



Investigating the Impression of National Clean Air Programme in Enhancement of Air Quality Characteristics for Non-attainment Cities of Uttarakhand

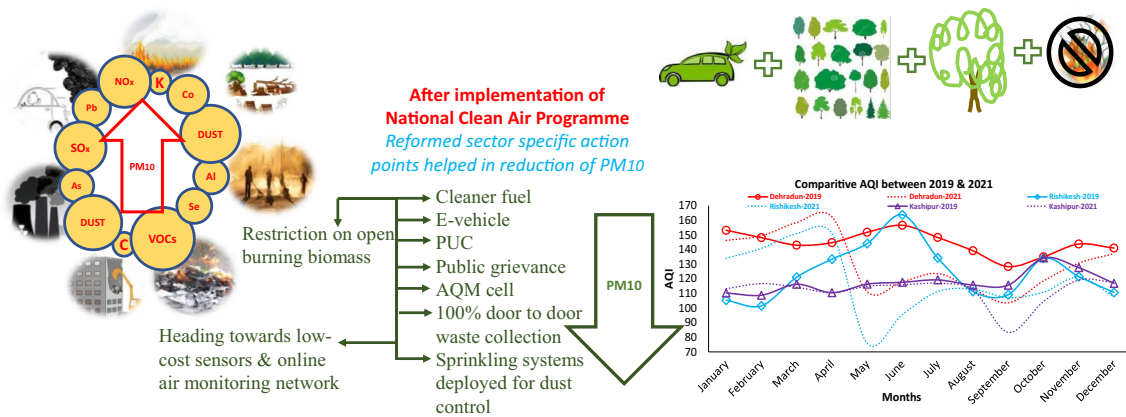
Ankur Kansal¹ · Sarada Prasanna Subudhi¹ · Prashant Pandey¹ · Deepak Gupta¹ · Tarangini Rawat¹ · Alok Sagar Gautam² · Sneha Gautam^{3,4}

Received: 7 January 2023 / Revised: 28 March 2023 / Accepted: 29 March 2023 / Published online: 6 April 2023
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Abstract

Developmental activities have become sweet poison nowadays. Such activities degrade local air quality status, which can severely impact human health and their surrounding environment. The present study examines Uttarakhand's air quality characteristics in non-attainment cities (Dehradun, Rishikesh, and Kashipur) to understand its cleansing processes. Under National Air Quality Monitoring Programme (NAMP), concentration of air pollutants (such as PM, SO_x and NO_x) was regularly monitored between 2015 and 2019 to evaluate the air quality status in the state. The NAMP highlights the higher concentration of PM₁₀ in Dehradun, Rishikesh, and Kashipur, and hence it is imperative to reduce the concentration of PM₁₀ under the permissible limit. State has 30.2% urbanisation rate, and annual urban growth rate of 4.0% much higher than the rural growth rate (1.2%) of the state, which results in 3 times higher amount of PM₁₀ to the permissible limit. Moreover, 1.5–2-time higher amount of PM₁₀ were recorded in Rishikesh, and Kashipur. In making sustainable future, various sector-specific strategies and sustainable approaches under National Clean Air Programme (NCAP) were launched to combat this critical situation. While comparing with the present air quality status, Dehradun experienced 12% reduction in PM₁₀; whereas for Rishikesh and Kashipur, only 4.1% and 0.866% reduction were observed. The effective implementation of sector-specific action points will be the key factor in improvement of air quality of the Uttarakhand state.

Graphical Abstract



Keywords Air quality · Non-attainment city · National Clean Air Programme · PM₁₀

1 Introduction

Uttarakhand state is considered the youngest mountainous region of Garhwal and Kumaon, comprising 13 ecologically fragile districts susceptible to earthquakes and landslides (O'Donnell 2018). The state is blessed with dense forest, ample of water sources in form of glaciers, river and covered with snow-clad mountain peaks. Immense potential of the resources, the state government has declared Uttarakhand as a herbal state.

Within a very short span of its existence, Uttarakhand state has become as a significant destination for investments in many industries like: manufacturing, tourism and infrastructure. Natural activities such as: forest fire and anthropogenic activities such as urbanisation, and industrialisation are the major source for the emission of particulate matter (PM), SO_x, NO_x, carbon dioxide (CO₂) and other greenhouse gases (Chauhan and Pawar 2010; Joshi and Mahadev 2011). The most pronounced impacts of the emitted smoke after forest fires are PM_{2.5} and PM₁₀ and such conditions have created immense pressure on nature and consequently, the state's air quality has been steadily deteriorating.

Since the last decade, the state has promoted industries such as sugar milling, wood and paper products, woollen garments, and leather goods. Such notable sectors continuously contributing dust, smoke, fumes and other toxic gases to the atmosphere which leads to variation in temperatures, precipitation, vegetation, and moisture at regional level and hence to global climate change. Such development activities cause irreparable damage to the ecology and environment and often breaching the environment's carrying capacity (Guo and Kota et al. 2019). These sectors are major contributors to dust, smoke, fumes and other toxic gases that lead to variation in temperatures, precipitation, vegetation, and moisture at regional level, and hence to global climate change. Major sources of air pollutants include vehicles, industries, rampant constructions, biomass burning, diesel gensets, commercial and domestic use of fuel, which are responsible for its worsening air quality (Chauhan and Pawar 2010). Additionally, geographical and meteorological conditions in the state do not allow for easy pollution dispersal. Therefore, regular monitoring of air quality status in India was promoted and the Government of India has enacted the Air (Prevention and Control of Pollution) Act in 1981 and the Environment (Protection) Act in 1986. Subsequently in 1986, the Central Pollution Control Board (CPCB) under the Air (Prevention and Control of Pollution) Act-1981 established a national ambient air quality monitoring system with the purpose to collect the air pollution data with a wide network of monitoring stations throughout the country. As a result, various programmes and approaches were promoted to control the air pollution.

