Chapter 56
Effect of Meteorology Parameters on Air Pollutant Standard Index in the Urban Area (Case Study in Jakarta)

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Abstract This paper aims to analyze the significant correlation between air quality and meteorological variables (temperature, RH, radiation) in the DKI Jakarta areas time 2017–2020. Data analysis used secondary data on air pollutant standard index from Provincial Environment Service DKI Jakarta consisting of PM_{10}, NO_2, SO_2, CO, and O_3 parameters. Meteorological data uses data from BMKG, which consists of meteorological parameters, namely: solar radiation duration, temperature, and relative humidity. Air temperature, humidity, and radiation are part of the meteorological parameters that can affect the concentration of pollutants in the air. The results of the correlation of pollutants with meteorology parameters show that PM_{10} has the strongest correlation with the 3 meteorology components. Sun's duration and PM_{10} have a correlation of 0.69. Temperature and PM_{10} correlation have correlation of 0.55. And the correlation between PM_{10} and RH is inversely proportional, and the correlation value is 0.82.

56.1 Introduction

The city of Jakarta, as the capital city of Indonesia, has various kinds of progress in various sectors, both industry, tourism, education and the environment. In a higher population rate, which of course also increases the mobility and activities of people living in the city of Jakarta and surrounding cities such as Depok, Bekasi, Bogor. The rapid progress of the city of Jakarta has an impact on the environment, especially the air quality in DKI Jakarta. Increasing industrial and transportation activity was associated with air pollution, especially in the urban and industrial areas. Biomass burning and urban air pollution that occur, consecutively, in several wildfire-prone provinces and big cities in Indonesia are likely worsened in the future [1].

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Table 56.1 Air pollutant standard index range

Category	Range
Good	0-50
Moderate	51-100
Unhealthy	101-199
Very unhealthy	200-299
Dangerous	300–more

The Air Pollutant Standard Index is a number that does not have units that describe the condition of ambient air quality at specific location and time based on the impact on human health, aesthetic value, and other living things. The air quality standard index officially used in Indonesia is the Air Pollutant Standard Index (ISPU); this is following the Ministerial Decree State Environment: KEP 45/MENLH/1997 concerning Standard Index Air Pollutants [2] (Table 56.1).

Air pollution in an urban area is a dynamic mixture of pollutants emitted from numerous sources, including motor vehicles and other anthropogenic activities. The impact of air pollution can be one of the reasons for civilization diseases [3].

Besides emission factors, local meteorological conditions, especially wind, air temperature, rainfall, and radiation factors, also affect the concentration and distribution of pollutants in the air [4]. The concentration of pollutants in the atmosphere is not only influenced by the number of pollutant sources, but also by meteorological parameters, namely air temperature and wind speed [5]. In addition, the increase in temperature and rainfall also affects the increase in CO_2 from the surface [6]. From several locations, temperature and RH are also significant contributors to the variability of the concentration of CO_2. Mahesh et al., research the correlation of meteorological factors with CO_2, statistical analysis of the data shows that precipitation and relative humidity independently correlated 55% ($r = -0.55$) and 32% ($r = -0.32$), respectively [7]. Influences of prevailing meteorology (air temperature, wind speed, wind direction, and relative humidity) on GHGs have also been investigated. CO_2 and CH_4 show a strong positive correlation during winter, pre-monsoon, monsoon, and post-monsoon with correlation coefficients (Rs) equal to 0.80, 0.80, 0.61, and 0.72 respectively [8].

Radiation also affects the concentration of NO_x in the atmosphere. In summer, NO converted to NO_x increases with the increase in solar radiation. For example, in some large cities in Japan, due to the increase in urban population, the atmospheric temperature tends to be increased, which is strongly correlated with high NO_2 concentration It is also supported by research in Bahrain, which showed the highest NO_x concentration was in the urban areas with high traffic density [9].

