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Sustainable Ambient Environment to Prevent Future Outbreaks: How Ambient Environment Relates to COVID-19 Local Transmission in Lima, Peru

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Abstract: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), universally recognized as COVID-19, is currently is a global issue. Our study uses multivariate regression for determining the relationship between the ambient environment and COVID-19 cases in Lima. We also forecast the pattern trajectory of COVID-19 cases with variables using an Auto-Regressive Integrated Moving Average Model (ARIMA). There is a significant association between ambient temperature and PM_{10} and COVID-19 cases, while no significant correlation has been seen for $PM_{2.5}$. All variables in the multivariate regression model have $R^2 = 0.788$, which describes a significant exposure to COVID-19 cases in Lima. ARIMA (1,1,1), during observation time of $PM_{2.5}$, PM_{10}, and average temperature, is found to be suitable for forecasting COVID-19 cases in Lima. This result indicates that the expected high particle concentration and low ambient temperature in the coming season will further facilitate the transmission of the coronavirus if there is no other policy intervention. A suggested sustainable policy related to ambient environment and the lessons learned from different countries to prevent future outbreaks are also discussed in this study.

Keywords: COVID-19; correlation; forecasting; ambient temperature; $PM_{2.5}$; PM_{10}

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or COVID-19, as it is known, is a global epidemic that has produced severe casualties throughout the world. In general, most SARS-CoV-2 patients show slight symptoms with a dry cough, sore throat, and fever [1–3]. On the other hand, some infected patients could have complications that increase a patient's mortality rate [2,4]. COVID-19 has been spread over 220 countries as of mid-May (https://COVID19.who.int/), causing the deaths of 346,762 people around the world, which is expected to rise continuously. The WHO declared this virus a pandemic from 11 February 2020, as in subsequent months global transmission occurred rapidly [5–9]. A total of 41.3% of patients were infected in hospital by person to person transmission [10]. A previous COVID-19 transmission study found a pattern of respiratory droplets and contact routes in human to human transmission [11–13].

Since the beginning of this outbreak, the SARS-CoV-2 characteristics have been identified [14], as has how it correlates with other diseases [15]. Several studies have been carried out to gain a better understanding of COVID-19 local transmission specifically in an ambient environment, since some of them have pointed out the capability of the COVID-19 virus to transmit through the air in an ambient air environment [16,17]. Different research has highlighted an ambient environment for the possibility for COVID-19 transmission [5,7,18–23] and how these factors determine COVID-19 mortality cases [5]. However, a different pattern has found that there is no correlation between temperature and confirmed cases of COVID-19 [24,25]. Acute respiratory inflammation and asthma attacks have been associated with exposure to air pollutants [26]. The length of exposure was also related to mortality [27–29] and different health cases that have been admitted to hospital [30–32]. Particulate matter with a diameter of 2.5 to 10 μm, considered as inhalable coarse particles, is a key indicator of air pollution [33,34]. Previous studies have shown the significantly positive association of ambient air contamination and confirmed cases of COVID-19 specifically for $PM_{2.5}$ and PM_{10} [26,35,36]. It has also been revealed that an increment of 1 $\mu g/m^3$ in $PM_{2.5}$ is linked with a 15% increase in the COVID-19 mortality rate [37].

In Peru, on 6 March 2020 the first imported COVID-19 case was confirmed. In their history of travel, the citizen had been to different countries in Europe, such as France, Spain, and the Czech Republic, reporting 6 social contacts, 3 flight contacts, 21 contacts with medical staff, and 12 housing contacts. Subsequently, cases were confirmed between his contacts. Until 5 May, all the regions in Peru have confirmed transmission. In terms of air pollution and the ambient air contaminant threats to human health, there is enough proof that shows a correlation between pollutants and an increment in the risk of numerous diseases [36]. The National Environment Council carried out an inventory of the total atmospheric emissions in Lima, estimating 86% for the transport sector and 14% for the industry sector [38]. Studies carried by MINAM (Ministerio del Ambiente) show that 10 microns and particles in suspension are equivalent to 5.8% and 4.7% of the total deaths that occurred during 2007, respectively. The local policy guidelines in Lima are: establish and implement measures to prevent and diminish the polluting effects of air on people's health by preventing, reducing, or mitigating gaseous emissions and particulate matter from different activities and implement and integrate air quality and noise monitoring networks, making maps of the dispersion of air pollutants [39].

