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SPATIAL PATTERNS OF AIR POLLUTION IN LAHORE

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Abstract

Man's environment has always been important during the human history. However, with the advent of technology it became more important in man's life and, eventually, has been focused by the environmentalist. The advancement in technology has provided unprecedented facilities to humans on the earth. But on the dark side of this advancement, a number of environmental problems such as global warming, deforestation and more importantly air pollution have appeared in human life causing the great danger to the future of man on the earth. Air pollution problem is specifically linked with the urban settlements due to industrial development as well as motor vehicles. The problem of air pollution is not a problem of developed countries only but it is also very much observed in developing countries like Pakistan. This paper is an attempt to measure the patters of air pollution in Lahore, the second largest urban settlement of Pakistan.

Introduction

Environmental problems such as smog, acid rain, the green house effect and "holes" in the ozone layer have been the focus of the environmentalists due to their harmful effects on man and its environment. Until 1950s, environmental pollution has been ignored because of earth's own ability to absorb and purify minor quantities of pollution. However, since 1950s the rapid growth of industrialization, the use of motorized vehicles, explosion of human population and the indiscriminate discharge of gases into the atmosphere by industries has forced the scientists to focus the magnitude and gravity of this problem. Barker et al. (1989) have pointed out that the amount of the pollutant put into the air, amount of the space into which the pollutants are dispersed and the mechanism that removes pollutants from the air determined the level of air pollution. Air pollutants come from many different sources: stationary sources such as factories, power plants, and smelters and smaller sources such as dry cleaners and degreasing operations. Mobile sources such as cars, buses, trucks, trains, and aeroplanes; and naturally occurring sources such as windblown dust, and volcanic eruptions, all contribute to air pollution. Kupchella, 1989; Mishra, 1990 and Nebel, 1996).

Scientists believe that inhalation of highly acidic fog and dry acid particles are a major cause of breathing and respiratory problems. In addition there is evidence that inhalation of such particles renders lung tissues more susceptible to the carcinogenic effects of to the pollutants. Climate has always been affected by the human activities. The rapid growth of population, changes in land use and immense growth in transportation vehicles are contributing in deteriorating the climatic conditions on the earth surface (Trivedi and Raj, 1992). In fact, this alteration is being caused by the addition of carbon dioxide and certain other gases to the atmosphere resulting in rising sea levels and insecure climatic changes throughout the world. This carbon dioxide effect is also known as 'the green house effect',

On the global level, carbon dioxide in the atmosphere plays very important role. Carbon dioxide absorbs the infrared radiation, it becomes warm and thus in tern warms the rest of the atmosphere. Consequently, it follows that greater the amount of infrared that will be absorbed and the warmer will be the atmosphere. Meteorologists are now in general agreement that if a doubling of carbon dioxide level to 600 ppm is used as a reference point, the overall warming will be between 1.5 ºC and 4.5 ºC, warming is likely to be more

pronounced in polar region as much as 10 ºC, and less pronounced in equatorial region 1 ºC –2 ºC. The increase of Carbon dioxide in the atmosphere is the major cause of depletion of Ozone layer in the atmosphere. Depletion of ozone shield is a serious problem in the atmosphere. If the full amount of ultraviolet radiation falling on the upper atmosphere came through the earth's surface, it is doubtful if any life could survive, plants and animals alike would simply be "cooked"; even the small amount that does come through is responsible for all the sunburns and some 200,000 cases of skin cancer per year in the U.S.A. (Miller; 2000)

In terms of Pakistan 'Environmental Act 1997', the air pollution is the release of any substance like soot, smoke, dust particles, odour, light, electromagnetic radiation, heat, fumes, communication exhaust, gases, noxious gases, hazardous substances and radioactive substances into the atmosphere to the extent, which have adverse environmental effects or on human health and safety and property, or on biodiversity. Impurities in fuel, poor fuel air ratio, or too high or too low combustion temperature cause the main pollution in the air. Industrial resources emit air pollutants through combustion of fuel, chemical processes, manufacturing, grinding, mixing, evaporation, and drying processes. The industrial units emit carbon monoxide, carbon dioxide, nitrogen dioxide, and sulphur dioxide, organic vapour, and organic compounds etc.

