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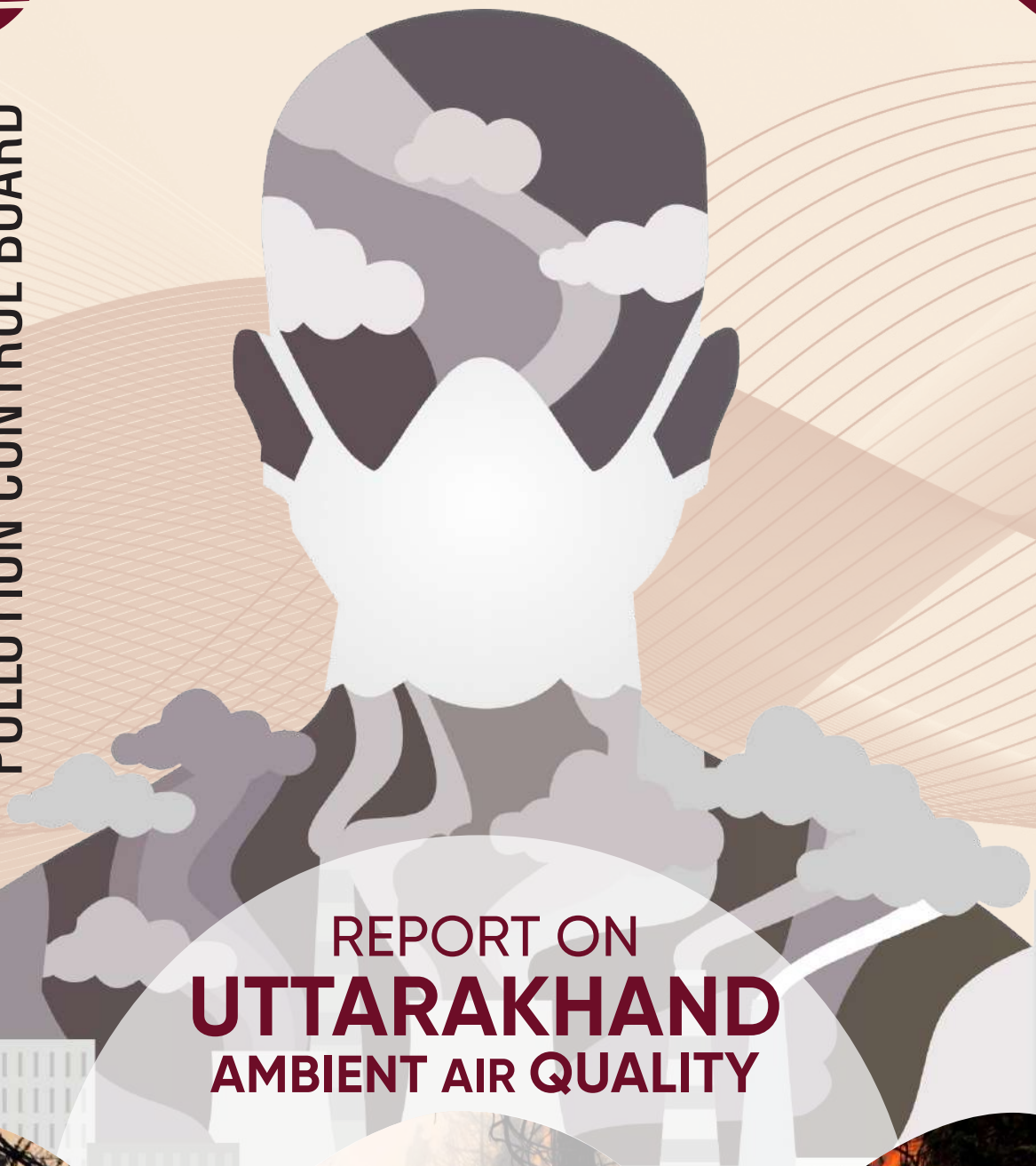
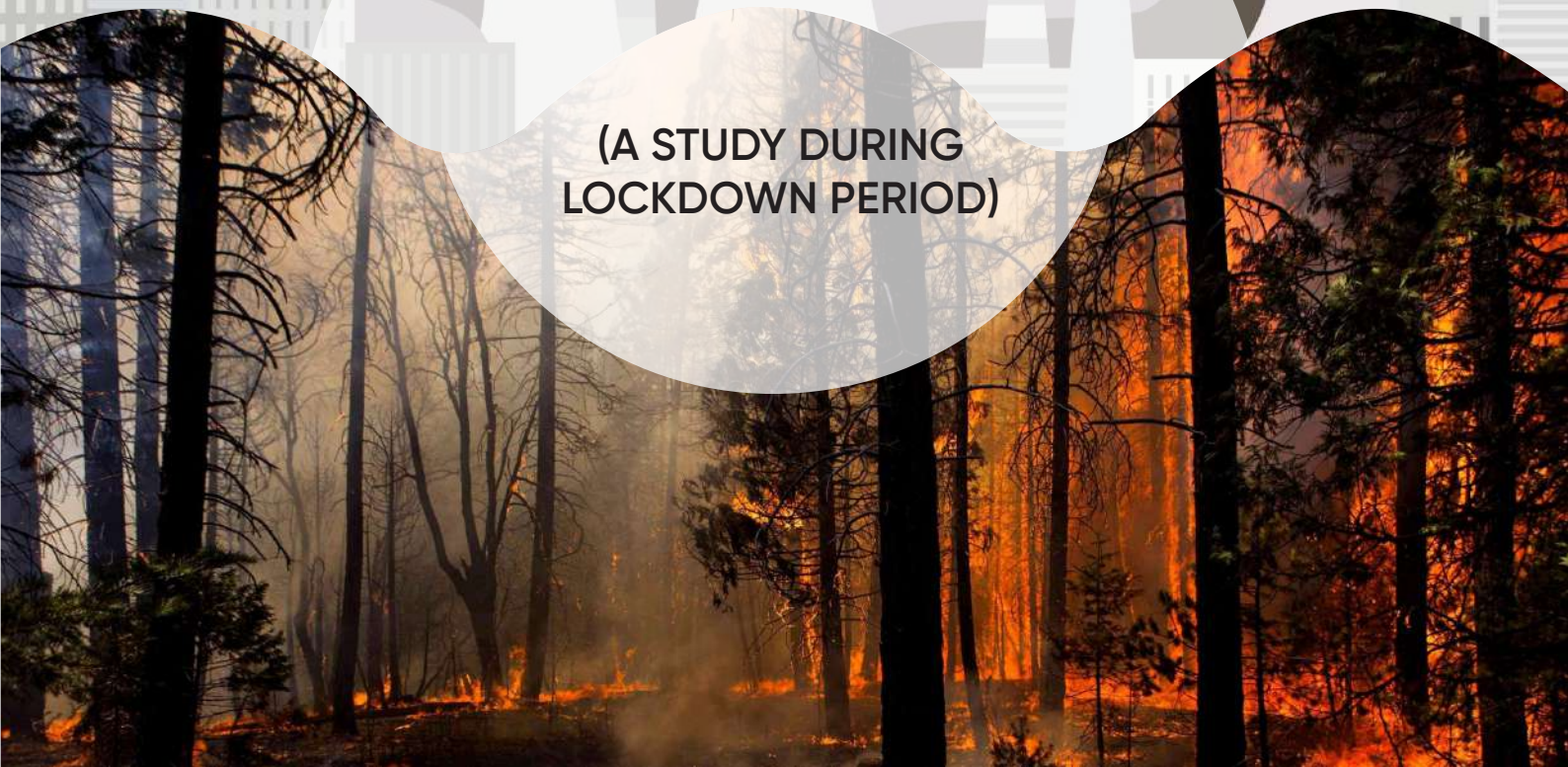


