Spatio - Temporal changes and impact of air pollution on human health: A case study of Dehradun City

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Abstract

Hazardous chemicals escape to the environment by a number of natural and/or anthropogenic activities and may cause adverse effects on human health and the environment. Increased combustion of fossil fuels in the last century is responsible for the progressive change in the atmospheric composition. Air pollutants, such as carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), volatile organic compounds (VOCs), ozone (O_3), heavy metals, and respirable particulate matter (PM2.5 and PM10), differ in their chemical composition, reaction properties, emission, time of disintegration and ability to diffuse in long or short distances. Air pollution has both acute and chronic effects on human health, affecting a number of different systems and organs. It ranges from minor upper respiratory irritation to chronic respiratory and heart disease, lung cancer, acute respiratory infections in children and chronic bronchitis in adults, aggravating pre-existing heart and lung disease, or asthmatic attacks. In addition, short- and long-term exposures have also been linked with premature mortality and reduced life expectancy. These effects of air pollutants on human health and their mechanism of action are briefly discussed.

Keywords: Air pollutant | Human health | Cellular actions | Detoxification

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Introduction

The study of air pollution in geography requires spatio-temporal scientific analysis. Geographical study of air pollution in Dehradun city area takes into account the impact of various pollutants in the atmosphere in spatio-temporal context (Singh, 1988, 1992). It also examines the effect of pollutants on human health as well as on plants and animals in the study area. Many of the research work has been undertaken on different aspects of air pollution in the field of geography but significant work with an impact on human health has been conducted in this area by

analyzing the spatial pattern of air pollution, air quality and its impact through this study. Thus the air pollution is defined as the presence of any solid, liquid or gaseous substance present in atmosphere in such concentration as may be or tends to be injurious to human beings or other living creatures or plants or property or environment.

Air quality in the Indian cities is deteriorating due to rapid and unplanned developmental processes (Singh et al 2007; Gupta et al. 2009). After the creation of a new state Uttarakhand, in the year 2000, most of the cities of the state, especially Dehradun the capital city, suffered tremendous pressure of increasing population accompanied with the rapid increase in the number of vehicles. Air quality status in Dehradun city revealed that SO_2 and NO_x concentrations are under prescribed limit of CPCB, but SPM and RSPM exceed the limit (Chauhan et al. 2010). In comparison with the earlier years 2004 and 2006, air pollution as indicated by similar lichen shows a considerable increase in the total metal concentration (especially Pb) in the ambient air of Dehradun city, which may be attributed to exponential rise in the traffic activity in the last 5 years.

Sources of air pollution in Dehradun City

After the creation of a new state Uttarakhand in the year 2000, Dehradun the capital city suffered tremendous pressure of increasing population accompanied with the rapid increase in the number of vehicles. Air quality status in Dehradun city revealed that SO_2 and NO_x concentrations were still under permissible limits but SPM and RSPM

concentration are problematic. In the hill station of mussoorie that over looks the town of Dehradun in uttarakhand could do without. Every winter, thick blue smoke envelops this town casting a shadow on one of the most picturesque valleys in Asia. This sometimes gives rise to a lateral inversion that does not allow hot air to rise from the valley. As a result smoke settles over the valley. Air pollution in Dehradun has been in the headlines for some time now. However the SPM levels have shown a downward trend over the years, they are still above the prescribed limits at all the monitoring sites in Dehradun. In 1997, the city's annual average SPM level was more than twice the permissible limit and the maximum SPM level was more than thrice the standard. Moreover SPM levels were higher in residential areas as compared to industrial areas. However in 2011 the scenario has changed somewhat with an increment in the number of vehicles i.e. 1,54,666 plus local transport modes and the levels of all the pollutants have increased manifold.

To know the actual situation of air quality and its impact on human health sample surveys have been undertaken. Study reveals that after been designated as capital city the concentration of dust and particulate matter has adversely affected the human as well as plant life. For this three monitoring stations have been selected *i.e.* Clock Tower, Sahastradhara Crossing and Himalayan Drug company. The result have been compared with the National air quality Standards. For air pollutants concentration study, due consideration has been given to meteorological data such as

temperature, relative humidity, wind speed and wind direction.