In Pakistan, the awareness regarding environmental problems is growing day by day. The Government of Pakistan has implemented 'Environmental Protection Act (EPA) 1997' to procure the environmental condition in Pakistan. Environmental Protection Departments (EPA) have been established to monitor the environment in all provinces of the country. These departments are engaged to implement the Environmental Laws at the source levels i.e. industries. They are also involved to monitor and measure the level of environmental conditions especially air pollution. Studies carried out by EPAs such as Shagufta (1998) have begun to appear. These studies clearly indicate that our vehicles emit 25 times more hydrocarbons and 3.6 times more nitrous oxide than those in the United States. Nitrogen dioxide present in our environment is much more than United Nations specified limit of 0.05 ppm. Lahore is the second largest city of Pakistan. The city with an estimated population of 6 millions is growing day by day due growth of industries. Eventually, the industrial pollution, heavy traffic, and high density of population contributing the increase in the level of air pollution

DATA SOURCES AND METHODOLGY

This research explored the extent of air pollutants in Lahore city. The main objectives were:

- To observe the air pollution level in different parts of the city.
- To find out the spatial pattern of air pollution in the city.
- To see the differences in the air pollution levels among major parts of the city.

In order to achieve the objectives of the research primary and secondary data were used. For primary data collection ten sampling sites were chosen. A sampling point was selected if it met the following requirements;

- It is not directly exposed to varying amount of gas.
- It produces a homogenous level of pollutants
- Day conditions at the sampling point are consistent.
- The point is located where the maximum people are expected to be affected by the pollution

Figure 1 shows the location of sampling sites taken for this purpose. Various statistical, graphical and GIS techniques were used to analyse and present.

Lahore urban area with sampling sites for Air Pollution

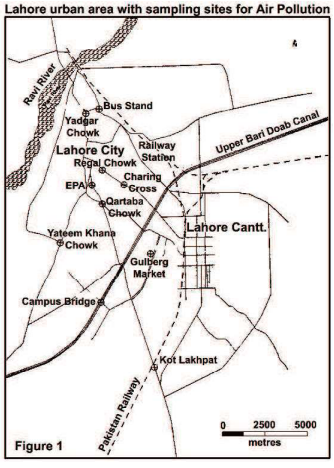


Figure 1

AIR POLLUTION

Air pollution is the contamination of the atmosphere by harmful vapours, aerosols and dust particles, resulting principally from the activities of man but to a lesser extent from natural processes. Primary pollutants include pollen particles, salt-water spray, wind-blown dust and fine debris from volcanic eruptions. Most man made pollution involves the products of combustion smoke, carbon monoxide and lead, and oxides of nitrogen and sulphur dioxide-through other industrial processes, crop spraying and atmospheric nuclear explosions also contribute. Most air pollutants arise in the urban environment, with a large portion of that coming from automobiles (Koramm, 1973 and Painter, 1974). It is important to note that concentration of any gas is effected by a number of factors. For instance, wind speed is very important factor in determining the level of pollutants because it disperse and transfer air pollutants at any place. High speed wind will immediately transfer air pollutants from the source to places of wind direction and, hence, low level of air pollution is measured at the source place. On the other hand, the effected areas may not have air pollution sources but high level of air pollution can be measured due to transfer of air pollutants from source places. Wind direction affects the accuracy of the reading because if the reading is taken in the opposite side of the wind direction the level of pollutant may deviate from the actual level. Temperature is the major factor in determining the level of air pollutants. If the temperature is very high at sampling place, it can speed up the reaction of pollutants during the day time but the conditions may be reverse during the nights. High humidity can disturb the concentration of any pollutant Barometric pressure is also noted because temperature and pressure are inversely proportion to each other. So any change in the pressure may change the reading. Sunshine is directly involved in making change in the intensity of various gases. Usually readings are taken during the daytime in the presence of sunshine because in cloudiness humidity increases and gas particles tend to cluster and disturb the accuracy.