However, since the result varies between each region, it is important to narrow down the study to a specific region to provide useful suggestions for policymakers and the public. The research problem is the fact that the cases of COVID-19 cases in Lima, Peru, have increased day by day. It is important to find the influence factors especially related to ambient temperature and air pollutants, since some research has found the possibility of the transmission of COVID-19 through airborne transmission.

The purpose of this research is to investigate the possibilities that the transmission of COVID-19 in Lima, Peru, is influenced by ambient temperature and several ambient pollutants and how its policy influence the local transmission. In this research, the correlation between ambient temperature and several ambient pollutants with cases of COVID-19 infection was investigated. The pattern trajectory of COVID-19 cases was forecasted. Based on the result of this study, the local government in Peru may have input to generate policies for combating the COVID-19 virus.

This study was conducted in Lima, since Lima, the capital of Peru, is considered as one of the most contaminated cities in South America in terms of air pollution, the Vehicles in Lima is predicted around 1752 million old unit which used daily, and the growth of vehicles has been 7% per year for the last 10 years [40]. These factors represent nearly 80% of the air pollution emissions in Lima. Furthermore, the districts that register most particulate matter are Ate, Independencia, La Victoria, Santa Anita, and Rimac [41]. This short-term study was conducted during the initial outbreak in Lima, since it is intended to be initial research to give an overview of the ambient environment with the local transmission of COVID-19 in the first stage of the outbreak.

2. Materials and Methods

2.1. Data Collection

The daily cases of COVID-19 in Lima were compiled. The data ertr collected from the formal sources of the Ministry of Health; the National Institute of Health; and the National Center of Epidemiology, Prevention and Control of diseases, Ministry of Health, Peru (https://COVID-19.minsa.gob.pe/sala_situacional.asp). The scope for independent variables was limited to $PM_{2.5}$, PM_{10}, and temperature. Daily historical $PM_{2.5}$ (μg/m^3), PM_{10} (μg/m^3), and temperature (°C) data in Lima, Peru, were obtained from official websites (https://senamhi.gob.pe/). We used the daily average data from five different stations in Lima located in Campo De Marte, San Borja, San Juan De Lurighanco, San Martin De Porres, Santa Anita, and the US Embassy for statistical analysis. All the data were collected from the period of 7 March to 10 May 2020.

2.2. Statistical Analysis

2.2.1. Ambient Environment Relationship with COVID-19 Infected Case

We used multivariate regression for measuring the relationship between the ambient temperature and pollutants ($PM_{2.5}$ and PM_{10}) with cases of COVID-19 infections in Lima. Multiple regression finds the connection of the dependent variable and each independent variable, while controlling for all other variables [42]. With this method, we may find the correlation of each variable and the influence of the independent variables on COVID-19 cases.

2.2.2. Forecasting the Pattern of COVID-19 Infected Cases

Autoregressive Integrated Moving Average Process (ARIMA) is a model that is purposely applied to analyze time-series data [43]. ARIMA consists of different models based on the function and need, such as an autoregressive (AR) model, a moving average (MA) model, and a seasonal autoregressive integrated moving average (SARIMA) model [44]. ARIMA is well known for its ease of use and interpretation, but this model may be considered as a precision model only for a short-term period [45]. The ARIMA model is represented as ARIMA (p, d, q) in scientific literature, where p is the order of the autoregressive (AR) model, d is the order of differencing, and q is the order of the moving average (MA) model [46]. In this study, ARIMA is used to find the most suitable model configuration that can be used to forecast confirmed-, outpatient-, and inpatient-n COVID-19 cases using weather data, including average temperature, relative humidity, and precipitation as the independent variables. The Box–Jenkins approach is used for the ARIMA (p, d, q) modeling of the time series. This process is designed to take advantage of the relationship in the sequentially lagged association that usually exists in a collected data timeframe [47]. To select the best configuration of ARIMA (p, d, q) models for this case, their goodness of fit has been compared using both the Akaike Information Criteria (AIC) and the Root Mean Square Error (RMSE) number. The AIC number measures both the fit of a model and the unreliability of a model [48]. We used the Akaike Information Criteria and the Root Mean Square Error to select the best configuration of the ARIMA (p, d, q) models for this case [49]. In this study, AIC is used to assess the complexity of the model [50], in which the minimum AIC number will indicate the model with the best goodness of fit [51].

