Evaluation of Indoor and Outdoor Air Quality for Inner-City Hospitals in Haldwani (Uttarakhand)

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Abstract

The availability of clean air is a vital to human survival. Several factors contribute to a decline in air quality, including industrialisation, an increase in vehicles, construction work, and deforestation. People may be more vulnerable to air pollution in hospitals, which are microenvironments. Using data from the year 2022, the current study analyses the ambient air quality for urban hospitals situated in Haldwani, Uttarakhand, and compares it to that of other hospitals, using CO_2, HCHO, TVOC, $PM_{2.5}$, PM_{10}, CO, SO_2, and NO_2 data from the year 2022. The use of the Air Quality Index (AQI) and seasonal variations in air pollution concentrations are also discussed. Assessing the health effects of increased air pollution in hospitals. These monitoring results show the complexity of the interaction of indoor and outdoor air quality around building envelopes and the uniqueness of ventilation type and location. Other factors such as urban planning orientation, wide occupancy of buildings and different ventilation. All methods contributed to the entry of outdoor air pollutants into poor indoor air quality. Protecting patients and healthcare workers from nosocomial infections and work-related illnesses. The complex hospital environment requires special attention to ensure healthy indoor air quality. This study provides comprehensive information of various air pollutants in the crucial indoor and outdoor environment, which helps researchers, policy maker and governmental official in the field to classify and further reduce the IAQ pollution.

Keyword-Haldwani, Air Quality monitoring, microenvironment, $PM_{2.5}$, PM_{10}, Hospitals, TVOC

Introduction

According to the most recent global burden of disease study [1], air pollution has been identified as a major health risk worldwide, causing 3.7 million premature deaths and ranking as the fourth leading risk factor for early humanity in 2019. It also affects human and animal health on several levels [2,3].Nowadays air pollution is one of the world's most crucial challenges, mainly in the cities of developing-country due to hurried population growth, increased automobile use, and industry. Motor vehicles have long been regarded as the leading resource of air pollution in cities, accounting for 60 to 70% of pollutants in the urban environment. In India, the principal air pollutants are SO_2, NO_2, CO, PM, and CO_2. Studies on air pollution in India's major cities revealed that ambient air pollution concentrations are at levels that could cause substantial health impacts. The continuous expansion in population, along with a lack of appropriate air pollution management methods, indicates that conditions in Indian cities are likely to worsen in the future[4,5].In order to protect patients and healthcare staff from hospital-acquired, nosocomial infections and occupational disorders, the complex hospital environment necessitates specific attention to ensure healthy indoor air quality (IAQ).IAQ problems in hospitals can lead to building-related illnesses such headaches, fatigue, eye and skin irritations, and other symptoms related to human health [6,7](Leung and [8-10]. the air released from healthcare conveniences contains a wide range of particle and gaseous contaminants, including carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde (HCHO), total volatile organic compounds (TVOC), respirable suspended particles, radon, and total bacterial count. Indoor air pollutants are a term used to express these toxins. [6,11].All of these pollutants can impact human health by causing cardiovascular and respiratory disease, neurological impairments, an increased risk of preterm birth, and even mortality and morbidity. Indoor limits/standards have been documented by many organisations and independent agencies such as the Central Pollution Control Board (CPCB), World Health Organization (WHO), prominent researchers, National Ambient Air Quality Standards (NAAQS) and the Environmental Protection Agency (EPA) to save from harm the public's health, particularly that of "sensitive" people with lung disease (such as asthma, cough, and wheeze), children, and the elderly. Table 7summarises the limit values for parameters that affect IAQ.Various studies related to air pollution are also conducted in India at various hospital sites, that indicate pollution levels vary significantly depending on location, time, length of sampling, and climatic circumstances.

Materials and Methods

Location of study area

Haldwani is the second most populated city situated at latitude 29.22°Nand longitude 79.52°E, in the Nainital district, state of Uttarakhand, on the right bank of the Gaula River, in the Kumaon Himalayas' immediate foothills (Fig.1). The entire area is 44.11 square kilometres.

The population of this city is 350,762 people. It is also the most populous city in the Kumaon region. Haldwani is also well-known as financial capital of Uttarakhand. As it hosts the majority of the state's mercantile, financial, and industrial operations. The city has experienced substantial urbanisation since the establishment of the SIDCUL Integrated Industrial Estate (IIE).In addition, most towns and cities are built in close propinquity to several industrial sites, factories (such SIDCUL's Rudrapur Integrated Industrial Estate) and many small businesses. Because most housing complexes, as well as hospitals, schools, business, and governmental facilities, are to be found in the downwind of contaminated air originate from such plants, there is a risk of adverse health impacts from the ambient air.

