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A Quantitative Assessment of Air Particulate Matter Concentration and Its Correlation with the Climatic Factors of Dinajpur City, Bangladesh

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ABSTRACT

Particulate matter (PM) is the air pollutant that poses the most significant risk to human health compared to other measured criteria pollutants. One of our main goals was to assess the quantities of particulate matter (0.3-10µm) in the Dinajpur municipality's sensitive zones, roads, and residential and commercial buildings. Light scattering particle counters, the Extech VPC-300, were used to measure particulate matter and climatic data at 26 distinct locations in Dinajpur. R 4.2.2 and the data analysis tool in Microsoft Excel were utilized for the statistical analysis. The highest values for PM 0.3, 0.5, 1, 2.5, 5, and 10 µm are 335195, 138118, 37965, 12995, 2087, and 2507 and medium value is accordingly 221304, 71873, 16681, 3393, 361 and 454, respectively. The PM 0.5 µm particle range, which includes 12 samples, is highly concerned and getting closer to the hazardous red polluted zone. Most places of PM 2.5 µm exceed the 2000 particles, which are hazardous for people. The link between climatic variables and particulate matter (PM 0.5-10 µm) significantly correlated with temperature. Humidity and PM (0.3-10 µm) measurements in the study area show a negative correlation. According to observations, factors contributing to the high PM concentration include excessive human movement, combustion byproducts of black smoke, road dust, waste, garbage in every possible place, and rice mill industry emissions.

Keywords: Air quality, Particulate matter, Pollution, Health impact, Auto rice mill, and Climatic factor.

INTRODUCTION:

The relationship between air pollution and climate change negatively impacts the environment. Air pollution is the presence of harmful substances in the atmosphere that can negatively affect human health. Every person has the right to access clean air free of all types of contaminants. In 1987, the World Health Organization (WHO) published guidelines for air quality, mentioning the limits of all the parameters or substances that remain in the air (WHO, 1987). Air pollutants can take many forms, including gases, such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), oxides of nitrogen (NOx), and particulate matter (PM 0.3-10), which consists of tiny particles of dust, dirt, soot, and other materials suspended in the air (WHO, 2018). Numerous negative consequences that these pollutants may have include respiratory and cardiovascular issues, decreased visibility, acid rain, harm to crops and ecosystems, and many others (Wambebe and Duan, 2020). Both industrialized and developing nations are affected by the global issue of air pollution, a severe public health concern that causes millions of premature deaths annually (Hei, 2019). Particulate matter (PM) is a complex mixture of solid and liquid particles suspended in the air. These particles vary in size, shape, and content and can be naturally occurring or man-made. Between PM 2.5 µm and PM10 µm are the size ranges most frequently examined. Fine particles are those with a diameter of 2.5 µm or less, and coarse particles have a diameter of 10 µm or less.

