RELATIONSHIPS BETWEEN METEOROLOGICAL PARAMETERS AND PM_{10} CONCENTRATIONS AT URBAN LOCATION IN HA NOI CITY FROM 2010 TO 2019

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Abstract: *This paper evaluates the effects of meteorological factors including temperature, humidity, wind speed and precipitation on PM_{10} concentration at Nguyen Van Cu air quality monitoring station in Hanoi during the period of 2010-2019. The Spearman correlation coefficient between PM_{10} concentration and precipitation is negative implying an appearance of the washing effect. In addition, the relationships between PM_{10} concentration and wind speed as well as temperature are also inversely correlated which means when the air was stagnant, less disturbed and diffused due to low wind conditions, the concentration of PM_{10} would increase. Moreover, humidity has a positive correlation with PM_{10} concentration. Through the linear correlation analysis, it can be determined that most of the PM_{10} that appeared in the area had an anthropogenic origin, largely due to emissions from transportation activities.*

Keywords: *PM_{10} concentration, meteorology, air pollution, Spearman.*

1. Introduction

Dust pollution has recently been considered one of the emerging issues in Viet Nam. In 2016, the National Environmental Status Report showed that the average annual concentration of PM_{10} (particulate matter with a diameter of 10 micrometers or less) in big cities such as Ha Noi, Ho Chi Minh, Hai Phong, and Da Nang generally exceeded the recommendations of the World Health Organization (20 µg/m^3) [8].

In general, meteorological factors (wind direction, wind speed, temperature, relative humidity, and precipitation) are closely related to the formation, accumulation and dispersion of air and dust pollutants into the surrounding environment [2]. According to Zheng et al. (2013) [12], air quality will be assessed as good with high temperatures and low humidity; meanwhile, high dust concentrations could appear at low or high wind speeds instead of moderate wind speeds. In general, wind speed is one of the most important parameters affecting dust concentration. Higher wind speeds lead to better dust dilution, or precipitation can create a washing effect [2]. Relative humidity can be positively correlated with finer dust particles by increasing their hygroscopic properties and solubility in the atmosphere, and inversely correlated with coarse dust particles because it reduces the formation of particles [7]. Changes in temperature during winter days may be related to heat inversions that reduce disturbed boundary layers height and dust diffusion [3]. Small dust concentration during summertime is associated with high temperatures and good disturbance [10]. Generally, in the context of climate change, the effects of meteorological factors on air pollutants become increasingly concerned [4]. The knowledge of weather conditions and their impacts on air pollution can assist in devising specific strategies to reduce pollution in cities [6].

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Until now, very few studies related to the impact assessment of meteorological factors on air pollution in general and dust pollution in particular have been published in the country. This study aims to evaluate the impact of meteorological factors such as temperature, humidity, wind speed, and precipitation on PM_{10} concentration in Ha Noi city from 2010 to 2019.

2. Data and Methodology

2.1. Data

This study mainly focuses on the evaluation and development of the relationship between PM_{10} concentration and meteorological factors. Meteorological data from 2010 to 2019 including hourly rainfall, temperature, humidity, and wind speed monitored 4 times/day (1 am, 7 am, 1 pm, 7 pm) was collected from Ha Dong meteorological station under the Viet Nam Meteorological and Hydrological Administration. Hourly PM_{10} concentration data from 2010-2019 was collected from Nguyen Van Cu air quality monitoring station under the Viet Nam Environment Administration (Figure 1).

