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Assessment of Physical and Chemical Attributes of Road Dust of Dhaka-Natore Highway

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Abstract

Precise particle size distribution (PSD) and compositional analysis are remarkably relevant for road dust management because most of the dust collected is discharged on the next side of the road or at landfill sites. The representative road dust samples from the Rajshahi- Natore highway were analyzed for particle size distribution and other relevant parameters such as effective size, median particle size, coefficient of uniformity, coefficient of gradation. Road dust contributes significantly to the water environment through storm-water runoff. Therefore, this study aims to examine the chemical attributes of dust also. The PSD curves of the dusts from 26 locations indicated that the road dusts were poorly graded with an average coefficient of uniformity 1.16 and coefficient of curvature 0.72. The average pH value of the road dust samples was found to be 7.2. Average Electric Conductivity was found 168.27 µS/cm and it was found higher in the market areas. Presence of particles with diameter smaller than 75µm was found with an average of 26.50%. The correlations between median size & effective size and electric conductivity and effective size were statistically insignificant. Road dust is a more sensitive indication of urban ecosystem health. There is a considerable lack of understanding in cities and towns of Bangladesh about the composition of road dust. Therefore, this study will help to perceive the current scenario of dust composition for the concerned authorities.

Keywords: *Road dust; Highway; Physicochemical attributes; monitoring.*

1 Introduction

The Earth's crust is the main source of dust, making it the most significant and persistent element influencing both human health and the environment (Yongming et al., 2006). It is a more sensitive indication of urban ecosystem health than single compartmental monitoring of one element of environment because it reflects pollutants from severalmedia (Nicholson, 1988). Both stationary and moving sources can emit heavy metals, which can then infiltrate the water, air, soil, plants, animals, and human bodies (Adriano, 2001). Construction sites evolve dust particles in routine activities like cutting, drilling and grindings which generate ultra-fine particles of silica known as respirable crystalline silica become a vital source of pollution (Gondwal & Mandal, 2021). The re-suspension of road construction materials during construction is also having an adverse impact to the environment. The main causes of PM pollution in metropolitan areas of both developed and developing nations are the re-suspension of road dust and tyre and brake wear (Keuken et al., 2010). One of the six most important sources of suspended particulate matter (PM) in urban atmosphere is the road dust blown by traffic (Belis et al., 2013). Thus, the chemical and physical characterization of road dust size fractions is critical for understanding the interactions between various urban and industrial environments and identifying pollution sources (Gulia et al., 2019). Due to the lack of research in emerging cities of Bangladesh, a study is planned to assess the levels and pollutant characteristics of potentially in road dust as it is evident that systematic investigation on the qualitative and quantitative influence of parameter such as pH value, electric conductivity, particle size distribution are the prime attributes of road dust.

2 Materials and methods

2.1 Study area

Two neighboring districts of Rajshahi and also Natore located within the mid-western Bangladesh and in the division of Rajshahi. Rajshahi is located at the longitude of 24.3745° North and latitude of 88.6042° East. Natore is located at the 24.4102° North longitude and 89.0076° East latitude. The highway connecting these two districts is N6 which is one of the eight major national highways. The dust samples were collected from the shoulder of its portion of Rajshahi (R680) - Belpukur (N603) - Chawk Bidaynath (N602) - Harispur (N602). This is a two lane and both way road and the distance are of 39.5 kilometers. The roads elevation is significantly higher than farmlands beside it except the market areas and some minor industrial places.

Figure 1. A satellite view of the Rajshahi – Natore highway.

2.2 Collection of samples

The sample was taken from the Rajshahi-Natore Highway(N6). Plastic dust pan and brushwas used to collect the dust (Khan & Strand, 2018). A roughly 300 - 400gm of dusts werecollected on separate plastic bags which were labelled as the locations. The same process was repeated on almost every kilometer post on the highway. Gravels and other larger particles were taken by roughly scrapping from the pan or handpicked. It was difficult to signify all the samples by their distances from Natore or Rajshahi since the kilometer posts writings were irregular. The distances were then calculated by using Google Maps. The samples were labeled chronologically using alphabets and the distances from Rajshahi which are demonstrated in table 1

