

Assessment of Ambient Air Pollution and Mitigation Strategies towards Achieving Air Quality Index (AQI) in the Indian Himalayan Region

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Abstract: *Indian Himalayan Region is a house of many hill stations having vast aesthetic and natural beauty with pleasant pollution free climate and peaceful places. The IHR is stretched over 10 states in the Northern and North-East region of India. The Himalaya is vulnerable to both natural and man-made processes by its nature. Though air pollution is a major concern of metropolitan cities but the Himalayan region is also not spared. The air quality in the Indian Himalayan Region is also rapidly deteriorating. Ambient air has become a scarce due to manmade vulnerable processes. Due to increase in transportation and industrial activities there is increasing in aerosol load in Himalayan regions. Locally, the air pollution is caused by vehicular emission and biomass burning. National Ambient Air Quality Standards (NAAQS) specifies the maximum amount of particulate matter (PM) present in outdoor air. The air quality is measured with presence of particulate matter of size PM 10 and PM 2.5. In a comparative study, the daily mean concentrations of both ambient PM 2.5 and PM 10 at different sampling sites in the IHR (Kashmir, Kullu, Dehradun, Nainital, Darjeeling, Jorhat) during winter and summer, the ambient particulate pollutants were observed well within the permissible limit prescribed by NAAQS. To maintain and regulate these air quality standards, various mitigation strategies for the Indian Himalayan Region are suggested.*

Keywords: Air Quality, Air Pollution, Particulate Matter, Tourism, Indian Himalayan Region, Policy

1. Introduction

The Himalaya, 'abode of snow' is a mountain range in Asia, stretched over 2,500 km from northwest to northeast and has a unique place in the world mountain ecosystem. The Indian Himalayan Region (IHR) is a part of Himalaya that spreads over 10 states of Indian republic; Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, and hill regions of 2 states; Assam and West Bengal. Starting from foot-hills in the south (Siwaliks) the region extends to Tibetan plateau in the north (trans-Himalaya). It contributes about 16.2% of India's total geographical area, and most of the area is covered by snow-clad peaks, glaciers of higher Himalaya, dense forest cover of mid-Himalaya. The region is a natural habitat of numerous flora and fauna. It provides water to a large part of the Indian subcontinent. There is a thin and dispersed native population due to its physiographic condition and poor infrastructure development in IHR region. Ambient air is one of the most important components of the environment. One cannot think about the life, in the absence of air that we breathe. But today, breathing in fresh air has become a scarce because its quality is continuously being deteriorated with the ever-increasing human interferences. The atmosphere is a complex dynamic natural gaseous system that is essential to support life on the planet Earth. The anthropogenic activities in one or the other way emit pollutant substances into a fresh air.

2. Ambient Air Quality in the IHR

Air pollution is generally considered as the major problem of urban environment. But also, the Himalayas do not remain untouched by this pollution any longer today. The Himalaya is vulnerable to both natural and man-made

processes by its nature. For centuries, the ecosystem remains balanced ecologically as there were lesser to moderate amount of human interferences and it was able to sustain itself with this amount of human exploration and related activities in the area. But in recent years, the ecosystem has been disturbed to a larger extent due to high degree of human interferences in different tourist affected regions mainly hill stations of IHR. The ever-growing tourism activities in the hill spots have been degrading and deteriorating environmental components such as air, water, soil, land, forest, etc in the Himalaya. Among these components, air quality no longer remains as fresh as it was in past especially in tourism pressurized hill spots. Out of 10 people, nine are breathing highly polluted air on our Earth (WHO, 2018). An individual can feel air pollution only when various implications on health occur in a long run. As a result, most of the people underestimate this pollution in the hilly destinations where today the pollution status is relatively considered moderate compared to the metro cities in the plains.

Day by day increased in anthropogenic activities, increasing aerosol loading in Himalayan regions has adversely affected the Himalayan climate and glaciers (Ramanathan et al., 2001, Lau et al., 2006). Black carbon is an important component of atmospheric aerosol and is mostly produced by the incomplete combustion of fossil fuels and bio-fuels. It is of special interest because it absorbs short wave solar radiations, heats the air, and contributes to global warming, unlike most aerosols, which reflect short wave solar radiations to space and have a global cooling effect. Deposition of absorbing aerosols (mainly Black carbon and dust) on snow and ice, darkens the surface of the glaciers and snowpack, reduces reflectivity of the snow. As a result, it acts as a contributing factor in snowmelt, glacial retreat and decreased snowpack along with documented decreases

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in precipitation and warmer temperatures (Mote *et al.*, 2005).