Participating Hospitals

Indoor and Outdoor ambient air qualities were analysis at three public hospitals situated in Haldwani city of Uttarakhand. Such as Hospital-1(latitude 29°14’31” N, longitude79°32’08” E), Hospital-2 (latitude 29°13’44” N, longitude79°31’56” E) located in centre of the city, while Hospital-3 (latitude 29°13’20” N, longitude 79°30’19” E) is located more than 10 kilometres from the Haldwani city centre. The architecture of these hospitals was identical, with ceramic flooring. However, some windows were opened, especially during the summer. During the research period, no mechanical ventilation or air conditioning was used. Sample of air quality were taken simultaneously in various hospital rooms (entrance hall, Doctor’s room and patient room).

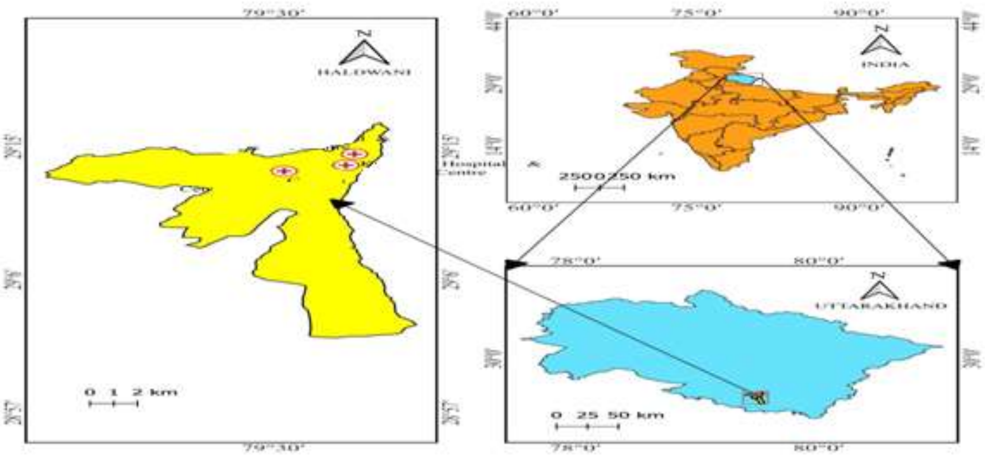

Figure 1: Show monitoring location of the study area

An Indoor Air Quality Monitor (Model HTO-136) is used to monitor HCHO, TVOC, CO2, PM2.5, and PM10 concentrations inside the hospital. The Indoor Air Quality Monitor built in DART Electrochemical Sensors will provide trustworthy measurement during real time monitoring. In winters 27th, 28th, and 29th of January, 2022, real-time monitoring was conducted at indoor and outdoor hospital sites for three days (from January 27, 2022 to January 29, 2022) and in summer season , May 9-29, 2022, real-time monitoring was conducted at indoor and outdoor hospital sites for three days (from May 9, 2022 to May 18, 2022).The indoor monitor was installed in the centre of corridors or rooms in three wards (Entrance Hall, Doctor's Cabin, and Patient Ward) at the Hospital-1, the Hospital-2,(Entrance Hall, Doctor's Cabin, and Patient Ward).The air quality sampling unit was placed 1.5 metres above the ground level, comparable to an adult's breathing zone. Over the course of three days, air quality monitoring was conducted at each monitoring location twice a day, once in the morning (08:00 to 12:00) and once in the afternoon (13:00 to 15:00).The overall monitoring duration at each sampling location during the sampling campaign was 60 minutes.

Results and Discussion

Table 1: The concentrations of air quality indicators at indoor of hospital

Hospital-1, Haldwani: Real Time Area AQI at Location: 29°14’31” N 79°32’08” E
Notation and Unit of1= $PM_{2.5}$,2= PM_{10},3= NO_2,4= SO_2 are in µg/m^3, 5=TVOC, 6=CO and 7=HCHO are in mg/m^3, 8=CO_2 and 9=O_3 are in ppm and ppb.