3. Results

3.1. Cases of COVID-19 Infection in Lima, Peru

Figure 1 shows a log of the COVID-19 daily cases in Lima, Peru, from 7 March 2020, to 12 May 2020. Until 10 May, Peru had confirmed 68,822 cases, 1961 cases of deaths, and a lethality of 2.85%. Patients are recorded according to their stage of life—children (2.4%), adolescents (1.2%), young people (12.2%), adults (70.6%), and older adults (13.6%). The clinical characteristics of positive cases of COVID-19 in percentages in Peru, 2020, are cough (71.7%), fever and chills (55.5%), general discomfort (53.9%), sore throat (54%), respiratory distress (31.6%), headache (30%), nasal congestion (25.1%), muscle pain (18.6%), diarrhea (13.8%), nausea and vomiting (8.3%), chest pain (7.7%), other symptoms (6.7%), joint pain (3.7%), abdominal pain (2.8%), and irritability (1.5%). Lima as the capital city of Peru and the region with the highest number of people infected with COVID-19; by 10 May, there were 43,284 cases [52]. The downward spike between 12 and w15 April 2020 was possibly caused by the absolute immobilization of all the Peruvian citizens in Lima during the pandemic and the different test capacity.

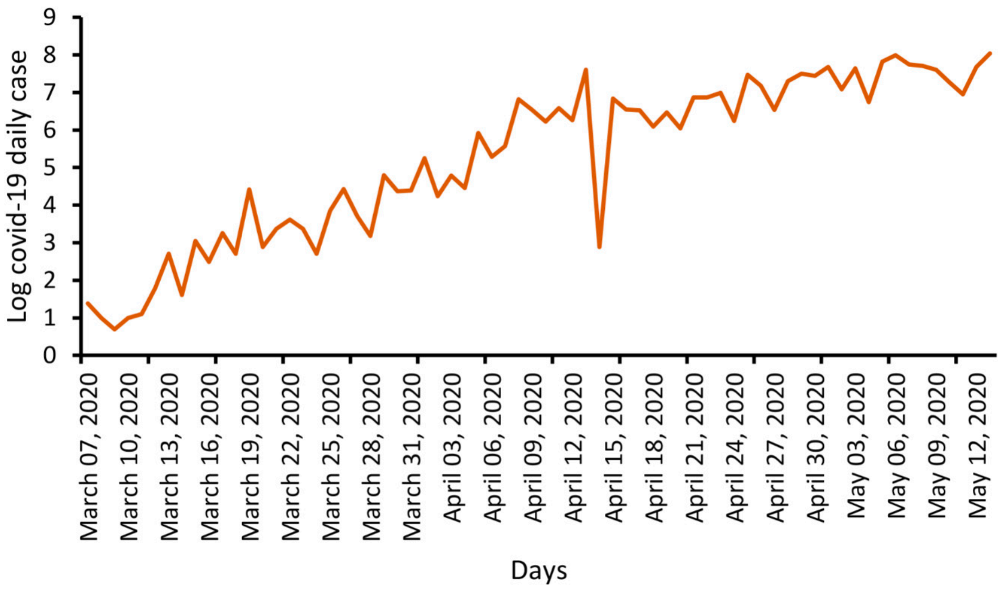

Figure 1. Daily number of COVID-19 cases in Lima.

