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Research Article

Consequences of Released Air Pollutants from Iron and Steel Industry on Human Health in Lahore, Pakistan

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Abstract: This study is focused on the relationship between industrial (iron and steel) air pollution and its effects on human health. Two groups of targeted populations were selected. Thirty-six (36) industries were selected for emission sampling. One hundred and fifty (150) respondents were taken from the nearby residential area using a random sampling method. Results show that the amount of pollutants emitted from the stack are above the threshold level. The national environmental quality standards of EPA (Environmental Protection Agency) for pollutants are SO_2 (1700 mg/ Nm^3), CO (800 mg/ Nm^3), NO_x (600 mg/Nm^3) and PM_{10} (300 mg/Nm^3) but emission values of these pollutants were much higher than standard values. A chi-square test was used for the analysis of data. The air quality index represents the key objective to increase awareness among citizens. The AQI used by EPA has been applied to the study area, to checks the air pollution in the study site. The obtained value from AQI has been accompanying by different colors letting this information be instinctive. The value of AQI of individual pollutants (PM_{10}, NO_x, SO_2, and CO) was lying between moderate to a very unhealthy category in the study area. The values of PM_{10} and SO_2 are threatening for everyone that may cause more serious health effects. The results of this research indicate that most of people are affected by industrial smoke and suffering from different kinds of allergies, headache, nose infection respiratory problems, stomach problems, high pulse rate and physiological diseases like short breath and feeling chocked in the study area.

Keywords: Air Pollution, Spatial Distribution, Health Issue, Industrial Emission, AQI (Air Quality Index).

1. INTRODUCTION

The quantity of industrial waste (emissions) has increased in the last few decades due to a surge of industrialization. This hazardous industrial waste has created health and environmental crisis throughout the world. Numerous manufacturing industries produce gas emissions and most important of these are iron and steel, plastic, glass, food, pulp, and paper, inorganic and organic chemical products. China is relying on coal for the production of 70% of its manufactured goods and due to coal-burning; many poison emissions are releasing in an atmosphere such as PM, SO_2, NO_x, CO, CO_2, etc. These emissions are releasing without any prior purification. Some small-scale processing plants like material coloring, lead battery, metal purification, etc are also emitted some precarious pollutants such as Cr, Pb, Hg, cyanide, etc which pollute the waterways, air, and soil too [1].

Sinter plant is the dominant plant in steel making that emits a large amount of iron oxide, sulfur oxide, calcium oxide, hydrocarbon, carbonaceous compound, chlorides, nitrogen dioxide and carbon monoxide [2]. Iron and steel industry emissions are polluting the waterways by releasing organic matter, oil metals, suspended solids, benzene, fluorides, and sulfate cyanides. These industries also have some negative impacts on the soil by producing slag, sludge, sulfur compounds, heavy metals, grease, and salt [3]. China steel plants were third larger emitter SO_2, NO_2, and PM in 2006. With the amount of 10%, 15%, 10% respectively [4].

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According to the international agency for research on cancer (IARC) in 2013, one of the outdoor air pollutant PM (particulate matter) known as carcinogenic for humans [5]. Socio-economic possessions are one of the reasons for increasing the concentration of NOx in urban localities. NO (Nitric Oxide) is produced from industrial power plants, iron and steel industries, and motor vehicle engines at high-temperature combustion processes [2]. The secretion source of sulfur dioxide is motor vehicle fuels and coal-based industries like iron and steel industry [6]. Sulfur dioxides are increasing as the consequence of human activities especially from the burning of fossil fuels [7].

Pakistan is the sixth heavily populated country but not the main manufacturer of iron and steel production. The steel industry plays a vital role in the Pakistan economy but it is haphazardly distributed. To develop its economy, Pakistan requires the establishment of new industrial plants. Due to unplanned industrial growth, these industrial units are emitting toxic elements and polluting the air and on the other hand water bodies and the land is affected by these toxic elements [8].

Karachi is the main sector of iron and steel production, the first largest metropolitan area and Lahore is the second largest financial center of the country as well as second place for iron and steel industry. The main industrial areas in Lahore are located in Badami bagh, Shahdara, G.T. road, Bund Road, Ferozepur Road, Multan road, etc. Besides their contribution to the economy, these industries are tremendously emitting pollutants in the atmosphere and consider as highly polluted area in Lahore. A large concentration of iron and steel industry are found on Bund road [28].

Pakistan steel industry mainly uses coal and natural gas as fuel. However, many small steel industries use tyres as fuel. Due to tyre burning, black plumes of smoke cover the sky day and night. The burning of Tyres emits numerous chemicals like lead, chromium, cadmium, and mercury that does not burn and they just get released into the atmosphere as fragmented ash. According to the American encyclopedia, Tyres smoke contains 407% more chromium, 392% more lead and 1448% more arsenic than coal. These toxic pollutants cause tremendous effects on human health.

Urban areas are greatly affected by nonstop emission of SO2, NO2, PM_{10}, PM2.5 and other trace metals that come from industries and vehicles. Industries and vehicles are responsible for high level of air pollutants like PM, NOx, SO2, CO, other organic, inorganic and traces metals that adversely affects the human health and environment [9-14]. The range of particulate matter from 10-2 µm causes pulmonary health problems. PM flows deep into the lungs and spoils the lower respiratory system. Coal dust also causes lung problems known as black lung diseases. This is the type of pneumoconiosis [15].

Higher rates of SO_2, NO_2, and CO are causing an increase in the pulse rate, while PM is associated with an increase in pulse pressure [16] and thus increases the risk factor for cardiovascular diseases [17]. Carbon monoxide (CO) is a powerful asphyxiating gas that interposes with the normal function of hemoglobin. Excess inhalation of CO and CO_2 causes' chest pain, drowsiness, headache, nausea, stupor, coma, disorientation and, in extreme cases cause death [9, 28].

High exposure to SOx can cause eye and throat irritation. SOx acts as an irritant gas in the respiratory tract; damages the mucous lining of the respiratory tract and chronic bronchitis [9]. The direct emission of CO_2 from china iron and steel industry was 15% of total emissions in china. This emission caused serious effects on the environment and human health [18], and too much inhalation of sulfur dioxide caused asthma [19].

The oxides of nitrogen are higher in the steel plant area than in other areas. Nitrogen oxide is causing serious lung issues among humans [20]. A review of studies, 3.1% of asthma symptoms increased by inhaling of NOx. Long-term exposure to NOx is slightly lowering the diastolic systolic pressure [11, 12, 6]. NOx is producing eye irritation, pulmonary edema (lung tissues) and respiratory pneumonia, damage cells, premature aging, etc [21].

Developing countries like Pakistan where new and modern chimneys not established in every iron and steel industry, so pollutants released from stack directly added into air. These pollutants are changed the air quality rapidly. Air Quality Index is a tool that has been used worldwide since the last 2-3 decades.

