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PROFILING TEMPORAL PATTERN OF PARTICULATE MATTER (PM_{10}) AND METEOROLOGICAL PARAMETERS IN JAKARTA PROVINCE DURING 2020-2021

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Abstract

Introduction: *Jakarta has recorded heightened air pollution for years, and particulate matter (PM_{10}) is one of the pollutants that could bring health burden in population. This study described the distribution of PM_{10} as well as analysed the correlation with meteorological parameters during 2020–2021 in Jakarta Province.* ***Methods:*** *Air quality standard index daily data from January 1st 2020 to March 31st 2021 was retrieved from the official data portal (https://data.jakarta.go.id/). The Spearman Rank correlation was employed to understand the correlation between PM_{10} Index with meteorological factors. Autoregressive Integrative Moving Average (ARIMA) model was constructed and Akaike Information Criterion (AIC) selected the model. Cross-correlation analysis explored the association between PM_{10} with meteorological parameters at multiple time lags.* ***Results and Discussion:*** *PM_{10} Index started to increase in April 2020 and reached its peak in August 2020. PM_{10} was positively correlated with temperature (p-value <0.05, R2: 0.134), but it was negatively correlated with humidity and wind speed (p-value <0.05, R2: -0.392 and -0.129). The high cross-correlation coefficients were found between PM_{10} and temperature at lag 0, humidity at lag 1 and wind speed at lag 1 (rho: 0.42, -0.38 and -0.24). The time series model ARIMA with parameter (p,d,q) (1,1,1) describes the fluctuation of PM_{10} index data with AIC 3552.75.* ***Conclusion:*** *PM_{10} concentration in Jakarta is significantly correlated with meteorological factors. The implementation of social restriction in Jakarta need to be supported by pollution control in the neighbouring areas in order to be able to reduce PM_{10} pollution level.*

INTRODUCTION

Air quality is a public health concern due to its significant health impact to global population, where 91% of the health events occurred in low middle income countries with air quality disruption. World Health Organization (WHO) underlines the key air pollutants are Particulate Matters (PM), Ozone (O_3), Nitrogen Oxide (NO_2) and Sulphur Dioxide (SO_2) (1). PM_{10} is a primary parameters for air pollution, that is composed of sulphate, sodium, mineral dust, nitrates, water, ammonia. It is a combination of liquid and solid air suspended materials with dimension of 10 microns or smaller that is able to enter the deep part of respiratory organs (1). Latent exposure to air pollutants including PM_{10} is the driving factors for health problems for individual (2) and community health such as increasing healthcare

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admission (3), an excessive risk of mortality rate due to cardiovascular health issues (4) and respiratory adverse condition, and initiates lung cancer (5).

The contributed regions for particulate pollutants are Africa, Mediterranean and South East Asia (SEA) (6), where fine particulate concentration in Eastern Mediterranean and Southeast Asia (SEA) was approximately 7 times higher than PM_{10} concentration at global scale (7). Jakarta, as one of densely populated areas in SEA with more than 10 million inhabitants (8) has been known for its air pollution from vehicle emission, industrial, manufacture and domestic activities (9). While, WHO reported that areas with more than 3 million residents, have PM_{10} pollution level approximately at 112.7 μg/m^3 during 2010–2019 (7). PM_{10} concentration in Jakarta has been the highest among other pollutants in Indonesia for years, as recorded in Central Jakarta District in 2019 (128 μ/Nm^3) (10). During Covid19 pandemic in 2020–2021, the Provincial Government of Jakarta implemented 12 stages of large scale social restriction as containment of Covid19 transmission with the duration of each stage was 14 days starting from 9th of April 2020 when the regulation was mandated (11). The restriction limited movement and activities from transportation, office work, school and education, religious and commercial activities (12–13). On the other hand, it has long been studied that emission resulted from transportation activities, vehicles and traffic emission took a major contribution for the city PM_{10} concentration (14).

It was globally reported that movement restriction during pandemic has resulted in significant decrease of air pollutants concentration in 34 countries for example fine particulate matters from January to May 2020 has declined 31 percent (15). A reduction about one third of PM_{10} concentration in the capital of Indonesia was recorded in the first phase of social restriction (16), as well as reduction for emission from gaseous and aerosol pollutants was captured during social restriction in May–August 2020. When the restriction was relaxed, geographical variation of PM_{10} elevated to 21.2% (17). On the other hand, study about the dynamics of Air Quality Index (AQI), $PM_{2.5}$ and $NO_{2.5}$ from 21 cities in Africa, America, Middle East and Asia found improvement of air quality during large social restriction, except in Jakarta that showed higher risk during lockdown in 2020 compared to the baseline period (2018–2019) represented by the higher AQI (18).

Several factors were indicated to have association with the concentration of air pollutants including of particulate matters in high anthropogenic and biogenic activities region particularly in capital cities. The influencing factors are land use, traffic emission, railways, air transportation, the existence other pollutants, mining industry, as well as meteorological parameters such as sun exposure, UV, rainfall, temperature (4), humidity and wind speed (14,19–20). Whereas in Jakarta, the particulate pollutant concentration in 2016–2018 was positively correlated with residential density, temperature and negatively correlated with vegetation index and humidity (20).