3. Issues and Concerns with respect to Air Pollution

Currently, in India air pollution is widespread in urban areas contributed by vehicular emission, and thermal power plants. However, there is a very little information about the air quality in rural and hill stations which are situated in Indian Himalayan Region. Air pollution has large impacts on the Indian Himalayan region affecting ecosystem, climate, monsoon, water, agriculture and health of people. In Indian Himalayan regional the problem of air pollution rises within its vicinity but the most of the pollution is transported from the Indo-Gangetic plains. The central Himalayan region is mostly affected by the transportation of the air pollution. The most affected areas in Indian Himalayan regions are the hill stations or can say urban cities and towns. One of the major air pollution problems created in hill stations are due to overcrowd of the people and the visitors coming in that particular hill station. Most of the hill stations in the IHR are converted into cities and these cities are slowly populated by the people who are migrating from different parts of India and abroad. The mountain ecosystem is a very fragile ecosystem and if only one aspect is changed the rest are also affected by this change. Himalaya is experiencing increase in the air pollution levels since last decade due to increase in transportation and industrial activities. Tourism is the largest retail industry in hill states. Although tourism was once thought of as a “smokeless” industry with few, if any, environmental impacts, recognition of its potential for adverse impacts are growing (Davies and Cahill, 2000). A trend of tourist arrival shows that in hill stations both foreign and domestic tourists have gradually increased over the period of time. Most tourism-related air pollutants come from automobiles (Andereck, 1993).



Figure 1: Glimpse of Air pollution in Himachal Pradesh

In winters, the air pollution problem is worse in hill stations, temperature over the Indian Gangatic plains are cold for frequent temperature inversion episodes - a layer of cool air is trapped near the ground under a layer of warm air. This condition suppresses the normal tendency of pollutants to rise and disperse over a wide area, trapping them instead in a relatively shallow boundary layer and causing winter haze to be optically thick. Winter air pollution is also increased by biofuel burning for heating, combined with increased open biomass burning. Increase in air pollution can cause the increase in greenhouse gas emission and these greenhouse gases can increase the temperature of earth, causes the melting of glaciers in our hill stations. There are many glaciers in IHR which are melting and one of the key factors is air pollution. In hill stations there is very less provision of managing the waste. And most of the time, it is dumped in open spaces or otherwise burned; both the practices cause air pollution and causes many health implications. The rural areas or less populated cities have the improved air quality. Air pollution is a major concern in hill stations. The policy needs to form strictly to improve the air quality of IHR.

4. Current Status of Ambient Air Pollution in Hill stations

Daily mean concentrations of both ambient PM 2.5 and PM 10 at different sampling sites in the IHR observed as; Kashmir (PM 2.5: $20.3 \pm 13.1 \mu\text{g m}^{-3}$; PM 10: $32.0 \pm 27.6 \mu\text{g m}^{-3}$), Kullu (PM 2.5: $30.8 \pm 17.2 \mu\text{g m}^{-3}$, PM 10: $48.5 \pm 16.2 \mu\text{g m}^{-3}$), Nainital (PM 10: $42.2 \pm 23.9 \mu\text{g m}^{-3}$), Dehradun (PM 2.5: $52.9 \pm 37.7 \mu\text{g m}^{-3}$) and Darjeeling (PM 2.5: $24.3 \pm 13.5 \mu\text{g m}^{-3}$, PM 10: $47.8 \pm 18.1 \mu\text{g m}^{-3}$) during winter, 2015 (Sen *et al.*, 2017). Daily mean mass concentration of PM 2.5 and PM 10 falls well within the permissible limit as per NAAQS at the above-mentioned sites. On the other hand, at Jorhat mass concentration of respirable particulates (PM10: $146.6 \pm 62.6 \mu\text{g m}^{-3}$) were observed considerably higher as compared to other sites in IHR (Sen *et al.*, 2017) and above permissible limit as per NAAQS. During summer, mean concentration of PM 2.5 and PM 10 were recorded as; Darjeeling PM 2.5: $31.3 \pm 20.0 \mu\text{g m}^{-3}$, PM 10: $51.2 \pm 29.2 \mu\text{g m}^{-3}$ in 2014 and in 2015, it was observed to be PM 2.5: $9.7 \pm 3.0 \mu\text{g m}^{-3}$, PM 10: $29.0 \pm 11.2 \mu\text{g m}^{-3}$, PM 10 concentration at Nainital was observed to be high ($97.8 \pm 50.3 \mu\text{g m}^{-3}$) during summer, 2015 (Sen *et al.*, 2017). In almost, all sites except the Jorhat sampling site, ambient particulate pollutants were observed