Patterns of Ozone (O_3) Concentration

Ground-level ozone (O_3), unlike other pollutants mentioned, is not emitted directly into the atmosphere, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2), hydrocarbons and sunlight. Sunlight provides the energy to initiate ozone formation; consequently, high levels of ozone are generally observed during hot, still sunny, summertime weather. Ozone irritates the airways of the lungs, increasing the symptoms of those suffering from asthma and lung diseases.

Table 1
Patterns of ozone (O_3) concentration (ppb)

STATION	1993	1996	2000	% change 1996-2000	% change 1993-2000
Regal Chowk	0.7	39.2	35	-11	4900
EPA	7.1	17	20	18	182
Campus Bridge	9.6	10.8	86	696	796
Yateem Khana Chowk	3.1	18.5	50	170	1513
Charring Cross	14.6	40	90	125	516
Yadgar Chowk	6.3	7.7	40	419	535
Gulberg Main Market	6	9.7	19	96	217
Qartaba Chowk	0.5	5	12	140	2300
B. B. Bus Station	21	27	30	11	43
Kot Lakhpat	10.2	10.7	15	40	47

Source: EPA & Field survey.

Table 1 describes the concentration of ozone gas in the city. It clearly reflects that a number of sites with high concentration of the ozone such as Yateem Khana Chowk with 50 ppb, and Campus Bridge with 86 ppb, and Charring Cross with 90 ppb. Some sampling stations show low concentration of the ozone such as Kot Lakhpat with 15 ppb, Yadgar Chowk with 14 ppb, and Qartaba Chowk with 12 ppb. The high concentration of the ozone at the above stations is due to hot, sunny days and concentration of NO_2. At Yadgar Chowk, its major cause of increase is the large number of vehicles passing through this station that is 74897 (Zahir, 1997).

