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Concentration of Pollutants and their Toxic Impact in the Residents of Firozabad City: India

Rita Dixit[1] and Rafat Khan[2]

[1]Department of Chemistry, Mahatma Gandhi Balika Vidyalya (P.G.) College, Frozabad, Affiliated to Dr. Bhimrao Ambedkar University, Agra, Uttar Pradesh, India

[2]Department of Zoology, Mahatma Gandhi Balika Vidyalya (P.G.) College, Frozabad, Affiliated to Dr. Bhimrao Ambedkar University, Agra, Uttar Pradesh, India

*Corresponding Author E-mail: reetadixit.chemistry@gmail.com

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Abstract

To learn about the toxicity of size-segregated particulate matter (PM) in human respiratory tracts, sensors in the glass industrial city of Firozabad monitored the mass and number of PM in real-time. The mean PM2.5 and PM10 concentrations were 40.89 and 68.15 µg/m3, respectively. The average concentration of PM10 was 1.65 times higher from the $PM_{2.5}$. $PM_{2.5}$ concentration in winter, summer and monsoon season at Firozabad city was observed as 50.44 µg/m3, 33.91µg/m3, and 38.33µg/m3 while PM10 was 65.26 µg/m3, 73.51 µg/m3, and 65.69 µg/m3. NOx Concentration was highest during the winter season 23.27ppb. Ozone concentration was observed highest in winter season (23.94). From the correlation analysis it was found that $PM_{2.5}$ showed strong correlation with the NOx (0.828) followed by Ozone (0.708) and Rh (0.759) while PM_{10} showed strong correlation with WS (0.994) followed by WD (0.980). Acute exposure to PM_{10} at industrial sites in Firozabad may cause health concerns in a vulnerable population, according to this study's findings. The exposure levels of children at the Firozabad sampling location were 122.1×10-1 and 4.30×10-1, respectively, for adults and children. All of the readings were higher above the safe limit, which is ELCR≥10-6.

Keywords: Real time monitoring; PM concentration; Correlation in Pollutants; Health Risk Assessment.

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Introduction

The 2019 Global Burden of Disease report ranks air pollution as the fifth most important risk factor for mortality globally, surpassing even the effects of alcohol consumption, physical inactivity, and hunger (HEI 2019). Rising levels of motorisation, industrialisation, and urbanisation are the leading drivers of air pollution in developing countries such as India. Toxic emissions (including PM, NOx, trace metals, and PAHs) from fossil fuel combustion, industrial processes, and human activities are the main cause of air pollution (Pant and Harrison 2013; Rajouriya *et al*. 2020). U.S. IEA (2016) predicts that, despite improvements in vehicle combustion efficiency and the availability of alternative fuels, conventional fuels will continue to be the primary propulsion technology in road transportation, with usage rising by 1.4% annually until 2040. The majority of the world's population lives in areas with ambient $PM_{2.5}$ concentrations that are higher than the recommended levels, leading to around 3.0 million premature deaths annually (WHO 2016). According to HEI (2019), air pollution was the sixth leading cause of death globally in 2017, responsible for almost 4.9 million deaths and 147 million years of unhealthy life wasted. Among the leading causes of death from COPD, type 2 diabetes, lung cancer, ischaemic heart disease, and stroke, air pollution accounts for 41% of all deaths (HEI 2019). Particulate matter, commonly known as particle pollution, is a major contributor to air pollution among other pollutants. It is characterized by solid or liquid droplets suspended in the atmosphere (Tiwari *et al*., 2020). These airborne particles come in a variety of sizes and forms, and depending on their size and shape, they are deposited into the respiratory tract of the lung. While fine particles ($PM_{2.5}$) gather deeper into the lungs region and pose a major threat to the population, coarse particles ($PM_{10-2.5}$) deposit into the upper respiratory tract (Rajouriya *et al*. 2020). The concentration of Particle Number (PN)—the sub-micrometer fraction—and the negative impacts on humans are mostly caused by emissions from vehicles and other human-made activities (Kumar *et al*. 2014). Harmful interactions between ultrafine particles and epithelial cells occur deeper in the respiratory organ (Terzano *et al*. 2010). Significant contributions to air pollution are also made by other pollutants, including NO2 and black carbon. A large amount of fine particulate matter (PM) in traffic situations comes from black carbon emissions, which are mostly produced by cars (Krecl *et al*., 2018). In addition to its negative effects on human health and the environment, which could lead to a decrease in life expectancy (Janssen *et* *al*., 2012; Bond *et al*., 2013), it also adds to global warming. Krecl *et al*. (2018) states that NO2—particularly NO and NO2 in cities—begins a chain reaction that results in eutrophication and acid deposition. It also serves as a precursor to other harmful secondary air pollutants, such as PM2 and O3. 5. This study aims to 1) determine the concentration of particulate matter in Firozabad Glass City, 2) analyse the effects of industrial particulate matter on locals, and 3) investigate the connection between particulate matter and meteorological variables. Five, to determine the dangers posed by Particulate Matter of varying sizes to human health.