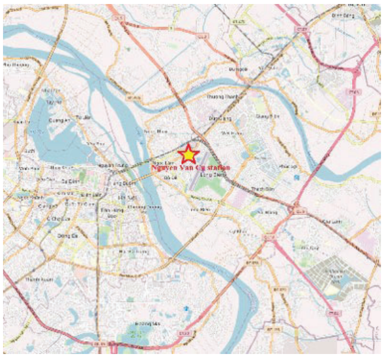

Figure 1. Location of Nguyen Van Cu air quality monitoring station in Ha Noi city

2.2. Methodology

To quantify the relationship between dust concentration and meteorological factors, this paper applied the Spearman correlation coefficient, denoted by r. This is the correlation coefficient utilized to measure the degree of linear correlation between two variables when the distribution of the variables is assumed not to be the normal distribution or in case of abnormal observed values (too large or too small).

$$r = 1-6\sum d^2/n(n^2-1)$$

The Spearman correlation coefficient will receive the values from +1 to -1. If $r>0$, there is a positive correlation between two variables that means the value of one variable increases then the value of the other also goes up and vice versa. If $r<0$, there is a negative correlation between two variables that means the value of one variable increases then the value of the other will decrease and vice versa. The higher the absolute value of *r*, the greater the degree of correlation between two variables, or the more consistent the data of the linear relationship between two variables.

The utilization of the correlation coefficient combined with the graph analysis provides insights into the relationship between dust concentration and meteorological factors.

3. Results and Discussion

3.1. Current status of PM_{10} concentration in Ha Noi city

The concentration of PM_{10} was evaluated by analyzing data collected at Nguyen Van Cu monitoring station from 2010 to 2019 (Figure 2).

The average hourly PM_{10} concentration ranged from 42 to 61 µg/m^3. It can be seen that during the day, there were 2 times (during rush hours) with high PM_{10} concentration; specifically, the average PM_{10} concentration was 60 µg/m^3 at 8 am, the figure reached 61 µg/m^3 at 7 pm. These values exceeded maximum allowable concentrations as regulated in the National Technical Regulation on Ambient Air Quality QCVN 05:2013/BTNMT (the annual average is

50 µg/m3). This high PM_{10} concentration was in accordance with the two peak periods of large traffic volume during the day. The results also indicate that the average hourly pollution level in the afternoon (1 pm - 3 pm) had the lowest concentration during the day.

From 2010 to 2019, the monitoring results of PM_{10} concentration in spring (March-May) were in the range of 45-58 µg/m3 (Figure 3). During the day, the high PM_{10} concentration was observed from 8 am-9 am (57 µg/m3) and 6 pm - 7 pm (58 µg/m3). Conversely, the lowest concentration reached at 2 am to 4 am, this was also the time with the lowest traffic volume in a day.