Figure 2. Ozone (O3) concentration with onr km buffer around sampling sites

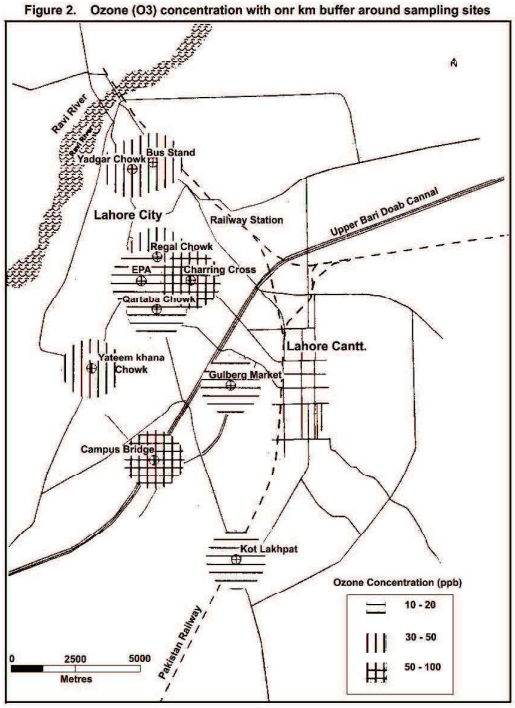


Fig. 2 also describes the concentration into different buffer zones around the sampling site with a radius of one kilometre. Three classes of concentration can be visualised. Lowest level of concentration can be seen at EPA, Qartaba Chowk, Gulberg Main Market and Kot Lakhpat. Perhaps, it is low pressure of traffic as well as open space which caused low concentration. Bus Stand, Yadgar Chowk and Yateem Khana Chowk have medium range of concentration which is certainly due to heavy traffic with open space. Heavy concentration can be seen at Charing Cross and Campus Bridge, which seems to be due to very heavy traffic concentration at these sites. Centre of the city consisting of EPA, Regal Chowk, Qartaba Chowk and Charing Cross which covers almost an area under 3 km radius reflects different intensities in spite of the fact that these are all very close to each other. However, keeping in mind the urban structure i.e. lay out of roads and streets it can be assumed that this difference is due to the urban structure which is a hindrance in dispersing the ozone concentration. On the whole, the figure presents the overall distribution of ozone concentration in the city. Table 1 also shows the concentration of ozone at the sampling sites from 1993 to 2000. It is very much clear from the table that the ozone concentration has increased within seven years tremendously especially Regal Chowk, Yateem Khana Chowk and Qartaba Chowk. In fact these sampling sites are located at the junction of major roads surrounded by buildings. The traffic load at these sites has increased enormously during this period due to urban expansion. The gas can not disperse or transfer immediately. The other places have much open spaces with some vegetation cover which helps in absorbing, dispersing and transfering this gas.

Patterns of sulphur dioxide (SO_2)

Sulphur dioxide is an acidic gas which combines with water vapour in the atmosphere to produce acid rain. Both wet and dry depositions have been implicated in the damage and destruction of vegetation and in the degradation of soils, building materials and watercourses. SO_2 in ambient air can also affect human health, particularly of those suffering from asthma and chronic lung diseases. The principal source of this gas is power stations burning fossil fuels which contain sulphur. Major SO_2 problems now only tend to occur in cities in which coal is still widely used for domestic heating, in industry and in power stations. As many power stations are now located away from urban areas, SO_2 emissions may affect air quality in both rural and urban areas. Even moderate concentrations may result in a fall in lung function in asthmatics. Tightness in the chest and coughing occur at high

Table 2
Patterns of Sulphur Dioxide (SO_2) Concentration(ppb)

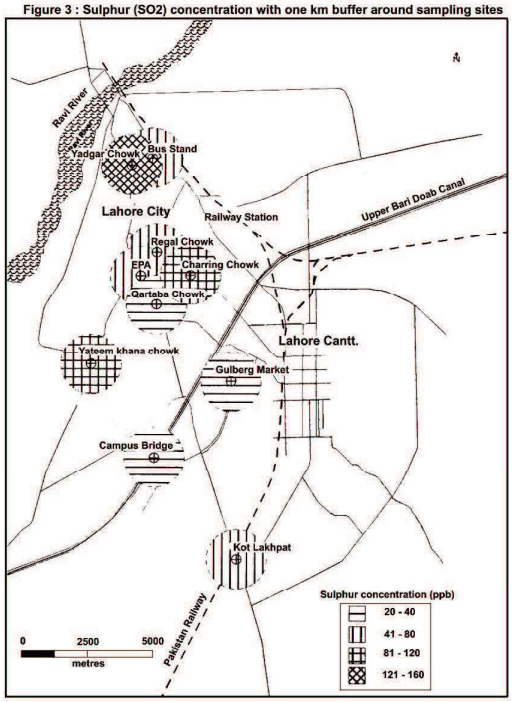
STATION	1993	1996	2000	% change 1996-2000	% change 1993-2000
Regal Chowk	7.2	19.2	80	317	1011
EPA	3	3.1	65	1997	2067
Campus Bridge	1.9	3	20	567	953
Yateem Khana Chowk	13	24.5	90	267	592
Charring Cross	3.6	27.4	90	228	2400
Yadgar Chowk	3	12.2	150	1130	4900
Gulberg Main Market	6.5	13.5	26	93	300
Qartaba Chowk	5.5	9.7	40	312	627
B. B. Bus Stand	10	22	60	173	500
Kot Lakhpat	3.7	10.5	50	376	1251

Source: EPA & Field survey.

levels, and lung function of asthmatics may be impaired to the extent that medical help is required. Sulphur dioxide pollution is considered more harmful when particulate and other pollution concentrations are high.

