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Interference Study of Pollutants Released from Various Industrial Areas in a Region: A Case Study

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Abstract Jodhpur is well known city of Rajasthan state in India and is a tourist place. Jodhpur is surrounded by industrial areas and defence installations. Air pollution is now becoming a challenge to the administration of a city because of its adverse effects on human beings. In this study four monitoring stations were selected to find pollution level in the ambient air. Air Quality Index was calculated by considering five pollutant parameters i.e. SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO at all monitoring stations. Minimum, average and maximum air quality index were calculated at each industrial area monitoring stations. It was observed that PM_{10} and $PM_{2.5}$ are responsible air pollutants which governs the air quality index. In this study duration weather was clear and wind direction was either from North direction or from North-East direction. SCREEN3 Air Dispersion Model was used to find the pollutant concentration with increasing distances from area sources. Modelled AQI was also calculated before and after overlapping zone using SCREEN3 Air Dispersion Model. It was observed that air pollution from one industrial area is interfering the AQI of other industrial area.

Keywords: *Air pollution, Industrial area, PM_{10}, $PM_{2.5}$, AQI, Air dispersion model*

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1. Introduction

Jodhpur is well known city of Rajasthan state in India and is a tourist place. Jodhpur is surrounded by industrial areas and defence installations. Jodhpur city has major four industrial areas. Basni industrial area has mainly textile / timber / Guar gum industrial units. Boranada industrial area has mainly Metal and Wooden Handicrafts industrial units, Mandore industrial area has oil mills/Guar gum/ textile / Stone Processing industrial units. Kankani industrial area has mainly handicraft / plastic industrial units. Air pollution is now becoming a challenge to the administration of a city because of its adverse effects on human beings. The acute health effect of suspended particulate matter (SPM), even at short term low levels exposure; include increased daily mortality and hospital admission rates for exacerbation of respiratory disease [1]. Long term exposure to PM2.5 increases the risk of the non accidental mortality. Living close to busy traffic appears to be associated with elevated risk [2]. The available human clinical results do not establish a mechanistic pathway leading to adverse health impacts for short term NO2 exposure at present day ambient environment [3]. In all the analytical studies total mortality was directly associated with long term exposure to particulate matter [4]. Therefore it is now essential to have knowledge about the AQI in various reasons because of industrial areas and effects of one industrial area on other. The AQI was divided in six categories considering five pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, and CO) as per the norms given by Central Pollution Control Board (CPCB) of India. Air quality index values are typically grouped into various ranges [5] and is given in Figure 1 and breakpoint concentration for various pollutants are given in Table 1 [6].

AQI	Good	Satisfactory	Moderate	Poor	Very Poor	Severe
Description	(0-50)	(51-100)	(101-200)	(201-300)	(301-400)	(>401)

Figure 1. Overall AQI Systems [5]

Table 1. Breakpoints for AQI Scale 0-500 (Units: µg/m^3 unless mentioned otherwise)[6]

AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	CO 8-hr (mg/m^3)	SO_2 24-hr
Good (0-50)	0-50	0-30	0-40	0-1.0	0-40
Satisfactory (51-100)	51-100	31-60	41-80	1.1-2.0	41-80
Moderately polluted (101-200)	101-250	61-9-	81-180	2.1-10	81-380
poor (201-300)	251-350	91-120	181-280	10-17	381-800
Very poor (301-400)	351-430	121-250	281-400	17-34	801-1600
Severe (401-500)	430+	250+	400+	34+	1600+

2. Methodology, Observations and Analysis

For this study four industrial areas of Jodhpur were selected and are Bornada Industrial Area, Basni (Phase I & II), Mandore Industrial Area and Kankani Industrial Area. Wind in Jodhpur city flow from either North-East direction or North direction in the maximum days of study duration. AQI was calculated by measuring concentration of PM_{10}, $PM_{2.5}$, NO_2, SO_2, and CO for each industrial area. An analysis was performed by the SCREEN3 Air Dispersion Model [7].

By using SCREEN3 Model, Graphs are plotted according to output result values. These were obtained using average wind speed 1.5 m/s , using stability class D and local meteorological condition, using the automated distances of Industrial Area up to 15 Km range in case of Basni and up to 24 Km range in case of Mandore Industrial Area.

