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Public health in Global South: effect of environmental pollutant PM2.5 on the incidence and mortality of SARS-CoV-2 in Karachi, Lahore, and Islamabad

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Abstract. – OBJECTIVE: Environmental pollution has undoubtedly been established as a planetary, intergenerational, and existential threat to global human health and safety. Environmental pollution is adversely affecting the world, mainly the countries where human health is not a priority aspect, and this has been exacerbated due to the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), and pandemic is known as "COVID pandemic". This study investigates the association of environmental pollutants, particulate matter (PM2.5), with SARS-CoV-2 daily cases and deaths in Karachi, Lahore, and Islamabad, Pakistan, presenting the perspectives from the Global South.

MATERIALS AND METHODS: The day-to-day PM2.5 levels were recorded from the metrological website, Real-Time Air Quality Index-AQI. The corresponding data on the COVID cases and deaths in Karachi, Lahore, and Islamabad were obtained from August 1, 2020, to September 30, 2021, from the Health Ministry and National Command Operations Centre Pakistan.

RESULTS: The mean values for PM2.5 in Karachi were 110.4±46.2; in Lahore 174.0±83.2; and in Islamabad 107.1±40.0. The COVID-19 mean daily cases in Karachi were 538.9±446.6; Lahore 398.3±403.1; and Islamabad 212.2±187.6; and mean daily deaths in Karachi were 9.2±8.3; Lahore 9.3±9.7; and Islamabad 1.8±1.8. The results further depicted that the SARS-CoV-2 cases were 2.86 times higher in Karachi and 1.4 times higher in Lahore than in Islamabad. Similarly, the SARS-CoV-2 deaths were 3.6 and 2.8 times higher in Karachi and Lahore, respectively, compared to Islamabad.

CONCLUSIONS: The findings claim that cases and deaths augmented significantly along with PM2.5 levels. These empirical estimates demonstrate an association between PM2.5 and SARS-CoV-2 daily cases and deaths in the cities of the Global South. These findings can contribute to policy-making decisions about addressing air pollutants and climate concerns in developing countries and create an urgency to develop a strategy for minimizing environmental pollution. This study can also steer the actions needed to address the environmental problems in developing countries to improve public health and safety.

Key Words:
Global south, Environmental pollutant, PM2.5, SARS-CoV-2, Pakistan.

Introduction

Over the past three decades, environmental pollution has markedly changed the climate and weather conditions and adversely affected global health, economies, and education[1]. The world witnessed a counterproductive change in the earth's systems comprising land, water, and air. Of these, the most important is the air, as it affects all species in all places. The environment on earth is constantly changing, and living systems evolve within them. Humans have become the planet's dominant species, changing the earth's environment and living systems[2].

Environmental pollution and climate change have undoubtedly been established as a planetary, intergenerational, and existential threat

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to human health and safety[3]. This is further compounded by the rapid growth of unplanned industrialization in the Global North and South. Environmental pollution is also a significant component adversely affecting the large population in developing countries. This has been exacerbated due to the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) pandemic known as the "COVID pandemic". The quality at any given place in 2021 is not what it was in the same place a hundred years ago in 1921. Industrialization, urbanization, and population growth have immensely changed the environment and weather conditions[3]. On December 5-9, 1952, the great smog of London killed approximately 10,000 people and created medical emergency conditions[4]. This was only a precursor of the air environment and health status we are witnessing in the present era. Today, the smoke emitting factories, vehicles, and ships all are damaging mother earth's air balance. These all are the sources of carbon emissions and air pollution. Ironically, we have all converted the sinks of carbon as Amazon forests (lungs of the world) and other natural habitats as carbon sources. The recently repeated incidences of wildfires in many countries, including Australia, Turkey, and the USA, are major causes of air pollutants and pandemics[5].

The empirical data[6] and literature have established a direct link between environmental pollution and adverse conditions of human and animal health and safety. The various diseases such as bronchial asthma, chronic respiratory infections, and coronary artery-associated diseases are exaggerated due to air pollutants[6]. In addition to the physical health, it also affects emotional and psychological health, which largely remains unaccounted for. The literature also establishes that poor air quality and allied pollution can increase cases and deaths due to SARS-CoV-2[7].