It is used for measuring the air pollution hot spots in the area for explaining management and existing activities. The previous version was commonly built for measuring ambient air for a while [22]. AQI is the simplest and extensively used tool to measure all parameters of air pollution of an area. In recent times central pollution control board (CPCB) that is for single pollutants acclaimed the breakpoint concentration method for measurement of AQI. This level of AQI is used for decision-making. The concept of breakpoint concentration level was also adopted by China and USEPA for the last decade for their development [25-27]. The pollutant that has the highest AQI value delineates the total AQI for an hour. The four contaminants calculated for the AQI are a good indicator of diurnal air quality. Moreover, the Air Quality Index does not justify for pollen levels or temperature that can raise sensitivity to air pollutants [23] main objective of this research is to monitor the stack emission relation with Air quality and health issues in the study area which include an industrial area and some area on a small distance from it.

2. STUDY AREA

This study was carried out in the two towns of Lahore, Shalamar, and Wagah, located in northeast Lahore. The total area of these towns is 186.69 km^2 [24]. These towns are categorized as heavy industrial area. Almost all the re-rolling iron and steel plants are locating in these towns. The sampling sites were located 74˚23'24 to 74˚34'23 E longitude and 31˚35'24 to 31˚36'17 N latitude. Sampling was performed in monsoon. The average temperature was 32˚C in June and in January the coldest month 14˚C and annual rainfall were 70mm. The main source of pollution was iron and steel industry, vehicles and human activities.

3. MATERIAL AND METHODS

3.1. Preparation of Filter Paper for PM_{10}

With the help of EPA scientists in EPA labs before sampling prepared standard filter papers. Bearing temperature of Electric furnace was 1500˚C. 36 rounded filter papers in china dish placed into the Electric furnace at 600˚C for 1.5 hours after some time, these rounded filter papers placed into electric desiccator for 24 hours. After one day, weighted the filter papers one by one carefully by analytical balance.

3.2. Collection of Stack Gases Samples

36 Samples were collected from 36 emblematic steel plants. Each plant had two different workshops,

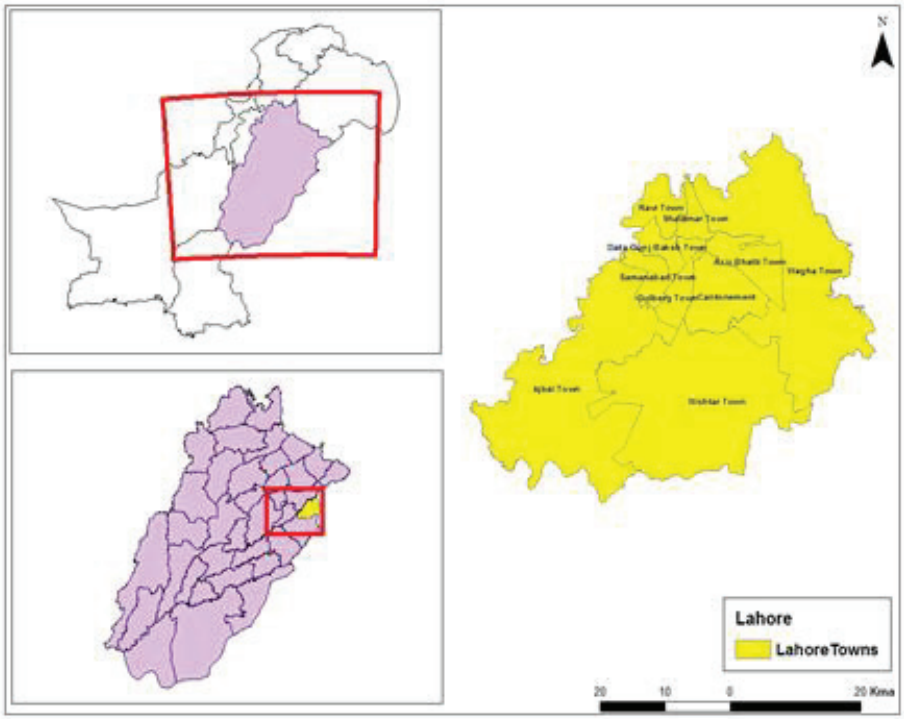

Fig. 1. Location of Lahore

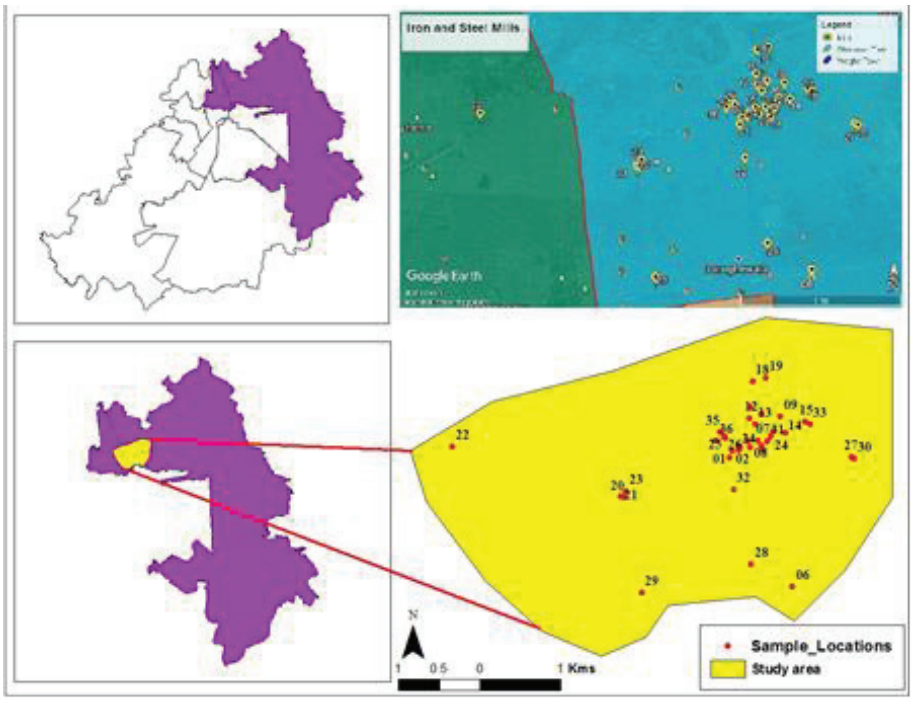

Fig. 2. Sampling locations in study area

converter steelmaking workshop, and sintering workshop. Air samples were collected from the downwind of the stack emitting gases which were almost 2.5-3 feet above the ground level that brings out in the iron ore sintering process at each of the 36 plants. All air samples were collected at high air volume by using Kane-May SGA9 Single Gas Analyzer (kane-may SGA91, kane-may SGA93, kane-may SGA94 have different ranges, 0 to 2000 ppm, 0 to 500 ppm, 0 to 15000 mg/m^3 respectively. Accuracy is 5% of reading). The particulate matter was collected on the clean filter paper, prepared in the laboratory. Each air sample was collected for approximately 4 to 5 hours at the flow rate of 0.075m^2 per mint.

