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Impact of environmental pollutants Particulate Matter PM2.5, carbon monoxide, nitrogen dioxide and ozone on the incidence of Monkeypox cases

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Abstract. – OBJECTIVE: The human monkeypox disease (MPXD), is an emerging zoonotic disease caused by the monkeypox virus. The rapid spread of human monkeypox cases has developed an alarming situation worldwide. This study evaluated the impact of day-to-day air pollutants, particulate matter PM2.5, Carbon monoxide (CO), Nitrogen dioxide (NO_2), and Ozone (O_3) on the daily incidence of monkeypox cases in New York City, United States of America.

MATERIALS AND METHODS: The daily data on air pollutants and monkeypox cases were recorded from May 1, 2022, to August 16, 2022. The everyday concentrations of "PM2.5, CO, NO_2, and O_3 were recorded from the metrological website "Real-Time Air Quality Index-AQI" and human monkeypox cases were documented from the official website of "NVC Health". The mean values along with correlations were performed to investigate the impact of environmental pollutants on the occurrence of monkeypox cases in New York, city USA.

RESULTS: The mean value for the concentration of CO in the air was 25.61 ppm, NO_2 38.16 ppm, O_3 9.46 µg/m^3 and PM2.5 was 1.82 ppm. The air pollutants, CO, and NO_2 have a positive association (p=0.001) with daily monkeypox cases in New York, USA. The correlation analysis showed significant relationships between CO and NO_2 and the number of monkeypox cases (r=0.298, p<0.002), (r=0.513, p<0.001), respectively. The linear regression analysis also showed that CO has a positive impact on monkeypox cases (β=0.298, p<0.001). With one unit increase in the CO levels in the air, the number of monkeypox cases increased by 0.298 units, and adjusted R-square shows a 0.08 or 8% variation in the number of monkeypox cases due to an increase in CO in the environment. Moreover, NO_2 has a significant positive impact on monkeypox cases (β=0.513, p<0.001), with a one-unit increase in NO_2 concentration in the air, the monkeypox cases increased by 0.513. The adjusted R-square shows that NO_2 causes a 25.7% variation in the increase in monkeypox cases. However, Ozone (β=0.018. p>0.05) and PM2.5 (β=-0.122, p>0.05) does not have a significant correlation with monkeypox cases in the city of New York.

CONCLUSIONS: Environmental pollutants NO_2 and CO have a positive relationship with the number of daily monkeypox cases in New York City, USA. The air pollutants which have a high concentration in the environment have a strong relationship with the occurrence of monkeypox cases. Environmental pollution may be a risk factor for the increasing occurrence of monkeypox cases. Health officials must take priority preventive measures to curtail environmental pollution to combat the monkeypox disease.

Key Words:
Pollution, Monkeypox, Incidence, New York.

Introduction

Human monkeypox is a zoonotic disease caused by a monkeypox virus (MPXV), which belongs to the genus *Orthopoxvirus,* subfamily *Chordopoxvirinae* and family *poxviridae*[1,2]. The monkeypox virus was found for the first time in 1958 in monkeys, which were housed in the research institute in Copenhagen, Denmark[3]. In September 1970, the MPXV was identified in humans in the Democratic Republic of Congo[4,6]. Human monkeypox disease was later transmitted outside the endemic African countries to non-endemic nations, including the United States of America in 2003[7].

This year, from early May 2022, the monkeypox virus swiftly spread from endemic to non-endemic regions. On September 16, 2022,

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the disease involved 103 countries worldwide, and infected 60, 799 people; 579 cases from endemic 07 African countries and 60, 220 cases from 96 non-endemic countries in Europe, North and South America, Australia, and Asia[8]. However, in the United States of America, the total number of monkeypox cases is 23,117, and the highest number of cases are reported in California 4453, New York 3719, Florida 2301, Texas 2017, Georgia 1641, and Illinois 1198[9].

The spread of monkeypox cases has caused a frightening situation globally[10]. The possible route of transmission of MPXV is animal-to-human and human-to-human. The respiratory droplets, direct or indirect contact with body fluids, skin lesions of an infected person, and contaminated surfaces in a patient's environment have been associated with inter-human transmission[2,11-13]. Viral infections have a transmission linkage with environmental conditions[14,15]. The science community has been trying to identify a possible linkage between the spread of human monkeypox cases and its association with environmental pollution. This study is aimed at investigating the impact of environmental pollutants, PM2.5, NO_2, CO, and O_3, and daily cases of monkeypox disease in New York, USA

Materials and Methods

This study investigated the impact of four environmental pollutants, namely particulate matter PM2.5, CO, NO_2, and O_3, in New York, USA and their impact on the occurrence of monkeypox cases. The daily number of cases and concentrations of environmental pollutants in the New York, USA was recorded from May 1, 2022, to August 16, 2022.