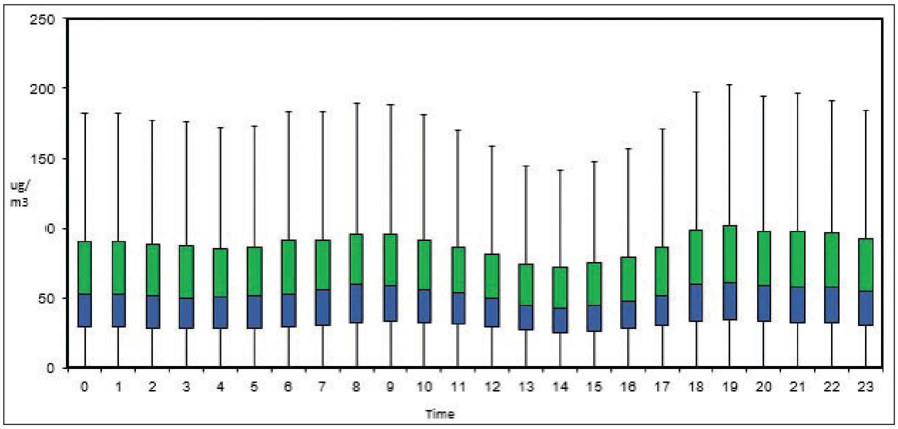

Figure 2. The hourly PM_{10} concentration between 2010 and 2019

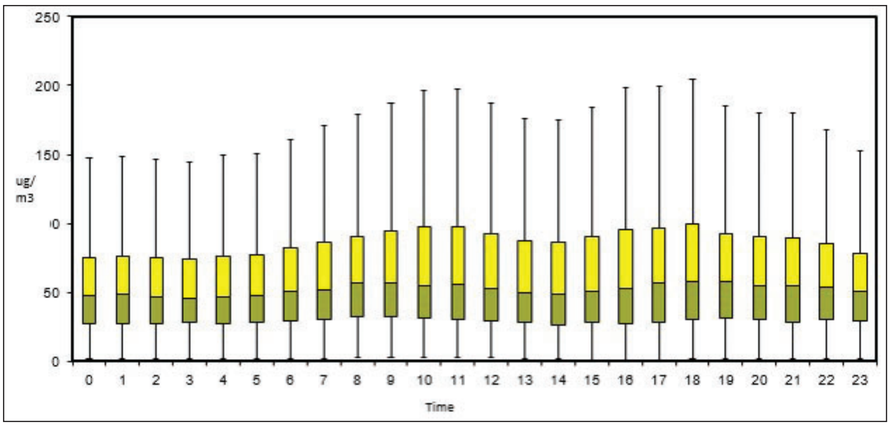

Figure 3. The hourly PM_{10} concentration in spring between 2010 and 2019

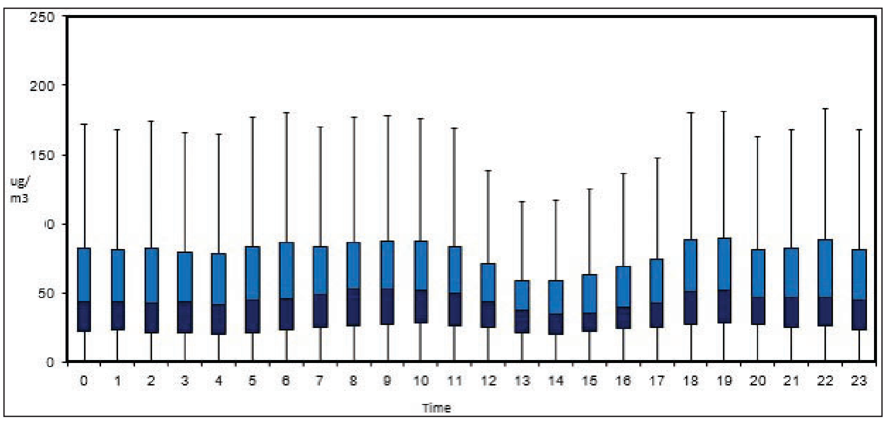

Figure 4. The hourly PM_{10} concentration in summer between 2010 and 2019

In the summertime, from June to August (Figure 4), the PM_{10} concentration showed the difference in the peak and off-peak hours during the day. The fluctuation level of the dust concentration was also greater in peak hours and lower in the remaining time frame, especially the lowest at 1-2 pm. In the afternoon, the traffic volume usually reached the lowest during the summertime, among hot days. Specifically, the monitoring result showed that the PM_{10} concentration in this period ranged from 34-53 µg/m^3. This PM_{10} concentration exceeded the QCVN 05: 2013/BTNMT (annual average) mainly in peak hours. In contrast, the values in off-peak hours were all below the standard.