3.2. Correlation Between Variables with COVID-19 Cases

Multivariate regression was used to illustrate the coefficients related to each variable and to test their significance. The multivariate regression was used for determining the correlation between average temperature, $PM_{2.5}$, PM_{10}, and cases of COVID-19 cases. In this study, we analyzed the logarithm data of the COVID-19 daily cases, average temperature, $PM_{2.5}$, and PM_{10}. Figure 2 presents the probability output normal distribution of COVID-19 daily cases. The 68 normal COVID-19 daily cases form a nearly linear pattern, which indicates that the data set was normally distributed data. The results denoted that the R square value was 0.788, which explains 78.8% of the variation in the average temperature, $PM_{2.5}$ and PM_{10} variables. The other 21.2% was unexplained due to factors which were not in the model or measurement error.

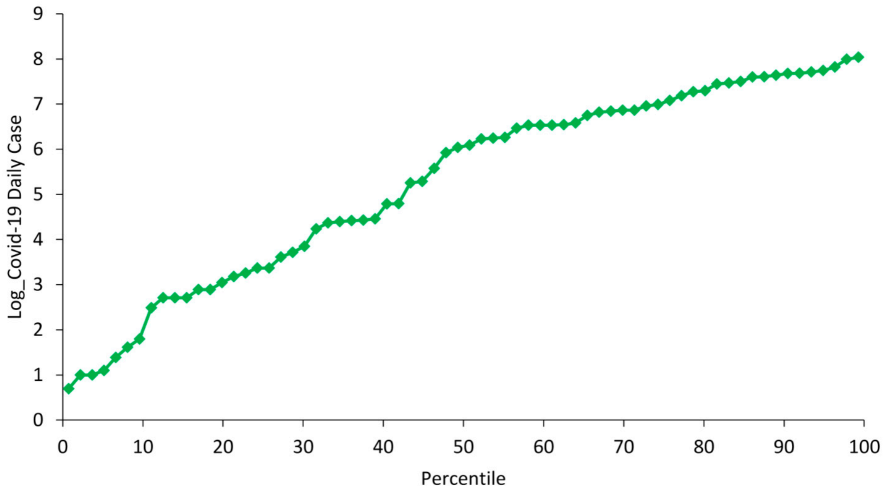

Figure 2. Normal probability output distribution plot of COVID-19 daily cases.

Table 1 describes the ANOVA result, which explains the multivariate regression model of COVID-19 cases in Lima. The categorical independent variables tested are ambient temperature and ambient particulate pollutants, including average temperature, $PM_{2.5}$, and PM_{10}. The F value of 79.33975 indicates that the null hypothesis is rejected and concludes that independent variables are useful for explaining the COVID-19 confirmed cases. The output presents average temperature, and the $PM_{2.5}$ and PM_{10} models show a significant exposure of COVID-19 cases since the significance value is less than $p = 0.05$.

Table 1. ANOVA of COVID-19 multivariate regression in Lima.

	df	SS	MS	F	Significance F
Regression	3	244.8397	81.61323	79.33975	1.57×10^{-21}
Residual	64	65.83392	1.028655		
Total	67	310.6736			

An estimation of regression analysis model and output is shown in Table 2. The coefficient number points out the average temperature, and the $PM_{2.5}$ and PM_{10} independent variables contribute to the regression model. The transformation of COVID-19 cases in Lima is associated with an increase in the unit of an independent variable while controlling for the other independent variables. We use variation inflation factor (VIF) to validate the assumption of multivariate regression. The VIF is run with different independent variables individually. The VIF numbers for average temperature, $PM_{2.5}$, and PM_{10} are 2.6, 3.2, and 3.6, respectively, which indicates that a moderate correlation occurred between the independent variables and dependent variables in the model.

Table 2. Estimated regression analysis model and output.

	Coefficients	Standard Error	t Stat	p-Value
Intercept	54.34278	9.820579	5.533562	6.25×10^{-7}
$PM_{2.5}$	0.173609	0.220736	0.7865	0.434477
PM_{10}	0.739323	0.368269	2.007559	0.048916
Average Temperature	−16.3385	2.999513	−5.44705	8.71×10^{-7}