Measurements of Air Pollutants and Monkeypox Cases

Data for the daily number of monkeypox cases were recorded from the official website of NVC Health, 2022[16]. The daily concentrations of PM2.5, NO_2, CO and O_3 were obtained from the metrological website, Real-Time Air Quality Index-AQI[17]. The data were obtained before the first case of human monkeypox reported in New York, the USA from May 1, 2022, to August 16, 2022.

The research team members found the day-to-day detailed data on air pollutants from the Real-Time Air Quality Index-AQI[17]. AQI provided information about measurement protocols. Air pollutants were measured hourly over 24 hours each day. The AQI monitoring stations used high-tech laser particle sensors to measure real-time environmental pollution. One investigator obtained day-to-day information on air pollutants, PM2.5, NO_2, CO and O_3 levels from the metrological website Real-Time Air Quality Index-AQI[17]. The research team members also recorded the human monkeypox daily cases from the official website of NVC Health[16]. However, for the validation of the data, another research team member re-checked the entire information.

Statistical Analysis

The data were analyzed using the IBM SPSS software version 22.0 for Microsoft (SPSS Corp., Armonk, NY, USA) to analyze the impact of environmental pollutants PM2.5, CO, NO_2 and O_3 on the number of daily cases reported for monkeypox virus in the New York, USA. In this study, while analyzing the data, first of all, descriptive statistics have been conducted by calculating the mean values of pollutants followed by correlation analysis to check the relationship between the number of cases reported and the number of pollutants in the environment and then the impact of these pollutants on the number of daily monkeypox cases has been studied using linear regression analysis. The goodness of fit and model tests for the regression models were tested using α=0.01 (99% Confidence interval). A p-value < 0.05 was considered statistically significant.

Ethical Statement

The human monkeypox cases and environmental pollutants were obtained from publicly available databases; hence, ethical approval was not required.

Results

The mean values of environmental pollutants PM2.5, NO_2, CO, and O_3 and monkeypox cases are presented in Table I, Figure 1. The results of descriptive statistics indicate that the mean value (Mean ± SD) for the concentration of Carbon monoxide in the environment was 25.61 ppm, Nitrogen dioxide 38.16 ppm, Ozone O_3 9.46 $\mu g/m^3$, and PM2.5 was 1.82 ppm (Table I, Figure 1). The results reveal that the air pollutants, CO and NO_2

Table I. Environmental pollutants and monkeypox cases mean values with a significance level.

Environmental pollutant	Mean ± SD	Monkeypox cases mean ± SD	*p*-value
Carbon Monoxide (CO) ppm	25.61 ± 10.14	20.42 ± 27.85	$p = 0.001$
Nitrogen dioxide (NO_2) ppm	38.16 ± 17.90		$p = 0.001$
Ozone (O_3) µg/m^3	9.46 ± 3.31		$p = 0.001$
Particulate matter (PM2.5) ppm	1.82 ± 0.95		$p = 0.001$

Air pollutants and monkeypox cases mean values are presented daily basis from May 1, 2022, to August 16, 2022.

have a positive association with daily monkeypox cases (p=0.001), in New York, city USA.

Table II shows the correlation analysis to indicate the relationship between the air pollutants PM2.5, NO_2, CO, and O_3 with the number of monkeypox cases. It was identified that the two pollutants CO and NO_2 show statistically significant relationships with the number of monkeypox cases. The CO have a significant positive relationship with the number of monkeypox cases (r=0.298, p<0.001) which means that with an increase in the amount of CO in the air, more people were likely to suffer from monkeypox disease. Moreover, NO_2 shows a moderate positive and significant relationship with the number of monkeypox cases (r=0.513, p<0.001) (Table II) which also indicate that the higher the amount of NO_2 in the air, the higher the cases of monkeypox. However, the results do not show a significant relationship between the PM2.5, O_3 and monkeypox cases.