Table 1. Sample labels & locations

Sample No.	Sample Label	Kilometer Post No.	Co-ordinate of the locations	Distance from Rajshahi (km)
1	A	Natore 40 km	24º21’50” N 88º37’55” E	00
2	B	Natore 38 km	24º22’02” N 88º39’18” E	02
3	C	Natore 37 km	24º21’54” N 88º40’08” E	03
4	D	Natore 36 km	23°21’55” N 88°40’13” E	04
5	E	Natore 35 km	24º21’53” N 88º40’48” E	05
6	F	Natore 34 km	24º21’43” N 88º41’28” E	06
7	G	Natore 33 km	24º21’37” N 88º42’09” E	07
8	H	Natore 32 km	24º21’46” N 88º42’44” E	08
9	I	Natore 31 km	24º21’55” N 88º43’18” E	09
10	J	Natore 29 km	24º22’00” N 88º43’53” E	11
11	K	Natore 27 km	24º02’04” N 88º44’26” E	13
12	L	Natore 24 km	24º22’07” N 88º45’30” E	16

Sample No.	Sample Label	Kilometer Post No.	Co-ordinate of the locations	Distance from Rajshahi (km)
13	M	Natore 22 km	24º22’37” N 88º45’40” E	18
14	N	Natore 23 km	24º22’53” N 88º46’46” E	17
15	O	Natore 21 km	24º22’48” N 88º47’55” E	19
16	P	Natore 20 km	24º22’38” N 88º48’29” E	20
17	Q	Natore 19 km	24º22’29” N 88º49’02” E	21
18	R	Natore 18 km	24º22’24” N 88º49’37” E	22
19	S	Natore 17 km	24º22’20” N 88º50’20” E	23
20	T	Natore 16 km	24º22’07” N 88º51’08” E	24
21	U	Natore 12 km	24º22’21” N 88º53’18” E	28
22	V	Natore 11 km	24º22’22” N 88º53’58” E	29
23	W	Natore 10 km	24º22’39” N 88º54’27” E	30
24	X	Natore 09 km	24º23’01” N 88º54’52” E	31
25	Y	Natore 07 km	24º23’35” N 88º55’53” E	33
26	Z	Natore 06 km	24º23’53” N 88º56’23” E	34

2.3 Sample Preparation

The sample dusts were sieved through by mechanical shaker with #40 sieve (425 micron)(Jan et al., 2021). The particles that had passed through were collected and weighted for physiochemical analysis. On contrast, the retained particles were thrown away as residue. The collected samples were air dried before passing through sieves (Pan et al., 2017). For chloride concentration, alkalinity and conductivity analysis, 20gm of sample dust was mixed with 400ml of distilled water, shaken on an orbital mechanical shaker, and filtered for analysis (Lierop, 1990). Particle size distribution (PSD) was determined using sieve analysis with ISO 3310: BS 410-1:2000 sieves, excluding sizes larger than 0.425mm and including 0.212mm and 0.250mm sieves. The retained particles on each sieve were weighed, and the percentage finer was calculated. The resulting data were used to plot the PSD curve.

3. Results and Discussions

3.1 Physical Analysis

Sieve analysis values were plotted on a semi-log graph to accommodate a wide particle size range. The percentage finer was calculated and plotted against particle size for each location. Individual D_{10}, D_{30}, D_{50}, and D_{60} values were determined to assess gradation conditions. By combining the graphs, a comprehensive understanding of soil gradation across the selected road was obtained that is presented in figure 2. The analysis also revealed the predominant particle sizes in different locations. Additionally, the percentage weight of dust passed through the smallest mesh provided insights into the presence of particulate matter. According to the combined graph, the majority of samples show an increase in the amount of finer particles, which is predominantly caused by vehicle abrasion on the road surface and the movement of lighter particles by water and wind (Kumar & Elumalai, 2018). The finer particles in Sample ID-F, which was next to a gas station with significant traffic, were caused by vehicle impact and particle deposition during refueling. Sample ID-J, which was close to trees, showed a larger median value in the curve, which was probably caused by the trees' absorption of smaller particles (Febrianti et al., 2020). Effective particle size is diameter of the 10% finer particles. Figure 3 illustrated the variation of the finer particles’ sizes of location from the samples were collected. In this study, minimum value of D_{10} was found as 0.09mm and maximum value was 0.22mm with an average value of 0.135mm. Higher D_{10} values were found in the places of heavier traffic. The market areas and busy roads e.g., roads in front of educational institution generally possesses heavy traffic density. The vehicles when removes fine particles along the course of their movement leaving coarser particles which produced such value. The collected samples showed an average of 26.50% of particles ranging from 1.94% to 48.62% in small sizes in figure 4. Dusty areas like markets, intersections, bus stoppages, and road construction sites had higher percentages. These findings are concerning as smaller particles have a higher likelihood of entering the human body, causing health hazards such as follicle blockage and discomfort. Finer particles remain suspended in the air due to their low weight (Burton, 1996).

