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COVID-19 pandemic in Uttarakhand, India: Environmental recovery or degradation?

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ABSTRACT

The human coronavirus disease-2019 (COVID-19) caused by SARS-CoV-2 is now a global pandemic. Personal hygiene such as hand-washing, the use of personal protective equipment, and social distancing via local and national lockdowns are used to reduce the risk of transmission of SARS-CoV-2. COVID-19 and the associated lockdowns may have significant impacts on environmental quality and ergonomics. However, limited studies exists on the impacts of COVID-19 and the associated lockdowns on environmental quality and ergonomics in low-income settings. Therefore, the present study investigated the impacts of the COVID-19 outbreak on socioeconomics, ergonomics and environment (water quality, air quality and noise) in Uttarakhand, India. Approximately 55% of respondents experienced headaches, and the other common health-related issue was back pain, with 45% of respondents having problems with their backs. Water and air quality significantly improved during the lockdown relative to the pre-lockdown period, but was observed to return to their previous characteristics afterwards. Lockdowns significant increased the concentration of indoor air pollutants while noise pollution levels significantly declined. In summary, lockdowns have adverse impacts on ergonomics, resulting in work-related human health risks. The impacts of lockdowns on environmental quality are mixed: temporary improvements on water and air quality, and noise reduction were observed, but indoor air quality deteriorated. Therefore, during lockdowns there is a need to minimize the adverse environmental and ergonomic impacts of lockdowns while simultaneously enhancing the beneficial impacts.

1. Introduction

In the later part of the year 2019, there was an outbreak of the human coronavirus disease 2019 (COVID-19) which originated from Wuhan, China; one of the most densely populated cities with a population of more than eleven million [1,2]. Twenty-seven (27) cases of pneumonia of unknown etiology were initially reported in Wuhan, and the patients showed common symptoms of fever, dry cough, and dyspnea. All the cases were related to the Huanan Seafood market of Wuhan city which trades in live animals including bats, fish, and snakes [3,4]. It was declared as pandemic by WHO on 11 March 2020 with total confirmed cases of 9720 including 213 fatalities till 31 January in China [5,6]. Through numerous studies conducted it was found that bats are the probable source which leads to the spread of this infectious virus [7]. Coronaviruses are a group of enveloped, widely varied, ribonucleic acid

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Nomenclature

WHO	World Health Organization
CDC	Centers for Disease Control and Prevention
PM	Particulate matter
BOD	Biochemical oxygen demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
TWA	Time weighted Average
TDS	Total Dissolved Solids
MPN	Most Probable Number
CPCB	Central Pollution Control Board
VOCs	Volatile organic compounds
IAQ	Indoor Air Quality

(RNA) viruses with a single molecule of linear positive-sense and single-stranded [8,9].

Infected individuals had respiratory disorder (ranging from mild to severe) but patients showing mild symptoms did not require any special medical attention. Severe cases required special care due to more severe respiratory problems which may finally lead to fatality [10,11]. In four to five days symptoms may occur or the person could be complete asymptomatic. The appearance of the symptoms totally depends upon the individual immunity which includes fever, throat problem, loss of smell and taste, difficulty in breathing, rashes on skin [12–14]. Elderly people above seventy years are more prone to get affected as well as those having a medical history of diabetes, heart disease, and respiratory disorders [15–17]. As of 8 January 2021, India has reported 10.4 million total cases in which 10 million had recovered and 150 thousand people have lost their life due to the ongoing pandemic. Two vaccines have been approved for emergency use only and other vaccine trials are going on which are a sign of positive outcomes [18]. The virus is primarily transmitted by droplets that are produced when a person having the disease exhales, coughs or sneezes, and these droplets (diameter is > 5–10 micrometer) tend to stay in the air for 3 h and are capable of reaching a distance of up to 10 m [19,20]. There are high chances of getting infected by coming closer to the vicinity of an infected person or touching the mouth, nose, or eyes after touching a contaminated surface [21–23]. The studies describing the pathophysiological behavior of COVID-19 have considerable doubt about its spread mechanism [24,25]. The present information is primarily derived from related coronaviruses spread by respiratory formative from human-to-human [26,27].

When a patient is symptomatic, viruses are typically the most infectious. However, evidence is indicating that transmission among humans can occur during the asymptomatic incubation time, estimated to be 2–10 days [28,29]. Various international bodies like the World Health Organization (WHO) and Center for Disease Control and Prevention (CDC) released several advisory guidelines to decrease the spread rate [30]. They suggest restricting travel to high-risk areas, and interaction with symptomatic people, and stopping the intake of meat from regions with a confirmed outbreak of COVID-19 [31]. Frequent hand washing, use of sanitizer and use of face masks are strongly recommended [32–34]. Countries like Japan and India use applications like 'Bebot' and 'Arogya setu' which provides the current status of the disease, preventive measures to stop the spread, and a symptom checker as well [35–37]. To avoid a deteriorating pandemic situation, the Indian government took stringent public health measures such as the stay-at-home directive or national lockdown. In certain nations, this has restricted their operations, minimized road traffic, and forced flights to a stand-still [38,39].

The first confirmed case of COVID-19 in India was identified in Kerala, on 30 January 2020, when a university student from Wuhan returned to the state [40,41]. There was a rising number of cases in India, hence, lockdown was implemented throughout the country starting from 25 March till 31 May 2020 (Lockdown from Phase 1 to phase 4). Depending on the conditions, the lockdown continued until 30 June 2020 in various parts [42–44]. The lockdown helped to bring the daily case tally to 6.3% from 11.8%, but the government could not impose lockdown for a long time as it had a negative effect on the economy. A feasible alternative was to quarantine extremely sensitive areas so that only those infected by the virus remain in that zone to avoid further spread [45].

Studies show that there was a positive impact on the environment due to the implementation of lockdown which helps in reducing various greenhouse gases and helps in improving the water quality [46,47]. It has been found that air pollution reduces to 50% in Barcelona during the lockdown phase [48]. During the lockdown, China's carbon emissions fell by 25% which is 1 million tons when compared to the last year data of the same period [49]. In the month of March, there was a decrease in $PM_{2.5}$ in the United States, United Arab Emirates, Spain, and Italy which was due to complete shutdown [50]. In Delhi, compared to the pre-lockdown period, PM_{10} and $PM_{2.5}$ concentrations decreased by half. Air quality has improved up to 60% in industrial and transportation areas whereas it was reported that on the second and fourth day of the lockdown, air quality improved by around 40–50% [51]. Similarly, Vembanad lake in India shows an improvement in water quality as particulate matter concentration declined by approximately 16% [52]. Water pollution in Venice, Italy [53,54]was reduced as a result of the shutdown, and the city's water canals became more transparent than before [55].

Following the outbreak of COVID-19 pandemic, people have lived through different phases of lockdowns, and the majority of them started to work from home. Working from home has its own challenges such as working without proper workstations. In addition, long working hours associated with working from home may result in work-related health risks such as musculoskeletal disorders, and prolonged exposure to adverse indoor pollution. Lockdowns may also have significant impacts on various aspects of environmental quality. Existing literature documenting the impacts of COVID-19 and lockdowns is limited to environmental quality focusing mainly on one aspect such as water or air quality. Other studies investigated the impacts of COVID-19 and lockdowns on socio-economics.