The main thrust of the present paper is to investigate and assess the impression of the National Clean Air Programme (NCAP) in Uttarakhand state launched in January 2019. Under NCAP, sector-specific action points are to be implemented in the targeted non-attainment cities to reduce 20–30% of PM₁₀ by 2024–25. The paper also highlights up to what extent the NCAP has succeeded in reducing the PM₁₀ concentration in the last two years.

2 Methodology

2.1 Study Sites: Non-attainment Cities in Uttarakhand

Central Pollution Control Board (CPCB) has defined non-attainment city as one, the air quality of which falls short and did not meet the national ambient air quality standards. In the condition, CPCB has listed 132 cities that are violating National Ambient air quality standards (NAAQS) consecutively for five years on the basis of the ambient air quality data obtained under National Air Quality Monitoring Programme (NAMP). The concentration of PM₁₀ and PM_{2.5} was recorded to prepare a database which reflects the monitoring efforts undertaken. In case of Uttarakhand state, data received from various air monitoring stations imitate the capital city of the state (Dehradun) as well as Rishikesh and Kashipur have higher concentration of PM₁₀. Consequences of experiencing higher concentration than the permissible limit for five consecutive years marked these cities as non-attainment city.

Three cities recognised as non-attainment cities in Uttarakhand are: Dehradun, Rishikesh and Kashipur. In these cities, different sites were identified for the data collection which are detailed below in Table 1.

Table 1 Details of the established monitoring stations in identified non-attainment cities are specified here

City	Identified hotspot	Latitude	Longitude
Dehradun	Clock tower	30.3243°N	78.0418°E
	Inter-State Bus Terminal (ISBT)	30.2879°N	77.9984°E
	Raipur Chowk, Raipur	30.3098°N	78.0937°E
Rishikesh	SPS hospital	30.1087°N	78.2958°E
	Rishikesh Nagar Nigam	30.1036°N	78.2949°E
	Kailash gate, Rishikesh	30.1078°N	78.2925°E
Kashipur	Railway Crossing, Ram Nagar Road	29.2047°N	78.9610°E
	Maharana Pratap Chowk	29.2031°N	78.9658°E
	Narayan Nagar, Bajpur Road	29.1121°N	79.0009°E
	Railway station, Kashipur	29.2048°N	78.9609°E

2.1.1 Dehradun

Clock tower (CT), Raipur Road (RR), and Inter-State Bus Terminal (ISBT).

Dehradun is situated at an altitude of 2200 feet above sea level. Dehradun enjoys a salubrious climate due to its location in the hilly part of the state. During the summer months, the temperature ranges between 36 and 16.7 °C. The winter months are colder with the maximum and minimum temperatures touching 23.4 °C and 5.2 °C, respectively. Dehradun experiences heavy to moderate showers during late June to mid-August. In the decade 1991–2001, Dehradun achieved decadal population growth rate of 39.73%, which was considerably higher than the national average of 21.53%.

2.1.2 Rishikesh

SPS Hospital, Rishikesh, Rishikesh Nagar Nigam, and Kailash Gate Rishikesh area has a population of 145,338 with a literacy rate of 76.4% and a sex ratio of 864 females per 1000 males. The decadal growth rate of Rishikesh tehsil was 38% which is higher than that of Uttarakhand (18.8%) and India (17.64%) indicating a high inflow of migrants (census 2011 vs 2001). Moreover, this is in line with the state decadal growth trends where urban areas have seen a growth of 40%, whereas rural areas are growing at around 11%.

2.1.3 Kashipur

Railway Crossing-Ram Nagar Road, Maharana Pratap Chowk, Narayan Nagar-Bajpur Road, and Railway station Kashipur block is located in Udham Singh Nagar district of Uttarakhand. The total population of Kashipur block is 134,253 with male population of 70,730 and female population of 63,523. There are 25,828 households in Kashipur block, Udham Singh Nagar district. Kashipur Block has a total working population of 45,638 of which 36,126 are main workers and 9512 are marginal workers. 6773 people are engaged fulltime in farming or cultivation, while 6773 persons pursue farming for less than 6 months in a year.

2.1.4 Data Sources

The daily average concentration of air pollutants such as: PM (PM₁₀ and PM_{2.5}), SO_x, and NO_x was collected from January 2015 to December 2021. The data were obtained from identified monitoring stations established in Dehradun, Rishikesh, and Kashipur under the initiative of NAMP. Daily concentration data of PM₁₀, PM_{2.5}, SO_x, and NO_x were retrieved and downloaded from the official website of data centre, Uttarakhand Pollution Control Board (UKPCB), Dehradun, Uttarakhand, India (<https://ueppcb.uk.gov.in/>

[pages/display/95-air-quality-data](https://ueppcb.uk.gov.in/pages/display/95-air-quality-data)). Data collected from different monitoring stations are regularly uploaded to the data centre website of the UKPCB, Dehradun.

2.2 Study Period

In the present study, years 2019 and 2021 were considered for the evaluation and comparative assessment of air quality characteristic before and after the implementation of National Clean Air Programme (NCAP). NCAP is India's flagship programme, with the objective to reduce 20–30% PM₁₀ by 2024–25. Ministry of Environment, Forest and Climate Change (MoEF&CC) directed the Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) for the implementation of NCAP. In the context, year 2019 is considered as the base year; whereas, 2021 is defined as resultant year. Moreover, time period up to 31 December 2019 is marked as pre-NCAP period and time period since 01 January 2021 is marked as post-NCAP period (initiation of implementation of sector-specific action points).