REPORT ON
UTTARAKHAND
AMBIENT AIR QUALITY

(A STUDY DURING
LOCKDOWN PERIOD)



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1. INTRODUCTION

We can survive without water for a few days. But we cannot live without breathing air even for a few moments. The air that we breathe directly gets into our bloodstream. Hence, it is necessary for us to ensure that the air quality is not polluted beyond the threshold limits. Air pollutants whether man made or natural are to be monitored to ascertain their concentration in the ambient air. Monitoring helps us to take necessary preventive and control measures. With this in view, the State Pollution Control Boards along with Central Pollution Control Board have set up a network of air quality monitoring stations (Total numbers 08), given in **Fig. 1**.

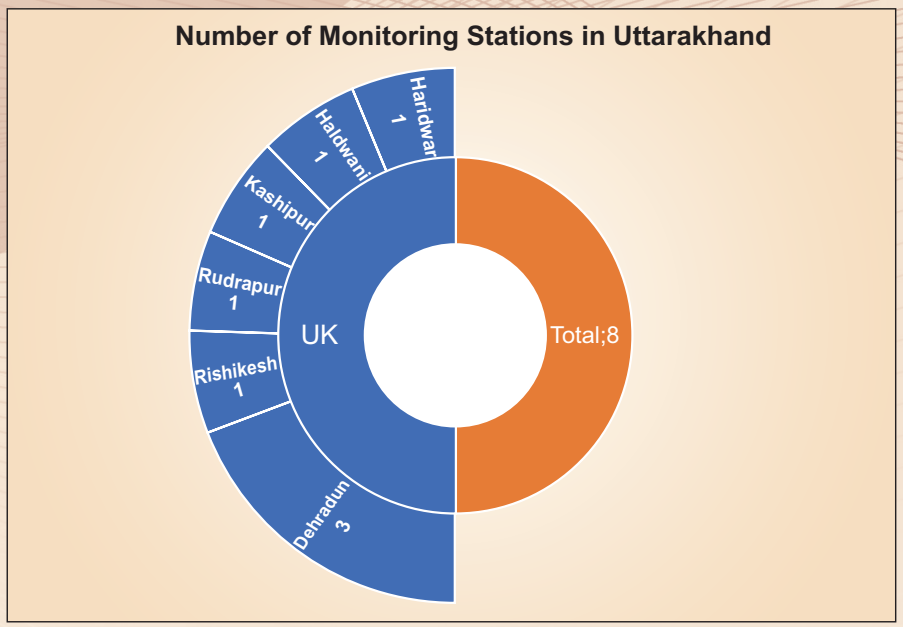

Fig. 1. Status of Ambient Air Quality Monitoring Station under NAMP in Uttarakhand.

