Spatial Analysis of COVID 19 in KSA Related to Air Pollution Factor

Najla Hamandi Alharbi(✉), Zainab S. Alharthi, Nuha A. Alanezi, and Liyakathunisa Syed

Department of Computer Science, Taibah University, Medina, Saudi Arabia
najla.hamandi@gmail.com

Abstract. The pathogen of the disease COVID-19 is the extreme acute respiratory syndrome COVID-19 especially in the elderly and asthmatics. In our study, we examine if long-term exposure to air pollution raises the infection situations of COVID-19 in kingdom of Saudi Arabia (KSA). Through our studies, we proved that there is an associative relationship among the air pollution factor besides, the spread of COVID-19. As the results showed that compounds of air pollution such as Carbon monoxide (CO), Ozone (O3), Sulphur dioxide (SO2), Nitrogen dioxide (NO2), and PARTICLES (PM10), are severely related to the occurrence of COVID-19 due to the rate of the ratio of these areas more in the areas with the most prevalence of cases of COVID-19, so we used in our study the SIR model. It is considered one of the easiest, most reliable tools, consisting of three compartments; prone, contaminated, and removed. Besides, we utilized the Runge-Kutta method.

Keywords: COVID 19 · Air pollution · SIR model · Runge-Kutta method

1 Introduction

There are different analysis methods for air pollution and covid-19. Due to its large harmful impacts on human health and all elements of the environment, air pollution has been of considerable concern. A rise in the number of cars is driving the rapid population growth in KSA. Dammam is known in KSA as one of the cities with most significance. It is the biggest seaport in the eastern province of KSA, which is one of the largest towns with the highest proportion. Due to the presence of a vast number of manufacturers, libraries, and various centers of government. Dammam is also a major Saudi oil industry (Aramco) administrative hot spot and is home to nearly 40% of KSA's manufacturing production. Therefore, highly industrial activity and heavily traffic movement are considered sources of air pollution in Dammam [1]. The coronavirus disease COVID-19 is a public health concern due to the disease's rapid spread. Due to inadequate research on the spatial analysis of the air quality factor in KSA specific to COVID 19. In this research, we try to investigate the correlation between air pollution and the increase in the COIVID 19 cases in KSA.

Y. H. Sheikh et al. (Eds.): AFRICOMM 2021, LNICST 443, pp. 443–457, 2022.
https://doi.org/10.1007/978-3-031-06374-9_29

Geographically in KSA, Riyadh is the most affected by the virus infection, spatially the eastern one that is most affected by the spread of the virus. Must be kept in mind Makkah, Madinah, Qatif, and Dammam are the most cases of contact. Latest research worldwide demonstrated that there are several factors air pollution and environmental aspects can lead to the magnitude and intensity of COVID spread. In [2] the authors believe that those with pre-existing conditions like respiratory problems and chronic diseases with air pollution could suffer from a higher risk of mortality. Latest research worldwide demonstrated that there are several factors air pollution and environmental aspects recent can lead to the magnitude and intensity of COVID spread. In [2] they believe that those with pre-existing conditions like and air pollution could suffer from a higher risk of mortality.

We claim in KSA that air-polluted areas can adversely impact the health result of patients with COVID-19 due to a possible reduction in the immune response. The primary aim of this research is to analyze COVID-19 in KSA. In KSA, air-polluted areas are more vulnerable to the spread of the COVID 19 disease. So the question arises [3], what is the influence of air pollution in eliciting systemic negative impacts oxidation processes of the lungs and mechanisms of immune alteration raising the exposure of people to COVID19. In different studies, excessive outdoor air pollution was associated with acute pulmonary infection, asthma, and Cardiopulmonary Illness Deaths. PM2.5 is known to be one of the key air quality risk elements for particles with aerodynamic diameters below 2.5 μm, that led to causing many million deaths worldwide each year. Besides, cofactor with indirect clinical symptoms associated with respiratory infection in the human body, and oxidation processes in the lungs and extrapulmonary organ may be ambient aerosol. In addition, the authors in 2003 [4] reported an environmental review of the previous SARS pandemic in China as well as observed that patients are possible to die in areas with medium levels of air pollution (API) than those in regions with low APIs. The key factors affecting the fatalities of the 2009 flu A(H1N1) pdm09 disease, that had major geographic variations, were examined in another report in 2017. 124 articles were reported in the study and 27 potential risk factors were examined, including PM10 levels. In comparison, the findings revealed that PM10 showed just 4% of the average difference among nations and that other elements had greater or equal weights: Age composition (forty percent), latitude (eight percent), circulating influenza A and B viruses mostly through disease (3–8%), and incidence of several infections (4–6%). Although the data interpretation is still uncertain, it is probable that outdoor air contamination may add to the high vulnerability of communal to COVID-19. Yet, wariness must be taken when interpreting large levels of traditional aerosol indicators, like PM10 and PM2.5 without chemical, biological and physical examination, into an increase in susceptibility or a clear interpretation of the mortality disparities different in various nations [3].

The rest of the sections in the research are categorized as follows: Some of the previous studies related to the research are discussed in Sect. 2. The suggested technique is outlined in Sect. 3 and the findings are displayed and discussed in Sect. 4. Conclusion is provided in Sect. 5.