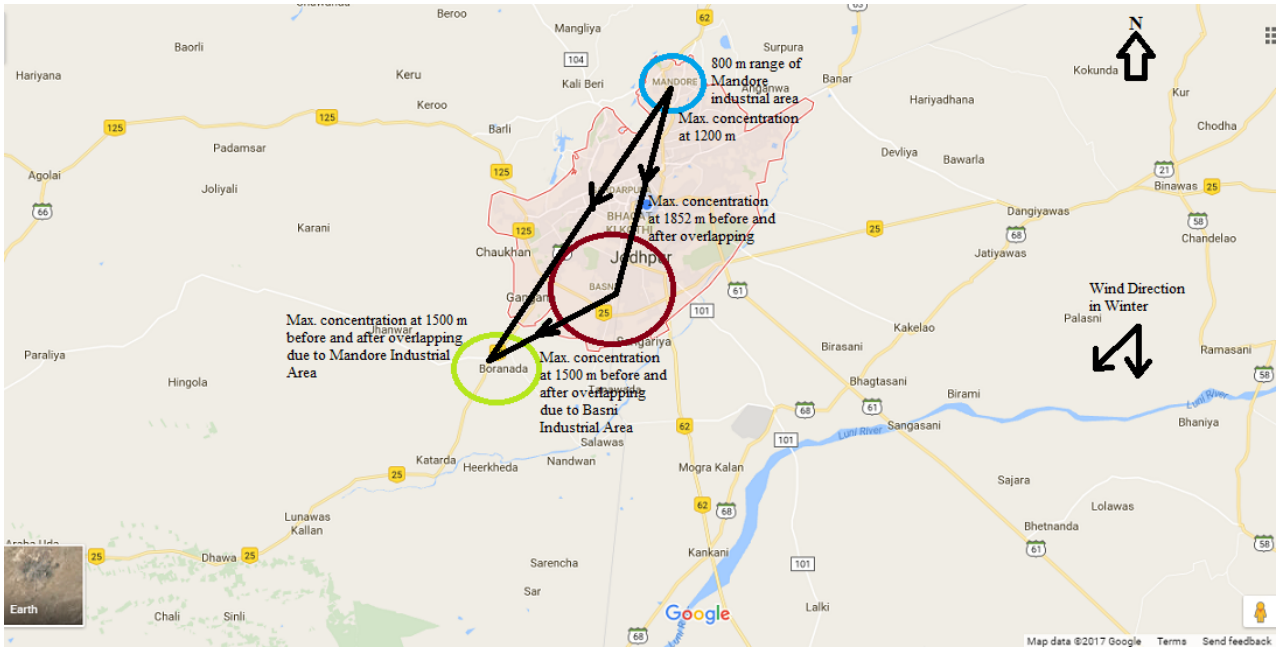

Figure 2. Map with overlapping of pollutant at maximum distance of Industrial Area

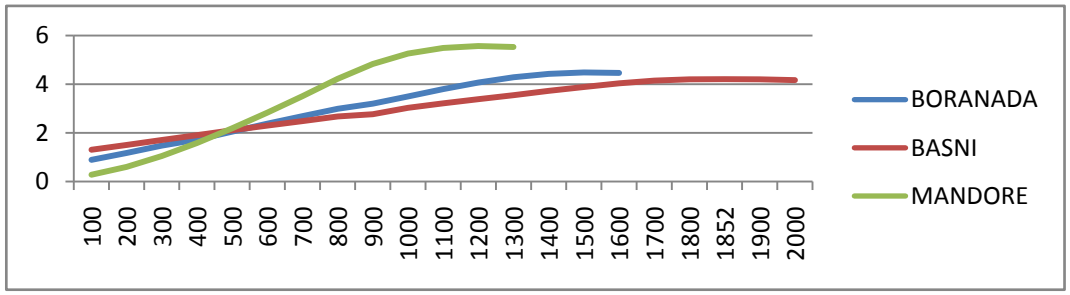

Figure 3. SO_2 concentration (µg/m^3) v/s automated distance within industrial areas