The human activities whether for cooking, space heating, transportation or for industrial production use fuels of various kinds. Burning of fuels leads to emission of combustion products, which contribute towards air pollution. Besides man made pollutants, air pollution such as in arid and semi-arid areas which are having high levels of suspended particulate matter (SPM) can also be caused by natural conditions.

A city-level and national level lockdown offers us an opportunity to examine how different pollutants may respond to human mobility restrictions, which provides a reference for policymakers and planners in considering milder forms of restrictions on human activities to improve air quality. Therefore, this report examines the impacts of the city wise and nation wise lockdown on air quality across 06 districts of Uttarakhand. The report makes an attempt to provide information regarding improvement of air quality during lockdown period in 2020 and 2021. The results initiatives taken for tightening of emission norms for vehicles and emissions from industrial sources are being felt through findings of air quality monitoring.

2. METHODOLOGY

The present study evaluated the changes in ambient air quality across Uttarakhand state due to statewide and nationwide lockdown amid the COVID-19 breakout. The criteria air pollutants are being monitored by the Uttarakhand pollution control board (UKPCB) over 8 monitoring stations in 6 cities where regular monitoring carried out twice a week. Under NAMP three main pollutants viz. Particulate Matter (PM_{10}), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) were monitored regularly at all locations. Out of other notified parameter like Particulate Matter ($PM_{2.5}$) are being measured at selected stations. The hourly concentrations of $PM_{2.5}$, PM_{10}, SO_2 and NO_2 over 6 cities, one station in each city, were considered for analysis and implementation. Three-time periods viz. 01 March 2019 – 30 May 2019 (No Lockdown period), 01 March 2020 – 30 May 2020 (Complete Lockdown period), 01 March 2021 – 30 May 2021 (Partial Lockdown period) were chosen to check the variation of air pollutant concentration. Available parameter datasets are subjected to statistical analysis and a monthly mean is obtained to understand the monthly and year-to-year variations in pollutant concentrations in 06 Uttarakhand cities as discussed in the sections. Government of India has notified Ambient Air Quality Standards which are given under the table: -

NATIONAL AMBIENT AIR QUALITY STANDARDS

S. No.	Pollutant	Time Weighted average	Concentration in Ambient Air		Methods of Measurement
			Industrial, Residential, Rural and Other Area	Ecologically sensitive area (notified by Central Govt.)	
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO_2), µg/m^3	Annual*	50	20	· Improved West and Geake · Ultraviolet fluorescence
		24 hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m^3	Annual*	40	30	· Modified Jacob & Hochheiser (Na-Arsenite) · Chemiluminescence
		24 hours**	80	80	
3	Particulate Matter (size less than 10 µm) or PM_{10}, µg/m^3	Annual*	60	60	· Gravimetric · TOEM · Beta attenuation
		24 hours**	100	100	
4	Particulate Matter (size less than 2.5 microns) or $PM_{2.5}$ µg/m^3	Annual*	40	40	· Gravimetric · TOEM · Beta attenuation
		24 hours**	60	60	

* Annual Arithmetic Mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

3. RESULTS AND DISCUSSION

Data Analysis

Ambient air quality trends have been analyzed for different stations in Uttarakhand for three datasets – a) March – May (2019), b) March – May (2020) and c) March – May (2021) to assess the state of air quality. The data was plotted for monthly average concentrations for each category of pollutant for different stations and was compared monthly and yearly.

3.1. Comparative AQI Analysis of Uttarakhand state

Table-01. Air Quality Index (AQI) across Uttarakhand state

Cities	Air Quality Index (AQI)								
	2019 (No Lockdown)			2020 (Complete Lockdown)			2021 (Partial Lockdown)		
	March	April	May	March	April (Include Lockdown 1 & 2)	May (Include Lockdown 3)	March	April	May (Include Partial Lockdown)
Dehradun	167	202	237	171	76	108	237	225	127
Rishikesh	121	133	144	109	59	92	212	194	89
Haridwar	123	121	123	116	46	49	120	195	101
Kashipur	116	111	116	120	76	103	114	111	116
Rudrapur	117	118	121	118	75	69	119	115	119
Haldwani	105	105	105	106	69	92	111	108	79

Good (0-50)	Minimal Impact
Satisfactory (51-100)	Minor breathing discomfort to sensitive people
Moderate (101-200)	Breathing discomfort to the people with lungs, asthma and heart diseases
Poor (201-300)	Breathing discomfort to most people on prolonged exposure
Very Poor (301-400)	Respiratory illness on prolonged exposure
Severe (>401)	Affects healthy people and seriously impacts those with existing diseases