Area	Winter Season									Summer Season								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Entrance Hall	84	129	0.011	0.006	1117	-	-	-	-	60	155	0.021	0.010	1094	-	-	-	-
Doctor’s Room	55	198	0.055	0.008	0874	-	-	-	-	46	118	0.064	0.011	0716	-	-	-	-
Patient’s Room	49	144	0.045	0.014	0845	-	-	-	-	44	113	0.400	0.057	0743	-	-	-	-

Table 2: The concentrations of air quality indicators at outdoor of hospital

Hospital-1, Haldwani: Real Time Area AQI at Location: 29°14’31” N 79°32’08” E
Notation and Unit of1= $PM_{2.5}$,2= PM_{10},3= NO_2,4= SO_2 are in µg/m^3, 5=TVOC, 6=CO and 7=HCHO are in mg/m^3, 8=CO_2 and 9=O_3 are in ppm and ppb.

Area	Winter Season									Summer Season								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Main Gate	**55**	**196**	-	-	-	**7.23**	**24.7**	**2**	**14**	**62**	**157**	-	-	-	**10.17**	**18.25**	**1**	**17**
Parking	48	163	-	-	-	5.66	28.4	2	14	53	139	-	-	-	11.11	16.20	1	18

Table 3: The concentrations of air quality indicators at indoor of hospital

Hospital-2, Haldwani: Real Time Area AQI at Location:29°13’44” N 79°31’56” E

Notation and Unit 1= $PM_{2.5}$,2= PM_{10},3= NO_2,4= SO_2 are in µg/m^3, 5=TVOC, 6=CO and 7=HCHO are in mg/m^3, 8=CO_2 and 9=O_3 are in ppm and ppb.

Area	Winter Season									Summer Season								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Entrance Hall	82	212	0.291	0.038	1005	-	-	-	-	62	163	2.906	0.096	724	-	-	-	-
Doctor’s Room	66	164	0.413	0.061	875	-	-	-	-	57	145	1.118	0.293	579	-	-	-	-
Patient’s Room	52	130	0.044	0.014	945	-	-	-	-	49	126	0.073	0.010	572	-	-	-	-

Table 4: The concentrations of air quality indicators at outdoor of hospitals

Hospital-2, Haldwani: Real Time Area AQI at Location:29°13’44” N 79°31’56” E

Notation and Unit 1= $PM_{2.5}$,2= PM_{10},3= NO_2,4= SO_2 are in µg/m^3, 5=TVOC, 6=CO and 7=HCHO are in mg/m^3, 8=CO_2 and 9=O_3 are in ppm and ppb.

Area	Winter Season									Summer Season								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Main Gate	**54**	**145**	**-**	**-**	**-**	7.02	22.5	2	14	49	134	-	-	-	7.62	14.60	1	21
Parking	57	158	-	-	-	5.11	27.6	2	14	53	126	-	-	-	12.22	14.02	1	18

Table 5: The concentrations of air quality indicators at indoor of hospital

Hospital-3, Haldwani: Real Time Area AQI at Location: 29°13’20” N79°30’19” E

Notation and Unit, 1= $PM_{2.5}$,2= PM_{10},3= NO_2,4= SO_2 are in µg/m^3, 5=TVOC, 6=CO and 7=HCHO are in mg/m^3, 8=CO_2 and 9=O_3 are in ppm and ppb.

Area	Winter Season									Summer Season								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Entrance Hall	84	207	0.011	0.033	645	-	-	-	-	71	188	0.021	0.041	516	-	-	-	-
Doctor’s Room	55	114	0.088	0.022	845	-	-	-	-	46	112	1.390	0.032	946	-	-	-	-
Patient’s Room	58	131	0.071	0.145	1086	-	-	-	-	49	125	1.732	0.377	1052	-	-	-	-

Table 6: The concentrations of air quality indicators at outdoor of hospital

Hospital-3, Haldwani: Real Time Area AQI at Location: 29°13’20” N79°30’19” E

Notation and Unit, 1= $PM_{2.5}$,2= PM_{10},3= NO_2,4= SO_2 are in µg/m^3, 5=TVOC, 6=CO and 7=HCHO are in mg/m^3, 8=CO_2 and 9=O_3 are in ppm and ppb.

Area	Winter Season									Summer Season								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

Main Gate	65	162	-	-	-	7.25	20.4	2	14	88	156	-	-	-	12.71	14.60	1	18
Parking	68	170	-	-	-	6.06	23.8	2	14	56	144	-	-	-	14.46	16.57	1	17

Table 7: Summary statistics for target pollutant concentrations in Hospitals, both indoors and outdoors.