Sulphur dioxide in 2000 is 150 ppb at Yadgar Chowk (Table 2). It's level is even higher than the level at which people experience bronchial spasms. According to the readings taken in 2000 concentration of the sulphur dioxide is higher at all the stations of Lahore taken as sampling points. Only at Campus Bridge its concentration is 20 ppb that is bearable. Figure 3 shows that the concentration of sulphur dioxide around sampling sites in one kilometre radius buffers in the city. At Yadgar Chowk and in its surroundings the concentration of the ozone ranges from 141 to 160 ppb and at Yateem Khana Chowk and Charring Cross ranges from 81 to 100 ppb. There is very high concentration of ozone in this area because of high traffic flow. Gulberg and Qartaba Chowk fall under the category ranges from 21 to 40 ppb. In these areas concentration of sulphur dioxide is low because these are the open spaces. At Yateem Khana Chowk and Charring Cross level of sulphur dioxide is 90 ppb which leads to the odour threshold level. Table 2 shows the change in Sulphur dioxide concentration from 1993 to 2000. High increase has occurred at EPA, and Yadgar Chowk. At the Mall Road (Regal Chowk) sulphur dioxide level is 7.2 ppb in 1993 and in 1996 it is 19.1 ppb. At Yateem Khana Chowk in 1996 the level of sulphur dioxide

Figure 3 : Sulphur (SO2) concentration with one km buffer around sampling sites



is 24.5 and in 2000 it is 90 ppb. An increase of 66 ppb can be seen in figure 4.7. This increase is because of high traffic flow through this Chowk. At Campus Bridge in 1993 the concentration of sulphur dioxide was 1.9 ppb, which increased upto 3.0 ppb in 1996. In 2000 its concentration is 20 ppb. This increase in concentration of sulphur dioxide is mainly because of traffic flow. It is very much

clear from the table that very high percentage change during the period 1993-2000 has occurred at Yadgar Chowk, Charing Cross and EPA sites.

Patterns of Nitrogen oxide (NOx)

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides - nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as NO_x - is road traffic, which is responsible for approximately half the emissions in developed countries. NO and NO_2 concentrations are therefore greatest in urban areas where traffic is heaviest. Other important sources are power stations, heating plants and industrial processes. Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. Continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children.

Table 3 describes the patterns of NOx concentration distribution in the Lahore city. It shows that at Charring Corss concentration of the NOx is 426 ppb and at Regal Chowk it is 300 ppb. Here its concentration is high because of heavy traffic pressure. At Yadgar Chowk and Gulberg main market concentration of NOx is 225 and 210 ppb respectively because these are the open areas with high traffic flow. At Yadgar Chowk NOx concentration may be high because of other factors such as vertical expansion of the buildings. At both places B. B. Bus Stand and Yateem Khana Chowk its concentration is 179 because these are the industrial areas, very congested, and with high traffic flow. Figure 4 also explains the patterns of NOx in buffer zones . At Charring Cross and its adjacent areas concentration of the NOx ranges from 401 to 500 ppb. While Regal Chowk, Yadgar Chowk, and Gulberg falls are under the category that ranges from 201 to 300 ppb. Campus Bridge, Yateem Khana Chowk, Badami Bagh, and Qartaba Chowk fall under the category that ranges from 101 to 200 ppb. Kot Lakhpat has low concentration of NOx that ranges from 0 to 100 ppb. It is evident from the figure that inner areas of the city have high concentration of nitrogen oxide while fringe areas have low or medium concentration of NOx. It should be kept in mind that the urban structure (high buildings) plays an important role in the distribution of different gases as it prevents the transfer of gases from one place to another place. Moreover, it makes a hindrance to mix the different gas levels.