To date, very limited comparative studies have investigated the impacts of COVID-19 lockdowns on socio-economics, ergonomics and environmental quality relative to pre- and post-lockdown periods. Moreover, integrative studies assessments the impacts of lockdowns on ergonomics, socioeconomic status and environmental quality in a single investigation are still lacking. Integrative studies encompassing socio-economics, ergonomics and various aspects of environmental quality provide a more comprehensive understanding of the impacts of lockdowns. Therefore, the objective of the present study is to investigate the impacts of COVID-19 lockdowns on the integrated aspects of socio-economic, ergonomic and environmental (water quality, air quality and noise) in Uttarakhand, India.

2. Methodology

2.1. Area of study

In the current article, socio-economic and ergonomic assessments of conditions of people working from home have been carried out for a group of 200 randomly selected people from various locations of Dehradun (Clement town, Prem Nagar, Raipur, Vasant Vihar, Patel Nagar) through a questionnaire. Assessment of water, ambient and indoor air quality has been carried out for Uttarakhand state of India before, during and after the lockdown phase of COVID-19. Uttarakhand state lies between 28°44' & 31°28' N Latitude and 77°35' & 81°01' E longitude, with a total geographical area of 53,483 km2. The state comprises of two region Garhwal and Kumaon. The state capital is Dehradun, situated at

an altitude of 640 m above mean sea level [56] flowchart summarizing the research methodology is presented as Fig. 1.

2.2. Socio-economic and ergonomic assessments

The study relies upon the primary data collected randomly from 200 people from the Dehradun district in the state of Uttarakhand, India. Socio-economic assessment was carried out for these 200 respondents and information for general awareness regarding COVID-19 was collected from the same respondents. The ergonomic assessment was carried out for the respondents working from home during the ongoing pandemic, and to determine the ill health effects and comparison of major health issues for various age groups. All the data were collected through a well-structured questionnaire comprising 35 questions. Details of correspondents age, social status, marital status, education, nature of family, general awareness about Covid-19, their mode of work, number of working hours per day, and other questions related to the ill-health effects were included in the questionnaire in order to obtain the required details for carrying out the assessment. The questionnaire has been developed by considering Occupational Safety and Health Administration (USA) & National Occupational Safety and Health (OSH-India) guidelines.

2.3. Location and time periods

The impact of lockdown on water, air, noise, and indoor air quality for selected two regions of Uttarakhand (Garhwal and Kumaon) was done for four time periods: (i) January 2020 to March 2020 (Pre-lockdown), (ii) April 2020 to June 2020 (During Lockdown), (iii) July 2020 to September 2020 (Post-lockdown), and (iv) October 2020 to December 2020 (Post-lockdown).

2.4. Water quality assessment

The water quality was determined for total 8 water bodies which are river Ganga at HarkiPauri, Haridwar, Yamuna at Dakpathar, Dehradun, Mandakini at Rudraprayag, Alaknanda and Bhagirathi at Devprayag before their confluence in the Garhwal region and Naini lake, Bhimtal lake in Nainital of Kumaon region. For each water body, samples were taken at downstream end of the 3 selected locations. The instruments and methods used for sampling and assessment of water quality parameters are mentioned in Table 1.

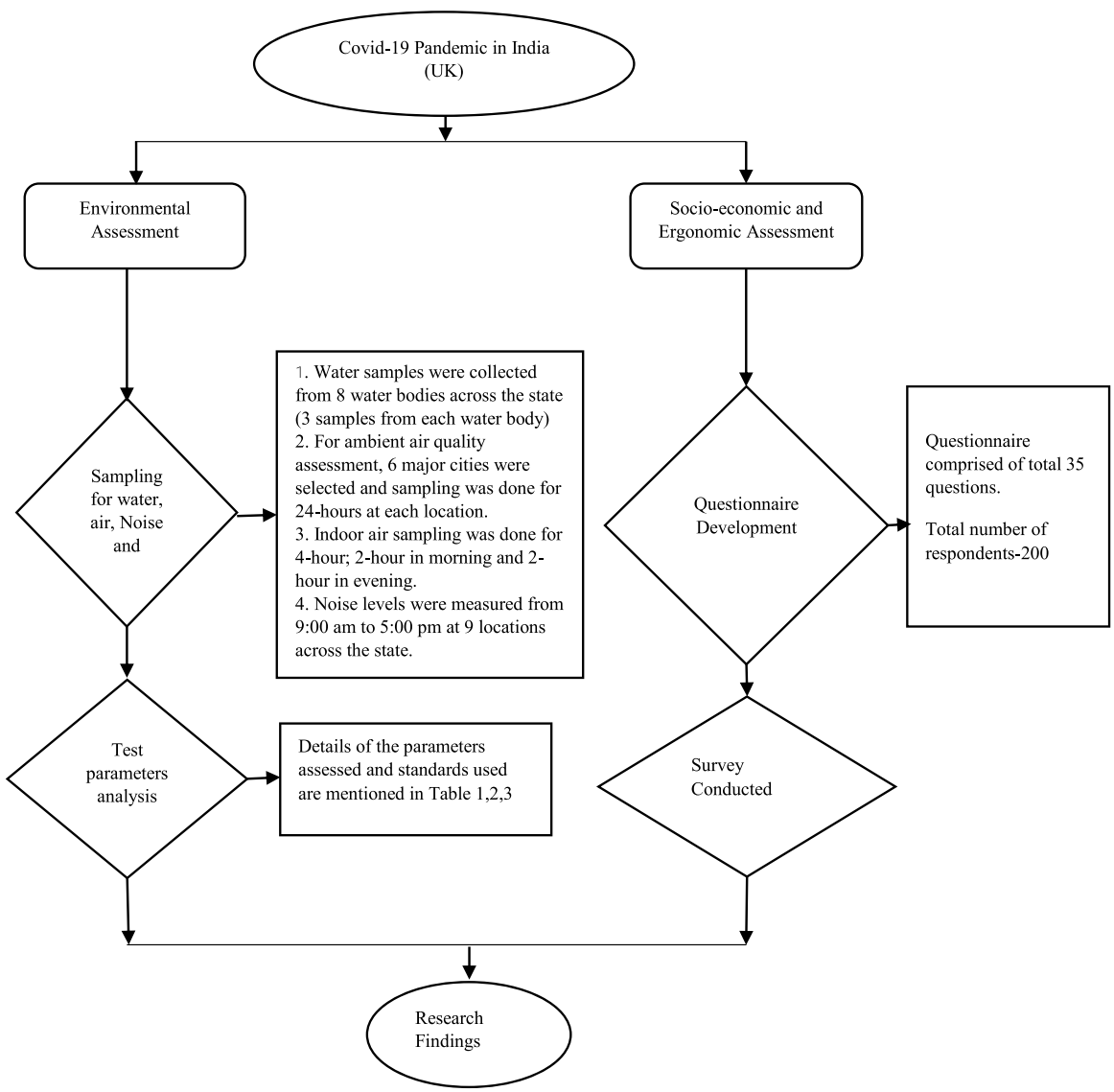

Fig. 1. A flowchart summarizing the research methodology.