Wind will affect the dispersion of pollutants (transport process) and determine which direction and how high the pollutant concentration is. SO_2, aerosols, nitrogen oxides, and hydrocarbons in the atmosphere will form a photochemical haze with the help of solar energy (radiation). SO_2 also, if it reacts with rainwater, will increase the acidity of rain water which can cause acidification water sources and reduction of soil nutrients; also cause corrosion metal and other building materials [10].

56.2 Data and Methods

56.2.1 Data

This study uses secondary data consisting of 2 primary data, namely meteorological data and air pollution data for time January 1, 2017; Dec 31, 2020 time period. Meteorological data comes from data released by the central BMKG consisting of relative humidity (RH), temperature, and duration of solar radiation, while air pollution data obtained from Provincial Environment Service DKI Jakarta in the form of air pollutant standard index (APSI) data of PM_{10}, O_3, CO, NO_2, and SO_2. These two types of meteorology and pollutant data use data for the 2017–2020 period due to the completeness of the available data.

56.2.2 Methods

To analyze the correlation between meteorological factors and air pollutant standard index, used Heil-Sen Siegel regression method [11].

Suppose the equation for the linear relationship of the independent variable (X) to the dependent variable (Y) is

$$Y = Q_o + Q_1 X + s$$

where β_o is the intercept, β_1 is the regression coefficient, and ε is residual; the value of β_1 is estimated by calculating the gradient of $n(n - 1)/2$ datum pairs, finding the median of the resulting gradient for each gradient between the datum and other $n - 1$ datums, then calculating the median of the n medians that have been obtained. The estimated value of a robust regression coefficient can be obtained by calculating the median of the following least-squares estimate

$$\tilde{\beta}_n = Median_i \left\{ \tilde{\beta}_1 = \frac{(Y_i - Y_j)}{(X_j - X_i)} : X_i \neq X_j,\ 1 \leq i < j \leq n \right\}$$

$$\tilde{\alpha}_n = Median_i \left\{ \tilde{\beta}_0 = \frac{(Y_j X_i - Y_i X_j)}{(X_j - X_i)} : X_i \neq X_j,\ 1 \leq i < j \leq n \right\}$$

Thus, the Theil-Sen Siegel regression equation is written as follows:

$$YTSS = \tilde{\alpha}n + \tilde{\beta}X$$

56.3 Result and Discussion

The meteorological parameters discussed in this study are sunshine duration, temperature, and relative humidity (RH). These three parameters will be associated with several pollutants, namely particulate matter (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO), to find out how the three meteorological parameters relate to the five pollutants. Thus, there are eight research variables. Each variable was observed from January 1, 2017; December 31, 2020. To obtain a clear pattern, the daily data were averaged per month (Table 56.2).

Figure 56.1 presents average seasonal data for relative humidity, temperature, and sunshine duration for 2017–2020. For seasonal data, the length of the sun's duration shows a similar pattern during 2017–2020. This pattern repeatedly happened for four years of observation. It's just that in 2020 there will be a slight decrease in the length of the sun's duration. The peak duration of solar radiation occurs in September–October November (purple) in transition season. In contrast the minimum value of solar radiation occurs in the wet season, namely Dec–Jan–Feb (the red one).

Temperature meteorological analysis data shows a pattern/trend of temperature increases, especially in 2019 during the observation period. The maximum temperature generally occurs in the dry season of June–July–August, with the highest temperature 29.64 °C (in 2019). Meanwhile, minimum temperature occurred during December–February (rainy season) with the lowest temp at 27.2 °C.

The relative humidity pattern in Jakarta from 2017 to 2020 shows a relatively constant. The results of the RH data analysis showed that the exact peak of RH occurred in February from 2017 to 2020. However, in February 2019, the peak RH value fell to 80%, lower than in 2017–2018, 83%. And peak RH increased in February 2020 by 85%. The increase in RH is thought to be due to the decrease in the standard index of air pollutants in the city of Jakarta during the Covid 19 pandemic.

