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Environmental Risk Assessment from 2018 to 2022 for Kota, Rajasthan (India)

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Abstract

Particulate matter pollution in the metropolis has become an international concern because of its dangerous short and long-term effects on humans and the environment. This research aims to quantify particulate matter's severe impact on inhabitants and identify the ecological environment risk category of Kota city, Rajasthan (India), throughout the selected study period from 2018 to 2022 for four years. Human health risk assessment has been assessed through AirQ+ software (WHO invented), while ecological hazard risk categories were recognised through risk quotient (RQ). The present scenario of particulate matter concentration is compared with standards given by different regulating agencies (WHO, USEPA, and Indian NAAQS) to verify particulate matter pollution. The current particulate matter concentration levels of Kota city are also compared with different regional cities of Rajasthan (India), namely, Jaipur, Udaipur, Ajmer, Pali, Alwar, and Jodhpur. The dust ratio ($PM_{2.5}/PM_{10}$) is computed for Kota and regional cities to validate the increasing levels of fine particulates than the larger ones. The four-year average concentration of PM_{10} and $PM_{2.5}$ were 121 and 58 μg/m^3, respectively, with a dust ratio of 0.48. Particulate matter concentrations (PM_{10} and $PM_{2.5}$) are violating the standards set by environmental agencies during the study period. The mean risk quotient (RQ) is 2.02 for PM_{10} and 1.43 for $PM_{2.5}$, which implies a high-risk hazard category (RQ > 1) in the ecological environment of Kota city. The mortality cases evaluated from AirQ+ software were 5024 for all natural causes, 885 for lung cancer, 272 for acute lower respiratory infection, 464 for COPD, 2060 for IHD, and 1880 for stroke. The number of hospital admissions was 1485 for respiratory disease, 58 for cardiovascular disease, and 784 for

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Keywords

ALRI; AirQ+; Asthma; COPD; Ecological Environmental Risk; Environmental Risk Assessment; Human Health Risk; IHD; LC; Mortality; PM_{10}; $PM_{2.5}$; Risk Quotient; Stroke.

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adult mortality (30+ years) to $PM_{2.5}$. Chronic bronchitis incidence in adults was 14469, postneonatal infant mortality was 355816, and the prevalence of bronchitis in children was 767due to PM_{10} exposure for a long time, while asthma symptoms in asthmatic children were 349 due to exposure for a short time. The results of this study are terrifying, and it is an earlier sign to government representatives and stakeholders to implement the new policies and technologies to curb the pollution level originating from particulate matter, otherwise, impacts on the environment become more acute.

Introduction

Continuously deteriorating quality of ambient air jeopardising human health.[1–3] The severity of the problem varies in industrial and developing countries.[4,5] Quick motorisation, rapid industrial and urban growth, and flying technological advancement have put air quality at stakeglobally.[6–8] Many of the less developed countries becoming urbanised and industrialised do not have the resources or enough technologies to dispose of the pollutants with minimal environmental impacts.[5,9] Humankind's ability to spontaneously assess and manage health risks has become fundamental to survival in today's changing environment.[10,11]

Particulate matter pollution is now a serious worldwide concern due to its severe consequences on an ecosystem's biotic and abiotic components.[12,13] Megacities of Rajasthan state of republic India have also experienced high concentration levels of particulate matter inthe last few years, which puts an additional load on the Indian economy.[14–18]

Fine particulate matter is getting more attention because of its small size. It has heterogeneous compositions of liquid and solid particles suspended in the environment. The size of dangerous particulates varies from large to too-small.[7,19] Some particulates are so large that they can be watched even through the bare eye, although the rest are so minute that they could only be monitored with the help of an electron microscope.[20,21] PM are broadly classified into two categories according to their aerodynamic diameter, i.e., $PM_{2.5}$ (Día ≤2.5 μm) and PM_{10} (Día ≤10 μm).[3,22]

Natural and man-made activities are answerable for the worst air quality.[5,23]. Volcanic eruption, dust storms, wildfires, burning of fossil fuel in coal-based industries.[24–26] vehicular emissions.[25,27] power generation.[8,28] oil refineries,[25] and stubble and wood burning are the leading causes of particulate matter formation.[29,30]

The undesired detrimental effect of particulates on the health of humans has mild, moderate, or severe impacts according to their concentration level and duration of exposure. It has become a significant environmental risk factor for all-cause and disease-specific morbidity & mortality.[31] Older age, Children, and pregnant women are susceptible to the exposure.[32,33] $PM_{2.5}$ exposure causes mortality fromlung cancer,[34] all-natural causes in adults (30+ years), chronic pulmonary obstructive disease (COPD),[11] acute lower respiratory infection (ALRI),[32] stroke,[35] ischemic heart disease (IHD),[34] and Short-term impacts increase hospital admissions from diseases related to respiratory, cardiovascular disease (CVD), stroke, and adult mortality.[36]

The ultimate objective of this work is to measure particulate matter's severe impact on inhabitants and identify the ecological environment risk category of Kota city, Rajasthan (India), during the observation period of four years (2018-2022). Not sufficient studies were available in the literature for Kota to quantify environmental risk. The educational hub of the Rajasthan state (India), Kota, is a rapid-growing metropolis with two million inhabitants. Kota is suffering from the harmful impact of particulate matter pollution.

Study Area & Research Methodology

Kota, an industrial and educational district of Rajasthan, ranks 16th in terms of population, 24th in a geographical area, and 7th in population density in the Rajasthan State of India. The population of Kota was 19, 51, 014 in 2021 as per the census of India, 2011.[37] PM_{10} and $PM_{2.5}$ are the parameters selected for the study. Four-year air quality data iscollected from January 2018 to December 2021. Seven monitoring sites on air quality were utilised to obtain the data to determine the city's air quality deterioration. Air quality stations for Kota are mentioned in Table 1.

