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AIR QUALITY INDICES TO UNDERSTAND THE AMBIENT AIR QUALITY IN VICINITY OF DAM SITES OF DIFFERENT IRRIGATION PROJECTS IN KARNATAKA STATE, INDIA

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ABSTRACT
Ambient air quality monitoring was carried out in the vicinity of dam and nearby residential sites in four river basins in Karnataka with reference to SPM, RSPM, SO_2 and NOx, employing Envirotech APM-460 Respirable Dust Sampler with provision to keep impingers having absorbing reagent. Further, three different methods of Air quality index (AQI) calculation on based on SPM and RSPM values were used to evaluate the prevailed ambient air quality in the near and surroundings areas at the time of dam constructional activities. The concentrations of SPM, RSPM, SO_2 and NO_x near the dam sites were respectively 540, 170, 5.8 and 17.9 $\mu g/m^3$ in Varahi river basin; 440, 158, 3.8 and 11.4 $\mu g/m^3$ in SLIS river basin and, 255.55, 83.3, 2.0 and 1.7$\mu g/m^3$ in SRLIS river basin. The SPM, RSPM and SO_2 concentrations was 340, 70 and 0.3 $\mu g/m^3$ in the vicinity of dam site of Bellary nala river basin while NO_x concentration was below the detectable limit. AQI calculations revealed that the dam sites in all four river basins were high to severely pollute compared to other monitored stations, owing to its construction activities.

KEYWORDS: Suspended particulate matter (SPM), Respirable suspended particulate matter (RSPM), Quality Rating, Air quality index (AQI), Oak Ridge National Air Quality Index (ORAQI).

INTRODUCTION

Air pollution a potentially lethal form of pollution occurs in the form of gases or particles in the atmosphere due to continuous mixing, transformation and trans-boundary transportation of air pollutants that make air quality of a locality unpredictable. The air we breathe can get polluted by natural contaminants like fogs, pollen, bacteria, mist products from volcanic eruption apart from mad-made contaminants like dust, smoke, fumes and gases from vehicles and industrials, aerosols *etc*. The growth of population, industry and number of vehicles and improper implementation of stringent emission standards make the problem of air pollution still worse (Ravindra *et al*., 2001). During the past decade, the annual mean levels of respirable suspended particulates and oxides of nitrogen and ozone have increased and exceeded the air quality (Chan-Yeung, 2000) and adverse health effects of air pollution, even at relatively low levels remain a public concern (Ren and Tong, 2008). However, the magnitude of effect estimates varies across cities and countries (Analitis *et al*., 2006; Katsouyanni *et al*., 2001; Samet *et al*., 2000a), hindering interpretation and generalization of the causal association between air pollution and health. Air pollution is increasingly documented as a threat to public health in most developing countries because the analysis at various localities showed that long-term exposure to $PM_{2.5}$ increases the risk of non-accidental mortality by 6% per a 10 $\mu g/m^3$ increase, independent of age, gender, and geographic region and exposure to SO_2 increases mortality from lung cancer (Chen *et al*., 2008; Dutton *et al*., 2009). Some investigators have attempted to explain the heterogeneity of effect estimates among regions in terms of different levels of air pollutants (Samoli *et al.*, 2001), characteristics of pollutants (Samoli *et al*., 2005), specific city characteristics (Samoli *et al*., 2007), and potential confounders including temperature and humidity (Aga *et al*., 2003; Zeka *et al*., 2005). Evaluation of current air quality levels, regulatory standards and scientific literature on outdoor and indoor air pollution, and health effects are important to identify the burden, develop and implement interventions and to fill knowledge gaps in urban areas (Nandasena *et al.*, 2010). The major sources for atmospheric particles are industrial activities, energy production, construction, urban waste treatment and vehicle exhaust (Bilos *et al*., 2001). The trends of urbanization and population growth has resulted more number of vehicles and contributing vehicular gaseous emissions such as SO_2, NO_x, CO, O_3, benzene and hydrocarbons (Bhanarkar *et al*., 2005). Even after decades of industrialization, air pollution has become a major environmental issue for both developed and developing countries as poor air quality has both acute and chronic effects on human health (Yang *et al.*, 2004, Afroz *et al.*, 2003). The relationship between environment and the development is one of the most burning issues of the present times. In recent years, a large number of studies on health impacts due to air pollution have been undertaken in developing countries (Anonymous, 1980). Despite the increasing evidence of negative impact of air quality on human health (Dockery *et al*., 1993a, b; Pope *et al*., 1995; Künzli *et al*., 2000), not much data on ambient air quality, a pre-requisite for health studies, is available for most of the medium size cities or towns.