Despite the growing studies to present the assessment of air quality in large cities in the world, there is still limited evidence of longer air quality in Jakarta Province during 2020–2021. This study aims to describe the temporal distribution and quantify the correlation between PM_{10} and meteorological parameters in Jakarta Province. This study will be useful in developing effective control techniques, provide baseline for future trend and support policy makers to address Jakarta's air pollution problem.

METHODS

Study Site

Jakarta Province is situated between 6^o 12' South Latitude and 106^o 48' East Longitude, seven meters above sea level. This province is bordered by West Java Province at Southern and Eastern part, Banten Province at Western part and Java Sea at Northern part. Jakarta Province with area 664.01 km^2 is administratively divided into 6 city districts (Seribu Island, South Jakarta, East Jakarta, Central Jakarta, West Jakarta and North Jakarta). The population of this province was 10,526,088 in 2020 with a reproduction rates 0.92%. Among them, 5.33 million are male and 5.23 million are female (21).

Study Design

This study analysed secondary data of PM_{10} index and meteorological parameters (average temperature, average humidity and wind speed) in Jakarta Province, Indonesia. The unit of analysis for this study was at population level of Jakarta Province with time unit was daily starting from 1st January 2020–31st March 2021 (456 days).

Data Sources and Variables

The air pollutants index data were obtained from Jakarta Province official website which provides datasets compiled from 5 monitoring stations (Bundaran HI, Kelapa Gading, Jagakarsa, Lubang Buaya, and Kebon Jeruk). The pollutants data used for this study was integrated from 5 stations where data were collected independently by 5 stations to minimize missing data. The data presented in Air Quality Standard was converted from the original concentration with the following formula as regulated by the Ministry of Environment and Forestry (22):

$$I = \frac{I_{upper} - I_{lower}}{X_{upper} - X_{lower}} (X_{real} - X_{lower}) + I_{lower}$$

I = Air pollutant index/ ISPU

I_{upper} = Upper limits of ISPU

I_{lower} = Lower limits of ISPU

X_{upper} = Upper limits of ambient concentration

X_{lower} = Lower limits of ambient concentration

X_{real} = Real pollutant concentration as the results of measurement

The meteorological data were extracted from Bureau of Meteorology, Climatology, and Geophysics (BMKG) website that provides open access daily datasets from 3 meteorological stations in DKI Jakarta (Tanjung Priok, Kemayoran and Halim Perdanakusuma). In this study, the researchers only used datasets from Kemayoran station, located in Central Jakarta.

Descriptive Analysis

The frequency distribution table describes PM_{10} air pollutant standard index and meteorological parameters, the time series plot was generated to see the temporal dynamics of the data from January 1st, 2020 to March 31st, 2021. The monthly boxplot examined the fluctuation of means from all variables in 15 months observation.

Spearman Rank Correlation analysis

Spearman Rank Correlation analysis was employed to examine the correlation and multicollinearity between PM_{10} and meteorological parameters. The value of rho, and p-value measured and determined the strength and significance of the correlation. Spearman Correlation Analysis was performed using R Studio software.

Temporal Analysis

The first step was defining the decomposition of PM_{10} data into time series components, the decomposition curve visualizes PM_{10} into observed data, trend, seasonal and outlier or remainder components. The next step is by checking for stationarity by using Dickey Fuller Augmented (ADF) test.

Autoregressive Integrated Moving Average (ARIMA) Model

Autoregressive Integrated Moving Average (ARIMA) model was employed to predict correlation within the time-series data. The analysis was started by identification the stationarity of the time-series datasets. The components of *p, d, q* where d or differencing is the order used to integrate Autoregressive (AR) and Moving Average (MA) component to achieve a stationary time-series. Moving average (MA) q is normally used to capture short-term association between consecutive data and it could explain temporal data's irregular component (23).

$$y_t = \varnothing_1 y_{t-1} + \varnothing_2 y_{t-2} + \ldots\ldots + \varnothing_p y_{t-p} + \omega_t = \sum_{i=1}^{p} \varnothing_i \, y_{t-i}$$

$$y_t = \theta_1 \omega_{t-1} + \theta_2 \omega_{t-2} + \ldots\ldots + \theta_p \omega_{t-p} + \omega_t = \sum_{j=1}^{p} \theta_j \, \omega_{j-q}$$

y_t represents stationarity process, $\varnothing_p$ is autoregression model *(p)* while ω_t is an outliers series. The AR estimates y_t based on the past events of $y_1, y_2, y_3 \ldots\ldots\ldots y_{t-1}$ The combination of y_t and ω_t represents as moving average *(q)*. The stationarity resulted by involving differencing process in ARIMA model is formulated as below:

$$\Delta^d y_t = \delta + \varnothing_1 \Delta^d y_{t-1} + \cdots + \varnothing_p \Delta^d y_{t-p} + \theta_1 \omega_{t-1} + \ldots\ldots + \theta_p \omega_{t-p} + \omega_t$$

The selection of ARIMA model components order by examine the correlogram of Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) curves plots as well as comparing the Akaike Information Criterion (AIC) values among constructed models. The analysis and model construction were performed using R Studio software with packages of astsa, tseries, FitAR, forecast.

This research has been registered and approved by the Health Research Ethics Committee of Faculty of Public Health, Universitas Airlangga on November 2nd, 2021 (reference number: 48/EA/KEPK/2021).