2.3 Air Quality Index (AQI) Status

The variation in the Air Quality Index (AQI) is a useful indicator for an overall assessment of possible health effects, as compared to that deduced from the individual pollutants. AQI is computed with the help of Eq. 1 (Aggarwal et al. 2020):

$$I_p = \left(\frac{I_{Hi} - I_{Lo}}{BPHi - BPLo} \right) (C_p - BPLo) + I_{Lo}, \quad (1)$$

where I_p is index of pollutant p , C_p is truncated concentration of pollutant p , $BPHi$ is concentration breakpoint, i.e. greater than or equal to C_p , $BPLo$ is concentration breakpoint, i.e. less than or equal to C_p , I_{Hi} is AQI value corresponding to $BPHi$, I_{Lo} is AQI value corresponding to $BPLo$.

2.4 Statistical Analysis

In this study, paired T test is used to present the statistical evidence for the differences occurred in concentration of PM₁₀. In underlying, null and alternate hypotheses were derived and defined as:

Null hypothesis: $H_0: \mu_1 = \mu_2 = 0$ (the mean concentration of PM₁₀ in 2019, μ_1 , is equal to mean concentration of PM₁₀, μ_2 , in 2021).

Whereas, alternate hypothesis is $H_1: \mu_1 \neq \mu_2 \neq 0$ (the mean concentration of PM₁₀ in 2019, μ_1 , is not equal to mean concentration of PM₁₀, μ_2 , in 2021).

In the calculation of test statistic t , the following formula in Eq. 2 was used in excel to test the assumed hypothesis (Kumar et al. 2021):

$$t = ((X_{\text{diff}} / \left(\frac{S_{\text{diff}}}{\sqrt{n}} \right)), \quad (2)$$

where x_{diff} is sample mean of the differences, s is sample standard deviation of the differences, n is sample size (i.e. number).

3 Results and Discussion

In the present study, concentration of various air pollutants is presented for major cities in Uttarakhand, *i.e.* Dehradun, Rishikesh, Haridwar, Kashipur, Haldwani, and Rudrapur. Nonetheless, available data sets for non-attainment cities (Dehradun, Rishikesh, and Kashipur) are subjected for analysis and comparison. So far, only these cities are marked as non-attainment cities under NCAP and well-thought-out for implementing sector-specific action points.

3.1 Air Quality Status and Trends

Here, variation in annual average concentration of air pollutants like PM_{10} , $\text{PM}_{2.5}$, SO_2 , and NO_2 in major cities of Uttarakhand is presented in Fig. 1. The measurement of $\text{PM}_{2.5}$ in Uttarakhand was started in 2019 in Dehradun city followed by Rishikesh, Haridwar and Haldwani in 2021. The daily concentration of SO_2 , and NO_2 was regularly monitored at Dehradun, Rishikesh and Haridwar; whereas their data collections at Kashipur, Haldwani and Rudrapur station were started in 2018. Considering responsible sources and with the help of NAMP, recorded concentration was assessed with NAAQS, India to understand their deviation from permissible limit and threat to environment and human health (Purohit et al. 2019). Table 2 illustrates the recorded annual average concentrations of pollutants from years 2015 to 2021. Since 2015, concentration of PM_{10} is being increased from $184.21 \mu\text{g}/\text{m}^3$ to $200.69 \mu\text{g}/\text{m}^3$ up to 2018, whereas, in year 2019, lower concentration, *i.e.* $166.68 \mu\text{g}/\text{m}^3$ was experienced, comparatively to passed years. While, Rishikesh experienced deterioration in air quality with the passing years from 2015 ($117.54 \mu\text{g}/\text{m}^3$) to 2019 ($136.31 \mu\text{g}/\text{m}^3$). Moreover, in Kashipur, maximum concentration of PM_{10}