Among air pollutants, particulate matter (PM) is a ubiquitous and it is especially a major problem due to its substantial adverse health effects, visibility reduction and soiling of buildings (Seinfield, 1975). Atmospheric particulate matters (PM) have been of significant environmental attention due to their impact on human health, plants, aquatic life and materials (Banerjee and Pandey, 1989; Pradeepta K. Bhuyan *et al.*, 2010). Further, the presence and distribution of varied concentration of pollutants in the atmosphere is mainly dependent upon the type of the source, such as fixed or mobile, anthropogenic or natural sources, and also associated with the level of economic activity. Additionally the meteorological and topographical factors directly affect the distribution and movement of these air pollutants, culminating in ambient concentrations that may harm people, structures, and environment. In general, the effects on people are most intense in large urban centers with significant emission sources, unfavorable dispersion characteristics and high population densities. Pollution type, extent, and duration of exposure, age, individual susceptibility, and other factors play a significant role in determining whether someone will experience pollution-related health problems. Hence, an attempt was made in the present study to compare the levels of SPM, RSPM, SO_2 and NO_2 during construction phase at different environmental backdrops near the vicinity of dam sites of four irrigation projects initiated at different river basins in Karnataka State, India, Namely, SLIS (Singatalur lift Irrigation scheme), SRLIS (Sri Rameshwara nala lift irrigation scheme) and Bellary nala river basins in Belgaum district and Varahi river basin in Udupi district. An effort has also been made to gather information on the noise quality prevailed near the dam site during construction.

Study Area

Varahi river basin, located in Udupi district, with its dam site situated at approximately 6 kms from Siddapura, Kundapura taluk, Udupi district with a latitude of 13^0 39'15" N and a longitude of 74^0 57'0"E. The total drainage area of the river is about 755.20 sq km. This river basin is having a catchment area of 293.0 Km^2 (29300 ha) command area of 157.02 Km^2 (15702 ha) covering part of Kundapura (83.24 Km^2) and Udupi (73.78 Km^2) taluks of Udupi District. River Varahi is a major west flowing river in the west coast in Udupi district, which originates from the high peaks of the Western Ghats near Guddakoppa village in Hosanagar taluk, Shimoga district at an altitude of about 761m above MSL and flows for a length of 88 kms. Stream collects heavy rainfall in the hilly region around Agumbe and Hulikal and tributaries like Hungedhole, Kabbenahole, Dasnakatte, Chakranadi *etc*., will join Varahi before emptying into the Arabian Sea. The net irrigable command area by flow irrigation is 129.79 Km^2 (12,979 ha) and by lift irrigation is 27.23 Km^2 (2723 ha), to provide enhanced irrigation facilities and an improved drinking water system to the villages of two taluks of Udupi district by means of canal system in addition to hydroelectric power generation.

SLIS (Singatalur lift Irrigation scheme) river basin stretched in Gadag, Koppal & Bellary districts, is subjected to frequent drought and famine, affecting the life and economic status of the population, which subsist mainly on agriculture. A barrage was constructed across Tungabhadra river near Hammigi village, which is geographically located at 15^0 02' N Latitude and 75^0 50' E Longitude, 30 Km towards south of Mundargi in Gadag district of Mundargi taluk and 12 Km west of Huvinahadagali town in Bellary district. The total catchment area is 19850 Km^2 (7754 sq. miles) and command area is 480.94 Km^2. The command area provides irrigation facility to taluks of Gadag, Koppal and Bellary districts, covering Mundargi and Gadag taluk in Gadag District; Koppal taluk in Koppal District on left side and Hadagali taluk in Bellary District on right side, which receives ill-distributed, very low rainfall.

SRLIS (Sri Rameshwara nala lift irrigation scheme) river basin comes under northern dry zone of tenfold Agro-climatic zone of Karnataka. An intake structure / lift (75^0 04' 15" E longitude and 16^0 19' 30" N latitude) has been constructed across the river Ghataprabha near Aralimatti village in Gokak Taluk, Belgaum District, which is located towards north of Koujalgi in Gokak Taluk. Its command area has been distributed in Ramdurg and Saudatti taluks of the Belgaum district. The net irrigable command area is 138.0 Km^2 (13800 ha). Gross command area of 180.23 Km^2 (18022.7 ha) was brought under irrigation from the proposed project covering 29 villages in Gokak, Ramdurg and Saundatti taluk of Belgaum district.

Bellary nala river basin fall under northern dry and transition zone of tenfold Agro-climatic zone of Karnataka and has a semiarid subtropical climate, located at 722m elevation above MSL (mean sea level). Bellary nala is a major tributary of Markandeya river, near Yellur village in Belgaum taluk, which carried with it sewerage water of Belgaum city along with the rainwater flow. The dam site of Bellary nala river basin is geographically located at 15^0 58' N latitude and 74^0 38' E Longitude, which crosses Bellary Nala near Karadigudda near Hudli village (about 26 km from Belgaum city) in Belgaum Taluk. The total catchment area of Bellary Nala is 254 km^2 (25400 ha). The net command area is 82 km^2 (8200 Ha) stretching to 15 km^2 (1500 ha) in Gokak and 67 km^2 (6700 ha) in Saudatti Taluks of Belgaum District. Bellary Nala irrigation project aimed at irrigating agricultural lands of drought fed villages coming under Gokak and Saundatti taluks, Belgaum district.

MATERIALS & METHODS

The number of locations depends upon the variability of concentration over the area under survey. In the present study, a spot-checking was done to decide the location besides considering practical factors. Accordingly, a total of 10, 9, 5 and 5 sampling stations were selected respectively in Varahi, SLIS, SRLIS and Bellary nala river basins.