Air pollutants, mainly particulate matter (PM2.5), are frequently found in large cities[7]. The literature establishes the link between PM2.5, carbon monoxide, ozone, nitrogen oxide, and other volatile organic compounds with the public health aspects[5,7]. In recent months, from Global South, Lahore, the capital city of Punjab province of Pakistan has become a highly polluted city[8]. Air pollution, mainly from motor vehicles, industries emissions, smoke from brick kilns, the burning of crop residue, and general waste are the leading causes of environmental pollution[8]. The air pollutants, particulate matter with an aerodynamic size of 2.5 μm in diameter (PM2.5) are considered one of the most toxic pollutants because of their ability to enter into the respiratory system, they cross the conducting zone and penetrate deep into the lungs, irritate and destroy the alveolar wall, and consequently impair lung function[9]. The studies[9] in toxicology and epidemiology demonstrated that respirable particles (PM2.5) are related to human diseases and mortality rates.

Air quality is determined by atmospheric aerosols and trace gases, adversely affecting human health. In this highly advanced world, it is easy to investigate air pollutants through satellite-based monitoring technology. The satellite-based technology can provide helpful information for estimating and mapping air pollution for monitoring regional and urban scale air quality[10]. In the present COVID-19 pandemic, few studies[5] established the link between air pollutants and SARS-Cov-2.

As per World Health Organization Report on October 26, 2022, worldwide, the number of SARS-CoV-2 confirmed cases are 625,740,449, and deaths 6,563,667. However, in Pakistan, SARS-CoV-2 cases are 1,573,725 and deaths 30,624 [11]. Pakistan established smart lockdown policies and taken preventive measures to minimize the COVID-19 pandemic situation in the country.

The literature is available from the developed nations of the Global North. However, in the Global South, the data is neither completely available nor is there enough coverage of this aspect in their societies and policies. This study addresses this gap whereby the linkage of PM2.5 with the cases and deaths due to COVID-19 in three major cities of Pakistan (Karachi, Lahore, and Islamabad) has been evaluated (Figure 1).

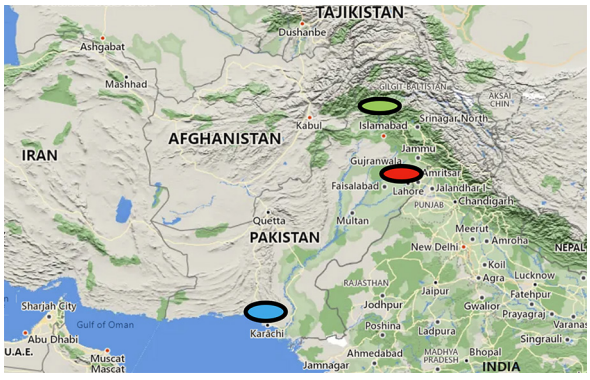

Figure 1. Map of Pakistan, highlighting selected cities: Karachi (*blue*), Lahore (*red*), and Islamabad (*green*).

Materials and Methods

This study assessed the ecological impact of air pollutant PM2.5 in three major cities of Pakistan, namely Karachi, Lahore, and Islamabad, and their association with new cases and deaths due to COVID-19. A co-investigator visited the Health Ministry and National Command Operations Centre database, (Islamabad, Pakistan), and obtained publicly available information about COVID-19 cases and deaths. The daily concentrations of PM2.5 were recorded from the metrological website Real-Time Air Quality Index- AQI[12].

The measurement of particulate matter (PM2.5) is based on Air Quality Index data daily. Most stations monitor the air pollutants data based on hourly readings[12] and mean values are recorded daily. The PM2.5 levels from 0-50 are considered healthy, 51-100 acceptable; 101-150 unhealthy, 151-200 harmful and anyone may be affected, 201-300 very unhealthy, and more than 300 hazardous and people may be seriously affected due to air pollution[12].

The data on the daily cases and deaths due to COVID-19 in Karachi, Lahore, and Islamabad were obtained from August 1, 2020, to September 30, 2021, from the Health Ministry and National Command Operations Centre database in Pakistan[13].

Statistical Analysis

The results were analyzed using Statistical Package for the Social Sciences version 23 (SPSS, IBM Corp., Armonk, NY, USA). A one-sample Kolmogorov-Smirnov test was used to evaluate the assumptions of normal distributions. Median (25^{th}-75^{th} quartiles) are reported for non-normally distributed quantitative variables (number of cases, deaths, and PM2.5). Spearman's Rho correlation was applied to assess the relationship between PM2.5 and the number of cases and deaths. Log transformation using a natural log was used to make data normal for regression analysis. The simple and multiple linear regression analysis was applied to assess the effect of PM2.5 levels and cities on the number of cases and deaths[7]. Dummy variables were made for Lahore and Karachi in multiple regression analysis, taking Islamabad as a reference city. The goodness of fit tests and model tests for all regression analyses were significant; an alpha lower than 0.05 was considered statistically significant.

