Published Online October 2022

Dept. of Mech. Engg.
CUET

Mechanical Engineering Research Journal
Vol. 12, pp. 30-40, 2020

ISSN: 1990-5491

PRIORITIZING THE FACTORS INFLUENCED PARTICULATE MATTER EMISSION APPLYING FUZZY TOPSIS

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ABSTRACT

Particulate matter (PM) is a key component of ambient air that has a significant influence on climate change and is harmful to human health. Particulate matter in the high atmosphere affects the earth's radiation, cloud formation, visibility of aviation traffic, and other natural processes. In contrast, particulate matter is a substantial obstacle in the lower atmosphere. The most concerning problem is that it harms human health and has a negative influence on natural systems such as forests, animals, and coastal regions. With the presence of PM, air quality continues to degrade. To address this issue, it is critical to understand the underlying causes of pollution. PM is made up of a variety of small particles that can stay in the air for a long time and enter respiratory tracts and lungs. The properties and concentration variations of PM are determined by the origin of these substances. Crystal matter, vehicle traffic and fuel burning, urbanization, industrialization, climatic change, natural resources, and other factors all contribute to significant variations in particulate matter concentrations. This research evaluated, identified, and classified the sources of PM emissions in order to address the issue in the context of Bangladesh. Furthermore, FUZZY TOPSIS logic was used to prioritize the PM variables, which would aid in understanding the dangerous causes of PM emission from all general sources. Meanwhile, the real-time air quality was examined the recent time air quality. Monthly, weekly and daily variation of PM10 was analyzed for a selected time period to clarify the aspect.

Keywords: *Particulate matter, urbanization, eco system, meteorological change, FUZZY TOPSIS.*

1. INTRODUCTION

For an instance, PM (black carbon or soot) which works as a heat-trapping agent, absorbing solar radiation, and even at great distances, decreasing reflectivity (albedo) by settling in snow and ice [1,2].

The contribution of particulates (from coal, diesel, and biomass burning) to climate change has been underestimated until recently. Though short-lived, the global warming potential per volume is 500 times than that of CO_2. On the other hand,

Received : *30 January 2021*
Revised : *18 January 2022*
Accepted : *21 April 2022*

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Numerous epidemiological studies have demonstrated adverse effects of particulate matter exposure on human health [4,5,6,7,8]. In addition, many developing countries are facing lot of troubles which are consequences of air pollution and it's becoming an acute problem day by day. For example, PM (black carbon or soot) acts as a heat-trapping agent while also absorbing solar energy and lowering reflectance (albedo) [3,4]. In recent years, the impact of particles (from coal, diesel, and biomass burning) to climate change has been overestimated. On the other hand, several epidemiological studies have shown that particulate matter exposure is harmful to human health [5,6,7,8]. Particulate matter (PM) of very tiny diameters enters the respiratory system by inhalation,

causing respiratory and cardiovascular illness, reproductive and central nervous system malfunction, and cancer. It has been proven that those who live in less polluted cities live longer than those who live in more polluted ones. [9,10].

Particulate matter (PM) in the environment is a complex mixture of solid and liquid particles floating in the air. Furthermore, the size, chemical content, and other physical and biological features of particles change depending on their origin and time of birth. As a result, numerous sources are responsible for increasing the density of particulate matter in ambient air. There are several causes of particulate matter emissions, including forest fires, as well as numerous repercussions of human activity, such as car emissions, the operation of manufacturing enterprises or coal power plants, and the use of biomass for cooking and heating. Particulate matter is mostly derived from natural and anthropogenic sources, with a significant portion created by anthropogenic activities such as building, fossil fuel combustion, bush burning (wildfires), agricultural, industrial, and mining. Furthermore, increased burning of fossil fuels during the previous century is to blame for changes in the composition of air pollutants in the atmosphere.

The study's main goal was to evaluate the most common causes of PM and categorize them so that they may be used in future research to find solutions to these recurring problems. To prioritize these sources, the decision-making tool FUZZY TOPSIS was employed. Because this instrument is new to this research sector, this study will assess the credibility of FUZZY TOPSIS. Chattogram, Bangladesh's largest city, was chosen to examine and prioritize the sources of PM. Furthermore, to assess the real-time situation of air pollution in this place, the real-time air quality level was studied from September to December of 2019. Data for this study were obtained from Bangladesh's Department of Environment's Continuous Air Quality Monitoring Station (CAMS).