Ambient air quality studies: Sample collection and Analysis

Ambient air quality status in the vicinity of dam sites of four river basins under construction was assessed by monitoring of criteria pollutants namely, total suspended particulate matter (TSPM), respirable suspended particulate matter (RSPM), nitrogen oxides (NO_x), oxides of sulphur (SO_2) using Envirotech APM-460 Respirable Dust Sampler by time averaged in–situ sampling method. The sampling was carried out from 08:00 hrs from morning to evening on each sampling day during pre-monsoon season of the year 2005. Initially, the Whatman glass microfiber filter paper (size: 8” x 10”) and plastic cup were conditioned in an oven at 60^0 C for 2 hr and their respective initial weights was taken immediately. The filter paper is placed over the filter paper holding assembly and the screws of the bracket were tightened while the plastic cup is fixed to cyclone hopper (Fig 1). Simultaneously, the air-dried and distilled water washed gaseous impingers/ gas sampler/ midget impingers/ bubblers having absorbing reagent were placed and connected to manifold inlet and outlet in the respirable dust sampler in order to dissolve gaseous SO_2 and oxides of nitrogen. The sampler was turned on after setting the sampling time to record the initial flow rate with the help of airflow manometer. Ambient air laden with suspended particulates enters the dust sampler though inlet pipe at a maintained flow rate of 0.9 to 1.2 m^3/min (average: 1.1 m^3/min) through high efficiency cyclone. As the air passes through the cyclone, coarse non-respirable dust particles (> 10 micron size) get separated from air stream by centrifugal forces acting on them, which cyclones conical hopper and collects in sampling plastic cup fitted at its bottom. The fine dust (< 10 micron particles) forming the respirable fraction of the total suspended particulate matter (TSPM) passes through cyclone and is carried by air stream to reach filter paper clamped between the top cover and filter paper adapter assembly. The respirable dust (RSPM) is retained by the filter paper (10 µ to 0.5 µ size) and carrier exhausted from the system through blower. The flow rate at the end of the desired sampling period was recorded and the sampler was switched off. Both the exposed filter and plastic cup were conditioned again for the same period as it was done prior to sampling to record their final weight after sampling. The passage of air entering in the cyclone is designed in such a way to prevent heavier settleable particles from reaching in the cyclone. The instrument provides instantaneous flow rate and the period of operation (on time) for calculation of air volume passed through the filter, while initial and final weights of exposed filter paper and plastic cup were used to calculate SPM and RSPM concentration.

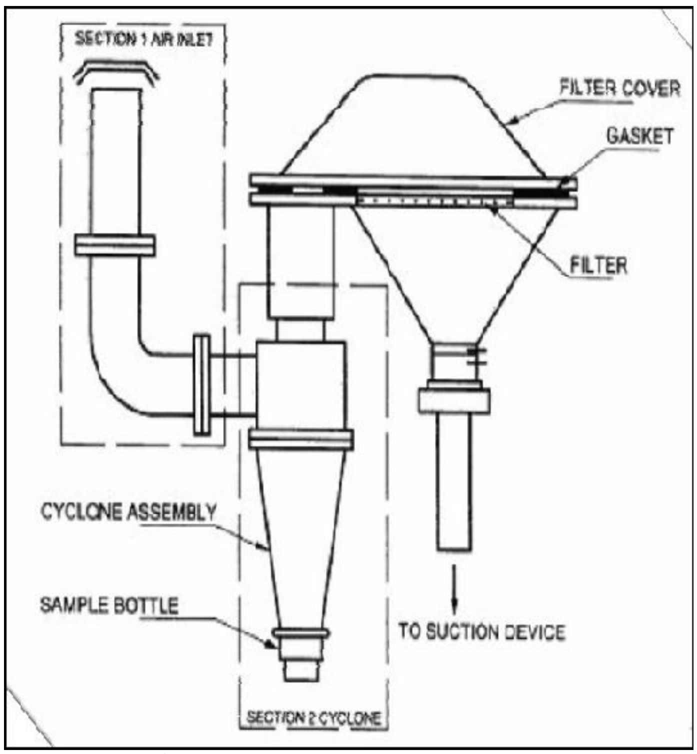

FIGURE 1. Schematic representation of Envirotech APM-460 High Volume Respirable Dust sampler equipped with Cyclone

The standard colorimetric methods were used for determining the concentration of NO_x and SO_2. The *Jacob and Hochheiser method* for NO_x (Jacobs and Hochheiser, 1958) and *Modified West and Gaeke / West and Ordiveza methods* for SO_2 (West and Gaeke, 1956; West and Ordiveza, 1962). The Noise levels were recorded using Sound level meter (Quest Make USA).