Methodology

2.1 Study Area- Within the Taj Trapezium Zone (TTZ), Firozabad City is home to a sizable glass manufacturing complex. Table lamps and bangles made of glass are among the city's most famous exports. Numerous glass manufacturing facilities in Firozabad, ranging from micro to large size, contribute to air pollution by releasing particulate matter (PM), organic compounds, and hazardous metals. These polluting industries are located near both urban and rural residential areas, which might have negative impacts on those who come into contact with them. Continuous real-time monitoring of size-segregated particulate matter (PM) in both number mode and mass mode was carried out in the urban industrial area of Firozabad (Fig. 1) from January to December 2024. The area spans 21.35 km2 and is located in Western Uttar Pradesh of North-Central India (27° 09′N, 78° 24’E). The population of the area is 2,498,156. (Firozabad district population census 2011, 2021, 2023, Uttar Pradesh literacy sex ratio and density).To find out how urban pollution affect rural areas, sampling data was collected from sensors in Vibhav Nagar and Firozabad Nagla Bhau.

Fig. 1 Realtime monitoring site (Nagla Bhau and Vibhav Nagar) at Firozabad Industrial City

2.2 Sampling and Instruments

According to Singh *et al*. (2021), air quality management sensors are devices that can estimate air pollution parameters or surrogate variables. Air quality management systems are platforms that integrate sensors and data in a way that provides relevant information to the intended users. When conducting AQM (in a laboratory or on the field), sensors might be located in the air, in orbit, or on the ground. Future parts will provide AQS and systems' category-by-category description and elaboration. The current investigation employed secondary data on pollutants. Sensor-based monitoring was used for sampling. The USEPA-provided toxicity model has been applied to the secondary data. Data on various contaminants were gathered from the CAAQMS during the investigation. Data was gathered from two Indian cities.

2.3 Meteorological Parameters- Meteorological parameters can play an important role to increase or decrease the pollutants concentration in the environment. During the study Correlation was done between the Pollutants concentration and meteorological data to find out the relation between the them.

2.4 Statistical Analysis

Health risk assessment by USEPA- The USEPA model was followed in the health risk evaluation. A specified equation was used to calculate the health effects of both acute and chronic exposure to PM10 (a non-carcinogenic substance). The literature shown in Greene and Morris 2006; USEPA 2014; USEPA 1997 provided the exposure factors. The excess lifetime cancer risk (ELCR) factor, which was computed using the formulas, indicates the carcinogenic risk caused by PM2.5. To determine the relationship between the pollutants and meteorological parameters, correlation analysis was performed.

Results and Discussion

3.1 Size segregated PM concentration

PM2.5 concentration in winter, summer and monsoon season at Firozabad city was observed as 50.44 µg/m3, 33.91µg/m3, and 38.33µg/m3 while PM10 was 65.26 µg/m3, 73.51 µg/m3, 65.69 µg/m3. PM2.5 concentration was highest during the winter season (50.44 µg/m3) while PM10 was highest in summer season 73.51 µg/m3. PM10 concentration was highest in all the seasons as compared to the PM2.5. The average Concentration of PM10 and PM2.5 was 68.15 µg/m3 and 40.89 µg/m3. The average concentration of PM10 was 1.65 times higher from the PM2.5.

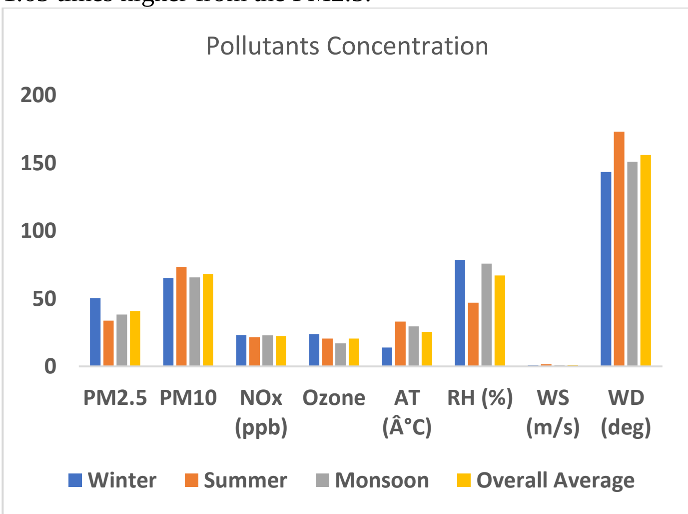

Fig. 2 Seasonal Pollutants and metrological parameters concentration in Firozabad

3.2 NOx, Ozone Concentration

NOx Concentration was highest during the winter season 23.27ppb. In summer and monsoon, the concentration of NOx was almost same. Ozone concentration was observed highest in winter season (23.94). The average concentration of NOx and Ozone was 22.61 and 20.54.

