

Hydropower projects and air Pollution in the Northwestern Indian Himalayas

Renu Lata*, Madhuri Rishi¹, Rajkumar Herojeet² and Konchok Dolma³

*G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Himachal Regional Centre, Mohal- Kullu, Himachal Pradesh, India

¹Department of Environment Studies, Panjab University, Chandigarh, India

²Post-Graduate Govt. College, Sec-11, Chandigarh, India

³EJM College Leh, Jammu & Kashmir, India

(Received 25 September, 2018; accepted 10 November, 2018)

ABSTRACT

Polluted air causes numerous fatal diseases to living things. The present paper discusses the ambient air quality around the Sorang Hydropower Project (100 MW) in district Kinnaur. The analysed air quality parameters are Sulphur Dioxide (SO₂), Oxides of Nitrogen (NO_x), Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM) where their concentration levels are well below the permissible limits for residential, rural and other areas. Higher SPM was observed in the study area which may be due to construction of roads, movement of automobiles and various other hydro activities in the region. This needs a policy implication while the projects remain under construction.

Key words: Hydropower projects, Air pollution, Sulphur dioxide, Oxides of nitrogen, Suspended particulate matter, Respirable suspended particulate matter, Kinnaur, Himalaya

Introduction

Atmosphere is an important segment of human environment and pollution in the air directly affects the human health. Air pollution is one of the serious issues in both developed and developing countries particularly in urban areas due to fast development of populace, industrialization and increasing the number of vehicles (Ghose *et al.*, 2005). Consistently, a large amount of harmful gases are released into the atmosphere from the burning of fossil fuels to operate industrial and domestic activities. Sulphur dioxide, nitrogen dioxide and suspended particulate matter (SPM) are considered to be significant air pollutants in India (Agarwal and Singh, 2000). Air is rendered impure by (i) inhalation of man and animals, ii) decomposition of organic mat-

ter, iii) combustion of fossil fuel (coal, gas, oil) (iv) trade, traffic and manufacturing processes that give off dust, fumes vapours and gases in the atmosphere (Ahmad and Bano, 2015). Today, urban air pollution is a matter of concern due to exposure of a large number of people and their adverse effects on human and environmental health (Barman *et al.*, 2010). In developing nation, 40- 80% of total air pollution is only attributed to vehicular emission (Ghose *et al.*, 2005). The urban population is mainly exposed to high level of air pollution including metals, and fine and ultrafine particles (Nolte *et al.*, 2002) from the vehicular emission (Sharma *et al.*, 2006). The exposure to air pollution can have long-term health effects, even though for short periods. Hence, there is a need to develop air quality management plan which not only considers the class of

Corresponding author's email : renu15_negi@yahoo.co.in

pollution level but also require strict action plan (Shukla *et al.*, 2016).

Central Pollution Control Board (CPCB), Government of India had developed the National Environment Air Quality Standards (NAAQS) in 1982 and later revision was done in 1994 and 2009 on air quality (Chhabra, 2002; Kishore *et al.*, 2016). At present, CPCB has implemented NAMP (National Air Quality Monitoring Programme) through 544 Ambient Air Quality Monitoring Stations in 255 cities covering 26 states and 5 Union Territories (Teri, 2015). The Himalayan region is one of the important geographic regions of India in terms of agriculture and horticulture products and most importantly maintaining weather conditions in the northern part of the country (Kuniyal *et al.*, 2011; Mallik *et al.*, 2012). Over the years, the environmental conditions of this pristine regions has been deteriorated due to rapid urbanization, land use pattern change, industrial and power plant emissions and biomass combustion emitted by local people (Tyagi *et al.*, 2016; Lal *et al.* 2012). Such developmental activities have led to increase the levels of primary and secondary pollutants in this region (Joshi and Semwal, 2011). Further, satellite based datasets indicates that Indo - Gangatic basin afflicted by high aerosol loading has global and regional implications (Ramanathan and Ramana, 2005). Therefore, the main objective of present paper is to examine the status of ambient air quality in and around Sorang hydropower project in district Kinnaur, Himachal Pradesh.

Study Area

Kinnaur district is a very scenic but is lesser known district of Himachal Pradesh on the Indo-Tibetan border. It is surrounded by Tibet in the east, Garhwal Himalaya in the south, Spiti valley in the north and Kullu district in the west. It lies between the north latitude 31°35'40" to 31°34'42" and the eastern longitude 77°52'38" to 78°51'28". Kinnaur district is about 235 km away from Shimla.