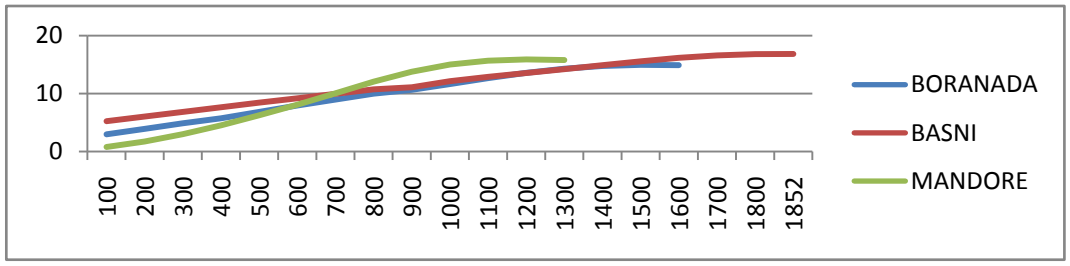

Figure 4. NO_2 concentration (µg/m^3) v/s automated distance within industrial areas

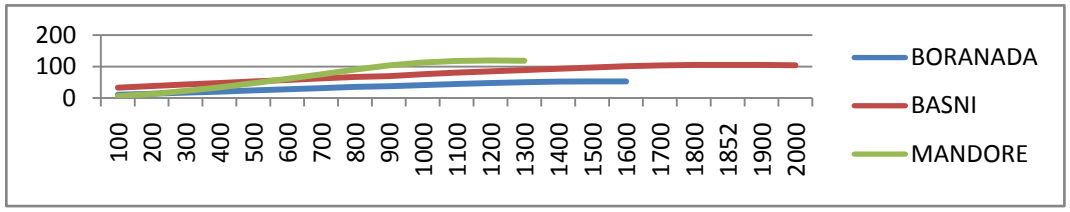

Figure 5. PM_{10} concentration (µg/m^3) v/s automated distance within industrial areas

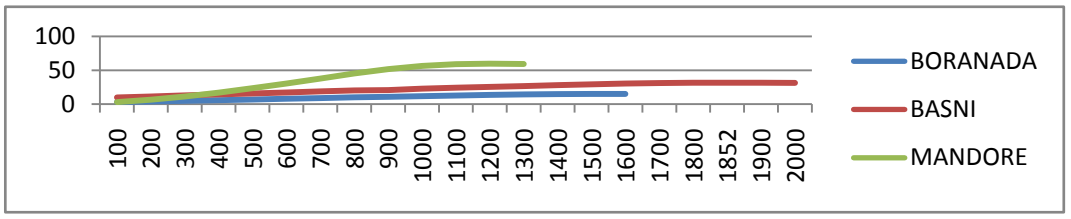

Figure 6. $PM_{2.5}$ concentration (µg/m^3) v/s automated distance within area

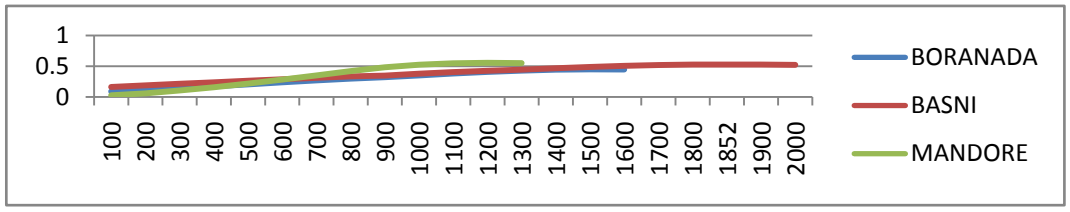

Figure 7. CO concentration (mg/m^3) v/s automated distance within industrial areas

By plotting the graph between pollutant concentration and automated distances within ranges of all industrial areas, it was observed that concentration of pollutants increase from centre to the boundary and then decrease continuously. Maximum concentration of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ was 4.21µg/m^3, 16.84µg/m^3, 105.2µg/m^3, 31.57µg/m^3 respectively and CO concentration was 0.526 mg/m^3 at 1852 m distance within boundary of Basni industrial area but these concentrations do not cross standard concentration except PM_{10}. Concentration of pollutants increases from centre of area to 1200 m near the boundary of Mandore industrial area and then decreases continuously. Maximum concentration of SO_2, NO_2, PM_{10} and $PM_{2.5}$ was 5.57µg/m^3, 15.91µg/m^3, 119.3µg/m^3, 59.66µg/m^3 respectively and CO concentration was 0.557mg/m^3 at 1200 m distance but these concentrations do not cross standard concentration except PM_{10}. Concentration of pollutants increases from centre of area to 1500 m near the boundary and then decreases continuously in Boranada industrial area. Maximum concentration of SO_2, NO_2, PM_{10} and $PM_{2.5}$ was 4.49µg/m^3, 14.96µg/m^3, 52.35µg/m^3, 14.86µg/m^3 respectively and CO concentration was 0.449 mg/m^3 at 1500 m distance but these concentrations do not cross standard concentration.