RESULTS

Descriptive Statistics

The descriptive distribution of PM_{10} index from January 1st, 2020 until March 31st, 2021 are presented in Table 1.

Table 1. Descriptive Distribution of Air Quality and Meteorological Parameters Index from January 2020–March 2021 in Jakarta

Variables	Min	Max	Median	Mean	SD
PM_{10} (ISPU Index)	22.00	111.00	60.00	58.88	15.66
Average Temperature (°C)	25.10	31.20	28.50	28.50	1.05
Average Humidity (%)	60.00	95.00	78.00	77.36	6.22
Wind speed (m/s)	0.00	4.00	2.00	1.65	0.69

The mean of PM_{10}, index during the study period was 58.88. The daily mean for meteorological indicators of average temperature, average humidity and wind speed were 28.50°C, 77.36% and 1.65 m/s respectively (Table 1). Figure 1 illustrated monthly fluctuation in box plots of monthly PM_{10} ISPU index, where increasing pattern was detected since April 2020. The highest mean was reported in August 2020 and the lowest mean of PM index mean was captured in December 2020. The box plot of temperature records relatively higher mean during March until November 2020 and the lowest temperature was in January 2021. While the box plot of humidity showed the decreasing pattern since March 2020 with the lowest mean was recorded in September 2020 (Figure 1). The figure 2 illustrated the decomposition of time series data of PM_{10} ISPU index and suggested that there was no trend detected.

Time-Series Analysis

The time series decomposition presents PM_{10} as observed data, trend, seasonal and random component. There was no clear trend of PM_{10} concentration index during the study period, however the seasonality is noticeable with similar pattern in each month, while the peak was in August 2020 (Figure 2). Table 2 suggests that PM_{10} meet the significance for stationarity with p-value <0.05.

Table 2. The Results of ADF (Augmented Dickey-Fuller) Test and KPSS Stationarity Analysis

Variables	Augmented Dickey-Fuller Test		KPSS Test for Level Stationarity	
	Dickey-Fuller	P-value	KPSS Level	P-value
PM_{10}	-3.6227	0.03068*	0.91355	0.01*

**significant*

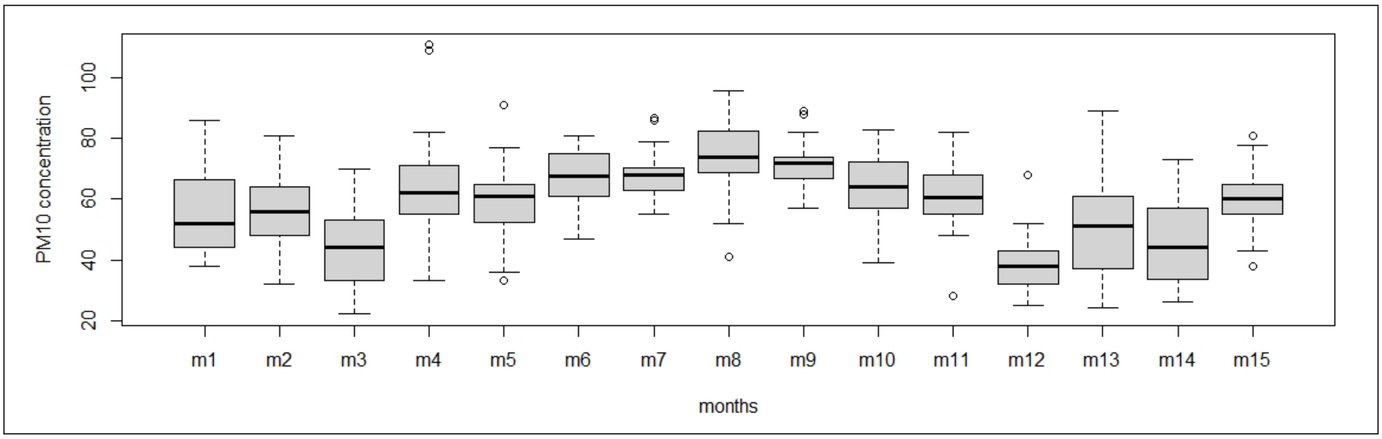

Figure 1. Box Plots of Monthly ISPU Index for PM_{10} from January 2020–March 2021