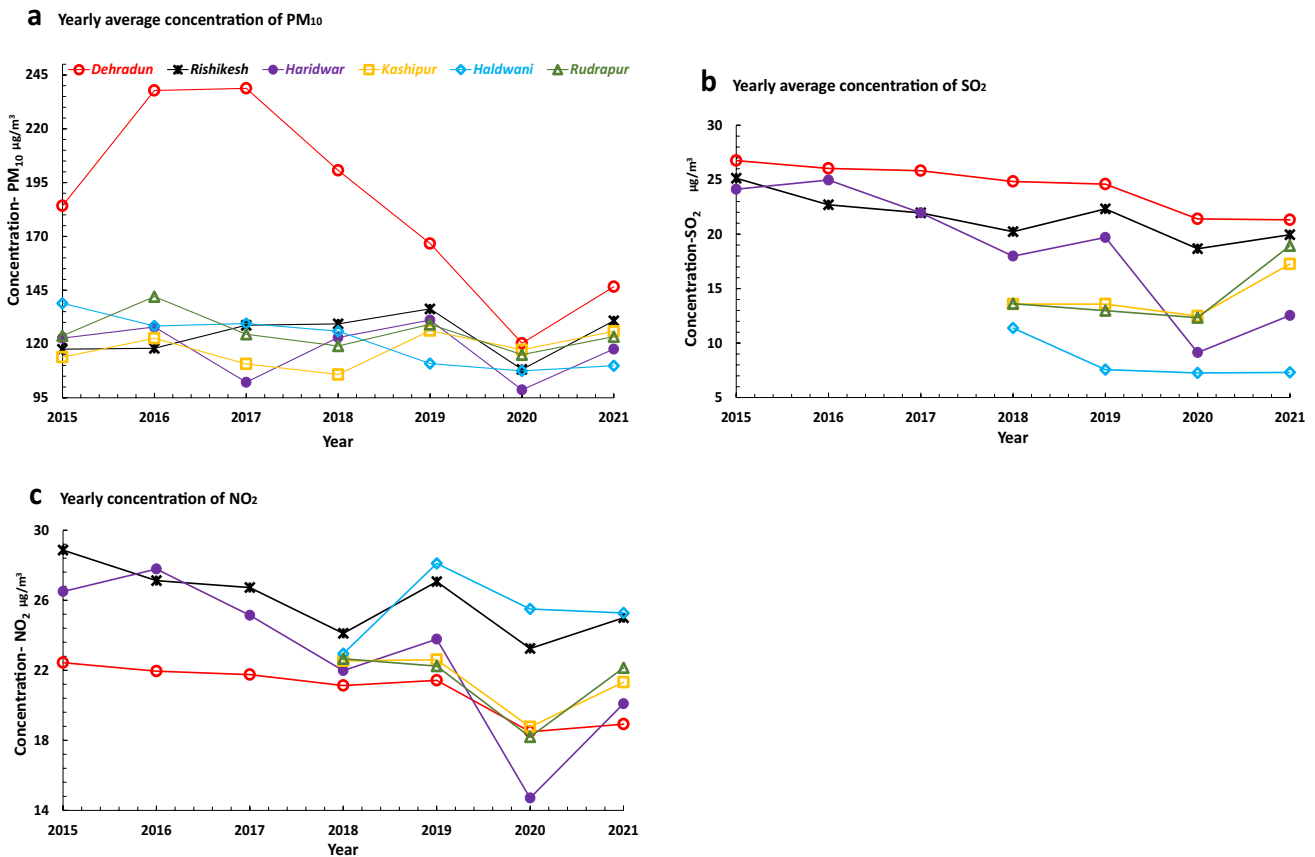


Fig. 1 Graphical representation trend of annual average concentration of $\text{PM}/\text{SO}_2/\text{NO}_2$ in major cities of Uttarakhand state

Table 2 Yearly concentration ($\mu\text{g}/\text{m}^3$) of various pollutants in Uttarakhand state is presented below for the last five years before the implementation of NCAP

Year	Dehradun	Rishikesh	Haridwar	Kashipur	Haldwani	Rudrapur
PM₁₀						
2015	184.21	117.54	122.68	113.89	138.89	123.80
2016	237.80	117.99	127.88	122.65	128.35	142.00
2017	238.81	128.70	102.26	110.71	129.48	124.52
2018	200.69	129.33	122.99	105.81	125.92	119.08
2019	166.68	136.31	131.15	126.19	110.90	129.12
SO₂						
2015	26.75	25.12	24.12	SO ₂ not monitored in this period		
2016	26.03	22.70	24.96			
2017	25.82	21.95	21.95			
2018	24.83	20.22	17.98	13.57	11.38	13.61
2019	24.59	22.31	19.69	13.58	07.57	12.98
NO₂						
2015	22.43	28.86	26.49	NO ₂ not monitored in this period		
2016	21.94	27.12	27.78			
2017	21.75	26.72	25.14			
2018	21.13	24.11	21.98	22.53	22.94	22.65
2019	21.42	27.05	23.77	22.60	28.10	22.23

was recorded as $126.19 \mu\text{g}/\text{m}^3$ in 2019; while, minimum was recorded as $105.81 \mu\text{g}/\text{m}^3$ in preceding year. The concentration of PM₁₀ is far greater than the prescribed permissible limit in NAAQS-India (annual average concentration of PM₁₀ is $60 \mu\text{g}/\text{m}^3$). The higher concentration reflects the increased number of state industries, explosive population growth, transportation, road construction, urban development, deforestation, and forest fire. Many published documents reveal that the state has around 30.2% urbanisation rate, and annual urban growth rate of 4.0% which is much higher than the rural growth rate (1.2%) of the state. While comparing among these cities, Dehradun had poor air quality status, even concentration of PM reached approximately twice in years 2016, 2017, and 2018 than Rishikesh and Kashipur, shown in Fig. 1a. It is noteworthy that capital of the state has experienced drastic enhancement in its urban population with an average annual growth rate of over 4% in the last decade, *i.e.* between the Census-2001 and Census-2011. Additionally, the state has experienced many natural and anthropogenic forest fire incidents that have had the most pronounced impact on higher concentrations of PM_{2.5} and PM₁₀ (Pawar et al. 2010 and Yarragunta et al. 2020).

In these cities, natural dust and particulate-laden smoke from diesel-fuelled vehicles (more than 126,452 vehicles), especially Vikram's, trucks, buses, three-wheelers and two-wheelers, are also the prominent sources of PM.

While, concentration of SO₂ in urban areas strongly depends on the emissions from metallurgical and coal-fired sources, NO₂ concentration is correlated with number of motor vehicles and fuel (petrol/diesel) used for transportation. In cities of Kashipur, Haldwani, and Rudrapur, SO₂

and NO₂ were measured in 2018. However, Table 2 portrays that the considered non-attainment cities do not have much variation with respect to concentration of SO₂ and NO₂. However, highest concentration of SO₂, *i.e.* $26.75 \mu\text{g}/\text{m}^3$ is recorded in Dehradun; whereas, highest concentration of NO₂, *i.e.* $28.86 \mu\text{g}/\text{m}^3$ is recorded in Rishikesh. Even, highest recorded concentration is under the permissible limit as per NAAQS (presented in Fig. 1a and c), and its annually average prescribed limits are 50 and $40 \mu\text{g}/\text{m}^3$ for SO₂ and NO₂, respectively. The yearly average concentration of SO₂ and NO₂ is summarised in Fig. 1b and c (Deep, Pandey et al. 2019).