well within the permissible limit prescribed by NAAQS 2009. If the ecosystem is disturbed more in terms of human interferences in the hill stations of IHR, then in near future the pollution level will be beyond the permissible limit and there will be no difference in air quality as of polluted urban plains. As per NAAQMS, 2011-12, in terms of ambient air

quality monitoring during 2010, the concentration of PM 10 exceeds the permissible limit in almost all hill stations except in Shimla and Aizawl station while SO₂ and NO₂ were observed well within the limit. The ambient air quality in ecologically sensitive areas in hill stations of IHR and for the year 2010 is depicted in the Table-1.

Table 1: Status of Ambient Air Quality in Ecologically Sensitive areas of IHR

State	City	Category	Annual Average (µg m ⁻³)		
			SO ₂	NO ₂	PM 10
Assam	Golaghat	Numaligarh	6	15	73*
Himachal Pradesh	Shimla	Hill station	3	13	58
Meghalaya	Shillong	Hill station	2	10	79*
Mizoram	Aizawl	Hill station	2	6	42
Nagaland	Kohima	Hill station	2	5	66*
Uttarakhand	Rishikesh	Hill station	-	-	212*

(Source: NAAQMS 2011-12)

* indicates concentration exceeding NAAQS

- indicates Monitoring not conducted

5. Policy and Programmes on Air Quality in India

▪ National Ambient Air Quality Standards (NAAQS)

The Ministry of Environment, Forest & Climate Change (MoEF & CC), Govt. of India, vide gazette notification, G.S.R826 (E), dated 16.11.2009 have notified the National Ambient Air Quality Standards by amending the Environment (Protection) Rules 1986. The revised National Ambient Air Quality Standards are depicted in Table- 2.

Table-2: National Ambient Air Quality Standards

S. No.	Parameters	Time	Limits as per CPCB (MoEF&CC)	
			Industrial, Residential, Rural & other areas	Ecologically Sensitive Area (notified by Central Govt.)
1	Particulate Matter PM 2.5 (µg/m ³)	Annual	40	40
		24 hours	60	60
2	Particulate Matter PM 10 (µg/m ³)	Annual	60	60
		24 hours	100	100
3	Sulphur Dioxide (SO ₂) (µg/m ³)	Annual	50	20
		24 hours	80	80
4	Oxides of Nitrogen (NO ₂) (µg/m ³)	Annual	40	30
		24 hours	80	80
5	Ammonia (NH ₃) (µg/m ³)	Annual	100	100
		24 hours	400	400

▪ National Air Quality Monitoring Programme (NAMP)

Central Pollution Control Board initiated National Ambient Air Quality Monitoring (NAAQM) programme in the year 1984 with 7 stations at Agra and Anpara. Subsequently the programme was renamed as National Air Quality Monitoring Programme (NAMP). Steadily the air quality monitoring network got strengthened by increasing the number of monitoring stations from 28 to 365 during 1985 – 2009. During the financial year 2010 – 11, 93 new stations were added and the number of stations under operation was raised to 456 covering 190 cities in 26 states and 5 Union Territories as on 31st March 2011. The objectives of the NAMP are:

- To determine status and trends of ambient air quality
- To ascertain whether the prescribed ambient air quality standards are violated
- To Identify Non-attainment Cities
- To obtain the knowledge and understanding necessary for developing preventive and corrective measures

➤ To understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of pollutants generated.

▪ National Clean Air Program (NCAP)

In recent years, medium and small towns and cities have also witnessed spurt in pollution thus getting fast reflected in the non-attainment cities of India. Air pollution has increasingly been becoming a serious concern, predominantly for health of the people. Air pollution emission issues are associated with many sectors which inter- alia include power, transport, industry, residential, construction, and agriculture. In order to address the issue, Government has undertaken many significant steps which include:

- Notification of National Ambient Air Quality Standards and sector specific emission and effluent standards for industries

- Setting up of monitoring network for assessment of ambient air quality
- Introduction of cleaner gaseous fuels like CNG, LPG etc and ethanol blending
- Launching of National Air Quality Index (AQI)
- Universalization of BS- IV for vehicles by 2017
- Leapfrogging from BS-IV to BS-VI standards for vehicles by 1st April, 2020
- Banning of burning of biomass
- Promotion of public transport network
- Pollution Under Control Certificate
- Issuance of directions under Air (Prevention and Control of Pollution) Act, 1981
- Installation of on-line continuous (24x7) monitoring devices by 17 highly polluting industrial sectors
- Ban on bursting of sound emitting crackers between 10 PM to 6 AM
- Notification of graded response action plan for Delhi and NCR identifying source wise actions for various levels of air pollution, etc.