The Sorang hydroelectric project is a run-of-the-river developmental project on a Sorang *Khad*, a tributary of River Satluj, in district Kinnaur which is about 170 km from the Himachal Pradesh state capital Shimla. The project consists of construction of a trench weir across Sorang *Khad* at an elevation of 1943.50 m. It will utilize the water in the Sorang *Khad* to generate electricity. The project will export approximately 464 GWh of electricity per annum (Lata *et al.*, 2015). Figure 1 shows the locations and

components of the Sorang hydropower project.

Materials and Methods

The sources of data in this research paper are mainly secondary (Norgial, 2008). However, field observations have been the primary way of analyzing the things. After a preliminary reconnaissance of the study area, the meteorological (predominant wind directions, and wind speed), topographic conditions and details on existing industrial activities in the study area, four stations were taken into account for carrying out Ambient Air Quality Monitoring (AAQM) by Norgial, 2008. The parameters which selected for analyzing ambient air quality status were Sulphur dioxide (SO₂), Oxides of Nitrogen (NO_x), Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM). The sample collection was carried out as per CPCB guidelines (2003). Gaseous pollutants like SO₂ and NO_x were exposed on 8-hourly basis three times in a day using respective absorbing media. SPM and RSPM were collected on 24 hourly average bases through Wattman Glass Micro Fiber Filter Paper (GFA). The prescribed standards procedures for sampling gaseous pollutants are listed in Table 1.

Results and Discussion

Local Meteorology

The study area experiences vagaries of weather due high altitude mountainous terrain. Though summer, autumn, winter and spring seasons are clearly figured in an orderly manner in the area with unusual rainfall, snowfall and hot summers. The climate of the upper Sutlej is characterized by the absence of monsoon rains. Snowfall occurs from October to May at higher altitudes, which then feeds the rivers and other drainage system. The study area lies on the dividing line between climatic zones I and III of India. The tropical monsoon climate, zone-I, extends up to catchment of the Sorang *Khad* which receives lot of snowfall with little rainfall every year from January to March. The winters continue till middle of March, thereafter, mercury continuously starts to rise till the onset of monsoon from June till September in low lying areas. During October and November, days are a bit warm and nights are comfortable. Minimum temperature goes down below 0 °C in the higher reaches during winters and maxi-

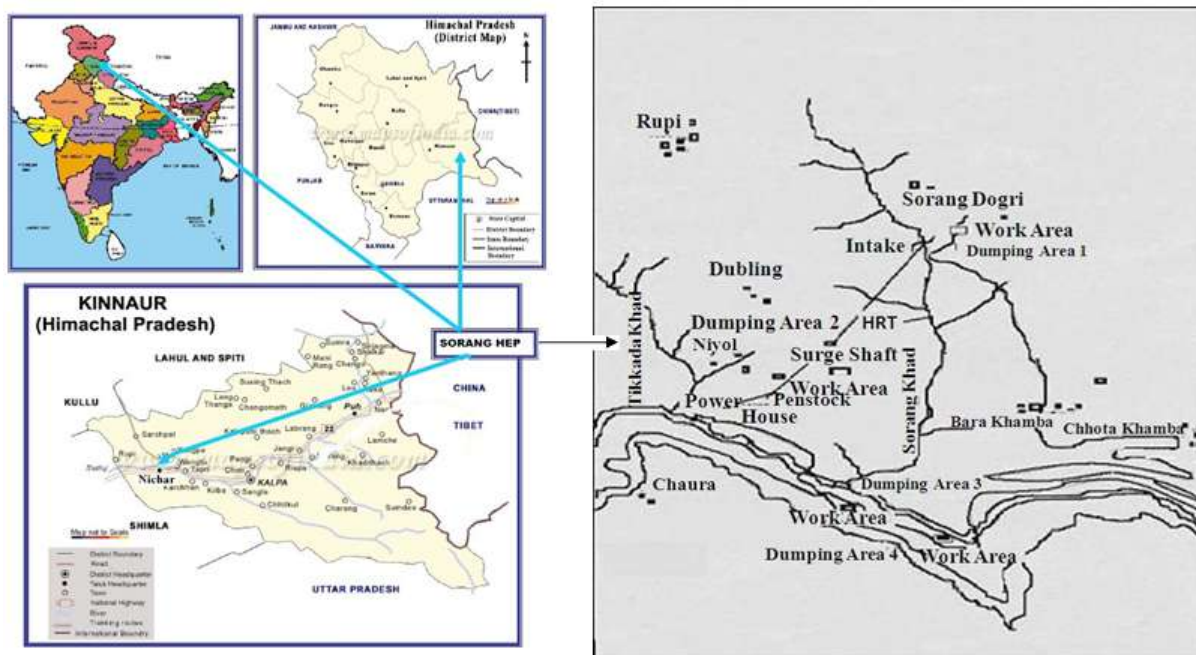


Fig. 1. Location and components of the Sorang hydroelectric project (100 MW)