Furthermore, the linear regression analysis shows the individual impact of all the pollutants CO, NO_2, O_3 and PM2.5 on the number of monkeypox cases (Table III). The CO has a significant positive impact on monkeypox cases (β=0.298, p<0.01) (Table III, Figure 2), , with one unit increase in the concentration of CO in the air, the number of cases increased by 0.298 units. The value of the adjusted R-square show 0.08 or 8% variation in the number of cases due to an increase in CO in the air. Additionally, NO_2 has a positive and significant impact on monkeypox cases (β=0.513, p<0.01) (Table III); one unit increase in NO_2 concentration in the air increases the monkeypox cases by 0.513. The adjusted R-square demonstrates that NO_2 causes a 25.7% increase in monkeypox cases.

However, ozone (β=0.018. p>0.05) and particulate matter PM2.5 (β=-0.122, p>0.05) did not have a significant impact on the increase in monkeypox cases in New York, USA (Table III). The adjusted R-square show that ozone has no contribution (0.00 or 0.0%) and PM2.5 has a 0.6% contribution in increasing the number of monkeypox cases which does not have a significant impact.

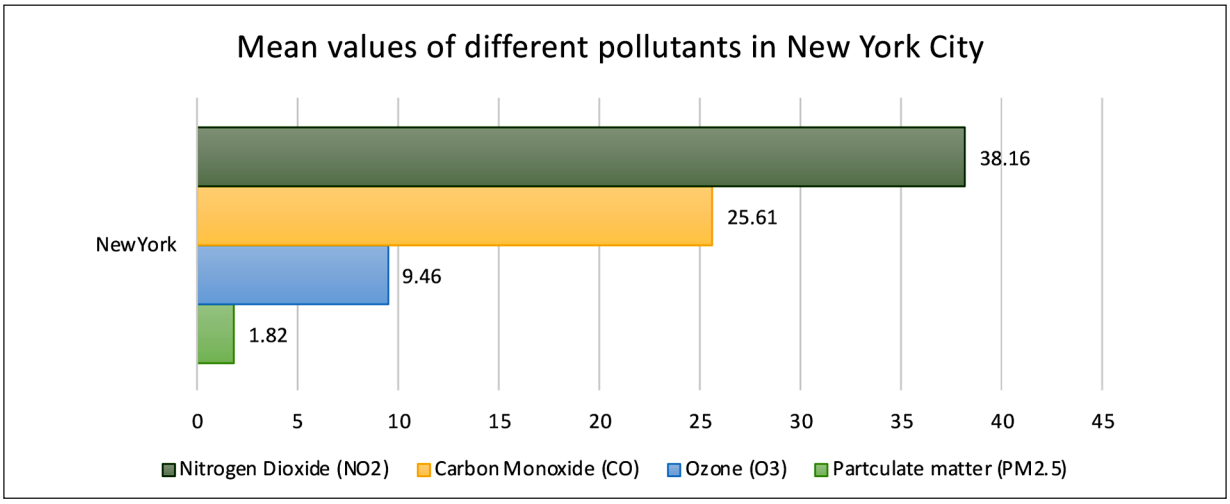

Figure 1. The mean values of environmental pollutants Nitrogen dioxide, Carbon monoxide, Ozone and Particulate Matter PM2.5 during the period from May 1, 2022, to August 16, 2022.

Table II. Correlation analysis: Carbon monoxide, Nitrogen dioxide, Ozone and Particulate matter PM2.5 with the number of monkeypox cases in New York, USA.

Variables	CO ppm	NO_2 ppm	O_3 µg/m³	PM2.5 ppm	Monkeypox cases (n)
Carbon Monoxide (CO) ppm	1				
Nitrogen dioxide (NO_2) ppm	0.101	1			
Ozone (O_3) µg/m³	0.003	0.061	1		
Particulate matter (PM2.5) ppm	0.254**	0.023	0.459**	1	
Monkeypox cases (n)	0.298**	0.513**	0.018	-0.122	1

**Correlation is significant at $p = 0.01$ (2-tailed); *Correlation is significant at $p = 0.05$ (2-tailed).

Discussion

The global geographic range of human monkeypox cases has increased significantly. The swift spread of human monkeypox disease has caused an alarming situation[10]. This study investigates the impact of environmental pollutants PM2.5, NO_2, CO, and O_3 on the occurrence of monkeypox cases in New York, city USA. It was identified that CO and NO_2 have a significant positive association with the number of monkeypox cases in New York, USA.

