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Assessment of respirable particulates in residential, industrial, agricultural and eco-sensitive area of Ranchi City, Jharkhand, India

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Abstract- Air pollution stemming from industrial point sources is a significant contributor to the air quality problems experienced by numerous communities worldwide. Nevertheless, emissions from these sources are technically manageable through the implementation of abatement technologies, provided that stringent regulatory conditions are included in their operational licenses. On the other hand, pollution arising from sources like soil erosion, forest fires, road dust, and biomass burning is influenced by a range of unpredictable natural or economic factors. This research paper presents a comprehensive analysis of air quality in various zones of a city over a one-year period of 2022. The study focuses on the concentration of particulate matters (PM10 and PM2.5) in four distinct areas: Harmu (Residential Area), Industrial Area Tupudana, Agricultural Area (Kanke), and an Eco-sensitive Area (Birsa Zoo). The findings reveal significant variations in air quality across the different zones, as well as noticeable seasonal trends. In the Harmu Residential Area, elevated levels of particulate matter, especially in the colder months, underscored the necessity for residents to embrace cleaner heating practices. The Particulate matters around the industrial area Tupudana were found maximum among the four sites studied but the emission is within the permissible limit currently but according to the pollutants level the trends were showing to be increased in future. The emission around eco-sensitive area of Birsa Biological-park were found rather high due to extreme vehicular movement in national highway 33 and in coming time it could create problems for the flora and fauna of the Birsa Biological-park. Agricultural Area (Kanke) maintained lower respirable particulate levels.

Key words: Particulate matters, Pollutants, Eco-sensitive, Emission, Ranchi

INTRODUCTION

Particulate matter (PM) consists of a diverse combination of solid particles and liquid droplets suspended in the atmosphere, exhibiting variations in terms of size, composition, and concentration. PM10, characterized by an aerodynamic diameter of less than 10 µm, can remain airborne for a range of minutes to hours and has the potential to travel up to 50 kilometres. In contrast, PM2.5 (fine) particles, being lighter, possess the ability to linger in the air for days or even weeks and can cover longer distances compared to the larger PM10 particles.[1] The presence of air pollutants depends not only on the quantity released from pollution sources but also on the atmosphere's capacity to either absorb or disperse these emissions. The air that envelops humans is a vital component for their survival, as all life forms rely on it. On average, a human requires a relatively constant intake of 10-20 cubic meters of air per day. Nevertheless, the external air comprises a variety of compounds and elements, some of which taint its purity. These impurities

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result from various factors, including human and animal respiration, the decomposition of organic matter, and the burning of coal, gas, and oil.

Moreover, industrial activities, transportation, and manufacturing processes release dust, fumes, vapours, and gases into the atmosphere, contributing to air pollution. In urban areas, vehicular emissions pose a significant concern due to their detrimental impact on both human health and the environment. Vehicular exhaust is a major source of elevated levels of air pollutants such as SPM, RSPM, SO_2, NOx, and various organic and inorganic contaminants, including trace metals. Fine particles, which are a major cause for concern, are primarily generated by vehicular exhaust emissions.[2] The yearly analysis of pollutant levels in Ranchi spanning from 2016 to 2020 highlights a notable concern regarding the city's air quality, with Particulate Matter (PM10) presenting a substantial challenge. Even though the levels of SO_2 and NO_2 consistently adhere to established regulatory limits, PM10 consistently surges to elevated concentrations.[3] In the Harmu Housing Colony, a residential area, PM2.5 concentrations vary between 39.13 and 61.02 $\mu g/m^3$, while PM10 levels fall in the range of 129.69 to 151.41 $\mu g/m^3$. In high-traffic areas such as Firayalal Main Road and Birsa Chowk, both PM2.5 and PM10 levels are relatively higher than those in the residential area, with PM2.5 concentrations ranging from 43.37 to 63.02 $\mu g/m^3$ and PM10 concentrations ranging from 137.24 to 168.24 $\mu g/m^3$. In the industrial zone of Tupudana, PM2.5 levels range from 46.14 to 58.92 $\mu g/m^3$, and PM10 levels range from 139.64 to 171.62 $\mu g/m^3$.[4] Air pollution has become a significant health concern for humans in recent decades, leading to many studies being conducted worldwide, including in India.[3-13] Various types of samplers have been utilized for the purpose of monitoring ambient ozone levels in different parts of the world, including Europe[14-20], and on a global scale.[21] The Ogawa samplers have emerged as the most widely used samplers in the United States.[22] The correlation between ozone concentrations measured using Ogawa samplers and UV continuous monitoring has resulted in linear correlations up to a dose of 52,500 ppb $O_3 \times$ h, with an R2 value of 0.9949. Moreover, the reliability of these samplers for long-term monitoring of O_3 (477 hours at 110 ppb) has been confirmed, while demonstrating very high precision with a relative standard deviation of 4.8%.[23] The presence of sulphur dioxide in the atmosphere has been linked to various adverse health effects, including respiratory and cardiovascular diseases. The World Health Organization guidelines recommend daily SO_2 exposure levels not exceeding 125.00$\mu g/m^3$ and mean annual levels below 50.00$\mu g/m^3$.[24] Several methods have been reported for determining SO_2 levels in the atmosphere, including spectrophotometric[25], chemiluminescence[26], ion chromatographic[27], spectrofluorometric[28], potentiometric[29], amperometry[30], and passive sampling methods[31]. In addition, online determinations of SO_2 in air have been reported based on sample collection using chromate-membrane cells or gas permeation denuders, followed by spectrophotometric flow injection analyses.[32,33] Similarly, various methods have been reported for determining ozone levels in ambient air, including spectrophotometric, chemiluminescence, potentiometric, amperometry, and passive sampling methods.[34-36]