Data for Air Pollutant Standard index PM_{10}, O_3, CO, NO_2, and SO_2 are presented in Fig. 56.2. PM_{10} shows the highest concentration in the dry season of JJA, this is caused by the accumulation of particulate dust. The increasing the PM_{10} pollutant index during this season. O_3 shows the highest pollutant index in July. This is to be linear with the high sunshine duration in the transition season. Increased surface ozone concentration (O_3) in July 2018 in line with the decrease in CO gas concentration in July 2018 related to the photo chemical reaction of CO oxidation [12].

In NO_2 and SO_2, there was a significant increase in the pollutant index in October 2020; this related to the resumption of community activities after the Covid19 (New Normal policy) pandemic. Ozone concentrations at the ground level, depend on the formation and dispersion processes. Formation process, mainly depends on the precursor sources, whereas, the dispersion of ozone depends on meteorological

Table 56.2 Meteorological data and air pollutant standard index in Jakarta in 2017–2020

Month	Sun's duration	Temperature	RH	PM_{10}	O_3	NO_2	SO_2	CO
Jan-17	3.76	28.15	77.52	40.32	51.06	11.94	30.94	31.42
Feb-17	3.42	27.25	82.07	46.25	59.93	13.50	31.00	39.61
Mar-17	4.45	28.09	78.42	58.74	78.26	17.58	37.39	42.68
Apr-17	4.09	28.55	77.60	58.43	91.73	16.97	36.67	38.20
May-17	4.15	29.05	75.90	73.90	97.61	17.16	43.48	36.19
Jun-17	4.37	28.70	76.87	65.13	77.70	13.80	46.00	38.73
Jul-17	4.50	28.63	73.94	67.74	101.94	16.00	47.94	36.84
Aug-17	5.32	28.69	69.39	71.65	102.84	12.48	50.94	35.06
Sep-17	6.70	28.83	72.20	72.87	101.90	15.47	51.67	30.67
Oct-17	5.53	28.96	74.61	62.61	101.58	18.32	51.90	38.65
Nov-17	3.61	28.27	78.17	52.63	89.83	16.27	53.30	35.07
Dec-17	3.61	28.22	76.52	38.42	51.19	12.03	45.10	29.74
Jan-18	3.05	27.77	76.48	35.71	57.77	12.19	46.13	21.06
Feb-18	3.70	27.15	82.57	47.75	68.75	14.39	30.75	43.50
Mar-18	4.17	27.90	79.74	58.19	109.68	17.23	29.39	31.48
Apr-18	5.00	28.63	78.57	62.50	103.93	17.80	29.30	25.50
May-18	4.99	29.40	73.52	76.52	129.42	16.19	26.19	22.74
Jun-18	4.58	28.87	75.17	66.67	133.00	13.97	26.83	19.40
Jul-18	5.19	28.21	70.84	80.35	158.00	18.84	30.23	21.16
Aug-18	5.34	28.18	70.10	72.23	157.90	15.90	31.55	17.77
Sep-18	6.70	28.76	68.37	68.33	149.80	15.37	34.97	21.33
Oct-18	5.53	29.48	71.39	69.06	141.52	15.39	32.06	21.42
Nov-18	3.61	28.90	75.53	62.00	120.60	17.80	26.77	25.93
Dec-18	3.61	28.74	74.81	51.58	95.29	15.19	25.77	20.45
Jan-19	3.05	27.95	79.97	51.90	92.45	9.39	11.77	17.24
Feb-19	3.70	28.28	80.21	58.79	90.64	9.89	14.50	21.79
Mar-19	4.17	28.16	78.55	54.52	107.03	9.52	14.65	17.61
Apr-19	5.00	28.88	78.43	58.23	90.64	9.57	14.40	21.33
May-19	4.99	29.64	73.77	67.97	92.39	9.77	18.90	22.58
Jun-19	4.58	29.18	71.90	69.63	102.83	8.67	19.30	17.80
Jul-19	5.19	28.71	68.48	73.48	97.29	9.35	21.97	16.77
Aug-19	5.34	28.28	68.61	74.06	121.32	8.50	21.27	13.97
Sep-19	6.56	28.84	68.67	74.40	125.50	5.00	22.93	12.40
Oct-19	6.41	29.55	68.90	72.32	143.97	8.32	21.29	8.79
Nov-19	3.40	29.55	71.00	68.87	132.77	9.20	20.93	18.29

