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Ambient air quality status of Jammu city

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Abstract

Present study has been taken up to monitor the ambient air quality status of Jammu city. The data for air quality parameters (sulphur dioxide, nitrogen dioxide, respirable suspended particulate matter, suspended particulate matter) has been collected for two heavy traffic areas vis. Satwari-Bikram Chowk road (Site-II) and Kunjwani-Narwal Byepass (Site-III) and compared with a reference location with low traffic area i.e. University of Jammu Campus (Site-I), for a period of two years i.e. December 2013- November 2015. Results revealed that sites- II and III recorded higher concentration of all the studied pollutants than Site-I. Further, all the sites registered higher concentrations of all the pollutants during winter season for both the years, while during monsoon season, the levels have been recorded to be least for all the sites. Air quality indices (AQI), computed from the selected data, revealed Sites-II and III to have moderate to severe air quality status whereas light to moderate air quality status have been recorded for Site-I.

Keywords: ***Ambient air quality, Air quality index, respirable suspended particulate matter, sulphur dioxide, suspended particulate matter, traffic***

Introduction

Air pollution has become a key environmental concern for both developed and developing countries of the world as deteriorating air quality produces both acute and chronic health effects in humans worldwide (Yang *et al.,* 2004; Afroz *et al..,* 2003). However, the amplitude of health impacts is different for different cities and countries (Analitis *et al.,* 2006; Katsouyanni *et al.,* 2001; Samet *et al..,* 2000), obstructing the understanding and universalization of the effect and cause relationship between air pollutants and human health (Bhuyan *et al.,* 2010). Mobile or vehicular pollution is primarily responsible for an array of serious health problems in urban areas since it is a source of suspended particulate matter (SPM), oxides of nitrogen (NO_x), oxides of sulphur (SO_x), carbon monoxide (CO), and volatile organic compounds (VOC). Vehicular exhausts also comprise of respirable particulate matter (RSPM) which infiltrate into the lungs and produce respiratory problems in exposed people, the study of RSPM holds significance in assessing the air quality status of the area (Ingle *et al.,* 2005). Several studies conducted in different parts of India to assess the ambient air quality (Goyal and Sidhartha, 2003; Ingle *et al.,* 2005; Goyal *et al.,* 2006 and Karda *et al.,* 2015) indicated vehicular pollution to be a major contributor for deterioration of ambient air quality. Jammu city too has witnessed massive increase in the number of vehicles over the years, thus leading to stupendous rise in levels of various pollutants in the ambient air. Table 1 depicts the trend of increase in the number of vehicles being registered every year with Regional Transport Offices (RTO) Jammu. Though few studies has been conducted to assess the air quality status of Jammu city at various locations for the years 2004 to 2005 (Sharma and Raina, 2012, 2013) and for 2007-2009 (Raina and Bala, 2011), no recent data is available, therefore the present investigation was undertaken to determine the present status of ambient air quality of selected locations of Jammu city.

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Materials and Method

Study area: Jammu (latitude $32^{0}44'$, longitude $74^{0}55'$, altitude 400m msl), the winter capital of Jammu and Kashmir state, is located on the Shivalik hill-lock of the Himalayas on the National Highway I A with an area of approximately 3,250 sq km. It is separated from Bahu-Mahamaya feature by Tawi River which is a tributary of river Chenab.

Collection of sample

Samples of the air has been collected from two sites of Jammu city having heavy traffic flow rate viz.

Table-1: Number of vehicles registered over the years in Jammu division by Regional Transport Office (RTO, Jammu)

Items	2010-11	2011-12	2012-13	2013-14	2014-15
Buses	328	260	294	323	185
Mini Buses	425	304	305	248	206
Cars/St.W	13409	15324	15896	16501	12914
Taxi/TS/MV	1449	1180	1615	817	579
Jeeps/Gypsy	324	92	53	80	53
3-Wheeler P/LC	1419	1693	1551	1310	1660
2-Wheeler	27411	31012	31515	34607	28578
Tractor(Pvt)	1400	1364	1143	1242	721
Trailors	22	33	11	19	13
Trucks	1545	1673	1307	772	515
Tanker	17	15	9	3	2
Ambulance	43	30	41	63	62
LGV	0	0	0	521	689
MGV	0	0	0	122	79
Delivery Van	0	0	0	727	383
Others	991	1266	695	30	24
TOTAL	48783	54246	54435	57385	46663

(Source: RTO Office, Jammu)

Satwari-Bikram Chowk road (Site-II) and Kunjwani-Narwal Byepass (Site-III). For reference, air quality of Jammu University campus (Site-I) has also been analyzed.