3.3. Lab Procedure

After collecting the samples, measurements were performed for NOx, CO and SO_2 in parts per million (ppm). PM_{10} filter paper (mg) samples were transported to the laboratory, stored these dusty filter papers in the electric desiccator for 24 hours at room temperature and again weight this filter paper until they were analyzed. The emissions from the stack of smelting furnace measured in mg/Nm^3 therefore, all values were converted into milligrams per cubic meter (mg/ Nm^3) through following steps For PM level measurement, Weight of filter paper

F_i = 0.1155 mg
F_f= 0.2743 mg
F_{net}= F_f-F_i =0.1588 mg
Time of PM sampling though filter paper from furnace
Time = 5 mint
Flow of warm air
Flow = 15 to 16 liter/mint
Volume of air = 15*5 ÷ 1000 = 0.075 m^2
Concentration of pollutants in iron and steel industries
Concentration of PM (dust) (mg) = x * 1000 ÷ 0.075 = x mg/ Nm^3
Concentration of CO (ppm) = x * 1000 ÷ 0.075 = x mg/ Nm^3
Concentration of NO_2 (ppm) = x * 1000 ÷ 0.075 = x mg/ Nm^3
Concentration of SO_2 (ppm) = x * 1000 ÷ 0.075 = x mg/ Nm^3
F_i stands for initial weight of filter paper before sampling.
F_f for final weight of filter paper after sampling.
F_{net} net weight of filter paper.

3.4. GIS and SPSS Analysis

GIS techniques were used to obtain the spatial distribution of air pollutants emitting from the iron and steel industry. The inverse distance weight

Table 1. Sampling locations in study area

No.	Iron and Steel re-rolling mills	PM (mg/Nm^3)	NO_x (mg/Nm^3)	SO_2 (mg/Nm^3)	CO (mg/Nm^3)
01	Malik Hafiz steel mill	1257	142	3880	2224
02	Ashfaq steel mill	1680	210	1032	2450
03	Haji Ilyas steel mill	748	148	1040	1448
04	Shahid Imtiaz steel mill	1246	196	2196	3456
05	Mashallah steel mill	1480	410	2040	1880
06	Asif Molding Unit	610	210	404	856
07	Shahid Kamran steel mill	1346	196	1894	1478
08	Waseem brother steel mill	987	96	428	1362
09	Chand borthers steel mill-I	1340	104	510	980
10	Chand brother steel mill-II	880	410	1740	1412
11	Bajwa steel mill	1048	214	1860	1238
12	Sultan steel mill	1040	840	2175	1834
13	Main Imran steel mill	964	1310	1890	1470
14	Karamat steel mill	1422	840	1980	1346
15	Suban steel mill	1004	210	1810	1220
16	Imtiaz steel mill	1630	1450	2014	3610
17	Shahid steel mill	3207	830	2045	2810
18	Madani steel mill	1780	1150	1880	1610
19	Fiaz steel mill	920	610	1890	1420
20	Faridia steel mill	1280	248	1810	1380
21	Ammar steel mill	1160	206	1420	1250
22	Lucky steel mill	1310	301	1720	1230
23	Arif steel mill	1420	410	1810	976
24	Haji steel mill	1264	104	1880	1096
25	Mushtaq steel mill	996	106	1306	1270
26	Asad steel mill	1860	98	1470	1590
27	S.A steel mill	2350	108	1860	2014
28	S.J steel mill	2680	134	3169	875
29	TM steel mill	2320	156	2365	1500
30	Fine steel mill	1531	180	2337	1008
31	Abid steel mill	1513	189	2343	1080
32	Madina steel mill	2117	180	2430	1540
33	Ghulzar steel mill	1520	2014	1200	1840
34	Malik Qausar steel mill	1380	1000	150	1510
35	Tariq steel mill	1482	104	110	2030
36	Rana steel mill	1178	108	118	1090

method was used to estimate the planar distribution of pollutants. Data were analyzed by using statistical packages social sciences (SPSS). Phi Cramer's V Chi-square test was used to find out the association between the independent variables (pollutants) and dependent variables (diseases).

3.5. Formulation of Hypothesis

H_0 There are no association b/w variables.
H_1 There are association b/w variables.

Level of Significance:

$$\alpha = 0.05$$

Test Statistical:

$$x^2 = \frac{\varepsilon(fo - fe)^2}{fe}$$

3.6. Chi-square Test

Chi-square Test was selected because the dependent variable has effects on human health. It has a

nominal level of data and independent variable air pollutants are ordinal nature data. Therefore, in this case, to find out the relationship between these two variables, Chi-square is the most suitable test.

3.7. AQI (Air Quality Index)

The data obtained from one monitoring station that is not far from the study area is used to calculate the air quality index for critical parameters. If the AQI is lower than 100, it shows the satisfactory condition of air and if the AQI exceeds the value of 100, it shows that air quality is decreasing and risk factors are found in the air. The calculated AQI is based on a breakpoint concentration of 24 hours for an average of CO, NOx, SO_2, and PM_{10}. AQI of individual pollutants was observed that were ranging from moderate to very unhealthy.

3.7.1. Formula of AQI

$$I = (I_{high} - I_{low} / C_{high} - C_{low})(C - C_{low}) + Ilow$$ ..... Eq. 1

3.7.2. Terminology

AQI Air quality index [-]
I [ ] Air Quality sub-index [-]
C Pollutant concentration [µg/m3], [ppm], or [ppb]
C*low* Concentration breakpoint that is ≤ C [µg/m3] or [ppm] or [ppb]
C*high* Concentration breakpoint that is ≥ C [µg/m3] or [ppm] or [ppb]
I*low* The index breakpoint corresponding to Clow [-]
I*high* The index breakpoint corresponding to Chigh [-]
m.avg (8 *hrs*) Moving average over eight hours [ppm] or [ppb]
avg (1 *hr*) Average hourly [ppb]
(24 *hrs*) Daily value [µg/m3]
The values of concentrations are used to calculate the AQI by using the above equation.

4. RESULTS AND DISCUSSION

All these four pollutants CO, NOx, SO_2 , and PM_{10} have combined effects on human health. Therefore, it was by some means difficult to show one pollutant and their effects on human health separately because PM_{10}, SO_2 , NOx, and CO caused respiratory problems, cardiovascular problems, and lung problems, etc. PM_{10} and SO_2 caused different kinds of allergies it may be internal and external allergies. NOx, CO, and SO_2 caused a high pulse rate and hypertension. Therefore, in the mention tables, the number of diseases and the number of responders were the same.