2 Related Work

Present some of related studies in this section of air pollution and covid-19. There are different analysis methods for air pollution and covid-10. Air pollution in KSA, Due to its large harmful impacts on human health and all elements of the environment, air pollution has been of considerable concern. A rise in the number of cars is driving the rapid population growth in KSA. Dammam is known in KSA as one of the cities with most significance. It is the biggest seaport in the eastern province of KSA, which is one of the largest towns with the highest proportion. Due to the presence of a vast number of manufacturers, libraries, and various centers of government. Dammam is also a major Saudi oil industry (Aramco) administrative hot spot and is home to nearly 40% of KSA's manufacturing production. Therefore, highly industrial activity and heavily traffic movement are considered sources of air pollution in Dammam [1].

According to [1] study, the mean PM10 concentrations observed in the study override all local and international criterations, where Sulphur dioxide (SO2), Nitrogen dioxide (NO2), levels were lower than their AQGs. The causes of industrial pollution and traffic operation greatly affect the atmosphere of Dammam [1]. Makkah really is one of the crowded in KSA's cities and it remnants busy for most of the year, and millions of people visit this spot, especially as during Hajj pilgrimage and the month of Ramadan. This research analyses the temporal variations of different air contaminants and attempts to graphically classify the origins of pollution of the main pollutants in Makkah. Temporal variations of different air pollutants (CO, NO, NOx, PM10, SO2, NO2, and O3) have been measured and pollutant concentrations have been found to be wellassociated with the normal movement of road traffic. In most of the substances, large concentrations are seen during the peak hours of morning traffic, excluding O3, which reveals the best amount as expected during the afternoon attributable to elevated solar radiation [5].

The coronavirus (COVID-19) disease has dissemination internationally, give raise to serious illness and death-rate. In anticipation of successful antiviral drugs, countries have utilized various public health measures to track the dissemination and management of healthcare needs. An unusual strategy was adopted by Sweden not to impose strict closures but instead to urge personal accountability. They evaluate the effects of it and other possible pandemic management techniques in Sweden. Utilizing population, jobs, and residential data, individual-based models of COVID-19 distribution in Sweden has been introduced. For COVID-19, the epidemiological parameters were tested over a narrow date range; several parameters were checked if major uncertainties persisted. The impacts of several public health initiatives were checked over 160 days were checked, evaluated for their impacts on the intensive care unit (ICU) request and mortality average, and contrast with the Swedish results during April 2020. Statistical sampling Ten separate move were conducted for all parameter set; the 90% confidence intervals (CIs) to calculated results via these moves were fairly narrow, specifying that unreliability of biological parameters are more restricted to overall sampling rather than statistical sampling. Disease transmission was modeled on an individual basis through discrete-time stochastic simulation; additional details are given and recorded elsewhere in the Supplementary Material. In summary, transmission can take place in places of work or in classrooms, homes, and neighborhoods. The sum of these exposures is the risk of being polluted by a person. Data for the interval up to twenty-one March were computed with COVID-19 distributed models, validated against registered average of death for the interval twenty-one March to six April, and analyzed against death data for the period from six April onwards. Since real-time polymerase chain reaction testing in Sweden was not conducted on a widespread basis, initial infections were determined in the time frame up to twenty-one March using back-calculation from ICU acceptances. So far the Swedish COVID-19 approach has grant a startling finding that mild mandates overlaid with voluntary initiatives will produce outcomes quite close to rigid late-onset mandates. This strategy, however, creates greater need for health services and more deaths than tight regulation at an early stage and relies on sustained public will [6].

On 31 December 2019, in China, Wuhan, a propagation of COVID-19 was registered. The epidemic expansion quickly to other cities Chinese and many countries. From sixteen January to six February 2020, the spatiotemporal model and the spatial correlation of the precocious phases of the COVID-19 disease in China were established in this research. The spatial disease models of COVID-19 were investigated in China in this study. A test was conducted to establish if there was a geographical correlation of COVID-19 infections using Moran's I spatial statistics for separate meanings of neighbors. The COVID-19 dataset was acquired from a Chinese site offering real-time data on the propagation of infectious disease. The website publishes, via region and date, statistics on recently reported cases in mainland China. There are thirty-one regions in China, and this study utilized three-week data from sixteen January to six February 2020, that was present in China through the initial COVID-19 phases. This study explored Moran's I a spatial dependency with different types of spatial relationships. As of around 22 January, a spatial clustering pattern was found in each kind of neighborhood, except for the bed-based neighborhood of the medical center. Five, two, and two cases were registered in the regions connected to Wuhan via train lines, including Shenzhen, Shanghai, and Beijing, on twenty-one January, the initial phase of COVID-19 in China, respectively. This indicates the likelihood of COVID-19 spreading from Wuhan through transport to other regions. The spatial dependence we found in this study also gives us this possibility. In China, the spatial diffusion of the COVID-19 disease has been noticed. The results indicated that most of the models suggested a strong spatial association of COVID19 diseases from around Habeebullah Turki 2013, apart from medical-care-based link models [7].

Researchers used the ARIMA model in [8] to expect the predictable number of COVID-19 situations in KSA every day over the next four weeks. Four diverse forecasting models were applied in the first; Moving Average (MA), Autoregressive (AR) Model, a mixture of (MA) and (AR) is (ARMA), and incorporated ARMA (ARIMA), to identify the acceptable better model. They obtained the ARIMA model from the results and performed preferable than the other models. The results of the forecast indicated that the trajectory of KSA will keep to increase and could get to 7,668 new situations every day and more than 127,129 cumulative everyday situations for four weeks if strict control measures and precautionary measures to minimize the propagation of COVID-19 were not enforced. In an attempt to prevent a scenario like this, a group of drastic preventive and control measures is recommended.