Table 1
Instruments/methods used for water quality assessment.

Water quality Parameters assessed	Instruments/Method used	Indian standard Code
• Hardness	Titrimetric analysis in Laboratory	IS 3025 (P-20) (1983)
• Alkalinity	Titrimetric analysis in Laboratory	IS 3025(P-23) 1983
• Total dissolved solids	Gravimetric analysis	IS 3025(P-16) 1984
• Total Coliform	Colony Counter	IS:1622 1981 R-2003
• BOD	BOD incubator (model no. SONAR 8450)	IS 3025 (P-21)
• COD	COD digestion unit from Wealtech Corp. (model no. HB1)	IS 3025 (P-58)
• Dissolved oxygen	Winkler method (Titrimetric analysis)	IS 3025 (P-38)
• pH	Digital pH meter (Thermo fisher star A11)	IS 3025 (P-11) 1983

2.5. Ambient air quality assessment

The ambient air quality assessment was determined at Garhwal and Kumaon region of Uttarakhand. At 6 different locations which are Dehradun, Rishikesh, Haridwar, Haldwani, Kashipur and Rudrapur. The sampling was done for a period of 24 h and at each location 3 samples were collected at breathing height (1.5–2.0 m). The instruments and methods used for sampling and assessment of ambient air quality parameters are mentioned in Table 2.

2.6. Indoor air quality assessment

Sampling was done from a period of 21st February to 28th December (310 days,60 households were selected for indoor air monitoring and they were selected on the basis of ventilation area available within the house. CO_2, CO, O_3, VOC (Volatile Organic Compounds) and formaldehyde levels were measured for an indoor setting with 10–15% ventilation area (natural ventilation). Indoor air sampling was done for a period of 4-h (2 h in morning and 2 h in evening) throughout the sampling period. Residents were present during the measurement at the sampling location. The instruments and methods used for sampling and assessment of indoor air quality parameters are mentioned in Table 3.

2.7. Ambient noise pollution assessment

The noise levels for various zones i.e., industrial, commercial, residential and silence were measured using a digital noise level meter from Instrumex with a measurement range of 30–130 dB. Eight hours' time-weighted average sound level (TWA) was measured from 9:00 am to 5:00 pm at 9 locations across the state.

Table 2
Instruments/methods used for Ambient air quality assessment.

Ambient air quality Parameters assessed	Instruments/Method used	Indian standard Code
• $PM_{2.5}$	$PM_{2.5}$/ PM_{10} sampler (model Ecotech AAS 127)	IS 5182 (P-24): 2019
• PM_{10}	$PM_{2.5}$/ PM_{10} sampler (model Ecotech AAS 127)	IS 5182 (P-23): 2004
• SO_2	Respirable Dust sampler + UV Spectroscopy (UV 1900i/Shimadzu)	IS 5182 (P-2): 2001
• NO_2	Respirable Dust sampler + UV Spectroscopy (UV 1900i/Shimadzu)	IS 5182 (P-6): 2006

Table 3
Instruments/methods used for Ambient air quality assessment.

Indoor air quality Parameters assessed	Instruments/Method used
• CO	HSETIN HT-1000
• CO_2	Extech CO250
• HCHO and VOC	Trotec BQ16
• O_3	OZ001 by Forensics

3. Results and discussion

3.1. Socio-economic assessment

The assessment gives clear data regarding the age group in which 78 respondents were in majority (age group in between 26 and 35) whereas much of the respondents also belongs to other younger community (Fig. 2: a and b). Individuals from nuclear families were 108 and the one from joint family were 31 (Fig. 2: c). Marital and educational status gives a picture that the majority of people were married and having senior secondary education (Fig. 2: d and e). The assessment of 200 respondents provides with the data that 133 knows about health hazard due to COVID-19, 104 people focus on precautionary measures, 141 people do not have the proper knowledge to use the protective equipment and 156 people were not using Aarogya Setu application this application is to spread awareness of COVID–19 and to connect essential COVID–19-related health services to the people of India, results are shown in Fig. 3.

After estimating and evaluating socioeconomic status it is clear that the impact of the pandemic on individual life is different [57]. The various parameter such as age group, education, nature of family, population density plays a significant role while doing a socioeconomic assessment. Moreover, it has a disastrous impact on the lower-income group of society, social distancing is a worldwide strategy adopted that has ensured that it is possible to contain COVID-19 [58,59]. A highly populated area ensures that social distancing in the urban sector is quite difficult.

3.2. Hazards and effects of improper ergonomic conditions

51% of people were from the age group of 26–35 (Fig. 4: c). About 73% of the people were working from home and 50% of the individuals were working for over 10 h instead of the normal 8 h (Fig. 4: b and d). As a result, most of them were having ill-health and headache, back pain and shoulder pain was found to be common in all age groups (Fig. 4: e). People over the age of 35 were having multiple ill health effects where headache and back pain were more prominent (Fig. 5).

Ergonomics is the improvement of interaction between worker and the machine, making the interaction more suitable for the human body. The interface should be designed in a way that does not cause any strain on muscles or any joint [60]. Amidst this pandemic, there has been a shift in large numbers of working personnel to work in a home arrangement setting [61,62]. Along with this shift of workforce working from homes various musculoskeletal disorders like shoulder pain, neck pain, wrist pain, eye strain, swollen feel and headache are associated with people working continuously on computers [63,64]. Most modern work organization are equipped with workstations designed by considering ergonomic factors [65,66].

3.3. Water quality of major water bodies of Uttarakhand

The results of water quality assessment for the rivers Ganga at HarkiPauri, Haridwar, Yamuna at Dakpathar, Dehradun, Mandakini at Rudraprayag, Alaknanda and Bhagirathi at Devprayag before their confluence of Garhwal region and Naini lake, Bhimtal lake in Nainital of Kumaon region are depicted in Fig. 4. During the lockdown, the hardness levels for all the water bodies were reduced, the mean and SD for

