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ASSESSMENT OF AMBIENT AIR QUALITY AND ITS SOURCES AROUND HYDROPOWER PROJECTS USING HYSPLIT MODEL AND AIR QUALITY INDEX IN ALAKNANDA BASIN, GARHWAL HIMALAYA, INDIA

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ABSTRACT

Particulate pollutants below 10 micron (PM_{10}) and gaseous pollutants such as Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Ammonia (NH_3) were monitored. In and around the commissioned hydroelectric project Srinagar Garhwal, PM_{10} concentration was found as low as 88.1±2.0 µg m^{-3} ranging from 63.6 to 104.2 µg m^{-3}. On the other hand, Tapovan-Vishnugad Hydroelectric Project (HEP) under construction has relatively higher PM_{10} pollution with a mean value of 104.2±1.1 µg m^{-3}. It was observed that in and around the Tapovan-Vishnugad HEP the particulate pollutants have crossed the permissible limit (100 µg m^{-3}) Prescribed by National Ambient Air Quality Standards (NAAQS), India. However, gaseous pollutants except particulate pollutants at each site were well within the permissible limit. The analyzed results were further supported by Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and Concentration weight Trajectory (CWT) analysis which indicated that both Tapovan-Vishnugad and Srinagar sites of the hydropower projects activities are the major source of particulate pollutants in the region.

KEY WORDS : Particulate matter <10 µ, Nitrogen Dioxide, Sulphur Dioxide, Ammonia, HYSPLIT, CALIPSO, CWT, Hydroelectric Projects

INTRODUCTION

Hydropower projects usually involve large scale and long period of construction, and a large number of construction workers and machines. In the construction process, the activities such as land occupation, quarrying, earth borrowing and waste disposal have major impacts on environment. The growing number of HEPs needs to be studied in relation to the sustainable development perspective. There is a need to assess the prime impacts of HEPs in relation to environment in terms of air quality and aerosol status. The concentration of aerosols has been increasing due to different developmental and other anthropogenic activities; consequently imparting an increasing impact upon climate change

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(Kourtin and Schatz, 1998). Air pollution is a significant problem in the construction sites of the hydropower projects under construction. Therefore, the present study was carried out to determine particulate pollutants like particulate matter below 10 micron (PM_{10}) and gaseous pollutants like Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Ammonia (NH_3). A number of studies have been carried out all over the world by different researchers on the air quality parameters (Kuniyal *et al*., 2005; Kuniyal *et al*., 2007; Kuniyal *et al.,* 2009; Katsouyanni *et al.,* 2001; Guleria *et al*., 2011a; Guleria *et al.*, 2011b; Sharma *et al.,* 2011a; Sharma *et al.,* 2011b; Sharma and Kuniyal, 2013; Sharma *et al.,* 2013; Afroz *et al.,* 2003; Yang *et al.,* 2004; Barman *et al.,* 2010).

Air pollution is one of the negative impacts during construction of hydropower projects. Increase in vehicles and machinery of heavy use increases the concentration of Total Suspended Particulates Matter (TSP), Green Houses Gasses (GHGs) like surface Ozone (O_3) and others gaseous pollutants (Fergusson, 1990). Besides, construction activities have modified natural flow of river both in upstream and downstream of the projects. It can also affect the micro-benthic life in a river system (Sharma *et al*., 2000; Jain *et al.,* 1996) and accelerate the problems of land pollution due to indiscriminate muck (solid waste) dumping. There is a lack of proper mechanism to Collect, Transport and Disposal (CTD) of waste due to inadequate infrastructures to deal with the waste in the region.

MATERIALS AND METHODS

Study Area

The present study deals with the impacts of hydropower construction on air quality in the Alaknanda basin. It is situated between latitudes 30°13236222 N (Srinagar HEP) to 30°3228773 N (Tapovan-Vishnugad HEP) and between longitudes 78°4828623 E (Srinagar HEP) to 79°3123253 E (Tapovan-Vishnugad) (Fig. 1).