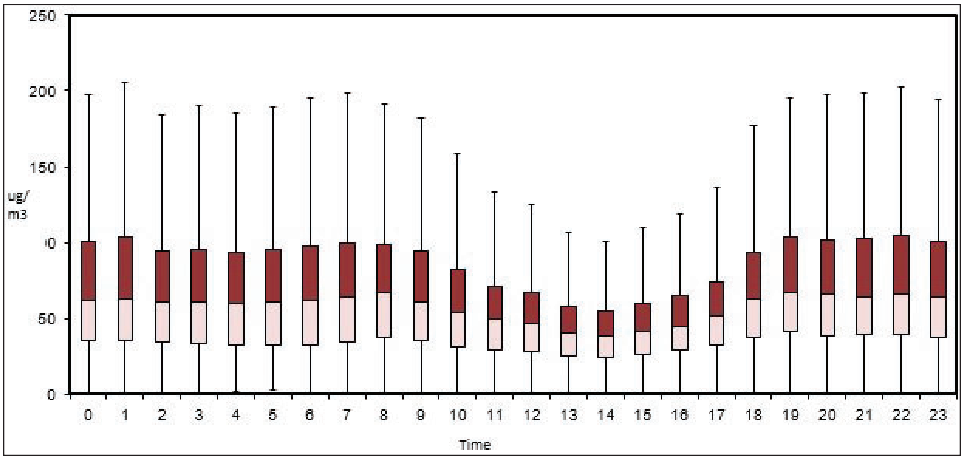

Figure 5. The hourly PM_{10} concentration in autumn between 2010 and 2019

The monitoring results of PM_{10} concentration in autumn (September - November) ranged from 38 to 67 µg/m^3 (Figure 5). Generally, the times with high PM_{10} concentration during the day were at about 8 am (67 µg/m^3) and 7 pm (67 µg/m^3). Conversely, the lowest concentration values were recorded at 2 pm (38 µg/m^3). It could be seen that the PM_{10} concentration exceeded the QCVN 05: 2013/BTNMT (annual average) at most hours of the day; some observed times were lower than the standard from 12 pm - 4 pm. During the nighttime, PM_{10} concentration still exceeded the permitted value when the traffic density decreased. It is well reported in the literature that transportation from neighboring areas is one source that contributed to the dust pollution in Ha Noi city.

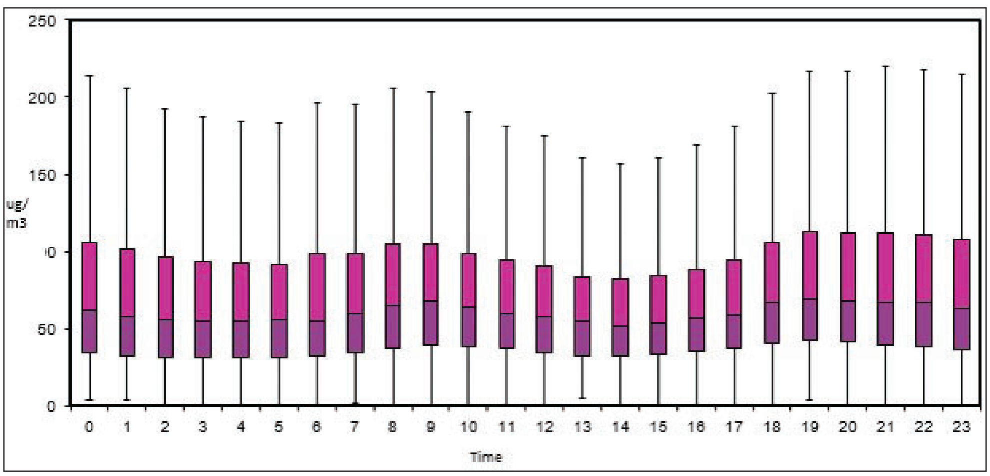

Figure 6. The hourly PM_{10} concentration in winter between 2010 and 2019

In winter, from December of the previous year to February of the following year (Figure 6), the average PM_{10} concentration was highest in the year and exceeded the QCVN 05: 2013/BTNMT (annual average) in all time frames. The fluctuation level of PM_{10} concentration in winter was also larger than the rest of the year. The monitoring result shows that the PM_{10} concentration in this period ranged from 52 to 70 µg/m^3. Specifically, the PM_{10} concentration reached the highest values at around 9 am (68 µg/m^3) and 7 pm (70 µg/m^3); on the contrary, the lowest concentration was monitored at 2 pm (52 µg/m^3).

From 2010 to 2019, the high PM_{10} level was observed in winter, followed by spring, autumn and summer. The average hourly PM_{10} concentration in summer (45 µg/m^3) was much lower than in spring (52 µg/m^3), autumn (57 µg/m^3) and winter (60 µg/m^3).

3.2. Data of meteorological factors

The analysis of meteorological data at Ha Dong station in the period of 2010-2019 (Table 1) indicated that the mean daily maximum and minimum temperatures in Ha Noi reached 30.0^{o}C and 16.6^{o}C in June and January respectively. Besides, the average humidity in summer and spring was higher than in autumn and winter. The average daily humidity value was highest in March (84.8%) and lowest in November (77.3%). In general, the humidity tended to decrease from spring to winter.