(continued)

Table 56.2 (continued)

Month	Sun's duration	Temperature	RH	PM_{10}	O_3	NO_2	SO_2	CO
Dec-19	3.50	28.48	79.10	63.55	104.84	8.52	18.32	24.68
Jan-20	2.92	27.88	83.06	56.42	71.33	11.97	34.97	32.06
Feb-20	2.91	27.67	84.25	56.52	92.72	14.14	25.72	35.62
Mar-20	4.14	28.57	79.55	60.16	113.03	15.55	22.19	37.55

Fig. 56.1 Seasonal meteorological data

factors. In addition, the level of ozone concentration at the surface can be estimated by the result of source and sink mechanism, which predominately rely on the meteorological conditions of the environment [13]. The high pollutant index of NO_2 and SO_2 is thought to come from transportation activities.

The implementation impact of the Working from home policy regarding the Covid-19 pandemic on air quality conditions in Jakarta can be seen qualitatively

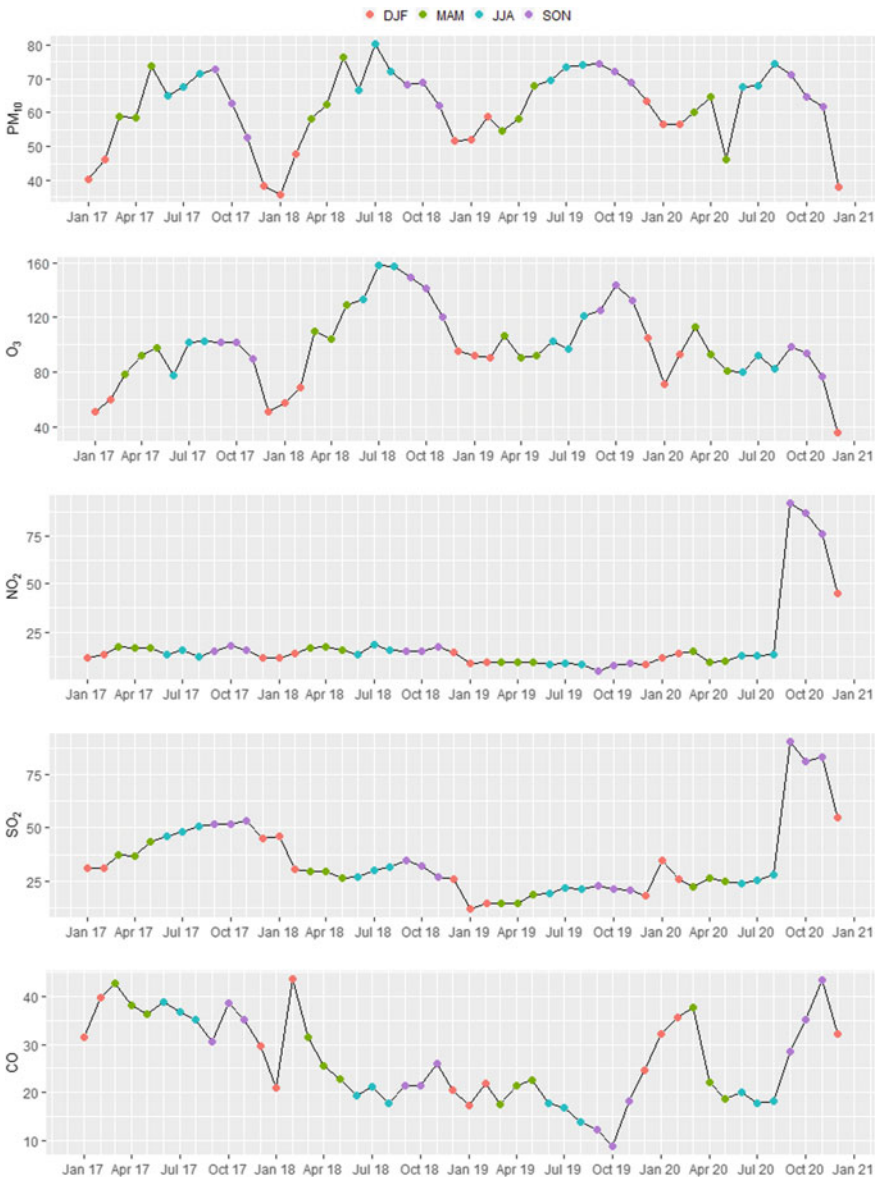

Fig. 56.2 Seasonal air pollutant standard index

and quantitatively, especially decrease in PM10 concentration levels [14]. Based on air pollutant standard index data, it is known after the implementation of the new normal policy, there was a significant increase in pollutant in Jakarta, especially the SO2 and NO2 parameters (Fig. 56.2). CO concentration was increased significantly with the implementation of the new normal policy during the period of covid-19 pandemic.

56.3.1 The Correlation Between the Meteorology with Pollutants

The correlation between the independent variables and the dependent variables can be analyzed through regression analysis. In this case, each meteorological parameters act as an independent variable and pollutant as the dependent variable, with the correlation pattern assumed to be linear. From the way of correlation that are built, the correlation value between variables can be received.