3.3. Trajectory Forecast of COVID-19 Cases Using ARIMA in Lima

The ARIMA analysis is used for COVID-19 cases, ambient environment, and pollutant data (average temperature, $PM_{2.5}$, and PM_{10}). We observed the COVID-19 cases with the ambient environment (average temperature, $PM_{2.5}$, and PM_{10}) data to find the best combination for the ARIMA (p,d,q) model. Based on the model characteristics, we establish three models—ARIMA (1,1,1) lag 2,3,5, ARIMA (1,1,1) lag 1,3,6, and ARIMA (2,0,3) lag 1,3,6—with $PM_{2.5}$, PM_{10}, and average temperature lag, respectively, as presented in Table 3. For the COVID-19 cases, the best model is ARIMA (1,1,1), where the lag terms for $PM_{2.5}$, PM_{10}, and average temperature are 1, 3, and 6, respectively. The AIC (Akaike's Information Criteria) of the ARIMA (1,1,1) model is 118. 916, which reveals the lowest AIC numbers compared to the other proposed models.

Table 3. ARIMA model for COVID-19 cases in Lima with average temperature, $PM_{2.5}$, and PM_{10}.

ARIMA (p,d,q)	Lag	Akaike's Information Criteria	Root Mean Square Error
1,1,1	$PM_{2.5}$ (1) + PM_{10} (3) + Average Temperature (6)	118.916	0.72757
2,0,3	$PM_{2.5}$ (1) + PM_{10} (3) + Average Temperature (6)	123.142	0.63601
1,1,1	$PM_{2.5}$ (2) + PM_{10} (3) + Average Temperature (5)	123.466	0.67957

For forecasting comparison, we use these three models to predict the amount of COVID-19 cases by extrapolating the pattern several days ahead. The forecast of those three models is shown in Figure 3.