2. FORMATION OF PARTICULATE MATTER

When particulate matter is discharged into the atmosphere, it instantly begins to engage in a broad spectrum of chemistry and physics. The chemical and physical composition of particulate matter (such as size, shape, and number) can be severely changed until they are eventually removed from the climate by regular cycles [11]. Aerodynamic diameter measurement is used in this cycle to assess molecular size [12]. Wilson and Suh presented a schematic graph of an environmental particle airborne surface area circulation that included the primary sources of mass for each mode, the prime cycle associated with embedding mass in each mode, and the key expulsion mechanisms[13].

The three "modes" or size ranges of ambient air PM are ultrafine, collecting, and coarse particles. Ultrafine particles have a diameter of less than 0.1m and are created with the help of nucleation and concentration processes . Newly born particles from any source are included in nuclei mode. Particles in the nucleation range have a one-hour lifetime because they soon agglomerate with larger particles or fill in as cloud and haze bead cores. This size range is only discovered when fresh discharge sources are close to a measurement site or when new particles have just formed in the climate [14]. Coagulation quantifies transform these nuclei into larger size particles (PM0.1). Some particles characterized with a diameter between 0.1 and 2.5 m and are created by the gathering and coagulation of smaller particles, they are known as amassing mode particles. The combustion of fossil fuels and secondary atmospheric change are the common sources of PM2.5 particles. Particles made up of a few smaller particles are linked to the larger particles or to one other, and they fly through the air as a single molecule. In the amassing mode, the agglomeration of nuclei onto particles reduces the number of nuclei by 79 percent per hour. Coagulation, according to Whytlaw-Gray and Patterson should be an important factor affecting the size distribution of atmospheric particle aerosols[15,16]. Junge went on to say that the lower end of the particle size distribution, below 1.0m, is determined by the sense of balance between the sources and the coagulation decomposition of the particles [17]. The larger particles come to blows quickly, while the medium-sized ones take their time. The unit density sphere can be used to design the relationship between particle diameter and setting velocity [18]. Table 1 lists the most prevalent sources of PM.

Table 1: Sources of Particulate matter

	Sources	Classes	Reference
1	Urban construction project	Urbanization	19,20,21
2	Over population		
3	Multiple building construction		
4	Road construction reappearing		
5	Mobile emission		
6	Burning of fossil fuel	Combustion	22,23,24
7	Burning dust of straw waste		
8	Burning biomass		
9	Coal combustion		
10	Non ferrous metallurgy	Industrialization	25,26,27
11	Heavy material processing (steel & iron)		
12	Textile and clothing industry		
13	Chemical industry		
14	Electronic industry		
15	Coal power plant		
16	Soil dust	Primaryand natural sources	28,29,30
17	Forest fires		
18	Sea salt		
19	Mineral plant		
20	Volcanic eruption		
21	Cooking	Indoor sources	31,32,33
22	Vacuuming		
23	Smoking		
24	Office equipment (computer, printer, photocopier)		
25	Temperature, rain fall, humidity		

3. SOURCE OF PARTICULATE MATTER IN CHATTOGRAM

Chattogram is the second largest city in Bangladesh, which is very famous for its commercial and business importance. previous studies 7 source factors for both coarse and fine PM fractions. The identified sources are brick kilns, wood burning, metal smelters, road dust, motor vehicles, soil dust, sea salt, Zn source and fugitive Pb sources depending on the size fraction of PM. The city dweller suffers various health issues for extreme levels of particulate matter concentration.

3.1 Brick kiln

Brick kiln is a very important industry in Bangladesh, 1% of the country's GDP depends on it and the livelihood of at least 1 million people depends on it. Due to the scarcity of stone, bricks are used as the main raw material in the architectural industry of the country and their use has increased by 5.6% annually between 1996 and 2005. The brick-making process has been identified as a risk factor for air pollution. Although brick-making is a necessary part of architectural construction, many brick kilns use old-fashioned methods that waste energy and are more polluting.