Ethics Approval

The data were obtained from the open source at the area level and did not encompass the subjects, patients, or medical accounts. Consequently, no official approval from an official ethical review board was necessitated.

Results

The PM2.5 mean values for Karachi were 110.4±46.2; Lahore 174.0±83.2; Islamabad 107.1±40.0. The COVID-19 mean cases in Karachi was 538.9±446.6; Lahore 398.3±403.1; Islamabad 212.2±187.6; deaths in Karachi were 9.2±8.3; Lahore 9.3±9.7; Islamabad 1.8±1.8. (Table I). The PM2.5 median values for Karachi were 92.5 (77.8-143.3); Lahore 152 (121-217); Islamabad 104 (80-135). The COVID-19 median cases in Karachi were 398 (200-751.5); in Lahore 284.5 (86-527.8); in Islamabad 142 (73-321.3); deaths in Karachi were 7 (3-13); Lahore 6 (2-13); Islamabad 1 (0-3) (Table I).

Initially, simple regression analysis was used to determine the effect of PM2.5 levels on COVID-19 cases in different cities. The correla-

Table I. The mean and median values for air pollutant PM2.5, SARS-CoV-2 cases, and deaths in the major cities of Pakistan: Karachi, Lahore, and Islamabad.

Variables	City	Mean ± SD	Median (IQR)	Minimum	Maximum
SARS-CoV-2 cases (n)	Karachi	538.9 ± 446.6	398 (200-751.5)	19.0	2,632.0
	Lahore	398.3 ± 403.1	284.5 (86-527.8)	4.0	1,748.0
	Islamabad	212.2 ± 187.6	142 (73-321.3)	4.0	856.0
SARS-CoV-2 deaths (n)	Karachi	9.2 ± 8.3	7 (3-13)	0.0	60.0
	Lahore	9.3 ± 9.7	6 (2-13)	0.0	54.0
	Islamabad	1.8 ± 1.8	1 (0-3)	0.0	10.0
PM 2.5 (μm)	Karachi	110.4 ± 46.2	92.5 (77.8-143.3)	9.0	285.0
	Lahore	174.0 ± 83.2	152 (121-217)	5.0	466.0
	Islamabad	107.1 ± 40.0	104 (80-135)	22.0	219.0

Table II. Linear regression analysis showing the effect of PM2.5 levels on cases and death in Karachi, Lahore, and Islamabad.

Variables	City	For cases				For death			
				95% CI				95% CI	
		β	*p*-value	Lower	Upper	β	*p*-value	Lower	Upper
PM 2.5 (µm)	Karachi	0.004	0.000*	0.002	0.005	0.001	0.650	-0.002	0.002
	Lahore	0.003	0.000*	0.001	0.004	0.002	0.001*	0.001	0.003
	Islamabad	0.003	0.023*	0.000	0.005	0.001	0.283	-0.001	0.002

*Significant.

tion was applied to evaluate the linkage between PM2.5 with the number of cases and deaths. Results indicated that PM2.5 was weakly positively correlated with the number of cases and deaths. Results revealed that Karachi city is significantly associated with cases. In multivariate regression analysis, Lahore and Karachi were significantly associated with cases. This indicates that cases were substantially higher in Lahore and Karachi than in Islamabad (Table II).

Moreover, simple regression analysis was also used to determine the effect of PM2.5 levels on deaths due to COVID-19. Results revealed that PM2.5 levels in Lahore and Karachi were significantly associated with deaths. It indicates that the number of deaths increases with the increase in PM2.5 levels. In multivariate regression analysis, Lahore and Karachi were also significantly associated with deaths (Tables III, IV). This indicates that fatalities were substantially higher in Lahore and Karachi than in Islamabad.

The results further depicted that, for each 10 unit increase in PM2.5, in Karachi, Lahore, and Islamabad, the number of SARS-CoV-2 cases significantly increased by 10 cases in each city; for each 10 unit increase in PM2.5, the number of deaths increased by ten deaths in each city. The results further depicted that the cases were 2.86 times higher in Karachi and 1.4 times higher in Lahore than in Islamabad. Similarly, death rate was 3.6 and 2.8 times higher in Karachi and Lahore, respectively, compared to Islamabad. The correlation between PM2.5 with the number of SARS-CoV-2 cases was 0.123 (p=0.0001), and deaths were 0.170 (p=0.0001) (Figure 2).