The air pollutant standard index data for NO_2 and SO_2 in October 2020 experienced a significant increase, in contrast to other data. The solution to this problem is to use the Thiel -Sen-Siegel method [11]. This method is also relatively better for data that is not normally distributed and data with non-homogeneous variance (heteroscedasticity).

The results of the analysis in the form of correlation values obtain based on the Theil-Sen-Siegel method regression model are presented in Table 56.3 with a visualization of the correlation pattern in Figs. 56.3, 56.4 and 56.5 (Table 56.4).

For the sun's duration with a significance level of 5%, it was found that there was a significant linear relationship between the length of sun's duration and PM_{10}, O_3, NO_2, CO, while the relationship with SO_2 is not significant. The correlation value between sun's duration and air pollution standard index is presented in Table 56.5.

For the temperature with a significance level of 5%, it was found that there was a significant linear relationship between the temperature on PM_{10}, O_3, and CO, while

Table 56.3 Summary statistics of research variables

Research variable	Min	Max	Mean	Std Dev
Suns's duration	2.91	6.70	4.53	1.02
Temp	27.15	29.64	28.62	0.60
RH	68.37	84.25	75.28	4.27
PM_{10}	35.71	80.35	62.02	10.95
O_3	35.29	158.00	98.79	27.36
NO_2	5.00	91.70	18.32	18.34
SO_2	11.77	90.33	34.12	17.39
CO	8.79	43.50	26.65	9.12