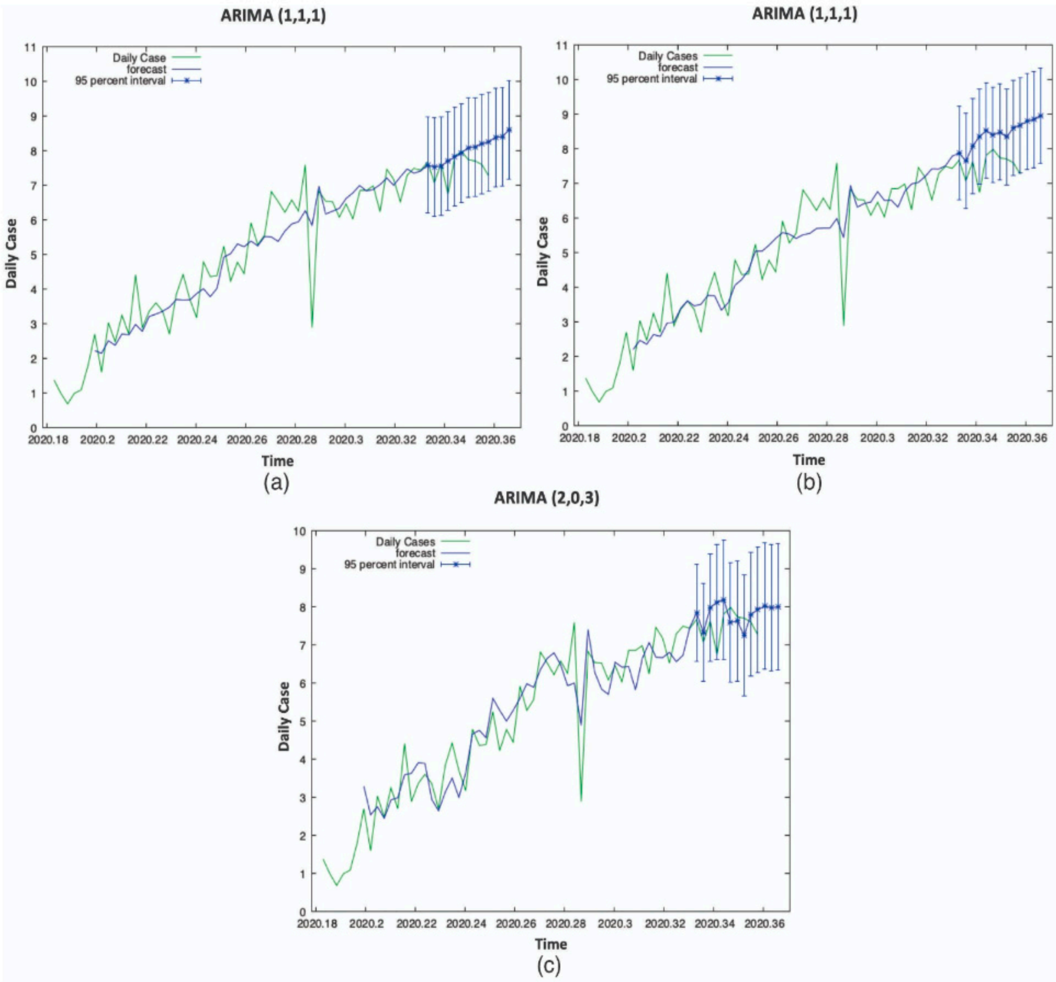

Figure 3. COVID-19 cases forecast graph in Lima for (**a**) 1,1,1 lag 2,3,5, (**b**) 1,1,1 lag 1,3,6, and (**c**) 2,0,3 lag 1,3,6, with a respective lag of $PM_{2.5}$, PM_{10}, and average temperature.

4. Discussion

4.1. Correlation between COVID-19 Cases and Ambient Environment

We explored the relationship of ambient temperature, $PM_{2.5}$, and PM_{10} and COVID-19 cases using multivariate regression and a COVID-19 pattern forecast using ARIMA for those variables. Based on the result of the multivariate regression analysis, the exposure–response relationship is significantly correlated, as proven by R^2 = 0.788, in which ambient environment cannot explain 78% of the cases, although a strong association between ambient environment and the number of cases was found. However, each exposure (independent) variable is defined with a different *p*-value. A low *p*-value (<0.05) for average temperature and PM_{10} indicates that those changing variables will highly be associated with the COVID-19 daily case numbers. In contrast, a larger *p*-value (>0.05) in $PM_{2.5}$ suggests that changes in the $PM_{2.5}$ variables are not associated with changes in the COVID-19 infected cases. In another definition, the multivariate regression model is significant for determining the correlation between COVID-19 cases and the ambient environment, but only two individual variables (average temperature and PM_{10}) are significant, while the $PM_{2.5}$ exposure is not associated with COVID-19 cases in Lima. Different studies mention that temperature has a different pattern in the southern hemisphere and northern hemisphere. In the southern hemisphere, the cases increase when the temperature decreases. In the northern hemisphere, the cases increase when the temperature also increases [53,54]. Since our result shows that two variables have a relationship with COVID-19 cases, the relationship of environmental pollutants must be examined with a multi-causal approach [55,56].

Table 4 presents a comparison of the statistical results for ambient environment and coronavirus transmission that mentions a different result for ambient temperature correlation with COVID-19 transmission. Several studies have found that ambient temperature is highly correlated with coronavirus survival and transmission [21,57–59]. Similar to the previous studies, our study finds that ambient temperature plays significant role in COVID-19 case transmission in Lima. Nevertheless, different studies in cooler ambient temperature have found that there is no correlation between ambient temperature and COVID-19 dispersion [24,35].

Table 4. Statistical comparison result for ambient environment and COVID-19 cases in different regions.

No	Correlation	*p*-Value	Variable	Method	Region	References
1	Correlated	<0.05	Mean $PM_{2.5}$	Pearson	Italy	[60]
2	Correlated	<0.01	Mean $PM_{2.5}$	Pearson	Northern Italy	[61]
3	Correlated Correlated Correlated	<0.01 <0.01 <0.01	Mean PM_{10} Mean $PM_{2.5}$ Mean PM_{10}	Spearman	California, US	[62]
4	Significant	<0.01	Mean temperature	Spearman	China	[7]
5	Not correlated	0.28	Mean temperature	Multiple regression	China City inside Hubei	[24]
6	correlated Not correlated Correlated	<0.05 >0.05 <0.05	Mean temperature Mean $PM_{2.5}$ Mean PM_{10}	Pearson	Lima, Peru	Current study