Table 1: GPS locations of air monitoring sites available in Kota city, Rajasthan (India).

Site	Site Type	Latitude (degree)	Longitude (degree)	Description
AQS-1	Manual	25.13	75.82	Fire Station, Shrinathpuram
AQS-2	Manual	25.16	75.83	Municipal Corporation Building
AQS-3	Manual	25.13	75.80	Rajasthan Technical University
AQS-4	Manual	25.12	75.86	RSPCB, Regional Office
AQS-5	Manual	25.17	75.91	Samcore Glass Limited
AQS-6	Manual	25.22	75.84	Sewage Treatment Plant, Balita
AQS-7	Continuous	25.14	75.82	Shrinathpuram Stadium

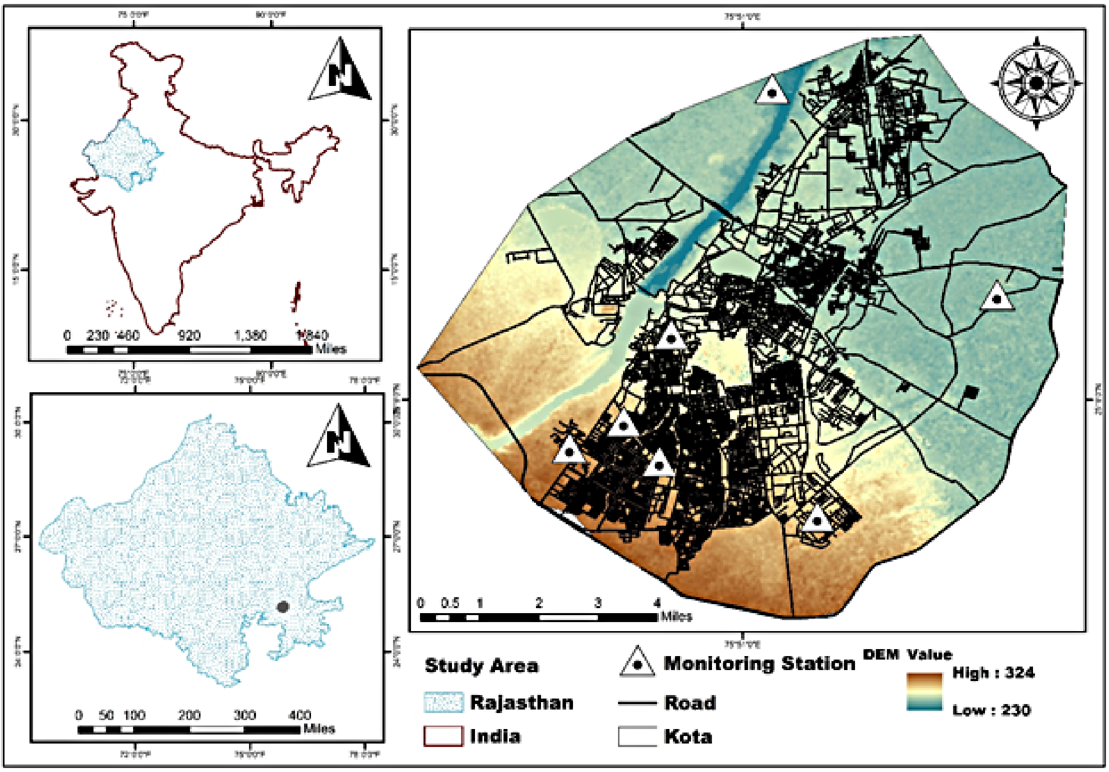

Fig. 1: Study area map including air monitoring stations for Kota city, Rajasthan, (India).

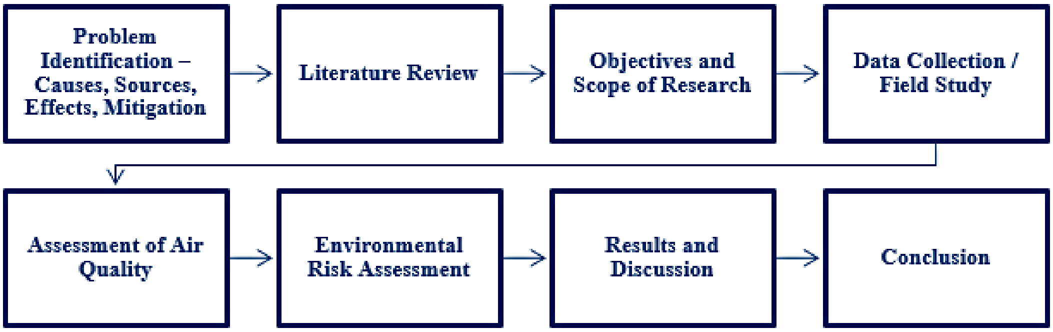

Fig. 2: Step-by-step procedure followed in this study to complete the research work.

The average PM_{10} and $PM_{2.5}$ concentrations are also compared with other regional districts of Rajasthan, namely, Jaipur, Udaipur, Ajmer, Pali, Alwar, and Jodhpur, with an additional 10 continuously monitoring air quality stations, including one continuous air quality station for Kota. The research methodology for the study is exhibited in Figure 2. Human health risk assessment has been evaluated with the help of AirQ+ software (WHO invented), while ecological hazard risk categories were recognised through risk quotient (RQ). A comparison with different regional cities, namely, Jaipur, Udaipur, Ajmer, Pali, Alwar, and Jodhpur, has also been done for $PM_{2.5}$ andPM_{10} concentrations. The dust ratio ($PM_{2.5}/PM_{10}$) is computed for Kota and regional cities to validate the increasing levels of fine particulates than the larger ones. The fine particles have the capability of penetrating deeper into the respiratory tract which has more severe consequences for human beings than the large ones.The standards for PM_{10} and $PM_{2.5}$ prescribed by different agencies worldwide are shown in Table 2.