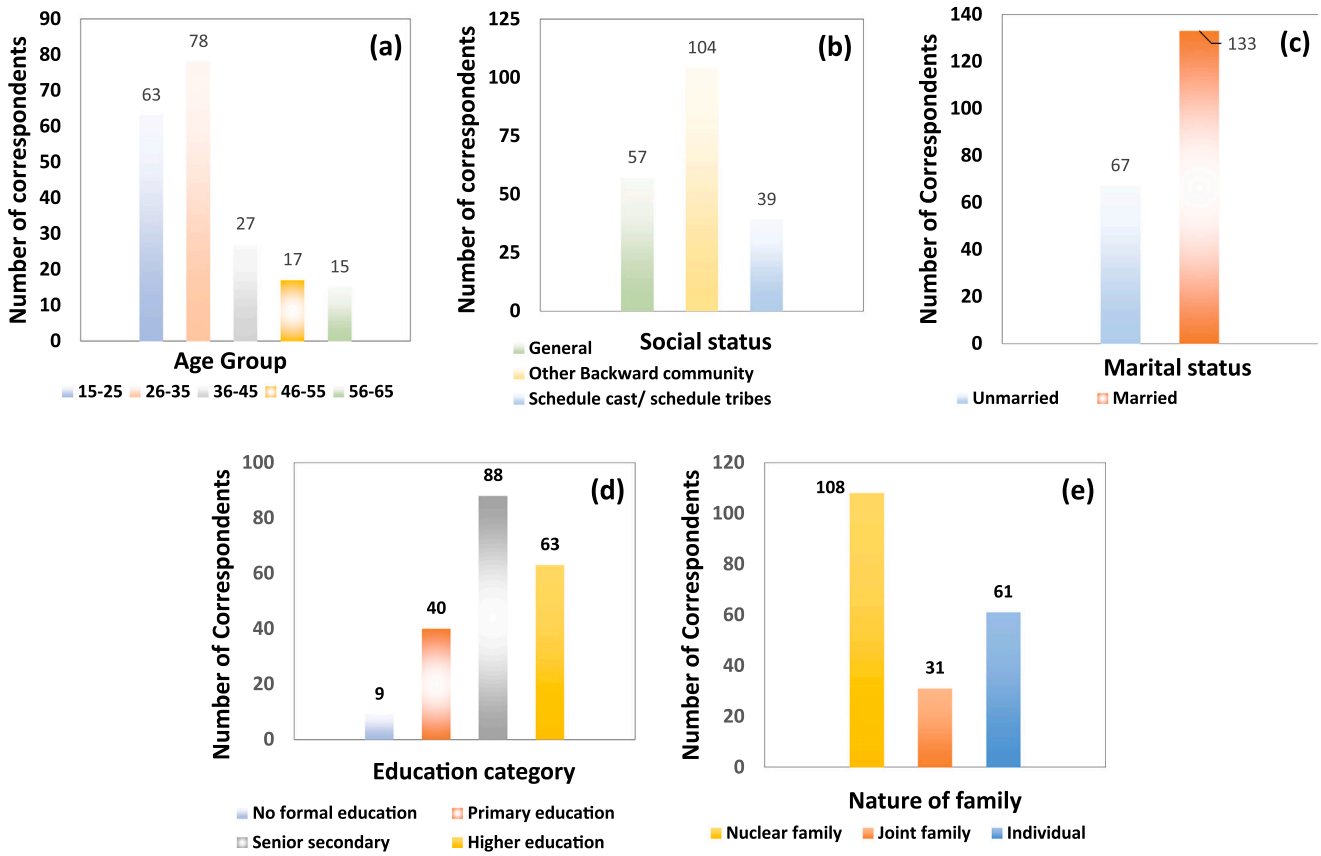

Fig. 2. Socio-Economic Assessment: (a) age group; (b) social status; (c) marital status; (d) education; and (e) nature of family.

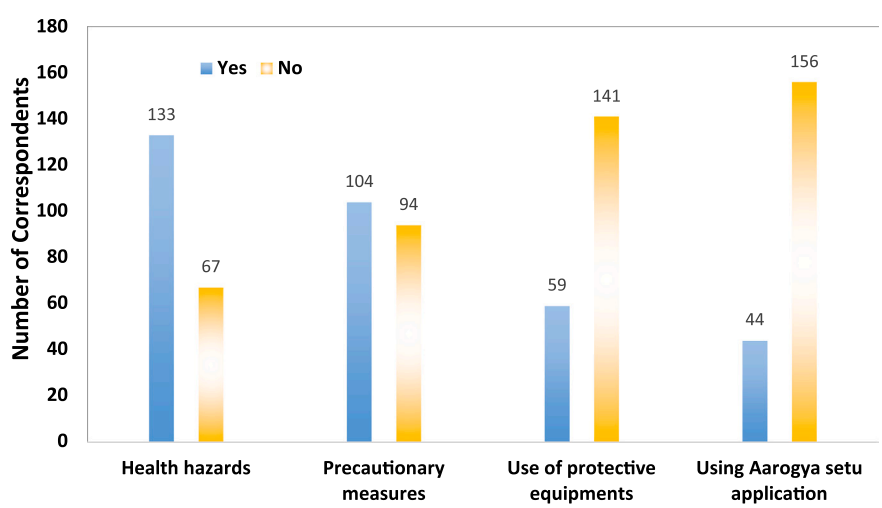

Fig. 3. Awareness about Covid-19.

Ganga and Yamuna during lockdown i.e., quarter-2 was observed to be 67 ± 8.88 mg/L and 55 ± 6.05 mg/L, respectively but these levels started to increase once again after the lockdown was lifted in the quarter-3 (Fig. 6: a). The results for alkalinity are depicted in Fig. 6: b. The variation in the levels of alkalinity reveals that the levels declined during the lockdown, the mean and SD for Ganga and Yamuna during the lockdown was observed to be 60 ± 7.59 mg/L and 50 ± 6.89 mg/L, respectively. However, the levels began to rise in the third and fourth quarters. Total Dissolved Solids (TDS) levels are shown in Fig. 6: c. A decline in TDS concentrations can be observed for the lockdown period. After the monsoon period i.e., quarter-3 there was a significant increase in the TDS concentrations. The total coliform index of Ganga and Yamuna was reduced to 50 MPN/100 ml, 40 MPN/100 ml respectively during the lockdown period (Fig. 6: d). The results for BOD, COD and Dissolved Oxygen (DO) are depicted in the Fig. 6: d–f, respectively. pH of Ganga, Yamuna, Mandakni, Alaknanda before the lockdown was 8, 8.2, 7.8, 7.9 respectively before lockdown which reduced to 7.54, 8.05, 7.41, 7.3 respectively during lockdown (Fig. 6: g). Hardness, alkalinity, TDS, total coliform MPN and pH have improved for all these water bodies across the state during the lockdown imposed due to COVID-19. The reason for improved water quality is reduced human activities and lesser discharge of industrial effluents into these water bodies.

