Air pollution and associated self-reported effects on the exposed students at Malakand division, Pakistan

Sana Ullah · Naeem Ullah ·
Sohail Ahmed Rajper · Ilyas Ahmad · Zhongqiu Li

Received: 28 March 2021 / Accepted: 22 September 2021 / Published online: 8 October 2021
© The Author(s), under exclusive licence to Springer Nature Switzerland AG 2021

Abstract Air pollution is associated with several severe physical, behavioral, and psychological health risks and glitches. Air pollution has been linked to 11 million premature deaths in Pakistan, out of the total 153 million premature deaths worldwide. Air pollution is continuously growing as a threatening challenge for Pakistan. Keeping this in view, the current study was designed to assess air pollution in terms of air quality index (AQI), particulate matters (PM_{2.5} and

PM₁₀), SO₂, NO₂, and O₃ over six districts of Malakand division, Northern Pakistan. The second part of the study appraised the associated self-reported effects of air pollution on Pakistani students and the practices, perceptions, and awareness of the students regarding air pollution through a closed-ended questionnaire, administered to 4100 students. The first section of the questionnaire was focused on the physical effects associated with air pollution; the second section was focused on air pollution-linked behavior and psychology; the third portion was focused on perception and awareness of the subjects, whereas the final section was focused on practices and concerns of the subjects regarding air pollution. The students reported that exposure to air pollution significantly affected their physical health, behavior, and psychology. The subjects were aware of the different air pollutants and health complications associated with air pollution, and therefore had adopted preventive measures. It was concluded that air pollution had adverse impacts on the physical and psychological health of the respondents, which consequently altered their behavior. Mass awareness, proper mitigating plan, suitable management, and implementation of strict environmental laws are suggested before the air gets further polluted and becomes life-threatening.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10661-021-09484-2>.

S. Ullah (✉) · S. A. Rajper · Z. Li (✉)
School of Life Sciences, Nanjing University, Nanjing,
Jiangsu 210023, People's Republic of China
e-mail: sanaullah@ue.edu.pk

Z. Li
e-mail: lizq@nju.edu.cn

S. Ullah
Department of Zoology, Division of Science
and Technology, University of Education, Lahore 54000,
Pakistan

N. Ullah
Department of Management Sciences, Abdul Wali Khan
University Mardan, Timergara Campus, Timergara 18300,
Pakistan

I. Ahmad
Department of Economics and Business Administration,
University of Education, Jauharabad Campus,
41200 Jauharabad, Pakistan

Keywords Air pollution · Physical effects · Behavioral effects · Psychology · Prevention · Knowledge · Perceptions

Introduction

Humans are continuously evolving to be better adapted and suited to their surroundings; however, pollution has been an off-putting factor for them for a very long. Air pollution got more severe and threatening with material and technological advancements. These developmental approaches led to chemical, physical, and biological modifications of the environment. These alterations are in different aspects including air, water, and general environmental setups, which consequently disturb nature's balance and its regenerative capabilities. Rapid and continuously increasing industrialization, mechanized transportation, population growth, and alarming urbanization introduce and add hundreds of new elements, which subsequently disturb the environment. Factories and mills add a mammoth 25 billion pounds of toxic pollutants every year to the atmosphere and 22 billion pounds of pesticides are employed in the agriculture sector per year, which means eight pounds of pesticides per citizen (Roman & Idrees, 2013). Even, some illegal pesticides carrying different hazardous materials are used. Most of the artificial chemicals are not screened from a toxicological standpoint; still, the annual global production of synthetic chemicals exponentially grew since the start of the twentieth century (Donohoe, 2003).

In Pakistan, the swift increase in vehicles' number and common use of low-quality fuel is prominent sources of air pollution. Emission from vehicles (carbon and lead) contributes the highest to air pollution in urbanized cities including Karachi, Islamabad, Faisalabad, and Lahore (Roman & Idrees, 2013). The scenario remains the same globally and a 29% increase has been recorded in the atmospheric CO₂ since the start of industrialization, while its production reached 6–8 billion tons per year (Donohoe, 2003). Apart from this, there are other different natural and anthropogenic causes of air pollution. The natural ones include dust from barren lands, methane from food digestion by the animals, radioactive decay of the earth's crust emitting radon and wildfires giving rise to CO and smoke, and volcanic eruption producing ash particulates, chlorine, and sulfur. However, the most important and lethal cause of atmospheric pollution is ill-anthropogenic activities. These include

the excessive use of fossil fuels (coal, gas, and oil use — largest source of air pollution), mobile sources (marine vessels, aircraft, motor vehicles, etc.), chemicals, dust, fumes (paints, aerosol sprays, varnish, hair spray, etc.), and continuous population growth.

Air pollution is the result of introducing new biological materials, particulate matter, and chemicals that can harm or adversely affect human beings and other organisms. These can seriously damage the built environment or natural environment and disrupt the atmosphere, which is a complex dynamic system of natural gases and essential for life. Man-made advancements led to the depletion of the Stratospheric zone, identified as grave threatening for earth's ecosystem generally and for human health in particular. However, the concerns and threats are continuously increasing with different environmental deteriorating factors, for example, the addition of new machines, chemical mills, vehicles, factories, industrial smoke, and atomic radiations. Air pollution adversely affects the biosphere (humans, animals, and plants) and damage human property such as their houses or other buildings. The major classes of pollutants are hydrocarbons, carbon monoxide, sulfur oxide, nitrogen oxides, and particulate matter (i.e., PM_{2.5}, PM₁₀, etc.). An increase in the concentration of these pollutants leads to different problems for human health. These problems may be in the form of a medical emergency (different diseases and disorders) or an economic burden. Several studies have explored and discussed the association of different disorders with air pollution (Abelsohn & Stieb, 2011; Rajper et al., 2018). In severe cases of air pollution, it can lead to death. According to a report published by The News, 153 million premature deaths are linked with air pollution globally and 11 million of these deaths have been reported from Pakistan (Hasan, 2018).

Due to the threatening consequence of air pollution across the globe, more specifically around the developing countries including Pakistan, breakthrough research, enormous positive input, mass awareness, and pollution mitigating steps are necessarily required. The bigger cities in Pakistan enjoy the existence of different environmental promoting activities from different environmental protection agencies and government or non-governmental organizations. However, the smaller and farther cities, towns, villages, valleys, and some divisions or districts lack

such kind of attention. Malakand division is among those divisions of Pakistan, lacking proper attention. The scenario is even more threatening from the new developmental point of view. On account of having dense forests, rivers, and hill stations, different projects have been initiated in the districts of Malakand division such as hydropower projects, industries, and expanding networks of roads without proper environmental management planning leading to excessive deforestation and polluted water and air (Ullah & Li, 2019).