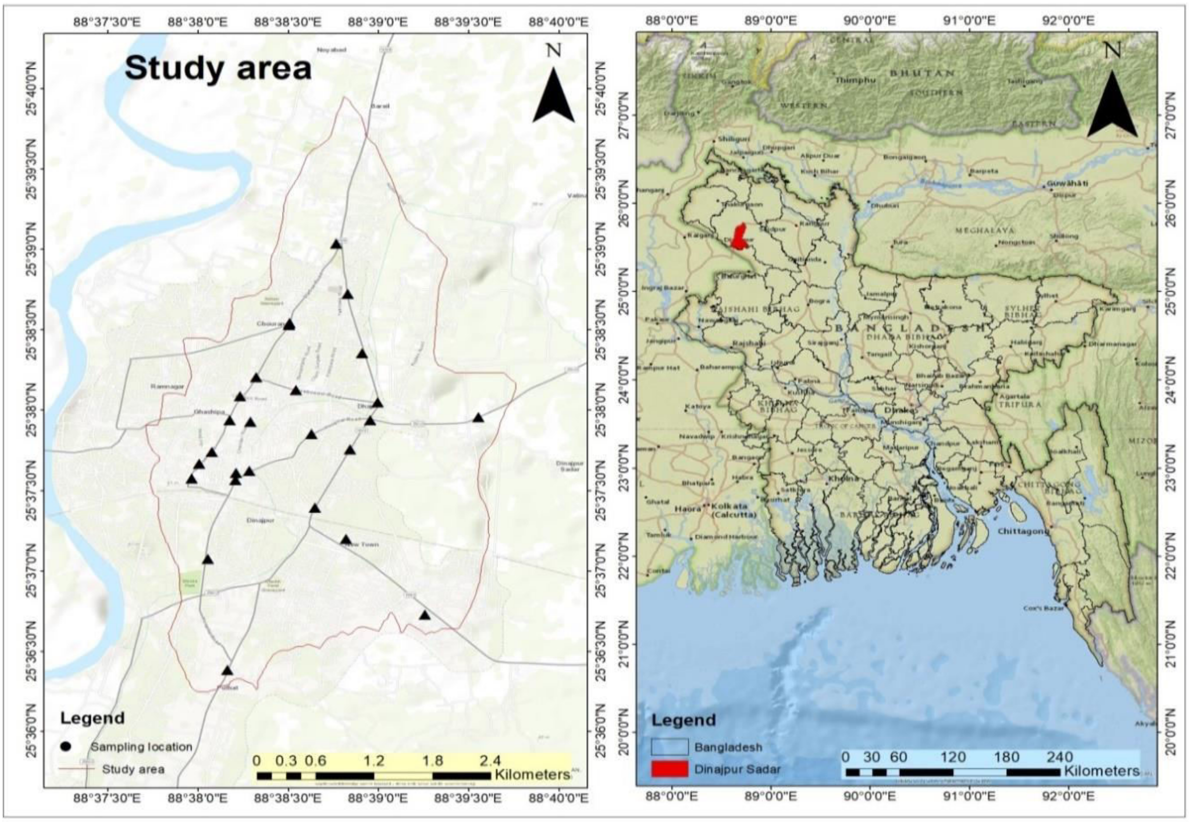
WHO reported that more than 91% of people in the world live in poor air quality areas concerning particulate matter (PM2.5 and PM10 µm), sulfur dioxide (SO_2), ozone (O_3), and nitrogen dioxide (NO_2) (WHO, 2018). PM2.5 µm is considered more harmful to human health because it can penetrate deep into the lungs and even enter the bloodstream. In so many cities where factories and automobiles are continuously operating, the air quality in these cities is inferior. The Atomic Energy Centre, Dhaka (AECD), a division of the Bangladesh Atomic Energy Commission (BAEC), monitors PM 2.5-10µm as a part of the regional air quality monitoring network of 15 countries in Southeast Asia (Hopke *et al.,* 2008).

According to studies, Dhaka has high levels of fine particulate matter, which has an ongoing negative influence on public health (Gurjar *et al.,* 2010). According to a 2012 report from the Department of Environment, air pollution is one of main environmental issues of Bangladesh (DoE, 2012). Bangladesh was listed as having the fourth-highest level of pollution among the 91 nations in the world (Haque and Rinkey, 2019). The study area, Dinajpur, has been growing at a rate that has coincided with the growth of the city and is also experiencing air pollution because of trade, commerce, shopping, education, culture, and other activities. The primary goals are to analyze the particulate matter PM (0.3-10 µm) condition in the Dinajpur municipality's sensitive zones, roadways, and commercial areas and to classify its sources. We also focus on the correlation between the PM and different climatic parameters.

METHODOLOGY:

Study Area

On a stable geographic topography, Dinajpur City is situated at 25°35′ N latitude and 88°40′ E longitude on the eastern bank of the Punarbhaba River. According to the census performed in 2023, the Dinajpur municipality has a total area of around 24.50 square kilometers, a population density of 7247 people per square kilometer, and 1,86,727 inhabitants (GoB, 2023).



Map 1: Sampling location of PM (0.3-10) of Dinajpur municipality.

Table 1: The Sampling point characteristics and weather parameters across the Dinajpur Municipality.