Table 1. Procedure for determining various air quality parameters

Parameters	Testing Procedure
SPM	Gravimetric method using Respirable Dust Sampler
RSPM	Envirotech RDS - APM 460; IS: 5182 (Part-IV)
SO ₂	Absorption in Potassium Tetra Chloromercurate followed by Chlorimetric estimation using P-Rosaniline Hydrochloride and Formaldehyde (IS: 5182 Part - II).
NO _x	Absorption in dilute NaOH and then estimated calorimetrically with sulphanilamide and N (I-Nephthyle)

imum exceeds even 40 °C in summers.

Temperature and Humidity

The average minimum and maximum temperatures observed were ranged from -2.9 °C and 24 °C respectively. Humidity levels recorded in the region are generally low throughout the year except for monsoon period. During summer season, humidity is lowest (23%) while in monsoon, it goes as high as 70-80%. The highest level of humidity (75%) was observed in August month. The month-wise variations in temperature and relative humidity of the study area are given in Figure 2.

Rainfall

The state of Himachal Pradesh average rainfall is 1152 mm as per the rainfall records maintained by the Directorate of Land Records, Himachal Pradesh.

Generally, Kinnaur receives scanty rainfall as compared to rest of the parts of Himachal Pradesh. The catchment area of Sorang Khad receives rainfall mostly in the monsoon period between July and October. The SW monsoon normally strikes the region at the end of June. About 60 to 70 % of the annual rainfall occurs in the monsoon months (June to September). The post - monsoon season normally last less than two months and is comparatively dry. The area also receives winter rain and snow due to the western disturbance in the months of December to March. The rain gauge station is located at Rampur and Nichar where rainfall data is collected for the present study. However, these are the nearest rain gauge station which is situated outside the catchment area of Sorang Khad. The daily rainfall data for the year 1999-2010 have been collected for different seasons as shown in Fig. 3. These rainfall

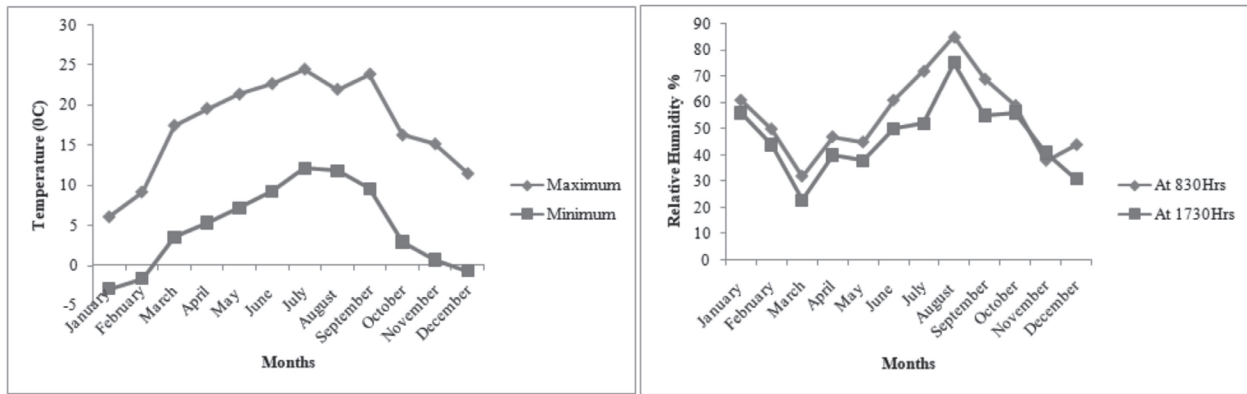


Fig. 2. Month-wise variation in Temperature and Relative humidity in the study area

(Source: Indian Meteorological Department, Shimla, 2010)

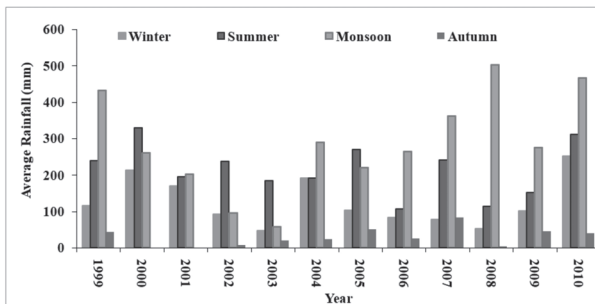


Fig. 3. Total seasonal Rainfall (mm) recorded at rain gauge station at Nichar, district Kinnaur during different seasons from 1999 to 2010