STUDY AREA

Ranchi, located in the Chota Nagpur Plateau region in eastern India, is the capital city of the state of Jharkhand, Situated in the southern part of Jharkhand. Ranchi District is situated within the geographic coordinates of latitude 22°30' North to 23°36' North, and longitude 84°54' East to 85°54' East. Additionally, the Tropic of Cancer, which is located at 23.5° North, passes through Ranchi District. Ranchi is surrounded by forests and hills, and has an average elevation of 651 meters above sea level. The city experiences a tropical climate with hot summers and cool winters, with average annual temperatures ranging from around 16°C to 36°C. According to the 2011 Census of India, Ranchi has a population of approximately 1.1 million, making it one of the most populous cities in Jharkhand. Ranchi is a prominent commercial and industrial centre in Jharkhand, with a diverse economy that encompasses sectors such as mining, manufacturing, services, and agriculture. The city is known for its abundant mineral resources, including coal, mica, and limestone, which contribute to its economy. The areas selected for sampling were indicated below in the map in figure 1. These sites were as follows Site-1 is Harmu Housing Colony, Argora is a core residential area where as site-2 is Industrial area of Tupudana, site-3 is Agriculture area of Kanke and site-4 is eco-sensitive area of Birsa Biological park were selected.

Figure 1: Map of four sites of Ranchi city from where the air sampling was taken for 24hrs

MATERIAL & METHODS

PM10 and PM 2.5 samplings were conducted using the filter paper for respective particulate matters in the four different sites of the Ranchi city using a high-volume sampler (Anderson Model) with a flow rate ranging from 1.2 to 1.4 m^3/min. The sampler was positioned at a height of three meters above ground level at sampling sites. A total of four samples were collected every month, spanning a period of one year from January 2022 to December 2022. PM10 & PM2.5 levels were measured throughout a 24 hour period each month on same date (i.e., on 5th, 12th, 19th & 27th day) on monthly basis and the average of each day is given below in the table 1.

Table 1- Data of Particulate matters (PM10 & PM2.5) (in µg/m³) of four locations of Ranchi city from January 2022 to December 2022.

Months	Residential Area Harmu		Industrial Area Tupudana		Agricultural Area (Kanke)		Eco-sensitive Area (Birsa Zoo)	
	PM_{10} (in µg/m³)	$PM_{2.5}$ (in µg/m³)	PM_{10} (in µg/m³)	$PM_{2.5}$ (in µg/m³)	PM_{10} (in µg/m³)	$PM_{2.5}$ (in µg/m³)	PM_{10} (in µg/m³)	$PM_{2.5}$ (in µg/m³)
January	103.67	39.50	112.21	59.39	96.30	39.30	94.24	40.59
February	105.23	40.14	119.23	58.92	96.65	38.68	94.90	41.10
March	104.12	40.50	117.21	58.64	95.73	37.65	95.12	39.90
April	102.30	41.32	110.31	57.50	96.26	37.52	95.62	40.45
May	99.65	41.26	111.51	56.76	93.29	36.54	96.30	41.67
June	107.24	40.67	117.21	57.10	90.97	35.60	94.67	42.50
July	93.32	39.20	100.15	50.24	80.19	34.51	90.21	38.25
August	96.27	38.21	105.20	51.20	86.53	35.27	92.29	39.62
September	101.10	39.49	116.32	53.40	87.61	36.10	91.90	38.95
October	107.5	40.15	116.34	54.13	88.43	36.53	93.87	37.54
November	106.25	39.87	114.31	55.63	86.54	34.90	89.96	38.40
December	105.36	40.17	117.30	57.41	84.21	33.25	91.00	39.50