ID	Sampling point	Latitude	Longitude	Site Characteristics	Temperature (°C)	Humidity (%)
1	Barabandar Horishovar Moor	25.6354	88.64239	Residential, Commercial	30.7	76.8
2	Kalitola (Thanar Moor)	25.63674	88.63872	Residential, Commercial	31.3	77.3
3	Charubabur Moor	25.63475	88.63722	Commercial	32.4	77.8
4	Modern Moor	25.63229	88.63627	Residential, Commercial	31.2	74.8
5	Jail Road	25.62898	88.6346	Commercial	33.2	76.7
6	Lily Moor	25.62776	88.63346	Residential, Commercial	34.6	67.8
7	Station Road	25.62622	88.63276	Commercial	33.5	71.8
8	C&B Moor	25.61791	88.63425	Residential, Commercial	31.5	75
9	Pulhat Moor	25.60638	88.63608	Commercial, Industrial	32.7	71.1
10	In front of the Diabetic Hospital	25.61996	88.646981	Commercial, Healthcare	32.7	71.2
11	North Balubari Gov. School	25.630863	88.643803	Residential, commercial, Educational	31.5	74.5
12	Mata Sagor Dumping area	25.632621	88.659239	Residential, Dumping station	32.8	75
13	Chourangi Moor	25.642176	88.641752	Commercial	31.7	75.6
14	Nimtola Moor	25.632105	88.638171	Residential, Commercial	31.4	77.2
15	Butibabur Moor	25.626788	88.636837	Residential, Commercial	32.2	77.1
16	Labaid diagnostic Center	25.627029	88.638075	Healthcare, Commercial	33.1	75.5
17	Sadar Hospital	25.626054	88.636824	Healthcare, Commercial	32.5	75.7
18	Chirirbandar Bus Stand	25.63412	88.649905	Bus terminal, commercial	32.8	74.1
19	Maharaja School	25.632254	88.649239	Residential, Commercial	31.7	72.8
20	Dinajpur Polytechnic Institute	25.623224	88.644145	Residential, Educational	32.2	75.1
21	ARMCH	25.612113	88.654262	Educational & Healthcare	32.1	76.4
22	Mount Everest College	25.639227	88.648492	commercial, Educational	32.7	74.1
23	Central Bus Cerminal	25.64539	88.647157	Bus terminal, Commercial	33.8	69.4
24	7 no ward waste dumping site	25.629253	88.64735	Residential,	32.5	71.8
25	Shuihari	25.642375	88.641803	Residential	31.9	72.5
26	Dinajpur Govt. College	25.650587	88.646103	Educational	32.1	76.8

Particulate Matter Measurement and Analysis

For this research, the PM (0.3-10 µm) value from the outside of the workplace environment was obtained. Data on the particulate matter have been gathered from 26 distinct locations (**Table 1**). Data was obtained using differential mode by the Extech VPC300 model. Differential mode measures all particles that are greater than or equal to the particle size selected in the Sample Volume field but less than the next largest particle size (Extech Manual, 2016). Statistical analysis was completed by using R 4.2.2 and Microsoft Excel.

RESULT AND DISCUSSION:

The city of Dinajpur has a mean of 454 for PM 10 µm, with the highest value being 2507 and the lowest being 52. Conversely, 335195, 138118, 37965, 12995, and 2087 have the highest values of PM 0.3, 0.5, 1, 2.5, and 5 µm, respectively. The EXTEC VCP 300 reference format indicates that the majority of the areas are highly polluted, as indicated by this measured result. Particulate matter concentrations are more significant in dry conditions, as indicated by the temperature and average humidity of 75.0%. Based on the measured statistics, the air quality of the study area is very unhealthy for individuals.

Table 2: A matrix showing the correlations between climatic variables and Particulate Matter (PM 0.3-10 µm).