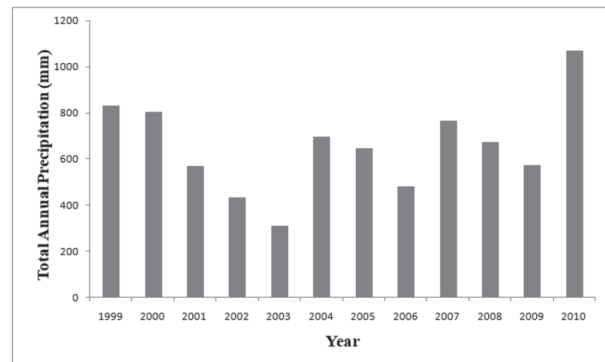


Fig. 4. Total annual precipitation at Nichar, district Kinnaur, 1999-2010

(Source: Indian meteorological department, 2010)

data can be used to check the consistency and validation of stream flows as recorded by stream flow gauging of the Sorang *Khad* and the total annual precipitation of the study area from the year 1999 to 2010 is shown in Figure 4.

Wind

The wind pattern in mountainous region varies in different valleys owing to the topography of the land. The micro - meteorological parameters like wind speed and wind directions in the study area were recorded at four different locations for predicting the onsite climate changes that may occur due to the project. The details of the locations are presented in Table 2. Based on the secondary data collected, wind roses were prepared to see the predominant winds at all the four locations. Individual wind rose diagram for each location is prepared and is presented in Figure 5 (a-d).

At station 'A' wind directions were SSW and NW. While at station 'B' it was observed that the main wind directions were SSW, SW and SEE (ESE).

The calm condition at this station was observed to be 50.7%.

On the other hand, at station 'C' the predominant wind directions were SE and NE. The calm condition at this station was observed to be 60.5%. At station 'D' it was noticed that the predominant wind directions were SW and ESE (SEE). So it is evident from the wind rose that at every station wind direction is changing, thus this may have little bit effects from outside pollution sources.

Table 2. Wind monitoring stations

Station	Description of the locations
A	Village Chaura on right side of River Sutlej
B	Village Nigulsari on NH – 22
C	Village Chhota Khamba on left side of River Sutlej
D	Intake site, village Sorang

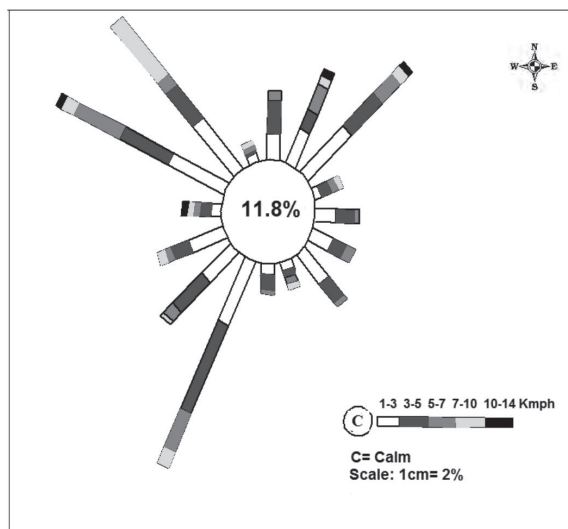
(Source: IMD, 2010)

Ambient Air quality

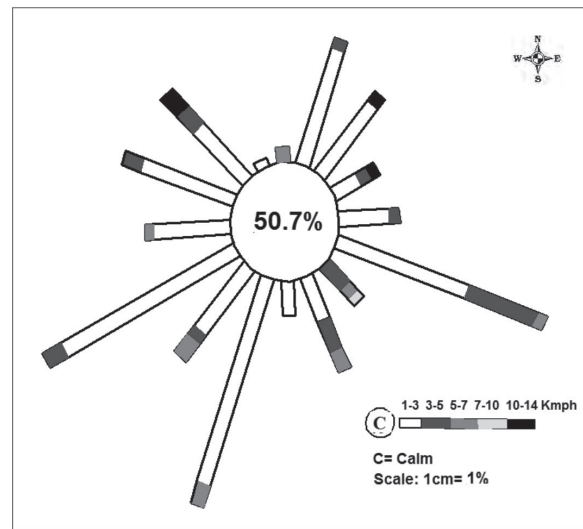
The ambient air quality around the SHEP site is of utmost importance with respect to air pollution and related activities. The sources of air pollution in the region are vehicular traffic, dust arising from unpaved village roads and domestic fuel burning. For pollution free dry air at ground level, gaseous components are expressed as percentage by volume for nitrogen 78%, oxygen 20.94% and water vapours (1-3%). Minor components include Ar, CO₂ and trace components include Ne, He, CH₄, H and NH₃. These parameters vary considerably with altitude.