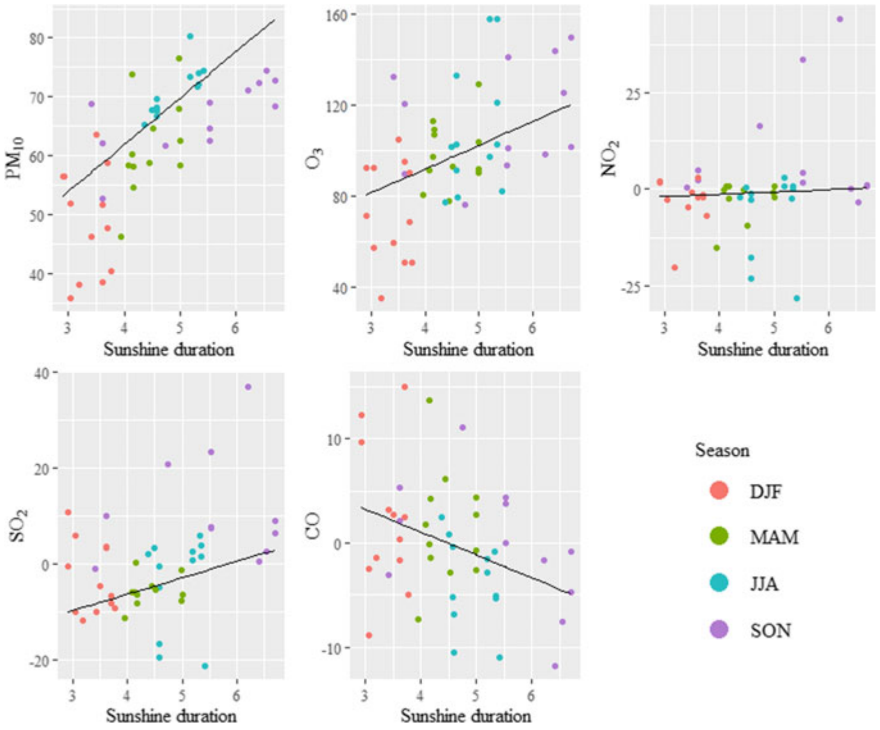

Fig. 56.3 Correlation between sunshine duration and air pollutant standard index PM_{10}, O_3, NO_2, SO_2, CO

the relationship with SO_2 and NO_2 is not significant. The correlation value between T and air pollution standard index is presented in Table 56.6.

Relative humidity (RH), with a significance level of 5%, found a significant linear correlation between temperature and PM_{10}, O_3, and CO, while correlation with NO_2 and SO_2 is not significant. The correlation value between RH and air pollution standard index is presented in Table 56.7.

56.4 Summary and Conclusion

The results of the correlation analysis between meteorological parameters data and air pollutant standard index parameters show the effect of pollutants are positively correlated with the sun's durations, except parameter pollutant CO that has negative correlation. The correlation between temperature and air pollutants is positive, meaning that the higher temperature, the higher the concentration. RH is negatively correlated with the air pollutant standard index for all parameters, except for CO.