PM Size	*PM 0.3*	*PM 0.5*	*PM 1*	*PM 2.5*	*PM 5*	*PM 10*
Temperature	0.08	0.11	0.19	0.24	0.17	0.22
Humidity	-0.05	-0.05	-0.08	-0.08	0.01	-0.06

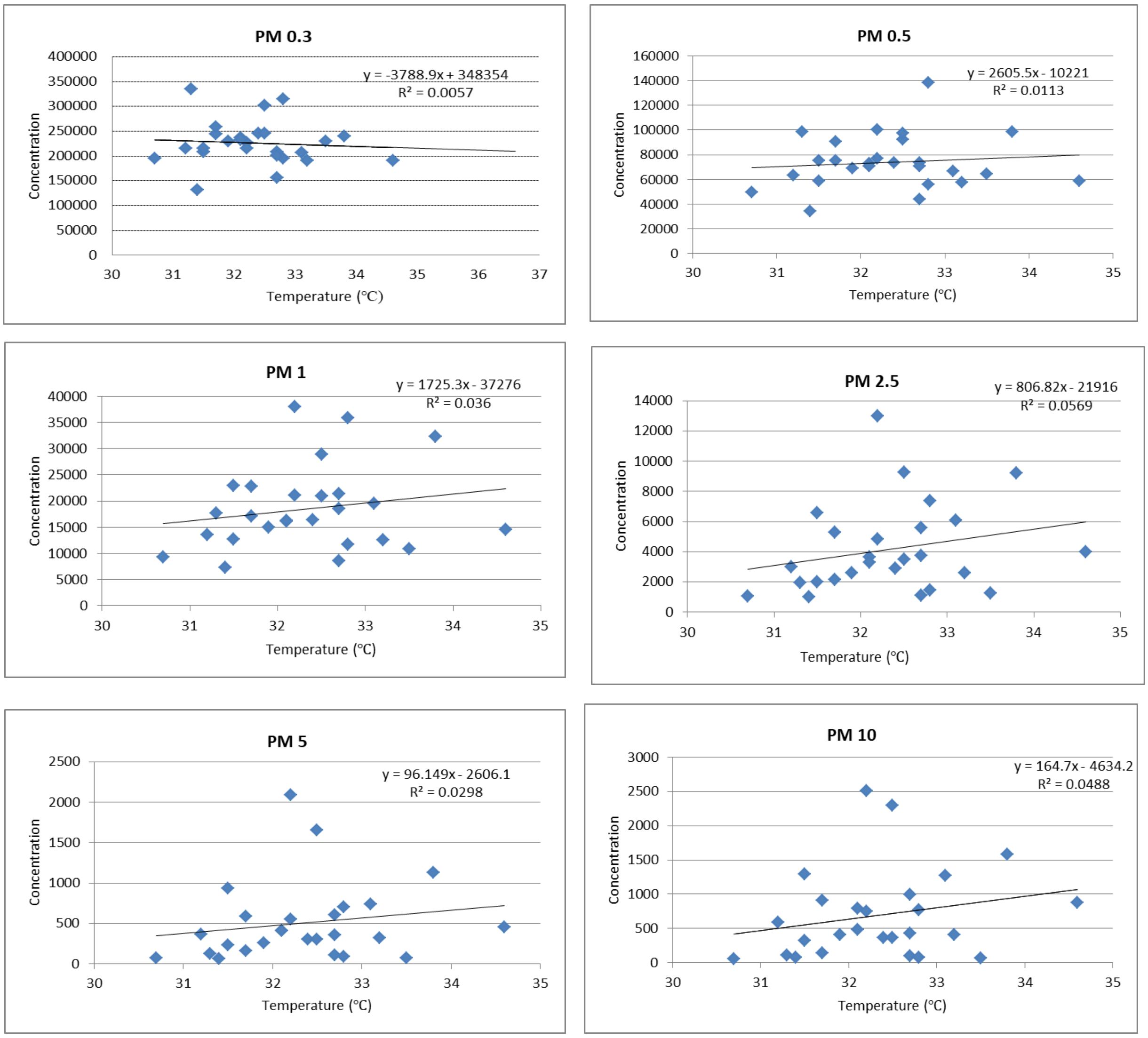


Fig. 1: Linear regression analysis of particulate matter (PM 0.3-10) with temperature.

The correlation value between climatic variables and particulate matter (PM 0.5-10 µm) (**Table 2**) is significantly correlated with temperature. Humidity and PM (0.3-10 µm) had a weak or negative correlation when measured in the study area. It implies that while PM spreads more quickly through the air when temperatures rise, its spreading is inversely correlated with increasing humidity levels. The linear regression analysis of temperature and particulate matter (PM 0.3-10 µm) is shown in **Fig. 1**. The coefficient shows that for every additional degree Celsius, PM increases by 0.3 on average.