In [9] the authors investigated a designed survey for the common population in KSA to determine the extent of psychological effect through the disease. In the early phase of the eruption, they performed an online survey that used a snowball sampling method. Data on several sides of sharer knowledge, interests, sociodemographic, mental health, and psychological impact were collected in the surveys. For mental health cases and psychological effects, the impact of the Stress Scale (DASS-21) and the Depression, Anxiety and Incident Scale-Revised was evaluated (IES-R). Of the findings, 1160 respondents were enrolled in the study. In conclusion, 23.6% reported the medium to the extreme psychological effect of the eruption, 24%, 22.3%, and 28.3% registered medium to serious anxiety, stress symptoms, and depression. The outcomes presented that approximately one-fourth of the public population specimen tested mild for extreme psychological effects in the precocious phase of the COVID-19 eruption in KSA. These preventive steps appear to have a preventative effect on the individual's mental health. In the early stages of the eruption, their results can be utilized to shore up psychological intrusion targeted at vulnerable communities and to introduce interventions for public mental health.

SIR model utilized in many studies to analyze the diffusion of COVID-19. So, in [10] utilized a numerical model for forecasting the eruption has been utilized to assess how the easy restriction, population mixing, and quarantine have an impact on outbreak progress. Consequently, the model smooths the way to the authority to manage measures' concerned policy that can control and eliminate the infection.

In our present time [11], which as the Covid-19 pandemic continues authors by Majid et al. found a link between long since exposure to air-pollution and COVID-19 death. Using high geographical resolution, they examine the influence of long since exposure to NO2 and PM2.5 on COVID-19 death in England. About 38,573 COVID-19 deaths at the Lower Layer Super Production Area stage were included in this national cross-sectional analysis in England up to June 30, 2020. Average NO2 and PM2.5 concentrations were also taken from the Pollution Climate Mapping throughout 2014–2018. To measure the impact of air pollution when controlling for a set of confusing and spatial self-correlation, they utilized Bayesian hierarchical models. After correcting for confusing and spatial autocorrelation, they found a 0.5% (95% credible interval: −0.2%, 1.2%) as well as 1.4% (95% CrI: −2.1%, 5.1%) rise in COVID-19 death rate for each 1 $\mu g/m^3$ rise in NO2 and PM2.5 respectively. This corresponds to a posterior likelihood of a beneficial impact equivalent to, respectively, 0.93 as well as 0.78. Besides, Powerful trends, similar to various pollutants, were exhibited via the spatial relative risk at the LSOA level. This will theoretically detect the spread of disease during the first phase of the disease. Finally, their study offers some evidence of the impacts of long since NO2 exposure on COVID-19 death, and although the influence of PM2.5 remains more uncertain.

This analysis [12] is an extension to recent COVID-19 articles and gives a spatial analysis. It is a summary that describes with GIS as well as spatial-statistical methods the trends and tools that are being carried out. Beneficial methods may be COVID-19 experiments with GIS. In decision-making including, more significantly, civic mobilization and reactions from the population. It is important to minimize the spatial-temporal complexities of COVID-19, which is why such work is carried out in all areas of the universe. This is primarily attributed to the opening up of vast volumes of data of geographic information by public institutions, foreign organizations and private corporations.

In [13] investigated the relationship of COVID-19 infection rate and key variables such are air pollution, geometeorological and social parameters in Dhaka, Bangladesh. Common air pollutants in Dhaka include PM2.5, PM10, COx, NOx, SOx, and dust. The pollutants have been occasioned by industrial emissions, construction activities, high traffic density and rapid urbanization. Out of the seven air pollution parameters that were investigated, five parameters were found to be high correlated with COVID-19.

In [14] investigated concentration of fine particle matter (PM2.5), ozone (O3) and atmospheric pollutants in nine New York counties with the highest cases of COVID-19 infections. The researchers used a linear model with spatial and temporal components to represent the effects of spatial and temporal association in variance of estimates that would reduce false rejection of results. The design of the model was to study how the reduction of human activities could influence PM2.5 and ozone (O3) concentrations in urbanized areas. The findings of the research were that the spatiotemporal distribution of PM2.5 and O3 concentrations did not affect the new cases of COVID-19 in the nine counties once the meteorological variables and the spatial and temporal dependencies were controlled. The research concluded that COVID-19 contagion was influenced by social activities and mobility.

3 Methodology

3.1 Data Collection

Data Collection First, we obtain the dataset of the COVID-19 cases counts "KSA Coronavirus illness (COVID-19) situation". It was collected by the Kaggle website and the King Abdullah Center for Petroleum Studies and Research for more than 12 cities in KSA (representing 98% of the population) up to December 11, 2020. (https://www.kaggle.com/kerneler/starter-covid-ksa-4e62c779-2).

(https://datasource.kapsarc.org/explore/dataset/saudi-arabia-coronavirus-disease-covid-19-situation/information/?disjunctive.daily_cumulative&disjunctive.indicator&disjunctive.event&disjunctive.city_en&disjunctive.region_en). This source gives the most comprehensive cities-level COVID-19 data which includes the number of accumulative and new cases and assured situations informed in every city across KSA, updated daily. The study region is KSA that has a population of up to 33.7 million people and 13 provinces (administrative region), and 136 are rustic.