2.1. Overlapping Analysis

(a) Overlapping of Mandore Industrial Area pollution on Basni Industrial Area when wind direction is from North:

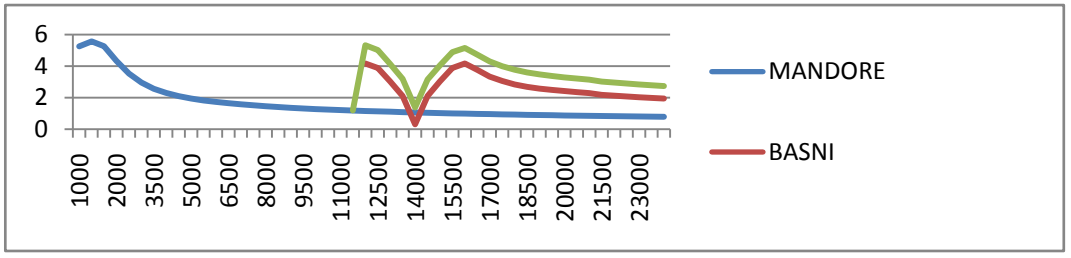

Figure 8. SO_2 (µg/m^3) v/s automated distance from Mandore Industrial Area

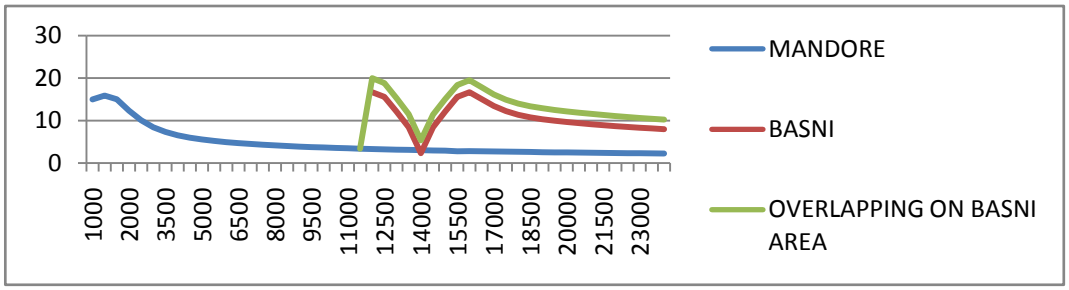

Figure 9. NO_2 (µg/m^3) v/s automated distance from Mandore Industrial Area

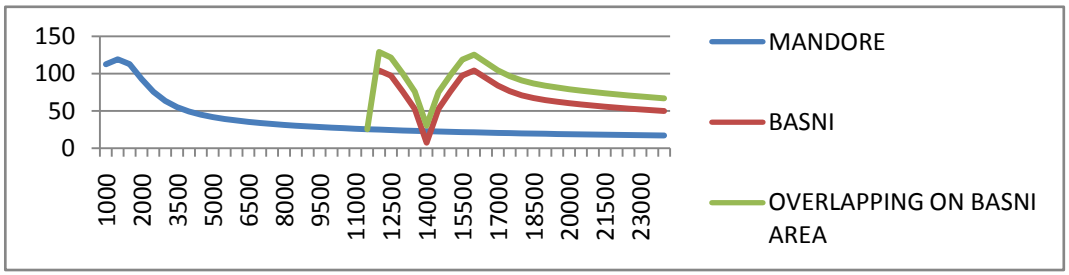

Figure 10. PM_{10} (µg/m^3) v/s automated distance from Mandore Industrial Area

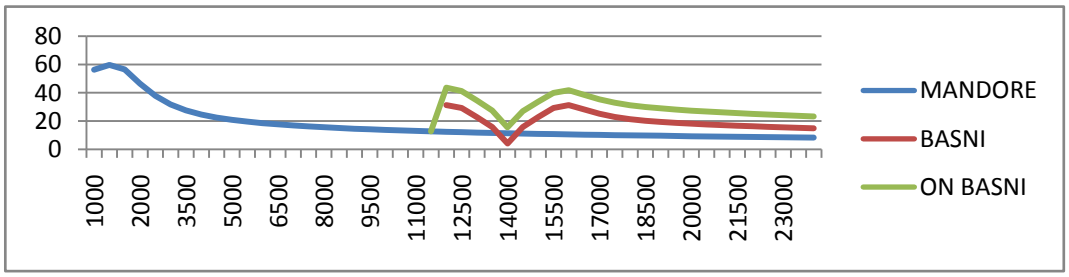

Figure 11. $PM_{2.5}$ (µg/m^3) v/s automated distance from Mandore Industrial Area

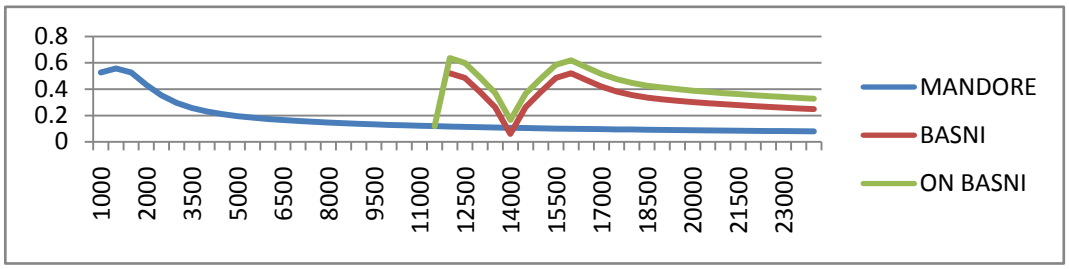

Figure 12. CO (mg/m^3) v/s automated distance from Mandore Industrial Area

In Mandore Industrial Area, concentration of all five pollutant increase up to boundary i.e. 1200 m for Mandore Industrial Area. After crossing the boundary, concentration decrease with increase the distance from boundary. If wind direction is from North Direction then it affects Basni industrial area pollutant concentrations and increase the pollutant concentration upon Basni industrial area range i.e. 1852 m and further decrease the pollutant concentration with increase of distance from both area sources. Maximum concentration of pollutant of Basni industrial