In recent times when due to the COVID-19 lockdown across the globe a significant decrease in air pollution was observed, recent reports revealed an increase in air pollution in Pakistan even in the capital city, Islamabad (The Express Tribune, 2020). Keeping in view the current scenario, the current study was carried out in six districts (Dir Lower, Dir Upper, Chitral, Swat, Buner, and Shangla) of the Malakand division (Khyber Pakhtunkhwa, north-western province of Pakistan) to know the self-reported physical and psychological effects of air pollution on the students. The study also evaluated the level of awareness, adoption of preventive measures against air pollution, and sources of knowledge of the recruited subjects.

Materials and methods

The study was undertaken according to the Ethics Review Committee of NJU (No. 2009–116). To acquire data/information, the review committee approves informed verbal consent. Therefore, the questionnaire was administered after the informed consent of the students. They were informed thoroughly regarding the content and purpose of the study. The students were told about their right to answering all or part of the Google survey form and that they can withdraw from the study or stop at any time point.

We designed a comprehensive questionnaire and administered it randomly among students from different universities in China (Rajper et al., 2018). The same questionnaire was administered to 4100 students through Google form, mostly from the universities of Khyber Pakhtunkhwa province. The questionnaires sharing identical answers to all the questions or missing answers were excluded. A total of 4021

questionnaires were selected for analysis and inclusion in the study. The respondents were from six districts of the northern part of Pakistan, known as the Malakand division. The districts included district Dir Lower, district Upper Dir, district Chitral, district Swat, district Buner, and district Shangla (Fig. 1).

The questionnaire was consisting of several questions to know about the individual impacts of air pollution on both physical, and psychological, and behavioral health of the students. The questionnaire was in English because of being the official language for higher education in Pakistan. The questionnaire consisted of four sections. The first two parts were dedicated to reporting any physical effects, and psychological and behavioral adversity associated with air pollution. The third part was about the knowledge, attitude, and practices (KAP) of the students about air pollution. The fourth part evaluated the sources of knowledge and general perceptions of the students regarding air pollution and the different health risks associated with air pollution. The survey was conducted from December 2018 through February 2019.

Malakand division was selected for the study because of bearing in mind the continuously increasing population, several under-construction hydropower projects, and other developmental projects such as a major link (by the name of Swat Expressway) to the main motorway scheme of roads, and variation among the districts such as different population density, road networks, weather, literacy rate, forests and vegetation, ecotourism, and industries. The randomly recruited students were from different areas such as living in industrial zones (higher fossil fuel use, combustions, and effluent emissions), having complex road networks (higher emission from transportation), highly congested areas, and remote areas (mostly less crowded, lesser population, and lesser or no industries and/or road networks). Based on these differences, these districts were supposed to have different levels or concentrations of air pollutants and were therefore observed every month (Dec 2018–Feb 2019). The level and concentrations of air pollutants were measured by using portable multifunctional air quality detectors (VSON Technology Co. Ltd. China).

The collected data was imported to MS Excel and analyzed in Statistix (V. 10). Based on our previous study, the data was explored through chi-square (independence) test to examine different types of associations such as gender-, district-, and age-dependent

Fig. 1 Geographical locations of the sampled districts

association of physical and behavioral or psychological effects, adoption of preventive measures, awareness, and perceptions of the respondents. The demographics and all the sections of the questionnaires were summarized using descriptive statistics (proportion/frequencies/percentages). Bonferroni adjustment (correction) was carried out to avoid and adjust family-wise error, through adjusting α value (α_{original}) by defining new α value ($\alpha_{\text{altered}} = 0.05/\text{number of possible analysis/comparisons for each question/section of the questionnaire}$). The Bonferroni type adjustment and the calculated values are shown in Table S1. To find out the difference among the studied districts for the level of pollutants, the data were analyzed through ANOVA followed by Tukey HSD. A p -value of less than 0.05 was considered to be statistically significant.

Results

A total of 4100 students were recruited for the study from the Malakand division, studying at different universities across Pakistan. However, most of the subjects were from the larger universities of north-western Khyber Pakhtunkhwa province such as the University of Malakand (14.9%), University of Swat (13.8%), University of Peshawar (12.0%), and Abdul Wali Khan University Mardan (10.7%). Table S2 shows the list of the universities and the gender-wise number of students from each university. The highest number of subjects was recruited from the district Dir Lower (28.2), followed by district Swat (24.5) and district Dir Upper (20.7%). The students were divided into five age classes. Most of the recruited subjects were in the age range 26–30 (34.5%) followed by the

age range 16–20 (32.5). Similarly, 58.4% of the subjects were males while 41.6% were female students. Table S2 shows district-, gender-, and age-wise division of the subjects whereas Table S3 shows the number of students recruited across different universities across the country.

The level of air pollutants was varying across the districts as well as across the observing months (Dec 2018, Jan 2019, and Feb 2019). Table S4 shows the recorded level and concentration of air pollution in terms of AQI (air quality index), $PM_{2.5}$ (particulate matters having a smaller size than $2.5\ \mu m$), PM_{10} (particulate matters having a smaller size than $10\ \mu m$), SO_2 , NO_2 , CO , and O_3 . The highest level of AQI, $PM_{2.5}$, PM_{10} , SO_2 , and NO_2 was recorded at district Swat; however, the least level of the pollutants was recorded at district Chitral. Figure 2 shows the variation of air pollutants across the Malakand division.

The first section of the questionnaire covered the physical effects reported by the students in response to air pollution. Over 90% of the students reported that they always or often felt the adverse effects of air pollution, indicating a serious concern regarding air pollution in the near future. Of the total respondents, 31.3% (always) and 48.8% (often) faced ENT (ear, nose, and throat) problems, irritations, or allergies.

The respiratory problems were reported to be lesser as compared to the previous question, i.e., always (15.1%) and often (15.7%). Similarly, 13.7% of the students reported that they always suffer from sleeping disorders or disruption; however, 52.5% and 27.4% of the students reported that they often and sometimes suffer so, respectively. Table 1 shows the reported physical health effects of air pollution.

The second portion of the questionnaire consisted of the behavioral and psychological effects of air pollution. A total of 82.0%, 85.7%, 88.8%, and 82.5% of students reported that they feel depressed, jog faster and for a shorter time, walk faster, and feel aggressive on hazy days or when there is heavy air pollution. Table 2 shows the reported behavioral and psychological effects of air pollution.

The third portion of the questionnaire was regarding the adoption of preventive measures to mitigate air pollution-based health effects. Of the total respondents, 71.2% reported that they use respiratory masks, 51.7% wear eyeglasses or goggles, 69.4% drink more water to flush out toxins, and 56.6% reported that they eat rich food to enhance their immunity. Table 3 shows the preventive measures adopted by the recruited students to prevent the ill effects of air pollution.