3.2 Efforts to Reduce PM₁₀

3.2.1 NCAP Initiative (MoEF&CC)

Under NCAP, many sector-wise strategies were considered and supposed as number of required targets. City-wise action points were implemented to achieve the short- and long-term target of reducing PM by 20–30% concentration by 2024 as compared to 2017 (Ganguly et al. 2020, Roychowdhury et al. 2020). Here, some of the focused objectives and targeted aim under NCAP are (Bhole):

- Upsurge the CAAQMS stations
- Development of the monitoring network
- Heading towards low-cost sensors and establishing super monitoring network
- Managing household fuel combustion
- Establishing an air information centre.

Hence, Table 3 summarises the snap of many developed and implemented sector-specific action points in Uttarakhand's identified non-attainment cities. Many actions points are either to be initiated or in progress and some of them are completed which are detailed below:

3.2.2 Analysis of Air Quality Variability After Implementation of NCAP

Another worth noting condition of improvement in air quality can be observed while comparing the concentration of PM_{10} between 2019 and 2021 which is graphically highlighted in Fig. 2.

The concentration of PM_{10} and other pollutants in non-attainment cities and other major cities is presented below in Table 4. It is important to highlight that the significant reduction of 12% can be observed in Dehradun city; whereas 4.1% and 0.866% are achieved in Rishikesh and Kashipur, respectively. The reasons could be probably outdated vehicles, traffic congestion due to narrow inter-city road, dust, construction and demolition. Under NCAP, major key factors which show its hold in controlling air pollution are: cities heading towards e-vehicles, restriction on biomass burning, taking care of rules and regulation during building construction and demolition, covering of loaded vehicles during transportation, shifting industries towards cleaner fuel, promoting alternative fuel to petrol/diesel, phasing out 15-year-old diesel vehicles, restriction of D.G sets, daily water sprinkling on roads, regular waste collection, augmentation in green cover/belt area and awareness programmes on health impact of air pollution and role of individuals to combat air pollution. At this point, it could be concluded that many of sector-specific action points (mentioned in Table 3) have taken effect or in process and hence, the PM_{10} concentration is expected to decrease and achieve the reduction percentage prescribed by CPCB (Zhang and Geng 2019a, b, Anilkumar et al. 2021).

3.3 Air Quality Index (AQI) Status for the Non-attainment Cities on Monthly Basis Between 2019 and 2021

In the present study, AQI values are calculated on monthly and yearly basis for considered non-attainment cities which are presented in the Fig. 3. This index reflects the status of air quality in terms of their impact extent to human health. Many studies have been previously reported the higher AQI values in between 2010 and 2015. Average AQI in Dehradun was evaluated higher than 250, which is a serious threat to human health and can cause breathing discomfort on prolonged exposure (Deep et al. 2019). Although, lower AQI value has been observed for the years 2019, 2020, and 2021 which are 144.47, 120.06 and 131.06, respectively, as

presented in Fig. 3. These evaluated AQI values are then compared with the Indian AQI range and probable impacts, presented in Fig. 3, and it could be pretended that Dehradun is categorised under moderate status, *i.e.* 101–200 that may cause breathing discomfort to the people.

For the same year, the other two cities, *i.e.* Rishikesh and Kashipur, also fall under the moderate status with the same impact on health, with AQI values of 124.20, 103.89, and 118.13 for Rishikesh, and 117.46, 110.81, and 111.62 for Kashipur. In comparison of years 2021 with 2019, it is fair to say that 9.2% reduction in AQI values is noticed for Dehradun; whereas, 4.7% and 4.9% reduction were seen in Rishikesh and Kashipur, respectively, as shown in Fig. 4. This might be due to restrictions on outdated vehicles and shifting towards alternate fuels like CNG/PNG to petrol or diesel. Moreover, after March 2020, Uttarakhand state was also under lockdown condition which restricts the transportation, shutting of industries that reduced the AQI value in 2020, and it might have impression on the successive year 2021. This indicates the implementation of various sector-specific strategies in cities for the reduction of PM_{10} .

3.4 Statistical Analysis

Further in the study, paired *T* test presents the statistical differences occurred in concentration of PM_{10} between years 2019 and 2021 (*i.e.* before and after the implementation of sector-specific strategies under NCAP).

In this, the significance level for Dehradun was assumed to be $\alpha=0.05$; whereas for Rishikesh and Kashipur, it was $\alpha=0.7$. There was a marginal difference in the concentration of PM_{10} between 2019 and 2021 for Rishikesh and Kashipur. Table 5 concludes the statistical analysis of the variation in concentration of PM_{10} before and after implementation of NCAP.

In consideration of $P(T \leq t)$ two-tail, since the *p*-value is less than the significance level for Dehradun, Rishikesh and Kashipur, as a result null hypothesis is rejected. In case, sufficient evidence supports a higher mean concentration of PM_{10} in 2019 compared to the mean concentration in 2021.

While taking *t* Critical two-tail, the critical value of the test turns out to be 1.79, 0.39, and 0.39 for Dehradun, Rishikesh, and Kashipur which is found lower than the test statistic *t* value, since null hypothesis is rejected.