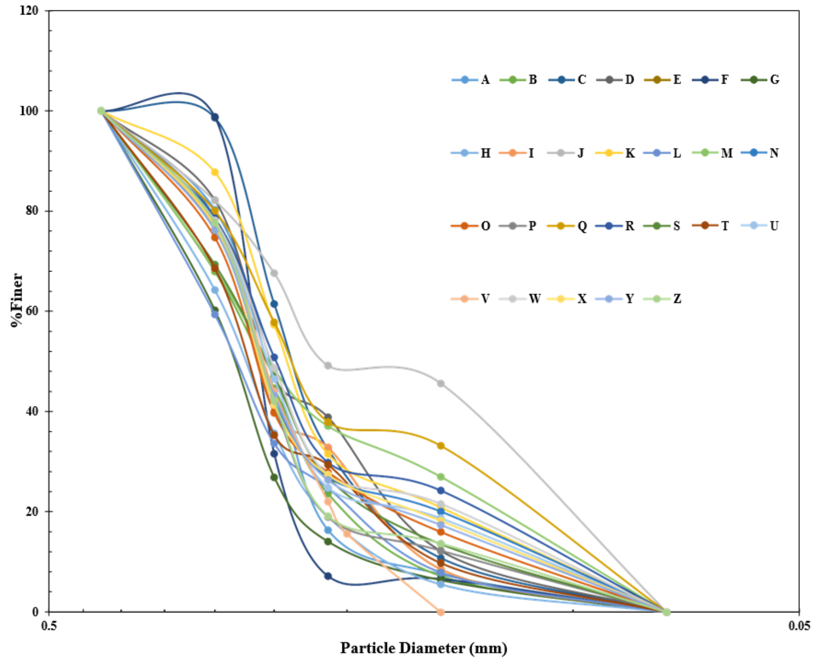
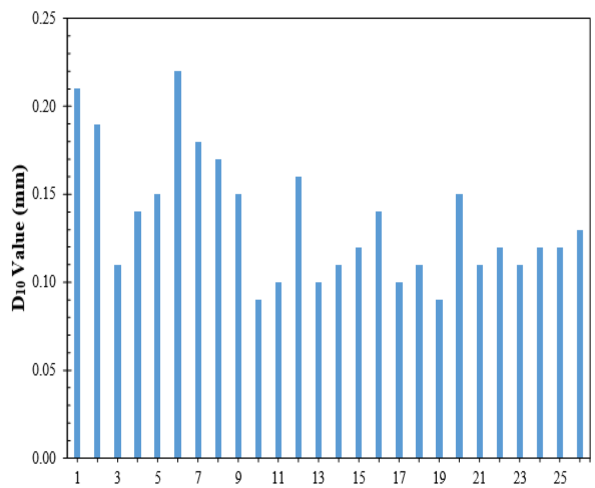


Figure 2: Combined PSD curves in a single graph.