The brick kiln is identified as one of the sources for the increase of polluted particles in the air of Dhaka city. During 2006-07, the number of airborne contaminants from brick kilns was significant. Hundreds of brick kilns in Chattogram are being run illegally and rules and regulations are not being followed in them, due to which the amount of polluted air and polluted particles emitted from this sector is increasing day by day.

3.2 Motor vehicles emission

Improper vehicle maintenance, a lack of enforcement measures for emission requirements, and insufficient traffic management, resulting in very sluggish traffic speeds, are all to blame for excessive vehicle emissions. High levels of emissions are occurring, notably from diesel cars and motorbikes, due to their low levels of engine technology and a lack of a comprehensive vehicle emission inspection and maintenance (I&M) program, as well as the overall poor application of vehicle emission requirements. Various forms of toxic hydrocarbons and organic oxygenates (acrolein, acetaldehyde...), carbon monoxide, nitrogen oxides, and soot particles release from motor vehicle exhaust, posing a major health risk to humans [vehical emission report].

Chattogram (latitude 22.22N, longitude 91.47E) contains Bangladesh's largest port and is extensively traveled, with the core city area encompassing around 10km2. The city's primary road network runs northward into the port region and southward toward the industrial sectors. These highways are likewise extensively traveled, with constant traffic congestion throughout the day. Trucks transporting goods between the port and industrial areas account for a significant portion of the traffic, and the combination of the area's hilly terrain, the stop-and-go nature of the congested traffic, and the age and heavy loading of the majority of the trucks results in large emissions of black diesel smoke.

3.3 Road dust

Road dust is composed of solid particles created by mechanical material processing such as crushing, grinding, quick impact, handling, detonation, and decrepitation of organic and inorganic materials such as rock, ore, and metal. When this dust becomes airborne, it is known as road dust. The friction of tires driving over unpaved dirt roads and dust-covered paved roads causes this dust to become airborne. Fugitive dust is dust that does not come from a specific point source, such as industrial smokestacks. Potential sources of this type of dust include open fields, roadways, and storage piles . Solid trash in Chattogram is derived from a number of building construction operations as well as a variety of other municipal activities that is also causes road dust.

3.4 Sea salt

The presence of sea salt in Chattogram's atmosphere may be seen due to its geographic location. Relations between unclean air and sea salt aerosol from the ocean can result in high surface ozone levels, impacting air quality in densely populated coastal areas. Chlorine is well-known for its role in the breakdown of stratospheric ozone, which culminated in the formation of the ozone hole and the exposure of the Earth's surface to hazardous quantities of UV radiation. Chlorine, on the other hand, can promote ozone formation in the right chemical conditions, such as near the Earth's surface. In this situation, ozone acts as a pollutant, harming people, materials, and plants.

3.5 Zn sources from industry

Various enterprises in Chittagong utilize Zn for electroplating (Pb is added to increase reflectivity). The battery sector, as well as the secondary Pb smelter, where rejected batteries are reprocessed to manufacture new Pb batteries, are the other Pb sources. Steel mills, on the other hand, produce a significant quantity of PM. Cement plants in Chittagong has an impact on their environment. All these industries have strong influence to increase air pollution

3.6 Burning wood and solid waste

Chattogram City Corporation generates hundreds of tons of municipal solid trash every day. Combustion is the only way to dispose of these wastes, which create a large quantity of smock, particulate matter, and other air pollutants throughout the process. Similarly, in several Chattogram castles, burning wood has played an important role in increasing pollution.

3.7 Various Construction Project

Fine particulate matter (PM2.5) is mostly produced by brick kilns and motor vehicles, whereas coarse particulate matter (PM10) is produced by building construction and road dust in Bangladeshi cities such as Chattogram. According to the Chattogram Citi company, 17 development projects that are a major cause of air pollution have been underway in the last year. They highly accountable for PM10 emission.