Fig. 2 Level of pollutants across the studied districts. Data presented as mean $\pm$ SE ($n=3$). Means with different superscripted letters are significantly different ($p < 0.05$). (ANOVA followed by Tukey HSD test)

Table 1 Air pollution caused physical health effects reported by the respondents

Physical effects	Always (%)	Often (%)	Sometimes (%)	Rarely (%)	Never (%)
Felt air pollution effects	2969 (73.8)	868 (21.6)	173 (4.3)	8 (0.2)	3 (0.1)
ENT problems/irritation/allergies	1258 (31.3)	1964 (48.8)	736 (18.3)	59 (1.5)	4 (0.1)
Respiratory problems	607 (15.1)	632 (15.7)	1638 (40.7)	838 (20.8)	306 (7.6)
Coughing or wheezing	227 (5.6)	1409 (35.1)	1317 (32.8)	946 (23.5)	122 (3)
Headaches and dizziness	390 (9.7)	1198 (29.8)	1117 (27.8)	1024 (25.5)	292 (7.3)
Reduced energy level	253 (6.3)	630 (15.7)	709 (17.6)	1045 (26)	1384 (34.4)
Sleeping disorder/disruption, i.e., insomnia	549 (13.7)	2110 (52.5)	1104 (27.4)	195 (4.8)	63 (1.6)

The fourth and last part of the questionnaire assessed the knowledge, perception, and sources of knowledge of the students regarding air pollution. Over 93% of the students were of the view that there should be smoking designated places and should be prohibited in general places. Of the total subjects, 77.2% were aware of the disorders and deaths associated with air pollution, 63.3% were aware of the major air pollutants, and 69.1% of students reported that the GDP growth of Pakistan leading to health losses is not acceptable or affordable. Table 4 shows the level of awareness and perceptions of the subject of air pollution.

In response to a question regarding the sources of pollution (three options selection), the students reported vehicle exhaust, biomass burning, and emission from industries to be the major sources of pollution in Pakistan. Figure 3A shows the responses regarding air pollution sources. However, in response to a question regarding the source of knowledge about air pollution (selection of as many options as applicable), most of the students reported television to be the major source of knowledge, followed by the internet and newspaper. Figure 3B

shows the reported sources of knowledge about air pollution.

Table 5 shows gender- and district-dependent, while Table 6 shows age-dependent physical health effects of air pollution. Table 7 shows gender- and district-dependent while Table 8 shows age-dependent behavioral and psychological effects of air pollution. Tables 9 and 10 show gender- and district-dependent, and age-dependent adoption of practices to prevent ill effects of air pollution. Table 11 shows gender- and district-dependent while Table 12 shows age-dependent knowledge and perception of the students regarding air pollution.

Discussion

Pakistan has been named as one of the fastest-growing economies in Asia. However, this advancement is coupled with the rapid growth of population, industrialization, and urbanization leading to severe air pollution. At this stage, Pakistan is faced with many challenges; however, urban air pollution is one of the most challenging and notable issues. Air pollution is more severe in the larger cities as compared to rural setups or countryside due to modern industrialization and urban reconstructions. For example cities like Lahore, Karachi,

Table 2 Reported behavioral and psychological effects associated with air pollution

Behavioral effects	Yes (%)	No (%)
Depressed	3297 (82.0)	724 (18.0)
Jog faster and for a short time	3444 (85.7)	577 (14.3)
Walk faster	3570 (88.8)	451 (11.2)
Anxiety	3037 (75.5)	984 (24.5)
Aggressiveness	3316 (82.5)	705 (17.5)
Aggressiveness during cold days	1059 (26.3)	2962 (73.7)
Aggressiveness during hot days	3117 (77.5)	904 (22.5)

Table 3 Preventive measure adapted to prevent ill effects of air pollution

Preventive measures	Yes (%)	No (%)
Use of respiratory mask	2862 (71.2)	1159 (28.8)
Wear eyeglasses or goggles	2080 (51.7)	1941 (48.3)
Drink more water	2789 (69.4)	1232 (30.6)
Build immunity with rich food	2270 (56.5)	1751 (43.5)

Table 4 Level of awareness and perceptions of the respondents regarding air pollution

Awareness/perception	Yes (%)	No (%)
Smoking should be prohibited	3758 (93.5)	263 (6.5)
Air pollution mediated deaths	3104 (77.2)	917 (22.8)
Accept health loss over GDP growth	1244 (30.9)	2777 (69.1)
Awareness about air pollutants	2545 (63.3)	1476 (36.7)

Peshawar, and Islamabad established different industries and improved substantially an infrastructure point of view such as initiation of subway or metro systems. These advancements attracted a lot of migrant workers to move to these cities and increased the pressure on the

carrying capacities of these cities resulting in urban air pollution. Consequently, consistent and long-term air pollution has been the major source of respiratory diseases and weak immune system in big cities around the globe (Fossati et al., 2006; Gül et al., 2011; Roman & Idrees, 2013; Zhang et al., 2008).

The current study assessed the self-reported physical and behavioral or psychological effects of air pollution, adopting different strategies to avoid the ill effects of air pollution. The perception of the students regarding air pollution and their level of awareness regarding air pollution were investigated. This study was the first of its type in the northern part of Pakistan for developing a model regarding a prominent and threatening social dilemma — air pollution. Our study provides valuable insight for covering the gap between health risk

Fig. 3 **A** Perception of the sources of air pollution generation (selection of any three options). **B** Sources of knowledge of the respondents regarding air pollution (selection as much options as apply)

Table 5 Gender- and district-dependent physical effects of air pollution on the respondents

Gender	Always		Often		Sometimes		Rarely		Never		<i>p</i> -value*	χ^2
	<i>n</i>	%	<i>n</i>	%	<i>N</i>	%	<i>n</i>	%	<i>n</i>	%		
Felt effects of air pollution												
Male	1825	77.7	411	17.5	102	4.3	8	0.3	3	0.1	0.000^a	63.00
Female	1144	68.4	457	27.3	71	4.2	0	0.0	0	0.0		
Sneezing, runny nose, dry throat, or eye Irritation												
Male	671	28.6	1057	45.0	561	23.9	56	2.4	4	0.2	0.000^a	161.72
Female	587	35.1	907	54.2	175	10.5	3	0.2	0	0.0		
Breath shortening or reduced lung function												
Male	283	12.0	321	13.7	987	42.0	521	22.2	237	10.1	0.000^a	102.67
Female	324	19.4	311	18.6	651	38.9	317	19.0	69	4.1		
Coughing or wheezing												
Male	74	3.2	571	24.3	746	31.8	847	36.1	111	4.7	0.000^a	680.05
Female	153	9.2	838	50.1	571	34.2	99	5.9	11	0.7		
Headache and dizziness												
Male	177	7.5	540	23.0	361	15.4	993	42.3	278	11.8	0.000^a	1217.6
Female	213	12.7	658	39.4	756	45.2	31	1.9	14	0.8		
Reduced energy level												
Male	67	2.9	273	11.6	220	9.4	549	23.4	1240	52.8	0.000^a	952.88
Female	186	11.1	357	21.4	489	29.2	496	29.7	144	8.6		
Sleep deprivation or sleeping disorders												
Male	340	14.5	996	42.4	780	33.2	181	7.7	52	2.2	0.000^a	290.15
Female	209	12.5	1114	66.6	324	19.4	14	0.8	11	0.7		
Adverse physical effects reported by the respondents across the studied districts												
Dir (Lower)	1367	17.2	2321	29.2	1689	21.3	1711	21.6	850	10.7	0.000^a	2416.74
Dir (Upper)	1034	17.8	1234	21.2	1735	29.8	1234	21.2	587	10.1		
Chitral	763	26.1	798	27.3	987	33.8	201	6.9	170	5.8		
Swat	1675	24.2	2756	39.9	1604	23.2	578	8.4	296	4.3		
Buner	876	29.9	921	31.5	540	18.5	357	12.2	232	7.9		
Shangla	538	33.0	781	47.9	239	14.7	34	2.1	39	2.4		
Total responses	6253	22.2	8811	31.3	6794	24.1	4115	14.6	2174	7.7	28,147	

