An Analysis of Road Dust Samples to Understand the Influence of Vehicle Density on the Heavy Metal Accumulation in Kannur District, Kerala, India

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Abstract: *The present study is an attempt to assess the heavy metal buildup in road dust samples of heavy traffic areas of Narath Panchayath, Kannur district. Samples have been collected from the roadside and are analyzed using X-Ray Fluorescence (XRF) spectroscopy technique. The study also deals with health effects associated with heavy metal accumulation in the study area by calculating and interpreting the various hazard index parameters such as contamination factor, enrichment factor, geo-accumulation index, pollution load index, and degree of contamination. The concentration of heavy metals such as Fe, Co, Ni, Cu, Zn, As, Cd, and Pb has been quantified and reported in the ppb units. It is observed that the study area has a specific higher concentration of Fe and a lower concentration of Cd. The index parameters were calculated from the observed concentration of heavy metals and thereby pollution rate is understood. The study indicates that the metallic dust emitted from the vehicles significantly contributed to the heavy metal concentration in the area. The buildup of heavy metals is also influenced by traffic density, weather conditions, and human and industrial activities in that area. The detailed results and discussion of the present systematic investigation are given in the manuscript.*

Key Words: *Heavy Metal, Accumulation, XRF, Hazard Index Parameter, Concentration.*

Introduction

Nowadays, the rate of environmental pollution is quite high and rather accelerated pace. The contamination of any part of the environment can be considered pollution and it changes the structure of the environment and causes an imbalance in the natural environment. In general, environmental pollution is the effect of undesirable changes in the surroundings that have harmful effects on plants, animals, and human beings. The pollution is caused by human activities, and undesirable substances, which ultimately have a detrimental effect on the environment. The air, water, soil, radioactive, thermal and heavy metal pollution, etc. are a few of the significant types of pollution.

The present work is an attempt to understand heavy metal pollution in some selected regions of the environment. The sources of heavy metal pollution may be natural or anthropogenic. Heavy metal contamination of soil has a serious concern as heavy metal components of soil are arsenic, cadmium, mercury, lead, zinc, and chromium. The areas near metal industries, and metal smelting and mining are the regions where heavy metal contamination is reported high. The heavy metals are poisonous even at low concentrations and they are non-degradable. The identified best solution to mitigate the soil pollution due to heavy metal accumulation is planting of trees which are bio-accumulators of heavy metals and that can also keep the environment evergreen.

Materials and Methods

The heavy metal contamination of road dusts in Narath Panchayath located at Kannur district is analyzed using the X-Ray Fluorescence technology. The latitudes and longitudes of the sampling points have been noted using GPS map camera. The location and road mapping are done using the geographical data (Fig.1). The samples have been collected following the standard procedure and analyzed using well established nuclear techniques. Rate of pollution in the environment of the region and associated health effects have been understood by calculating and interpreting the pollution index parameters. The pollution indices such as contamination factor (CF), enrichment factor (EF), geo-accumulation index (I_{geo}), pollution load index (PLI), and degree of contamination (C_d) are calculated and analyzed for better understanding of the heavy metal contamination and risk to the environment. The calculation of pollution indices were done using the standard equations well reported in scientific journals (Vineethkumar et al., 2020).

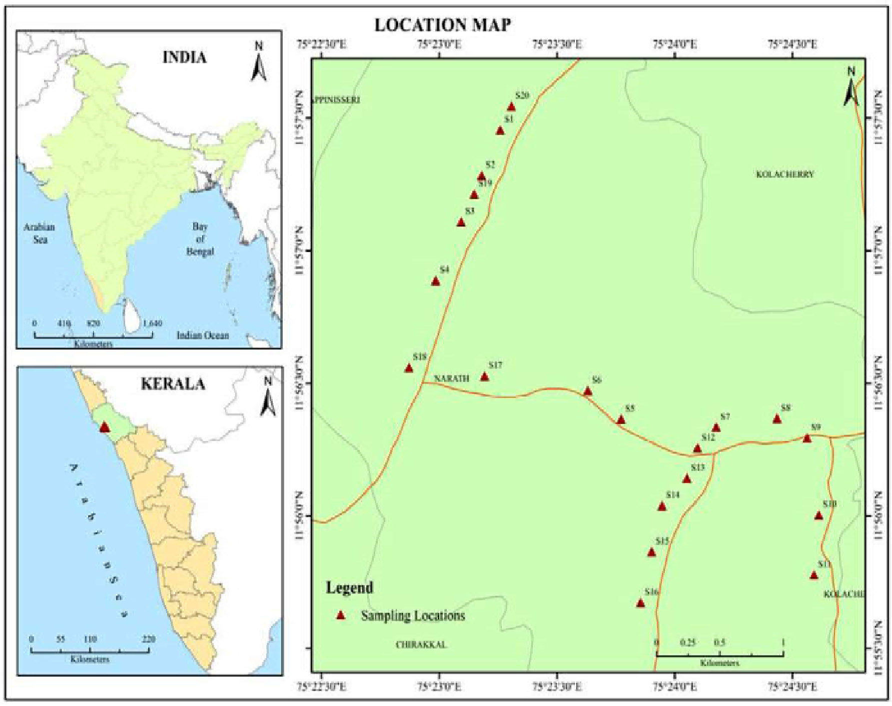

Fig. 1: Location map of the study area

1. Contamination Factor (CF)

Contamination factor is the ratio of concentration of element ‘x’ and concentration of reference element.

$$CF = (C_x)_{sediment} \;/\; (C_x)_{reference}$$

Where, $(C_x)_{sediment}$ refers to the concentration of element ‘x’ and $(C_x)_{reference}$ is the concentration of reference element. The level of contamination can be classified on the basis of CF as given below.