3.5 Limitation of the Study: Exclusion of Year 2020 in Comparative Study

The air quality status of all cities in Uttarakhand state after March 2020 was significantly lower than the preceding year. Table 4 shows the concentration of various pollutants in year 2020, which is considered as lockdown period. The cause for this substantial improvement in air quality is probably

Table 3 Specific sectors and undertaken action points with the aim to reduce PM_{10} in cities are concluded

S. no.	Sector wise action points	Dehradun	Rishikesh	Kashipur
1	Capacity Building, Monitoring Network and Source Apportionment	CAAQMS station is established and running at Doon university location	1 CAAQMS is under installation process. Whereas, AQM cell in city has been established	1 CAAQMS is under installation process. Monitoring stations have been increased from 01 to 03 with the establishment of AQM cell;
2	Public Outreach	Under this sector UKPCB and associated departments issued the advisory to maintain vehicle fitness and minimise the use of personal vehicles Web-based android app for redressal of public complaints (Public Grievance) on air pollution	Under this sector UKPCB and associated departments issued the advisory to maintain vehicle fitness and minimise the use of personal vehicles Web-based android app for redressal of public complaints (Public Grievance) on air pollution	Under this sector UKPCB and associated departments issued the advisory to maintain vehicle fitness and minimise the use of personal vehicles Web-based android app for redressal of public complaints (Public Grievance) on air pollution
3	Road Dust and Construction and Demolition	More than 2 mounted vacuum cleaning machine and road sweeping machine are diploid for cleaning Total 03 sites are designated for disposal of demolition waste which are: 1-Harbhajwala khasra no.85(A)/0.438 Hec- tor; 2-Khulhaan/Karanpur khasra no. 2(A)/0.4000 Hec- tor; 3-Behind DJT, Makkawala khasra no.86(A)/89 0.300 Hec- tor Sprinkling systems are used to control the dust generated by construction and demolition activities Curtain is mandatory around the walls at construction site. Departments also charges fine to avoid the rules and regulation for the storage and transportation of construction materials	Directions are issued to respective departments to monitor & ensure road maintenance, creating green buffers Vehicles are charged fine in violating the rules to the non-carrying of goods	Efforts are made to lift garbage from highway roads, twice a day Almost 100% door to door waste collection is achieved and are maintained on daily basis Sweeping and sprinkling of water on street is done on daily basis
4	Vehicles	More than 113 PUC centre are operational in Dehradun jurisdiction In this context, total 04 CNG supply stations, 3824 E- Rikshaws, and 606 Electric Vehicles are operational	In this sector, for not having Pollution Control Certificate, Rs 2500 will be charged for the first time which will be increased to Rs 5000 for the second or subsequent offense	In this sector, around 18 PUC are operational in Kashipur city 01 CNG supply station and 351 CNG /LPG driven commercial vehicles are operational About 1626 non-commercial vehicles, 3312 E-Rikshaws (P) are running in city
5	Industries	It is directed to the industries to install required air pollution abatement equipment/devices	In the city pet coke and furnace oil for the new units are restricted Use of 800 KW D.G. sets in Rishikesh is restricted no region found using such D.G sets	About 08 units are identified and directed to switchover cleaner fuel and 03 units are using LPG/PNG as a fuel Illegal operational D.G sets are identified in Kashipur and directed to seal with charged fine and are regularly monitored

Table 3 (continued)

S. no.	Sector wise action points	Dehradun	Rishikesh	Kashipur
6	Waste and Biomass- Dumping and Burning	Notice is issued and challans are imposed in case of open burning of municipal solid waste, biomass, plastic, horticulture waste, etc.	It is ensured to have availability of affordable cleaner cooking fuels (LPG in urban areas & biogas in rural areas)	In Kashipur burning of crop residuals are restricted, which was the major air pollutant source in city
7	Domestic fuel	In Dehradun city about to 27,526 Dhabas/Hotels/Eateries are using cleaner fuel for their commercial purpose. Directions are also issued for 100% spread of LPG. A joint inspection by departments is in progress to ensure retrofitted emission control system for DG sets with 800 KW or more capacity in Dehradun city	In Rishikesh city, introduction of improved chullahs (low emission chullahs), directions and action points are under progress	In this section: PNG is now available in Kashipur and presently O3 industries are operational using this fuel
8	PM ₁₀ concentration (µg/m ³)	146.6	130.7	125.8

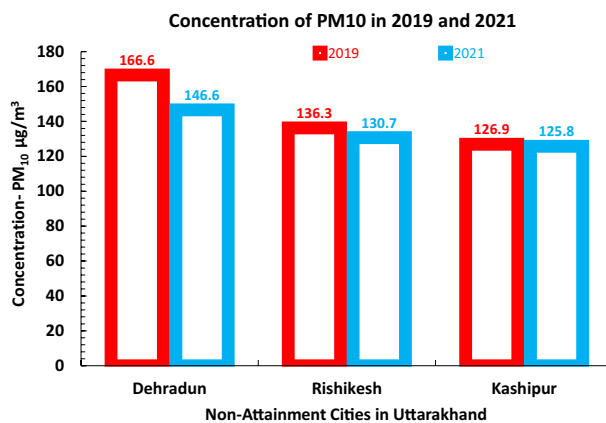


Fig. 2 Reduction in concentration of PM10 after NCAP

related to the nation-wide COVID-19 lockdown after 25th March 2020.

In the lockdown decision, certain factors that played an important role can be concluded as.