Table 2: Ongoing development projects in recent year

SL No.	Projects
1	Improvement of Port Connecting Road by RCC from Alanker to Nimtola. (Ch-0.00km-2.00km)
2	Improvement of Port Connecting Road by RCC from Alanker to Nimtola. (Ch-2.00km-4.00km)
3	Improvement of Port Connecting Road by RCC from Alanker to Nimtola. (Ch-4.00km-6.00km)
4	Improvement of Agrabad Access Road by over lay and wideining with RCC
5	Construction of 1200 m long overpass starting from Sagarika road Alankar crossing to A. K. Khan Crossing
6	Construction of 1200 m long overpass at Jakir Hossain Road Rail crossing (1)
7	Construction of 650 m long overpass at New Market Crossin
8	New construction of Six Stored building at Patanga girls high School & College cum Cyclone shelter
9	New construction of Mohabbat Ali Girls High School cum Cyclone shelter
10	New construction of Ahmed Mia City Corp. girls School cum Cyclone shelter
11	Re-construction of Laldighi central disaster management control office, library and community center cum cyclone shelter
12	Re-construction of East Madarbari girls high school cum cyclone shelter
13	Re-construction of West Madarbari girls high school cum cyclone shelter
14	New construction of Patantully boys high school cum cyclone center
15	New construction of Rabindra Nazrul high school cum cyclone center
16	Construction of 65m bridge on Marinars Road
17	Re-construction of road by RCC from Sotsong Asrom Nibashi to Soroni Road (2.0 km)

4. METHODOLOGY

The entire research process is divided into six parts which was discussed in the paper. Flow Chart of the methodology is depicted in Fig. 1

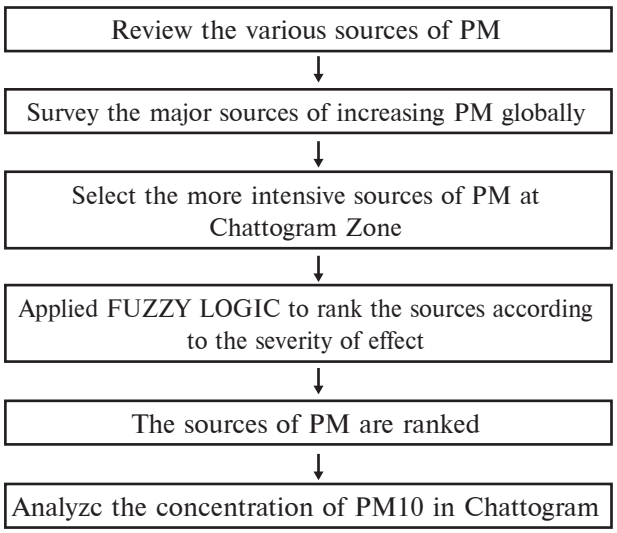

Fig1: Flow chart of the research process

5 PRIORITIZING THE SOURCES OF PARTICULATE MATTER WITH FUZZY ALGORITHM

Chattogram is Bangladesh's largest industrial district, where city people face a severe difficulty with the increasing concentration of PM This condition is caused by a wide variety of factors. Because Chattogram is an industrial zone, two sorts of industries are commonly found here: textile and garment industry and heavy metal industry (steel industry). As a result, one of the primary issues is their contribution to rising PM. On the other side, the ongoing urbanization process is also to blame for this air pollution problem, as are construction projects, automobile emissions, and overcrowding. To fix this problem, it is vital to identify which fundamental factors are contributing the most to it. A survey was conducted to determine the primary reasons of rising PM levels. However, nine intense sources are chosen from a variety of sources for additional investigation. The study's goal was to rate these nine sources based on

their intensity. Fuzzy TOPSIS, a multi-decision -making algorithm, was used to identify and ranked the sources that are mostly responsible for the increase in PM in the air. Tables 3, 4, 5, and 6 describe the entire calibration and ranking process. For this estimate, the opinions of four experts in this subject were evaluated.

5.1 FUZZY algorithm

The Fuzzy TOPSIS method is used to prioritize PM sources. This algorithm has eight stages. These stages are outlined in full below:

Step1: collecting data from the decision maker and convert them into FUZZY number.

Step 2: The TOPSIS method evaluates the following fuzzy decision matrix. This step includes neutralizing the weight of decision matrix and generating fuzzy un- weighted matrix (R).To generate R, following relationship can be applied.