The Alaknanda basin comprises of eighteen development blocks of Bageshwar, Chamoli, Rudraprayag, Tehri and Pauri districts of Uttarakhand. The region is characterized by difficult terrain, wide variation in slopes and altitude (650 m to > 5000 m), high rainfall and humidity, low solar radiation and extremely low (highly elevated regions) to very high temperatures (valley regions during the summer). Climate ranges from sub-tropical to alpine. The infrastructure facilities like roads, transport, communication, industries, health care and agriculture are inadequate in the region. The supply of inputs, marketing, institutional credit and extension services are still inadequate, which is resulting in the poor growth of agriculture sector despite good potential. Majority of the population is largely dependent on agriculture and allied land based activities.

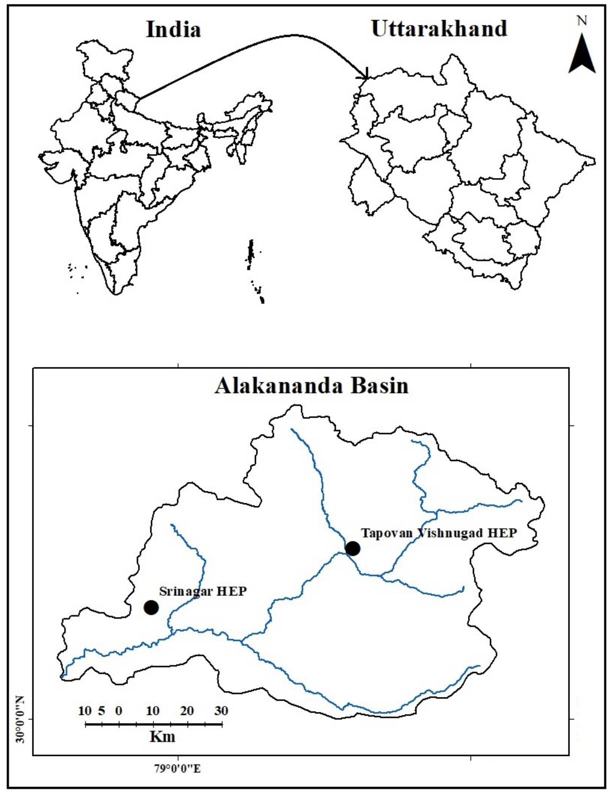

Fig. 1. Location of the study area in the Alaknanda basin, Uttarakhand

METHODOLOGY

Ambient air quality was assessed at two locations. One site was near under construction project site, i.e. Tapovan-Vishnugad (520 MW) HEP. While the other site Srinagar HEP (330 MW), was the commissioned project. The project under construction was further and consequent pollution load affected by the surrounding projects always remains on ambient air quality up to reasonable distance. In addition to Tapovan-Vishnugad (520MW) under construction projects, there were other projects like, Vishnugad-Pipalkoti (444 MW), Lata-Tapovan (171 MW) and Vishnupryag (400 MW) projects, which were located from the main project at an aerial distance of 2.27 km, 1.10 km, and 1.89 km, respectively (Table 1).

Dust Sampler (RDS; Envirotech NL-460) was used to monitor Particulate Matter below 10 micron (PM_{10}) under ambient air quality monitoring based on filtration-gravimetric method where Whatman filter paper (20.3×25.4 cm) was used. The samples were exposed on 24 hourly basis for a week's duration during post-monsoon (05-14 October, 2015) and post-monsoon (18-25 November, 2016). The gaseous pollutants such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and ammonia (NH_3) were also monitored simultaneously in an attached Impinger with the RDS, and analyzed the same following the modified methods of West and Gaeke (1956), Jocobs and Hochheiser (1958). The seven days back air mass trajectories were drawn at a height of 1800m, 2500m and 3000m Above Ground Level (AGL) at Tapovan-Vishnugad project affected site. Drawn at a height of 1000m, 2000m and 2500m Above Ground Level (AGL) at Srinagar project affected site each monitoring site. CALIPSO observations were also made in order to provide the vertical aerosol profile and the spatial distribution of aerosols during the dust events.