Table 1 summarizes the Ambient air quality standards recommended by National Ambient Air Quality Standards (NAAQS), Central Pollution Control Board CPCB) and World Health Organization (WHO) while Table 2 provides the Ambient air quality standards for noise levels adopted by CPCB, Government of India**.**

TABLE 1. National Ambient Air Quality Standards (NAAQS / CPCB) and WHO Recommendations

Parameter	Time Weighted Average	Concentration in Ambient Air			WHO Recommendations
		Residential and other Areas	Industrial Area	Sensitive Area	
SPM ($\mu g/m^3$)	24 Hours	200	500	100	150-230
	Annual	140	360	70	60-90
RSPM ($\mu g/m^3$)	24 Hours	100	150	75	70
	Annual	60	120	50	---
Sulphur Dioxide ($\mu g/m^3$)	10 Minutes	-	-	-	500
	1 Hour	-	-	-	350
	24 Hours	80	120	30	100-150
	Annual	60	80	15	40-60
Nitrogen Oxide ($\mu g/m^3$)	1 Hour	-	-	-	400
	24 Hours	80	120	30	150
	Annual	60	80	15	-
Carbon monoxide (mg/L)	1 Hour	04	10	02	30
	8 Hours	02	05	01	10
Carbon dioxide (mg/L)	1 hour	--	--	--	--
	8 hour	--	--	--	--

TABLE 2. Ambient Quality Standards of Noise levels adopted by CPCB

Area Code	Area	Permissible levels of Noise in Ambient Air	
		Day Time (6 am to 9 pm)	Night Time (9 pm to 6 am)
A	Industrial Area	75	70
B	Commercial area	65	55
C	Residential Area	55	45
D	Sensitive Area (areas up to 100 meter around such premises as hospitals, educational institution, courts)	50	40

Air Pollution Indices (APIs)/ Air Quality Indices (AQIs)

An environmental index is a tool, which is used to report the overall environmental status and trends based on a specific standard and was developed on the lines of health index and measured by the degree of human suffering. Each AQI category makes it easier for the general public to understand how clean or polluted the air is. Overall air pollution measures can be used to give meaningful assessment of air pollution to the common man. They also helps to evaluate the alternative air pollution control policies or control equipment which, for instances, can reduce the level of certain pollutants while increasing the levels of others. AQI can represent the overall air quality status in a better way since the cumulative effect of all the pollutants and the related standard can be taken into account. As a result we can obtain an equation, which transforms the parameter values by means of numerical manipulation into a more simple and precise form. To evaluate overall air pollution due to various pollutants is complex as it consists of an ill-defined mixture of several pollutants from different sources. The index of specific pollutant is derived mainly from the physical measurement of pollutants like SPM, RSPM, SO_2 and NO_2. In the present study, three different methods were followed to calculate ambient quality indices although several methods and equations used for determining the AQI (Inhaber, 1974).

Method I

Air Quality Index (AQI) is calculated based on the average of the sum of the ratios of three pollutants (RAPM, SOs and NOx) to their respective air quality standards. The average is then multiplied by 100 to get the AQI index (Rao and Rao, 2001).The AQI values compared with rating scale. AQI was calculated using the method suggested by Tiwari and Ali (1987) and followed by Kaushik *et al*. (2006). For AQI, the air quality rating of each quality parameters / pollutant (here RSPM and SPM only) was calculated first by the following formula:

$$Q = \left(\frac{V}{V_S}\right) 100 \dots\dots\dots\dots\dots\dots (1)$$

Where,

Q = represents quality rating,

V = the observed value of the air quality parameters pollutant (SPM, RSPM)

V_S= the standard value for that pollutant recommended by NAAQS / CPCB for different areas (CPCB, 1994).

If Q < 100, the given parameter is within the prescribed limit. On the other hand, if Q > 100, it implies that the I^{th} parameter exceeds the prescribed standard and the ambient air is harmful for breathing by human beings. It is assumed that all the parameters have the equal importance and so only the unweighted air quality indices are calculated. The geometric unweighted AQI may be calculated from the quality rating Q by taking their geometric mean.

$$\mathrm{AQI} = [\pi Q_{i=1}^{n}]^{(1/n)} \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

This relation is simplified to some extent by taking the common logarithm on both sides.

$$\mathrm{Log\ AQI} = [\mathrm{Log}\ Q_1 + \mathrm{Log}\ Q_2 + \ldots\ldots + \mathrm{Log}\ Q_n]/n \ldots\ldots(3)$$

Combining the right hand side factors

$$\mathrm{Log\ AQI} = \left[\sum_{i=1}^{n} \mathrm{Log}\ Q_1\right]/n \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Hence,

$$\mathrm{AQI} = \mathrm{Antilog}\left[\sum_{i=1}^{n} \mathrm{Log}\ Q_1\right]/n \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The ambient air quality index can be calculated using equation 1 and 5. Alam *et al*., (1999) has established seven grades (viz., I to VII grades) of air quality categories such as *very clean* (AQI < 10), *clean* (10 ≥ AQI < 25), *fairly clean* (25 ≥ AQI < 50), *moderately polluted* (50 ≥ AQI < 75), *polluted* (75 ≥ AQI < 100), *highly polluted* (100 ≥ AQI < 125) and *severely polluted* (AQI ≥ 125). Based on these standard AQI values, air quality of the observed air samples can be compared and inferred.