- Strict traffic controls (preventing immigration and emigration of people into the city),
- The shutting of industrial and commercial enterprises,
- Restriction on public and private vehicle movement, and
- Home quarantine measures.

However, some industrial areas in state such as Rudrapur, Kashipur, and Haldwani have not observed much reduction in air pollution as some of the industries in cities were operational. Whereas, with time, the gradual lifting of the lockdown and gradually returning to normal life again impacts the air pollution. This release significantly contributed an upsurge of air pollutants amount with the opening of industries, transportation and migration. In a lockdown, it is assumed that no certain efforts have been made to cut off the concentration of air pollutants and hence, lockdown period is excluded from the study.

3.6 Proposed Future Aspects

Besides implementation of proposed action points, every citizen must participate and make specific changes in their lifestyle to reduce air pollution. In this context, some major aspects are discussed and needed to understand for sustainable environment:

Promoting urban green roof and vertical gardening could reduce air pollutants, especially in urban areas.

Modification is necessary in existing rules and regulations for getting approval for construction, especially in developing country. Plantation should be mandate and its minimum length to be achieved before construction at approved lease

Table 4 Air quality status and trend after implementation of NCAP

Air Pollutant	Year	Dehradun	Rishikesh	Haridwar	Kashipur	Haldwani	Rudrapur
PM ₁₀	2020	120.35	108.17	98.71	117.30	107.51	115.01
	2021	146.60	130.77	117.65	125.84	109.88	123.38
PM _{2.5}	2020	78.62	NA	NA	NA	NA	NA
	2021	87.39	76.32	80.88	NA	36.92	NA
SO _x	2020	21.40	18.66	9.135	12.47	7.26	12.33
	2021	21.31	19.94	12.54	17.25	7.31	18.93
NO _x	2020	18.48	23.24	14.70	18.76	25.50	18.19
	2021	18.92	24.99	20.09	21.31	25.27	22.14

*NA Not available

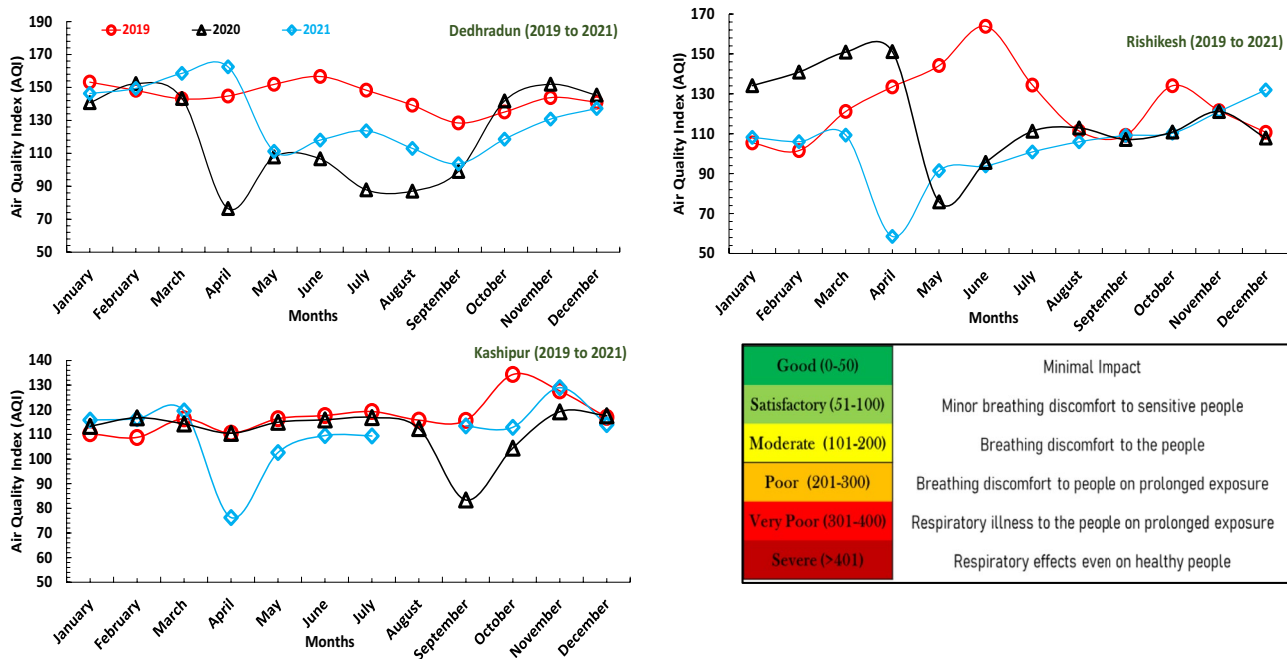


Fig. 3 Monthly and yearly average AQI values for non-attainment cities from 2019 to 2021 with Indian AQI range and probable health impacts

Fig. 4 Comparison of air quality index of non-attainment cities between 2019 and 2021