Spatio-Temporal pattern of air pollution

Air pollution is a major problem in Dehradun city due to all round development of urbanized activities. To evaluate the air quality in the city jurisdiction, three parameters *i.e.* SPM, SO_2 and NO have been analysed during the period of 2001 as base year, 2011 and 2015 as current year. However in 2015 the recording of RSPM

was also started with the increment of air borne diseases.

To know the actual situation of air quality and its impact on human health, sample surveys data has been acknowledged from the year 2001 to 2015. As the concrete purpose of the study is to show the temporal and spatial variation in Ambient air quality of the Dehradun city before being the capital city i.e. before 2000 and after that.

Sampling sites/ Years	SO_2			NO_2			RSPM			SPM		
	2001	2011	2015	2001	2011	2015	2001	2011	2015	2001	2011	2015
Clock Tower	17	23.2	26	16.3	24.6	25.8	NA	176.22	188.25	226.0	361.0	398.4
Sahastradhara Crossing	16.2	21.1	25.1	15.9	24.6	25.7	NA	120.32	140.64	203.2	303.3	352.2
Himalayan Drug Comp.	16.8	23.3	25.2	16.2	24.7	26.1	NA	117.33	138.32	205.1	301.6	262.4

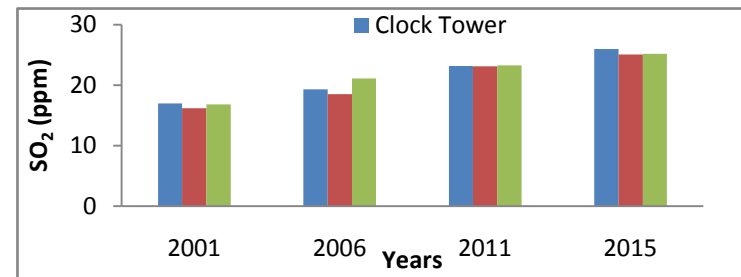**Source:** Pollution control board, Dehradun (U. K)

Table 1: Spatial variation of air pollution in Dehradun City

From above tables, spatial variation of air pollution in 2001, the value of SO_2, NO_2 and SPM was highest at Clock Tower i.e. 17 ppm, 16.3 ppm and 226 ppm respectively. In 2011 the SO_2 and NO_2 is highest at Himalayan Drug i.e. 23.3 ppm and 24.7 ppm respectively. The value of SPM and RSPM is highest at the Clock Tower. i.e. 361 ppm and 176.22 ppm respectively. In 2015 the value of SO_2, RSPM and SPM is highest at Clock Tower i.e. 26 ppm, 188.3 ppm and 398.4ppm respectively as shown in the Table 1.
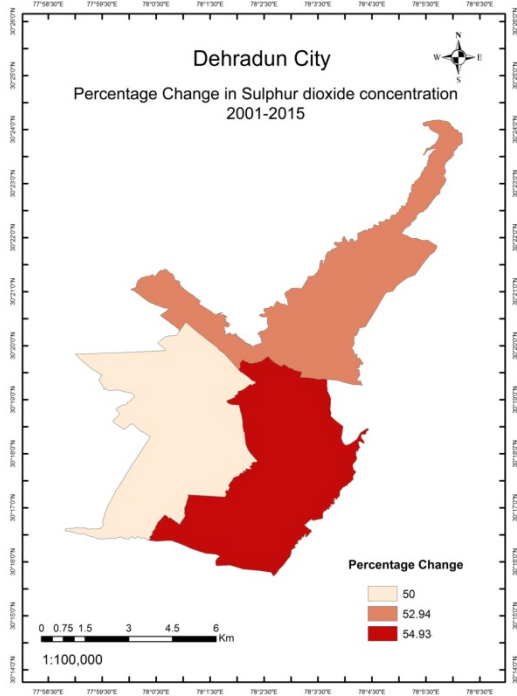