Table 2: Standards for particulate matter prescribed by global agencies.[24,35,38–43]

Regulating Agency	PM_{10} concentration, µg/m³		$PM_{2.5}$ concentration, µg/m³	
	Annual	24-hour	Annual	24-hour
WHO[44]	15	45	5	15
EPA, U.S.	-	150	15	35
NAAQS, India[45]	60	100	40	60

Environmental Risk Assessment

This study implements the environmental risk assessment for Kota due to particulate matter with the help of ecological environmental risk and human health risk assessments. Risk Quotient has been estimated to determine the hazard risk category for ecological environmental risk assessment. At the same time, the AirQ+ software is used to estimate human health risk analysis.

Ecological Environmental Risk

Ecological environment risk is a semi-qualitative risk based on particulate matter's physical and chemical characteristics to evaluate the ecological environment's probable risk category (Table 3). A risk Quotient is calculated with the help of the following equation.[10,46]

$$RQ_p = C_{AP}/C_{LP} \quad ...(1)$$

Where:
RQ_p = RQ for the pth pollutant,
C_{Ap} = Ambient quantity of the pth pollutant, µg/m³, and
C_{Lp} = Standard Limiting forthe pth pollutant, µg/m³.

Human Health Risk Assessment

WHO developed AirQ+ software, which is used to assess human health risks from particulate matter. Default relative risk (RR) values for mortality from

COPD, IHD, stroke, all-natural causes, LC, ALRI, HA-RD, HA-CVD, adult mortality, chronic bronchitis, bronchitis in kids, asthma in kids, postneonatal infant mortality, asthma symptoms in asthmatic kids were 1013, 132, 49, 101, 436, 436, 1260, 101, 1013, 1013, 66, 497, and 66 respectively.[32–34,36,47,48]

Table 3: Classification of different categories of environmental risk.

Risk Level	RQ Value	Hazard	Risk Level	RQ Value	Hazard
A.	< 0.01	Very Low Risk	C.	0.1-1	Medium Risk
B.	0.01-0.1	Low Risk	D.	≥ 1	High Risk

Results and Discussion

The results of this study reveal that $PM_{2.5}$ and PM_{10} concentrations for Kota, Jaipur Ajmer, Udaipur, Pali, Jodhpur, and Alwar of Rajasthan werehigher than those recommended by different agencies worldwide shown in Table 2. Particulate Matter concentrations for Kota, Jaipur, Ajmer, Udaipur, Pali, Jodhpur, and Alwar are shown in Figure 3.

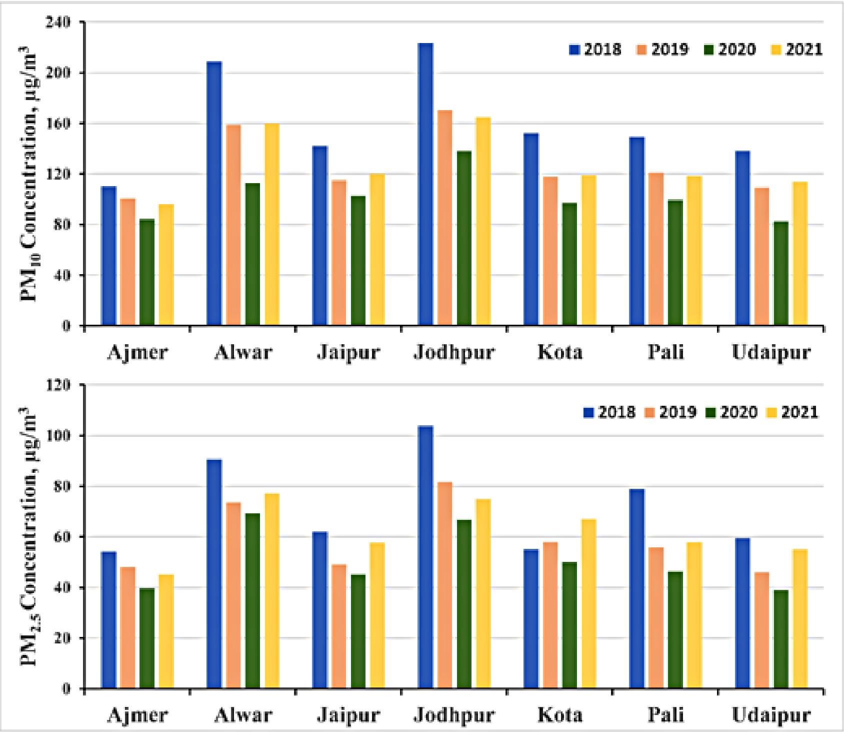

Fig. 3: The concentration of particulate matter in prominent regional cities nearby Kota.