Method II

The Oak Ridge National Air Quality Index (ORNAQI) can be considered for the relative ranking of an overall air quality status at different locations of the study area. AQI for each location in the study area was estimated with the help of a mathematical equation developed by the Oak Ridge National Laboratory (ORNL), USA as given below.

$$\mathrm{AQI} = \left[39.02 \sum \frac{X_i}{X_S}\right]^{0.967} \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where X_i = value of air quality parameters (SPM, RSPM)
X_s= Standard prescribed for air quality parameters

Relative ORAQI can be placed under five grades of air quality categories (viz., A to E) such as *clean air* (0 ≥ AQI ≤ 25), *light air pollution* (26 ≥ AQI ≤ 50), *moderate air pollution* (51 ≥ AQI ≤ 75), *heavy air pollution* (76 ≥ AQI ≤ 100), *severe air pollution* (AQI > 100). Accordingly, none or minimal health effects is associated with *clean air* while, *light air pollution* leads to possible respiratory or cardiac effect for most sensitive individuals. *Moderate air pollution* leads to increasing like hood of respiratory and cardio-vascular symptoms and illness while *heavy air pollution* to aggravation of heart or lung disease, increased risk of death in children (heart and lung disease) and increased effects in general population. Further, serious aggravation of heart or lung disease/ increased risk of premature death / series risk of cardio-respiratory symptoms in general populations are associated with *severe air pollution*. Air quality of the sampled air samples can be compared and interpreted based on these relative ORAQI values.

Method III

Air quality index (AQI) was done for combining qualitative measures with qualitative concept of the environment. An 'index' is a single number derived from two or more indicators. The first step in computing index is to calculate the individual indicator (viz., sub-indices), one for each assessment variable. There are many methods by which sub-indices can be calculated viz., linear, segmented linear, non-linear functions or by using the actual concentrations. The sub-index here is calculated as follows:

$$I_i = \frac{W_i X_i}{X_{si}} \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where
W_i = weightage of pollutant 'i'
X_i= Concentration of pollutant 'i' (µg/m^3)
X_s= Standard of pollutant 'i' (µg/m^3)

All air pollutant variables (SPM, RSPM) have been given equal importance or given same weightage (W_i = 1) and same averaging time as that of the standards. Thus, the total index is calculated as follows:

$$I = \sqrt{\frac{1}{N}\sum_{i=1}^{N} I_i^{\,2}} \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where N= the number of air quality variables.

The descriptor categories '*Acceptable*' (0.0 ≥ AQI ≤ 0.5) corresponds to values of concentrations near their background levels; '*Unacceptable'* (0.51 ≥ AQI ≤ 1.0) to values near standard levels; *'Alert'* (1.01 ≥ AQI ≤ 2.0) values slightly greater than standard values; and *'Significantly harmful'* (AQI ≥ 2.01) to levels which are far greater than the standards.

RESULTS & DISCUSSION

Variation in Ambient Air pollutants such as SPM, RSPM, SO_2, NO_x and noise levels in the study area are presented in Table 3.

The concentrations of SPM, RSPM, SO_2 and NO_x near the dam site of Varahi river basin area were respectively 540, 170, 5.8 and 17.9 µg/m^3 while the same pollutants were measured as 440, 158, 3.8 and 11.4 µg/m^3 near the dam site of SLIS river basin area. The quantities of these air pollutants were respectively 255.55, 83.3, 2.0 and 1.7µg/m^3 near the dam site of SRLIS river basin area. The SPM, RSPM and SO_2 concentrations was 340, 70 and 0.3 µg/m^3 in the vicinity of dam site of Bellary nala river basin and the NO_x concentration was below the detectable limit. The SPM concentration was recorded as respectively 550, 440, 255.55 and 340 µg/m^3 in the dam sites of Varahi, SLIS, SRLIS and Bellary nala river basins (Fig 2). Suspended particulates quality in the ambient air near the dam site of Varahi river basin belong to Critical pollution level (C) due to extensive dam construction activities compared to high (H), moderate (M), moderate (M) pollution levels respectively near the dam sites of SLIS, SRLIS and Bellary nala river basins. Further, SPM concentration was found to vary from 15-67 μg/m^3, 27.5 - 42.5 μg/m^3, 72.22 - 144.4 μg/m^3 and 40 - 225 μg/m^3 at rest of the monitoring stations respectively in Varahi, SLIS, SRLIS and Bellary nala river basins. At all these stations, the ambient air quality was depicting low pollution level (L) based on SPM values (Fig 2).

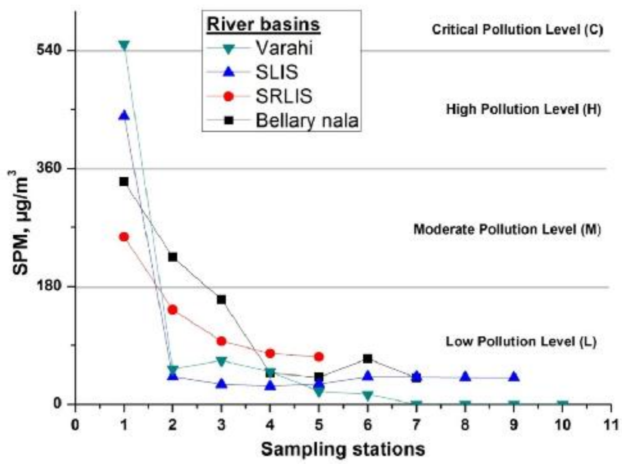

FIGURE 2. Variation in SPM concentration in the study area

The RSPM concentration was found to be respectively 170, 158, 83.3 and 70 μg/m^3 in the dam sites of Varahi, SLIS, SRLIS and Bellary nala river basins (Fig 3). Respirable particulates quality in the ambient air belong to high pollution level (H) near dam sites of Varahi and SLIS river basins while it was moderate pollution level (M) in the vicinity of dam site of SRLIS and Bellary nala river basins. Further, the RSPM concentration near the rest of the monitoring stations in Varahi, SLIS, SRLIS and Bellary nala river basins was in the range of 8-26 μg/m^3, 8.5 - 16.1 μg/m^3, 43.77 - 60.11 μg/m^3 and 10 - 38 μg/m^3 respectively. At all these stations, the ambient air quality was depicting low pollution level (L) based on RSPM values (Fig 3).