area is at the boundary of area after overlapping. Maximum concentration of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ was 5.33µg/m^3, 19.98µg/m^3, 129.03µg/m^3, 43.68µg/m^3 respectively and CO concentration was 0.637mg/m^3 near the boundary of Basni industrial area after overlapping, combined concentration further decrease with increase of distances from area sources.

(b) Overlapping of Mandore Industrial Area pollution on Boranada Industrial Area, Basni Industrial Area pollution on Boranada Industrial Area and combined overlapping on Boranada Industrial Area due to both Industrial Area when wind direction is from North-East:

In Mandore Industrial Area, concentration of all five pollutant increase up to boundary i.e. 1200 m for Mandore Industrial Area. After crossing the boundary, concentration decrease with increase of distance from boundary. If wind direction is from North-East Direction then its impact on Boranada industrial area pollutant concentrations is very less. Increase of pollutant concentration upon Boranada industrial area range i.e. 1500 m and further decrease the pollutant concentration with increase of distance from industrial area sources.

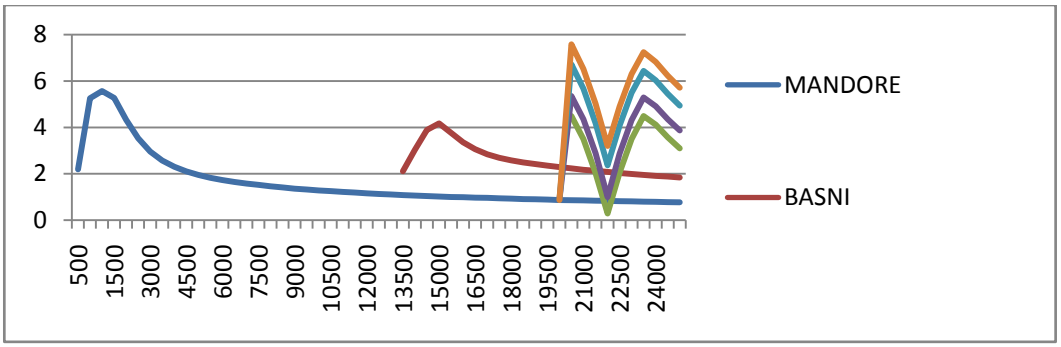

Figure 13. SO_2 (µg/m^3) v/s distance and overlapping in Boranada Industrial Area