4.1. Spatial Pattern of Nitrogen Oxides (NOx) (mg/ Nm^3) in Study Area

Figure 3 light color shows less concentration of NOx mg/Nm^3. The national environmental quality standard (NEQS) of EPA for NOx is 600 mg/Nm^3. The sample industries were found to be located in the Shalamar Town, Akhri mint stop and Dhobi Ghaat. These industries Faridia Steel Mill, Ammar Steel Mill, Lucky re-rolling steel mill, Arif Steel Mill, TM steel re-rolling mill were released lower amount 99 to 310 of NOx (mg/Nm^3) instead Wagah Town show in above industrial pollutants table. Dark color shows the highest concentration of NOx (mg/Nm^3) in the study area. Only one industry

Table 2. EPA table of breakpoints

PM_{10} ug/m3 Clow –Chigh (24 hr)	**NO_2 ppb Clow –Chigh (avg 1 hr)**	**SO_2 ppb Clow-Chigh (avg 1 hr)**	**CO ppm Clow-Chigh (m. avg 8 hr)**	**AQI *I*low-*I*high**	**AQI category**
0 - 54	0 – 53	0 - 35	0.0 - 4.4	0 - 50	Good
55 - 154	54-100	36 - 75	4.5 - 9.4	51 - 100	Moderate
155 - 254	101-360	76 - 185	9.5 - 12.4	101 -150	Unhealthy for Sensitive Groups
255 - 354	361-649	186 - 304	12.5 - 15.4	151 -200	Unhealthy
355 - 424	650-1249	305 - 604	15.5 - 30.4	201 -300	Very Unhealthy
425 - 504	1250-1649	605 - 804	30.5 - 40.4	> 300	Hazardous

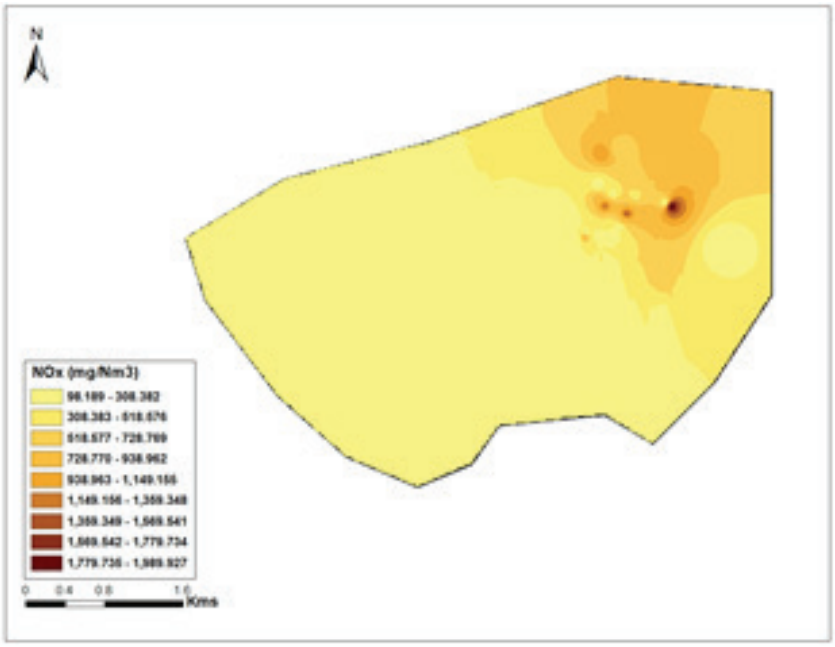

Fig. 3. Spatial Pattern of NOx (mg/Nm3) in study area

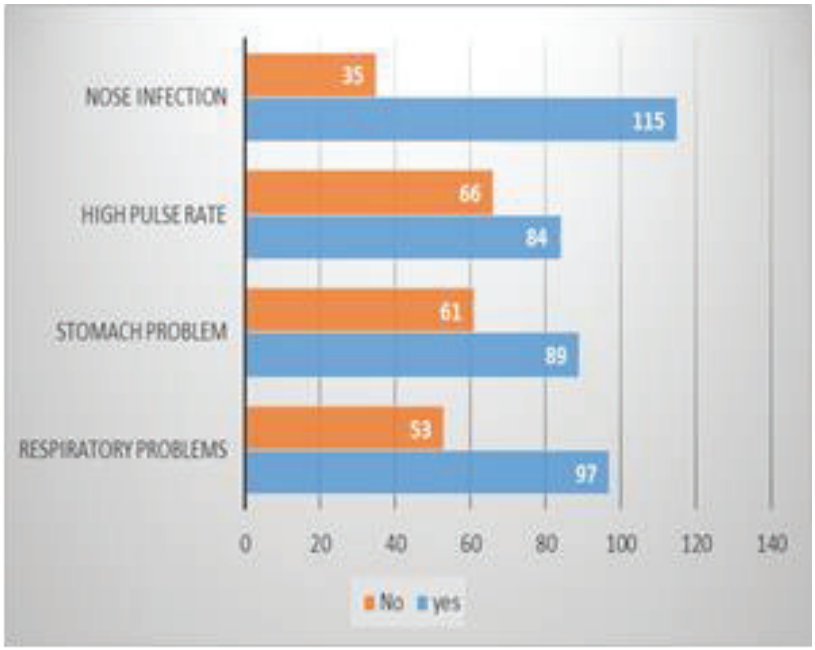

Fig. 4. Effects of industrial NOx on Human health

Table 3. Diseases caused by NOx in the study area

No	Diseases	Yes	No	Phi Cramer's V Value	Significant
1	Respiratory Problem	97	53	0.492	0.014
2	Stomach Problem	89	61	0.465	0.039
3	High Pulse Rate	84	66	0.462	0.044
4	Nose Infection	115	35	0.528	0.003

Source: Primary data computed by Cross tabulation

Ghulzar re-rolling steel mill located in Shadi Pura was emitting the highest concentration of 2014 (mg/Nm^3) of NOx.

Figure 4 shows the amount of NOx in the study area while Figure 4 shows that 97 persons out of 150 were suffering from nose infection, 84 persons from high pulse rate, 97 persons and 89 persons suffered from respiratory and stomach problems, respectively in the study area. Nitric oxide (NO) does not respectably affect human health because of NO so easily oxides to NOx. High-level exposure to nitrogen dioxide emitting from iron and steel industry and urban smoke can damage the human respiratory tract, caused asthma, and increases a person's vulnerability to respiratory infection and serious chronic lung problems.

Table 3, S No 1 shows the p-value 0.014 and -value 0.05. The p-value is less than alpha therefore alternative hypothesis Hi is accepted and rejects the null hypothesis H0. It means that NOx released from the iron and steel industry causes respiratory problem in people living near the periphery of the industry. The same is further confirmed by applying the chi-square test. The next stage is to check the degree of relationship between these two variables. The value of Phi Cramer's V is 0.492, which shows that there is a strong association between NOx released from iron and steel in the alternative hypothesis. NOx released from the iron and steel industry caused a high pulse rate or high blood pressure in people. It is tested by the chi-square test. To check the degree of association between variables, Phi Cramer's V value is 0.462, which indicates that there is a less association between emitted NOx and high pulse rate.