*Bold value represents *p*-value < 0.05^a*p*-value < α altered (significant after Bonferroni adjustment)

awareness of air pollution and scientific research. It also provides key theoretical references for decision-makers and risk management of air pollution and useful measure to prevent or reduce the risks. Understanding public perceptions of air pollution and associated health risk is important for designing policies and intervention programs (Omanga et al., 2014). It is also necessary for air pollution reduction, and health risk reduction or prevention (Howel et al., 2002). However, the local masses must be aware of and rectify misunderstandings regarding air pollution and associated health risk.

This will enhance their comprehension as well as they can cooperate with the policymakers or environmental protection management agencies or organizations. This will not only make the execution of the policies easy but will also lower the policy cost.

There is plenty of literature available demonstrating the adverse impact of air pollution on humans. A plethora of research studies revealed the hostile effects of polluted air on the respiratory system (Fossati et al., 2006; Gül et al., 2011; Zhang et al., 2008). The key respiratory disorders reported are coughing, emphysema,

Table 6 Age-dependent physical effects of air pollution on the respondents

Age range	Always		Often		Sometimes		Rarely		Never		<i>p</i> -value*	χ^2
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%		
Felt effects of air pollution												
16–20	954	73.0	283	21.7	70	5.4	0	0.0	0	0.0	0.000^a	276.84
21–25	612	87.8	51	7.3	31	4.4	2	0.3	1	0.1		
26–30	993	71.6	389	28.0	4	0.3	0	0.0	1	0.1		
31–35	321	67.2	102	21.3	51	10.7	3	0.6	1	0.2		
≥36	89	58.6	43	28.3	17	11.2	3	2.0	0	0.0		
Sneezing, runny nose, dry throat, or eye irritation												
16–20	519	39.7	532	40.7	239	18.3	15	1.1	2	0.2	0.000^a	166.82
21–25	198	28.4	421	60.4	66	9.5	11	1.6	1	0.1		
26–30	351	25.3	741	53.4	273	19.7	21	1.5	1	0.1		
31–35	134	28.0	213	44.6	127	26.6	4	0.8	0	0.0		
≥36	56	36.8	57	37.5	31	20.4	8	5.3	0	0.0		
Breath shortening or reduced lung function												
16–20	198	15.1	201	15.4	683	52.3	201	15.4	24	1.8	0.000^a	1018.6
21–25	107	15.4	178	25.5	289	41.5	97	13.9	26	3.7		
26–30	92	6.6	214	15.4	523	37.7	467	33.7	91	6.6		
31–35	145	30.3	30	6.3	99	20.7	50	10.5	154	32.2		
≥36	65	42.8	9	5.9	44	28.9	23	15.1	11	7.2		
Coughing or wheezing												
16–20	78	6.0	546	41.8	601	46.0	77	5.9	5	0.4	0.000^a	1309.12
21–25	66	9.5	102	14.6	314	45.1	213	30.6	2	0.3		
26–30	73	5.3	467	33.7	287	20.7	558	40.2	2	0.1		
31–35	8	1.7	205	42.9	87	18.2	85	17.8	93	19.5		
≥36	2	1.3	89	58.5	28	18.4	13	8.6	20	13.2		
Headache and dizziness												
16–20	119	9.1	366	28.0	465	35.6	201	15.4	156	11.9	0.000^a	574.39
21–25	84	12.1	163	23.4	217	31.1	197	28.3	36	5.2		
26–30	123	8.9	512	36.9	389	28.0	285	20.5	78	5.6		
31–35	43	9.0	99	20.7	29	6.1	297	62.1	10	2.1		
≥36	21	13.8	58	38.2	17	11.2	44	28.9	12	7.9		
Reduced energy level												
16–20	54	4.1	178	13.6	213	16.3	587	44.9	275	21.0	0.000^a	717.7
21–25	41	5.9	87	12.5	178	25.5	211	30.3	180	25.8		
26–30	145	10.5	227	16.4	267	19.3	204	14.7	544	39.2		
31–35	10	2.1	101	21.1	43	9.0	36	7.5	288	60.3		
≥36	3	2.0	37	24.3	8	5.3	7	4.6	97	63.8		
Sleep deprivation or sleeping disorders												
16–20	139	10.6	699	53.5	431	33.0	32	2.4	6	0.5	0.000^a	390.49
21–25	97	13.9	302	43.3	170	24.4	104	14.9	24	3.4		
26–30	201	14.5	796	57.4	370	26.7	11	0.8	9	0.6		
31–35	78	16.3	246	51.5	116	24.3	27	5.6	11	2.3		
≥36	34	22.4	67	44.1	17	11.2	21	13.8	13	8.6		

*Bold value represents *p*-value < 0.05

^a*p*-value < α altered (significant after Bonferroni adjustment)

Table 7 Reported gender- and district-dependent behavioral and psychological effects of air pollution