Fig. 1: Spatio-temporal Variation of SO_2 during 2001 to 2015

Temporal variations of air pollution of Dehradun city of SO_2 at Clock Tower shows in table 2 that the change in percentage was 13.5 percent in 2006, 36.5 percent in 2011 and 52.9 percent in 2015 from the base year. At Sahastradhara Crossing the change of SO_2 in 2006 in percentage was 14.2 in 2001, 42.6 in 2011 and 54.9 percent in 2015 from the base year. At Himalayan Drug the change of SO_2 in percentage was 25.6 in 2006, 38.9 in 2011 and 50 in 2015 from the base year. The highest

Sampling sites	2001	2006	2011	2015
Clock Tower	17	19.3	23.2	26
Sahastradhara Crossing	16.2	18.5	23.1	25.1
Himalayan Drug Comp.	16.8	21.1	23.3	25.2

Source: Pollution control board, Dehradun (U. K)

Table 2: Temporal variation of SO_2

change of SO_2 from the base year to 2015 is 52.9 percent recorded at two places at Clock Tower and Sahastradhara Crossing.
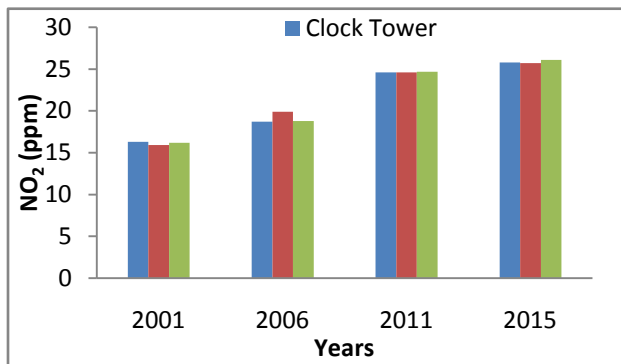

Fig. 2 : Percentage of Change in Sulphur Dioxide Concentration in Dehradun City from 2001 to 201

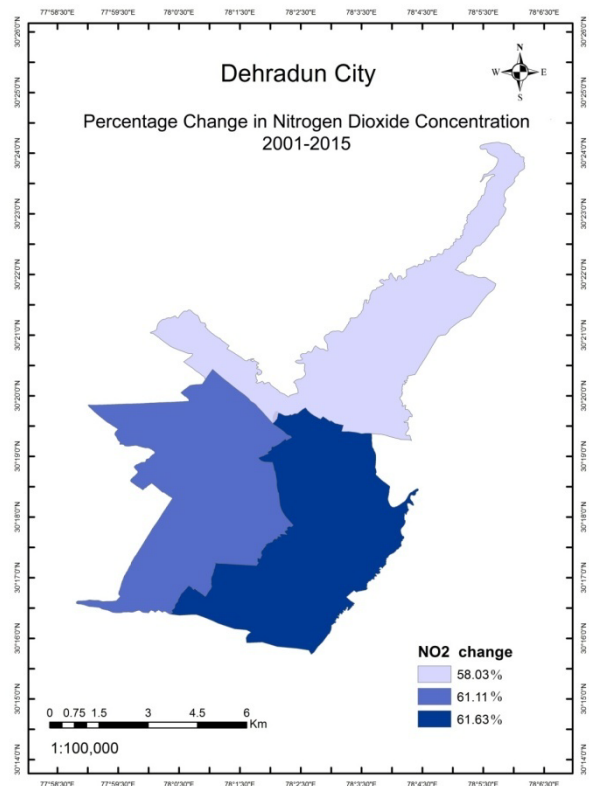| Sampling sites	2001	2006	2011	2015
Clock Tower	16.3	18.7	24.6	25.8
Sahastradhara Crossing	15.9	19.9	24.6	25.7
Himalayan Drug Comp.	16.2	18.8	24.7	26.1

Source: Pollution control board, Dehradun (U. K)

Table 3: Temporal variation of NO_2

Fig. 3: Spatio - temporal Variation of NO_2 during 2001 to 2015

Temporal variations of air pollution of Dehradun city of NO_2 (as shown in table 3) at Clock Tower shows in above table that the change in percentage was 14.2 in 2006, 50.8 in 2011 and 58 percent in 2015 from the base year. At Sahastradhara Crossing the change of NO_2 in 2006 in percentage was 25.2 in 2001, 55.1 in 2011 and 61.6 in 2015 from the base year. At Himalayan Drug company the change of NO_2 in percentage was 16 percent in 2006, 52.6 in 2011 and 61.1 in 2015 from the base year. The highest change of NO_2 from the base year to 2015 is 61.6 percent recorded at Sahastradhara Crossing.