In the last point of the table, point out that the p-value is 0.003 and -value is 0.05, which accept the alternative hypothesis. NOx emitting from the iron and steel industry caused nose infection and nose block in people who living near the iron and steel industry. Next, check the grade of the relationship between variables. The value of Phi Cramer's V is 0.528 showing the strong association between NOx released from the iron and steel industry and Nose infection.

4.2. Spatial Pattern of Sulfur Dioxide (SO_2) (mg/Nm^3) in Study Area

In Figure 5 the highest emission of SO_2 (mg/Nm^3) is shown with a dark color that was about 3880(mg/Nm^3). The national environmental quality standards of EPA for SO_2 is 1700 mg/Nm^3. Only six plants out of thirty-six, Asif Moulding Unit Zatoon Colony, Waseem Brother Steel Re-Rolling Mills, Chand Brothers (Yaseen) Re-Rolling Mills, Malik Quasar Steel Re-Rolling Centre Mills, Tariq

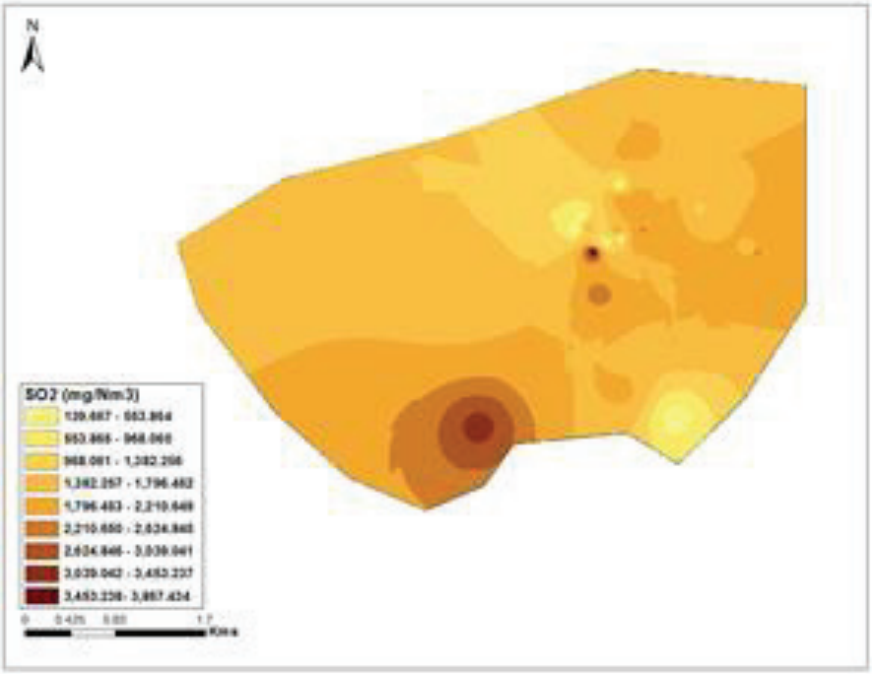

Fig. 5. Spatial Pattern of SO_2 (mg/Nm^3) in study area

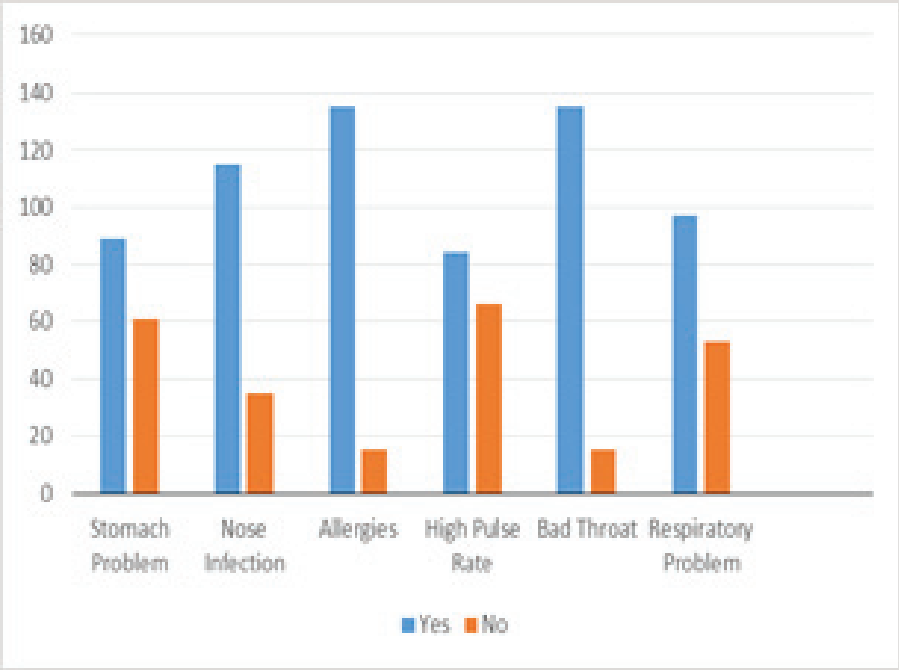

Fig. 6. Effects of industrial SO_2 on human health

Steel Furnace and Rana Safdar Steel Re-Rolling Mills located at different places were emitting less amount of SO_2 (mg/Nm^3) in an atmosphere that refer above industrial pollutants table1. The rest of the industries were emitting SO_2 (mg/Nm^3) above the threshold value.

Sulfur dioxide (SO_2), is a colorless gas with an irritating and prickly odor. The basic source of SO_2 is the burning of fossil fuels containing Sulphur like coal and oil. The emission of SO_2 has two different Side effects on the environment. Upper level of SO_2 contributes the diluting the acid deposition is known as acid rain and lower level of SO_2 affects human health by causing eye irritation, asthma, bad throat, respiratory irritation and some other diseases such as chronic bronchitis infection. SO_2 and its aerosols are also damaged the other part of the ecosystem and vegetation. Figure 6 indicates that 135 persons, 115 persons and 135 persons out of 150 respondents suffered from different types of allergies, nose infection, and bad throat respectively. The high rate of diseases related to SO_2 was observed where a large amount of SO_2 emitting from the iron and steel industry.

In table 4, point number one marks as p-value 0.004 and -value is 0.05 because p-value is less than -value so it can be able to accept the alternative hypothesis H_1. It describes the people who were living near the iron and steel industry were suffering from stomach problems caused by SO_2. A chi-square test was used to prove the hypothesis. After accepting the H_1, the next step is to find the notch of the relationship between these two variables. The Phi Cramer's V value is 0.557, which shows the strong association between SO_2 releasing from iron and steel industry and stomach problems.

The second point in the table indicates that the p-value is 0.018 that is lesser than the value of 0.05. So, accept the alternative hypothesis. Industrial SO_2 caused nose infections and nose block in the residents of the study area. The value of Phi Cramer's V is 0.520, which shows that there is a strong association between SO_2 and Nose infection.