NOx concentration has risen at Yadgar Chowk during 1993 to 1996 (Table 3). The concentration of the NOx is high at Yadgar Chowk because a huge flock of traffic passes through this Chowk. At Charring Cross in 1993, its concentration was 52 ppb, in 1996 114 ppb but in 2000 it was 426 ppb because according to a survey the motor vehicles

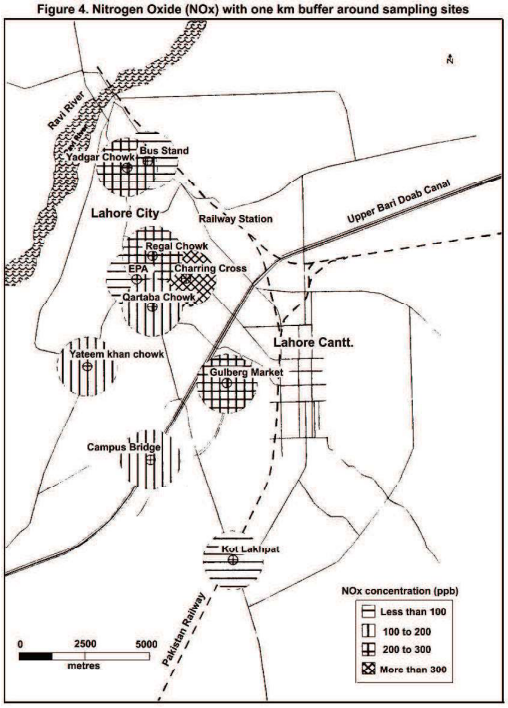
Table 3
Patterns of NOx concentration (ppb)

STATION	1993	1996	2000	% change 1996-2000	% change 1993-2000
Regal Chowk	35.1	129	300	133	755
EPA	22.1	23.6	106	349	380
Campus Bridge	4.3	17.3	154	790	3481
Yateem Khana Chowk	86	91	179	97	108
Charring Cross	52	114	426	274	719
Yadgar Chowk	70	158	225	42	221
Gulberg Main Market	65	124	210	69	223
Qartaba Chowk	69	126	150	19	117
B. B. Bus Stand	37	58	179	209	384
Kot Lakhpat	3.7	27	96	256	2495

Source: EPA & Field survey

passing through this Chowk in 24 hours were 74493. (Zahir, 1997)

Figure 4. Nitrogen Oxide (NOx) with one km buffer around sampling sites



Patterns of Carbon Monoxide (CO)

Carbon monoxide (CO) is a toxic gas which is emitted into the atmosphere as a result of combustion processes, and is also formed by the oxidation of hydrocarbons and other organic compounds. In European urban areas, CO is produced almost entirely (90%) from road traffic emissions. It survives in the atmosphere for a period of approximately one month but is eventually oxidised to carbon dioxide (CO_2). This gas prevents the normal transport of oxygen by the blood. This can lead to a significant reduction in the supply of oxygen to the heart, particularly in people suffering from heart disease.

Concentration of carbon monoxide at Badami Bagh and Qartaba Chowk is 74 and 22 ppm respectively as shown in the Table 4. Concentration of carbon monoxide at Yadgar Chowk, Mall Road (Regal Chowk), and Charring Cross is 80, 64, and 50 respectively. Concentration of the carbon monoxide at the above stations is high enough to produce headache, and strain on the heart. As described in the Figure 5 the concentration of the carbon monoxide falls between 70 and 80 ppm at the Yadgar Chowk and its adjoining areas because of high traffic flow. At Mall road concentration of the carbon monoxide ranges from 50 and 60. At Gulberg and the adjoining areas concentration of carbon monoxide falls between 3000 and 4000 ppb because these areas are commercial as well as industrial. Carbon monoxide is mainly produce due to the combustion of fuel in the motor vehicles and by industries. So, it has very high concentration at Kot Lakhpat, Yadgar Chowk and Badami Bagh Bus Stand which are not only industrial areas but these have also very high traffic concentration. Medium rage of concentration can be seen in the centre of the city mainly due to motor vehicles.