Fig. 4 : Percentage of Change in Nitrogen Dioxide Concentration in Dehradun City from 2001 to 2015

Sampling sites	2001	2006	2011	2015
Clock Tower	NA	NA	176.22	188.25
Sahastradhara Crossing	NA	NA	120.32	140.64
Himalayan Drug Comp.	NA	NA	117.33	138.32

Source: Pollution control board, Dehradun (U. K)

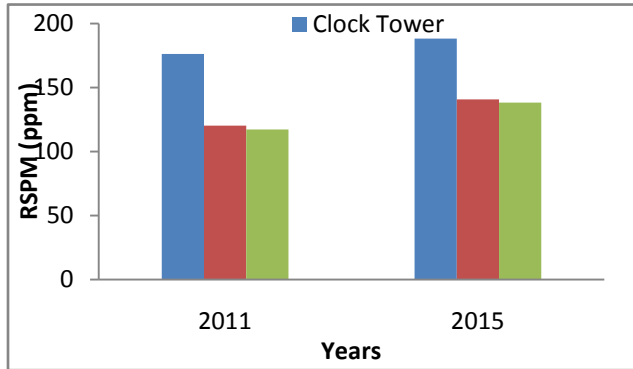**Table 4:** Temporal variation of RSPM

Fig. 5: Spatio-temporal Variation of RSPM during 2011 and 2015

The collective description of RSPM could not be used as pollution survey was not engaged in collecting levels for RSPM uptill 2006 however the data for 2011 and 2015 depicts that the level of RSPM is highest at Clock Tower *i.e.* 176.22 ppm and 188.25 ppm respectively.

Sampling sites	2001	2006	2011	2015
Clock Tower	226	301.4	361	398.4
Sahastradhara Crossing	203.2	225.4	303.3	352.3
Himalayan Drug Comp.	205.1	224	301.6	362.4

Source: Pollution control board, Dehradun (U. K)

Table 5: Temporal variation of SPM

Temporal variations of air pollution of Dehradun city of SPM at Clock Tower shows in table 4.13 that the change in percentage was 33.4 in 2006, 59.7 in 2011 and 76.3percent in

2015 from the base year. At Sahastradhara Crossing the change of SPM in 2006 in percentage was 25.7 in 2006, 49.3 in 2011 and

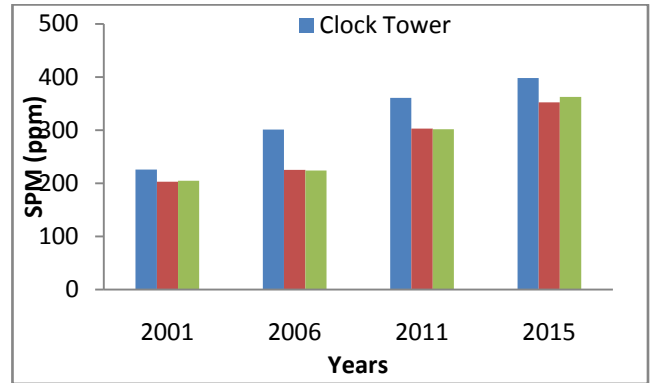**Fig. 6:** Spatio-temporal Variation of SPM during 2001 to 2015