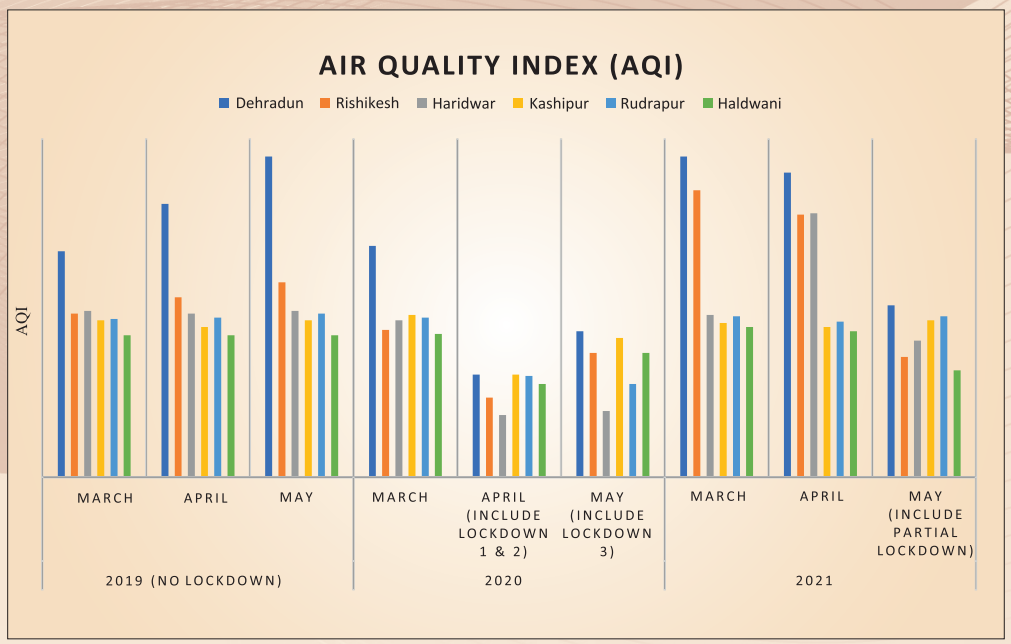

Fig. 2. Monthly Average Air Quality Index in Uttarakhand cities

The nationwide and state-wide lockdown implemented in India since 25 March 2020 has significantly improved the air quality in Uttarakhand. Fig. 2 represent the variation in AQI from 2019 to 2021. Mostly in all cities, a significant reduction in AQI values can be observed during lockdown phase in 2020.

The restrictions placed on transport sector, industrial and commercial activities have significantly reduced the key air pollutants (PM_{10}, $PM_{2.5}$ and NO_2) during lockdown phase. Overall, PM_{10} and $PM_{2.5}$ levels were reduced by 50%, during the lockdown period as compared to pre-lockdown period.

The impact of lockdown is clearly visible in Dehradun city. All key air pollutant has shown a decline in trends during lockdown phase in 2020 than in previous year 2019 **(Fig. 4 – Fig. 7).**