3.3 Correlation analysis in Pollutants and meteorological parameters

Table 1 Correlation analysis between the Pollutants and meteorological parameters

	PM2.5	*PM10*	*NOx*	*Ozone*	*AT*	*RH*	*WS*	*WD*
PM2.5	1							
PM10	-0.739	1.000						
NOx	0.828	-0.990	1.000					
Ozone	0.708	-0.047	0.190	1.000				
AT	-0.997	0.683	-0.781	-0.762	1.000			
RH	0.759	-1.000	0.994	0.077	-0.705	1.000		
WS	-0.664	0.994	-0.969	0.058	0.603	-0.991	1.000	
WD	-0.858	0.980	-0.998	-0.245	0.815	-0.985	0.954	1

During the research work correlation analysis was performed between Pollutants and metrological parameters data (Table 1). From the correlation analysis it was found that PM2.5 showed strong correlation with the NOx (0.828) followed by Ozone (0.708) and Rh (0.759) while PM10 showed strong correlation with WS (0.994) followed by WD (0.980) indicating common sources in the environment. NOx showed positively correlation with Rh. It means NOx increases with the Rh values. Correlation between Pollutants and meteorological data depicted in table 1.

3.4 Health Risk Assessment

In the absence of carcinogenic effects when HQ <1.0, the population is at risk, and in the presence of carcinogenic effects when HQ > 1.0, non-carcinogenic health risks may be present. Acute exposure to PM10 at industrial sites in Firozabad may cause health concerns in a vulnerable population, according to this study's findings. Acute exposure to PM10 in Firozabad city may induce a variety of non-carcinogenic disorders in youngsters. Nevertheless, due to the fact that HQ <1 at all locations, there was no non-carcinogenic danger to adults and children from chronic exposure to PM10. Table 2 displays the findings of the health risk assessment.

Table 2 Environmental Exposure Assessment of PM10 and PM2.5 at Residential and Traffic Sites: Carcinogenic and Non-Carcinogenic Health Risks

HQ (Hazard Quotient)				
S.No.	**Particulate**	**Exposure Scenario**	**Child**	**Adult**
1	PM_{10}	Acute	1.255	0.235
2	PM_{10}	Chronic	0.055	0.010
ELCR (Excess Lifetime Cancer Risk)				
S.No.	**Particulate**	**Child**	**Adult**	
1	PM2.5	122.1 X10-1	4.30X10-1	

The exposure levels of children at the Firozabad sampling location were 122.1×10-1 and 4.30×10-1, respectively, for adults and children. The exposed population, including both children and adults, may be at risk of developing malignant diseases due to PM2.5 exposure, as all the values surpassed the safer limit (ELCR≥10-6) set by the US Environmental Protection Agency.

Conclusion

In order to determine the toxicity of size-segregated particulate matter (PM) in the human respiratory tract, sensors in the glass industrial city of Firozabad monitored the mass and quantity of PM in real-time. The mean concentrations of PM2.5 and PM10 were 40.89 µg/m3 and 68.15 µg/m3, respectively. The average PM10 concentration was 1.65 times greater than the PM2.5 concentration. In Firozabad city, the PM2.5 concentrations during the winter, summer, and monsoon seasons were 50.44 µg/m3, 33.91 µg/m3, and 38.33 µg/m3, but the PM10 concentrations were 65.26 µg/m3, 73.51 µg/m3, and 65.69 µg/m3. The winter season had the greatest NOx concentration, which was 23.27 ppb. The winter season had the highest ozone concentration (23.94). According to the correlation analysis, PM2.5's strong correlation with NOx (0.828), Ozone (0.708), and Rh (0.759) was followed by PM10's strong correlation with WS (0.994) and WD (0.980). The study's findings indicate that children, a vulnerable exposed group, may be at risk of experiencing health issues as a result of acute exposure to PM10 at industrial sites in Firozabad. The ELCR values for exposed youngsters at the Firozabad sampling location were 122.1×10-1, while those for adults and children were 4.30×10-1. Every number was higher than the safest limit (ELCR≥10-6).

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