The Concentration Weighted Trajectory model (CWT) analysis was also done (Stohl, 1996) for Tapovan-Vishnugad HEP and Srinagar Garhwal HEP affected site to identified potential source of particulate pollutants. The results obtained from PM_{10} concentration and gases pollutants were compared with National Ambient Air Quality Standards (Table 2)

Air Quality Index (AQI) was also computed to know the overall pollution status. The AQI was measured modifying the formula used by Bhaskar and Mehta (2010) as follows:

Air Quality Index (AQI) is calculated by this formula

$$AQI = \left(\frac{M_{ob}}{M_{st}}\right)\times 100$$

where, M_{ob} = observed value of air pollutants,

M_{st} = standard value of permissible limit of NAAQS

RESULTS AND DISCUSSION

Air pollution is one of the negative impacts due to introducing hydropower projects in any of the geographic entity especially during construction period. Increase in vehicular influx and excessive use of machinery have changed the background concentration of Particulate Matter below 10 micron in size (PM_{10}) and gaseous pollutant like NO_2, SO_2 and NH_3.

Concentration of PM_{10}

The study of air quality under observation showed that there was a change in air quality during construction phase of the projects. The highest

Table 1. Aerial distance of hydropower projects under construction and commissioned stages from air quality monitoring sites

Projects	Capacity (MW)	Powerhouse altitude (m)	Aerial distance (km)
Tapovan-Vishnugad	520	1355	0
Vishnupryag	400	1428	1.89
Lata-Tapovan	171	1866	1.70
Vishnugad-Pipelkoti	444	1120	2.27

Table 2 Permissible limits Concentration of Ambient Air Quality (CPCB2012)

Pollutants	Time	Permissible limits Concentration in ambient air		
		Sensitive of Area	Industrial Area	Residential, Rural & Other areas
Sulphur Dioxide (SO_2)	24 hours	80 μg m^{-3}	80 μg m^{-3}	80 μg m^{-3}
Oxide of Nitrogen asNO_2	24 hours	80 μg m^{-3}	80 μg m^{-3}	80 μg m^{-3}
Ammonia (NH_3)	24 hours	-	-	400 μg m^{-3}
Respirable Particulate Matter (RPM), (size less than 10 μm)	24 hours	100 μg m^{-3}	100 μg m^{-3}	100 μg m^{-3}

concentration of PM_{10} observed in Tapovan-Vishnugad project affected areas were 126.3 µg m^{-3} on October 09, 2015 and 128.5 µg m^{-3} on November 20, 2016 (Fig. 2). This value of PM_{10} was recorded minimum 87.1 µg m^{-3} on October 07, 2015. The average concentration of PM_{10} in Tapovan-Vishnugad was observed as 104.2±1.1 µg m^{-3}.

While the status of PM_{10} in Srinagar-Garhwal HEP was observed 104.2 µg m^{-3} as maximum on October 07, 2015 and 106.9 µg m^{-3} on November 23, 2016 (Annexure 1). While 63.6 µg m^{-3} minimum on October 09, 2015 (Fig. 2). The average concentration of PM_{10} in Srinagar was observed 88.1±2.0 µg m^{-3}. The concentrations of these pollutants during the observation period were higher than National Ambient Air Quality Standards especially in the projects under concentration (Table 1).