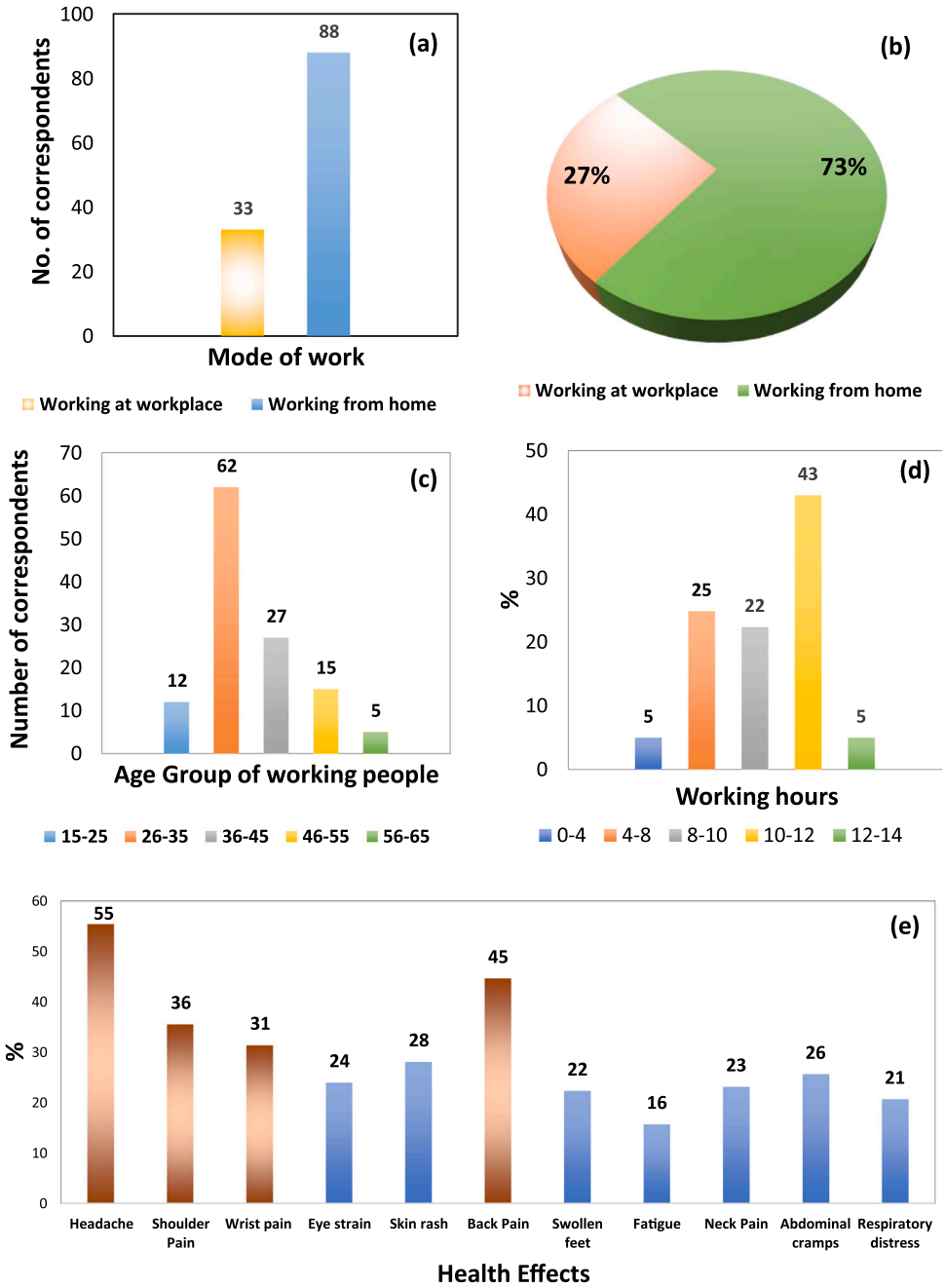

Fig. 4. Assessment of Ergonomic conditions and ill-health effects: (a) mode of work; (b) percentage of model of work; (c) age; (d) working hours; and (e) ill health effects.

It is necessary and crucial to test the water before it is used for drinking, domestic purposes, or industrial and agricultural use. The choice of monitoring parameters depends on the purpose of use and what quality of water is needed. For testing the physical properties like temperature, pH, color, TDS, odor etc., physical tests must be performed [67,68]. On the other hand, chemical testing is done to measure properties like hardness, alkalinity, BOD, COD and DO etc. Hasadsri and Maleewong [69]. For assessment of water quality, these parameters should be measured and monitored regularly [70]. pH determines water's corrosive behavior, and water is more corrosive when the pH is on the lower scale, alkalinity and conductivity of water depend upon its pH [71,72]. The toxicity of various substances in water is affected by pH, hardness, and alkalinity. Water with high alkalinity is not fit for industrial use as it causes operating problems in boilers [73]. DO is one of the most critical parameters. Its relationship with the water body provides details like bacterial activity, availability of nutrients, in the water body, stratification. During summers, the DO increases because of increased temperature and bright sunlight [74]. BOD is a measure of contamination of organic matter in water and is the quantity of dissolved oxygen needed for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials. (e.g., iron, sulfites) [75]. COD is measured to know the dissolved oxygen which is needed for the chemical oxidation of organic matter. COD and BOD are prime indicators of the environmental health of a water body [76]. The hardness of rivers varies from one season to another, it is higher in the rainy season and lower during winters. For Himalayan River calcium ions are the major contributor to total hardness [77,78].

The water quality of rivers degrades because of anthropogenic activities such as industrial effluents, sewage discharge and surface runoff [79,80]. Less human and industrial activity during the lockdown phase

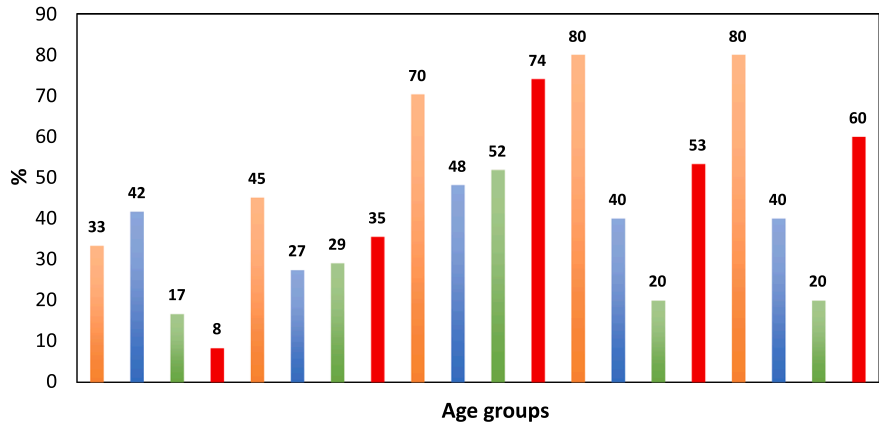

Fig. 5. Comparison of major health issues for different age groups.

has shown improvement in the water quality of major rivers in Uttarakhand. Many of these rivers like Ganga and Yamuna are associated with religious activities [81]. Every year, millions of people from all over the country visit them for performing religious activities. Ganga river at Rishikesh is also famous for river rafting and other water sports [82,83]. The major contamination points for river Ganga are located along the downstream of Haridwar [84].

3.4. Ambient air quality of Uttarakhand

The results for ambient air quality assessment of Garhwal and Kumaon region of Uttarakhand are shown in Fig. 7. During the 2nd quarter i.e., lockdown phase, a significant reduction in the concentration levels of pollutants like PM_{10}, $PM_{2.5}$, SO_2, NO_2 was observed which began to rise again in third and fourth quarter. The concentration of these pollutants was under the prescribed limits as suggested by National Ambient Air Quality Standards (NAAQS for $PM_{2.5} = 60\ \mu g\ m^{-3}$, $PM_{10} = 100\ \mu g\ m^{-3}$, $SO_2 = 80\ \mu g\ m^{-3}$, $NO_2 = 80\ \mu g\ m^{-3}$ based on 24-h average).