73.4 in 2015 from the base year. At Himalayan Drug the change of SPM in percentage was 19 percent in 2006, 47.1 in 2011 and 76.7 in 2015 from the base year. The highest change of SPM from the base year to 2015 is 76.7 percent recorded at Himalayan Drug.
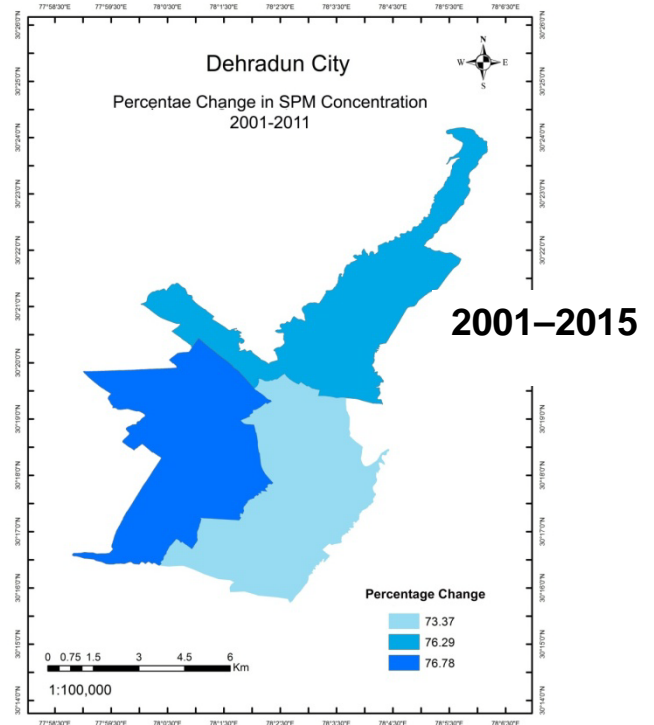

Fig. 7: Percentage Change in SPM Concentration in Dehradun City from 2001 to 2015

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Impact of air pollution on human health

The impact on public health has been the prevalence of respiratory diseases which has risen alarmingly over the past decade and most cases are linked to air pollution.

Study Sites	Ast hma	Bronchi tis	Tuberculo sis	Tonsi ls	Comm on cold
Vasant Vihar	5	18	8	15	17
Nehru colony	7	28	9	19	24
Patel nagar	4	17	5	16	17
Rajpur	8	23	9	28	38
Dallanwala	12	34	13	39	44
Deepnagar	17	28	16	47	56
Majra	11	28	19	59	66

Source: Pollution control board, Dehradun (U. K)

Table 6: Annual incidence rate of Diseases (patient per 1000 person) 2001

The Spatial pattern of air–borne disease in 2001 revealed in the above table 4.14 that the total annual registered cases of Asthma in 2001 was 64/1000 person and the maximum cases i.e. 17/1000 person were acknowledged from Deepnagar and the total annual registered case of bronchitis were 176/1000 person from the city and the maximum cases were from Dallanwala i.e. 34. The total case of tubercolosis, tonsils and common cold were 79/1000 person, 223/1000 person and 262/1000 person respectively from City and the maximum cases of tubercolosis, tonsils and common cold were from Majra i.e. 19/1000 person, 59/1000 person and 66/1000 person respectively.

Study Sites	Asthma	Bronc hitis	Tuberculosis	Tons ils	Commo n cold
Vasant vihar	6	29	10	29	36
Nehru colony	11	44	13	35	39
Patel nagar	5	33	9	29	32
Rajpur	19	49	23	48	54
Dallanwala	15	57	18	51	57
Deepnagar	21	43	23	69	73
Majra	18	34	25	77	85

Source: Pollution control board, Dehradun (U. K)

Table 7: Annual incidence rate of Diseases (patient per 1000 person) 2006

In 2006 total cases of asthma were 95/1000 person and the maximum cases were from Rajpur i.e. 19/1000 person (as shown in table 4.15). The total cases of bronchitis from the city were 289/1000 person and maximum cases from Dallanwala i.e. 57/1000 person and the total cases of tubercolosis, tonsils and common cold from the city were 121/1000 person, 338/1000 person and 376/1000 person respectively and the maximum cases of these three diseases from Majra i.e. 25/1000 person (tubercolosis), 77/1000 person (tonsils) and 85/1000 person (common cold).