It is also evident from the figures 2 and 3 that SPM and RSPM values got drastically reduced in the monitoring stations away from the dam sites in all the four river basins due to minimal / no dam constructional activities and they belong to low pollution level (L) category. On comparison with the available NAAQS / CPCB air quality standards, it was found that the SPM and RSPM concentrations near the dam sites of four river basins were well above the prescribed standards. Contrast to this, it was below the prescribed standards near rest of monitoring stations in all the four river basins.

TABLE 3. Results of Ambient Air Quality and Noise levels in the study area

Sl. No	Location	Ambient Air quality				AQI Calculation Method using SPM & RSPM data			Noise Level (dB)
		SPM	PM_{10}	SO_2	NO_X	I	II	III	
Varahi river basin, Udupi district									
1	Dam site	550	170	5.8	17.9	223.33	38.88	1.58	102.08
2	Forest area (viz., beginning of the proposed canal & likely submergence area)	54	22	ND	ND	83.33	19.31	0.59	84.2
3	Forest area (near 1.5 Km proposed canal work area)	67	26	ND	ND	101.67	23.78	0.72	65.2
4	50m from dam site	50	22	ND	ND	24.67	3.87	0.17	93.2
5	100mfrom dam site	20	15	ND	ND	14.00	1.63	0.10	76.4
6	150m from dam site	15	9	ND	ND	9.00	1.22	0.06	74.1
7	200mfrom dam site	Nil	8	ND	ND	----	----	----	73.2
8	250mfrom dam site	Nil	nil	ND	ND	----	----	----	70.2
9	300mfrom dam site	Nil	nil	ND	ND	----	----	----	52.0
10	500m from dam site	Nil	nil	ND	ND	----	----	----	43.5
SLIS river basin, Belgaum district									
1	Dam site	440	158	3.8	11.4	87.82	31.46	1.37	73.45
2	200m from dam site	42.5	10.0	ND	ND	6.14	3.25	0.39	73.2
3	250m from dam site	30.5	8.5	ND	ND	5.00	2.37	0.30	71.5

4	300m from dam site	27.5	9.0	ND	ND	5.10	2.15	0.08	70.2
5	500m from dam site	31.0	8.5	ND	ND	5.02	2.40	0.08	68.5
6	Hamgi Residential area	42.0	14.0	ND	ND	24.50	7.77	0.25	71.07
7	Bidrahalli village	41.6	14.5	ND	ND	24.90	7.71	0.25	70.95
8	Magala village	41.0	16.1	ND	ND	26.35	7.61	0.26	71.04
9	Allipura village	40.8	10.0	ND	ND	20.20	7.52	0.21	71.24
SRLIS river basin, Belgaum district									
1	Dam site, Aralimatti village	255.55	83.3	2.0	1.7	47.24	18.55	0.75	76.27
2	Koujalagi (near bus stand)	144.4	47.33	10.1	1.5	81.27	26.11	0.84	73.54
3	Kulgod (near bus stand)	96.29	43.77	2.8	1.4	67.84	17.44	0.65	74.37
4	Mallikeri (near bus stop)	77.70	58.55	10.1	6.8	77.98	14.38	0.69	73.00
5	Bhagojikoppa (near bus stop)	72.22	60.11	8.5	10.2	78.17	13.44	0.68	73.24
Bellary nala river basin, Belgaum district									
1	Dam site	340	70	0.30	ND	114.67	24.22	0.81	79.59
2	50 m away from dam site	225	38	ND	ND	70.33	24.60	0.50	70.03
3	100 m away from dam site	160	26	ND	ND	49.33	17.46	0.35	70.1
4	150 m away from dam site	48	16	ND	ND	20.27	7.39	0.14	Low
5	200 m away from dam site	41	12	ND	ND	16.20	5.95	0.11	Low
6	Near bank of Bellary Nala	70	21	ND	ND	28.00	10.10	0.20	70.76
7	Kurabaratii	40	10	ND	ND	30.00	7.38	0.21	low

Note: Values of SPM, RSPM, SO_x, NO_x are in $\mu g/m^3$; ND – Non-detectable

The concentrations of gaseous air pollutants like SO_2 and NO_x concentrations were below detection limit at majority of monitoring stations away from dam sites of Varahi, SLIS and Bellary nala river basins. While SO_2 and NO_x concentrations ranged from 2.0 -10.1 $\mu g/m^3$ and 1.4 - 10.2 $\mu g/m^3$ near the monitoring areas in SRLIS river basin, but well below the prescribed air quality standards.