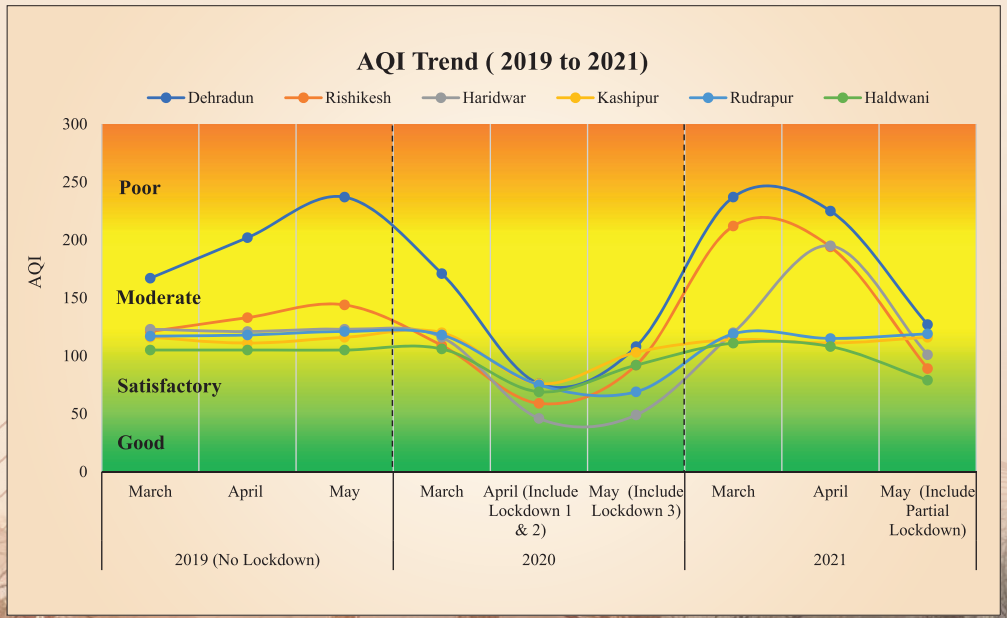

Fig. 3. Air Quality Index Trend in Mar to May month from 2019 to 2021

3.2. Month wise Data Analysis (March – May)

3.2.1. Year 2019

Table-02. Air Quality Parameter Concentration in 2019

Ambient Air Quality Characteristics (March 2019)					
Name of City	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**NO_2**	**AQI**
Dehradun	164.61	79.98	25.59	29.41	167.00
Rishikesh	131.66	NA	22.49	27.52	121.00
Haridwar	134.26	NA	22.27	26.69	123.00
Kashipur	124.48	NA	13.27	22.52	116.00
Rudrapur	125.50	NA	13.43	22.86	117.00
Haldwani	107.43	NA	6.94	26.43	105.00
Ambient Air Quality Characteristics (April 2019)					
Name of City	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**NO_2**	**AQI**
Dehradun	167.16	90.62	26.03	30.34	202.00
Rishikesh	150.20	NA	23.73	28.37	133.00
Haridwar	131.88	NA	22.40	26.54	121.00
Kashipur	115.78	NA	13.45	22.35	111.00
Rudrapur	126.69	NA	13.44	22.35	118.00
Haldwani	107.43	NA	6.45	29.44	105.00
Ambient Air Quality Characteristics (May 2019)					
Name of City	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**NO_2**	**AQI**
Dehradun	177.78	101.02	25.10	29.43	237.00
Rishikesh	166.21	NA	23.95	28.46	144.00
Haridwar	134.16	NA	22.05	26.30	123.00
Kashipur	124.58	NA	13.72	22.72	116.00
Rudrapur	131.10	NA	13.62	22.73	121.00
Haldwani	107.94	NA	6.55	29.83	105.00

3.2.2. Year 2020

Table-03. Air Quality Parameter Concentration in 2020

Ambient Air Quality Characteristics (March 2020)					
Name of City	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**NO_2**	**AQI**
Dehradun	164.99	81.29	24.99	28.17	171
Rishikesh	113.96	NA	23.53	27.18	109
Haridwar	123.32	NA	16.04	20.40	116
Kashipur	129.32	NA	13.34	22.52	120
Rudrapur	127.08	NA	13.13	22.05	118
Haldwani	109.01	NA	7.23	27.46	106

Ambient Air Quality Characteristics (April 2020)					
Name of City	PM_{10}	$PM_{2.5}$	SO_2	NO_2	AQI
Dehradun	76.48	42.07	7.77	9.48	76
Rishikesh	58.55	NA	5.98	7.62	59
Haridwar	46.08	NA	3.03	8.79	46
Kashipur	76.30	NA	8.70	13.15	76
Rudrapur	75.30	NA	8.64	13.44	75
Haldwani	68.66	NA	5.06	16.61	69
Ambient Air Quality Characteristics (May 2020)					
Name of City	PM_{10}	$PM_{2.5}$	SO_2	NO_2	AQI
Dehradun	111.71	60.99	15.70	19.99	108
Rishikesh	91.52	NA	11.43	14.55	92
Haridwar	49.43	NA	3.54	8.68	49
Kashipur	103.95	NA	10.32	14.63	103
Rudrapur	68.66	NA	5.06	16.61	69
Haldwani	92.01	NA	5.93	23.71	92

3.2.3. Year 2021

Table-04. Air Quality Parameter Concentration in 2020

Ambient Air Quality Characteristics (March 2021)					
Name of City	PM_{10}	$PM_{2.5}$	SO_2	NO_2	AQI
Dehradun	190.49	101.08	23.03	27.55	237
Rishikesh	176.37	93.73	21.28	26.50	212
Haridwar	130.65	NA	11.87	20.66	120
Kashipur	121.37	NA	19.09	22.83	114
Rudrapur	127.89	NA	19.15	23.31	119
Haldwani	116.26	NA	8.25	27.84	111
Ambient Air Quality Characteristics (April 2021)					
Name of City	PM_{10}	$PM_{2.5}$	SO_2	NO_2	AQI
Dehradun	190.79	97.38	22.01	27.32	225
Rishikesh	172.28	88.22	18.41	25.10	194
Haridwar	118.73	88.60	11.05	17.75	195
Kashipur	116.37	NA	18.84	21.76	111
Rudrapur	122.33	NA	19.20	23.09	115
Haldwani	112.52	NA	8.07	27.22	108
Ambient Air Quality Characteristics (May 2021)					
Name of City	PM_{10}	$PM_{2.5}$	SO_2	NO_2	AQI
Dehradun	117.26	67.97	16.76	22.67	127
Rishikesh	79.18	53.11	17.12	21.72	89
Haridwar	102.13	61.43	9.07	13.71	101
Kashipur	123.83	NA	19.62	24.59	116
Rudrapur	128.67	NA	21.52	26.05	119
Haldwani	78.97	NA	5.12	20.81	79