Air pollution is one of the serious issues which the entire world is facing especially for the countries who are in their developing phase. After liberalization in 1990, India has seen economic growth, rapid urbanization, industrialization, and huge infrastructure development [85]. At the same time, India's level of air pollution has risen to significant health risk and source of substantial premature mortality. According to a survey in India, around 1 million people lost their lives in the year 2015 due to poor air quality with the particulate matter as a major source. In recent years, cities of India are among the top twenty most contaminated cities in the world and did not meet the environmental air quality criteria given by Central Pollution Control Board-India (CPCB) and WHO [86,87]. Emission from vehicle and industries are the major source for contributing the particulate matter [88, 89]. A study was conducted to analyze the ambient air quality for Mumbai and Delhi and it was found that there was a substantial decrease in the emission of NO_2, PM_{10} and NO_2 was recorded during the lockdown time [90]. As the lockdown was implemented most of the activities and vehicular movement was restricted to a considerable extent helping the air quality to improve [91,92]. However, through various measures, if the air quality could be improved it would help in decreasing the number of cases of asthma, heart problems, respiratory disorder etc. Samet et al. [93].

3.5. Indoor air quality during COVID-19 lockdown phase

The results for indoor air quality assessment are depicted in Fig. 8. During the lockdown phase increase in concentration levels of these pollutants was observed, also seasonal variation can be observed for volatile organic compounds (VOCs) and HCHO (Fig. 8: d and e). Results were similar to a study performed by A. Kumar in 2014, the VOC levels in the winter season were higher than summer season [94].

An average human being spends most of the time indoors (ranging from 85% to 90%), the understanding ambient environment is important, the indoor environment is majorly polluted from indoor pollutants like humans and combustion processes in the kitchen or living room. Cattaneo et al. [95]. There has been growing awareness about the adverse health effects of poor Indoor air quality (IAQ) in the last two decades, researchers across the globe are performing numerous studies to assess the IAQ. During the distinct phases of lockdown due to the pandemic, people spent all their time indoors, which might have a possibility to increase indoor air pollution having an adverse impact on human health [96]. Indoor air contaminant originates from a wide variety of sources. They are generated during various human activities and infiltration from outside increases the level of pollutant concentration [97]. The concentration of pollutants depends on the air confined in an indoor environment, the rate of release or removal of pollutants and the rate at which it is removed, the air exchange rate with outside air [98]. VOCs such as benzene, toluene, xylenes, and formaldehyde are commonly released indoor air pollutant. Several indoor air contaminants are human carcinogen and have various other adverse effects on human health such as eyes, skin irritation and a wide variety of respiratory diseases can be associated with these indoor contaminants. Bravi et al. [99]. Households with biomass fuel burning and charcoal burning have elevated levels of PM_{10} and carbon monoxide than those where clean fuels are used [100]. Various respiratory disorders such as asthma, chronic obstructive pulmonary disease etc. are caused by the smoke of biomass fuel [101,102].

3.6. Ambient noise pollution assessment

The results for ambient noise before the lockdown period ranges from 46 to 73 dB(A) and during the lockdown phase, it was reduced to 41–57 dB(A), shown in Fig. 8. The standard value of different zones is given by CPCB in Table 4 The noise level observed from Dehradun region i.e., from EC road, Doon DNA labs, Paltan market, Clement town, Police line were 51 dB, 47 dB, 57 dB, 44 dB, 41 dB respectively during lockdown phase, whereas data observed from Kumaon region i.e., Bus stand (Nainital), Vishal mega mart (Haldwani), Queens School Haldwani, Canal Road (Haldwani) were 46 dB, 45 dB, 44 dB and 45 dB respectively during lockdown phase. The study clearly illustrates that noise level was reduced during lockdown when compared with pre lockdown data (Fig. 9) As per WHO noise pollution is ranked among the top three hazardous pollutions. There are many adverse effects when a person is exposed to either short term or long-term range resulting in high blood pressure, depression, hormonal disturbance, anxiety etc. Lai and Huang [103]. Through the study, it is clear that a 5 dB rise in roadside noise will increase the risk of hypertension by 3.4% [104].