The microorganisms, bacteria, spores, viruses and yeast are spread from infected patients to the environment, adjacent areas and surfaces frequently touched and stuff used by the patient[18]. The MPXV can spread through contact with an infected individual's lesions, scabs, skin or mucosal surface particles. The aerosol spread has been found in animal populations[19]. Moreover, contact with an ill patient's respiratory droplets, secretions, lesions materials, body fluids and polluted personal objects can contaminate the environment, and result in the spreading of the virus in the surrounding people[20].

The incubation period of human monkeypox diseases is about 7 days, ranging from 3-20 days[21]. The pox virus can remain active on linens, clothing, and environmental surfaces, particularly in dark, cool, and low-humidity environments. The virus can be contagious for about 15 days and can persist in an environment for weeks or months. The porous materials, bedding, and clothing may harbour the virus for longer periods than non-porous materials, such as plastic, glass, and metal surfaces[22].

Susan et al[23] reported that the monkeypox virus DNA lies on the surfaces in hospitals and households. Indeed, the monkeypox virus was found in air and dust samples which were collected during a bed linen change in rooms used by a monkeypox patient. The authors found widespread MPXV DNA contamination in the environment occupied by the infected symptomatic individuals.

There is no available literature that can demonstrate the impact of air pollutants on the incidence of monkeypox cases. To our knowledge, this is the first study to investigate the impact of air pollutants on the incidence of monkeypox cases in New York, USA. It is worthwhile to consider the role of air pollutants in the spread of other viruses, such as Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) during the COVID-19 pandemic. The SARS-CoV-2 virus is transmitted through various air pollutants. The literature indicates that environmental pollutants can contribute to the spread of SARS-CoV-2 disease[14,15]. The studies published from various re-

Table III. Linear regression between air pollutants Carbon monoxide, Nitrogen dioxide, Ozone and Particulate matter PM2.5 with the number of monkeypox cases.

Environmental pollutants	B	S.E	Exp (β)	*p*-value	*Adjusted R-square*
Carbon Monoxide (CO) ppm	0.800	0.249	0.298	0.002*	0.080
Nitrogen dioxide (NO_2) ppm	1.307	0.212	0.513	0.001*	0.257
Ozone (O_3) µg/m³	0.145	0.797	0.018	0.856	0.001
Particulate matter (PM2.5) ppm	-3.450	2.743	-0.122	0.211	0.006

*Statistically significant at 5% level of significance: S.E = standard error, β = coefficient estimates; Exp (β) = exponentiated values.