Contamination Factor	Contamination Level
$CF < 1$	Low contamination
$1 \leq CF < 3$	Moderate contamination
$3 \leq CF < 6$	Considerable contamination
$CF > 6$	Very high contamination

Rudnick and Gao (2003), Salah et al. (2012)

2. Enrichment Factor (EF)

Enrichment factor is the ratio of the concentration ratio of element 'x' to Fe in sediment sample and unpolluted reference sample.

$EF = (C_x/C_{Fe})_{sediment} \ / (C_x/C_{Fe})_{reference}$ Where, $(C_x/C_{Fe})_{sediment}$ and $(C_x/C_{Fe})_{reference}$ denote the concentration ratio of element 'x' to Fe in sediment sample and unpolluted reference baseline respectively. The sediment quality can be classified based on enrichment factor as given below.

Enrichment Factor	Sediment Quality
$EF < 2$	Deficiency to minimal enrichment
$2 < EF < 5$	Moderate enrichment
$5 < EF < 20$	Significant enrichment
$20 < EF < 40$	Very high enrichment
$EF > 40$	Extremely high enrichment

Barbieri (2016), Mei et al. (2011)

3. Geo-accumulation Index (I_{geo})

Geo-accumulation index was introduced by Muller. It is classified into seven classes according to the pollution intensity. It can be calculated by the equation

$$I_{geo} = \log_2[C_x/1.5B_x]$$

Where, C_x is the concentration of metal 'x' in the sediment and B_x is the geo-chemical background value of metal 'x'. The factor 1.5 is used in the equation to compensate the variation in background date due to lithogenic effects. The pollution intensity can be classified on the basis of I_{geo} as given below.

Geo-accumulation Index	I_{geo} class	Pollution Intensity
>5	6	Very strongly polluted
>4 – 5	5	Strong to very strongly polluted
>3 – 4	4	Strongly polluted
>2 – 3	3	Moderately to strongly polluted
>1 - 2	2	Moderately polluted
>0 - 1	1	Unpolluted to moderate polluted
<0	0	Practically unpolluted

Muller (1979)

4. Pollution Load Index (PLI)

Pollution load index is the product of contamination factor of all the samples raise to the power of. $\left(1/_{n}\right)$ Pollution load index can be calculated by

$$PLI = [CF_1 * CF_2 * CF_3 * \ldots\ldots\ldots\ldots * CF_n]^{1/n}$$

Where, CF_n is the value of contamination factor for metal 'n' and 'n' is the number of metals present in the analysis. The classification of pollution level on the basis of PLI is given below.

Pollution Load Index	Pollution Level
≤ 1	No metal pollution
>1	Metal pollution exist

Tomlinson et al. (1980), Bramha et al. (2014)

5. Degree of Contamination (C_d)

Degree of contamination is the average of contamination factors of all the samples. It can be determined by

$$C_d = \frac{\sum CF}{n}$$

Where, CF is the contamination factor and n is the number of analyzed heavy metals. The classification of contamination status on the basis of modified degree of contamination is shown below

C_d Level	Contamination Status
$C_d < 8$	Low degree of contamination
$8 \leq C_d < 16$	Moderate degree of contamination
$16 \leq C_d < 32$	Considerable degree of contamination
$C_d \geq 32$	Very high degree of contamination
	Indicating serious anthropogenic pollution

Bramha et al., 2014, Sivakumar et al., 2016

Results and Discussion

The statistical data of concentration heavy metals in the road dust soil samples collected from Narath Panchayath is given in the Table 1. The results indicate that Narath Panchayath has higher concentration of Fe (2574 ppm) and lower concentration of Cd (5.34 ppm). The concentration of heavy metals decreased from Fe > Zn > Ni > Co > Pb > Cu > As > Cd.