The third point of the table shows the p-value is 0.014, which is, less than -value 0.05 that reject the H0 and accepts the H1. SO_2 that comes from the iron and steel industry caused different kinds of allergies like skin allergy, eye irritation, sneezing, etc. in people who living near the iron steel plants. Phi Cramer's value is 0.526 which shows the degree of association between variables. There is a strong association between SO_2 and allergies.

The fourth point in cross-tabulation signifies the value of p that is 0.003. The alpha value 0.05 is greater than the p-value, so it can able to reject

the null hypothesis. People living near plants are suffering from a high pulse rate caused by industrial SO_2. Phi Cramer's V value that is 0.561 shows the degree of association between variables. Therefore, there is a strong association between SO_2 and high pulse rate.

Point number five of the table shows the p-value 0.006 that is less than -value 0.05. So, the alternative hypothesis is accepted rather than the null hypothesis. People who are living near the iron and steel industry are suffering from Asthma caused by industrial SO_2. The value of Phi Cramer's is 0.548, which shows a strong association between Asthma and SO_2.

The sixth point in the table expresses the p-value that is 0.048 and -value is 0.05 because the value of p is less than the value of so accept the alternative hypothesis. It can elaborate as industrial SO_2 caused bad throat in residents of the study area. Phi Cramer's V value that is 0.452 shows the degree of association between variables so; there is less association between SO_2 and bad throat.

The last point of the cross-tabulation points out the p-value is 0.010 and -value is 0.05, which is less the alpha value. An alternative hypothesis is accepted. People of the study area are badly suffering from respiratory problems caused by industrial SO_2. Phi Cramer's V value is 0.536 which shows the strong association between respiratory problem and SO_2.

4.3. Spatial Patterns of Carbon Monoxide (CO) (mg/Nm^3) in Study Area

The NEQS (national environmental quality standard) of EPA for CO is 800 mg/Nm^3. All industries like Asif molding steel mill, Sultan re-rolling steel mill, Mian Imran re-rolling steel mill, Subhan Foundry steel mill, Arif steel mill, and TM steel re-rolling mill, etc. located at shalamar town and Wagah town were emitting CO (mg/Nm^3) above the threshold level of EPA. Dark color shows the highest emission of CO (mg/Nm^3) in the study area. Industries such as Shahid Imtiaz Steel Re-Rolling Mills, Imtiaz Re-Rolling Mills and S.A Steel Re-Rolling Mill were located at Bhani road and Darogha wala was emitting the highest concentration of CO (mg/Nm^3) that was shown above industrial pollutants table.

CO is easily absorbed in human and animal lungs where it reacts with hemoglobin and reduces the carrying capacity of oxygenated blood. It caused a deficiency of oxygen in the tissues and the body's organs. Figure 8 shows that 76 persons out of 150 respondents suffered from feeling chocked and 93 persons, 132 persons were suffered from short breathing and headache (extreme to low-level pain) respectively. CO caused serious problems for humans as respiratory diseases, cardiovascular diseases, chest pain, serve headache, sleepiness, cardiovascular and respiratory physiological diseases like feeling chocked, short breath, etc. Little concentration of CO caused several diseases if it is inhaled continuously. Therefore, diseases related to CO such as chest pain; headache and

Table 4. Diseases caused by NOx in study area

No	Diseases	Yes	No	Phi Cramer's V Value	Significant
1	Stomach Problem	89	61	0.557	0.004
2	Nose Infection	115	35	0.520	0.018
3	Allergies	135	15	0.526	0.014
4	High Pulse Rate	84	66	0.561	0.003
5	Asthma	120	30	0.548	0.006
6	Bad Throat	135	15	0.452	0.048
7	Respiratory Problem	97	53	0.536	0.010

Source: Primary data computed by cross tabulation

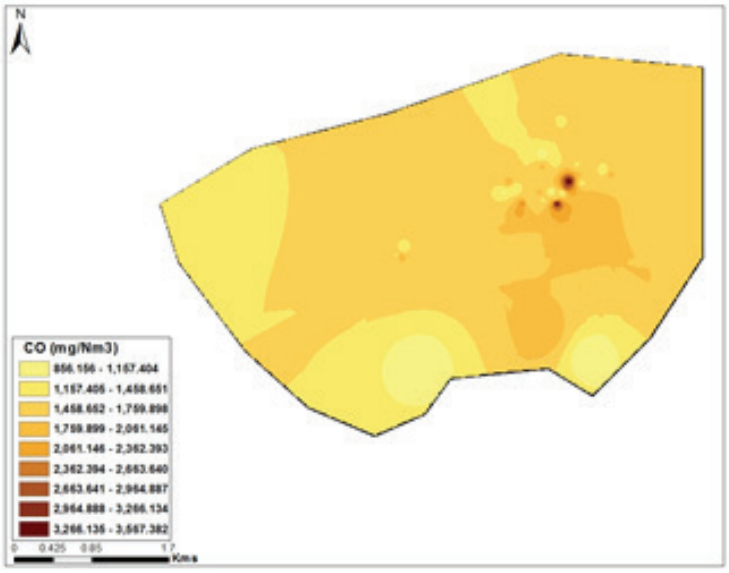

Fig. 7. Spatial Pattern of CO (mg/Nm3) in study area.

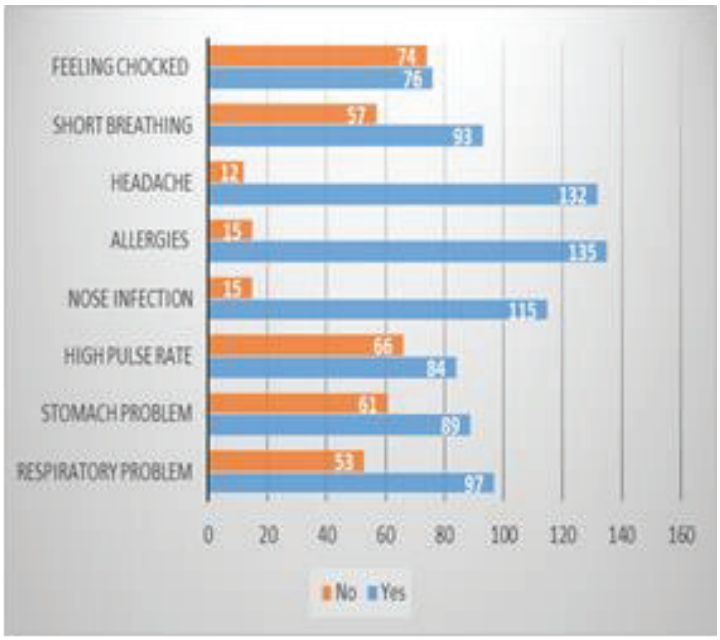

Fig. 8. Effects of industrial CO on human health

short breath were observed in the whole study area.

In Table 5, point number one shows the p-value, which is 0.018. The p-value is less than the value of alpha so alternative hypothesis H1 is accepted rather than null hypothesis H0. The emission of CO above the threshold caused respiratory problems in people who are living near the study area. To check the degree of link between these two variables. The value of Phi Cramer's is 0.537 that indicates the strong association between respiratory problems and CO released from iron and steel plants in the study area.