Analysis of parameter

The air sampling has been carried out at all the three sites on seasonal basis for a period of two years i.e. December 2013 to November 2015. Envirotech High Volume Respirable Dust Sampler APM 460 BL along with a gaseous sampling attachment (APM 411) has been used for sampling. Sulphur dioxide in the ambient air has been analyzed by using modified West and Gaeke Method (Bureau of Indian Standards, 2001) and Nitrogen dioxide has been analyzed by modified Jacob and Hochheiser method (Bureau of Indian Standards, 2006-a). Gravimetric method has been used for the analysis of Respirable particulate matter (Bureau of Indian Standards, 2006-b) and Suspended particulate matter (Bureau of Indian Standards, 1999). RSPM have been trapped by Whatman glass fibre filter papers and SPM have been collected in the dust cups. The sampling has been carried out in accordance with the guidelines prescribed by Central Pollution Control Board (CPCB), gaseous pollutants (for 4 hours duration) and particulate pollutants (for 8 hours duration). Total Suspended Particulate Matter (TSPM) has also been calculated by summing up the concentrations of RSPM and SPM. Triplicate samples have been collected and analyzed for all the seasons and depicted in the results. Air quality indices (AQI) have also been calculated from the collected data using the mathematical formula suggested by Rao and Rao (1998):

$$AQI = 1/3\left[\left(SO_2/sSo_2\right) + \left(NO_x/sNO_x\right) + \left(SPM/sSPM\right)\right] \times 100$$

Where,

SO_2= Individual concentration of sulphur dioxide

NO_x= Individual concentration of nitrogen oxide

SPM= Individual concentration of suspended particulate matter

sSO_2, sNo_x and sSPM= standards of ambient air quality of SO_2, No_x and SPM prescribed by CPCB (Table-4).

Results and Discussion

The data comprising of average concentration of SO_2, NO_2, RSPM and SPM for the studied sites during the study period has been depicted in Tables-2 and 3. For Site-I, the average concentration of SO_2 and NO_2 during the first year study period ranged from 5.550 µg/m^3 to 12.728

Table-2: Seasonal averages of SO_2 and NO_2 at study sites in Jammu city for the study period (December 2013 to November 2015)

			First year (December 2013-November 2015)			Second year (December 2013-November 2015)			Two years
Sites	Seasons	Parameters	Max ($\mu g/m^3$)	Min ($\mu g/m^3$)	Average ($\mu g/m^3$)± Std dev	Max ($\mu g/m^3$)	Min ($\mu g/m^3$)	Average ($\mu g/m^3$)± Std dev	Average ($\mu g/m^3$)± Std dev
Site-I University Campus	Monsoon	SO_2	7.071	3.969	5.550±1.55	8.257	5.794	6.858±1.26	6.204±1.45
		NO_2	8.335	5.834	7.224±1.27	9.169	5.417	7.085±1.91	7.154±1.45
	Summer	SO_2	10.99	7.89	9.291±1.57	14.644	9.900	11.937±2.44	10.614±2.34
		NO_2	22.509	10.00	15.561±6.37	24.176	11.670	17.229±6.37	16.395±5.77
	Winter	SO_2	14.0	11.633	12.728±1.2	16.743	12.181	14.005±2.41	13.367±1.84
		NO_2	35.014	19.174	27.233±7.92	38.350	30.846	33.903±3.94	30.568±6.68
Site-II Satwari-Bikram chowk road	Monsoon	SO_2	29.88	20.027	24.954±4.93	32.071	18.841	24.802±6.71	24.878±5.27
		NO_2	40.850	25.844	34.459±7.75	45.019	29.179	36.126±8.1	35.293±7.15
	Summer	SO_2	35.498	24.498	29.486±5.48	40.374	26.779	32.832±6.92	31.159±5.88
		NO_2	55.857	20.01	39.183±18.05	59.193	31.680	43.352±14.22	41.268±14.71
	Winter	SO_2	45.94	37.728	41.986±4.11	60.630	41.378	51.445±9.65	46.715±8.42
		NO_2	71.698	42.518	57.247±14.59	82.537	61.694	71.421±10.49	64.334±13.76
Site-III Kunjwani-Narwal Byepass	Monsoon	SO_2	23.951	11.907	17.229±6.14	27.509	10.812	19.967±8.46	18.598±6.78
		NO_2	37.5160	21.675	29.179±7.95	44.186	23.343	32.514±10.64	30.846±8.60
	Summer	SO_2	37.272	22.947	30.094±7.16	41.834	29.334	36.390±6.4	33.242±6.99
		NO_2	65.029	33.347	48.354±15.91	64.195	35.848	49.744±14.18	49.049±13.50
	Winter	SO_2	44.936	34.170	39.249±5.41	54.151	39.279	47.065±7.46	43.157±7.23
		NO_2	72.532	62.528	66.974±5.09	78.369	56.692	67.530±10.84	67.252±7.58