Discussion

The present study demonstrated that the SARS-CoV-2 cases and deaths were higher in Karachi and Lahore than in Islamabad. The findings claim that SARS-CoV-2 cases and deaths augmented significantly with PM2.5 levels. The recent literature highlights the impact of air pollution on COVID-19 raising a concern that air pollution is a significant air quality and life safety issue. Liu et al[14] examined the relationship between PM2.5 and COVID-19 and concluded that air pollutants increased the spread of COVID-19. Similarly, Lorenzo et al[15] assessed the linkage between air pollutant concentrations and daily COVID-19

Table III. The simple and multiple linear regression analysis shows the effect of PM2.5 levels on cases in Karachi, Lahore, and Islamabad.

Variables	Category	Simple regression				Multiple regression			
				95% CI				95% CI	
		β	*p*-value	Lower	Upper	β	*p*-value	Lower	Upper
PM2.5 (µm)	PM2.5	0.003	0.000*	0.001	0.003	0.003	0.000*	0.002	0.004
City	Islamabad#								
	Karachi	1.051	0.000*	0.921	1.201	0.051	0.000*	0.913	1.189
	Lahore	0.335	0.000*	0.385	0.665	0.335	0.000*	0.183	0.486

*Significant. #Considered as reference.

Table IV. The simple and multiple linear regression analysis shows the effect of PM2.5 levels on death in Karachi, Lahore, and Islamabad.

Variables	Category	Simple regression				Multiple regression			
				95% CI				95% CI	
		β	*p*-value	Lower	Upper	β	*p*-value	Lower	Upper
PM2.5 (µm)	PM2.5	0.003	0.000*	0.002	0.004	0.002	0.000*	0.001	0.002
City	Islamabad#								
	Karachi	1.273	0.000*	1.152	1.404	1.273	0.000*	1.147	1.399
	Lahore	1.037	0.000*	1.017	1.270	1.037	0.000*	0.898	1.175

*Significant. #Considered as reference.

cases in Singapore. The authors observed significant positive associations between PM2.5 with COVID-19 cases.

From the Global North, Meo et al[5,7,16] conducted a series of studies on the impact of air pollutants and SARS-CoV-2 cases and deaths. The studies based on the data from USA[5,7,15,16] and Europe[17] revealed that air pollutants have a positive association with SARS-CoV-2 cases and deaths. Similarly, literature from European countries in the Global North and other countries shows that high levels of air pollution have a significant impact on the increased rates of confirmed COVID-19 cases and deaths[17-20]. Limited literature is available from the Global South about air pollution and its linkage with SARS-CoV-2 cases and deaths. A study[21] from India provides evidence that large cities with more pollution are the hotspot of carbon emissions and are highly susceptible to COVID-19 cases. Air pollutants could predispose the population toward COVID-19-associated immunopathology, enhancing virus-induced tissue inflammation and damage[22].

In addition to COVID-19, humanity has been fighting many respiratory infections over the years. However, with the findings linking air pollution's adverse effects on public health, we can adopt policies to alter the trajectory of public health through clean air. The droplets and small aerosols spread through breathing, coughing, and sneezing. Filtration and ventilation are the established techniques that reduce PM2.5 levels and result in clean air and reduce the spread of airborne respiratory diseases. The studies[7] conducted in this domain have shown a link that air pollutants PM2.5 facilitate the spread of respiratory viruses more than imagined. No one will drink or eat something full of dirt, chemicals, or