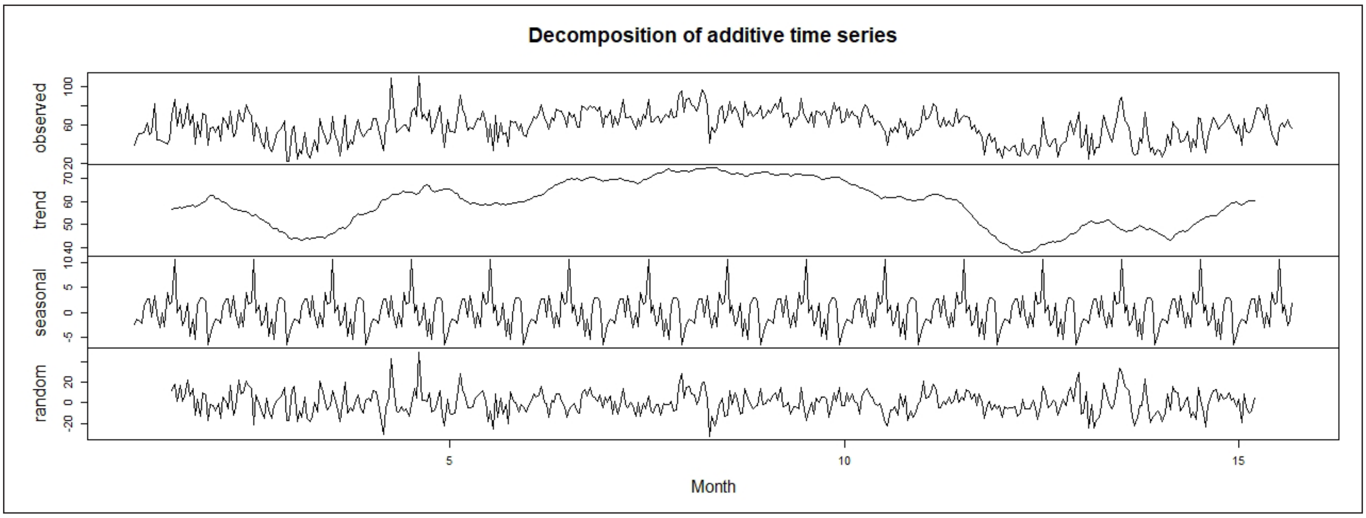

Figure 2. The Decomposition of Time Series Data for PM_{10} ISPU Index in Jakarta City from January 2020–March 2021

Autoregressive Integrated Moving Average (ARIMA) Model

The time series decomposition of PM_{10} (Figure 2) and the results of Augmented Dickey Fuller (ADF) test (Table 2) show that the data was stationary without trend pattern however the PM_{10} has profound seasonality. Therefore, the next analysis of ARIMA model was constructed to PM_{10} ISPU index daily data from 1st of January 2020–31st of March 2021. The Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) correlogram illustrated in Figure 3 determined the order of AR and MA components to construct ARIMA model, and the integration component by differencing the seasonality (Figure 3). Multiple models based on the possible order combination were examined and the model with the smallest AIC value was selected for the *p,d,q* order (1,1,1). Table 3 represents the results of model estimation using ARIMA framework for time series data of PM_{10} in Jakarta. The model selection was performed by consideration of AIC value 3552.75. Parameter estimation was determined using Maximum Likelihood (ML) method.

Table 3. The Results of ARIMA *P,D,Q* (1,1,1) Model Parameter for PM_{10} for the Actual ISPU Index Value

	AR1	MA1	AIC
Coefficient of estimate	0.310744*	-0.881811*	3552.75
Standard error	0.059828	0.032460	
Pr (>|z|)	2.059×10^{-7}	2.20×10^{-16}	

The Ljug-Box plot (Figure 4) illustrate that residuals of the model was insignificant at entire lags and showed non-zero autocorrelation. It represents that the model is appropriate. Holt-Winters exponential smoothing was employed to make short prediction of PM_{10} with interval estimate of Confidence Interval 95%. The pattern of the forecasting for the next 6 months demonstrates a decreasing pattern (Figure 5).

Spearman Rank Correlation Analysis

The correlation examination using Spearman Rank between variables is presented in Table 3, it shows that PM_{10} index was significantly correlated with all parameters, the positive correlation was demonstrated for PM_{10} with temperature, while negative correlation was demonstrated for PM_{10} with humidity and wind speed. The temperature showed negative correlation with relative humidity (Table 4).

Table 4. The Results of Spearman Correlation Test: Correlation Coefficient (Rho) Between Parameters for Checking Multicolleniarity

	PM_{10}	Temp	Hum	Wind Speed
PM_{10}	1			
Temperature	0.424**	1		
Humidity	-0.392**	-0.776**	1	
Wind speed	-0.129**	-0.018	-0.018	1

* $p < 0.05$ ** $p < 0.001$

Cross Correlation analysis

The cross correlation analysis between PM_{10} index and meteorological parameters of average temperature and average humidity in multiple lag were presented ion Figure 4 illustrated the highest correlation coefficient with was between PM and temperature without lag, followed by humidity lagged at 1 month, and wind speed lagged at 1 month, with coefficient correlation rho 0.42, -0.38 and -0.24 (Figure 6).