Study Sites	Asthma	Bronc hitis	Tuberculosis	Tons ils	Commo n cold
Vasant vihar	8	35	14	37	43
Nehru colony	14	67	22	47	54
Patel nagar	12	56	16	47	56
Rajpur	25	73	32	71	77
Dallanwala	21	79	27	67	73
Deepnagar	26	65	37	82	88
Majra	23	54	33	86	99

Source: Pollution control board, Dehradun (U. K)

Table 8: Annual incidence rate of Diseases (patient per 1000 person) 2011

In 2011 the total number of cases of asthma and tubercolosis were 129/1000 person and 181/1000 person respectively and the maximum cases were from Deepnagar i.e. 26/1000 person (Asthma) and 37/1000 person (tubercolosis). The total cases of bronchitis in the city were 429/1000 person and maximum cases were from Nehru colony i.e. 67/1000 person. The total cases of tonsils and common cold were 437/1000 person and 490 /1000 person respectively from the city and maximum cases of both these diseases were from Majara i.e. 86/1000 person and 99/1000 person respectively.

Study Sites	Asthma	Bronc hitis	Tuberculosis	Tons ils	Commo n cold
Vasant vihar	11	54	17	53	57
Nehru colony	33	89	31	63	69
Patel nagar	29	76	32	71	76
Rajpur	45	98	55	82	89
Dallanwala	29	104	35	86	92
Deepnagar	37	86	44	98	108
Majra	43	63	54	103	116

Source: Pollution control board, Dehradun (U. K)

Table 9: Annual incidence rate of Diseases (patient per 1000 person) 2015

In 2015 the total number of cases of asthma and tubercolosis were 227/1000 person and 268/1000 person respectively from the city and the maximum cases were from Rajpur i.e. 45 (Asthma) and 55 (tubercolosis) (as shown in table 4.17). The total cases of bronchitis in the city were 570/1000 person and maximum cases were from Dallanwala i.e. 104/1000 person. The total cases of tonsils and common cold were 556 /1000 person and 607 /1000 person respectively from the city and maximum cases of both these diseases were from Majra i.e. 103 /1000 person and 116 /1000 person respectively.

Study Sites	2001	2006	2011	2015
Vasant vihar	5	6	8	11
Nehru colony	7	11	14	33
Patel nagar	4	5	12	29
Rajpur	8	19	25	45
Dallanwala	12	15	21	29
Deepnagar	17	21	26	37
Majra	11	18	23	43

Source: Pollution control board, Dehradun (U. K)

Table 10: Annual incidence rate of Asthma (patient per 1000 person)

The annual incidence rate of asthma in 2006 and 2011 from the base year the maximum rate of change was 137.5 percent and 212.5 percent respectively at Rajpur and in 2015 the maximum change was at Patel nagar *i.e.* 625 percent, the minimum change from 2001 to 2006 was 20 percent at Vasant Vihar and

minimum in 2011 and 2015 at Deepnagar i.e. 52.9 percent and 117. 6 percent respectively.

Study Sites	2001	2006	2011	2015
Vasant vihar	18	29	35	54
Nehru colony	28	34	67	89
Patel nagar	17	33	56	76
Rajpur	23	49	73	98
Dallanwala	34	57	79	104
Deepnagar	28	43	65	86
Majra	28	34	54	63

Source: Pollution control board, Dehradun (U. K)

Table 11: Annual incidence rate of Bronchitis (patient per 1000 person)