The annual particulate matter concentrations are mentioned in Table 4 for each sampling location in the city. The PM_{10} concentrations for Kota were 152, 118, 97, and 119 µg/m³ in 2018, 2019, 2020, and 2021, respectively. The $PM_{2.5}$ concentrations for Kota were 55, 58, 50, and 67 µg/m3 in 2018, 2019, 2020, and 2021, respectively. The dust ratio for Kota were 0.36, 0.49, 0.52, and 0.56 in 2018, 2019, 2020, and 2021 respectively. An increasing trend has been seen inthe dust ratio duringthe observation of four years. The dust ratio varies from place to palace and year to year. The $PM_{2.5}$ concentration gradually increased during observation except in 2020 due to Covid-19 lockdown restrictions all over India in 2020.[49,50]

A decreasing trend has been observed for PM_{10} till 2020, but it again starts increasing in 2021 with tremendous speed. Several studies suggest that these restrictions help to improve air quality worldwide. The annual particulate matter concentrations are exhibited in Figure 4 for each sampling location in the metropolitan area. 121 and 57 µg/m³ were the mean PM_{10} and $PM_{2.5}$ concentration,respectively. At the same time, the average dust ratio was 0.48. The dust Ratio ($PM_{2.5}$/ PM_{10}) in prominent places of Rajasthan State, India, is graphically presented in Figure 5. The dust ratio for Kota city is gradually rising from 0.36 to 0.51. The dust ratio for Kota was 0.36 in 2018, 0.49 in 2019, 0.51 in 2020, and 0.56 in 2021. High dust ratio values confirm the higher concentration of fine particles ($PM_{2.5}$) compared to larger particles (PM_{10}). The fine particles have the capability of penetrating deeper into the respiratory tract and creating many adverse effects on the human body. Hence, it is becoming a more serious concern for the inhabitants of Kota city.

Table 4: Annual PM_{10} and $PM_{2.5}$ data for each station of Kota city, Rajasthan (India).

PM_{10}								
Year	**AQS-1**	**AQS-2**	**AQS-3**	**AQS-4**	**AQS-5**	**AQS-6**	**AQS-7**	**Kota**
2018	144	124	182	180	147	143	143	152
2019	107	108	139	147	108	107	107	118
2020	82	109	83	127	97	NA	82	97
2021	108	122	97	150	131	NA	108	119
Average	110	116	125	151	120	125	110	122
$PM_{2.5}$								
Year	**AQS-1**	**AQS-2**	**AQS-3**	**AQS-4**	**AQS-5**	**AQS-6**	**AQS-7**	**Kota**
2018	51	46	65	65	52	52	52	55
2019	52	53	68	72	53	53	53	58
2020	42	56	43	65	50	NA	42	50
2021	61	68	55	84	73	NA	61	67
Average	52	56	58	72	57	53	52	58

*NA stands for not availability of data.

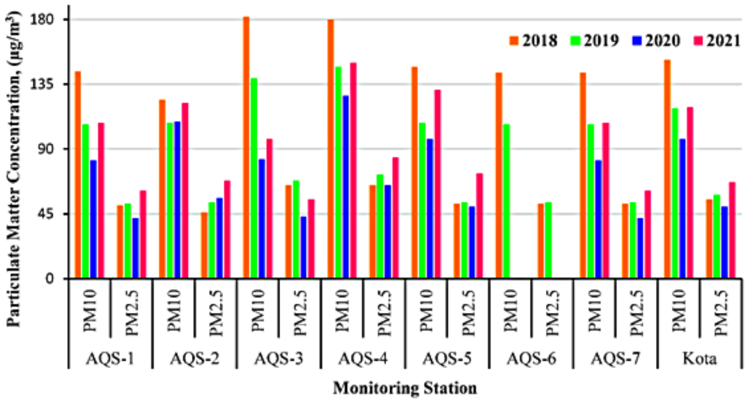

Fig. 4: Particulate matter concentration in Kota, Rajasthan State, India.

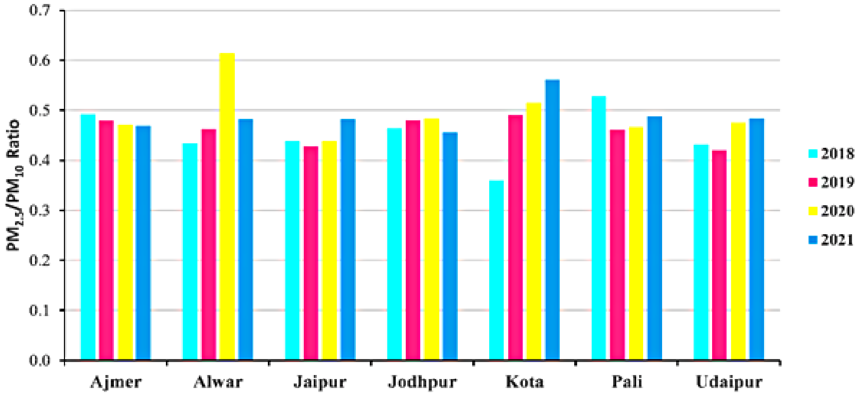

Fig. 5: Dust Ratio ($PM_{2.5}/PM_{10}$) in prominent places of Rajasthan State, India.

Ecological Environmental Risk

The risk quotient can be assessed by determining the potential risk of particulate pollutants to the ecological environment. The risk quotient values for PM_{10} were 2.53, 1.96, 1.61, and 1.99 in 2018, 2019, 2020, and 2021, respectively, while the values for $PM_{2.5}$ were 1.36, 1.44, 1.25, and 1.68 in 2018, 2019, 2020, and 2021, respectively. The whole of India was suffering from Corona Virus outbreaks in 2021. The citizens strictly followed lockdown restrictions to complete their duty toward the nation. Transport and industrial activities were under the limitation of government orders which positively impacted the quality of ambient air. The air pollutants concentrations went down, and inhabitants had clean air to breathe. Several studies on air quality reveala meaningful impact of lockdown restrictions on the air quality globally,[2,50–52] and a reduction in particulate matter pollution level was also seen in 2020 for Kota, also leading to low values of RQ for PM_{10} and $PM_{2.5}$. The risk quotient values for Kota were calculated with the help of equation 1, which is mentioned in Table 5. The PM_{10} and $PM_{2.5}$ for Kota were computed through the average of all monitoring stations' concentrations (Table 4). RQ values for each year for Kota city are evaluated from average PM_{10} and $PM_{2.5}$ concentrations.