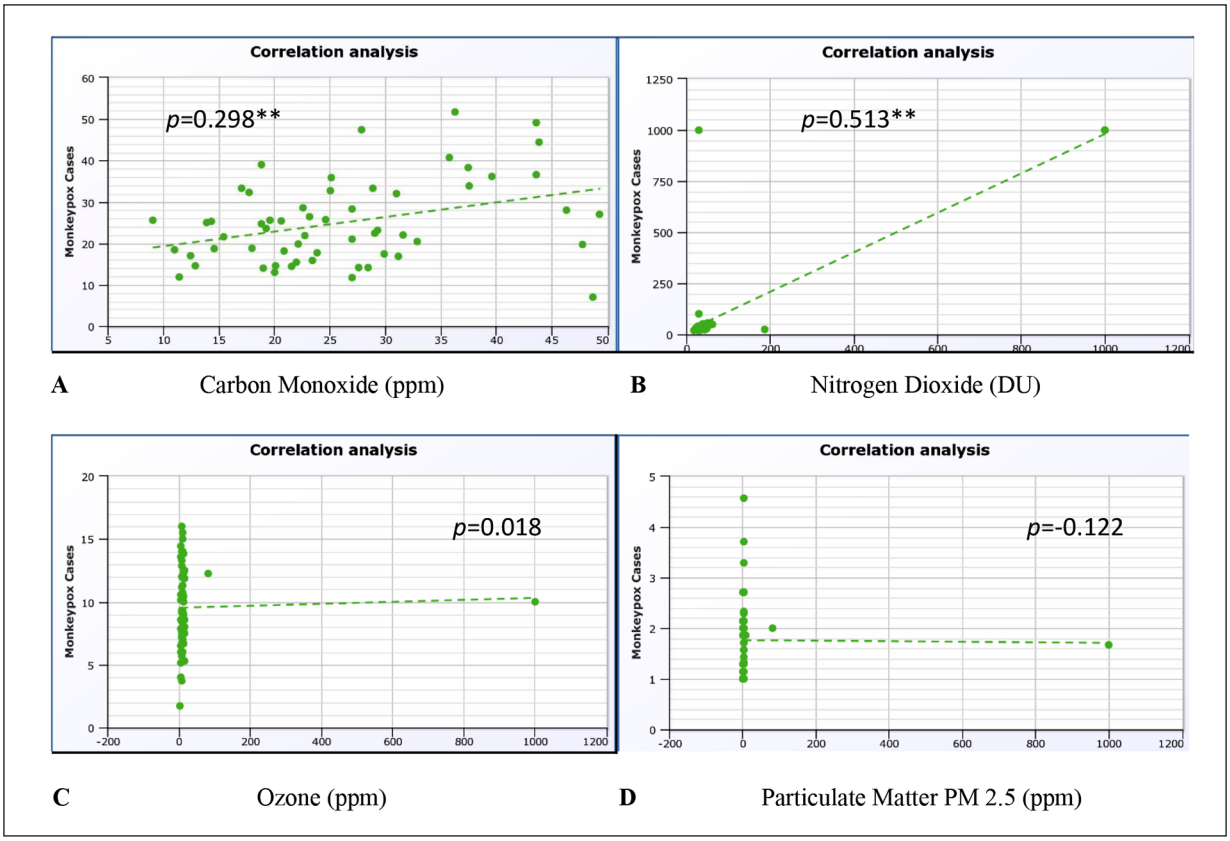

Figure 2. Scatter plot for the relationship between (**A**) Carbon monoxide (**B**) Nitrogen dioxide (**C**) Ozone and (**D**) Particulate matter PM2.5 with number of monkeypox cases.

gions of the globe, including the United States of America[24]; the United Kingdom[15]; Italy[25]; Saudi Arabia[26], and India[27], have established a link between environmental pollution and an increased incidence of SARS-CoV-2.

The present study demonstrates the influence of levels of air pollutants concentrations, positively associated with the number of daily cases of monkeypox. In the present study, it was identified that monkeypox cases were linked to some air pollutants NO_2, and CO in New York, USA. The study findings favour the hypothesis that environmental pollutants are associated with increased daily cases of monkeypox in various countries.

This study has established credible pathways to understand the relationship between increased air pollutants and increased cases of monkeypox in New York, USA. The monkeypox virus is inanimate but can be carried by air, dust, fine particles, ultrafine particles, and earth substances. Environmental pollutants can carry the infected particles from surfaces and transport them over a long distance. Once the substances contaminated with the monkeypox virus, enter the environment, they can come in close contact with humans, enter the body, and infect the people. The study findings provide evidence that air pollutants can transport vectors for the monkeypox virus, promote viral entry into the body and cause infection. These mechanisms are consistent with the hypothesis that air pollutants have resulted in an increased number of monkeypox cases in New York, city USA.

Study Strengths and Limitations

This study investigates the impact of environmental pollutants on the incidence of monkeypox cases in New York, USA. The levels of air pollutants, PM2.5, NO_2, CO, O_3, and monkeypox cases in New York, USA were documented from May 1, 2022, to August 16, 2022. This is the first study that investigated the impact of environmental pollutants on the incidence of monkeypox cases. This study has some limitations. First limitation: we were unable to collect information on other pollutants and climate conditions which may affect the dynamics of the monkeypox cases. We did not

collect information about temperature, humidity, changes in societal patterns, gatherings, or non-compliance with preventive measures. Another limitation is that we recorded the air pollutants data from four different pollutants measuring stations and data were missing in some stations, hence, we were unable to collect the data for other stations placed in New York, USA. It is therefore suggested that further similar studies may be conducted to reach better conclusions.

Conclusions

Environmental pollutants NO_2 and CO have a positive impact on the daily monkeypox cases in New York City, USA. The air pollutants which have a high concentration in the environment have an increasing relationship with the occurrence of monkeypox cases. Environmental pollution may be a risk factor for the increasing incidence of monkeypox cases. The global health authorities must take preventive measures to minimize environmental pollution to combat the monkeypox disease.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authorship Contribution Statement

SAM: project supervision, writing-reviewing and editing. AAM, HTMA, JAK data collection, data checking, data entry and analysis.

Ethical Approval

The data were obtained from publicly available sites; hence ethical approval was not required.

Data Availability

Data may be provided on reasonable request to the corresponding author.

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