Air is never found clean due to natural and anthropogenic pollutions. Gases such as CO, SO₂, and H₂S are continuously released into the atmosphere through natural activities, e.g., volcanic activity, vegetation decay and forest fires. Besides, solids and liquids particles are distributed throughout the air by winds and explosion.

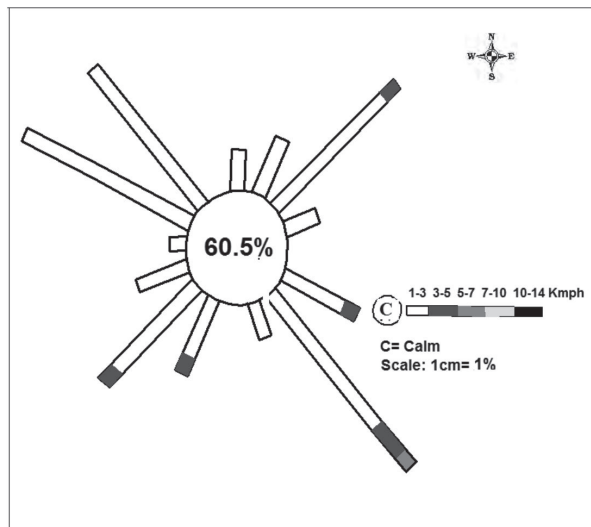
In addition to natural pollutants, there are man-made pollutants like gases, mists, particulates and aerosols resulting from chemical and biological processes. The air pollutants present in atmosphere disturbs its dynamic equilibrium and thereby, affect man and his environment. There are mainly four air



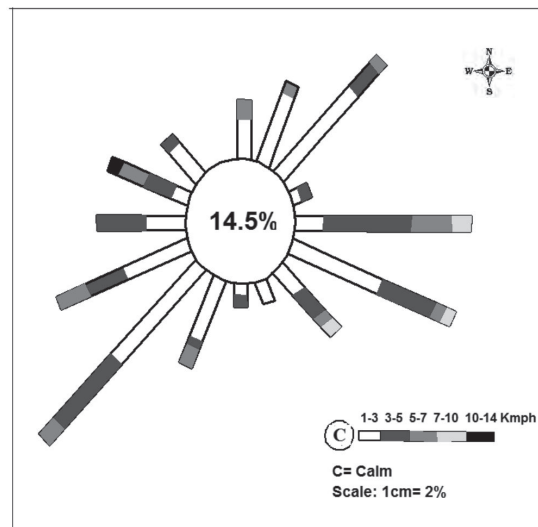
(a) Wind Rose at 'A' Station



(b) Wind Rose at 'B' Station



(c) Wind Rose at 'C' Station



(d) Wind Rose at 'D' Station

Fig. 5. Wind Rose at different locations of the study area

pollutants; sulphur dioxides (SO_2) emitted mainly by power stations and industry, oxides of nitrogen (NO_x) emitted mainly by vehicles and suspended particulate matter (SPM) mainly soot resulting from combustion of fuels and other construction activities (Norgial, 2008). After conducting a reconnaissance survey of the study area four stations were identified for carrying out Ambient Air Quality Monitoring (AAQM). The results of the samples collected from different locations are given in Table 3. The distribution of air quality parameters at different locations are given in Figure 6 (a-d).

Particulate Matter consists of different solid and liquid particles consisting of soil, soot, lead, asbestos and sulphuric acid droplets that are suspended in the atmosphere. Suspended particulates reduce visibility by scattering and absorbing sunlight, corrode metals and erode buildings when the air is humid. Smaller particles are inhaled into the respiratory system causing health problems. Lead and asbestos particles are especially harmful.

In the study area, the concentration of suspended particulate matter was found between $39 \mu\text{g m}^{-3}$ and $184 \mu\text{g m}^{-3}$. The maximum concentration ($184 \mu\text{g m}^{-3}$) of suspended particulate matter was found in village Nigulsari near National Highway and minimum concentration ($39 \mu\text{g m}^{-3}$) at Sorang *Nala* (intake site). The high concentration of suspended particulate matter may be due to the construction of roads, vehicular emission and other construction activities in the area.