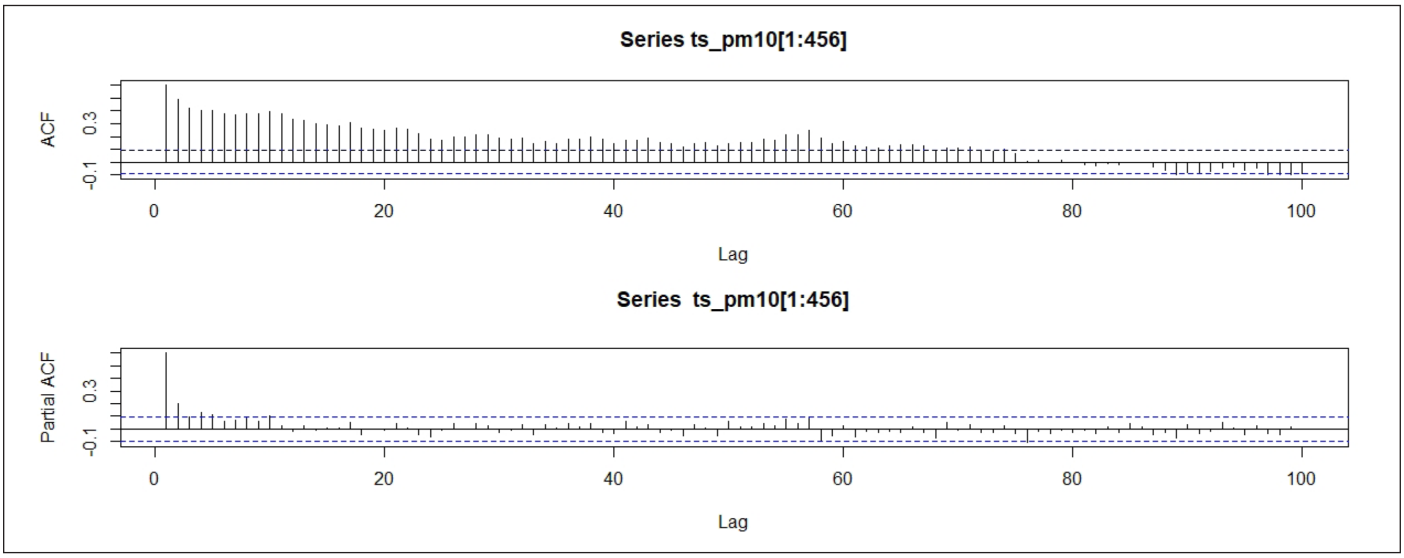

Figure 3. The Plots of Auto Correlation Function (ACF) And Partial Auto Correlation Function (PACF) for PM_{10} ISPU Index Data in Jakarta

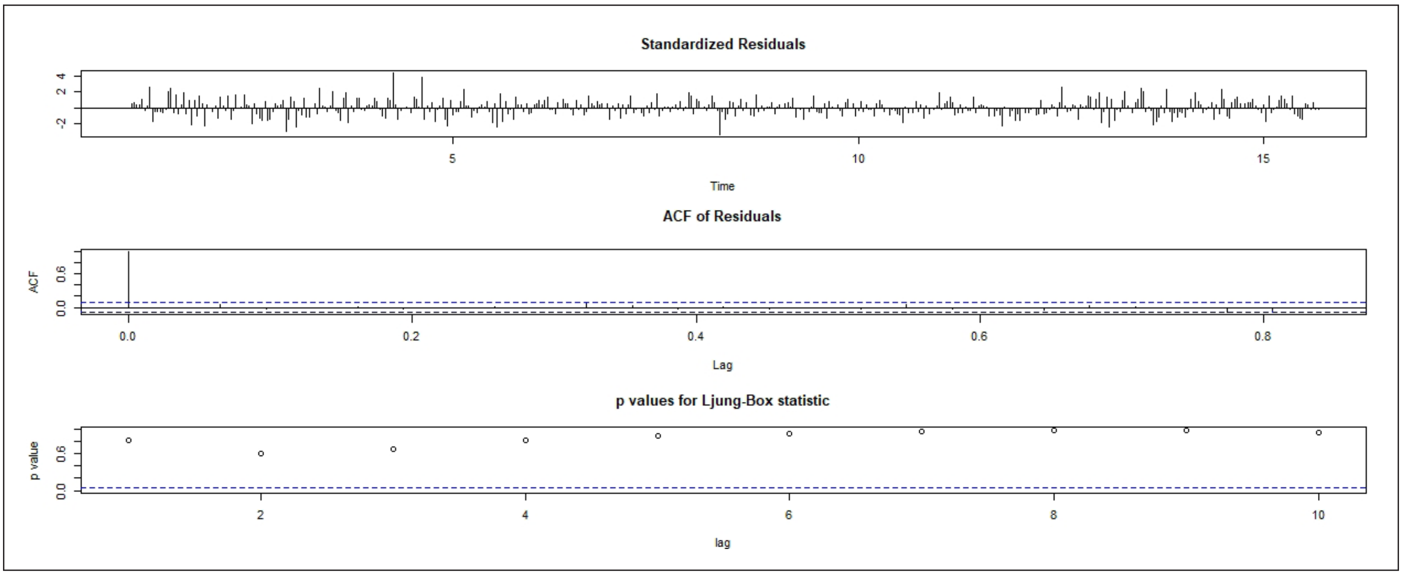

Figure 4. The Plots of Residuals of the Model After Integration of Differencing Component into ARIMA Model with P,D,Q Parameters (1,1,1)