Table 5: RQ value and relative risk category for PM_{10} and $PM_{2.5}$.

	Year	RQ	Hazard		Year	RQ	Hazard
	2018	02.53	H		2018	01.36	H
PM_{10}	2019	01.96	H	**$PM_{2.5}$**	2019	01.44	H
	2020	01.61	H		2020	01.25	H
	2021	01.99	H		2021	01.68	H
	Average	**02.02**	**H**		**Average**	**01.43**	**H**

*H stands for High.

Human Health Risk Assessment

The average annual PM_{10} and $PM_{2.5}$ were 123 and 57 µg/m^3, respectively, during the observation of four years for Kota city. The particulate matter concentration plays a vital role in conducting the impact analysis through software (AirQ+). The estimated effects of PM_{10} and $PM_{2.5}$ are mentioned in Table 6.

The ENACs for all-cause mortality from $PM_{2.5}$ exposure for a long period was maximum at the AQS-4 location with 6365 deaths, followed by the AQS-3 location (5128 deaths), AQS-5 location (5036 deaths), AQS-2 (4943 deaths), AQS-1 (4565 deaths), AQS-6 (4565 deaths), AQS-7 (4565 deaths). The average all-cause mortality for Kota city is 5024 due to $PM_{2.5}$ exposure for a long period.

Table 6: Station Wise Distribution of ENACs for Disease Caused by PM_{10} and $PM_{2.5}$.

Disease	Air Monitoring Station						
	AQS-1	**AQS-2**	**AQS-3**	**AQS-4**	**AQS-5**	**AQS-6**	**AQS-7**
All-Cause Mortality	4565	4943	5128	6365	5036	4565	4565
Lung Cancer	809	872	903	1103	887	809	809
ALRI	256	269	276	316	273	256	256
COPD	436	460	471	543	465	436	436
IHD	1962	2047	2088	2334	2068	1962	1962
Stroke	1777	1865	1908	2171	1887	1777	1777
Chronic Bronchitis	13685	14119	14719	16151	14460	13685	13685
Bronchitis in Kids	715	743	782	882	765	715	715
Asthma in Kids	321	338	362	430	352	362	321
HA-RD	1260	1442	1532	2153	1487	1532	1260
HA-CVD	49	56	60	85	58	60	49
Mortality adults	664	760	808	1142	784	664	664
Postneonatal Infant Mortality	325475	341237	364196	426146	354092	325475	325475

*ENAC stands for the estimated number of attributable cases.

The lung cancer mortality was 1103 for the AQS-4 location, 903 for the AQS-3 location, 887 for the AQS-5 location, 872 for the AQS-2 location, and 809 for the AQS-1, AQS-6, and AQS-7 locations. The average lung cancer mortality for Kota city is 885 due to $PM_{2.5}$ exposure over a long period. The ALRI mortality was leading at the AQS-4 location (316 deaths), followed by the AQS-3 location (276 deaths), the AQS-5 location (273 deaths), the AQS-2 l 7 location (269 deaths), and 256 for the AQS-1, AQS-6, and AQS-7 locations. The average ALRI mortality for Kota city is 272 due to $PM_{2.5}$ exposure for a long period. The COPD mortality was maximum at the AQS-4 location with 543 deaths, followed by the AQS-3 location (471 deaths), AQS-5 location (465 deaths), AQS-2 (460 deaths), AQS-1 (436 deaths), AQS-6 (436 deaths), AQS-7 (436 deaths). The average COPD mortality for Kota city is 464 due to $PM_{2.5}$ exposure for a long period.

The IHD mortality was 2334 for the AQS-4 location, 2088 for the AQS-3 location, 2068 for the AQS-5 location, 2047 for the AQS-2 location, and 1962 for the AQS-1, AQS-6, and AQS-7 locations. The average IHD mortality for Kota city is 2060 due to $PM_{2.5}$ exposure for a long period. Stroke mortality was leading at the AQS-4 location (2171 deaths), followed by the AQS-3 location (1908 deaths), the AQS-5 location (1887 deaths), the AQS-2 location (1865 deaths), and 1777 for the AQS-1, AQS-6, and AQS-7 locations. The average stroke mortality for Kota city is 1880 due to $PM_{2.5}$ exposure for a long period.The postneonatal infant mortality due to PM_{10} exposure for a long period was maximum at the S-4 location with 426146 deaths, followed by the AQS-3 location (364196 deaths), AQS-5 location (354092 deaths), AQS-6 (354095 deaths), AQS-2 (341237 deaths), AQS-1 (325475 deaths), AQS-7 (325475 deaths). The average postneonatal infant mortality for Kota city is 355816 due to PM_{10} exposure for a long period.

The chronic bronchitis incidence in adults was 16151 for the AQS-4 location, 14719 for the AQS-3 location, 14460 for the AQS-5 and AQS-6 locations, 14119 for the AQS-2 location, and 13685 for the AQS-1 and AQS-7 locations. The average chronic bronchitis incidence in adults for Kota city is 14469 due to PM_{10} exposure for a long period. The prevalence of bronchitis in kids was foremost at the AQS-4 location (882 cases), followed by the AQS-3 location (782 cases), the AQS-5 and AQS-6 locations (765 cases), the AQS-2 location (743 cases), and 715 for the AQS-1, and AQS-7 locations. The prevalence of bronchitis in kids in Kota city is 767 due to PM_{10} exposure for a long period.The hospital admission for respiratory disease (HA-RD) from $PM_{2.5}$ exposure for a short period was maximum at the AQS-4 location with 2153 cases, followed by the AQS-3 location (1532 cases), AQS-5 location (1487 cases), AQS-2 (1442 cases), AQS-1, AQS-6, and AQS-7 (1260 cases). The average HA-RD for Kota city is 1485 due to $PM_{2.5}$ exposure for a short period.