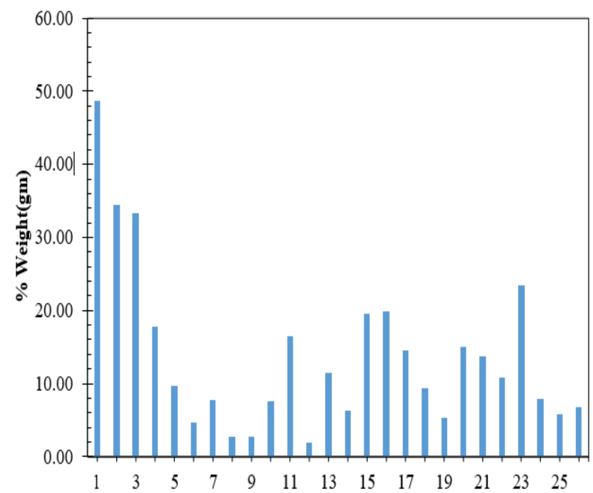


Figure 3: Effective sizes of road dusts on 26 locations

Figure 4: Percentage of particles smaller than 75μm

3.2 Chemical Analysis

The minimum and maximum and mean value and standard deviation was determined. Table 2 showed the range and variation of effective size (D_{10}), mediansize (D_{50}), uniformity co-efficient (Cu), co-efficient of curvature (Cu), pH, electricconductivity, chloride concentration of the samples that were collected along the 39.5kmhighway of this mid-western region of Bangladesh. In this study, minimum concentration of Cl– was found as 13mg/L and maximum value was 21mg/L with an average value of 18.54mg/L. According to Litalien et al. (2020) up to 150mg/L concentration level, the soil is suitable for crops. The chloride contents found in our soil samples were way smaller than 150mg/L which is the permissible level of chloride concentration. So, the storm water that would carry the chemical contents from the road dusts to the farmlands would not affect the crop yield.

Table 2: Descriptive analysis of road dust samples

Parameters	Minimum	Maximum	Mean	Median	Standard deviation
D_{10} (mm)	0.09	0.220	0.135	0.12	0.036
D_{50} (mm)	0.14	0.290	0.251	0.26	0.030
C_u	1.16	2.710	2.090	2.08	0.410
C_c	0.72	1.60	1.21	1.17	0.27
pH	6.90	7.5	7.15	7.10	0.21
Alkalinity (mg/L)	2.90	3.3	3.092	3.10	0.11
EC (μS/cm)	150	500	300.00	150.00	119.164
Cl^- (mg/L)	13.00	21.00	18.54	19.00	2.35

There were several points near which road or building construction works were going on such as road widening in the Rajshahi City Corporation area and some other disjunct building constructions were going on here and there. Higher pH values were found around these types of areas. The reason behind this was almost all the construction materials that are usually used are of alkaline properties with high pH values. Islam et al. (2017) found that the average pH value of soil around the Rajshahi, Natore area is moderate. Since, higher pH values were obtained in the same areas, it can be said that the construction materials are the driving factor for the higher pH values as a newly casted concrete has pH value of higher than 12 and less downed to the value of 7.5 to 9 (Ismail & Sadek Ghabrial, 2009). Kasimov et al. (2019) found an average electric conductivity of 211μS/cm inside the city of Moscow, Russia whereas the study found an average 168.27μS/cm with maximum 300μS/cm and minimum of 100μS/cm. The higher values are from the market areas and the lower values are from the areas of road between farmlands which also clenched the background data used on that paper such as 70μS/cm on the forest areas. Road dusts had high EC, which is due to the presence of significant quantities of soluble substances of technogenic origin e.g., mobile battery, battery water etc. Again, P. Rácz (2009) analyzed that the loose soil has higher electric conductivity. Since the road shoulders on the market areas are subjected to more abrasion, those soil would have higher conductivity than other areas. The data found in the study also supported that analysis.

4. Conclusions

Road dust samples were analyzed, and the results revealed some significant information on the physical and chemical properties of the dust. The majority of the dust samples were badly graded, according to the Particle Size Distribution (PSD) curves, most likely as a result of continual abrasion from vehicle movement. The pH value of 7.2, which is close to neutral, denotes a balanced composition with few acidic or basic components. The alkalinity readings and pH values matched, supporting the samples' overall neutrality. Higher electrical conductivity (EC) values were found in market and heavily populated regions, indicating the impact of human activity on the makeup of road dust. Due to the ease of inhalation, the presence of particulate matter with a diameter less than 75 m, averaging at 26.50%, poses possible health hazards. However, there were no statistically significant associations between EC and effective size or between median size and effective size. These findings highlight the need for actions to limit emissions and prevent potential health and environmental consequences by offering insightful information about the physical and chemical properties of road dust. To provide a safe and healthy environment for the community, additional study and suitable action are required to address the problems related to poorly graded dust, high electrical conductivity, and the presence of fine particulate matter.

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