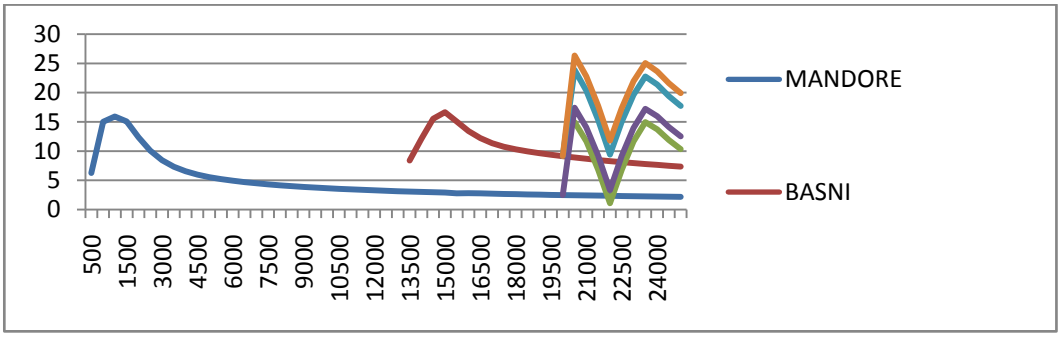

Figure 14. NO_2 (µg/m^3) v/s distance and overlapping in Boranada Industrial Area

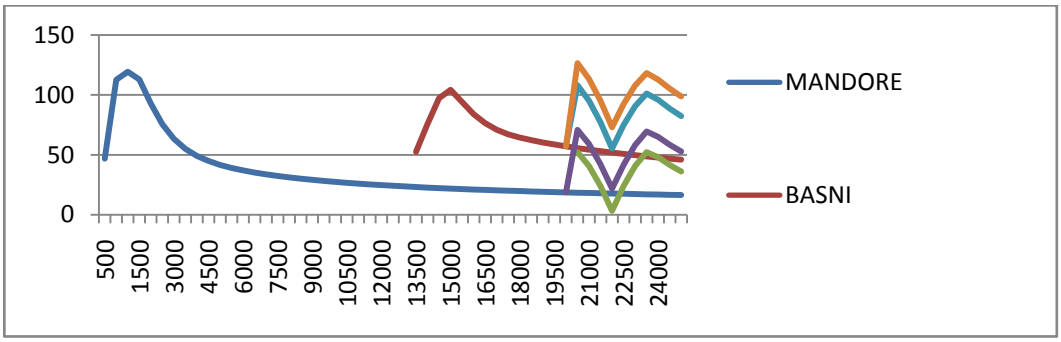

Figure 15. PM_{10} (µg/m^3) v/s distance and overlapping in Boranada Industrial Area

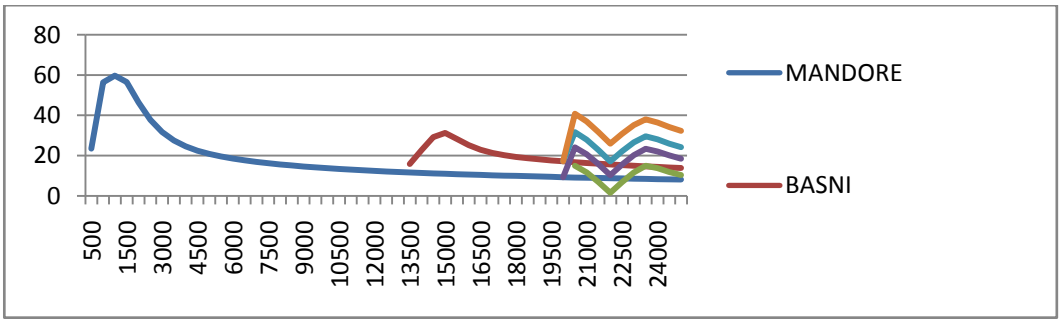

Figure 16. $PM_{2.5}$ (µg/m^3) v/s distance and overlapping in Boranada Industrial Area