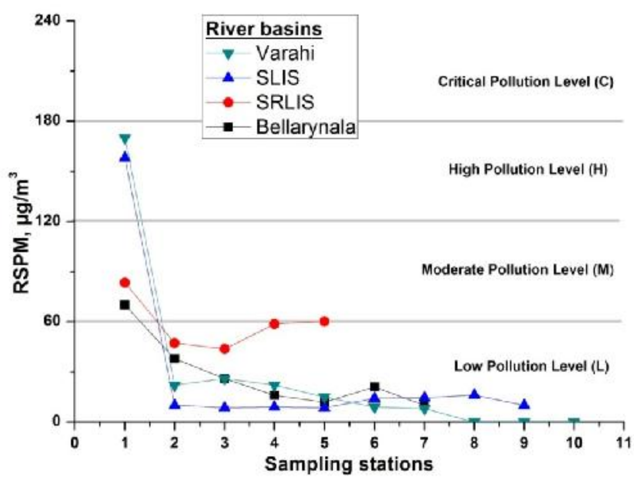

FIGURE 3. Variation in RSPM concentration in the study area

Air quality indices

The spatial variation in air quality indices calculated by three different methods for all the four river basins and their categorization are presented in Figures 4, 5 and 6. It can be noticed that higher value of an index refers to a greater level of air pollution and consequently greater health risks.

Method 1 way of AQI calculation for the dam sites of Varahi, SLIS, SRLIS and Bellary nala river basins was found to be 223.33, 87.82, 47.24 and 114.67 respectively. In contrast, it was found to vary from 9.00 to 101.67, 5.0 to 26.35, 67.84 to 81.27 and 16.2 to 70.33 respectively for rest of monitoring stations in Varahi, SLIS, SRLIS and Bellary nala river basins. From figure 4, it is apparent that the dam site of Varahi, SLIS, SRLIS and bellary nala river basins were severely polluted, polluted, fairly clean and highly polluted respectively. Except for SRLIS river basins, rest of monitoring stations in other river basins fall under very clean to moderately polluted / polluted category (Fig 4). These differentiations can be attributed to the extent of dam constructional activities such as digging, crushing of granites/stones, loading / unloading of raw materials, ground dust by movement of vehicles, etc.

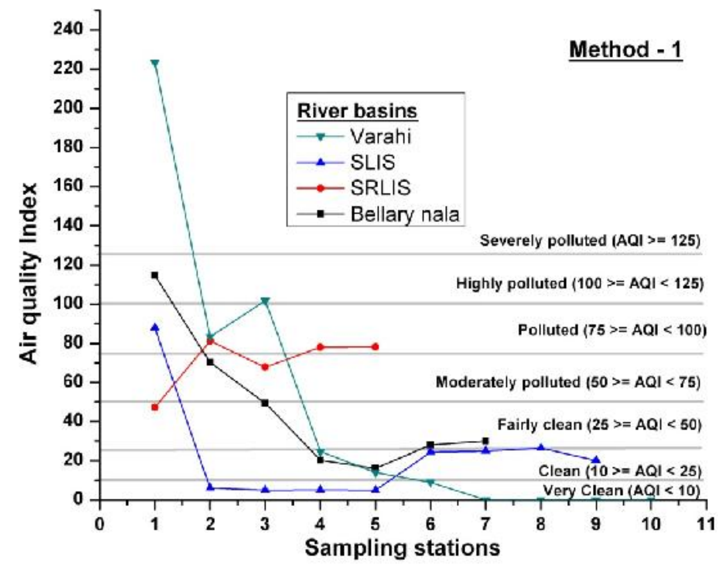

FIGURE 4. Variation in Method 1 based Air quality index in the study area

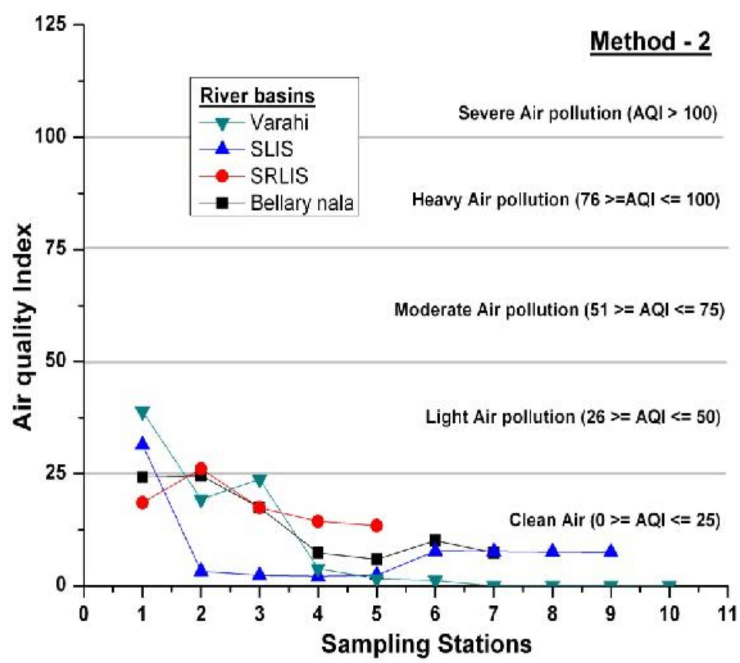

FIGURE 5. Variation in Method 2 based Air quality index in the study area

The AQI calculation by method 2 was found to be 38.88, 31.46, 18.55 and 24.22 respectively for the dam sites of Varahi, SLIS, SRLIS and Bellary nala river basins. It was varying from 1.22 to 23.78, 2.15 to 7.77, 13.44 to 26.11 and 7.38 to 24.6 respectively for rest of monitoring stations in Varahi, SLIS, SRLIS and Bellary nala river basins. It is apparent from figure 5 that the dam site of Varahi, SLIS and Bellary nala river basins were showing light air pollution while that of SRLIS river basin was having clean air; while rest of monitoring stations in all the river basins fall under clean air category (Fig 5).