We obtained air pollution dataset of each regions in KSA. This air pollution dataset consists of the names of the regions, daily record dates, and primary pollutants in detail. The regions range of Makkah Al Mukarramah, Hail, Al Madinah Al Munawwarah, Ar Riyad, Al Qaseem, Tabuk, Jazan, Eastern Region, Abha, Al Qurayyat, Al Bahah and Jeddah. Main contaminants such as NO2, CO, PM10 and SO2. The air pollution dataset collected from annual report for air quality from the General Authority of Meteorology and Environmental Protection in KSA for 2020. (https://ncm.gov.sa/Ar/Environment/AirQuality/Pages/AQ-Reports.aspx?folderID=84154daa-5d72-4bb9-a32f-517b969d00ca).

3.2 Proposed Methodology

We identify the spatiotemporal difference of air pollution and its associated with COVID-19 in KSA using descriptive statistics and geographical methods.

3.3 Statistical Analysis

The study of data obtained using the Social Sciences Statistical Kit (SPSS). We utilize secondary industry ratio (SIR) model by fourth-order Runge-Kutta method which developed by Yang et al. (2014). By using of Range-kutta method for 3 dimensions (susceptible, infected, and recovered) which is known as SIR model to examine the impact of pollution with COVID-19 among cities-level. SIR is a popular utilized model for transmission of the disease from human to human. SIR is considered to be one of the most reliable simple tools. Therefore, SIR model has been used in several studies to analyze the spread of COVID-19.

3.4 Spatial Analysis

We studying the pollution spatial distribution and studied whether long-term average exposure to fine particulate matter (PM10) impacts increased situations of COVID-19 in KSA using GIS techniques. In this project, the GIS software used here is ARC GIS. The GIS software used here in this project is ARC GIS. The ARC Map 10.8 edition is used for the additional mapping method. The excel sheet (below table) with the longitudinal and latitude information of the air pollution data has been added to the program and the file is right-clicked to award the Y-axis for the latitudes and X-axis for the longitudes that produce a point file determination of the sampling stations in the form of point characteristics, see Table 1.

Table 1. The air quality data with the latitude and longitudinal details in KSA.

Region\City	Latitude	Longitude	CO	SO2	NO2	O3	PM10
Makkah Al Mukarramah	21.41689	39.89905	0.86	7.48	19.89	27.24	123.71
Hail	21.50344	39.17937	0.94	4.5	9.35	39.34	115.21
Al Madinah Al Munawwarah	24.52465	39.56918	0.98	3.86	20.97	32.6	118.68
Ar Riyad	24.71355	46.6753	2.69	10.14	38.25	26.88	142.8
Al Qaseem	26.20783	43.48374	1.29	2.78	5.64	37.8	171.12
Tabuk	28.38351	36.56619	2.06	4.12	8.14	56.18	99.24
Jazan	16.88936	42.57057	1.03	5	4.6	11.02	25.41
Eastern Region	23.16697	49.36532	2.99	5.88	22.25	32.47	88.07
Abha	18.24647	42.51172	0.63	2.94	4.98	28.84	74.55
Al Qurayyat	31.32964	37.36135	0.65	7.47		34.07	54.9
Al Bahah	20.02174	41.47127	0.94	5.76	23.5	24	47.15
Jeddah	21.48581	39.19251	3.31	10.76	28.85	39.33	109.92

The point view file added is translated into a shape file creating sampling station points. The spatial analyst module of ArcGIS is used for generation of GIS map themes showing the intensity and spatial distribution of various air pollutants over the sampling stations.

Spatial maps have been developed by the IDW method for and parameter that affects air quality. Inverse distance weighting (IDW) is somewhat of a deterministic procedure of univariate interpolation with a known scattered range of points. Calculate the set values for unknown points by utilizing a weighted average of the available values for the known points. Spatial interpolation is a very main attribute of a GIS that is often utilized in different fields to predict and represent. Good output acceleration [15] can be achieved by the IDW interpolation algorithm. There are several different methods, such as precise/approximate interpolation, global/local interpolation, and point interpolation/area interpolation, to define spatial interpolation procedures. For both local and global interpolations, there are many mechanisms: fourier series and trend surface analysis are examples of global mechanisms, whereas local mechanisms are B-splines, proximal, and Kriging techniques. The IDW spatial interpolation algorithm, in particular, is a model algorithm for local interpolation.

4 Results and Discussion

Figure 1 show the relationship among PM10 parameter of air pollution with COVID-19 in KSA. Seems to indicate a direct proportion relationship among PM10 and COVID-19 cases (Fig. 2).