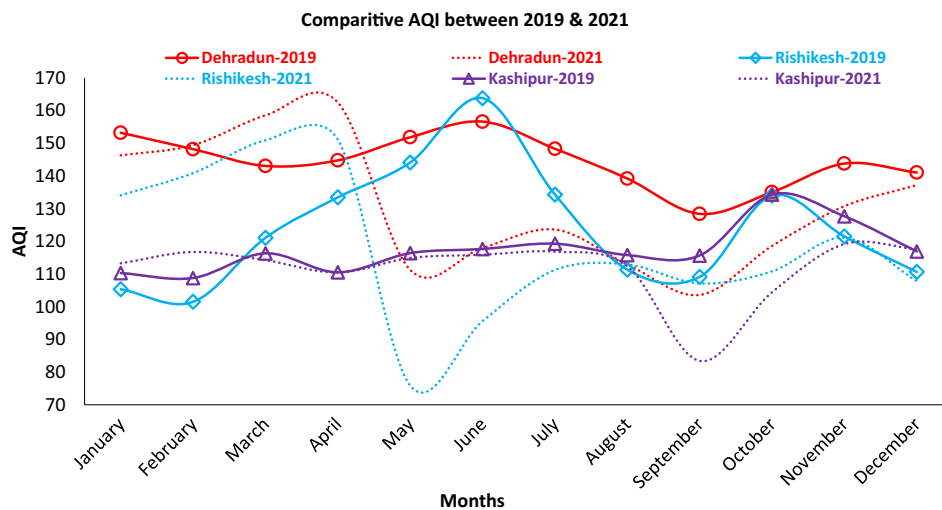


Table 5 Statistical analysis of differences occurred in concentration of PM₁₀ before and after implementation of NCAP

Dehradun <i>t</i> test: paired two sample for means 2019–2021		Rishikesh <i>t</i> test: paired two sample for means 2019–2021		Kashipur <i>t</i> test: paired two sample for means 2019–2021	
Mean	166.70 132.12	Mean	136.31 128.65	Mean	126.19 118.13
Variance	142.46 1589.07	Variance	759.15 1002.70	Variance	117.64 153.75
Observations	12 12	Observations	12 12	Observations	12 12
Pearson correlation	0.02	Pearson correlation	−0.44	Pearson correlation	−0.07
Hypothesised Mean Difference	0	Hypothesised Mean Difference	0	Hypothesised Mean Difference	0
Df	11	df	11	df	11
<i>t</i> Stat	2.90	<i>t</i> Stat	0.52	<i>t</i> Stat	1.63
P(T ≤ <i>t</i>) one-tail	0.007	P(T ≤ <i>t</i>) one-tail	0.30	P(T ≤ <i>t</i>) one-tail	0.06
<i>t</i> Critical one-tail	1.36	<i>t</i> Critical one-tail	−0.53	<i>t</i> Critical one-tail	−0.53
P(T ≤ <i>t</i>) two-tail	0.014	P(T ≤ <i>t</i>) two-tail	0.60	P(T ≤ <i>t</i>) two-tail	0.13
<i>t</i> Critical two-tail	1.79	<i>t</i> Critical two-tail	0.39	<i>t</i> Critical two-tail	0.39

area or certain time period to be decided for plant growth (to become healthy) after plantation.

Giant sprinklers may be introduced that could suppress the dust particles and other pollutants by spraying water into the air.

Introducing such special tiles coated with titanium oxide having capacity to convert harmful nitrogen oxide into lesser harmful compound after activation in the presence of UV radiations.

Smoking is a serious issue in urban areas especially in developing countries and is much needed to have certain instruction while smoking. No alternative is better than banning smoking in public areas. The public smoking ban could help reduce PM and carcinogenic volatile organic compounds and have long-term benefits, probably reducing heart attack cases.

Further, school, colleges, and universities need to regulate their instructions to develop parking areas outside the campus boundary and only allow bicycles inside the campus premises.

4 Conclusion

The present study highlights the implementation of sector-specific action points under the NCAP in improvement of air quality status of non-attainment cities in Uttarakhand. To promote better air quality in the state, air data were obtained from nine different monitoring stations established in Dehradun, Rishikesh, and Kashipur under initiative of NAMP for different years are assessed. As the annual average concentration of PM₁₀, PM_{2.5}, SO_x, and NO_x were increasing linearly with time. Thus, the lockdown positively contributed to Uttarakhand's air quality improvement and thus made a positive contribution in enhancement of air quality. However,

considerable amount of concentration of pollutants was increasing in 2021 with the release in lockdown. Regardless, NCAP contributed to controlling air pollution and policy-makers are highly concerned with the benefits of reducing emissions when considering appropriate pollution prevention and control strategies. Executing sector-specific actions in 2021 shows the considerable of reduction in PM₁₀ in for Dehradun; whereas, Rishikesh and Kashipur are expected to achieve more percentage of reduction. Therefore, it is important to execute all the considered action points in NCAP for the upgradation of air quality. In addition, it is also essential to observe and assess the detailed execution of action points under NCAP to improve environmental conditions and human health.

Acknowledgements Authors would like to thank to all academic institutions and research organizations that extended their support throughout the study work.

Funding Yes.

Availability of Data and Materials On request.

Declarations

Conflict of Interest The authors declare no conflict of interest.

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent for Publication Not applicable.

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Authors and Affiliations

Ankur Kansal¹ · Sarada Prasannan Subuddhi¹ · Prashant Pandey¹ · Deepak Gupta¹ · Tarangini Rawat¹ · Alok Sagar Gautam² · Sneha Gautam^{3,4} 

✉ Ankur Kansal
kansal2ankur@gmail.com

✉ Sneha Gautam
snehagautam@karunya.edu

Alok Sagar Gautam
phyalok@gmail.com

² Department of Physics, Hemvati Nandan Bahuguna Garhwal University, Srinagar, Uttarakhand 246174, India

³ Department of Civil Engineering, Karunya Institute of Technology and Sciences, Coimbatore, TN, India

⁴ Water Institute, A Centre of Excellence, Karunya Institute of Technology and Sciences, Coimbatore, TN, India

¹ Uttarakhand Pollution Control Board, IT Park, Sahastradhara Road, Dehradun, Uttarakhand 248001, India