The AQI calculation based on method 3 was found to be 1.58, 1.37, 0.75 and 0.81 respectively for the dam sites of Varahi, SLIS, SRLIS and Bellary nala river basins. It varied from 0.06 to 0.72, 0.08 to 0.39, 0.65 to 0.84 and 0.11 to 0.50 respectively for rest of monitoring stations in Varahi, SLIS, SRLIS and Bellary nala river basins. It is obvious from figure 6 that the air quality near the dam sites of Varahi and SLIS river basins was at an 'Alert' level while that of SRLIS and Bellary nala river basins was at an 'unacceptable' level. Ambient air quality at rest of the monitoring stations in the four river basins was in the range of acceptable to unacceptable level (Fig 6).

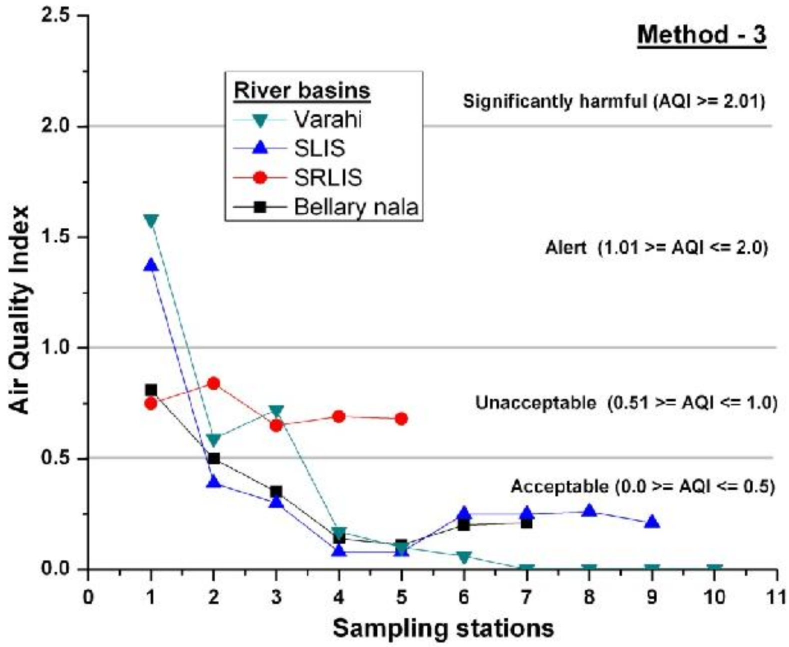

FIGURE 6. Variation in Method 3 based Air quality index in the study area

From three different ways of AQI calculations, it can be concluded that dam sites in all four river basins were high to severely polluted compared to residential / commercial areas located away from dam site, attributed to dam construction activities. These results are in agreement with the findings of Mahuya Dasgupta Adak et al. (2002) in that maximum particulate matters will be present near the higher activity zone and gradually diminished in the areas away from this. Further, high level of RSPM, TSPM, NO_x and SO_2 are due to in-migration, export of various commodities, which in turn due to elevated auto-exhaust emissions due to increase in number of automobiles (Anupama Rashmi et al., 2011) as noticed in the present study.

Noise determination

It is apparent that the noise level recorded (> 70 DB) at majority of the monitored stations (Table 3) in all four river basins was above the permissible limits during the day time given in Table 2. Noise measurements was also made during night time to verify the impact of construction activity and the values obtained were very less (<BDL or low) and hence the results were not included. The noise near the dam sites arose due to rock drilling, movement of truck and tractor, truck boulder loading / unloading, etc. In order to control the effect of high levels of noise prevailing at the dam sites and rock drilling area, work force including labourers and other staff were suggested to wear earplugs / ear muffs during working hours.

CONCLUSION

Air pollution due to particulate matters is considered as a major, serious worldwide public health problem for residents because of their synergetic action. It is evident from the present study that large quantity of particulate matters existed in the vicinity of dam sites of four river basins, attributed to construction activities. The level of particulates will surely come down upon completion of dam construction as evident from their levels near other monitoring stations away from dam sites in the present study. Further, high amount of particulate matter in ambient air is an impact to the surrounding environment disturbing the ecological cycle of the area, and hence air pollution measured in the terms of Air Quality Index can be useful in establishing a meaningful assessment of air pollution in the common man's perception. Also, appropriate pollution control and management plans like mandatory use of electro-static precipitator, application of filters, air purifiers, plantation for green-belt, etc. should be implemented for the betterment of the civic life.

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