) suggest that the mean average concentration of Copper (Cu) of different road groups classified are not found to be significantly different ($F_{3,402} = 2.446$ and $p > \alpha = 0.05$). One-way ANOVA test was carried out using IBM SPSS statistics software. An ANOVA Table 9 displays the

Table 5: Road dust metal concentrations (mg kg^{-1}) in Chandragiri Municipality and other cities across the world

S. No.	City	Zn (µg/g)	Cu (µg/g)	Cd (µg/g)	Reference
1	Chandragiri Municipality (Present Study)	73.81	40.64	Not detected	-
2	Calcutta	159	44	3.12	[6]
3	Ottawa	112.5	65.84	0.37	[6]
4	Beijing	214	42	-	[7]
5	Dhaka	154	46	-	[8]

Table 6: Result of computation of one way ANOVA test for zinc

Source of Variation	SoS	df	MSS	F	p-value	F crit
Between the Groups	5322.92	2	2661.46	5.744758	0.009148	3.402826
Within the Groups	11118.84	24	463.285	-	-	-
Total Value	16441.76	26	-	-	-	-

Table 7: Test of Variance Homogeneity

Statistic of Levene	df1	df2	Sig.
Mean based	2	24	0.634
Median based	2	24	0.639
Median based and with adjusted df	2	22.789	0.640
Trimmed mean based	2	24	0.613

outcomes of the calculations that result in the F-statistic.

The result of ANOVA test justifies the fact that there's no any significant difference in the release of copper due to the vehicle volume in the classified road. Which may be because of the major contributor of copper to the road dust from vehicle is because of brake abrasion. We all know the fact that the brake abrasion is very low in comparison to tire abrasion. Hence we can conclude that copper concentration found in street dust of study area are somehow equally distributed which may be because of the other contributor of copper to the terrestrial environment. Few other contributor of copper rather the vehicular emission is: burning of coal, construction activities, uses of fertilizers, etc.

6. Conclusion

The primary goal of this research was to determine how vehicles affects heavy metal contribution to roadside dust. The following conclusions have been drawn in light of the outcome:

1. Average heavy metals (Zn and Cu) concentration ($< 150\,\mu m$) of road side dust sample collected from high traffic road was found to be 1.57 times greater for zinc and 1.94 times greater for copper than the average concentration of road side dust samples from medium traffic roads.
2. One-way ANOVA test carried out by keeping vehicular count as an independent variable and concentration of heavy metals as dependent variables justifies the fact that there is a significant difference between Zn concentrations in classified road groups. Therefore, it can be said that vehicle volume directly affects the contribution of zinc in roadside dust.
3. Cu concentration did not show any significant difference during average mean comparison using one-way ANOVA test. Hence, it justifies the fact that Cu contribution to the terrestrial environment may be due to other activities like construction activities, burning of coal, etc.

Table 8: Post hoc comparison test

Methods	Roadtype		Mean Difference (IJ)	Std. Error	Sig.	95 % Confidence Interval Lower Bound	95 % Confidence Interval Upper Bound
Scheffe	High Traffic	Medium Traffic	26.97756*	10.14658	0.045	0.5075	53.4476
		Low Traffic	31.96333*	10.14658	0.016	5.4933	58.4334
	Medium Traffic	High Traffic	-26.97756*	10.14658	0.045	-53.4476	-0.5075
		Low Traffic	4.98578	10.14658	0.887	-21.4843	31.4558
	Low Traffic	High Traffic	-31.96333*	10.14658	0.016	-58.4334	-5.4933
		Medium Traffic	-4.98578	10.14658	0.887	-31.4558	21.4843
Bonferroni	High Traffic	Medium Traffic	26.97756*	10.14658	0.041	0.8639	53.0912
		Low Traffic	31.96333*	10.14658	0.013	5.8497	58.0770
	Medium Traffic	High Traffic	-26.97756*	10.14658	0.041	-53.0912	-0.8639
		Medium Traffic	4.98578	10.14658	1.000	-21.1279	31.0994
	Low Traffic	High Traffic	-31.96333*	10.14658	0.013	-58.0770	-5.8497
		Medium Traffic	-4.98578	10.14658	1.000	-31.0994	21.1279
Sidak	High Traffic	Medium Traffic	26.97756*	10.14658	0.041	0.9406	53.0146
		Low Traffic	31.96333*	10.14658	0.013	5.9263	58.0003
	Medium Traffic	High Traffic	-26.97756*	10.14658	0.041	-53.0146	-0.9406
		Low Traffic	4.98578	10.14658	0.948	-21.0512	31.0228
	Low Traffic	High Traffic	-31.96333*	10.14658	0.013	-58.0003	-5.9263
		Medium Traffic	-4.98578	10.14658	0.948	-31.0228	21.0512

Table 9: Result of computation of one way ANOVA test for copper

Source of Variation	SoS	df	MSS	F	p-value	F crit
Between the Groups	2759.381	2	1379.691	2.445741	0.107968	3.402826
Within the Groups	13538.87	24	564.1196	-	-	-
Total Value	16298.25	26	-	-	-	-

References

[1] Tanushree B, Chakraborty S, Bhumika F, et al. Heavy metal concentrations in street and leaf deposited dust in anand city, india[J]. Research Journal of Chemical Sciences, 2011, 1(5): 61-66.

[2] Shakya P R, Pradhananga A R. Determination and contamination assessment of pb, cd, and hg in roadside dust along kathmandu-bhaktapur road section of arniko highway, nepal[J]. Research Journal of Chemical Sciences, 2013, 3(9): 2231-2606.

[3] Lekhak B, Amatya I M. Kinetics of suspended solids removal in tube settler[J/OL]. Journal of Innovations in Engineering Education, 2021, 4(2): 81-84. DOI: 10.3126/jiee.v4i2.38713.

[4] Bhattacharya T, Chakraborty S, Tuteja D, et al. Zinc and chromium load in road dust, suspended particulate matter and foliar dust deposits of anand city, gujarat[J/OL]. Open Journal of Metal, 2013, 03(02): 42-50. DOI: 10.4236/ojmetal.2013.32a1006.

[5] Shakya S, Baral S, Belbase P, et al. Determination and contamination assessment of heavy metals in street dust from different types of land-use in kathmandu district, nepal[J/OL]. Journal of Institute of Science and Technology, 2019, 24(1): 6-18. DOI: 10.3126/jist.v24i1.24622.

[6] Suryawanshi P V, Rajaram B S, Bhanarkar A D, et al. Determining heavy metal contamination of road dust in delhi, india[J/OL]. Atmosfera, 2016, 29(3): 221-234. DOI: 10.20937/ATM.2016.29.03.04.

[7] Tanner P A, Ma H L, Yu P K N. Fingerprinting metals in urban street dust of beijing, shanghai, and hong kong[J/OL]. Environmental Science and Technology, 2008, 42(19): 7111-7117. DOI: 10.1021/es8007613.

[8] Rajaram B S, Suryawanshi P V, Bhanarkar A D, et al. Heavy metals contamination in road dust in delhi city, india[J/OL]. Environmental Earth Sciences, 2014, 72(10): 3929-3938. DOI: 10.1007/s12665-014-3281-y.

[9] Aguilera A, Bautista F, Gutiérrez-Ruiz M, et al. Heavy metal pollution of street dust in the largest city of mexico, sources and health risk assessment[J/OL]. Environmental Monitoring and Assessment, 2021, 193(4). DOI: 10.1007/s10661-021-08993-4.