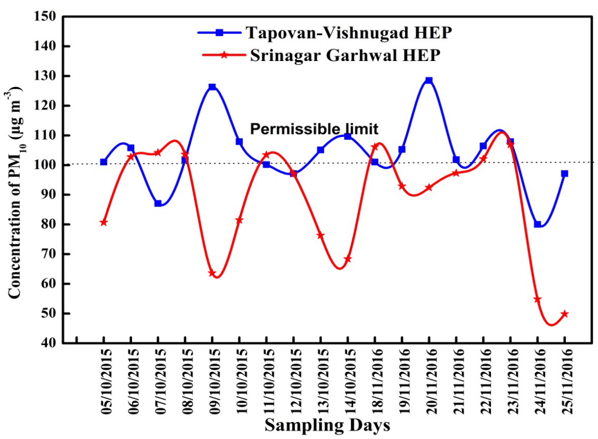

Fig. 2. PM_{10} concentration at under construction of Tapovan-Vishnugad and commissioned Srinagar projects

Concentration of gaseous pollutants

A study of air quality in terms of gaseous pollutants during post-monsoon season shows a change in its quality at the time of construction phase of the project.

The level of SO_2 shows that there was a change in the quality status during construction phase of the project. In Tapovan-Vishnugad HEP, the maximum SO_2 was 5.8 µg m^{-3} on 07 October 2015 and the minimum was 2.2 µg m^{-3} on 11 October 2015 (Annexure 2). The average concentration of SO_2 was observed 3.5±0.8 µg m^{-3} and 4.5 µg m^{-3} as maximum on 20 November 2016, while 2.8 µg m^{-3} as minimum on 23 October 2016 (Fig. 3). The average concentration was found to be 3.5±0.2 µg m^{-3} in Tapovan-Vishnugad project. On the other hand, these values in Srinagar project were maximum with 4.7 µg m^{-3} on 06 October 2015 and minimum with 2.6 µg m^{-3} on 14 October 2015. The average value of NH_3 in this project was observed 3.5±0.5 µg m^{-3}. While 5.2 µg m^{-3} as maximum on 20 November 2016, and 2.0 µg m^{-3} as minimum on 22 November 2016 (Fig. 3). The average concentration was found to be 4.4±0.2 µg m^{-3}.

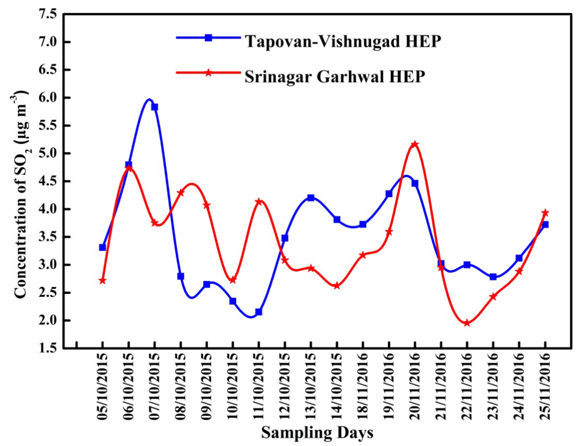

Fig. 3. SO_2 Concentration at under construction Tapovan-Vishnugad and commissioned Srinagar Garhwal projects

In the present investigation, we have shown the concentration of NO_2 in figure (4) at selected sites. The concentration of NO_2 was observed 6.5 µg m^{-3} as maximum on 07 October 2015, and 3.4 µg m^{-3} as minimum on 12 October 2015 (Fig. 4). The average concentration was found to be 4.8±0.6 µg m^{-3}. While 5.8 µg m^{-3} as maximum on 19 November 2016 (Annexure 2), and 3.8 µg m^{-3} as minimum on 25 October 2016 (Fig. 4). The average concentration