In January 2019, the government launched the National Clean Air Program (NCAP), a five-year action plan to curb air pollution, build a pan-India air quality monitoring network, and improve citizen awareness. The programme focuses on 102 polluted Indian cities and aims to reduce PM 2.5 levels by 20-30 % over the next five years.

▪ Acts related to Air as a Natural Resource:

- 1948 – The Factories Act and Amendment in 1987 was the first to express concern for the working environment of the workers. The amendment of 1987 has sharpened its environmental focus and expanded its application to hazardous processes.
- 1981 - The Air (Prevention and Control of Pollution) Act provides for the control and abatement of air pollution. It entrusts the power of enforcing this act to the CPCB.
- 1982 - The Air (Prevention and Control of Pollution) Rules defines the procedures of the meetings of the Boards and the powers entrusted to them.
- 1982 - The Atomic Energy Act deals with the radioactive waste.
- 1987 - The Air (Prevention and Control of Pollution) Amendment Act empowers the central and state pollution control boards to meet with grave emergencies of air pollution.
- 1988 - The Motor Vehicles Act states that all hazardous waste is to be properly packaged, labelled, and transported.

▪ Rules related to Air Pollution:

- The Air (Prevention and Control of Pollution) (Union Territories) Rules, 1983
- The Air (Prevention and Control of Pollution) Rules, 1982

Current Challenges and Probable Solutions

Air pollution is a major environmental health problem affecting everyone. It occurs when the environment is contaminated by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere.

Stoves at home, motor vehicles, industrial facilities and forest fires are the common sources of air pollution in hill states. In IHR, the planning of a city is much unregulated and air quality is highly affected by it. Densely distributed and deep street canyons (buildings with large building height to road width ratios) can block and weaken the approaching wind, thus reducing its air dispersion capability (Cheng *et al.*, 2009; Li *et al.*, 2009, 2010). The challenges faced by hill stations in IHR in case of Air pollution are:

- Biomass burning
- Excessive use of Fossil Fuels
- Forest fires
- Vehicular emission due to tourist inflow beyond the carrying capacity
- Unregulated planning (policy level)
- Transport of Pollutants from Indo Gangetic Plains
- Deforestation
- Lack of Education about Air pollution and its health impact

Probable Solutions: The following could be probable solutions for improving the air quality in the India Himalayan Region:

- Environment education and awareness
- Regulated tourism
- Reduction in biomass burning
- Mitigating Transport Emissions
- Clean energy
- Extension of Air quality monitoring stations
- Afforestation
- Promotion of Climate engineering
- Extensive air pollution study on biotic components
- Amendment in Air (prevention and control of pollution) act 1981

A Case Study of Rohtang Pass in Himachal Pradesh

This tourist spot is termed as the Crown Jewel of Himachal Pradesh. Heavy tourism besides being a boost to economy of Himachal Pradesh, is also causes the adverse impact on ecosystem. Unregulated and heavy tourist inflow beyond carrying capacity, misuse of natural resources, construction of infrastructures, unmanaged waste and other activities associated with tourism can show devastating impacts. The characteristic of this tourist spot is unique and vulnerable. This tourist spot is situated to the north of Manali Town which have an influx of around 11 lakh visitors annually. This site has a crucial and strategic role in governing the ecology as well as the atmospheric conditions influencing the local environment and economy of the area. As per the report of the expert committee constituted by the High Court of Himachal Pradesh, vide order dated 12th October, 2010, nearly 10,000 persons visit this tourist spot and nearly 3600 (75%) taxis goes to Rohtang Pass per day in the month of May and June, every year and the number is further increasing. The resources of the town are limited and affecting its carrying capacity, over construction, increased vehicular traffic and associated air pollution shows its impact on snow caps. It has been reported that nearly 87.3% of the total vehicles plying on Rohtang Pass belong to

tourists only. Due to this, there is a decrease in snowfall pattern in the valley over the period of years.