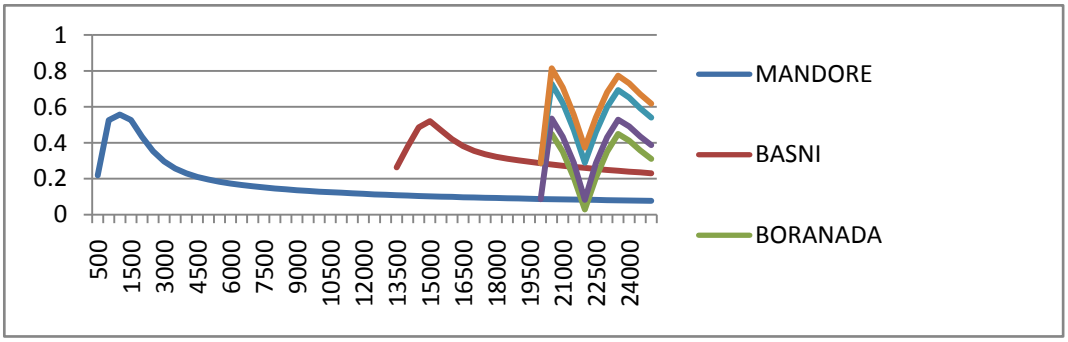

Figure 17. CO (mg/m^3) v/s distance and overlapping in Boranada Industrial Area

Maximum concentration of pollutants of Boranada industrial area is at the boundary of area after overlapping. Maximum concentration of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ was 5.35μg/m^3, 17.43μg/m^3, 70.84μg/m^3, 24.09μg/m^3 respectively and CO concentration was 0.535mg/m^3 near the boundary of Boranada industrial area after overlapping and combined concentration further decrease with increase of distances from area sources.

In Basni Industrial Area, concentration of all five pollutant increase first up to boundary i.e. 2000 m. After crossing the boundary, concentration decrease with increase of distance from boundary. If wind direction is from North-East Direction then it has large impact on Boranada industrial area pollutant concentrations and increase the pollutant concentration upon Boranada industrial area range i.e. 1500 m and further decrease the pollutant concentration with increase of distance from industrial area sources. Maximum concentration of pollutant in this Boranada industrial area was at the boundary of area after overlapping. Maximum concentration of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ was 6.72μg/m^3, 23.88μg/m^3, 108.10μg/m^3, 31.68μg/m^3 respectively and CO concentration was 0.728mg/m^3 near the boundary of Boranada industrial area after overlapping and combined concentration further decrease with increase of distances from area sources.

If wind direction is from North-East then it can be possible that Maximum concentration of pollutant in overlapping zone of Boranada industrial area was due to both Mandore and Basni Industrial Area. Maximum concentration of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ was 7.58μg/m^3, 26.35μg/m^3, 126.59μg/m^3, 40.81μg/m^3 respectively and CO concentration was 0.814mg/m^3 near the boundary of Boranada industrial area after overlapping due to three industrial area and combined concentration further decrease with increase of distances from area sources.

(c) Maximum. AQI of industrial area before and after overlapping:

Table 2 to Table 5 indicate Air Quality Index before and after overlapping of pollutants and critical distance from starting of industrial area.

Table 2. Modelled AQI before and after overlapping in Basni Industrial Area due to Mandore Industrial Area

Pollutant	Sub-Index		Maximum value of Air Quality Index		Critical Overlapping Distance (metre)
	Before Overlapping	After Overlapping	Before Overlapping	After Overlapping	
SO_2	5.21	6.66	102.8	119.35	12148
NO_2	20.84	24.38			
PM_{10}	102.8	119.35			
$PM_{2.5}$	52.10	72.80			
CO	26.05	31.85			

Table 3. Modelled AQI before and after overlapping in Boranada Industrial Area due to Mandore Industrial Area

Pollutant	Sub-Index		Air Quality Index		Critical Overlapping Distance (metre)
	Before Overlapping	After Overlapping	Before Overlapping	After Overlapping	
SO_2	5.61	6.69	52.36	70.84	20500
NO_2	18.70	21.79			
PM_{10}	52.36	70.84			
$PM_{2.5}$	24.93	40.15			
CO	22.45	26.75			