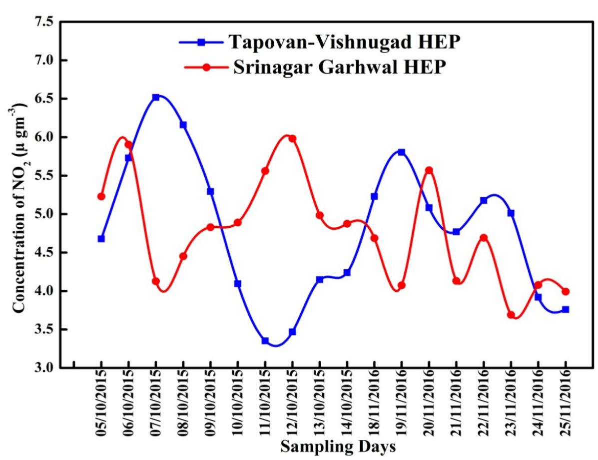

Fig. 4. NO_2 Concentration at under construction Tapovan-Vishnugad and commissioned Srinagar projects

was found to be 4.8±0.2 µg m^{-3} in Tapovan-Vishnugad project. On the other hand, the values in Srinagar project were maximum with 6.0 µg m^{-3} on 06 October 2015 and minimum with 4.1 µg m^{-3}on 07 October 2015. The average value of NH_3 in this project was observed to be 5.1±0.3 µg m^{-3}, 5.6 µg m^{-3} as maximum on 20 November 2016, and 3.7 µg m^{-3} as minimum on 23 November 2016. The average concentration was found to be 4.4±0.2 µg m^{-3}.

The concentration of NH_3 was also observed in Tapovan-Vishnugad and Srinagar projects. During post-monsoon season in Tapovan-Vishnugad project, it was found maximum 7.9 µg m^{-3} on 12 October 2015 and minimum as 5.6 µg m^{-3} on 11 October 2015. While 6.4 µg m^{-3} as maximum on 18 November 2016, and 5.0 µg m^{-3} as minimum on 23 November 2016. The average value at this project was observed 5.6±0.2 µg m^{-3}. On the other hand, concentration of NH_3 in Srinagar project was maximum with 5.8 µg m^{-3} on 09 October 2015 (Annexure 2) and minimum with 4.2 µg m^{-3}on 08 October 2015. The average value of NH_3 in this project was observed 5.2±0.2 µg m^{-3}. While 7.5 µg m^{-3} as maximum on 18 November 2016, and 4.6 µg m^{-3} as minimum on 22 November 2016 (Fig.5). The average concentration was found to be 5.7±0.3 µg m^{-3}.

Analysis of air mass back Trajectories' and CALIPSOObservations

The five day back trajectories were drawn using HYSPLIT model from National Oceanographic and Atmospheric Administration to indicate long range transport source during pollution episodes. The trajectories were drawn during one episodes at

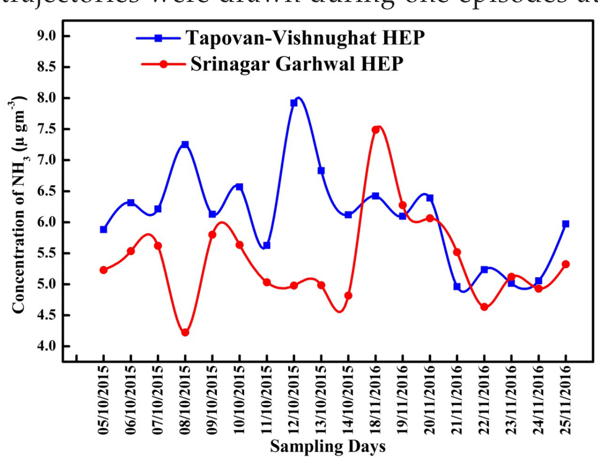

Fig. 5. NH_3 Concentration at under construction Tapovan-Vishnugad and commissioned Srinagar projects

(*i.e.*, November 20, 2016 at Tapovan-Vishnugad and November 23, 2016 Srinagar project affected sites) during the occasion of high pollution days.

In and around Tapovan-Vishnugad the highest concentration of particulate pollutants were measured as 128.5 µg m^{-3} on November 20, 2016 when the back trajectory was coming from Algeria. The trajectory thereafter passed through Bulgaria, Turkmenistan, Afghanistan and Pakistan (Fig. 6), and reached at Tapovan-Vishnugad project site.