NA – Not Avalaible

3.3. Monthly graphical representation of PM_{10}, $PM_{2.5}$, SO_2 and NO_2

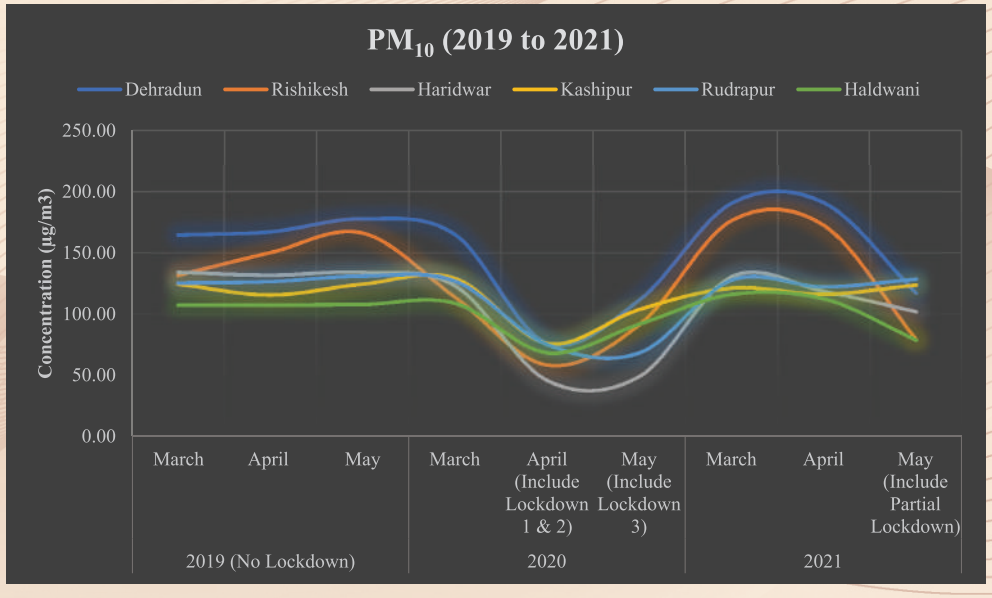

Fig. 4. Monthly Average Particulate matter (PM_{10}) concentration in Uttarakhand cities

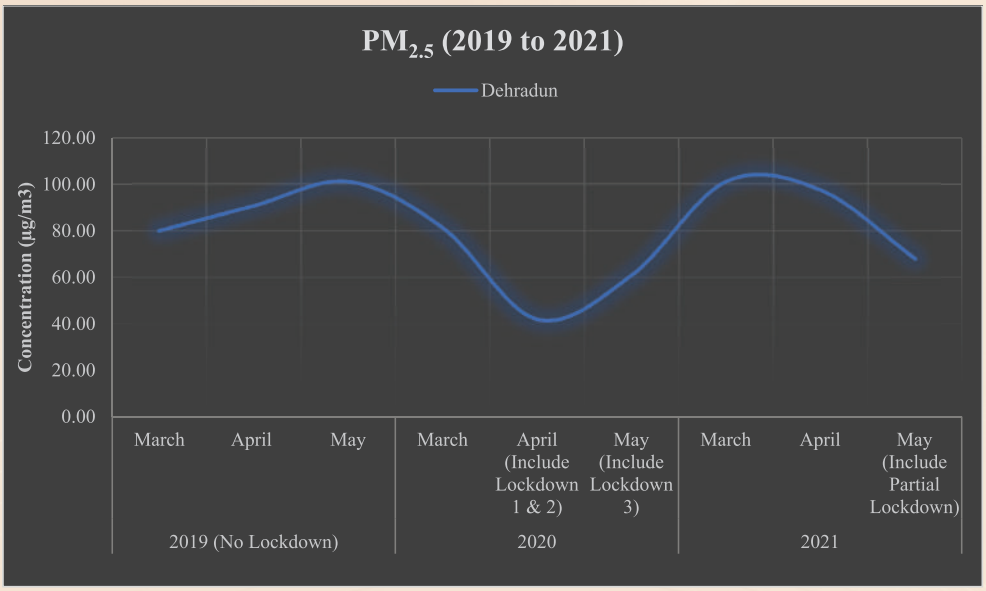

Fig. 5. Monthly Average Particulate matter ($PM_{2.5}$) concentration in Uttarakhand cities