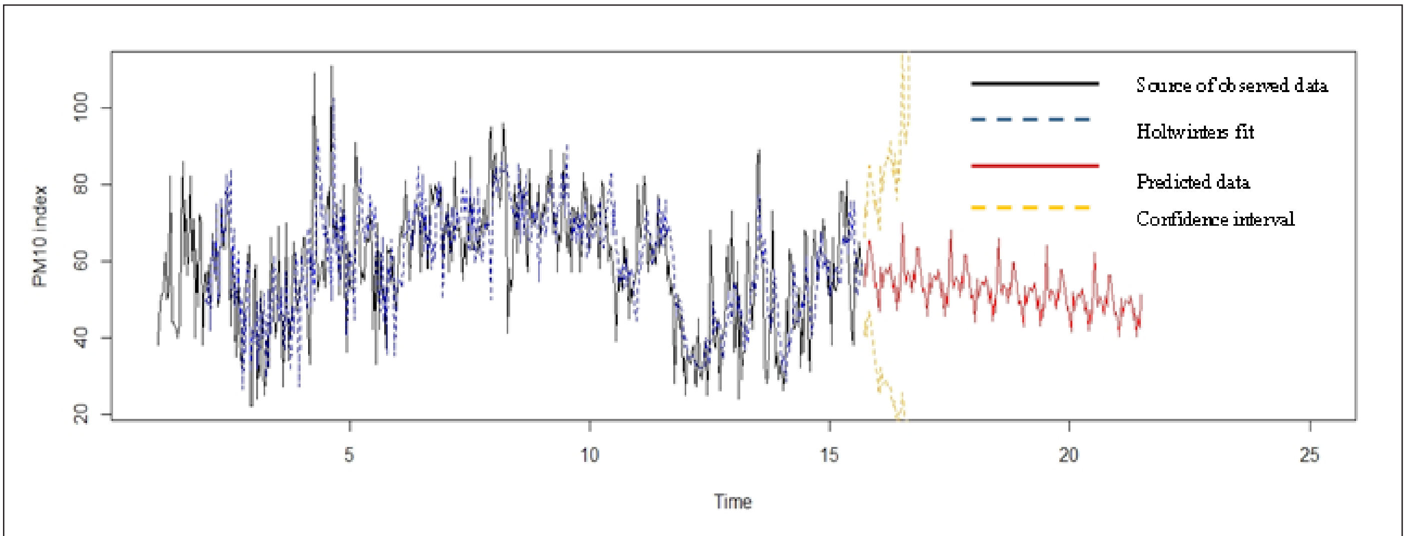

Figure 5. The Prediction of PM_{10} ISPU Index Data Using Holtwinters Forecasting for the Next 6 Months

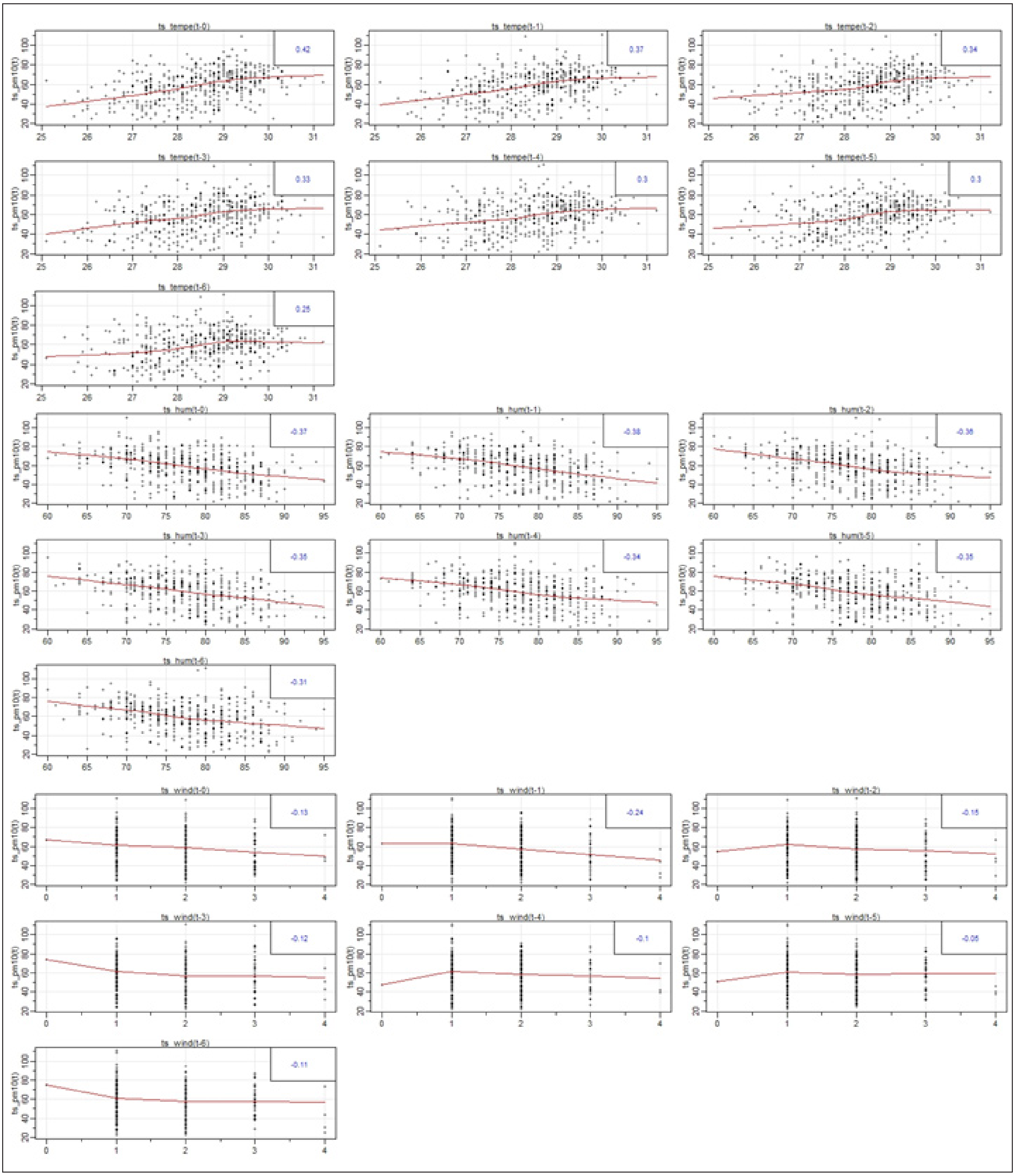

Figure 6. Cross Correlation Function Curve Between PM_{10} ISPU Index and Meteorological Factors of Temperature, Humidity and Wind Speed With Lag 1 – 7 Days In Jakarta