Gender	Yes		No		<i>p</i> -value *	χ^2
	<i>N</i>	%	<i>n</i>	%		
Feeling sad, depressed and unpleasant during hazy climate						
Male	1776	75.6	573	24.4	0.000^a	156.14
Female	1521	91.0	151	9.0		
Haze affecting the daily routine exercise						
Male	1890	80.5	459	19.5	0.000^a	123.83
Female	1554	92.9	118	7.1		
Haze affecting routine exercise speed						
Male	2164	92.1	185	7.9	0.000^a	63.3
Female	1406	84.1	266	15.9		
Anxiety and depression						
Male	1753	74.6	596	25.4	0.1152 ^b	2.48
Female	1284	76.8	388	23.2		
Aggression/aggressive behavior						
Male	1954	83.2	395	16.8	0.1562 ^b	2.01
Female	1362	81.5	310	18.5		
More aggressive in colder days/season						
Male	644	27.4	1705	72.6	0.0655 ^b	3.39
Female	415	24.8	1257	75.2		
More aggressive in hotter/warmer days/season						
Male	1976	84.1	373	15.9	0.000^a	141.32
Female	1141	68.2	531	31.8		
Adverse behavioral effects reported by the respondents across study sites/cities						
Dir (L)	6484	81.7	1454	18.3	0.000^a	2767.55
Dir (U)	3107	53.5	2717	46.7		
Chitral	1729	59.2	1190	40.8		
Swat	6096	88.2	813	11.8		
Buner	2383	81.4	543	18.6		
Shangla	1041	63.8	590	36.2		
Total responses	20,840	74.0	7307	26.0		

* Bold value represents *p*-value < 0.05

^a*p*-value < α altered (significant after Bonferroni adjustment)

^b*p*-value > α altered (non-significant after Bonferroni adjustment)

bronchitis, and lung cancer (Mabahwi et al., 2014). Exposure to air pollution for a prolonged duration renders the already suffering individuals more vulnerable such as asthmatic patients and those who suffered from chronic obstructive pulmonary disease or cardiac failure (Abelsohn & Stieb, 2011). Similarly, the most vulnerable individuals are those who are already suffering from respiratory disorders (Rajper et al., 2018).

In the current study, over 73% of students reported that they always experience the physical effects of air pollution, over 21% reported that they often experience so, while a meager 0.1% reported that they never felt so. This indicated the intimidating consequences of air pollution in the study areas. Over 31% of the students always and over 48% often experienced ENT

problems (irritation and allergies), over 15% often and over 15% often experienced respiratory problems, over 5% always and over 35% often experienced coughing or wheezing, over 9% always and 29.8% often experienced headaches and dizziness, and over 6% always and over 15% often felt reduced energy level, whereas over 13% always and 52.5% often suffered from sleeping disorders due to air pollution. Significant ($p < 0.05$) gender-, age-, and district-dependent differences were observed in the reported physical effects of air pollution. The variation in the responses might be attributed to the different health status of the subjects, their genetic polymorphism, and the duration of exposure to polluted air or variation in the level of air pollution across the districts

Table 8 Age-dependent behavioral and psychological effects of air pollution on the students

Age ranges	Yes		No		<i>p</i> -value*	χ^2
	<i>N</i>	%	<i>n</i>	%		
Feeling sad, depressed, and unpleasant during hazy climate						
16–20	1198	91.7	109	8.3	0.000^a	408.62
21–25	550	78.9	147	21.1		
26–30	1194	86.1	193	13.9		
31–35	290	60.7	188	39.3		
≥ 36	65	42.8	87	57.2		
Haze affecting the daily routine exercise						
16–20	1182	90.4	125	9.6	0.000^a	337.38
21–25	640	91.8	57	8.2		
26–30	1188	95.7	199	14.3		
31–35	375	78.5	103	21.5		
≥ 36	59	38.8	93	61.2		
Haze affecting routine exercise speed						
16–20	1202	92.0	105	8.0	0.000^a	140.54
21–25	646	92.7	51	7.3		
26–30	1235	89.0	152	11.0		
31–35	389	81.4	89	18.6		
≥ 36	98	64.5	54	35.5		
Anxiety and depression						
16–20	928	71.0	379	29.0	0.000^a	125.54
21–25	548	78.6	149	21.4		
26–30	1120	80.7	267	19.3		
31–35	375	78.5	103	21.5		
≥ 36	66	43.4	86	56.6		
Aggression/aggressive behavior						
16–20	1164	89.1	143	10.9	0.000^a	281.86
21–25	592	84.9	105	15.1		
26–30	1185	85.4	202	14.6		
31–35	279	58.4	199	41.6		
≥ 36	96	63.2	56	36.8		
More aggressive in colder days/season						
16–20	456	34.9	851	65.1	0.000^a	125.2
21–25	121	17.4	576	82.6		
26–30	389	28.0	998	72.0		
31–35	65	13.6	413	86.4		
≥ 36	28	18.4	124	81.6		
More aggressive in hotter/warmer days/season						
16–20	1032	79.0	275	21.0	0.000^a	27.52
21–25	554	79.5	143	20.5		
26–30	1042	75.1	345	24.9		
31–35	391	81.8	87	18.2		
≥ 36	98	64.5	54	35.5		

*Bold value represents
p-value < 0.05

^a*p*-value < α altered
(significant after Bonferroni
adjustment)

Table 9 Gender- and district-dependent adoption of practices to prevent the adverse effects of air pollution

Gender	Yes		No		<i>p</i> -value *	χ^2
	<i>N</i>	%	<i>n</i>	%		
Use of respiratory mask to cover nose and mouth						
Male	1491	63.5	858	36.5	0.000^a	163.37
Female	1371	82.0	301	18.0		
Use of glasses/goggles during the haze						
Male	1278	54.4	1071	45.6	0.000^a	16.22
Female	802	48.0	870	52.0		
Drinking enough water						
Male	1425	60.7	924	39.3	0.000^a	201.05
Female	1364	81.6	308	18.4		
Boost up immunity by eating a rich diet including Vit. C, E, or omega-3-fatty acid, etc						
Male	1065	45.3	1284	54.7	0.000^a	283.9
Female	1205	72.1	467	27.9		
Preventive measures adopted by the respondents across study sites/cities						
Dir (L)	2765	61.0	1771	39.0	0.000^a	641.96
Dir (U)	2082	62.6	1246	37.4		
Chitral	901	54.0	767	46.0		
Swat	3021	76.5	927	23.5		
Buner	776	46.4	896	53.6		
Shangla	456	48.9	476	51.1		
Total responses	10,001	62.2	6083	37.8	16,084	

*Bold value represents *p*-value < 0.05

^a*p*-value < α altered (significant after Bonferroni adjustment)

(Gilliland, 2009; London, 2007; Sandström & Kelly, 2009). The results of the current study are consistent with earlier studies, demonstrating similar adverse impacts of polluted air on the health of the recruited subjects (Donaldson & William, 1998; Pope III et al., 2002; Yu et al., 2016).