Table-3: Seasonal averages of RSPM, SPM & TSPM at study sites in Jammu city for the study period (December 2013 to November 2015)

			First year (December 2013-November 2015)			**Second year (December 2013-November 2015)**			**Two years**
Sites	**Seasons**	**Parameters**	**Max ($\mu g/m^3$)**	**Min ($\mu g/m^3$)**	**Average ($\mu g/m^3$) ±Std dev**	**Max ($\mu g/m^3$)**	**Min ($\mu g/m^3$)**	**Average ($\mu g/m^3$) ±Std dev**	**Average ($\mu g/m^3$) ±Std dev**
Site-I University Campus	Monsoon	RSPM	76.952	59.790	67.677±8.66	66.667	53.419	60.740±6.73	64.208±7.91
		SPM	97.597	72.87	81.444±14.00	135.234	98.960	113.678±19.08	97.561±23.14
		TSPM	174.55	132.66	149.120±22.34	197.369	152.379	174.418±22.51	161.769±24.38
	Summer	RSPM	91.967	79.909	87.008±6.31	93.423	79.909	87.493±6.91	87.250±5.92
		SPM	125.751	104.642	112.973±11.23	142.000	117.960	129.935±12.02	121.454±13.95
		TSPM	214.90	184.551	199.981±15.18	223.268	207.107	217.428±8.96	208.704±14.68
	Winter	RSPM	149.573	99.119	116.729±28.47	183.333	113.304	143.671±35.93	130.20±32.53
		SPM	176.28	140.67	153.374±19.88	201.858	142.544	163.759±33.07	158.566±25.05
		TSPM	292.745	242.17	270.103±25.70	336.233	260.179	307.430±41.25	288.766±36.91
Site-II Satwari-Bikram chowk road	Monsoon	RSPM	185.389	108.33	141.733±39.54	202.448	102.713	157.276±50.53	149.505±41.46
		SPM	275.33	140.625	204.084±67.69	400.190	180.235	271.252±114.78	237.667±91.95
		TSPM	460.719	248.955	345.817±107.03	202.448	102.713	428.528±78.25	251.546±127.54
	Summer	RSPM	402.188	279.07	354.714±66.22	451.852	297.365	376.757±77.33	365.735±65.51
		SPM	432.754	337.209	395.007±50.83	483.330	325.855	415.146±80.83	405.076±61.39
		TSPM	817.246	616.279	749.721±115.57	451.852	297.365	791.903±157.53	563.239±222.41
	Winter	RSPM	707.929	574.434	643.878±66.91	1029.531	776.973	888.753±128.75	766.316±162.51
		SPM	782.767	635.113	733.549±85.25	1272.249	817.230	1029.149±229.11	881.349±223.87
		TSPM	1490.696	1209.547	1377.427±148.32	1029.531	776.973	1917.902±336.04	1133.090±295.08
Site-III Kunjwani-Narwal Byepass	Monsoon	RSPM	202.448	110.239	156.555±46.11	242.424	95.721	172.775±73.63	164.66±55.66
		SPM	233.051	147.608	188.902±42.79	375.000	163.290	263.263±106.34	226.082±83.16
		TSPM	390.028	296.285	345.456±47.04	242.424	95.721	436.038±179.25	259.116±109.54
	Summer	RSPM	339.015	284.508	316.174±28.30	443.333	151.515	317.599±150.04	316.887±96.57
		SPM	376.894	339.574	358.267±18.66	478.330	321.970	389.240±80.43	373.753±54.91
		TSPM	701.894	624.082	674.441±43.67	443.333	151.515	706.839±202.71	496.020±219.01
	Winter	RSPM	754.45	545.345	645.644±104.81	970.209	726.651	829.239±126.23	737.441±144.50
		SPM	835.356	616.36	754.267±120.05	1010.467	894.010	957.558±58.95	855.912±139.83
		TSPM	1589.806	1161.705	1399.910±218.10	970.209	726.651	1786.797±85.62	1114.574±350.86