In 1993 at the Mall Road (Regal Chowk), concentration of the carbon monoxide is 27 ppm while in 1996 its concentration is 38 ppm which rise to 64 in 2000. So an increase of 37 ppm from 1993 to 2000. An increase in the traffic led to the increase in the carbon monoxide level. Very low level of concentration is at Gulberg and Campus its concentration is 410 and 360 ppb because these

Figure 5. Carbon monoxide (CO) with one km buffer around sampling sites

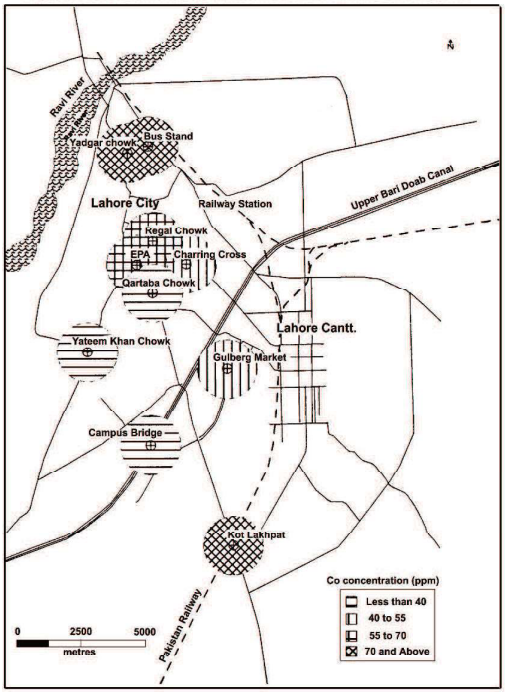


Table 4

Patterns of Carbon Monoxide (CO) Concentration (ppm)

STATION	1993	1996	2000	% change 1996-2000	% change 1993-2000
Regal Chowk	27	38	64	68	137
EPA	8	32	60	88	650
Campus Bridge	8	9	36	300	350
Yateem Khana Chowk	6	19	41	116	583
Charring Cross	4	52	50	-4	1150
Yadgar Chowk	4.5	23	80	248	1678
Gulberg Main Market	3.9	11	41	273	951
Qartaba Chowk	7	12	22	83	214
B. B. Bus Stand	35	39	74	90	111
Kot Lakhpat	12.6	40	79	98	527

Source: EPA & Field survey

are open spaces with the green belts.

Patterns of Particulate Matter (PM_{10})

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. PM_{10} particles (the fraction of particulates in air of very small size (<10 μm)) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. Larger particles meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by sedimentation. The principal source of airborne PM_{10} matter in European cities is road traffic emissions, particularly from diesel vehicles. Fine particles can be carried deep into the lungs where these can cause inflammation and a worsening of the condition of people with heart and lung diseases. In addition, these may carry surface-absorbed carcinogenic compounds into the lungs.

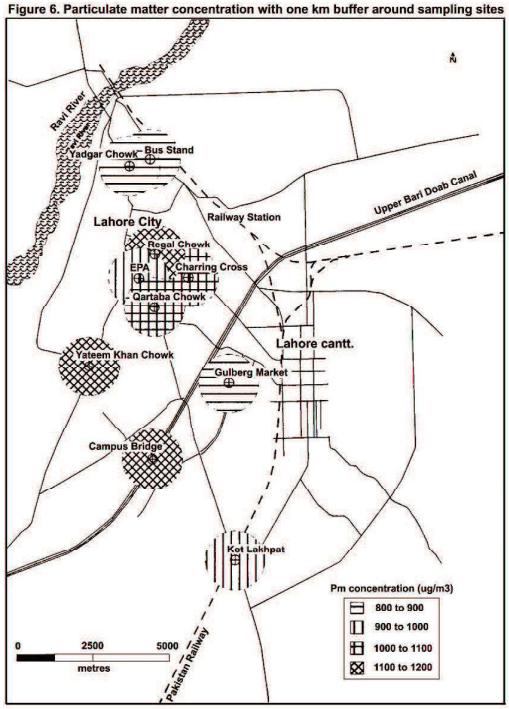
Table 5 shows that concentration of Particulate matter at Campus Bridge is 1165 ug/m^3. It may be high due to open space because with more sunshine in the open space level of Particulate matter