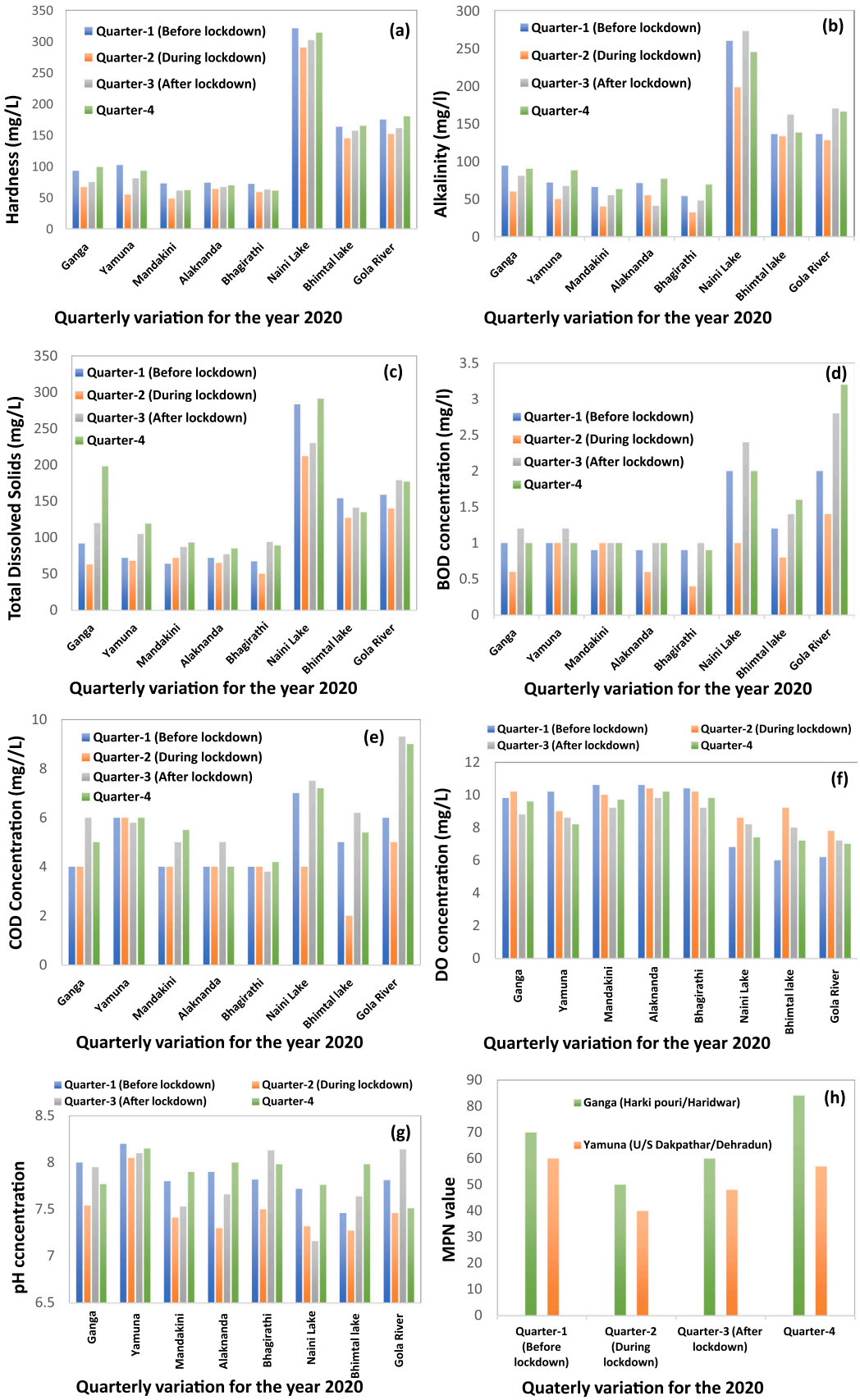

Fig. 6. Assessment of Water Quality parameters: (a) Hardness (mg/L); (b) Alkalinity (mg/L); (c) Total Dissolved Solids (mg/L); (d) BOD (mg/l); (e) COD (mg//L); (f) Dissolved Oxygen (mg/L); (g) pH of major streams of Uttarakhand; and (h) MPN for Ganga & Yamuna.

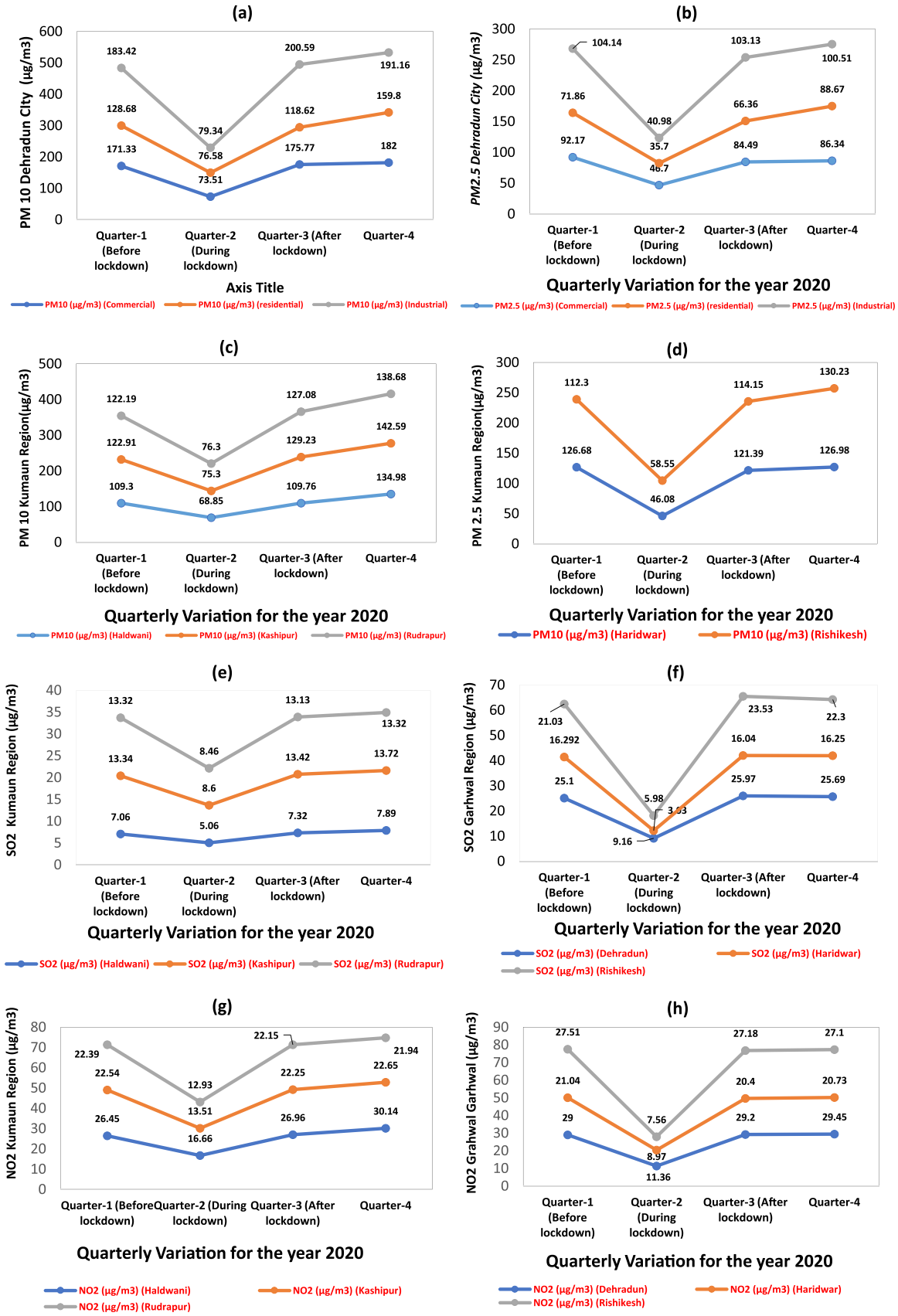

Fig. 7. Assessment of Ambient air quality: (a) PM10 Dehradun City; (b) PM2.5 Dehradun City; (c) PM10 Kumaon Region; (d) PM10 Rishikesh & Haridwar; (e) SO2 Kumaon Region; (f) SO2 Garhwal Region; (g) NO2 Kumaon Region; (h) NO2 Garhwal Region.