Table 4. Modelled AQI before and after overlapping in Boranada Industrial Area due to Basni Industrial Area

Pollutant	Sub-Index		Air Quality Index		Critical Overlapping Distance (metre)
	Before Overlapping	After Overlapping	Before Overlapping	After Overlapping	
SO_2	5.61	8.40	52.36	105.40	7500
NO_2	18.70	29.85			
PM_{10}	52.36	105.40			
$PM_{2.5}$	24.93	52.80			
CO	22.45	36.4			

Table 5. Modelled AQI before and after overlapping in Boranada Industrial Area due to Mandore Industrial Area and due to Basni Industrial Area

Pollutant	Sub-Index		Air Quality Index		Critical Overlapping Distance (metre)
	Before Overlapping	After Overlapping	Before Overlapping	After Overlapping	
SO_2	5.61	9.48	52.36	117.73	1500 metre from Boranada Industrial Area
NO_2	18.70	32.94			
PM_{10}	52.36	117.73			
$PM_{2.5}$	24.93	68.02			
CO	22.45	40.70			

By the modelling analysis, was observed that SO_2, NO_2 and CO sub index come under good AQI category before and after overlapping in all the overlapping zones of industrial areas. These three pollutants do not cross standard limit in all industrial area. PM_{10} sub index come under moderate category whether overlapping occur or not near Basni industrial area. $PM_{2.5}$ sub index come under satisfactory category before and after overlapping in Basni industrial area because of Mandore industrial area.

The overlapping zones in Boranada Industrial Area occur due to Mandore industrial area, Basni industrial area and due to both Basni and Mandore industrial area. PM_{10} sub index come under satisfactory category before overlapping in all the three cases. PM_{10} sub index come under satisfactory category after overlapping near Boranada industrial area due to Mandore industrial area. PM_{10} sub index come under moderate category after overlapping near Boranada industrial area because of less distance between Basni and Boranada industrial area due to Basni industrial area and also due to combined overlapping of both areas. $PM_{2.5}$ sub index come under good category before and after overlapping due to Mandore industrial area. $PM_{2.5}$ sub index come under good category before overlapping and $PM_{2.5}$ sub index come under satisfactory category after overlapping in Boranada industrial area due to Basni industrial area and also due to combined overlapping of both areas.

The prediction from model indicates that pollution is increasing beyond the safe limit because of overlapping of pollution from various industrial areas. The maximum AQI because of overlapping and critical distance are tabulated in the Table 6.

Table 6. Maximum AQI without and with overlapping and critical distance

Effect of Industrial Area	Effect on Industrial Area	Maximum Air Quality Index		Critical Distance (metre)
		Without overlapping	With overlapping	
Mandore	Basni	102.8	119.35	12148
Mandore	Boranada	52.36	70.84	20500
Basni	Boranada	52.36	105.40	7500
Mandore and Basni	Boranada	52.36	117.73	1500

It was observed that Basni and Mandore Industrial Area were most polluted area because of higher industrial units, higher production and vast vehicular pollution. Pollutant concentration also increases due to effect of wind direction. The concentration of various pollutants overlaps on that areas and increase the pollutants concentration and increase the AQI. Hence now any new industrial area should be established opposite the wind direction. If industrial area will be established in wind direction then there should be a large distance between two industrial areas to avoid overlapping.

3. Conclusion

The overall AQI can give clear view about ambient air and the critical pollutant mainly responsible for the quality of air which can be easier for a common man to understand. An effort has been made to find out the pollution level by finding Air Quality It was concluded that two industrial areas should be far away from each other to avoid overlapping and to reduce the pollutant concentrations. New Industrial area should be developed in the opposite direction of wind. Development of green belt around the town and in between the industrial areas will act as pollution control measures by increasing the aesthetic value and filtering of ambient air. The prediction from model indicates that pollutant concentration is increasing beyond the safe limits because of overlapping of pollution from various industrial areas. There is no effect on Kankani Industrial area due to large distance from other industrial areas and because of its location being opposite to wind direction. Hence, now the time has come to recommend that in future, new industrial areas be established by considering the overlapping pollution level and safe distance between two industrial areas .

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