The hospital admission due to cardiovascular disease (HA-CVD) was 85 for the AQS-4 location, 60 for the AQS-3 location, 58 for the AQS-5 location, 56 for the AQS-2 location, and 49 for the AQS-1, AQS-6, and AQS-7 locations. The average HACVD for Kota city is 58 due to $PM_{2.5}$ exposure for a short period. The all-cause mortality in adults was leading at the AQS-4 location (1142 deaths), followed by the AQS-3 location (808 deaths), the AQS-5 location (784 deaths), the AQS-2 location (760 deaths), and 664 for the AQS-1, AQS-6, and AQS-7 locations. The average all-cause mortality in adults for Kota city is 784 due to $PM_{2.5}$ exposure for a short period. The asthma symptoms in asthmatic kids due to PM_{10} exposure for a short period were maximum at the AQS-4 location with 430 cases, followed by the AQS-3 location (362 cases), AQS-5 location (352 cases), AQS-2 (338 cases), AQS-1, AQS-2, and AQS-7 (321 cases). The mean asthma symptoms in asthmatic kids for Kota city is 349 due to PM_{10} exposure for a short period.

The EAP and ENACPL for long and short-term effects of $PM_{2.5}$ and PM_{10} on humans. AirQ+ software gave the results at the ambient leveltabulated in Tables 7 and 8, respectively. Notably, the higher concentration of particulate matter station has high ENACs, EAP and ENACPL.

Table 7: Station Wise Distribution of EAP (%) for Disease Caused by PM_{10} and $PM_{2.5.}$

Disease	Air Monitoring Station						
	AQS-1	**AQS-2**	**AQS-3**	**AQS-4**	**AQS-5**	**AQS-6**	**AQS-7**
All-Cause Mortality	22.33	24.17	25.08	31.13	24.63	22.33	22.33
Lung Cancer	30.37	32.73	33.88	41.39	33.30	30.37	30.37
ALRI	25.83	27.23	27.89	31.97	27.56	25.83	25.83
COPD	21.39	22.55	23.11	26.61	22.83	21.39	21.39
IHD	22.30	23.26	23.72	26.52	23.49	22.30	22.30
Stroke	20.19	21.20	21.68	24.67	21.44	20.19	20.19
Chronic Bronchitis	66.93	69.05	71.99	78.99	70.72	70.72	66.93
Bronchitis in Kids	53.68	55.77	58.73	66.21	57.44	57.44	53.68
HA-RD	4.95	5.67	6.02	8.47	5.85	4.95	4.95
HA-CVD	2.42	2.77	2.95	4.17	2.86	2.42	2.42
Mortality adults	3.25	3.72	3.95	5.58	3.84	3.25	3.25
Asthma in Kids	24.13	25.38	27.21	32.25	26.40	24.13	24.13
Postneonatal Infant Mortality	32.44	34.01	36.30	42.48	35.30	35.30	32.44

*EAP stands for the estimated attributable proportion.

The individual station data is utilised to exhibit the spatial distribution of mortality due to all causes (natural), lung cancer, COPD, ALRI, Stroke and IHD in Kota city. The software employed to exhibit spatial variability is ESRI ArcGIS with the inverse distance weighing (IDW) interpolation method.

Table 8: Station Wise Distribution of ENACPL for Disease Caused by PM_{10} and $PM_{2.5.}$

Disease	Air Monitoring Station						
	AQS-1	**AQS-2**	**AQS-3**	**AQS-4**	**AQS-5**	**AQS-6**	**AQS-7**
All-Cause Mortality	226	245	254	315	249	226	226
Lung Cancer	40	43	45	55	44	40	40
ALRI	13	13	14	16	14	13	13
COPD	22	23	23	27	23	22	22
IHD	97	101	103	116	102	97	97
Stroke	88	92	95	108	93	88	88
Chronic Bronchitis	678	699	729	800	716	716	678
Bronchitis in Kids	35	37	39	44	38	38	35
HA-RD	62	71	76	107	74	62	62
HA-CVD	2	3	3	4	3	2	2
Mortality adults	33	38	40	57	39	33	33
Asthma in Kids	16	17	18	21	17	16	16
Postneonatal Infant Mortality	161	169	180	211	175	175	161

*ENACPL stands for the estimated number of attributable cases per lac population.

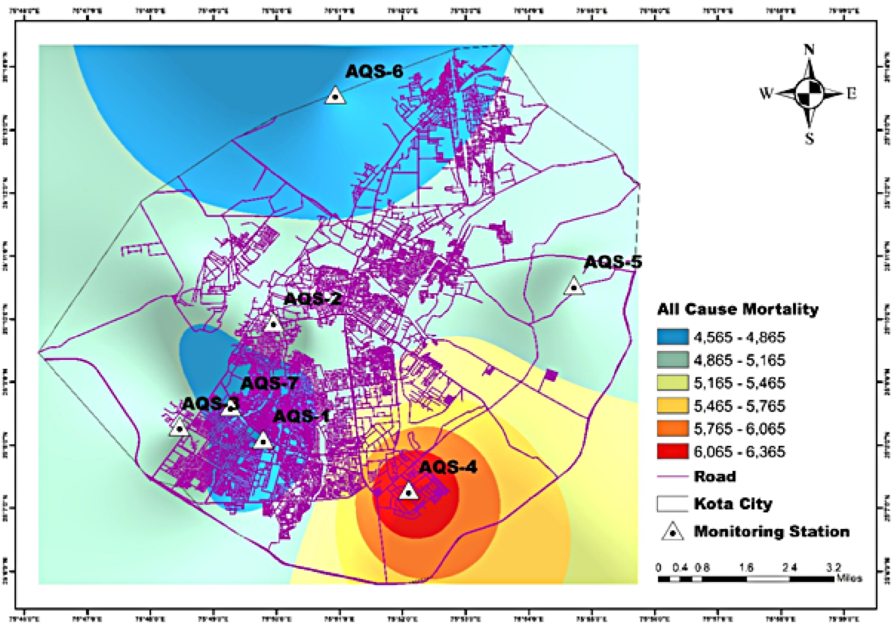

Fig. 6: Spatial distribution map for all-cause mortality in Kota city, Rajasthan (India).