The previous study on ambient pollutant exposure and COVID-19 has determined a significant relation between air pollutant and COVID-19 dispersion [26,35,36,63,64]. PM_{10} and $PM_{2.5}$ play a major role as ambient pollutants for COVID-19 dispersion [35,36]. In contrast, our study finds that PM_{10} has a significant correlation with daily COVID-19 cases, while $PM_{2.5}$ is not associated with the daily COVID-19 numbers in Lima. The different pattern in Lima may be caused by the low number of $PM_{2.5}$ data, since the data $PM_{2.5}$ from monitoring station have not existed for some period of time. In addition, aerosol samples was collected in Wuhan in February 2020, and no SARS-CoV-2

(<3 copies/m^3) concentration was found except in a crowd gathering of people with COVID-19 [63]. The PM_{10} and $PM_{2.5}$ maximum standards in Peru are 100 and 50 µg/m^3, respectively [65], and controlling the ambient air pollutant, specifically PM_{10}, is necessity for preventing the spread of coronavirus and other respiratory diseases in the future. As the current policy for tackling COVID-19 spread, the government suggests wearing a mask, correct hand washing, and social distancing [66]. In addition, the government also recommends avoiding traveling to China and other countries with high-level transmission, and quarantining entire cities or the country [67]. Based on the statistical result and reference studies, ambient environment has significant role in transmitting the coronavirus. Therefore, managing ambient environments is important for preventing future outbreaks.

It is still not clear whether the COVID-19 virus transmission in correspondence with ambient environment specifically affects the human body or the coronavirus itself. Therefore, further study is needed on the COVID-19 virus characteristics and survival rate inside the human body and ambient environment for better understanding the coronavirus transmission in Lima.

4.2. ARIMA Trajectory Pattern of COVID-19 Case in Lima

A time series analysis on the occurrence of various infected cases is very helpful in elaborating phenomena which explain the dynamics of the observed variables, and the ARIMA model is one of the widely known time-series forecasting methods with an acceptable forecasting performance [47]. In this study, we apply an ARIMA (p,d,q) model to analyze the COVID-19 trajectory pattern in Lima. Our findings revealed a linearity in the current COVID-19 daily cases in Lima and show a rapid growth phase. Although data extension is needed to provide a detailed forecast, the transmission models are found to have similar pattern, in which the COVID-19 cases in Lima tend to increase and there is no tendency toward a decrease. If there is no policy intervention or tactical management to interfere the transmission of COVID-19 in Lima, it is predicted that the COVID-19 cases will rise continuously.

4.3. Government Policy on Future Ambient Environment and COVID-19 Management

The result of this study shows that PM_{10} has strong correlation with COVID-19 case in Lima, Peru. Based on the monitoring data, PM_{10} in Lima majorly exceed the particulate matter standard (50 µg/m^3) [68]. The pollution is dispersed from south to northeast by winds, which probably contribute to the increase in respiratory diseases of the population exposed in these districts. The aim of maintaining air pollution should be strictly implemented since there is high probability correlation with COVID-19 outbreak. In line with the original purpose of air pollution prevention, with National Environmental Action Plan (PLANAA PERU 2011–2021), the goals for the year 2021 indicates that 13 cities in Peru, including Lima, have to maintain air quality and the second goal is that 10% decrease in morbidity in areas prioritized by air quality contamination exposure (particles and sulfur dioxide) [69]. A high rate of air pollution is found in Province of Lima and the constitutional Province of Callao due to the meteorological and soil relief conditions [39]. Therefore, in the District of San Borja-Lima some policy is taken by this district for air quality management such as promote adequate air quality management though pertinent technical instruments and develop actions to prevent and mitigate the impact of air pollutants on citizen health.

As comparison presented in Table 5, in northern China a study denoted that the reciprocal action effects of temperature and air pollution are decisive, and the leverage of air pollution on the COVID-19 distribution soars as the ambient temperature increases. This study revealed that the China government should take a policy to shift its energy infrastructure from fossil fuel-based to clean energies, especially in power plant and household heating, which are the dominant sources of air pollutant besides industrial production and traffic [70]. In the Lombardy region, Italy, a study denoted high levels of daily average ground levels of particle emission, weather and definite climate create a convincing effect on the rise of COVID-19 cases accumulative number, newly confirmed case and total mortality cases. This finding revealed a concern regarding future advancement of air quality in respective area which comply European Community standards [56].