A suitable environment, comfortable weather, and pollution-free air result in better mental health, positive psychological effects, and appropriate behaviors (Denissen et al., 2008; Guéguen, 2013; Guéguen & Jacob, 2014; Keller et al., 2005). Similarly, an unhealthy environment and polluted air result in hostile effects on psychological, behavioral, and mental health and lead to different abnormalities (Calderón-Garcidueñas et al., 2015; Hsiang et al., 2013; Lim et al., 2012; Vrijheid, 2000; Woodward et al., 2014). Air pollution mediates stress, leading to depression and altered behavior (Cho et al., 2014; Lim et al., 2012; Mabahwi et al., 2014). Poor atmospheric condition including polluted air is identified as the major reason for stress in humans (Sahari et al., 2017). In the current study, 82% of students reported that they feel depressed, 85.7% jog faster and for a shorter period, 88.8% walk faster, 75.5% suffer from anxiety,

and 82.5% feel aggressive in response to polluted air. Of the total students, 26.3% reported that they feel more aggressive when it is cold while 77.5% of the students reported that they feel more aggressive in hotter weather. The impacts of air pollution on the psychological conditions and sporting behavior of the respondents were obvious. Gender-, district-, and age-dependent significant ($p < 0.05$) differences were observed. Females and students from the 16–20 age range were observed to be more vulnerable as compared to males and students from the older age range (≥ 36 years), respectively. Similarly, the respondents from district Swat were observed to be more affected (psychologically or behaviorally) as compared to the other districts. The responses of the respondents from district Buner and district Lower Dir were observed to be relatively similar. We also observed the same adverse effects of air pollution on Chinese students in our earlier study (Rajper et al., 2018).

Air pollutants such as PMs, trace metals, and aerosols, lead to human bodies and penetrate deeply into the lungs. These are not easily removed through exhalation and disturb the physical strength and stamina to partake in sporty activities as well as alter the general

Table 10 Age-dependent adoption of practices to prevent adverse effects of air pollution

Age ranges	Yes		No		<i>p</i> -value	χ^2
	<i>n</i>	%	<i>N</i>	%		
Use of respiratory mask to cover nose and mouth						
16–20	940	71.9	367	28.1	0.000^a	62.88
21–25	420	60.3	277	39.7		
26–30	1064	76.7	323	23.3		
31–35	329	68.8	149	31.2		
≥ 36	109	71.7	43	28.3		
Use of glasses/goggles during the haze						
16–20	660	50.5	647	49.5	0.000^a	39.75
21–25	332	47.6	365	52.4		
26–30	709	51.1	678	48.9		
31–35	266	55.6	212	44.4		
≥ 36	113	74.3	39	25.7		
Drinking enough water						
16–20	804	61.5	503	38.5	0.000^a	153.71
21–25	430	61.7	267	38.3		
26–30	1009	72.7	378	27.3		
31–35	417	87.2	61	12.8		
≥ 36	129	84.9	23	15.1		
Boost up immunity by eating a rich diet including Vit. C, E or Omega–3–Fatty acid, etc						
16–20	689	52.7	618	47.3	0.000^a	62.25
21–25	394	56.5	303	43.5		
26–30	789	56.9	598	43.1		
31–35	267	55.9	211	44.1		
≥ 36	131	86.2	21	13.8		

*Bold value represents
p-value < 0.05

^a*p*-value < α altered
(significant after Bonferroni
adjustment)

willingness or duration of these activities (Chaudhari et al., 2012). Drinking more water and consuming energy-rich food is recommended to cope with such a scenario. In the current study, 69.4% of the students reported that they drink more water while 56.6% of the students reported that they consume rich food to build or boost their immunity. Likewise, 71.2% of students use respiratory masks and 51.7% wear goggles or eyeglasses to avoid harmful impacts when air gets polluted. A significant ($p < 0.05$) gender-dependent difference was observed in the adoption of preventive measures. A higher number of female students (82.0%) reported using respiratory masks as compared to male students (63.5%); however, a total of 54.4% male students reported using goggles or glasses as compared to 48.0% of the female students. Similarly, more female students (81.6%) reported that they drink more water to flush out toxins as compared to male students (60.7%). Over 72% of the female students consume a rich diet to boost up their immunity

while 45.3% of the male students reported doing so. An age-dependent significant ($p < 0.05$) difference was also observed, wherein in most of the cases the older (≥ 36 years old) were adopting more preventive measures such as using respiratory masks, wearing goggles or glasses, drinking more water, and consuming a rich diet.

The current study also evaluated the level of awareness and perceptions of the subject regarding air pollution. A total of 93.5% of students believed that open smoking should be prohibited and there should be separate smoking designated places, 77.2% were aware of the disorders or deaths associated with air pollution, 63.3% were aware of air pollutants, and 30.9% of the students reported that health losses in favor of GDP growth of Pakistan are acceptable and affordable. A gender-dependent significant ($p < 0.05$) difference was observed in the awareness level and perception except for awareness regarding different air pollutants (CO, SO₂,

Table 11 Gender- and district-dependent awareness and perceptions of air pollution

Gender	Yes		No		<i>p</i> -value*	χ^2
	<i>N</i>	%	<i>n</i>	%		
Prevention of smoking in public areas/there should be smoking designated areas						
Male	2116	90.1	233	9.9	0.000^a	105.48
Female	1642	98.2	30	1.8		
Air pollution is linked to respiratory and cardiovascular diseases/disorders						
Male	1697	72.2	652	27.8	0.000^a	78.67
Female	1407	84.2	265	15.8		
Pakistan's growth in GDP affecting the environment, is it acceptable/affordable?						
Male	923	39.3	1426	60.7	0.000^a	184.6
Female	321	19.2	1351	80.8		
Aware of different toxic substances such as CO, SO ₂ , NO ₂ , PM, etc						
Male	1458	62.1	891	37.9	0.0564 ^b	3.64
Female	1087	65.0	585	35		
Awareness level/perception of the respondents across study sites/cities						
Dir (L)	2968	65.4	1568	34.6	0.000^a	469.64
Dir (U)	2234	67.1	1094	32.9		
Chitral	1121	67.2	547	32.8		
Swat	3004	76.1	944	23.9		
Buner	901	53.9	771	46.1		
Shangla	423	45.4	509	54.6		
Total responses	10,651	66.2	5433	33.8	16,084	

* Bold value represents *p*-value < 0.05

^a *p*-value < α altered (significant after Bonferroni adjustment)

^b *p*-value > α altered (non-significant after Bonferroni adjustment)

NO₂, and particulate matters). It was observed that females were more aware of air pollution and its consequences. Females were more cautious about smoking and less than 20% were of the view that the growth of Pakistan's GDP affecting the environment is acceptable. An age-dependent significant ($p < 0.05$) difference was also observed. The older students were more aware as compared to the younger ones. Previous studies also revealed gender-dependent differences in the level of awareness and perceptions of air pollution (Badland & Duncan, 2009; Shi, 2015). Similarly, studies also revealed age-dependent satisfaction or dissatisfaction with the ambient air quality (Kim et al., 2012; Liu et al., 2016).