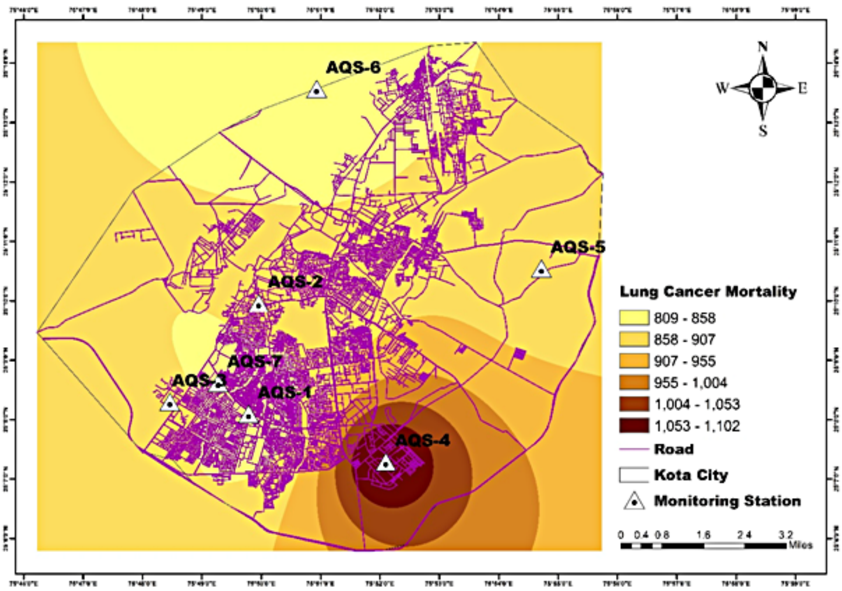

Fig. 7: Spatial distribution map for lung cancer mortality in Kota city, (India).

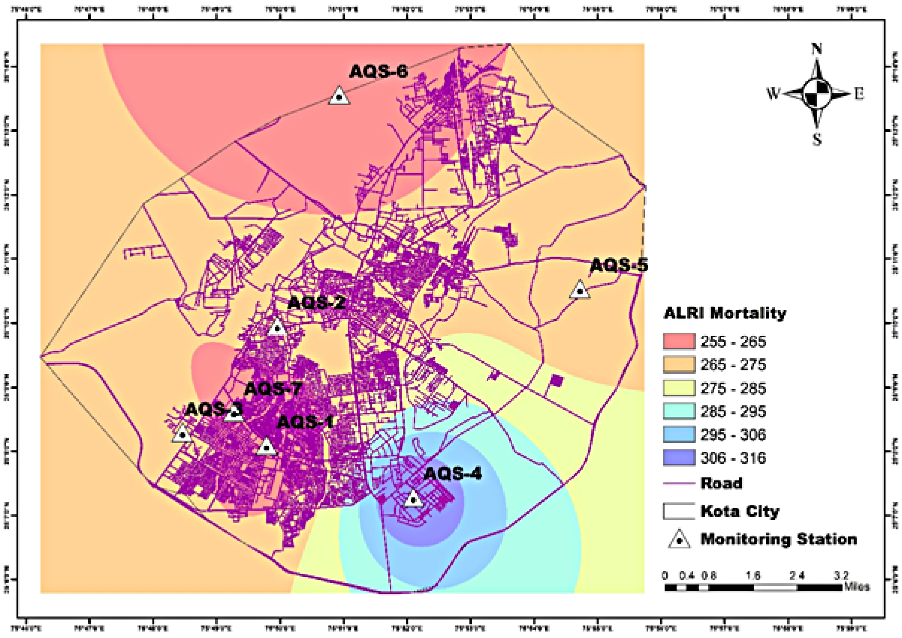

Fig. 8: Spatial distribution map for ALRI mortality in Kota city, Rajasthan (India).

The spatial variability maps for mortality due to all-natural causes (Figure 6), lung cancer (Figure 7), ALRI (Figure 8), COPD (Figure 9), IHD (Figure 10), and stroke (Figure 11) have been prepared through ESRI ArcGIS software. It can be easily verified through these maps that the peoples of the nearby area of station AQS-4 (Regional Office, RSPCB) are highly vulnerable to the adverse effect of particulate matter as this station has the peak average PM_{10} and $PM_{2.5}$ concentrations among all. The AQS-4 station is only 3.5 km from the city's center, the aerodrome circle. The AQS-6 station