Air Quality Parameters	Winter Season				Summer Season			
	Median	Mean	S. D.	Range	Median	Mean	S.D.	Range
$PM_{2.5}$	56	59.38	12.75	40	55	59	10.46	40
PM_{10}	137.5	148.5	32.3	100	156	154	17.7	70
TVOC	0.072	0.486	0.775	2.895	-	-	-	-
HCHO	0.032	0.070	0.100	0.371	-	-	-	-
CO_2	859	843	185	601	-	-	-	-
SO_2	-	-	-	-	7.43	8.88	2.97	9.35
NO_2	-	-	-	-	19.32	20.13	4.95	14.38
CO	-	-	-	-	1.5	1.5	0.5	1
O_3	-	-	-	-	15.5	16.08	2.28	7

The indoor-outdoor (I/O) concentration of $PM_{2.5}$ and PM_{10} during winter season were ranges from 49 to 84 µg/m^3 and129 to 198 µg/m^3 respectively in hospital-1.The indoor-outdoor (I/O) concentration of PM2.5 and PM10 were ranges from 52 to 84 µg/m^3 and130 to 212 µg/m^3 respectively in hospital-2, and The indoor-outdoor (I/O) concentration of $PM_{2.5}$ and PM_{10} were ranges from 55 to 84 µg/m^3 and114 to 207 µg/m^3 respectively in hospital-3,the study result show that concentration of $PM_{2.5}$ and PM_{10} vary due to several characteristics such as location of building, design of building or several human activity in and around the hospital.

The indoor-outdoor (I/O) concentration of $PM_{2.5}$ and PM_{10} during winter summer season were ranges from 44 to 60 µg/m^3 and113 to 155 µg/m^3 respectively in hospital-1.The indoor-outdoor (I/O) concentration of $PM_{2.5}$ and PM_{10} were ranges from 49 to 62 µg/m^3 and 126 to163 µg/m^3 respectively in hospital-2, and The indoor-outdoor (I/O) concentration of $PM_{2.5}$ and PM_{10} were ranges from 65 to 68 µg/m^3 and112 to 188 µg/m^3 respectively in hospital-3,the study result show that concentration of $PM_{2.5}$ and PM_{10} vary due to several characteristics such as location of building, design of building or several human activity in and around the all hospital, the concentration of $PM_{2.5}$ and PM_{10} are found higher than the permissible limit.

The indoor concentration of CO_2 during winter season were ranges from 845to 1117µg/m^3 in hospital-1.The indoor (I) concentration of CO_2 were ranges from 945 to 1005 µg/m^3 in hospital-2, and The indoor (I) concentration of CO_2were ranges from 645 to1086 µg/m^3 in hospital-3, the study result show that concentration of CO_2found higher than the permissible limit in all hospital.

The indoor-outdoor (I) concentration of CO_2 during summer season were ranges from 716 to 1094 µg/m^3 in hospital-1.The indoor-outdoor (I) concentration of CO_2 were ranges from 875 to 1005 µg/m^3 in hospital-2, and The indoor-outdoor (I) concentration of CO_2 were ranges from 516 to 1052 µg/m^3 in hospital-3, the study result show that concentration of CO_2 vary due to several characteristics and it is found higher than the permissible limit.

Conclusion

The concentrations of indoor and outdoor air quality were analysed in three public urban hospitals in Haldwani, Uttarakhand. Indoor air quality levels were determined to be lower than outdoor air quality levels. The relationship between indoor and outdoor air quality levels was investigated in order to find inside air quality predictors. Outdoor air quality concentrations were determined to become the key predictors affecting indoor air quality concentrations, respectively. During the investigation period, it was found that General Department of Hospital 3, located in a semi-urban area, moderately of the polluted area, was very high polluted. The current study, which looked at the association between indoor and outdoor air quality levels in hospital settings in study area, has a number of implications for local observational studies that might use outdoor air quality parameters to predict indoor environment quality of air. The majority of these researches are based on the impact of outside concentrations on the health of the occupants. The research results about the predictors of indoor air pollution concentrations, on the other hand, can help policymakers execute targeted interventions to enhance air quality, such as utilizing high-efficiency ventilation systems in hospitals. In furthermore, to investigate the influence of background activities and climatic variables on the change of interior dust, seasonal and seasonal variations of particles in the wards must be properly considered. This research could aid in the formulation of management plans and effective measures to improve hospital IAQ.

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