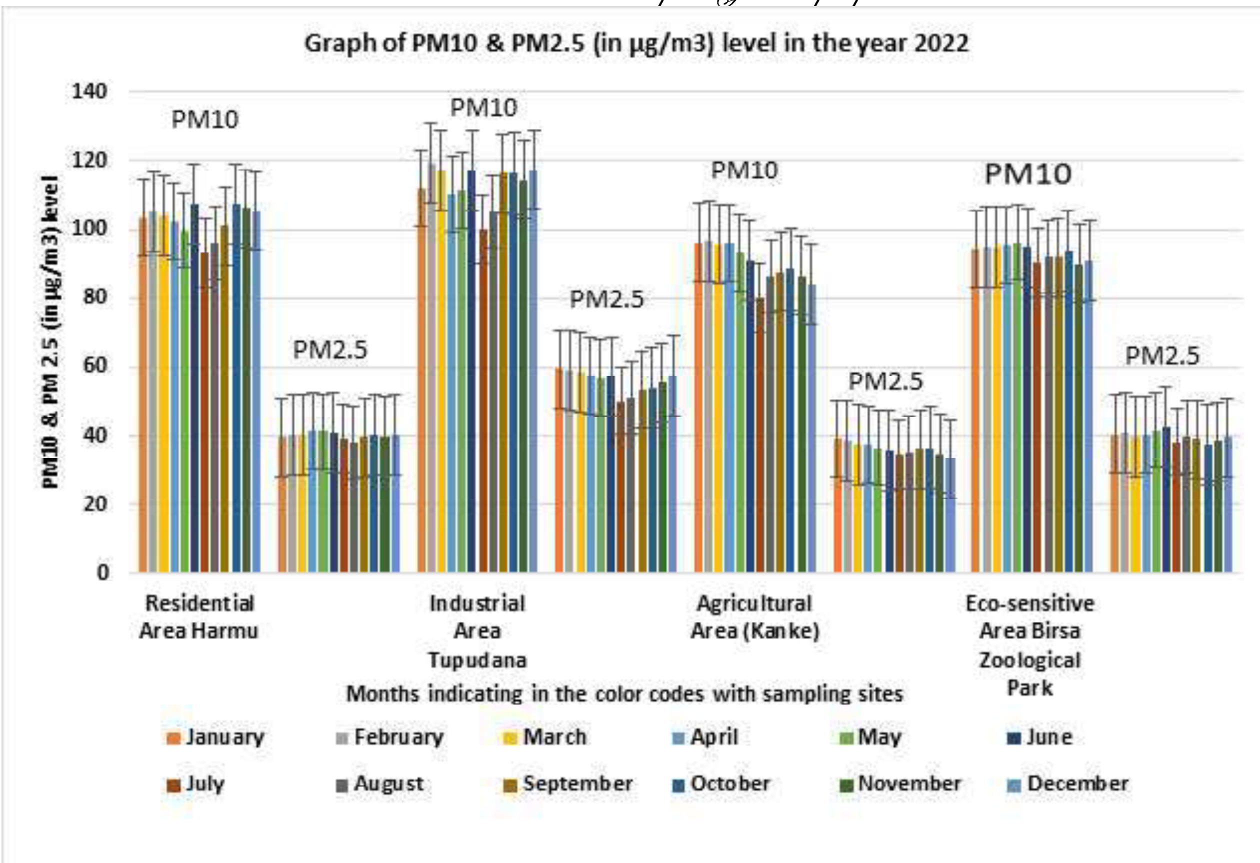

Figure 2: Graphs indicating the PM10 & PM2.5 (in µg/m^3) level in the Year 2022 of Ranchi