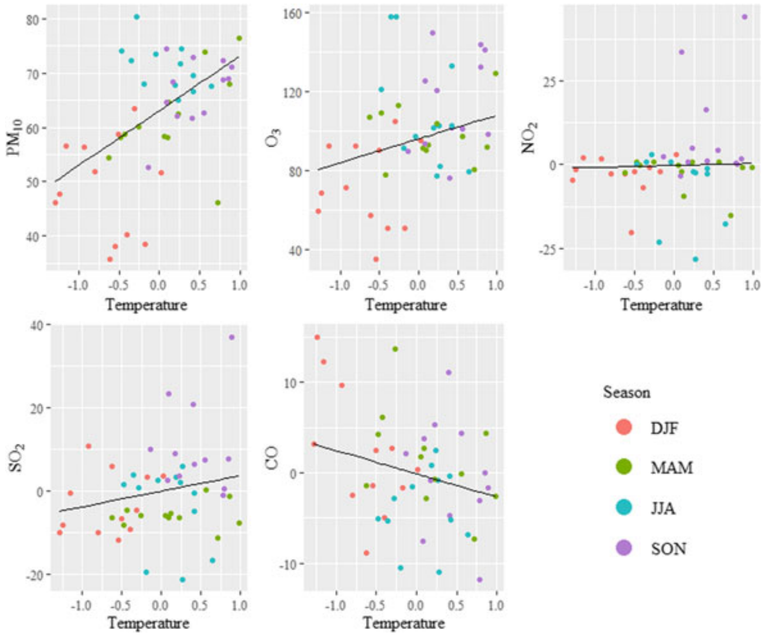

Fig. 56.4 Correlation between temperature and PM_{10}, O_3, NO_2, SO_2, CO

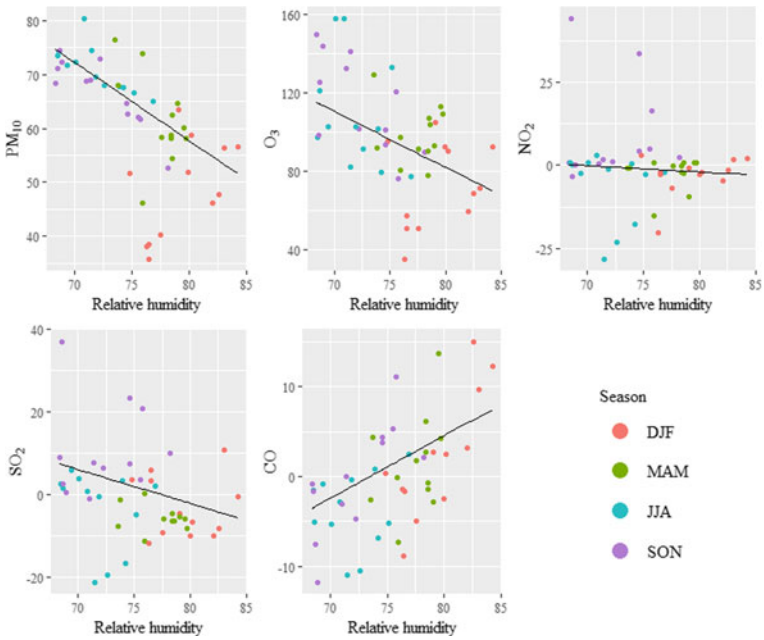

Fig. 56.5 Correlation between RH and PM_{10}, O_3, NO_2, SO_2, CO

Table 56.4 Correlation values based on Theil-Sen-Siegel method

	Sunshine duration	Temperature	RH
PM_{10}	0.696 (3.55 × 10–14)	0.552 (6.99 × 10–09)	−0.823 (1.68 × 10–09)
O_3	0.465 (4.75 × 10–09)	0.311 (0.0011)	−0.478 (5.00 × 10–08)
NO_2	0.103 (0.0198)	0.001 (0.988)	−0.013 (0.32036)
SO_2	0.045 (0.239)	−0.156 (0.375)	−0.065 (0.046053)
CO	−0.296 (4.90 × 10–05)	−0.300 (2.67 × 10–05)	0.539 (3.22 × 10–10)

Table 56.5 Correlation between sun's duration and air pollutant standard index

Meteorology	PM_{10}	O_3	CO	NO_2
Sun's duration	Moderate correlation (0.69) unidirectional More pro-longed sun-shine duration, the greater lPM_{10} level	Moderate correlation (0.46) unidirectional More pro-longed sun-shine duration, the greater the O_3 content	weak correlation (0.29) not in the same direction, more prolonged sun's duration, the lower the CO content	Very weak correlation (0.10) unidirectional more pro-longed sun's duration, the greater the NO_2 content

Table 56.6 Correlation between temperature and air pollutant standard index

Meteorology	PM_{10}	O_3	CO
Temperature	Moderate correlation (0.552) Uni directional The higher temp, the greater the level of PM_{10} Index	Weak correlation (0.31) Uni directional The higher the temperature, the greater the O_3 index	Weak correlation (−0.3) not in the same direction, The higher the temperature, the lower the CO level

Table 56.7 Correlation between RH and air pollutant standard index

Meteorology	PM_{10}	O_3	CO
Relative Humidity	Strong correlation (0.82) not in the same direction. The higher the relative humidity, the lower the PM_{10} level	Moderate correlation (−0.48) not in the same direction. The higher the relative humidity, the lower the O_3 content	Moderate correlation (0.54) unidirectional. The higher the relative humidity, the greater the CO level

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