The second point of cross-tabulation marks the p-value which is 0.005 and -value is 0.05 which is again less than and -value so it can again able to accept the alternative hypothesis means industrial CO caused stomach problems among residents of iron and steel plants. Phi Cramer's V value shows the degree of relationship between variables. It value is 0.569 which shows the strong association between CO and stomach problem.

The point number three of the table signifies the p-value 0.004, which is; less than -value is 0.05 so, an alternative hypothesis is accepted. It can be described as people who are living iron and steel plants are suffering from high pulse rate or high blood pressure caused by a high concentration of CO. Phi Cramer's Value is 0.573 which shows the strong association between high pulse rate and CO of iron and steel plant.

The fourth point of the table indicates the less p-value 0.019 than -value 0.05. H_1 accepted rather than H0. It can be described as CO released from industry caused nose infection and nose block among people of steel plant. Phi Cramer's value 0.535 shows the strong association between nose infection and industrial CO.

The point number fifth of the table points out the p-value 0.022, which is, less than -value 0.05. Less value of p indicates the acceptance of the alternative hypothesis means different kinds of allergies like skin allergy, eye allergy, coughing and sneezing also caused by CO of iron and steel plants. Phi Cramer's V value is 0.532, which shows the strong association between all kinds of allergies and CO.

The table point number sixth shows the p-value, which is 0.021, and -value is 0.05. The p-value is less than alpha value. It can accept the alternative hypothesis. People who are living near iron and steel plants suffered from severe headaches caused by industrial CO. After acquiescent alternative hypothesis, the following step to find the degree of association. The value of Phi Cramer's V is 0.533, which shows the strong association between variables.

The second last point of the table represents the p-value 0.047 and -value is 0.05 because the p-value is less than the value of alpha so, an alternative hypothesis is accepted which means industrial CO caused short breathing which is physiological disease among people of a steel plant. Phi Cramer's V value 0.511 indicates the little association between variables.

The last point of cross-tabulation signifies the p-value, which is 0.039, and α -value is 0.05. The p-value is less than α-value so H_1 is accepted and H0 rejected. The residents of iron and steel plants are suffering from feeling chocked by another physiological disease. The value of Phi Cramer's V 0.465 shows less association between these two variables.

4.4. Spatial Patterns of PM (mg/Nm^3) in Study Area

The threshold level set by EPA for PM_{10} is 300 mg/Nm^3. In Figure 9, Light and dark colors show the lower and higher quantity of PM_{10} (mg/Nm^3). Industries in Shalamar town and Wagah town such as Ashfaq steel mill, Haji Ilyas steel mill, Shahid Imtiaz steel mill, Malik Shahid re-rolling steel mill, Chand brothers steel mill, Subhan foundry steel mill, Imtiaz steel mill, Fiaz steel mill, Faridia steel mill, Ammar steel mill, Lucky steel mill, Tariq steel mill and Rana Safdar steel mill respectively were emitting 1187 to 1763 (mg/Nm^3) of PM_{10} that was

Table 5. Diseases caused by CO in the study area

No	Diseases	Yes	No	Phi Cramer's V Value	Significant
1	Respiratory Problem	97	53	0.537	0.018
2	Stomach Problem	89	61	0.569	0.005
3	High Pulse Rate	84	66	0.573	0.004
4	Nose Infection	115	15	0.535	0.019
5	Allergies	135	15	0.532	0.022
6	Headache	132	12	0.533	0.012
7	Short Breathing	93	57	0.511	0.047
8	Feeling Chocked	76	74	0.465	0.039

Source: Primary data computed by cross tabulation

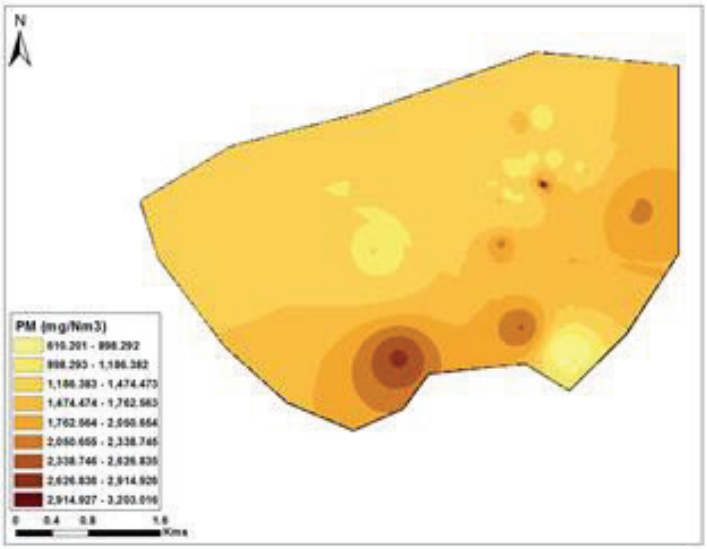

Fig. 9. Spatial Pattern of PM10 (mg/Nm3) in study

Fig. 10. Effects of industrial PM10 on human health

exceed from the national environmental quality standards. Only one iron and steel plant (Asif Molding steel re-rolling mill) in Darogha wala chock was releasing 610 (mg/Nm^3) of PM_{10} in the atmosphere, it shows by light color but it was also above the threshold level. Only one industry found in Darogha wala named by S.A Steel Re-Rolling Mill was emitting 3207(mg/Nm^3) highest level of PM2.5 in the air that shows by dark color in the above figure.

Major emission sources of PM_{10} are industries especially the iron and steel industry. Its higher and lower concentration causes serious and serve effects on human health. PM_{10} caused respiratory diseases including pulmonary problems, lung problems, and bronchitis problems, cardiovascular diseases, asthma, hypertension, pulse pressure, etc. in humans. Figure 10 shows those 120 persons out of 150, 70 persons, 97 persons and 115 persons were suffered from low-level asthma, hypertension, respiratory problems, and nose infection. The mention diseases are commonly observing in an adjacent area of study site because a lower and higher amount of PM_{10} affects human health.

The first point in table 6 indicates the p-value, which is 0.018. The significant value is less than alpha value 0.05 so accept the alternative hypothesis H_1 and reject the null hypothesis H0 that

means people who are living near iron and steel plants suffering from severe respiratory problems, including pulmonary problems, lung problems, and bronchitis problems. After accepting an alternative hypothesis, to find the degree of link between these variables is the next step. Phi Cramer's V value, which is 0.537, indicates the strong association between PM_{10} pollutant and respiratory problem.

The second point of table shows the 0.005 of p-value, which is, less than -value 0.05. Less value of p indicates the acceptance of alternative hypothesis, which means PM_{10}, is coming from iron and steel plants caused stomach problems in residents of the study area. Phi Cramer's value 0.569 shows that there is a strong association between these variables.