Step 3: Generate a weighted normalized decision matrix.

Step 4: Determine the ideal and negative-ideal CSF solutions.

Step-5: Calculate the sum of distances from positive and negative ideal solution for each factor.

Step-6: Calculate the relative closeness to the ideal solution.

Step-7: Prioritize the preference order based on the order of the values of C_{j-}

5.2 FUZZY Calculation

The factors that influence PM emission were chosen with a focus on the geography and current sources of PM in Chattogram, and four decision makers were selected to rate them. All decision-makers were specialized in this field.

Table 3: Decision matrix using linguistic variable

Factor	Decision Maker			
	D1	D2	D3	D4
Road dust (C1)	FH	M	FL	M
Construction project (C2)	FH	M	M	FH
Burning wood (C3)	M	FH	H	M
Solid waste burning (C4)	FH	FH	FH	M
Zn source from industry (C5)	FH	FH	M	H
Power plant (C6)	M	L	M	FH
Brick kiln (C7)	H	H	FH	FH
Sea salt (C8)	M	M	FL	L
Vehicles emission (C9)	M	H	M	M

Table 4: Distance D_j for criteria

Factors	Decision Maker				Average
	D1	D2	D3	D4	
C1	.342	.525	.719	.525	.528
C2	.342	.525	.525	.342	.434
C3	.525	.342	.183	.525	.394
C4	.342	.342	.342	.525	.388
C5	.342	.342	.525	.183	.348
C6	.525	.876	.525	.342	.567
C7	.183	.183	.342	.342	.262
C8	.525	.525	.719	.876	.661
C9	.525	.183	.525	.525	.440

Table5: Distance D− for criteria

Factors	Decision Maker				
	D1	D2	D3	D4	Average
C1	.719	.526	.342	.526	.528
C2	.719	.526	.526	.719	.622
C3	.526	.719	.879	.526	.662
C4	.719	.719	.719	.526	.670
C5	.719	.719	.526	.879	.710
C6	.526	.183	.526	.719	.89
C7	.879	.879	.719	.719	.796
C8	.526	.526	.342	.183	.397
C9	.526	.879	.526	.526	.614

Table 6: Closeness coefficients (CCi) of the three alternatives

S No	Factor	D^*	D^-	C	Priority
1	Road dust (C1)	.528	.528	.500	7
2	Construction project (C2)	.434	.622	.590	5
3	Burning wood(C3)	.394	.662	.627	4
4	Solid waste burning (C4)	.388	.6708	.634	3
5	Zn source from industry (C5)	.348	.710	.716	2
6	Power plant (C6)	.567	.489	.463	8
7	Brick kiln (C7)	.2623	.796	.752	1
8	Sea salt (C8)	.661	.394	.373	9
9	Vehicles emission(C9)	.440	.614	.582	6

To prioritize the CSFs for reducing PM sources, nine factors were considered: road dust (C1), construction project (C2), burning wood (C3), solid waste burning (C4), Zn source from industry (C5), power plant (C6), brick kiln (C7), sea salt (C8), and vehicle emissions (C9). Four

decision makers, DM1, DM2, DM3, and DM4, were asked to assess the significance of the aforementioned CSFs on a 5-point scale using the language labels low (L), fairly low (FL), medium (M), pretty high (FH), and high (H). Table 6 shows the results. Among the nine CSFs, the most significant was Brick kiln, and the least important was Sea salt. The overall prioritization of CSFs are

CSF7> CSF5> CSF4> CSF3> CSF2> CSF9> CSF1> CSF6> CSF8

6. ANALYZE THE CONCENTRATION OF PM10 IN CHATTOGRAM

The network for monitoring ambient air quality Bangladesh has eleven (11) permanent Continuous Air Monitoring Stations (CAMS) that gather data on different particle and gaseous pollution levels. In Chattogram, there are two CAMS stations: one at the TV station, Khulshi, and another at Agrabad. Data from TV station CAMS could not be gathered due to technical issues. As a result, Agrabad CAMS data was used for this study. The ambient air quality data for particulate matter 10 were gathered from the Continuous Air Quality Monitoring Station (CAMS) in Agrabad, Chittagong, from September 2019 to December 2019. The Agrabad CAMS side is known as CAMS-7 (22.32N 91.81E), and it is a popular location in Chattogram owing to its closeness to the ports and the vast amount of cars that pass through it. The density of PM10 was calibrated according to monthly variation, weekly variation, and temporal variation to investigate the severity of PM10. All of these investigations demonstrated that the presence of PM10 varied monthly according to meteorological changes. Furthermore, it was observed that the variation in PM concentration is directly connected to the different times of the day.