Table 5. Policy comparison related to ambient environment and COVID-19.

No	Suggested Policy	Region	References
1	Proposed clean and renewable energies	Northern China	[70]
2	Improvement air quality	Lombardy region, Italy	[56]

4.4. Future Mitigation as Consideration for Preventing Similar Outbreak

Our result finds strong correlation of ambient PM_{10}, temperature, and COVID-19 cases. On the contrary, ambient $PM_{2.5}$ is not related to COVID-19 cases. However, several studies presented in Table 3 that were conducted in different regions present a significant correlation for $PM_{2.5}$. For preventing future outbreaks and developing a better mitigation scenario, all possible variables in an ambient environment, including $PM_{2.5}$ and other pollutants, should be monitored and controlled. A sustainable policy for controlling ambient environment and monitoring the effectiveness of this policy are also important factors For instance, when China is concerned about environmental issues, a series of policies to protect the ambient environment are published. Nevertheless, the environmental regulations were monitored and it was found that the policies are ineffective. Hence, several recommendations are studied for better policies in the future [71].

There are some policies responses in education level that need to be taken, such as improving the quality of education through digital platforms, establishing a better connection for students to access to knowledge and information in order to maintain social distancing, training teachers to be able to use all the internet tools for classes online, and creating actions and protocols at schools for hand washing. At the same time, implement subsidies policies and partnerships to power companies that provides low prices in internet connection and electrical services, especially in remote areas, for socially vulnerable people and low-income families.

National policy has to be strengthened and the public health service system needs to be improved, with the compulsory use of masks for preventing respiratory diseases due to air pollution. Simultaneously, we need to promote the use of nonpolluting vehicles, the use of clean fuels, urban restructuring, and control emissions from the source. In addition, we need a reinforced policy for closing borders, identifying cases, tracking them, isolating and tracking people's contacts.

5. Study Limitation

Our study consists of three independent variables, including ambient mean temperature, PM_{10}, and $PM_{2.5}$, with the dependent variable of COVID-19 cases in Lima, Peru. Since early study is needed for determining deeper study, we conducted the study with limited variables and a short-term timeline during the first stage of COVID-19 transmission in Lima. Our result shows the relationship of PM_{10} and ambient temperature. COVID-19 can transmit through aerosol and attachment on particulate matter in ambient air. The results of this study need to be further studied for a long-term or seasonal ambient environment. Since there is also a possibility of COVID-19 character change [72,73], the effect of ambient environment during the short term in different periods of time may also studied. Potential bias may have occurred, since our data sheet is limited to three independent variables and a short-term period.

Since the outbreak began in Lima, studying the effectiveness of government policy during the pandemic is also important to validate our result. However, we do not have data access regarding government policy for countermeasures for the COVID-19 pandemic and human mobility in Lima.

6. Conclusions

This study finds that there is a statistically significant association between an ambient environment and COVID-19 cases (R^2 = 0.788). The PM_{10} and temperature conditions in the coming season are expected to further facilitate the transmission of the coronavirus. To the best of our knowledge, a different pattern of COVID-19 transmission in different regions has occurred even though the same independent variables were used. It is suggested that COVID-19 transmission research for specific region and laboratory studies should be conducted for better understanding the COVID-19 characteristics and local transmission.

There was an association between ambient temperature and PM_{10} with COVID-19 cases in Lima, while no association is shown for $PM_{2.5}$. ARIMA (1,1,1) with lag $PM_{2.5}$ (1), PM_{10} (3), and average temperature (6) was found to be the best-fitted model for forecasting COVID-19 cases in Lima. The result further shows that the COVID-19 case pattern trajectory remains increasing continuously if there is no intervention conducted. In addition, based on historical data, higher particle concentrations and lower ambient temperatures with a suitable time lag will likely result in more COVID-19 cases. Therefore, to prevent other outbreak in the future, managing ambient environments with a sustainable policy is important.

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