Table-5: Air quality indices of the selected sites during the study period (mean of three replicates ± SD)

		First year						Second year					
		Parameter (µg/m^3)				Air quality index	Remarks	Parameter (µg/m^3)				Air quality index	Remarks
Site	Season	SO_2	NO_2	RSPM	SPM			SO_2	NO_2	RSPM	SPM		
Site-I University Campus	Monsoon	5.550 ±1.55	7.224±1.27	67.677 ±8.66	81.444 ±14.00	27.88	Light air pollution (LAP)	6.858 ±1.26	7.085 ±1.91	60.740 ±6.73	113.678 ±19.08	26.05	Light air pollution (LAP)
	Summer	9.291 ±1.57	15.561 ±6.37	87.008 ±6.31	112.973 ±11.23	39.36	Light air pollution (LAP)	11.937 ±2.44	17.229±6.37	87.493 ±6.91	129.935 ±12.02	41.31	Light air pollution (LAP)
	Winter	12.728 ±1.2	27.23±7.92	116.729 ±28.47	153.374 ±19.88	55.56	Moderate air pollution (MAP)	14.005 ±2.41	33.903±3.94	143.671 ±35.93	163.759 ±33.07	67.84	Moderate air pollution (MAP)
Site-II Satwari-Bikram chowk road	Monsoon	24.954 ±4.93	34.459 ±7.75	141.733 ±39.54	204.084 ±67.69	71.99	Moderate air pollution (MAP)	24.802 ±6.71	36.126±8.1	157.276 ±50.53	271.252 ±114.78	77.80	Heavy air pollution (HAP)
	Summer	29.486 ±5.48	39.183 ±18.05	354.714 ±66.22	395.007 ±50.83	146.83	Severe air pollution (SAP)	32.832 ±6.92	43.352±14.22	376.757 ±77.33	415.146 ±80.83	157.31	Severe air pollution (SAP)
	Winter	41.986 ±4.11	57.247 ±14.59	643.878 ±66.91	733.549 ±85.25	255.95	Severe air pollution (SAP)	51.445 ±9.65	71.421±10.49	888.753 ±128.75	1029.149 ±229.11	347.41	Severe air pollution (SAP)
Site-III Kunjwani-Narwal Byepass	Monsoon	17.229 ±6.14	29.179 ±7.95	156.555 ±46.11	188.902 ±42.79	71.51	Moderate air pollution (MAP)	19.967 ±8.46	32.514±10.64	172.775 ±73.63	263.263 ±106.34	79.45	Heavy air pollution (HAP)
	Summer	30.094 ±7.16	48.354 ±15.91	316.174 ±28.30	358.267 ±18.66	138.06	Severe air pollution (SAP)	36.390 ±6.4	49.744±14.18	317.599 ±150.04	389.240 ±80.43	141.74	Severe air pollution (SAP)
	Winter	39.249 ±5.41	66.974 ±5.09	645.644 ±104.81	754.267 ±120.05	259.45	Severe air pollution (SAP)	47.065 ±7.46	67.530±10.84	829.239 ±126.23	957.558 ±58.95	324.13	Severe air pollution (SAP)