At the same time observation through CALIPSO (Fig. 7) showed that the vertical distributions of dust aerosols were mainly below 3 km at Shrinagar (J & K, India). It is thus made clear that all these observations through the trajectories proved that these trajectories were not crossed over the Shrinagar (J & K) region and not contributing directly to pollution episodes. This means that these episodes were caused due to local pollutants. While in case of PM_{10} in Srinagar the highest concentration was observed to be 106.8 µg m^{-3} as maximum on November 23, 2016.This time the back trajectory was coming from Cantabrian Mountains and thereafter passed through Algeria, Libya, Israel, Iran, Pakistan and ultimately reached at Srinagar affected project site (Fig. 6). Similarly CALIPSO observation (Fig. 7) showed that there was no any vertical distribution and movement of dust aerosols.

It is oblivious that through all these observations that, there were no any outer sources contributing to allied particulate pollution episodes. There are only local sources like hydropower project activities and vehicle traffic contributing to particulate pollution in the region.

Concentration weight Trajectory (CWT)

Further, the concentration of particulate matter with the Weighted Trajectory model (CWT) for selected sites around HEP from 5 to 14 October 2015 was also calculated. It was found that minor potential sources i.e. 10-20 µg m^{-3} of particulate pollutants were from the outer region of study sites but the major potential sources of particulate pollutants (>80µg m^{-3}) were identified as local from the project affected sites (Fig.8).

Air Quality Index (AQI)

The AQI is one of the most important tools which is used to report the overall air quality status and trends based on specific standards. This Index gives an idea about the environmental status as air quality and also tells the general public to understand how