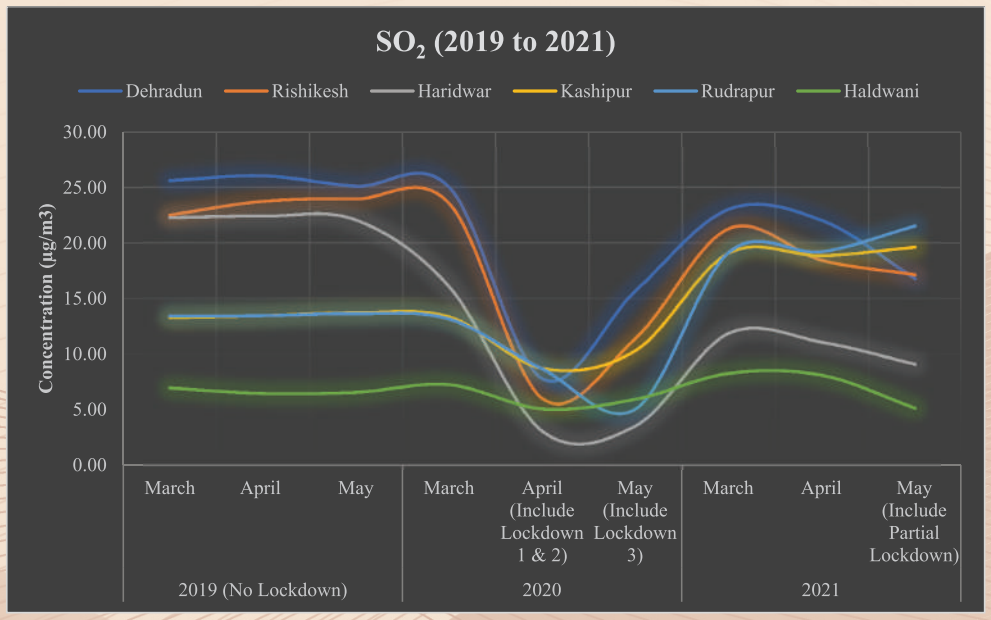

Fig. 6. Monthly Average Sulphur dioxide (SO_2) concentration in Uttarakhand cities.

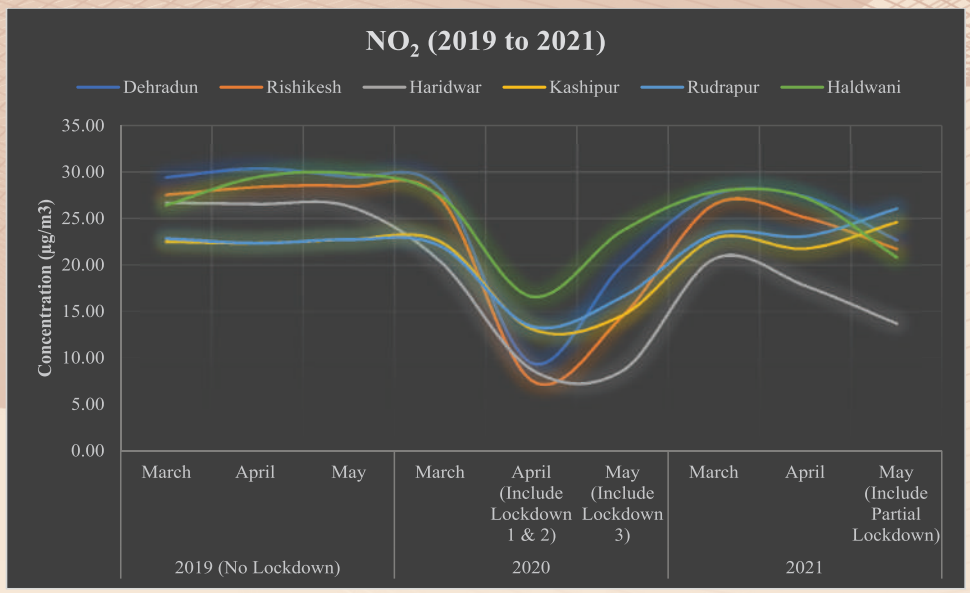

Fig. 7. Monthly Average Nitrogen dioxide (NO_2) concentration in Uttarakhand cities.

3.4. Yearly Variation of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 in Dehradun city

3.5. Yearly percentage change in AQI

Table-05. Yearly percentage change across Uttarakhand state

			AQI (Mar - May)		
			2019	2020	2021
Uttarakhand	AQI (Mar - May)	2019	-	31%↓	3%↑
		2020	31%↓	-	48%↑
		2021	3%↑	48%↑	-
Dehradun	AQI (Mar - May)	2019	-	41%↓	3%↓
		2020	41%↓	-	66%↑
		2021	3%↓	66%↑	-
Rishikesh	AQI (Mar - May)	2019	-	35%↓	24%↑
		2020	35%↓	-	90%↑
		2021	24%↑	90%↑	-
Haridwar	AQI (Mar - May)	2019	-	43%↓	13%↑
		2020	43%↓	-	97%↑
		2021	13%↑	97%↑	-
Kashipur	AQI (Mar - May)	2019	-	13%↓	1%↓
		2020	13%↓	-	14%↑
		2021	1%↓	14%↑	-
Rudrapur	AQI (Mar - May)	2019	-	26%↓	1%↓
		2020	26%↓	-	35%↑
		2021	1%↓	35%↑	-
Haldwani	AQI (Mar - May)	2019	-	15%↓	5%↓
		2020	15%↓	-	12%↑
		2021	5%↓	12%↑	-

WRPLOT based wind rose diagram has been plotted for Dehradun, Haldwani, Haridwar, Kashipur and Rudrapur stations throughout the lockdown period **(Fig. 8).** Wind speed and wind direction play a crucial role in the transport as well as the magnitude of the concentration of ambient air pollutants around monitoring stations.