6.1 The monthly discrepancy of average PM2.5

Figure 2 depicts the PM10 levels in Chattogram City in 2021. According to the research, the greatest concentration was 360.9789.30 rg/m^3 in December, while the smallest concentration was 29.9819.37 rg/m^3 in September. The month of December was found to be the most polluted of the four. Basically, air pollution rises throughout the winter season, which begins in October and ends in February. According to prior research, pollution levels begin to rise in October and peak between December and January. After then, it began to drop. This study significantly supports the statement, demonstrating that the density of PM10 increases from September to December. The fundamental reason for this situation is a decrease in temperature, humidity, and precipitation.

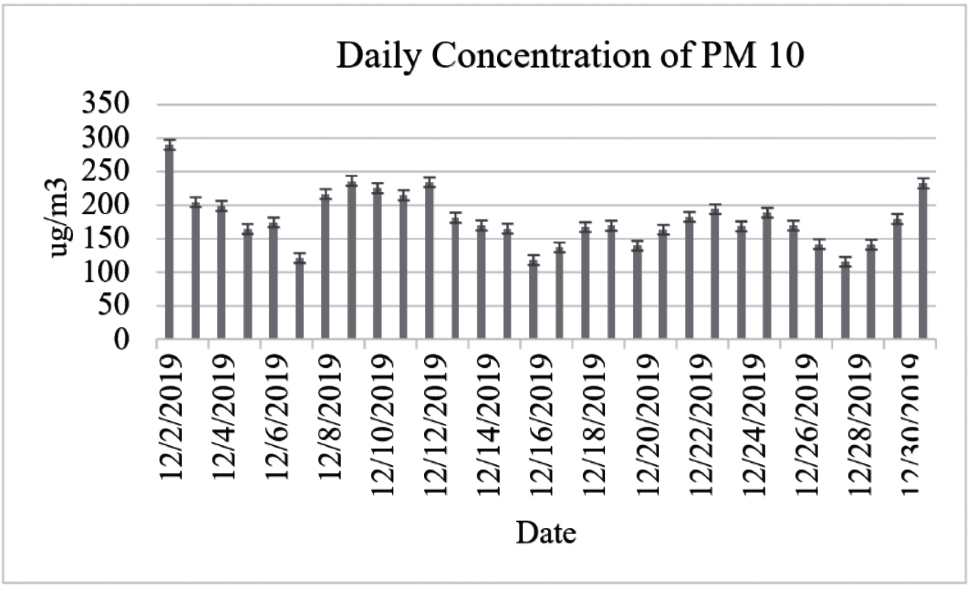

Fig 2 : Monthly variation of PM 10 Concentration from September to December 2019

6.2 Weekly variation of PM2.5

In the day-of-week analysis, the pollution levels generally follow a common pattern for each day of the week. No particular weekend effect was identified by this analysis. Figure 3 shows the fine particulate matter (PM10) concentrations were maximum on Monday (138.36±86.17 rg/m3) and minimum on Friday (103.35±63.72 rg/m3). Traffic flow in the city can be responsible for this little variation.