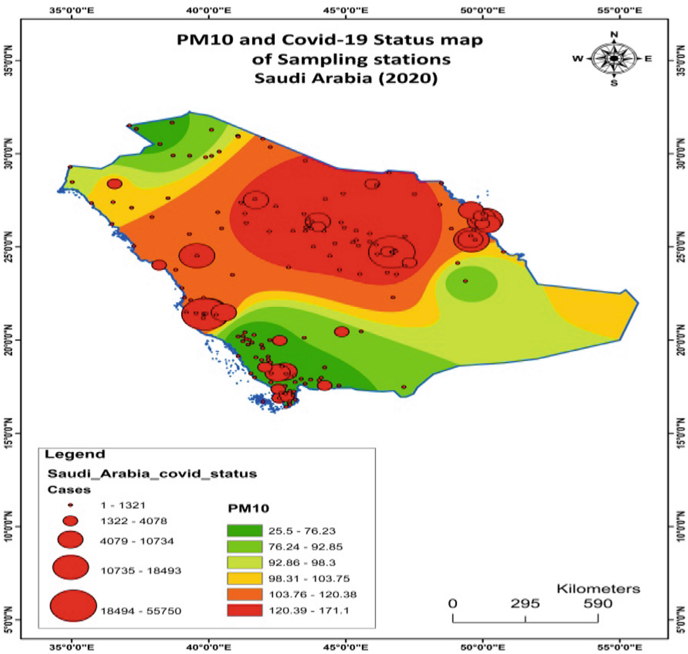

Fig. 1. Map of PM10 parameter of air pollution with Covid-19 in KSA.

The results of primary air pollution are CO, NO2, PM10, O3 and So2 on city-level of KSA show in Fig. 3, 4, 5 and 6 below.

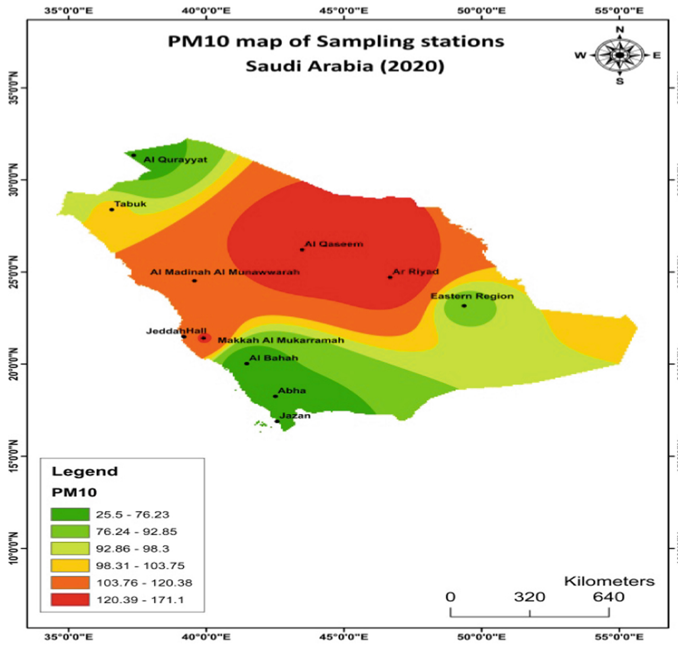

Fig. 2. Map of PM10 parameter in KSA.

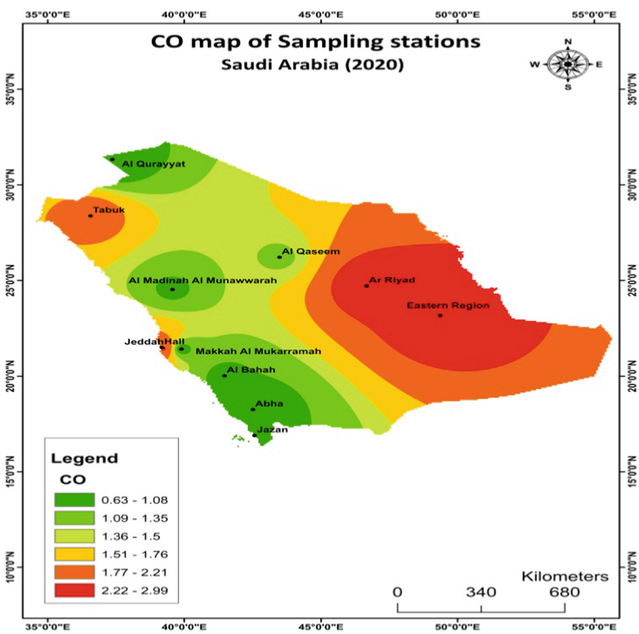

Fig. 3. Map of CO parameter in KSA.

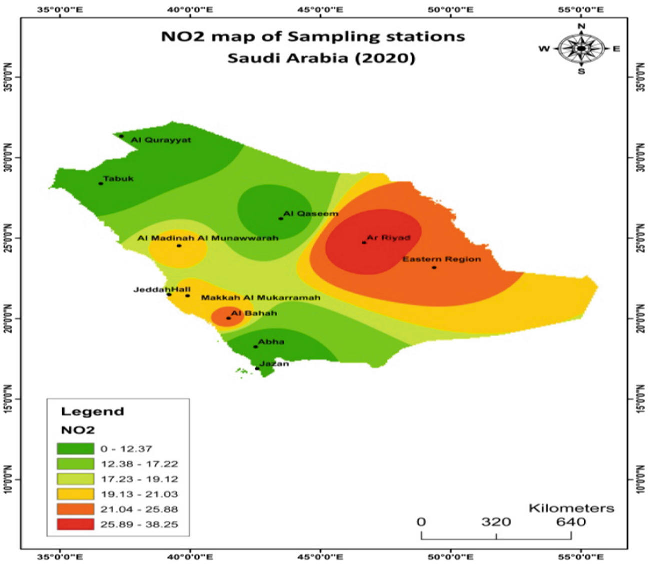

Fig. 4. Map of NO2 parameter in KSA.