Table 5

Patterns of Particulate matter (ug/m^3)

STATION	1993	1996	2000	% change 1996-2000	% change 1993-2000
Regal Chowk	390	465	1100	137	182
EPA	450	690	980	42	118
Campus Bridge	290	684	1165	70	302
Yateem Khana Chowk	639	913	1123	23	76
Charring Cross	587	630	1050	67	79
Yadgar Chowk	590	682	850	25	44
Gulberg Main Market	320	370	890	141	178
Qartaba Chowk	619	817	1030	26	66
B. B. Bus Station	400	682	860	26	115
Kot Lakhpat	455	473	930	97	104

Figure 6. Particulate matter concentration with one km buffer around sampling sites



becomes high and these remain suspended in the air for a long time. At Yateem Khana Chowk concentration of the Particulate matter is 1123 ug/m^3 because the motor vehicles passing through this Chowk is 21492 ug/m^3, which represents a high traffic volume. At Regal Chowk and Charring Cross concentration of the Particulate matter is 1100 ug/m^3 and 1050 respectively. Concentration of the Particulate matter is 980 and 890 ug/m^3 at EPA and Gulberg respectively. Figure 6 describes the spatial patterns of Particulate matter in different buffer zones around the sampling sites. Campus Bridge, Yateem Khana Chowk and the Qartaba Chowk have concentration of Particulate matter between 1000 and 1200 ug/m^3 and except Yadgar Chowk at all the stations these fall between 801and 1000 ug/m^3. The Figure clearly reflects that the inner areas of Lahore city have high concentration of Particulate matter while outer areas have low level of Particulate matter. High range of temperature during the day and urban structure in the city keep the level of concentration high during the day. In Table 5 the changing patterns of the Particulate matter in the city have been shown. In 1993 its concentration at Campus Bridge was 290 ug/m^3 and in 1996 it was 684 ug/m^3, while in 2000 it was 1165 ug/m^3. Its concentration has increased due to high traffic flow. At Yateem Khana Chowk it was 639 in 1993, 913 in 1996, and 1123 ug/m^3 in 2000 because it is an industrial and high traffic flow, area.

CONCLUSIONS

It is evident from the Tables and Figures that air pollution is increasing day by day in Lahore. A tremendous change has occurred during the period 1993 to 2000. Major areas of high air pollution are located in the centre of the city. Although, gases concentration varies area to area but it is very much clear that all sampling areas have high concentration of any of the measured gas or Particulate matter. For instance, Campus Bridge and Charing Cross have more concentration of ozone (O_3) gas while it is very low at Qartaba Chowk and Kot Lakhpat. Both extremes represent the presence of vegetation at these areas. It can be assumed that presence or absence of vegetation affect on the concentration of ozone (O_3). The high concentration of SO_2, CO and NO_X can be seen at those places (Regal Chowk, Yateem Khan and Yadgar Chowk) where a large number of motor vehicles pass during the day and night. High concentration of Particulate matter is present at those places where high concentration of carbon dioxide is found. These are the places which are surrounded by high buildings with heavy load of motor vehicles. Since the city of Lahore is the second largest urban centre and centre of economic activities so the air pollutants are dispersed all over the city. The absence of any wind movement in the city, presence of sun shine during the day and high temperatures all contribute to the high concentration of gases as well as Particulate matter. In order to keep the level of air pollution at low level there is a strong need to implement the environmental laws to monitor industrial and motor vehicles maintenance standards.

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