The Fe concentration ranges from 15632 ppm to 40151 ppm. The average crystal value of Fe is 47200 ppm (Vineethkumar et al., 2020), and the observed value is 25741 ppm. The concentration Zn ranges from 207 ppm to 725 ppm. The average crystal value for Zn is 95 ppm, and the observed mean value is 468.91 ppm. The Ni concentration ranges from 26.4 ppm to 142.1 ppm. The average crystal value for Ni is 68 ppm, and the observed mean value is 62.16 ppm. The concentration of Co ranges from 25 ppm to 96 ppm. The average crystal value of Co is 19 ppm, and the observed mean value is 61.55 ppm. The Pb concentration ranges from 11.5 ppm to 76.4 ppm. The average value of Pb is 20 ppm, and the observed mean value is 36.79 ppm. The Cu concentration ranges from 12.3 ppm to 52.12 ppm. The average crystal value is 45 ppm, and the observed mean value is 27.36 ppm. The concentration of Arsenic (As) ranges from 2.5 ppm to 9.8 ppm. The average reference crystal value of As is 13 ppm, and the obtained mean is less than average crystal value. The Cd concentration ranges from 1.45 ppm to 8.2 ppm. The average crystal value of Cd is 0.3 ppm, and the obtained mean value is 5.34 ppm.

Table 1: Statistical Parameters of Heavy Metals Concentration

Statistical Parameters	Fe	Co	Ni	Cu	Zn	As	Cd	Pb
Mean	25741	61.55	62.16	27.36	468.91	5.65	5.34	36.79
Minimum	15632	25	26.4	12.3	207	2.5	1.45	11.5
Maximum	40151	96	142.1	52.12	725	9.8	8.2	76.4
Std. Deviation	7634.1	22.52	35.29	10.06	147.12	2.02	1.94	19.18

The contamination factor of Fe, CF<1 indicates low level of contamination. The enrichment factor of Fe, EF<2 means the deficiency to minimal enrichment. The geoaccumulation index shows that the samples are practically unpolluted. The contamination factor of Zn, CF>6 indicates that the contamination level is very high. The enrichment factor of Zn, 5<EF<20 means enrichment is significant. The geoaccumulation index shows that samples are moderately polluted. The contamination factor of Ni, CF<1 indicates that the contamination level is low. The enrichment factor of Ni, 2<EF<5 means the enrichment is moderate. The geoaccumulation index shows that samples are practically unpolluted. The contamination factor of Co, 1≤CF<3 indicates the moderate level of contamination. The enrichment factor of Co, 2<EF<5 indicates the enrichment is moderate. The geoaccumulation index shows that the samples are in the category unpolluted to moderate polluted. The contamination factor of Pb, 1≤CF<3 indicates moderate level of contamination. The enrichment factor of Pb, 2< EF<5 shows the moderate enrichment. The geoaccumulation index shows the samples are practically unpolluted. The contamination factor of Cu, CF<1 indicates low level of contamination. The enrichment factor of Cu, EF<2 means the deficiency to the minimal enrichment of heavy metals. The geoaccumulation index shows that the samples are practically unpolluted. The contamination factor of As, CF<1 indicates low level of contamination. The enrichment factor of As, EF<2 indicates the deficiency to minimal enrichment. The geoaccumulation index indicates that all the samples are practically unpolluted with the presence of As. The contamination factor of Cd, CF>6 indicates high level of contamination. The enrichment factor of Cd, EF>40 indicates extremely high enrichment. The geoaccumulation index reflects the samples are moderately to strongly pollute with the presence of Cd.

Table 2: Contamination Factors of Heavy Metal Concentration

Contamination Factor	Fe	Co	Ni	Cu	Zn	As	Cd	Pb
Mean	0.55	3.24	0.91	0.61	4.94	0.43	17.79	1.84
Minimum	0.33	1.32	0.39	0.3	2.18	0.19	4.83	0.58
Maximum	0.85	5.05	2.09	1.16	7.63	0.75	27.33	3.21
Std. Deviation	0.16	1.19	0.52	0.22	1.55	0.16	6.45	0.96

Table 3: Enrichment Factors of Heavy Metal Concentration

Enrichment Factor	Fe	Co	Ni	Cu	Zn	As	Cd	Pb
Mean	1.00	6.62	1.83	1.27	9.85	0.82	37.43	3.65
Minimum	1.00	3.13	0.56	0.32	4.80	0.10	9.41	1.15
Maximum	1.00	14.92	6.17	3.06	20.14	1.64	80.71	8.94
Std. Deviation	0.00	3.60	1.35	0.69	4.60	0.38	20.56	2.27

Table 4: Pollution Load Index and Degree of Contamination

Parameter	Pollution Load Index	Degree of Contamination
Mean	1.60	3.79
Minimum	1.23	2.26
Maximum	2.07	5.50

Conclusion

The study indicates that the enhanced level of heavy metal concentration in road dust samples may be due to the metallic dust emitted from the vehicles. The concentration of heavy metals in road dust depends on the factors such as traffic density, weather conditions, human, and industrial activities in the area. The higher concentration of heavy metals can adversely affect the health of human beings residing near to elevated traffic density roads. The cause of heavy metal pollution also includes exhaust gases, brake pads, rubber tyres, oil leakages, and metal abrasions from motor vehicles. The pollution index clearly indicates that the carcinogenic metal doesnot possess any significant health risk to the inhabitants. Due to increasing population and vehicle density in the district, the intensity of pollution may increase along the national highway in the days to come. Certain protective and decisive measures for controlling and administering the vehicle density, promoting public transportation and encourage use of eco-friendly vehicles, relocating the residential areas away from the NH corridors are to be promoted.

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