A linear association between literacy and knowledge about the adverse health effects of air pollution has been reported (Brody et al., 2004; Ferreira et al., 2013). Similarly, an income-dependent significant difference in the knowledge of the respondents has also been reported (Fang et al., 2009; Onkal-Engin et al., 2004). In the current study, vehicle exhaust was reported as the major source of air pollution (85.0%), followed by biomass burning (51.4%), and emission

from the industries (50.4%). Television (77.9%) was reported to be the main source of knowledge regarding air pollution for the subjects, followed by the internet (59.9%), newspaper (59.6%), and radio (51.7%). Previous studies also reported television and the internet to be the main sources of knowledge about air pollution for the recruited students (Liu et al., 2016; Rajper et al., 2018).

The negative impacts of air pollution can be minimized by mass awareness; spreading knowledge regarding the hostilities of air pollution; its mitigation, reduction, or prevention; and rectifying the misunderstandings and misperceptions regarding air pollution among the general public. Informal communications, discussion, public conversations, and exchange of information about air pollution among relatives, family members, colleagues, and friends can play a key role in mass awareness and influencing risk perceptions of the public. Health and social workers can play a very positive role by disseminating knowledge and practices to be adopted against air pollution. Governmental and non-governmental environmental management and environmental protection agencies should arrange training, symposia, seminars,

Table 12 Age-dependent awareness and perceptions of air pollution

Age ranges	Yes		No		<i>p</i> -value*	χ^2
	<i>n</i>	%	<i>n</i>	%		
Smoke prevention in public areas/ restricted to smoke designated areas						
16–20	1217	93.1	90	6.9	0.000^a	34.9
21–25	655	94.0	42	6.0		
26–30	1326	95.6	61	4.4		
31–35	429	89.7	49	10.3		
≥ 36	131	86.2	21	13.8		
Air pollution is linked to respiratory and cardiovascular diseases/disorders						
16–20	961	73.5	346	26.5	0.000^a	67.59
21–25	499	71.6	198	28.4		
26–30	1089	78.5	298	21.5		
31–35	416	87.0	62	13.0		
≥ 36	139	91.4	13	8.6		
Pakistan's growth in GDP affecting the environment, is it acceptable/affordable?						
16–20	591	45.2	716	54.8	0.000^a	214.18
21–25	209	30.0	488	70.0		
26–30	320	23.1	1067	76.9		
31–35	111	23.2	367	76.8		
≥ 36	13	8.6	139	91.4		
Aware of different toxic substances such as CO, SO ₂ , NO ₂ , PM, etc						
16–20	724	55.4	583	44.6	0.000^a	160.51
21–25	398	57.1	299	42.9		
26–30	901	65.0	486	35.0		
31–35	381	79.7	97	20.3		
≥ 36	141	92.8	11	7.2		

*Bold value represents
p-value < 0.05

^a*p*-value < α altered
(significant after Bonferroni
adjustment)

and campaigns to increase awareness among local masses about air pollution and associated health risks. Alleviating remedies against air pollutions shall be broadcasted through TV channels and radio, published on the internet (blogs) and newspapers, and spread through the social media platform.

In the current study, an attempt was made to approach as many students as possible and equally from all the districts of the study area. However, like other studies, we had some limitations regarding the duration of the study, and time management while recruiting new students. During the current study, the main administrative units of the districts were selected for air quality detection, such as Timergara at district Lower Dir, Khas Dir Bazar at district Upper Dir, Mingora at district Swat, and Sawarhy at district Buner. However, it is suggested that the air quality parameters of the farther areas of the districts should

be assessed. The appraisal of the air quality index and level of the air pollutants at regular intervals is also suggested in the study area.

The baseline physiological conditions at the individual level were not adjusted for mental and behavioral health, due to the limited time frame and off-campus recruitment of the students through Google form (because most of the universities were closed at the study area). Moreover, the administered questionnaire was closed-ended. Therefore, for conducting the same survey in the future in another area, we recommend the inclusion of open-ended questions. This will extend the level of understanding regarding public perceptions, practices, attitudes, and the level of awareness regarding air pollution. These key points should be considered and the findings of the current study should be applied cautiously to another area or population.

Conclusion

The students of the Malakand division reported different physical (respiratory problems, ENT problems, allergies, reduced energy, sleeping disorder or disruption, etc.), behavioral (sporty behavior such as jogging speed and duration), and psychological (depression, anxiety, and aggression) effects of air pollution. These effects were observed to be gender-, age-, and district-dependent, as females, younger, and students from district Swat were more suffering. Owing to these health effects, the student adopted different prevention measures such as using masks, wearing goggles or eyeglasses, drinking more water, and consuming energy-rich food. Females were observed to be more careful and adopting preventive measures more often such as using masks, drinking more water, and consuming an energy-rich diet. Older respondents were found to be more caring as compared to younger ones. The subjects were aware of the major air pollutants and no gender-dependent difference was observed in this regard; however, an age-dependent difference was observed. Vehicle exhaust was reported to be the major source of air pollution and television to be the major source of information regarding air pollution.

Acknowledgements The author S. Ullah has been supported by the Chinese Scholarship Council and National Natural Science Foundation of China (No. 31772470) for his Ph.D. study. We are thankful to all the students, who participated in this study.

Data availability All the required data is provided in the article and associated supplementary material.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval The study was undertaken according to the Ethics Review Committee of NJU (No. 2009–116). To acquire data/information, the review committee approves informed verbal/written consent. Therefore, the questionnaire was administered after the informed consent of the students.