DISCUSSION

Summary of Findings

This current research revealed a significant correlation between PM_{10} concentration in Jakarta with the meteorological factors (temperature, humidity and wind speed). The average temperature was positively correlated with PM_{10}, while average humidity and wind speed were negatively correlated with PM_{10}. There was no apparent trend of PM_{10} during the study period, however the elevated concentration was detected since April 2020 and reached its peak around August–November 2020 before dropping to the lowest in December 2020. It is predicted that the concentration of PM_{10} would continue to decrease few months after study period.

Temporal Pattern of PM_{10}

The concentration increase was concurrent with the first implementation of large scale social restriction in Jakarta Province that was started in April 2020 (24), as reported by the previous study that fine particulate ($PM_{2.5}$) level in Jakarta was increasing about 14 percent during January–June 2020 and the Air Quality Index (AQI) in 2020 was higher than 2 years before (18). Despite the global decreasing trend of $PM_{2.5}$ level in majority of cities in the world during Covid19 lockdown implementation, comparing to the concentration before the restriction policy imposed, it was however, Jakarta together with Tokyo, Singapore, Hanoi and Kathmandu had approximately 11% higher in $PM_{2.5}$ level (25).

In fact, the Government of Jakarta Province implemented a multi-phase restriction and the source of pollution should have been lower in Jakarta. As there were 12 stages of large scale social restriction as containment of Covid19 transmission with the duration of each of stage was 14 days, the regulation was enacted in 9th of April 2020 (11). The restriction stages were 10th–23rd of April 2022, 24th of April–22nd of May 2022, 22nd of May–4th of June 2022, 5th of June–2nd of July 2022, 2nd–16th of July 2020, 16th–30th of July 2020, 30th of July–14th of August 2020, 14th–27th of August 2020, 27th of August–10th of September 2020, 14th–27th of September 2020, 28th September–11th of October 2022 (12–13).

The result could be driven by cross-border pollution as Jakarta is surrounded by outskirt areas such as Bogor, Depok, Tangerang, Bekasi, Karawang (8) as urban agglomeration cluster that still had a high intensity of industrial, commercial, office work, transportation and domestic activity during the pandemics 2020–2021 (26). The result is supported by similar findings from other cities, for instance, aerosols air pollutants generated from mainland China reached Japan after few hours, and it was supported by the favourable wind direction and meteorological condition (27). While emission binding policy cooperation between Hong Kong and Shenzhen was found substantially could minimize transboundary air pollution in both countries (28). The previous study in Jakarta compared air pollutants concentration during and after Covid19 pandemic lock-down in early 2020. It revealed that even though CO, NO_2, and SO_2 showed a decreasing concentration trend, however PM_{10} level was elevating about 10.9 percent (16). Thus, the large social restriction during pandemic did not significantly impact in lowering PM concentration in the capital without controlling the emission from the neighbouring areas.

The higher concentration of monthly PM_{10} index in Jakarta Province was recorded around August 2020 and remain relatively high until November 2020 before reached the lowest in December 2020. This finding is in line with the previous study about aerosol air pollution 2012–2016 in SEA region stated that in Maritime countries such as Indonesia reach the peak of PM_{10} level around September–October, exacerbated by forest burning (29). Particulate pollution levels and sources were differed in Jakarta between the dry and wet seasons in 2018–2019. Daily Particulate Matter ($PM_{2.5}$) levels were substantially greater in the dry season than in the wet season; however, the major sources contributing to $PM_{2.5}$ were more diversified in the wet season. Vehicle exhaust emissions contributed the most, 32–41 percent in the wet season and 42–57 percent in the dry season (9). Similar to the previous findings from Malaysia stated that PM_{10} level was affected by seasonal pattern, however there was insignificance variation between day and night (19).

Particulates pollutant across Indo-Gangetic Plain during the period of 2015–2018 showed the high concentration detected during winter and post monsoon, moreover the consistency of the fine particulates was contributed in majority by submicron particulates (69%), submicron aerosol (43%), mineral dusts (18%), and particles emitted from combusting process (30). In addition, study about aerosol air pollutant in SEA region for ground fine particulate found factors to drive the air quality disruption within the region such as urban-rural gradation, biomass combustion influence on atmospheric condition, seasonal and climate variation (29). While, In Indonesia, fine particulate and coarse particulate concentration in urban area are 1.24 and 2.03 heavier than rural areas respectively (29). Similarly, space-time variation of $PM_{2.5}$ was reported within intra-urban and intra-urban areas in the US (31). It highlighted that geographical and temporal factor take a crucial role in the distribution of PM_{10} pollutant in Jakarta.