Table 3: Air quality standard referenced in Extech manual, 2016.

Channel	Green	Yellow	Red
0.3um	0 to 100,000	100,001 to 250,000	250,001 to 500,000
0.5um	0 to 35,200	35,201 to 87,500	87,501 to 175,000
1.0um	0 to 8,320	8,321 to 20,800	20,801 to 41,600
2.5um	0 to 545	546 to 1,362	1,363 to 2,724
5.0um	0 to 193	194 to 483	484 to 966
10.0um	0 to 68	69 to 170	171 to 340

However, the r^2 values for PM 0.5, 1, 2.5, 5, and 10 µm are often low and have poor relationships with temperature. However, its significance at 1-5% indicates that particles have floated on air and that the dissemination of air particles is dependent on environmental factors. It shows that there are a few severely harmful regions, and the bulk of samples fall between the 200000-250000 particle range, which is regarded as a range of danger for humans.

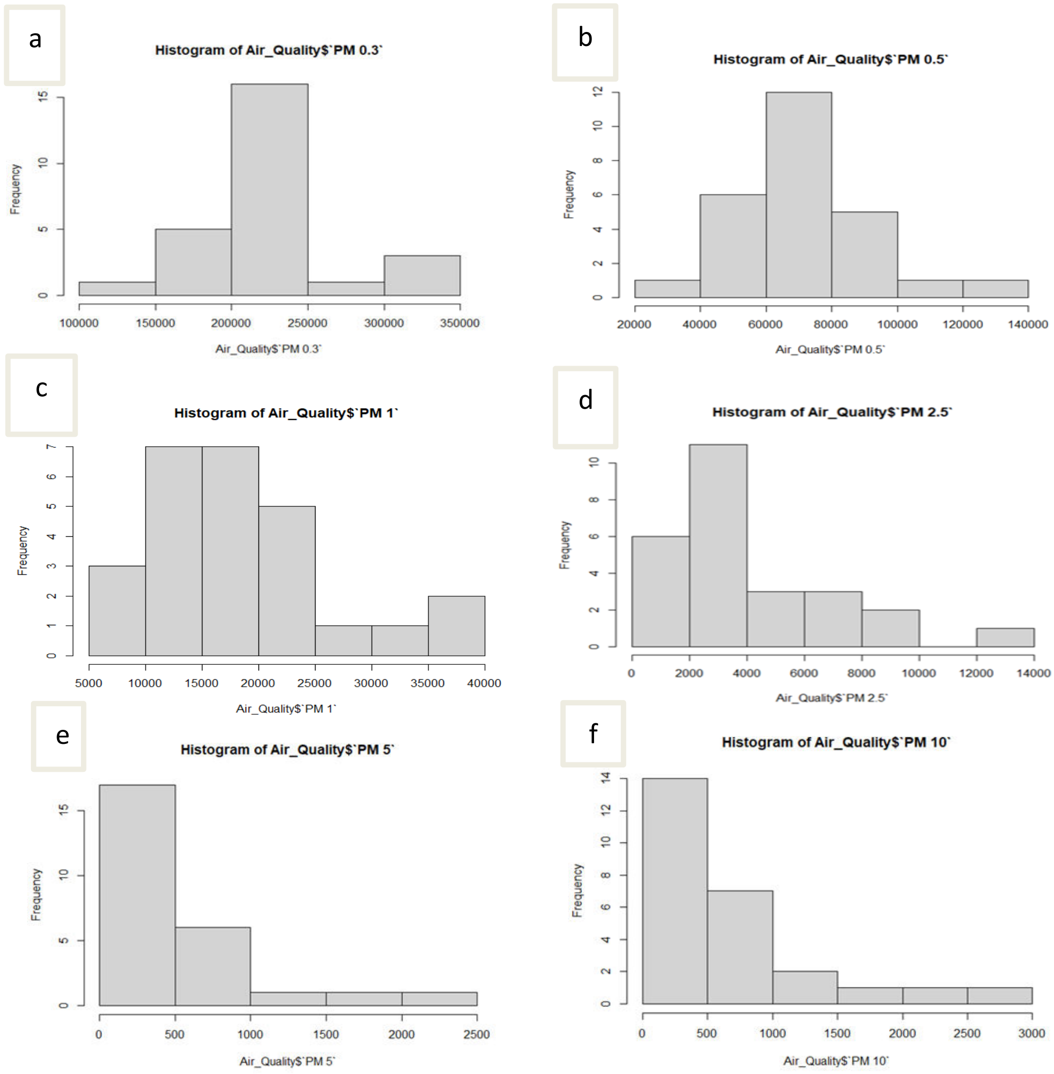


Fig. 2: Histogram on air particulate matter PM (0.3-10µm).

Similarly, **Fig. 2(b)** indicates that this histogram is unimodal, symmetric, and has no outlier. The PM 0.5 µm particle range 60000-80000 comprises of 12 samples, and while that range is cautious, it is moving into the dangerous red zone (**Table 3**). **Fig. 2(c)** states that the majority of the sampling regions are covered by PM 1 µm ranges of yellow categories (cautious) and that air movement spreads those to the entire city. The fact that over half of the sample point falls into the 20000-41000 red category (dangerous) range raises concerns. However, the PM 2.5 µm histogram indicates that these places PM 2.5 µm concentrations cover the red (hazardous) limits, which are extremely unhealthy for the local population. The majority of PM 5 µm readings are higher than the yellow and red zones, which denote low levels of air quality. The lowest number for PM 10 µm is 52 particles, which is very close to the yellow categories. However, another particle value covers the yellow (Cautious) category and exceeds the green (excellent) categories. It shows that after departing the warning zone, the highest sampling locations moved into dangerous regions. We observed that Butibabur Moor, a mixed-use area with both residential and commercial properties, had the highest rates of PM 1, 2.5, 5, and 10 µm particles. The values of 37965, 12995, 2087, and 2507 PM show that they are all in the red range, which is exceedingly harmful to human health. In addition to more residential areas, some of which are also outlined in yellow and red. Airborne particles often stand close to the red category and cross the yellow line in vulnerable regions, such as hospitals and