Based on the study conducted by the IIT Kanpur, Black Carbon produced by vehicles is being as the major causative factor for rapid melting of glaciers. The study suggests that 40% of the glacial retreat could be attributed to black carbon impact and hence Black carbon emission can increase warming and glacier retreat. The heavy tourism inflow also affects the ambient air quality of the surrounding area. TSP (Total Suspended Particle) at Kothi village near Rohtang Pass in the period 2010-2012 was observed to be 388.0 $\mu\text{g m}^{-3}$ on June 6, 2010 followed by 382.8 $\mu\text{g m}^{-3}$ on July 8, 2009 which indicates that during certain time, TSP Level remains above permissible limit. The values of PM 10 and PM 2.5 were found 62.4 $\mu\text{g m}^{-3}$ and 40.4 $\mu\text{g m}^{-3}$ for a monthly average. These values are within the limits of National Ambient Air Quality Standard (NAAQS). It was also observed that the increase in vehicular traffic in Rohtang Pass is resulting in Blackening/ Browning of Snow cover in Mountains, especially due to Air pollution (Black Carbon and Unburnt Hydrocarbons). Unmanaged tourism is also degrading the ecosystem of the fragile Rohtang pass. The National Green Tribunal (NGT) committee ordered the local government authorities to limit the tourism and vehicular activity at Rohtang Pass so that the Ecosystem of the Rohtang Pass will be healed (NGT report 6th Feb. 2014).

Suggestions and Future guidelines

- **Environment Education and Awareness:** Environmental Awareness and Education is a key area in each sector. The education system is presently not able to fully utilize the capacity due to the lack of sensitivity to local surroundings and the lack of curiosity of the environment. Environmental education should be taught as a compulsory subject in all levels of education system. There should be made intensive awareness, training and capacity building drives to know the status, causes and ill effects of pollution also to increase the skills related to environmental management of the individuals especially of the minority, isolated and marginalised people.
- **Regulated Tourism:** Anthropogenic emissions due to high tourist influx are the one of the major cause of air pollution in the hill stations of IHR. There should be adequate infrastructural, public transport facilities given to the tourists. There should be a manageable tourist inflow in a particular hill station of IHR. Local Government should define carrying capacity of the particular hill station and made tourist inflow and management related policies accordingly.
- **Reduction in Biomass Burning:** In hill stations, most of the people burn fuel wood for cooking as well as to save themselves from cold which causes high emissions especially in winter season. Traditional stoves should be advanced so that emission will reduce and efficiency will increase.
- **Mitigating Transport Emissions:** Old transport vehicles should be completely banned. Fuel as well as engine quality should be improved. Pollution level of the vehicles

should be checked time to time. If any vehicle found with exceeding permissible pollution limit, it should be fined heavily or banned. There should be a regulatory authority for carbon taxation for every vehicle. Electrical as well as the vehicles having fewer emissions should be promoted. Public transports should improve and promoted.

- **Clean Energy:** Clean energy such as solar power plant and wind power plants should be promoted. New innovations towards the clean energy should be promoted.
- **Air Quality Monitoring:** Ambient air quality stations should be extended to all hill stations of IHR. There should be proper management of the instruments such as calibration, maintenance, validation and certification for better data. There should be a provision of forecasting of air quality information in all sites.
- **Afforestation:** There should be more and more plantation to coup with air pollution level.
- **Policy and Acts:** Air (prevention and control of pollution) act 1981 should be amended and applied strongly.

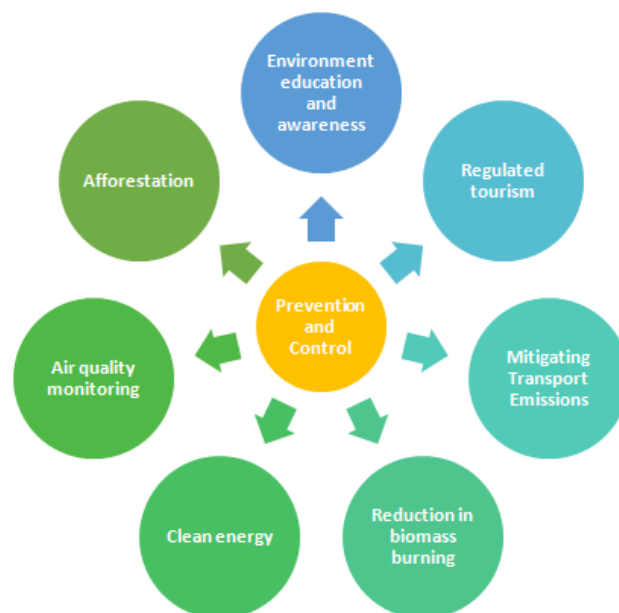


Figure 2: Taxonomy for Prevention and Control of Air pollution in the IHR.

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