The maximum change of Bronchitis from 2001 to 2006 was at Rajpur i.e. 113 and it was maximum in 2011 and 2015 from the base year was at Patel nagar *i.e.* 229.4 percent and 347.1 percent respectively. The minimum change of Bronchitis from the base year to 2001 is (21.4 percent), 2006 (92.9 percent), 2011 (125 percent) at Rajpur (as shown in table 4.19).
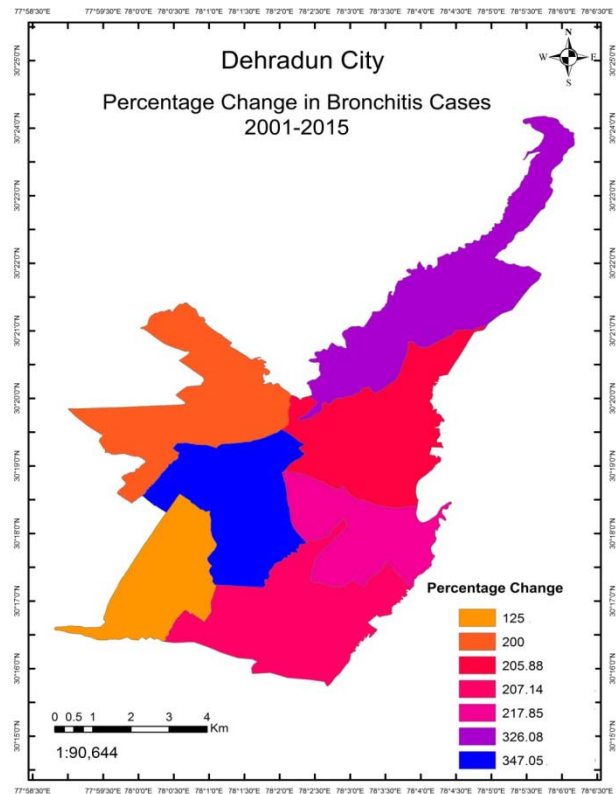
Fig. 8: Percentage Change in Bronchitis Cases in Dehradun City during 2001-2015

Study Sites	2001	2006	2011	2015
Vasant vihar	8	10	14	17
Nehru colony	9	13	22	31
Patel nagar	5	9	16	32
Rajpur	9	23	32	55
Dallanwala	13	18	27	35
Deepnagar	16	23	37	44
Majra	19	25	33	54

Source: Pollution control board, Dehradun (U. K)

**Table 12:** Annual incidence rate of Tuberculosis (patient per 1000 person)

While discussing the above table it is revealed that maximum change of Tuberculosis from 2001-2006 and 2011 was at Rajpur i.e. 155.6 percent and 255.6 percent respectively. It was maximum in 2015 at Patel nagar i.e. 540 percent from the base year. While discussing the minimum change was at Vasant Vihar (25 percent) in 2006 and 73.7 percent at Majra in 2006 and 169.2 percent at Dallanwala in 2015.

Study Sites	2001	2006	2011	2015
Vasant vihar	15	29	37	53
Nehru colony	19	35	47	63
Patel nagar	16	29	47	71
Rajpur	28	48	71	82
Dallanwala	39	51	67	86
Deepnagar	47	69	82	98
Majra	59	77	86	103

Source: Pollution control board, Dehradun (U. K)

Table 12: Annual incidence rate of Tonsilitis (patient per 1000 person)