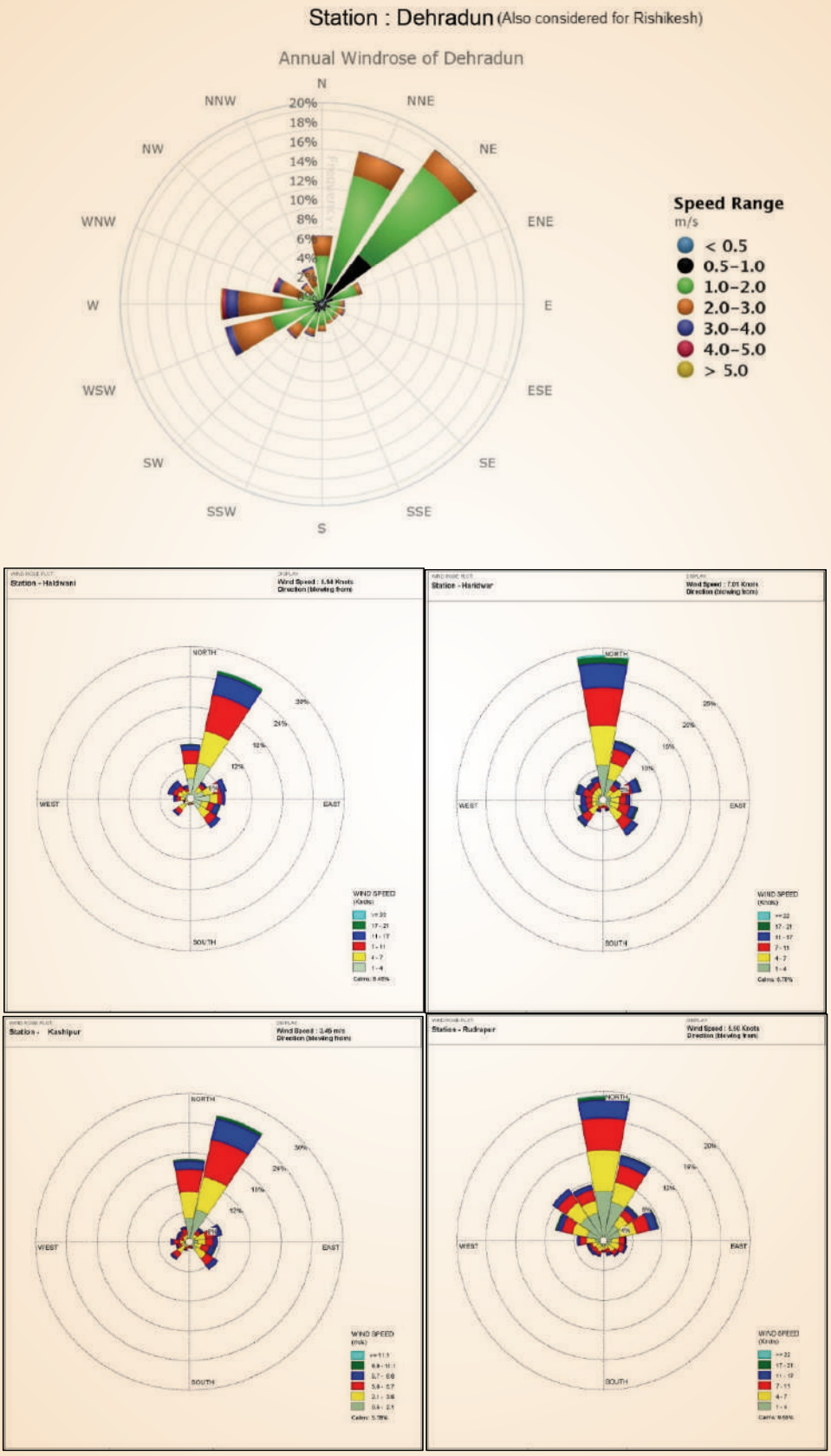

Fig. 8. WRPLOT based wind rose diagram of (a) Dehradun, (b) Haldwani, (c) Haridwar, (d) Kashipur and (e) Rudrapur showing wind direction and wind speed.

4. CONCLUSION

In the present study, comprehensively, effect of No Lockdown in 2019, Complete Nationwide Lockdown in 2020 and Partial Lockdown in 2021 on air quality of six major Uttarakhand cities (Dehradun, Rishikesh, Haridwar, Kashipur, Rudrapur and Haldwani) is analysed.

In 2020 Nationwide lockdown: - A significant reduction in concentration of PM_{10}, $PM_{2.5}$ and NO_2 was observed for Dehradun, Rishikesh and Haridwar during lockdown period. However, Kashipur, Rudrapur and Haldwani has not shown much reduction in air pollution due to the operational of some industries. Specifically, the results showed that the air quality index experiences a 31% larger reduction in the cities with lockdown. This significant decreases in 2020 were directly due to the reduction of emissions caused by lockdown, as citizen mobility was restricted, close down of industries and lack of influx of tourists.

On contrary, all of this pollutant concentration was found increased during partial lockdown 2021, which could be due to less restricted activities. The different lockdown phases across the State were differentiated based on subsequent relaxation to restart economic activities. These lockdown event has provided an actual example to determine how the pollutants can fluctuate due to different economic restrictions. Due to fear of infection, individuals supported the restrictions imposed by the lockdown.

5. ACKNOWLEDGEMENT

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