µg/m^3 and 7.224 µg/m^3 to 27.233 µg/m^3, respectively whereas during the second year, their values ranged from 6.858 µg/m^3 to 14.005 µg/m^3 and 7.085 µg/m^3 to 33.903 µg/m^3, respectively. The average concentration of RSPM and SPM during the first year study period ranged from 67.677µg/m^3 to 116.729µg/m^3 and 81.444µg/m^3 to 153.374µg/m^3, respectively whereas during the second year, their values ranged from 60.740µg/m^3 to 143.671µg/m^3 and 113.678 µg/m^3 to 163.759 µg/m^3, respectively. The average concentration of TSPM during the first year study period ranged from 149.120 µg/m^3 to 270.103 µg/m^3 whereas during the second year, their values ranged from 174.418 µg/m^3 to 307.430 µg/m^3.

Table-4: National ambient air quality standards, CPCB

Location type	Permissible limits in µg/m^3			
	SO_2	NO_2	RSPM	SPM
Industrial	80	80	100	200
Residential and other areas	80	80	100	200
Ecologically sensitive areas	80	80	100	200

Table-6. Rating scale for AQI.

Index value	Remarks/Category
0-25	Clean air (CA)
26-50	Light air pollution (LAP)
51-75	Moderate air pollution (MAP)
76-100	Heavy air pollution (HAP)
>100	Severe air pollution (SAP)

Source: Rao and Rao (1998)

For Site-II, the average concentration of SO_2 and NO_2 during the first year study period ranged from 24.954 µg/m^3 to 41.986 µg/m^3 and 34.459 µg/m^3 to 57.247 µg/m^3, respectively whereas during the second year, their values ranged from 24.802 µg/m^3 to 51.445 µg/m^3 and 36.126 µg/m^3 to 71.421 µg/m^3, respectively. The average concentration of RSPM and SPM during the first year study period ranged from 141.7333 µg/m^3 to 643.878 µg/m^3 and 204.084 µg/m^3 to 733.549 µg/m^3, respectively whereas during the second year, their values ranged from 157.276 µg/m^3 to 888.753 µg/m^3 and 271.252 µg/m^3 to 1029.149 µg/m^3. The average concentration of TSPM during the first year study period ranged from 345.817 µg/m^3 to 1377.427 µg/m^3, respectively whereas during the second year, their values ranged from 428.528 µg/m^3 to 1917.902 µg/m^3.