The third point of cross-tabulation marks the p-value, which is 0.019, and -value is 0.05. The lesser value of p can reject the null hypothesis and accept the alternative hypothesis. It means PM_{10} caused nose infection and nose block among residents of iron and steel plants. Phi Cramer's V value, which is 0.535, shows the strong association between PM_{10} and nose infection.

The point numbers four of the table point out the p-value 0.022, which is, less than -value 0.05. Alternative hypothesis again accepted and null hypothesis again rejected which means residents of iron and steel plants are suffering from severe different kind of allergies like severe skin problem (skin reddish, acne, tan color, etc.), eye infection (eye irritation, eye swelling, red eyes, etc.) sneezing and coughing and itching on body caused by high concentration of PM2.5 which emitting from iron and steel industry. Phi Cramer's V value shows the degree of connection between these two variables, its value is 0.532, which shows the strong association between different kinds of allergies and PM_{10} of iron steel plants.

The fifth point of the table points toward the p-value which is 0.004 because the p-value is less than 0.05 so, it can accept the H_1 which means people who are living near the iron and steel plants suffering from high pulse rate or high blood pressure caused by the emission of PM_{10}. To find the degree of correlation between variables, Phi Cramer's V value which is 0.573 shows, which there is a strong association between high pulse rate and PM_{10}.

The second last point of the table shows the 0.017 of p-value and 0.05 of -value. The greater value of Alpha can able to reject the null hypothesis and accept the alternative hypothesis. Hypertension is causing by PM_{10} because PM_{10} is fine soot particle, which spoils the house walls, clothes and skin as well. People are annoying and turn into hypertension disorder. Phi Cramer's V value, which is 0.539 shows that there is a strong association between hypertension and PM_{10} pollutant.

The last point of cross-tabulation is asthma, the p-value is 0.006 and -value is 0.05 because the p-value is less than alpha value so accepted the alternative hypothesis. Residents of iron and steel plants are suffering from asthma caused by continually inhaling of PM_{10}. Phi Cramer's V value

Table 6. Diseases caused by $PM_{10\ in}$ the study area

No	Diseases	Yes	No	Phi Cramer's V Value	Significant
1	Respiratory Problem	97	53	0.537	0.018
2	Stomach Problem	89	61	0.569	0.005
3	Nose Infection	115	35	0.535	0.019
4	Allergies	135	15	0.532	0.022
5	High Pulse Rate	84	66	0.573	0.004
6	Hypertension	70	80	0.539	0.017
7	Asthma	120	30	0.548	0.006

Source: Primary data computed by cross tabulation

Table 7. Calculated AQI of pollutants with category

Pollutants	EPA calculated AQI values	AQI (*I*low-*I*high)	AQI category
PM*$_{10}$ *ug/m3 *Clow –Chigh (24 hr)*	278	201 -300	Very Unhealthy
NO*$_2$ *ppb *Clow –Chigh (avg 1 hr)*	94	51 - 100	Moderate
SO*$_2$ *ppb *Clow-Chigh (avg 1 hr)*	106	101 -150	Unhealthy for Sensitive Groups
CO ppm *Clow-Chigh (m. avg 8 hr)*	59	51 - 100	Moderate

Source: Primary data computed by AQI calculation

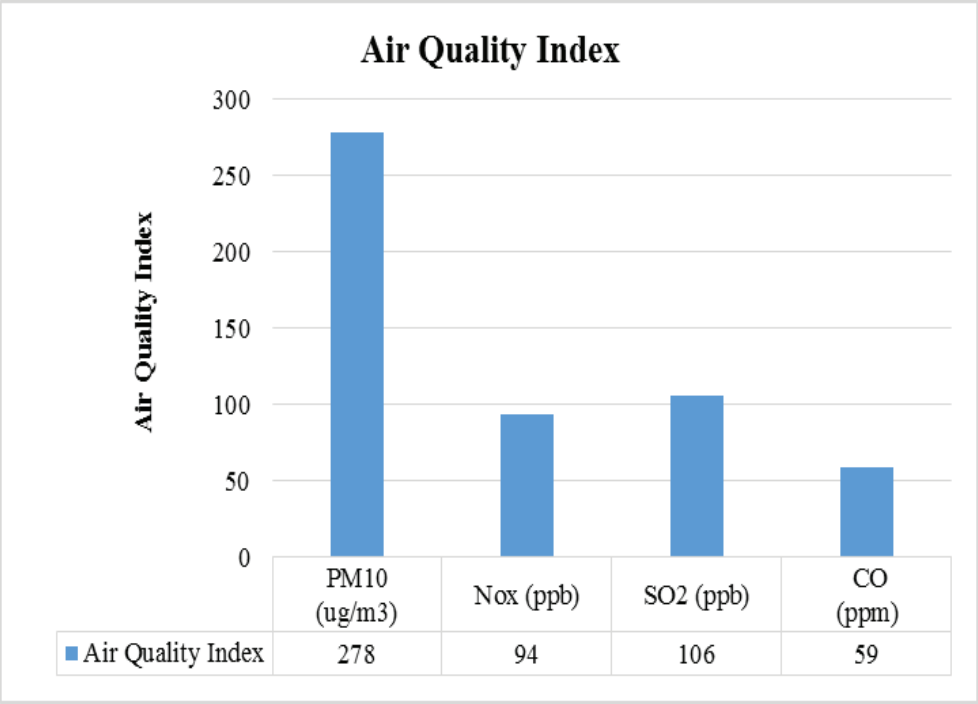

Fig. 11. Air quality index of study area

0.548 describes that there is a strong association between asthma and industrial PM_{10}.

4.5. Air Quality Index (AQI) of the study area

Air quality is affected due to emissions released from the iron and steel industry, smoke of traffic and construction of orange train in the study area. Due to the direct emission of stack pollutants from the air, AQI of industrial and adjacent areas is changed. The calculated AQI values were categorized from moderate to very unhealthy during research time. AQI values calculated for NOx were found moderate, SO2 was Unhealthy for Sensitive Groups, PM_{10} was very unhealthy and CO was in the moderate category during the study period.

5. CONCLUSION

The area along Basimor, Darogha Wala, Darogha Ring road and Moman Pura were the major locations where higher emission of pollutants was found. The highest emission rate of pollutants was found in Shadi Pura (Bhani Road).

People living in this area are directly suffering from diseases associated with air pollution. 90% of people suffering from different kind allergies like

skin allergy, eye allergy, sneezing and coughing etc. 88% headache, and 76.6% nose infection or nose block problem, 64.6% of respiratory problem, 59.3% of stomach problem, 56% of high pulse rate and 56.3% of people are suffering from physiological diseases like short breath and feeling chocked in study area. Iron and steel plants release polluted smoke in the air without treatment that severely affects the condition of residents. The values of AQI indicate the current air Quality condition in the study area. The individual Air Quality Index values can be very beneficial to identify the diseases caused by poor air quality. The results show the dare need to shift the iron and steel industry away from a residential area.

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