Correlation between PM_{10} and Meteorological Parameters

The significant correlation of meteorological components with fine particulate in Jakarta in this study agrees with the previous research that recorded variability of ground level emission in Jakarta City that was highly influenced by local atmospheric characteristics. It resulted in the widest Effect Factor (EF) standard deviation and high spatial variability for particulate pollutants ($PM_{2.5}$) in the Capital of Indonesia (32). While, study in Petailing Jaya found the characteristics of PM_{10} concentration was driven by seasonal dynamics during non-hazy climate (33). Moreover, maritime countries in SEA including Indonesia is considered to have relatively stable temperature, air humidity and rainfall (29). It can be underlined that meteorological in combination with anthropogenic factors drive fine particulate pollution in metropolitan urban areas including Jakarta.

PM_{10} Sources and Concentration

Jakarta emission inventory report for air pollutants recorded that transportations (57.99%), manufacturing industry (33.90%), energy industry (7.49%), domestic sector (0.54%), and commerce (0.08%) released as many as 8,817 tons PM_{10} per year in 2018 (34). Among all modes of transportation, land transportation was the dominant source of PM_{10} emissions, with diesel-fueled automobiles (trucks) accounting for the majority (2,817 ton per year or 56.42%), followed by buses and passenger cars using diesel fuel (34). The use of oil fuel produced the most PM_{10} emissions from the manufacturing industry (2,750 tons per year) and the energy industry (542 tons per year), despite the fact that the overall PM_{10} emission ratio from the energy sector against the manufacturing was 0.21 (34).

Similarly, PM_{10} was primarily emitted through oil fuel combustion (5 tons/year) in the commercial sector (34). In addition, non-combustion activities, such as those in the construction industry, released PM_{10}. However, the contribution was only temporary because it was based on the magnitude of construction activities each year, which comprised heavy equipment movement, transportation, site preparation and maturation, and construction. When compared to other industries' emissions, the construction sector generated 40% of PM_{10} emissions in 2018 (34). Similar to Petailing Jaya, that the source of the pollutants was identified from multiple sites including of dust produced from smelting and transportation activity, mineral dust, marine salt, mining industry, agriculture, industrial manufacturing, secondary inorganic aerosols, heat resulted from traffic and coal burning, and biomass combustion (33).

Coal power plants were indicated as one the sources of particulate matters 2.5 pollution in air ambient across the globe, while, most of the power plants were situated in the northern hemisphere that make the seasonal pollution impact is more profound (32). Interestingly, the reduction of coal power emission, particularly in Asia region has significant association with multiple health benefits. $PM_{2.5}$ concentration at night was considered lower than daytime, due to low temperature retains the plumes at ground surface resulted higher concentration at ground level and bring higher adverse health impacts (32). The other source of particulate pollutants in SEA region is biomass combustion and agriculture activities, moreover satellite MODIS data showed high annual forest fire intensity in Indonesia during dry season (from April to September or October within Java, Bali and North West Nusa) (29). The emission sources of PM_{10} have identical activities pattern with other pollutants sources such as SO_2, CO, and NO_2, that enables cross selection method in assessing air quality (19), whereas traffic and vehicle emission is frequently indicated as the primary contributor for the PM_{10} level in capital city (14). PM_{10} is composed from potential toxic substances including of Zn, Fe, Mn, Cu, Pb that were noticeable by using CPM spider web monitoring instrument (35).

Health Impacts of PM_{10} Pollution

Air pollutants were indicated to associate with community health outcome, for instance Poland study found that 5 cities displayed increasing healthcare admission for each of additional of 10 μg/m^3 of $PM_{2.5}$ level (3), as well as in Shenzen City that ambient concentration of air pollutants such NO_2 SO_2, and PM_{10} were found to have positive correlation with excess risk of mortality rate (5). There were multiple health problems, carcinogenicity and mortality resulted from particulate matters exposure (1). Individual exposure to air pollutants in China from 2016 to 2017 was associated with stroke fatality with larger impacts recorded on elderly population (4). Co-interaction between air pollution and the adverse climate condition could lead to hospitalization due to Acute Myocardial Infarction (AMI) (36). Furthermore, the substantial impacts of fine particulate matters pollutant latent exposure in environment could result on fatality due to cardiovascular and respiratory adverse condition, moreover it could initiate lung cancer (6). Therefore, air quality exposure in Jakarta as one of capitals in Asia could bring high health risk for its dense population.

Study Strength and Limitations

This study has several limitations, such as inconsistency of data that influenced the forecasting results. Insufficient information about geographical distribution, wind direction and the absence of health impacts measurement data make it challenging to mitigate the public health burden from PM_{10} emission. Aside from the limitations, this study could provide baseline information for air quality research in Jakarta Province as well as to replicate in other cities in Indonesia.

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CONCLUSION

The concentration of PM_{10} in Jakarta Province was associated with meteorological components and the social restriction did not significantly reduce the emission of fine particulate pollutant. Control of PM_{10} emission in the urban capital area need to be supported by integrative monitoring and intervention across neighbouring areas. Future research with analysis about geographical, wind direction and health outcome data could comprehend the mitigation of pollutants distribution and adverse health impacts in Jakarta Province.

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