As shown in the table 13 the maximum change of tonsils from 2001 to 2006 is 93.3 percent at Vasant Vihar and it was maximum in 2011 and 2015 at Patel Nagar *i.e.* 193.8 percent and 343.8 percent respectively from the base year. The minimum change under tonsillitis from the base year uptill 2015 was at Majra *i.e.* 30.5 percent (2001), 45.8 percent (2006), 74.6 percent (2011).
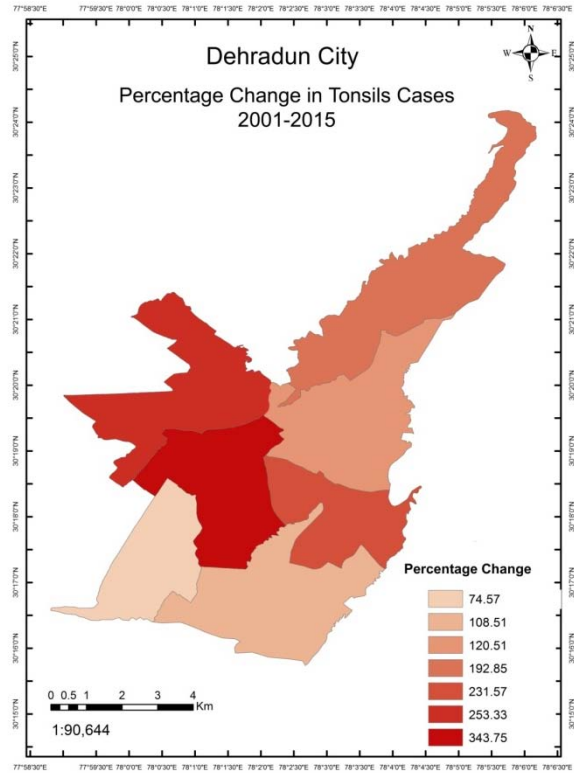
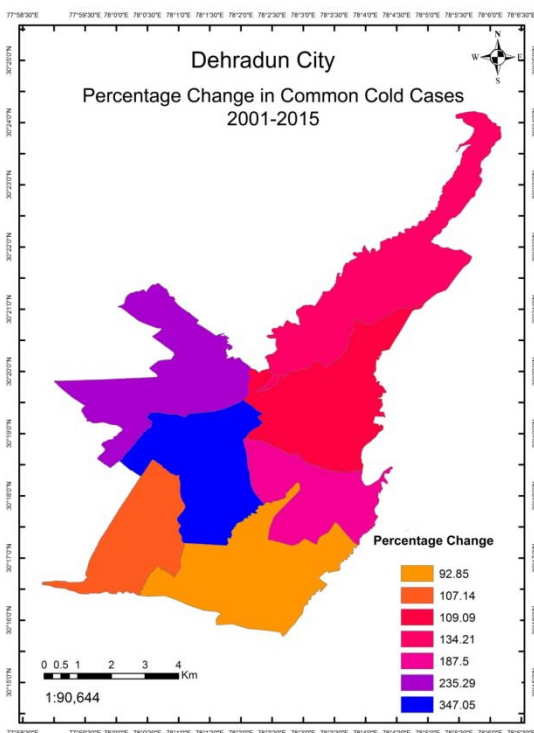**Fig. 9:** Percentage Change in Tonsils Cases in Dehradun City during 2001-2015

Study Sites	2001	2006	2011	2015
Vasant vihar	17	36	43	57
Nehru colony	24	39	54	69
Patel nagar	17	32	56	76
Rajpur	38	54	77	89
Dallanwala	44	57	73	92
Deepnagar	56	73	88	108
Majra	66	85	99	116

Source: Pollution control board, Dehradun (U. K)

Table 14: Annual incidence rate of Common cold (patient per 1000 person)

As shown in the table 14 the maximum change of Common cold recorded at Vasant vihar from base year to 2006 (235.3 percent). The minimum change of this disease recorded at Majra *i.e.* 28.8 percent (2006), 50 percent (2011), 75.8 percent (2015).

Fig. 10: Percentage Change in Common Cold Cases in Dehradun City during 2001-2015

Conclusion

After the creation of a new state Uttarakhand in the year 2000, Dehradun the capital city suffered tremendous pressure of increasing population accompanied with the rapid increase in the number of vehicles. Air quality status in Dehradun city revealed that SO_2 and NO_x concentrations were still under permissible limits but SPM and RSPM concentration are problematic. Air pollution in Dehradun has been in the headlines for sometime now. However the SPM levels have shown a downward trend over the years, they are still above the prescribed limits at all the monitoring sites in Dehradun. In 1997, the city's annual average SPM level was more than twice the permissible limit and the maximum SPM level was more than thrice the standard. Moreover SPM levels were higher in residential areas as compared to industrial areas. However in 2011 the scenario has changed somewhat with an increment in the number of vehicles, local transport modes and the levels of all the pollutants have increased manifold. To know the actual situation of air quality and its impact on human health sample surveys have been undertaken. Study reveals that after been designated as capital city the concentration of dust and particulate matter has adversely affected the human as well as plant life. For this three monitoring stations have been selected. i.e. Clock Tower, Sahastradhara Crossing and Himalayan Drug company.

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