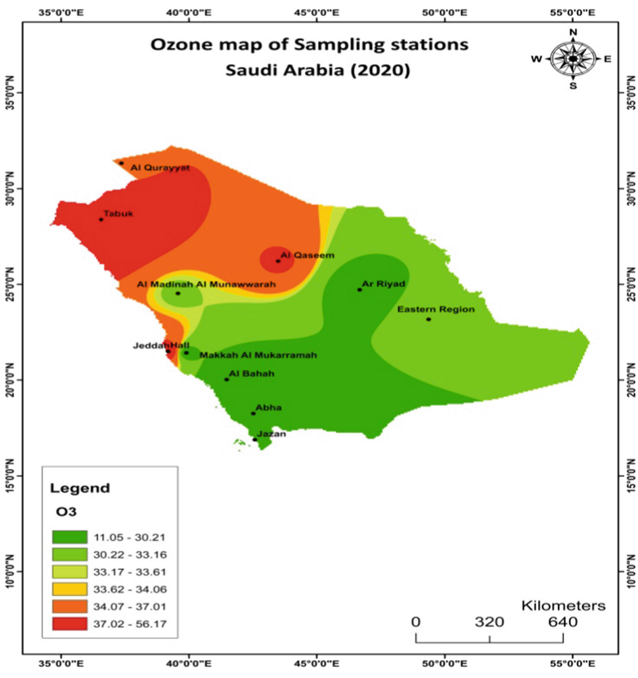

Fig. 5. Map of O3 parameter in KSA.

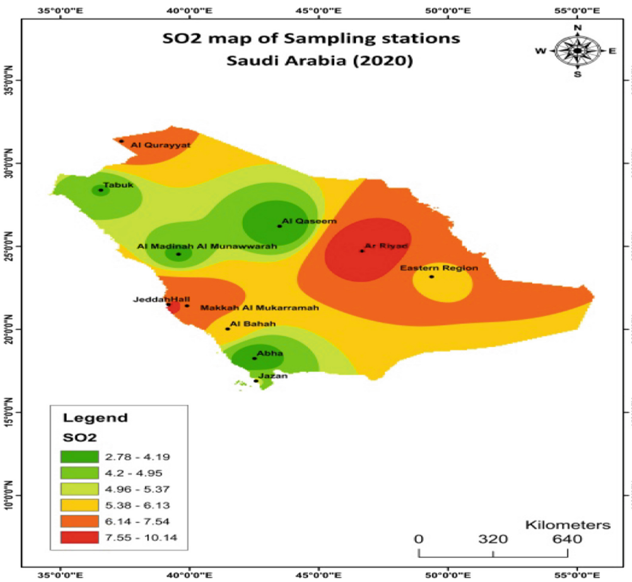

Fig. 6. Map of SO2 parameter in KSA.

A summary of the standard deviation (std) presented in Table 2 below

Table 2. Estimated pollution weighted city-level.

	Id	Province_State	Country_Region	Date	ConfirmedCases	Fatalities
0	1	None	KSA	2020-01-22	0.0	0.0
1	2	None	KSA	2020-01-23	0.0	0.0
2	3	None	KSA	2020-01-24	0.0	0.0
3	4	None	KSA	2020-01-25	0.0	0.0
4	5	None	KSA	2020-01-26	0.0	0.0

	ConfirmedCases	Fatalities
count	35765.000000	35765.000000
mean	3686.621278	244.761303
std	19044.393539	1838.775231
min	0.000000	0.000000
25%	0.000000	0.000000
50%	19.000000	0.000000
75%	539.000000	7.000000
max	345813.000000	33998.000000

Text (0.5, 0, ‘Date’) in Fig. 7, 8.

As shown in the Table 3 above, by comparing our study with the related works, it was found that our study outperforms them in several directions. First, our study focused on the impact of several factors of air pollution, such as PM10, SO2, NO2, CO, and O3 in several regions in the KSA such as Medina, Riyadh, AlQaseem, Tabuk and Jeddah….,

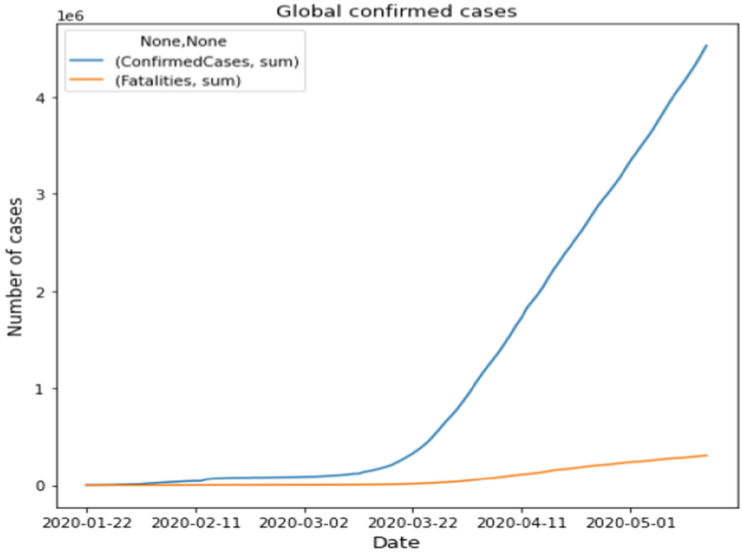

Fig. 7. Global confirmed cases.