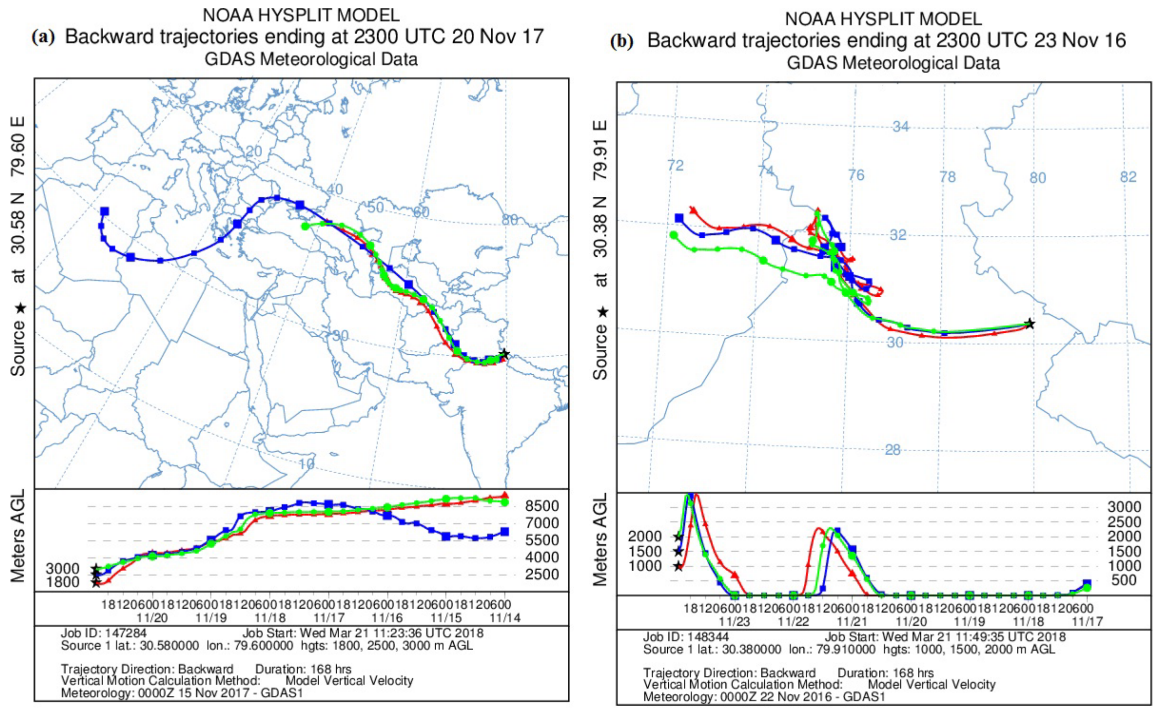

Fig. 6. Back trajectories using HYSPLIT Model to relate with highest particulate pollutants for: (a) Tapovan-Vishnugad (b) Srinagar Garhwal