Table 1. Meteorological data at Ha Dong station from 2010 to 2019

Month	Temperature (^{o}C)	Average wind speed (m/s)	Humidity (%)	Precipitation (mm)
1	16.6	1.6	81.1	40.2
2	18.2	1.9	81.0	13.7
3	20.9	1.9	84.8	50.7
4	24.5	2.0	84.2	92.8
5	28.3	2.0	81.1	198.0
6	30.0	1.7	78.3	202.8
7	29.4	1.7	81.0	316.8
8	28.8	1.5	82.9	364.9
9	28.0	1.5	82.0	224.8
10	25.8	1.5	77.3	117.5
11	22.9	1.5	78.4	42.9
12	18.2	1.5	75.4	30.1

(Source: Ha Dong meteorological station, 2019)

The average wind speed was high in spring, highest in April and May (at 2.0m/s). In contrast, the average wind speed was lowest during the autumn months (at 1.5m/s). Overall, the difference in wind speed during seasons in Ha Noi was insignificant, staying at around 1.5-2.0m/s.

The total monthly rainfall in summer reached the highest amount (at 364.9mm in September) and the lowest at 13.7mm in February. It should be pointed out that in Ha Noi, the rainy season is from May to November, and the dry season is the remaining months.

3.3. The correlation between PM_{10} concentration and meteorological factors

The monthly tendency of PM_{10} concentration at Nguyen Van Cu station and the meteorological factors including temperature, humidity, wind speed, and precipitation are shown in Figure 7. As can be seen, the wind speed and rainfall did not change much in comparison with the temperature and humidity. The humidity reached the highest in summer and the lowest in winter. Specifically, in summer, the humidity reached 83% which corresponded to the relatively low PM_{10} concentration at 52 μg/m^3. In winter, the prcipitation was very low and the lowest humidity stayed at about 73% in February. Meanwhile, the PM_{10} concentration was relatively high with an average of 74 μg/m^3.

During the summer months, in the context of the increased temperature and high humidity, the concentration of PM_{10} reached the smallest value (about 51 μg/m^3), which was 1.5 times lower than the winter months. Accordingly, there was an influence from the process of dust deposition and dust leaching.

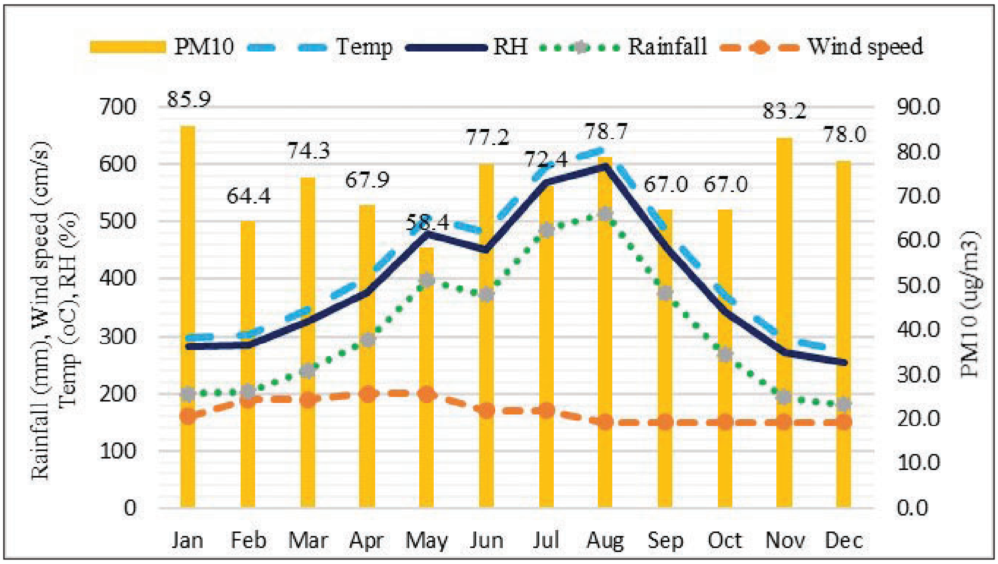

Figure 7. The monthly tendency of PM_{10} concentration and meteorological factors