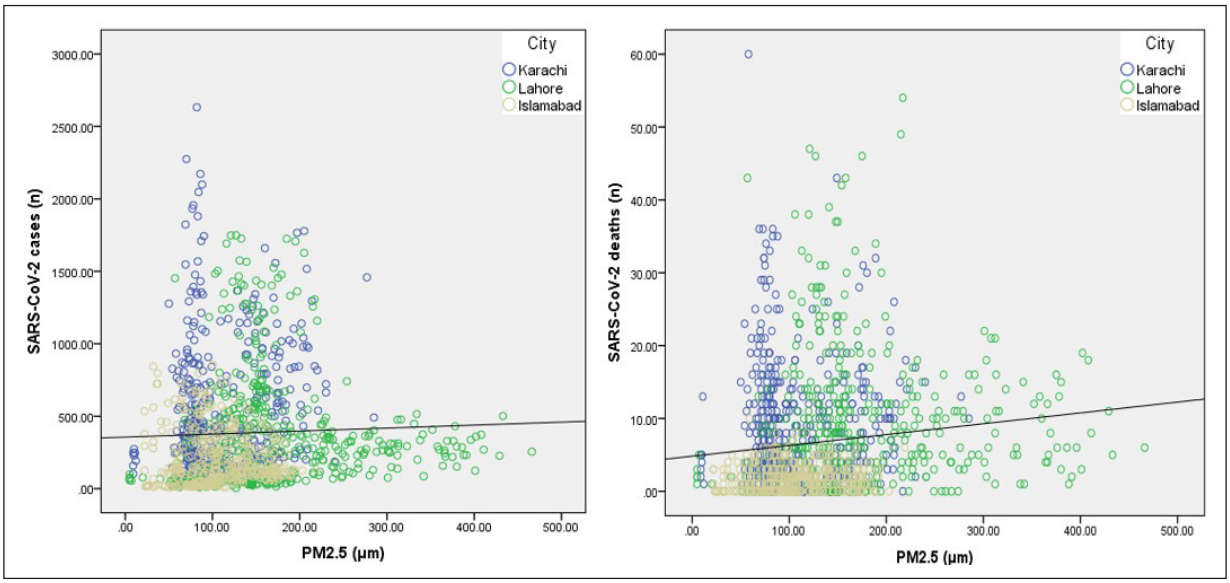

Figure 2. Correlation between PM2.5 and SARS-CoV-2 cases and deaths in Karachi, Lahore, and Islamabad.

pathogens. So why should polluted air be taken for granted? Does it not affect public health, especially for most people living in the Global South? Making air value better to reduce ailments should be a significant public health focus, especially in the backdrop of the deaths and destruction due to COVID-19.

The outbreak of SARS-CoV-2 virus is a matter of great concern and a global challenge for human survival. The virus can be easily transmitted in different environments and affects public health and safety[23]. The literature has established pathophysiological and epidemiological links between PM exposure and viral infections[5,7]. There is an association between airborne pollution and COVID-19 incidence[24]. The environmental pollution particulate matters act as a carrier of the infection, impairs immunity, makes people more susceptible to pathogens, and worsens the disease[25]. These studies[5,7,24,25] strengthen the linkage between the pollutants, particulate matter (PM-2.5μm), and COVID-19 cases and deaths. The present study findings highlighted that the particulate matter is the best carrier or transport vector source for the SARS-CoV-2 virus. This mechanism supports the hypothesis that PM2.5 increased the SARS-CoV-2 cases and deaths in Karachi and Lahore.

Environmental pollution enhances the SARS-CoV-2 spread, cases, and deaths; hence, it is more critical to minimize the pollution and fight against the invisible, elusive, and advancing enemy COVID-19 pandemic[26]. The regions where most environmental pollution is experienced should take concrete measures to address public health concerns. It is time to give additional importance to the environment, weather conditions, and public health.

Study Strengths and Limitations

The first strength of this study is that environmental pollution that remains neglected in the Global South is paid attention to public health in general and addressing the SARS-CoV-2 cases and deaths in particular. Second, we selected PM2.5 as this profoundly penetrates the respiratory system deep into the lungs. A constraint in this study was that we could not collect data on other pollutants like PM_{10}, CO, NO_2, O_3, and SO_2. Other factors such as humidity and temperature may also affect the cases and deaths due to SARS-CoV-2. Additionally, the SARS-CoV-2 cases and deaths may vary due to the social, genetic, economic, and community-based risk factors.

Conclusions

The air pollutant particulate matter PM2.5 in Karachi and Lahore was significantly increased than in Islamabad. Moreover, the COVID-19 mean daily cases and deaths in Karachi and Lahore were considerably higher than in Islamabad. The findings claim that SARS-CoV-2 cases and deaths augmented significantly with PM2.5 levels. These empirical estimates demonstrate an association between PM2.5 and SARS-CoV-2 daily cases and deaths in these cities from the Global South. The findings can contribute to policy-making decisions about addressing air pollutants and climate concerns in developing countries and create an urgency to develop a strategy pertaining to minimizing environmental pollution. The study's findings can steer the policymakers and global health officials in the general and Global South in particular in addressing the SARS-CoV-2 cases and deaths due to PM2.5 air pollutants.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authors' Contribution

SAM, KMS: research conceptualization, data collection, manuscript writing; AAM, TAK, ANA: literature re-view, data checking; SE, LAA, AY: data checking, data analysis. All authors have read and approved the manuscript.

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