Respirable Suspended Particulate Matter (RSPM)

During the study period, the concentration of RSPM was found to be low in all the sample sites, which were within the permissible limit of national ambient air quality standard ($100 \mu\text{g m}^{-3}$). The RSPM concentration in the study area was found between $54 \mu\text{g m}^{-3}$ and $20 \mu\text{g m}^{-3}$, with the maximum concentra-

tion near the powerhouse site ($54 \mu\text{g m}^{-3}$) and Nigulsari village ($41 \mu\text{g m}^{-3}$). The probable sources of RSPM includes unpaved road dust, air scattered dust and dust from agricultural activities and combustion processes.

Sulphur Dioxide (SO_2)

Sulphur dioxide is produced by the chemical interaction between sulphur and oxygen. Sulphur dioxide is a colorless, non-flammable gas with a strong irritating odour and is emitted as a primary air pollutant. They corrode metals, damage stone, plants and irritate the respiratory tracts of human and animals. Sulfur dioxide concentration in the study area was found between $2.5 \mu\text{g m}^{-3}$ to $25.3 \mu\text{g m}^{-3}$ and the maximum concentration ($25.3 \mu\text{g m}^{-3}$) was found near Nigulasari village. The main source of sulphur dioxide in the area may be due to vehicular traffic and other activities.

Oxides of Nitrogen (NO_x)

Oxides of nitrogen are produced by the chemical interactions between nitrogen and oxygen. They consist mainly of nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O). Nitrogen oxide inhibits plant growth and aggravates health problems such as asthma. They are involved in the production of photochemical smog, acid deposition and global warming. They cause metal to corrode and textiles to fade and deteriorate. The concentration of nitrogen oxide in the study area ranged from $2.3 \mu\text{g m}^{-3}$ to $25.1 \mu\text{g m}^{-3}$. The maximum concentration ($25.1 \mu\text{g m}^{-3}$) was found near village Nigulsari, which is mainly due to the burning of fossil fuels, emissions from vehicles and other construction activities.

The values of all the parameters were well below the permissible limits specified for residential, rural and other areas by Central Pollution Control Board (CPCB, 2003). The good ambient air quality around

Table 3. Ambient air quality monitoring locations

Sampling Locations	SPM ($\mu\text{g m}^{-3}$)		RSPM ($\mu\text{g m}^{-3}$)		SO ₂ ($\mu\text{g m}^{-3}$)		NOX ($\mu\text{g m}^{-3}$) (NO + NO ₂)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Power House Site	93.6	58.8	54	38	10.2	3.8	11.3	2.77
Village Nigulsari on NH – 22	184	92.2	41	32	25.3	2.5	25.1	3.6
Village Chhota Kamba	117	41	32	24	9.1	5.5	14.7	6.3
Sorang <i>Khad</i> (Intake Site)	78	39	25	20	5.4	4.4	14.9	2.3
* (NAAQS) CPCB 2003	200	100	80	80				

*National Ambient Air Quality Standards ($\mu\text{g m}^{-3}$)