DISCUSSION

The data presented in the table 1 and graphical representation in figure 2 shows the concentrations of various air pollutants, namely PM10 and PM2.5 at four different sites (Residential area Harmu, Industrial area Tupudana, Agricultural area Kanke, and Eco-sensitive area Birsa Biological-Park) during the year 2022. PM10 levels in Harmu showed a range from approximately 93.32 µg/m^3 in July to 107.5 µg/m^3 in October. The increased in PM10 during the colder months could be attributed to heating methods, including the use of solid fuels for heating, which is common in residential areas. PM2.5 concentrations range from 39.20 µg/m^3 in July to 40.15 µg/m^3 in October. The increased in PM2.5 during the colder months could also be linked to heating practices. The Industrial Area consistently had the highest levels of PM10, with concentrations varying from around 100.15 µg/m^3 in July to 116.34µg/m^3 in October. This area was likely influenced by industrial processes, emissions, and the presence of factories. PM2.5 levels were also consistently elevated, ranging from 50.24 µg/m^3 in July to 55.63 µg/m^3 in November. Industrial emissions and activities contributed significantly to the high PM2.5 levels. PM10 levels in Tupudana varied from approximately 80.19 µg/m^3 in July to 88.43 µg/m^3 in October. This area appeared to experience lower PM10 levels compared to the Industrial Area, possibly due to fewer industrial activities. PM2.5 concentrations ranged from 34.51 µg/m^3 in July to 36.53 µg/m^3 in October, further suggesting that Tupudana experienced lower pollution levels compared to the Industrial Area. The Agricultural Area exhibited relatively lower PM10 levels, ranging from approximately 90.21 µg/m^3 in July to 93.87 µg/m^3 in October. Agricultural activities might contribute to PM10 emissions but to a lesser extent compared to industrial processes. PM2.5 levels also showed a relatively low range, from 38.25 µg/m^3 in July to 37.54 µg/m^3 in October. This indicated that the impact of agricultural activities on PM2.5 is less pronounced than in industrial areas. The Eco-sensitive Area consistently shows lower PM10 levels, with concentrations varying from about 92.29 µg/m^3 in

August to 96.30 $\mu g/m^3$ in May. This area was likely well-preserved and less affected by industrial and vehicular emissions. PM2.5 levels in the Eco-sensitive Area were also lower, ranging from 39.62 $\mu g/m^3$ in August to 41.67 $\mu g/m^3$ in May, indicating better air quality compared to other zones. The Industrial Area consistently recorded the highest levels of both PM10 and PM2.5, making it a hotspot for air pollution. It was critical to address industrial emissions and implement pollution control measures in this area. Harmu, a residential area, also experienced relatively high levels of pollution, particularly during the winter months. This suggested the need for cleaner heating methods and improved indoor air quality measures for residents. Tupudana and the Agricultural Area (Kanke) exhibited relatively lower pollution levels compared to the Industrial and Residential Areas. This implied that these zones might have better air quality due to fewer industrial and vehicular emissions. The Eco-sensitive Area (Birsa Biological Park) consistently demonstrated the best air quality, with the lowest levels of PM10 and PM2.5. This area served as an example of what can be achieved with stringent environmental protection measures.

CONCLUSION

The data illustrated a consistent seasonal trend in air quality, with higher particulate matter levels during the winter months and lower levels during the summer. This seasonality is a common occurrence, often associated with meteorological conditions that lead to the accumulation of pollutants in the colder months. The Industrial Area consistently registered the highest levels of both PM10 and PM2.5, indicating that industrial emissions and processed significantly contribute to air pollution. It was imperative to implement stringent pollution control measures in these areas to mitigate their adverse effects on public health. The Residential Area (Harmu) experienced relatively high levels of particulate matter, particularly during the colder months. This highlighted the need for residents to adopt cleaner heating practices and for policymakers to enforce measures that enhance indoor air quality in residential zones. In contrast, the Eco-sensitive Area (Birsa Biological Park) and the Agricultural Area (Kanke) maintained lower pollutant levels, suggesting that these zones were less affected by industrial and vehicular emissions. Preserving and expanding eco-sensitive areas could be instrumental in maintaining better air quality within the city. High levels of PM10 and PM2.5, particularly in industrial areas, pose significant health risks to the population. Exposure to these pollutants could lead to respiratory and cardiovascular issues, making it crucial for public health authorities to address these concerns promptly. Implementing targeted pollution control measures in industrial areas. Promoting cleaner heating practices and indoor air quality improvements in residential zones. Preserving eco-sensitive areas to sustain better air quality and protect local ecosystems. Addressing seasonal variations with appropriate interventions during the winter months. Prioritizing public health by mitigating air pollution and its associated health risks. the data serves as a valuable resource for informed decision-making by city authorities, urban planners, and policymakers. By heeding these insights and implementing effective measures, we can work towards improving air quality, safeguarding public health, and creating more sustainable urban environments for the future.

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