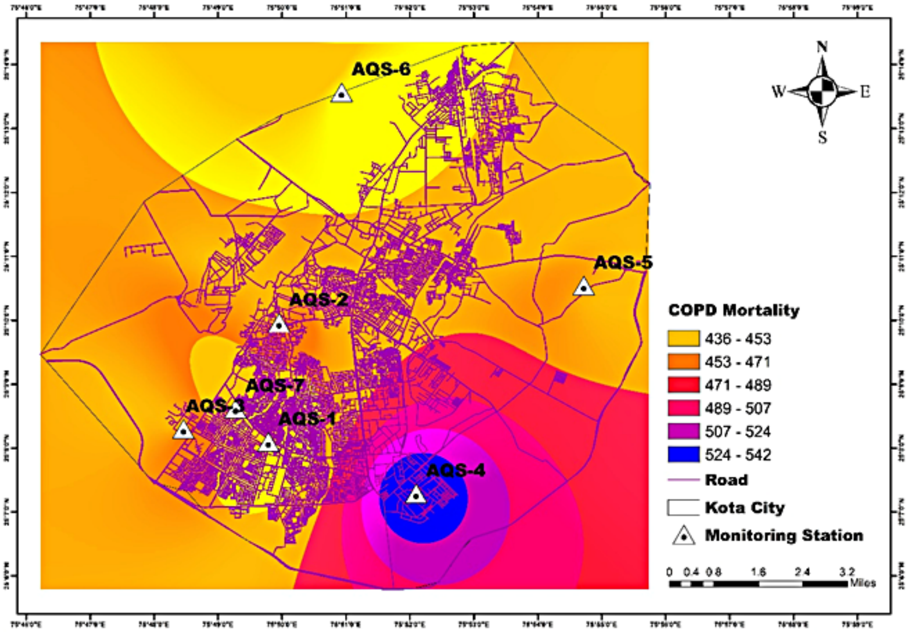

Fig. 9: Spatial distribution map for COPD mortality in Kota city, Rajasthan (India).

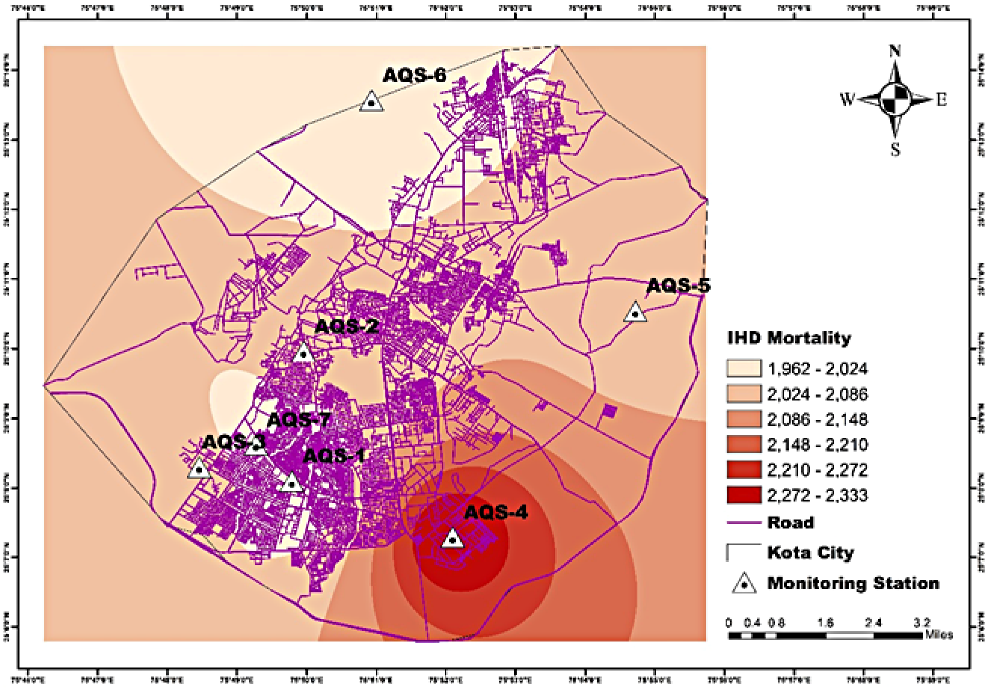

Fig. 10: Spatial distribution map for IHD mortality in Kota city, Rajasthan (India).

(Sewage Treatment Plant, Balita) is situated on the outer periphery of Kota city, almost 12 km from the city's center, the aerodrome circle, and it is the least susceptible to the adverse effect of particulate matter due absence of air pollution sources.

Conclusion

The present study reveals that the particulate matter concentration for Kota during the observation period is clearly violating the standards prescribed by the different global agencies, namely, WHO, USEPA, and Indian NAAQS. Particulate matter pollution is identified as the foremost cause of air pollution in Kota. The air quality monitoring station situated at Regional Office, RSPCB shows the maximum degradation in the air quality due to the presence of different micro, small and medium enterprises. Transportation of goods with the help of heavy vehicles puts an additional deterioration in the ambient air quality. The amount of fine particulate matter ($PM_{2.5}$) gradually increases in Kota city as the dust ratio shows an increasing trend during the observation period. The fine particles have the capability of penetrating deeper into the respiratory tract and creating many adverse effects on the human body. Hence, it is becoming a more serious concern for the inhabitants of Kota city.

The environmental risk assessment of particulate matter results shows that neither the state capital, Jaipur, nor other prominent cities such as Kota, Ajmer, Udaipur, Pali, Jodhpur, and Alwar of Rajasthan are competent to maintain or keep below the particulate matter concentration within the safe limits prescribed by different agencies worldwide. In other words, metro cities of Rajasthan state are suffering from regularly growing levels of particulate matter pollution. The ecological environment of Kota city is under massive threat as the hazard risk is in the high category (RQ>1) for PM_{10} and $PM_{2.5.}$ Ecological environment risk assessment suggests that Kota inhabitants are highly vulnerable to negative impacts caused by particulate matter. The order of mortality cases for Kota city evaluated through AirQ+ software is the all-natural cause (4565-6365) > IHD (1962-2333) > stroke (1776-2171) > lung cancer (809-1102) > COPD (436-542) > ALRI (255-316).

Improving the management of solid waste, restricting open burning, increasing green beltways, prohibiting old vehicles, planting different plants, and shifting towards clean energy vehicles would effectively lessen the consequence of particulate matter on people.

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Conflict of Interest

There is no conflict of interest between the authors.

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