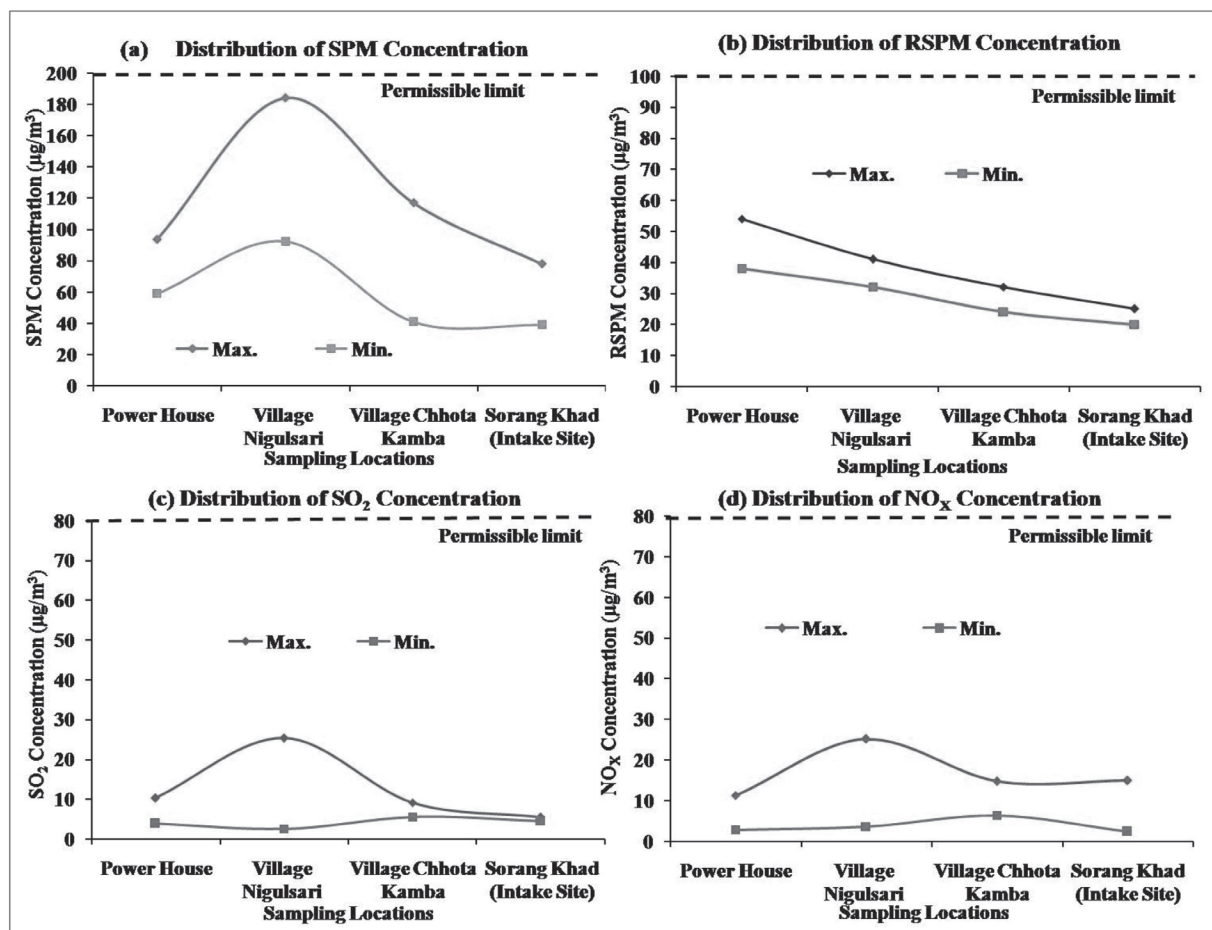


Fig. 6. Distribution of air quality parameters at different locations of the study area *Suspended Particulate Matter (SPM)*

project area can be attributed to the absence of industries, low vehicular traffic and low population density. The main source of gaseous emissions in the study area could be from cement mixing unit at Bhavanagar, which is about 4-5 km from Nigulsari, towards the south of Sorang. Also higher SPM observed in areas may be attributed to construction of roads and various other activities in the region which render dust and particulate matter suspended in the atmosphere [6 (a-d)].

Conclusion

The present study depicts that all the gaseous parameters were within the permissible limits with no alarming situation to human health risks. However, there is an urgent need to develop remote hill area environmental policy to protect rich biodiversity, wildlife and many important medicinal plant spe-

cies which are very sensitive to mild changes of air quality. Regulatory bodies such as Central Pollution Control Board and State Pollution Control Board need to establish ambient air quality stations to generate base line data, which will feed to future new ambient air policy to preserve pristine hilly areas and to understand the change in the air quality. Apart from this, ambient air quality monitoring data can be used for air modelling and validate scenarios of pollutant behaviour in response to changes in policy or pollution generation patterns.

Acknowledgement

The authors acknowledge with lot of thanks to the Director, G. B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora, Uttarakhand for providing the necessary facilities in the Himachal Regional Centre of the Institute.