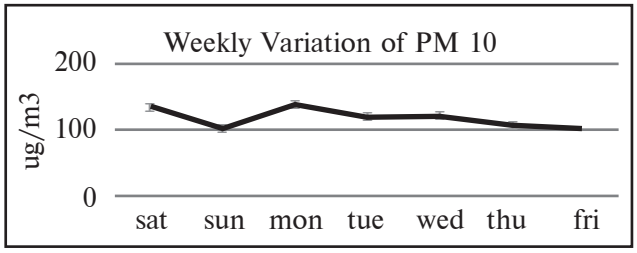

Fig 3: Weekly variation of PM 10 Concentration from September to December 2019

6.3 Shifting variation of PM2.5

In figure 4, the maximal PM2.5 concentrations (145.0886.56 g/m3) were detected in the evening, between 6pm and 9am. Interactions between pollution sources, photochemical processes, and meteorological conditions determine shift-wise fluctuations. High pollution concentrations detected at night may be due to local traffic flow laws in Chattogram (as diesel- powered buses and freight vehicles may only utilize the Dhaka city route at night between 10 p.m. and 5 a.m.), as well as low mixing height during the night.During the day, long-distance buses and heavy-duty diesel vehicles are prohibited from Dhaka to any roadway.

6.4 Number of AQI of PM2.5

A summary of the AQI ratings for Chattogram city in 2019 from September to December is presented in the Figure 5. In this study time, there were 672 hourly AQI “Good 1296were “Moderate,” 552 were rated “Unhealthy for sensitive groups,” 144were considered “Unhealthy”, 20 were rated “Very unhealthy” and 72 were found hazardous. Although some data could not be obtained, the quantity of missing data is so little that it may be overlooked. It was discovered that 45.38 percent of the hourly AQI were "Unhealthy." Although the categories "Very unhealthy" and "Hazardous" were 4.20 percent and 2.52 percent, respectively, this was enough to have an influence on human health.

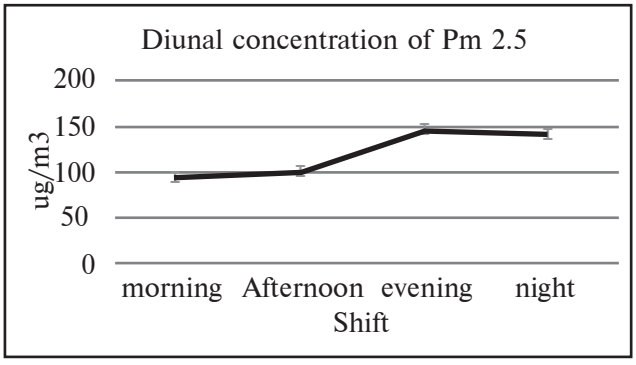

Fig 4: Diurnal average concentration of PM10

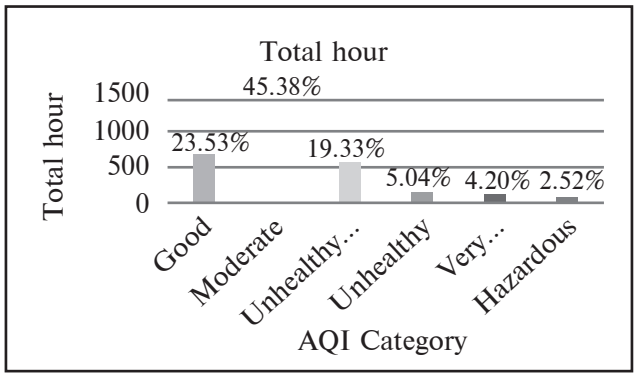

Fig. 5. Percentage of AQI in Chattogram city in 2019

7. CONCLUSION

PM has a negative impact on both the upper and lower atmospheres. Furthermore, the most susceptible concern is climate change, which is responsible for the increasing amount of PM in the air as well as its impact on human health. As a result, the study identified the critical sources of PM that contribute significantly to the growth in PM levels. In the future, this research will aid in categorizing the sources of PM and dealing with the issue. Because the study focused on the Chattogram area, which is one of Bangladesh's largest divisions, future studies in this area may be assessed using this research. Although brick kiln and industrial emissions have been recognized as the primary sources of air pollution, a variety of other causes are also to blame. In addition, the study revealed that December is the most hazardous month for air pollution, as the temperature, precipitation and humidity were low in this time. Similarly, it was instigated that the concentration of PM10 was high in night nigh time and the most of the time the air quality level of Chattogram was moderate. Finally, the research's analytical component indicated that the concentration of PM fluctuates over time depending on the month, week, and shift.

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