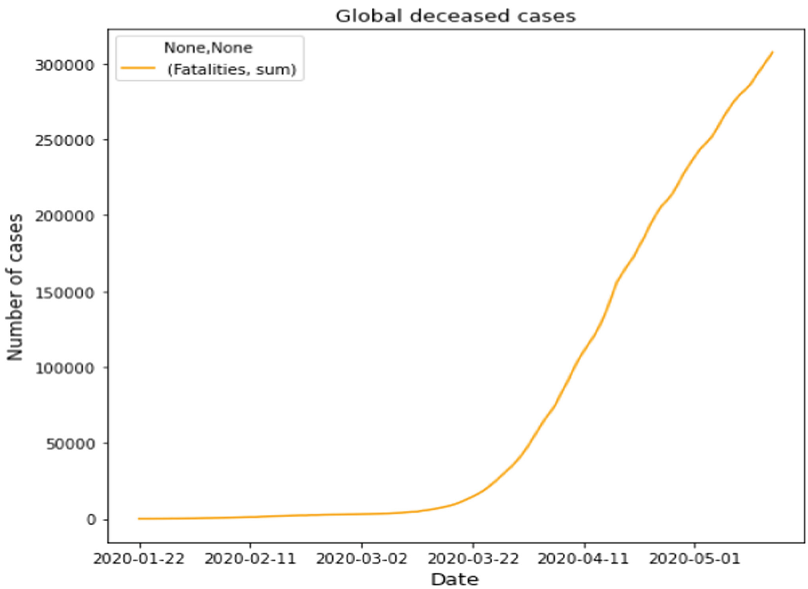

Fig. 8. Global deceased cases.

Table 3. Bench work and analysis.

Paper(s)	Proposed methodology	Results	Cities/Areas	Domain
How do air pollution and meteorological parameters contribute to the spread of COVID-19 in Saudi Arabia? [16]	Count data models are utilized in GLM. COVID-19 infection data were gathered in the form of count data with only non-negative integers. As a result, it indicates that Poisson regression (PR) is the right model for data from new COVID-19 cases	According to the findings, air pollution may be a major risk factor for respiratory illnesses and virus spread When it comes to limiting COVID-19 transmission in Saudi Arabia, however, meteorological factors and strong concentrations of air pollutants must be taken into consideration via public decision-makers	Riyadh, Jeddah, and Makkah	COVID-19 in Saudi Arabia, air pollution
Spatiotemporal Assessment of Air Quality and Heat Island Effect Due to Industrial Activities and Urbanization in Southern Riyadh, Saudi Arabia [17]	The research represents the distribution of questionnaires to 405 local inhabitants to collect their thoughts on air pollution. Analyses of Temporal and Spatial Patterns, The study utilized the Landsat 8 satellite sensor picture for thermal analysis. The NDVI was frequently utilized as an indicator of the vegetation index and to determine the LST	Thermal research of the area revealed that the highest temperatures were found in the Second Industrial City and Al-Misfat, indicating the presence of a thermal island effect caused by industrial operations in these areas	Riyadh	COVID-19 in Saudi Arabia, air pollution
Assessing the air quality of megacities during the COVID-19 pandemic lockdown: a case study from Makkah City, Saudi Arabia [18]	The present study used Microsoft Excel and the "Grapher" software products to analyze temporal changes in air quality data, as well as the "SURFER" software products to display spatial variations in air quality information in the form of contour maps	The results indicate that concentration rates decreased by 26.34% for SO2, 28.99% for NO2, 26.24% for CO, 11.62% for O3, and 30.03% for PM10 during the lockdown period compared to the pre-pandemic period. As a result, automobile traffic activities estimate 25–30% of the overall air pollution load in Makkah	Makkah	COVID-19 in Saudi Arabia, air pollution

(*continued*)

Table 3. (*continued*)

Paper(s)	Proposed methodology	Results	Cities/Areas	Domain
Spatial Analysis of COVID 19 in KSA related to Air Pollution Factor **Our Research**	Data Collection First, we obtain the dataset of the COVID-19 cases counts "KSA Coronavirus illness (COVID-19) situation, Statistical Analysis The study of data obtained using the Social Sciences Statistical Kit (SPSS). We utilize secondary industry ratio (SIR) model by fourth-order Runge-Kutta method. Consisting of three compartments; prone, contaminated, and removed	Our study provided many satisfactory results that proved the role of the air pollution factor PM10 in influencing the spread of COVID-19 especially in busy and central cities such as Riyadh, Madinah and Jeddah	Makkah Hail, Madinah, Riyad, AlQaseem, Tabuk, Jazan, Eastern Region, Abha, Al Qurayyat, A Bahah and Jeddah	COVID-19 in Saudi Arabia, air pollution

etc. Whereas related works were limited to cities or a specific city. Also, we found that the air pollution factors influencing heavily the spread of COVID-19, especially in busy and central cities. While the domain of our study at this time is new, trend, and wide. Moreover our study tending to update and renew about the Covid 19 or nCov2019.

5 Conclusion

In our research, we have dealt with all of the previous studies related to COVID-19 with air pollution and how COVID19 affects the most polluted and central cities. Our study provided many satisfactory results that proved the role of the air pollution factor PM10 in influencing the spread of COVID-19 especially in busy and central cities such as Riyadh, Madinah and Jeddah. In future work, we aim to discuss more pollution factors on a large scale worldwide. We also aim to discuss various factors such as smoking, age, and gender and their impact on COVID-19.