The relationship between PM_{10} concentration and meteorological factors was assessed by the Spearman correlation coefficient as indicated in Table 2. The PM_{10} concentration was inversely correlated with wind speed (except summer), and the highest correlation of PM_{10} concentration with wind speed was shown in winter (r = -0.47). The temperature was positively correlated with PM_{10} concentration in winter, and inversely correlated in the remaining seasons. The precipitation is negatively correlated with PM_{10} concentration in all seasons which characterized the dust deposition and leaching process, even though this correlation is not high.

Table 2. The correlation between concentration and meteorological factors

Correlation coefficient	Temperature	Humidity	Wind speed	Precipitation
Spring	-0.43	0.20	-0.18	-0.09
Summer	-0.02	0.11	0.02	-0.03
Autumn	-0.31	-0.09	-0.16	-0.16
Winter	0.05	0.05	-0.47	-0.10

As can be seen from Table 2, the PM_{10} concentration was reversely correlated with wind speed in spring, autumn, winter, and positively correlated in summer. The high correlation was seen in winter (r = -0.47). The inverse correlation between PM_{10} concentration and wind speed could reflect the characteristics of the predominant local pollution sources. Zhang et al. (2015) [11] also indicated that the horizontal dispersion plays a role in the adjustment of PM_{10} concentration in spring, autumn, and winter in Beijing when there is an inverse correlation between PM_{10} concentration and wind speed.

Regarding the temperature, the PM_{10} concentration showed a negative correlation in spring, autumn, and summer and a positive correlation in winter. The correlation coefficients in summer and autumn were much better than in spring and winter. The highest correlation occured in summer (r = -0.43). Accordingly, this indicated that an increased temperature is unfavorable to the formation of fine dust particles.

The inverse correlation between temperature and PM_{10} concentration could happen from the temperature inversion phenomenon. In the study on heat inversion in Ha Noi published by Trinh Thi Thuy et al. (2019) [9], the authors found that PM_{10} concentration was higher during the temperature inversion. However, the correlation between the average monthly dust concentration and total days of temperature inversion was low. Gramsch et al. (2014) [5] also indicated the low correlation between the average daily $PM_{2.5}$ concentration and the intensity of temperature inversion in Santiago de Chile (r^2 = 0.1233). The reason is that the meteorological factors have changed; the wind speed and humidity are often lower when the temperature inversion occurs.

The PM_{10} concentration was positively correlated with humidity in all seasons, except for autumn. However, the correlation was relatively low, the highest was only at r = 0.20 in spring. The positive correlation was characterized by the fact that the boundary layer would be lower with more humid air; therefore, leading to the increase of concentration of major air pollution sources [12].

Regarding the precipitation, the PM_{10} concentration had a negative correlation in all seasons that reflected the dust deposition and leaching process. Studies on urban air pollution have demonstrated that the rainfall will reduce the return of dust from the road surface and remove airborne dust [1]. Although the calculation results showed that the rainfall had a relatively low correlation with the PM_{10} concentration.

4. Conclusion

In general, the assessment results on the correlation between PM_{10} concentration and meteorological factors in Ha Noi between 2010 and 2019 indicated that the effects of seasonal changes were clear. In particular, the correlation between wind speed and PM_{10} concentration in winter was most clearly seen, probably due to the pollutant transportation in the area. The meteorological factors such as air temperature, humidity were also the factors that affected the increase or decrease of dust concentration. The dust concentration tended to be inversely proportional to temperature and direct proportional to humidity. High temperature and reduced pressure during summer helped bring moisture from the ground to the air layer above or to other areas, leading to a reduction of the dust amount. The study suggested that, the greater the humidity the less dust would spread from the pavement or adjacent areas, which led to a reduction in the PM_{10} concentration. These findings could contribute to the air quality management in the city.

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