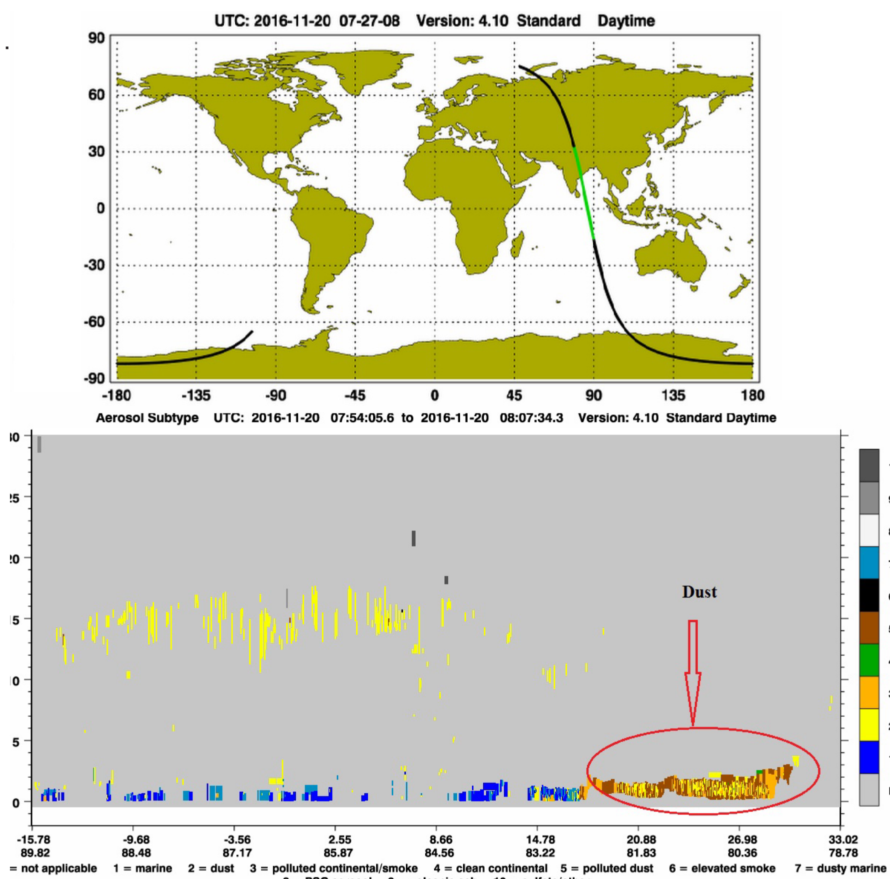

Fig. 7. CALIPSO Model to relate with highest particulate pollutants

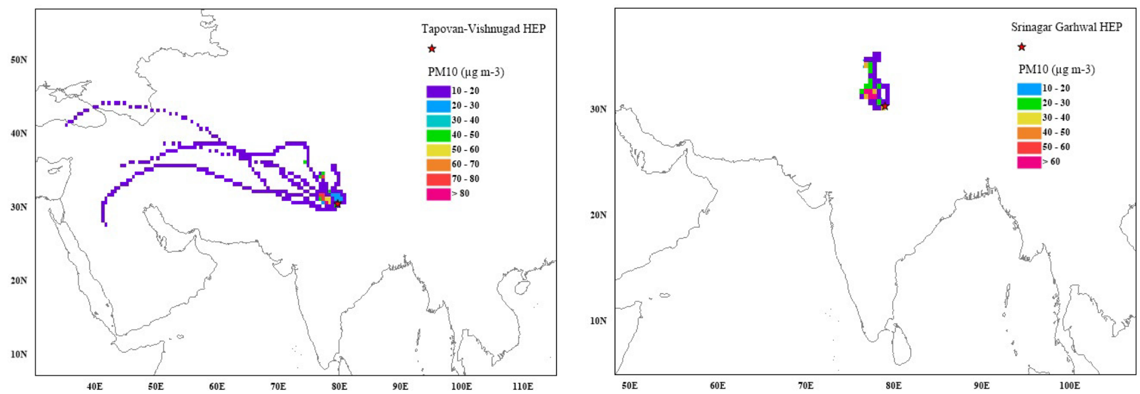

Fig. 8. Source apportionment using PM_{10} concentrated weighted trajectories at selected sites during study period. The color represents the PM_{10} ($\mu g\ m^{-3}$)

clear or pollute air they breathe daily. According to Environmental Protection Agency (EPA), it is divided in six different limits (Table 3).

Table 3. AQI values and level of health concerns

Sr. No.	AQI	Level of health concern (AQI)
1	**0-50**	**Good**
2	50-100	Moderate
3	101-150	Unhealthy for Sensitive Group
4	151-200	Unhealthy
5	200-300	Very Unhealthy
6	301-500	Hazardous

It is clear from the Figure 9 and Table 3 that the values of AQI are in the good range for measurement sites in the selected days. The AQI values were less than 50 at both the sampling sites which are under good category.

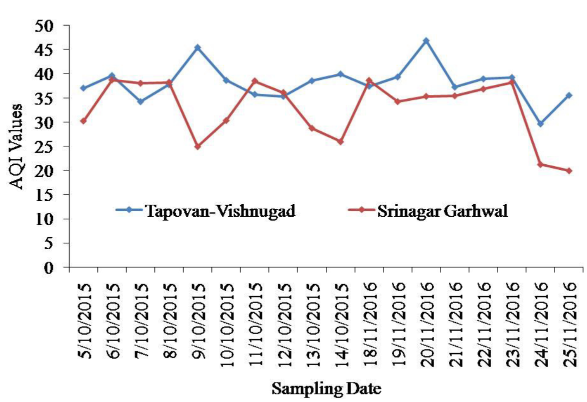

Fig. 9. Air Quality Index (AQI) in selected sites during study period

CONCLUSION

A study of Ambient Air quality in the study area revealed that the particulate Pollutants are high at Tapovan-Vishnugad HEP site as compared to Srinagar HEP. This may be due to Tapovan-Vishnugad and nearby Vishnugad-Pipalkoti HEP which are under-construction phase so the pollutants level is higher compared to the projects already commissioned. The concentration of PM_{10} has crossed the permissible limit ($100\mu g\ m^{-3}$) prescribed by National Ambient Air Quality Standards. While gaseous pollutants were found high in and around Srinagar projects as compared to the Tapovan-Vishnugad project. This may be due to the increased influx of traffic. Moreover, it is a densely populated town. However, it is noted that the concentration of gaseous pollutants concentration at each sites were well within the permissible limit. Through HYSPLIT, CALIPSO and CWT analysis it was found that both Tapovan-Vishnugad and Srinagar Garhwal sites of the hydropower projects activities have been the major source of particulate pollutants in the region. The AQI study reveals that air quality of Srinagar Garhwal and Tapovan-Vishnugad Joshimath are falls under good condition.

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