References

- Agrawal, M. and Singh, J. 2000. Impact of coal plant emission on the foliar elemental concentrations in plants in a low rainfall tropical region. *Environmental Monitoring & Assessment*. 60: 261-282.
- Ahmad, A. and Bano, N. 2015. Ambient air quality of Ferozabad city- A spatio-temporal analysis. *Journal of Global Biosciences*. 4 (2): 1488-1496.
- Barman, S.C., Kumar, N. and Singh, R. 2010. Assessment of urban air pollution and its probable health impact. *Journal of Environmental Biology*. 31(60): 931- 920.
- Central Pollution Control Board 2003. Guidelines for Ambient Air Quality Monitoring for Residential and other areas, Ministry of Environment, Forest & Climate Change, Government of India, New Delhi, 1-153.
- Chhabra, S.K. 2002. Air pollution and health, *Indian Journal of Chest Diseases and Allied Sciences*. 44 : 9-11.
- Ghose, M.K., Paul, R. and Banerjee, R.K. 2005. Assessment of the status of urban air pollution and its impact on human health in the city of Kolkata. *Environmental Monitoring and Assessment*. 108 : 151-167.
- Indian Meteorological Department, Shimla 2010. Rainfall Data and Distribution Pattern of Kinnaur District from Various Rain Gauge Stations, Himachal Pradesh, India, 10-50.
- Joshi, P.C. and Semwal, M. 2011. Distribution of air pollutants in ambient air of district Haridwar (Uttarakhand), India: A case study after establishment of state industrial development operation. *International Journal of Environmental Sciences*. 2(1): 237-258.
- Kishore, K. and Page, M.D. 2016. Impact of air pollution on health- recent advances. *Indian Journal of Air Pollution Control*. 16 (1): 50-60.
- Kuniyal, J. C., Vishnavarma, S. C. R. and Dhyani, P. P. 2011. Changes in the cultivation of apple from climate change: An analysis in Kullu valley of Himachal Pradesh, ENVIS Bulletin Himalayan Ecology, GBIPIED, 19, 76-82.
- Lal, S., Sahu, L. K., Venkataramani, S. and Mallik, C. 2012. Light non-methane hydrocarbons at two sites in the Indo-Gangetic Plain. *Journal of Environmental Monitoring*. doi:10.1039/C2EM10682E
- Lata, R., Rishi, M. S., Talwar, D. and Herojeet, R. 2015. Public Involvement in Environmental Impact Assessment: A Study of Sorang Hydroelectric Power Project in District Kinnaur Himachal Pradesh, India. *International Journal of Earth Sciences and Engineering*. 08 (04): 1711-1720.
- Mallik, C., Venkataramani, S. and Lal, S. 2012. Study of a high SO₂ event observed over an urban site in western India. *Asia-Pacific Journal of Atmospheric Sciences*. 48(2): 171-180. doi:10.1007/ s13143- 012-0017-3.
- Nemery, B., Hoet, P. H. and Niemmar, A. 2001. The Meuse Valley Fog of 1930: An air pollution disaster, *The Lancet*, 357: 704-708, DOI: 10.1016 / S0140-6736 (00) 04135-0.
- Norgial, T. 2008. A Comparative Case Study of Environmental Impact Assessment of Large and Small Hydroelectric Power Project in District Kinnaur, Himachal Pradesh, 2-66.
- Nolte, C.G., Schauer, J.J., Cass, G.R. and Simoneit, G.R. 2002. Trimethylsilyl derivatives of organic compounds on source samples and in atmosphere, i.e., fine particulate matter. *Environmental Science and Technology*. 36 : 4273-4281.
- Ramanathan, V. and Ramana, M. V. 2005. Persistent, widespread, and strongly absorbing haze over the Himalayan foothills and the Indo-Gangetic plains, *Pure and Applied Geophysics*, 162: 1609 – 1626. doi: 10.1007/ s00024-005-2685-8.
- Sharma, K., Singh, R., Barman, S.C., Mishra, D., Kumar, R., Negi, M.P.S., Mandal, S.K., Kisku, G.C., Khan, A. H., Kidwai, M.M. and Bhargava, S.K. 2006. Comparison of trace metals concentration in PM₁₀ of different locations of Lucknow city. *Bulletin of Environmental Contamination and Toxicology*. 77: 419-426.
- Shukla, A., Tyagi, S. K. and Thanaya, I. 2016. Investigations of missing values of air pollution data set using mathematical regression model and correlation study of pollutants in Delhi City. *Indian Journal of Air Pollution Control*. 16 (1): 33-40.
- Stanek, L. W., Brown, J. S., Stanek, J., Gift, J. and Costa, D.L. 2011. Air Pollution toxicology-A brief review of the rule of the science in shaping the current understanding of air pollution health risks. *Toxicological Sciences*. 120 : S8-S27, DOI: 10.1093 / toxsci / kfq367.
- TERI 2015. Air pollution and health discussion paper, the cost of air pollution 2014, OECD Publishing.
- Tyagi, S. K., Upadhyay, V. K., Kulshreshtha, D., Kumar, S., Krishnamurthy, P. and Sen, A. K. 2016. Study of background ambient air quality in Northern Himalayan regions: Uttarakhand and Himachal Pradesh, India, *Indian Journal of Air Pollution Control*. 16 (1): 1-9.
- U.N.F.C.C. 2006. Clean Development Mechanism Project Design Document Form (CDM-Pdd) Version, 03: 1-59.