References

1. ElSharkawy, M.F., Ibrahim, O.A.: Sources and concentrations of acidic constituents in the ambient air of Saudi Arabia. Air Qual. Atmos. Health **12**(10), 1207–1214 (2019). https://doi.org/10.1007/s11869-019-00737-1
2. Mollalo, A., Vahedi, B., Rivera, K.M.: GIS-based spatial modeling of COVID-19 incidence rate in the continental United States. Sci. Total Environ. **728**, 138884 (2020). https://doi.org/10.1016/j.scitotenv.2020.138884
3. Contini, D., Costabile, F.: Does air pollution influence COVID-19 outbreaks? Atmosphere (Basel) **11**(4), 377 (2020). https://doi.org/10.3390/ATMOS11040377

4. Cui, Y., et al.: Air pollution and case fatality of SARS in the People's Republic of China: an ecologic study. Environ. Heal. Glob. Access Sci. Source **2**, 1–5 (2003). https://doi.org/10.1186/1476-069X-2-1
5. Habeebullah, T.M.: An analysis of air pollution in Makkah - a view point of source identification. EnvironmentAsia **6**(2), 11–17 (2013). https://doi.org/10.14456/ea.2013.12
6. Kamerlin, S.C.L., Kasson, P.M.: Managing coronavirus disease 2019 spread with voluntary public health measures: Sweden as a case study for pandemic control. Clin. Infect. Dis. **71**(12), 3174–3181 (2020). https://doi.org/10.1093/cid/ciaa864
7. Kang, D., Choi, H., Kim, J.H., Choi, J.: Spatial epidemic dynamics of the COVID-19 outbreak in China. Int. J. Infect. Dis. **94**(January), 96–102 (2020). https://doi.org/10.1016/j.ijid.2020.03.076
8. Alzahrani, S.I., Aljamaan, I.A., Al-Fakih, E.A.: Forecasting the spread of the COVID-19 pandemic in Saudi Arabia using ARIMA prediction model under current public health interventions. J. Infect. Public Health **13**(7), 914–919 (2020). https://doi.org/10.1016/j.jiph.2020.06.001
9. Alkhamees, A.A., Alrashed, S.A., Alzunaydi, A.A., Almohimeed, A.S., Aljohani, M.S.: The psychological impact of COVID-19 pandemic on the general population of Saudi Arabia. Compr. Psychiatry **102**, 152192 (2020). https://doi.org/10.1016/j.comppsych.2020.152192
10. Mohammed, D.A., Tawfeeq, H.M., Ali, K.M., Rostam, H.M.: Analysis and prediction of COVID-19 outbreak by a numerical modelling. Iraqi J. Sci. **62**(5), 1452–1459 (2021). https://doi.org/10.24996/ijs.2021.62.5.8
11. Konstantinoudis, G., Padellini, T., Bennett, J., Davies, B., Ezzati, M., Blangiardo, M.: Long-term exposure to air-pollution and COVID-19 mortality in England: a hierarchical spatial analysis. Environ. Int. **146**(September 2020), 106316 (2021). https://doi.org/10.1016/j.envint.2020.106316
12. Franch-Pardo, I., Napoletano, B.M., Rosete-Verges, F., Billa, L.: Spatial analysis and GIS in the study of COVID-19. A review. Sci. Total Environ. **739**, 140033 (2020). https://doi.org/10.1016/j.scitotenv.2020.140033
13. Díaz-Avalos, C., Juan, P., Chaudhuri, S., Sáez, M., Serra, L.: Association between the new COVID-19 cases and air pollution with meteorological elements in nine counties of New York state. Int. J. Environ. Res. Public Health **17**(23), 1–18 (2020). https://doi.org/10.3390/ijerph17239055
14. Pascawati, N.A., Satoto, T.B.T.: Public knowledge, attitudes and practices towards COVID-19. Int. J. Public Heal. Sci. **9**(4), 292–302 (2020). https://doi.org/10.11591/ijphs.v9i4.20539
15. Huang, F., Liu, D., Tan, X., Wang, J., Chen, Y., He, B.: Explorations of the implementation of a parallel IDW interpolation algorithm in a Linux cluster-based parallel GIS. Comput. Geosci. **37**(4), 426–434 (2011). https://doi.org/10.1016/j.cageo.2010.05.024
16. Ben Maatoug, A., Triki, M.B., Fazel, H.: How do air pollution and meteorological parameters contribute to the spread of COVID-19 in Saudi Arabia? Environ. Sci. Pollut. Res. **28**(32), 44132–44139 (2021). https://doi.org/10.1007/s11356-021-13582-6
17. Salman, A., Al-Tayib, M., Hag-Elsafi, S., Zaidi, F.K., Al-Duwarij, N.: Spatiotemporal assessment of air quality and heat island effect due to industrial activities and urbanization in Southern Riyadh, Saudi Arabia. Appl. Sci. **11**(5), 1–16 (2021). https://doi.org/10.3390/app11052107
18. Morsy, E., Habeebullah, T.M., Othman, A.: Assessing the air quality of megacities during the COVID-19 pandemic lockdown: a case study from Makkah City, Saudi Arabia. Arab. J. Geosci. **14**(7), 1–12 (2021). https://doi.org/10.1007/s12517-021-06898-7