For Site-III, the average concentration of SO_2 and NO_2 during the first year study period ranged from 17.229 µg/m^3 to 39.249 µg/m^3 and 29.179 µg/m^3 to 66.974 µg/m^3 , respectively whereas during the second year, their values ranged from 19.967 µg/m^3 to 47.065 µg/m^3 and 32.514 µg/m^3 to 67.530 µg/m^3, respectively. The average concentration of RSPM and SPM during the first year study period ranged from 156.555 µg/m^3 to 645.644 µg/m^3 and 188.902 µg/m^3 to 754.267 µg/m^3, respectively whereas during the second year, their values ranged from 172.775 µg/m^3 to 829.239 µg/m^3 and 263.263 µg/m^3 to 957.558 µg/m^3, respectively. The average concentration of TSPM during the first year study period ranged from 345.456 µg/m^3 to 1399.910 µg/m^3 whereas during the second year, their values ranged from 436.038 µg/m^3 to 1786.797 µg/m^3. All the studied sites registered increase in the concentration of all the studied pollutants in the second year compared to first year. Also, in the present investigation, increase in the concentrations of all the studied parameter have been recorded as compared to the earlier study carried out by Raina and Bala (2011) in some of these areas. This indicates that every year we add up more pollutants to our ambient air rather than making efforts to alleviate the pollutant levels. It is evident from Table-1 that the number of vehicles plying on road is increasing each passing year thus adding up more pollutants to the ambient air than the previous year.Analysis of seasonal data revealed that all the studied pollutants registered maximum concentration during the winter season at all the sites whereas minimum concentrations have been observed during the monsoon season at all the sites.The lower concentrations of studied pollutants at Site –I can be attributed to comparatively low traffic flow rate, good road condition, greenery and well- managed vehicle movement as compared to Site- II and III.Frequent traffic jams due to poor driving sense and mismanagement of traffic, boarding and de-boarding of passengers from buses and matadors at undesignated places in Satwari-Bikram Chowk road (Site-2) leads to higher emission of pollutants. Emission rates from vehicles are higher during stop-and-go and congested traffic conditions than at free flow conditions with same average speed operation. More automobile emissions are released into the atmosphere when low speed conditions prevail due to traffic congestion (Nesamani, 2009; Sood, 2012).There is a heavy movement of both light and heavy vehicles on Kunjwani-Narwal Byepass (Site-3). Also, there are large number of automobile showrooms present on byepass, eventually plying of carriage trucks of new automobiles is a daily routine in this area. Vehicles with large engines produce more pollutants as pointed out by Fazal (2006). Lot of construction activities are also taking place at this site which contribute to higher emissions of coarse particulate matter (Namdeo and Bell, 2005 and Muchate and Chougule, 2011). During the monsoon season, low concentration of particulate matter and gaseous pollutants has been reported by various workers (Ingle *et al.,* 2005; Bhaskar and Mehta, 2010; Mamata and Bhassin, 2010; Sharma and Raina, 2012 and Sharma and Raina, 2015). In the present study also, lower concentration of pollutants, both particulate and gaseous, has been recorded during the monsoon season for both years at all the sites. This advocates the cleansing action of precipitation on the pollutants present in ambient air. Ravindra *et al.,* (2003) also reported the attenuation of concentration of the pollutants in the air due to changes in general wind direction and adequate precipitation.

Higher levels of particulate and gaseous pollutants have been observed during winter season for both the years at all the sites. Stable atmospheric conditions due to season-specific meteorological influences tend to hamper dispersion and removal of air pollutants, thus enhance the ground level concentration of pollutants. Removal of pollutants by wet scavenging is also greatly reduced in winters due to inadequate precipitation (Goyal and Sidhartha, 2003; Ingle *et al.,* 2005; Nidhi and Jayaraman, 2007 and Sharma and Raina, 2015).

Moderate levels of both particulate and gaseous pollutants have been observed during summer season for both the years at all the sites. The average height of planetary boundary layer is greatest in summer seasons, thus boosting the mixing of air and atmospheric dispersion, hence alleviate the concentration of pollutants in the atmosphere (Goyal and Sidhartha, 2003). Local disturbances in the atmosphere coupled with turbulent conditions caused by strong and medium winds, delay the breakdown of pollutants in the ambient air (Goswami and Baruah, 2008).

However, the concentration of gaseous pollutants has been found to be well within the NAAQS (National Ambient Air Quality Standards) limits as stipulated by CPCB (Central Pollution Control Board) presented in Table-4.Analysis of air quality indices of the selected sites for the study period depicted the apathy of expanding vehicular fleet in Jammu city every year. Site-I registered Light to moderate air pollution status whereas Site-II and III have registered moderate to severe air pollution category (Tables-5 and 6). As evident from the table, air quality of sites-II and III has deteriorated more in the second year of the study period (Dec 2014-Nov 2015) than the previous year, thereby indicating a clear impact of increasing vehicular pollution on the air quality of the city.

Conclusion

Present study revealed the higher concentration of all the studied pollutants viz. SO_2, NO_2, RSPM and SPM in the second year of study (i.e. Dec 2014-Nov 2015) from the previous year (i.e. December 2013 to November 2014) due to rise in number of vehicles plying on road. Seasonal analysis of data has pointed out that monsoon period recorded least concentration of pollutants while winter season registered highest levels of the year at all the sites. Air quality status of the Site-II and Site-III fall in moderate to severe air pollution quality category whereas Site-I fall in light to moderate air pollution quality category. Also, the ill-maintenance of the roads, plying of improperly managed and old vehicles on road, less green cover on roadsides and large number of vehicles being registered and commuting every day, are some of the major hurdles in the process of air pollution management.

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