schools. Because it affects patients' bodies quickly, it is a major problem for elderly people, babies, and other residents. However, gathering areas that provide a risk, such as bus and commercial terminals, are classified as red. In those areas, the highest concentration of PM 2.5 µm particles is 9268, while the lowest is 1113. The primary causes of rising airborne particles include people assembling, road dust and burning fuel from moving automobiles, transport, and brick crushing. Since the production of rice is the primary industry in this city, one of the main sources of PM was also a nearby automatic rice mill that released smoke and ash into the environment. In comparison to dry or rainy seasons, the air pollution level of Bangladesh gets worst in the winter season (Shams, 2017). The most lethal particles are those with a diameter of fewer than 10 micrometers because they can penetrate deeply into your lungs and some may even enter your bloodstream (EPA, 2022). Extremely sensitive people may think about restricting back on extended or strenuous activity in yellow zones. However, anyone with heart or lung illness, elderly people, and children should avoid prolonged or strenuous activity in red-flagged regions (EPA, 2022). Health impacts from particle exposure can take many different forms. Lowered lung functions, the formation of chronic bronchitis, and even early mortality have all been associated with long-term exposures, such as those persons who spend a lot of time in high-particle environments (American Lung Association, 2023).

CONCLUSION:

This research indicates that the Dinajpur municipality has high PM levels, which continue to have detrimental effects on public health. The vast majority of the sampling sites have air quality levels that are unhealthy to hazardous, exceeding green categories and changing from yellow to red zones. A risk to the public's health as well as that of patients, children, and expectant mothers exists because the red categories are close to the residential and sensitive zone. The transportation sector, roadside dust, and auto rice mill plants all released significant amounts of particulate matter. The transboundary transfer of PM, however, cannot yet be quantified. The quality of the air is greatly harmed by a lack of frequent monitoring and inspection of the major PM sources which must be addressed and evaluated appropriately.

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CONFLICTS OF INTEREST:

The authors declare that there is no conflict of interest.

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