References

- Abelsohn, A., & Stieb, D. M. (2011). Health effects of outdoor air pollution: Approach to counseling patients using the Air Quality Health Index. *Canadian Family Physician*, 57(8), 881–887.
- Badland, H. M., & Duncan, M. J. (2009). Perceptions of air pollution during the work-related commute by adults in Queensland, Australia. *Atmospheric Environment*, 43(36), 5791–5795.
- Brody, S. D., Peck, B. M., & Highfield, W. E. (2004). Examining localized patterns of air quality perception in Texas: A spatial and statistical analysis. *Risk Analysis: An International Journal*, 24(6), 1561–1574.
- Calderón-Garcidueñas, L., Calderón-Garcidueñas, A., Torres-Jardón, R., Avila-Ramírez, J., Kulesza, R. J., & Angiulli, A. D. (2015). Air pollution and your brain: What do you need to know right now. *Primary Health Care Research Development*, 16(4), 329–345.
- Chaudhari, P. R., Gupta, R., Gajghate, D. G., & Wate, S. R. (2012). Heavy metal pollution of ambient air in Nagpur City. *Environmental Monitoring Assessment*, 184(4), 2487–2496.
- Cho, J., Choi, Y. J., Suh, M., Sohn, J., Kim, H., Cho, S.-K., Ha, K. H., Kim, C., & Shin, D. C. (2014). Air pollution as a risk factor for depressive episode in patients with cardiovascular disease, diabetes mellitus, or asthma. *Journal of Affective Disorders*, 157, 45–51.
- Denissen, J. J., Butalid, L., Penke, L., & Van Aken, M. A. (2008). The effects of weather on daily mood: A multi-level approach. *Emotion*, 8(5), 662.
- Donaldson, K., & M. William. (1998). The mechanism of lung injury caused by PM10. In: R. E. Hester and R. M. Harrison (eds.), Air pollution and health. *The Royal Society of Chemistry*.
- Donohoe, M. (2003). Causes and health consequences of environmental degradation and social injustice. *Social Science Medicine*, 56(3), 573–587.
- Fang, M., Chan, C. K., & Yao, X. (2009). Managing air quality in a rapidly developing nation: China. *Atmospheric Environment*, 43(1), 79–86.
- Ferreira, S., Akay, A., Breerton, F., Cuñado, J., Martinsson, P., Moro, M., & Ningal, T. F. (2013). Life satisfaction and air quality in Europe. *Ecological Economics*, 88, 1–10.
- Fossati, S., Metruccio, F., Urso, P., Ruggeri, L., Ciammella, M., Colombo, S., Cerchiello, M., Mauro, A., Tibiletti, M., & Pecis, M. (2006). Effects of short-term exposure to urban particulate matter on cardiovascular and respiratory systems-The PM-CARE study. *Epidemiology*, 17(6), S528.
- Gilliland, F. D. (2009). Outdoor air pollution, genetic susceptibility, and asthma management: Opportunities for intervention to reduce the burden of asthma. *Pediatrics*, 123(Supplement 3), S168–S173.
- Guéguen, N. (2013). Weather and courtship behavior: A quasi-experiment with the flirty sunshine. *Social Influence*, 8(4), 312–319.
- Guéguen, N., & Jacob, C. (2014). Here comes the sun: Evidence of the effect of sun on compliance to a survey request. *Survey Practice*, 7(5).
- Gül, H., Gaga, E. O., Döğeroğlu, T., Özden, Ö., Ayvaz, Ö., Özel, S., & Güngör, G. (2011). Respiratory health symptoms among students exposed to different levels of air pollution in a Turkish city. *International Journal of Environmental Research and Public Health*, 8(4), 1110–1125.
- Hasan, M. (2018). 11 million premature deaths linked to air pollution in Pakistan. The News International. Lahore.

- Howel, D., Moffatt, S., Prince, H., Bush, J., & Dunn, C. E. (2002). Urban air quality in north-east England: Exploring the influences on local views and perceptions. *Risk Analysis*, 22(1), 121–130.
- Hsiang, S. M., Burke, M., & Miguel, E. (2013). Quantifying the influence of climate on human conflict. *Science*, 341(6151), 1235367.
- Keller, M. C., Fredrickson, B. L., Ybarra, O., Côté, S., Johnson, K., Mikels, J., Conway, A., & Wager, T. (2005). A warm heart and a clear head: The contingent effects of weather on mood and cognition. *Psychological Science*, 16(9), 724–731.
- Kim, M., Yi, O., & Kim, H. (2012). The role of differences in individual and community attributes in perceived air quality. *Science of the Total Environment*, 425, 20–26.
- Lim, Y. H., Kim, H., Kim, J. H., Bae, S., Park, H. Y., & Hong, Y. C. (2012). Air pollution and symptoms of depression in elderly adults. *Environmental Health Perspectives*, 120(7), 1023–1028.
- Liu, X., Zhu, H., Hu, Y., Feng, S., Chu, Y., Wu, Y., Wang, C., Zhang, Y., Yuan, Z., & Lu, Y. (2016). Public's health risk awareness on urban air pollution in Chinese megacities: The cases of Shanghai, Wuhan and Nanchang. *International Journal of Environmental Research and Public Health*, 13(9), 845.
- London, S. J. (2007). Gene–air pollution interactions in asthma. *Proceedings of the American Thoracic Society*, 4(3), 217–220.
- Mabahwi, N. A. B., Leh, O. L. H., & Omar, D. (2014). Human health and wellbeing: Human health effect of air pollution. *Procedia-Social Behavioral Sciences*, 153, 221–229.
- Omanga, E., Ulmer, L., Berhane, Z., & Gatari, M. (2014). Industrial air pollution in rural Kenya: Community awareness, risk perception and associations between risk variables. *BMC Public Health*, 14(1), 377.
- Onkal-Engin, G., Demir, I., & Hiz, H. (2004). Assessment of urban air quality in Istanbul using fuzzy synthetic evaluation. *Atmospheric Environment*, 38(23), 3809–3815.
- Pope, C. A., III., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., & Thurston, G. D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA*, 287(9), 1132–1141.
- Rajper, S. A., Ullah, S., & Li, Z. (2018). Exposure to air pollution and self-reported effects on Chinese students: A case study of 13 megacities. *PloS ONE*, 13(3), e0194364.
- Roman, M., & Idrees, M. (2013). A qualitative study of causes and effects of air pollution on human health in Faisalabad Pakistan. *International Journal of Environment, Ecology, Family and Urban Studies*, 3(1), 139–146.
- Sahari, S.-H., Yaman, Y. M., & Awang-Shuib, A.-R. (2017). Part-time adults students in Sarawak and environmental stress factors. *Journal of Asian Behavioural Studies*, 2(5), 65–72.
- Sandström, T., & Kelly, F. J. (2009). Traffic-related air pollution, genetics and asthma development in children. *Thorax*, 64(2), 98–99.
- Shi, X. (2015). Factors influencing the environmental satisfaction of local residents in the coal mining area. *China. Social Indicators Research*, 120(1), 67–77.
- The Express Tribune. (2020). Air quality in capital hits new low. The Express Tribune. <https://tribune.com.pk>. Accessed on March 28, 2021.
- Ullah, S., & Li, Z. (2019). Hydro-electric power in the Panjkora basin at the expense of environmental deterioration and biodiversity loss—Immediate action required for mitigation. *Environmental Science and Pollution Research*, 26(1), 1008–1011.
- Vrijheid, M. (2000). Health effects of residence near hazardous waste landfill sites: A review of epidemiologic literature. *Environmental Health Perspectives*, 108(Suppl 1), 101–112.
- Woodward, A., Smith, K. R., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., Olwoch, J., Revich, B., Sauerborn, R., & Chafe, Z. (2014). Climate change and health: On the latest IPCC report. *The Lancet*, 383(9924), 1185–1189.
- Yu, J., Kebin, L., Tang, Y., & Xu, J. (2016). Indoor environmental factors and occurrence of lung function decline in adult residents in summer in Southwest China. *Iranian Journal of Public Health*, 45(11), 1436.
- Zhang, H., Ye, Y., Diggle, P., & Shi, J. (2008). Joint modeling of time series measures and recurrent events and analysis of the effects of air quality on respiratory symptoms. *Journal of the American Statistical Association*, 103(481), 48–60.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.