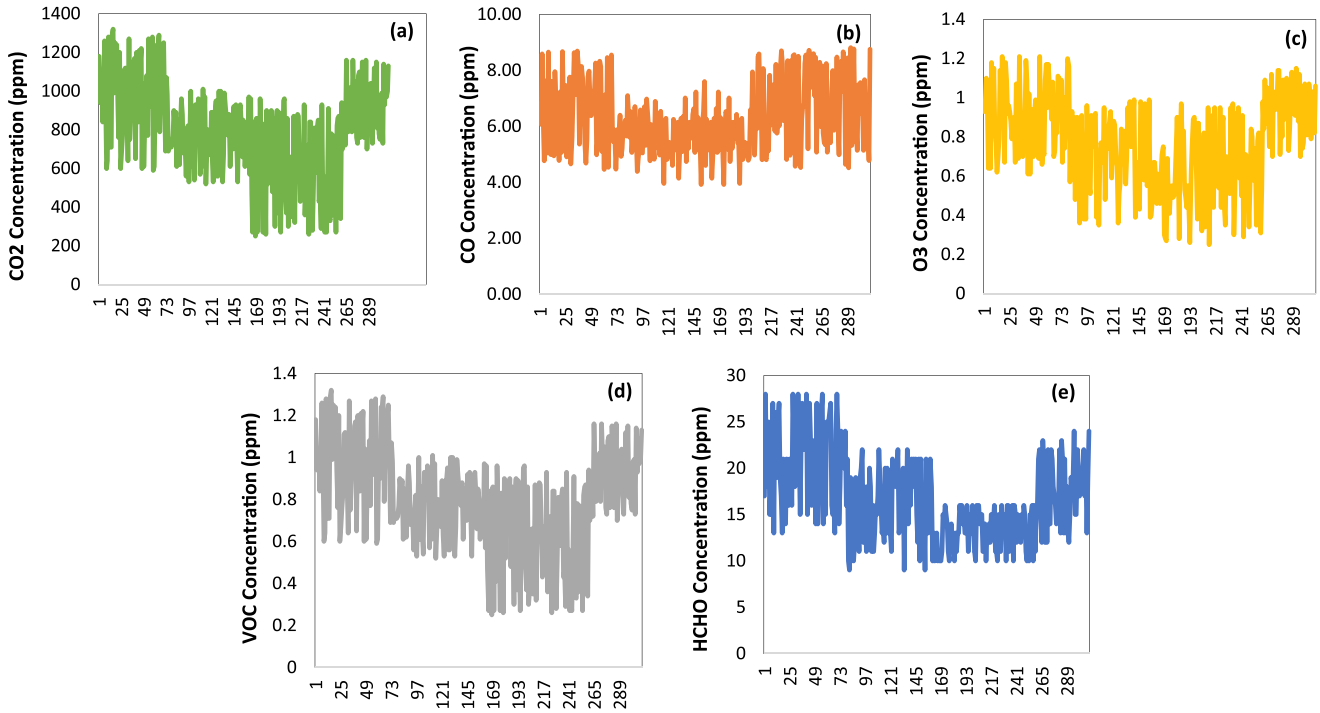

Fig. 8. Assessment of Indoor air quality: (a) CO2 (10–15% ventilation); (b) CO (10–15% ventilation); (c) Ozone (10–15% ventilation); (d) VOC (10–15% ventilation); and (e) HCHO (10–15% ventilation).

Table 4
Ambient noise standard values according to CPCB, India.

Zone category	Limit in dB (A) L_{eq}	
	Day time	Night time
Industrial	75	65
Commercial	65	55
Residential	55	45
Silence	50	40

Road traffic is one of the key sources of noise emission and the WHO estimates that around 40% of the population of Europe is subjected to a noisy environment [105,106]. Globally it was estimated that there was a reduction in the level of noise up to 35–68% during the lockdown period [107]. Noise pollution also affects marine life as various human activities such as the use of radar, boats etc. creates a lot of disturbance in the aquatic ecosystem (coral reefs) [108]. Most of the underwater noise resulting from human activity is estimated to be of lower Hertz [109]. The lockdown also impacted the aquatic environment because of COVID-19, all water transport movement was stopped which significantly helps to decrease the number of emissions generated by human activities.

4. Conclusions

The present paper investigated the impacts of the COVID-19 lockdowns on socioeconomics, ergonomics, and environment (water quality, air quality and noise) in Uttarakhand, India. The key findings and conclusion were as follows:

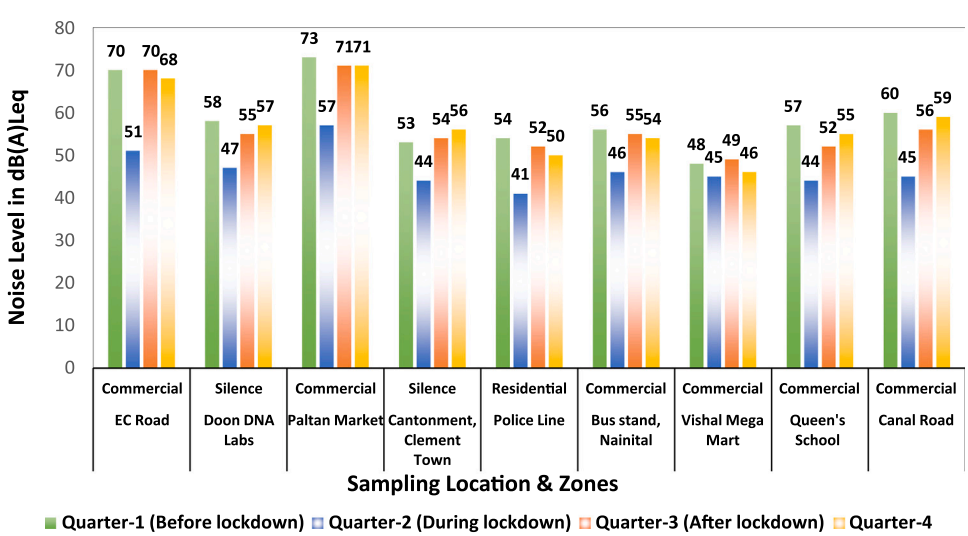

Fig. 9. Assessment of noise pollution.

- The results showed that 33% of respondents were unaware of the health hazards of COVID-19, despite various information provided by the government. Approximately 47% of individuals were not taking the right precautionary measures such as using masks, and face shields properly.
- With the shift of workforce working from homes due to the pandemic, people were working for long hours without any adequate workstations which lead to various musculoskeletal disorders in individuals of all age groups. Approximately 55% of the respondents experienced work-related health effects such as headache while 45% of respondents were having back pain. Therefore, to reduce the increasing cases of musculoskeletal disorders, there is need for raise awareness on the human health risks, improve occupation health procedures and policies, and provide appropriate work stations.
- The lockdown had a positive impact on water and air quality due to reduced tourist activities in Uttarakhand, but the effects were temporary.
- The concentrations of indoor air pollutants were higher during the lockdown phase due to increased indoor activities, but declined in the post-lockdown period.
- Lockdowns significantly reduced the ambient noise levels relative to the pre-pandemic period.

Overall, the present study provides a comprehensive and integrative understanding of the impacts of lockdowns on socio-economics, ergonomics, and environmental quality. This information can be used to developed strategies and policies to safeguard the environment and human health. Therefore, during lockdowns there is a need to minimize the adverse environmental and ergonomic impacts of lockdowns while simultaneously enhancing the beneficial impacts. Further research should focus on developing and pilot testing various control methods for the mitigation of the negative impacts of COVID-19 lockdowns.

CRediT authorship contribution statement

Abhishek Nandan: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization, Validation, Project administration. **N.A. Siddiqui:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization, Validation, Project administration. **Chandrakant Singh:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization, Validation, Project administration. **Ashish Aeri:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization, Validation, Project administration. **Willis Gwenzi:** Writing – original draft, Writing – review & editing, Visualization, Validation. **Joshua O. Ighalo:** Writing – original draft, Writing – review & editing, Visualization, Validation. **Patrícia de Carvalho Nagliate:** Writing – original draft, Writing – review & editing, Visualization, Validation. **Lucas Meili:** Writing – original draft, Writing – review & editing, Visualization, Validation. **Pardeep Singh:** Writing – original draft, Writing – review & editing, Visualization, Validation. **Nhamo Chaukura:** Writing – original draft, Writing – review & editing, Visualization, Validation. **Selvasembian Rangabhashiyam:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision, Validation, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jece.2021.106595.

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