Pak. j. sci. ind. res. Ser. A: phys. sci. 2011 **54** (2) 84-89

Investigation of Carbon Monoxide at Heavy Traffic Intersections of Karachi (Pakistan) using GIS to Evaluate Potential Risk Areas for Respiratory and Heart Diseases

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(received August 13, 2009; revised September 29, 2010; accepted October 8, 2010)

Abstract. Measurement of carbon monoxide in the ambient air at 36 locations on the busy roads of Karachi showed peak values of CO at 18 sites to be within the permissible limit of 10 ppm whereas up to 70 ppm at the other 18 sites. The evaluated carboxy haemoglobin (COHb) level was in the range of 1.1 to 15.8 %.

Keywords: carbon monoxide, air pollution, GIS, vehicular pollution

Introduction

Recent evidence in respect of air pollution indicates that transportation is the major source of air pollution in urban areas (Ghose *et al.,* 2004) and that traffic is the leading cause of pollutant emissions especially those of CO and NOx, VOCs, SOx and particulate matter (Harrop, 2002). It is estimated that road traffic contributes 60% of air pollution in urban areas (Anjaneyulu *et al.*, 2006).

Carbon monoxide is one of the major air pollutants in metropolitan cities. In central part of cities and during traffic jams, its concentration shoots up. CO discharged from motor vehicles and other sources has indirect effects on climatic change and adverse effects on the health of the exposed humans (Khan *et al.,* 1996; Khalil, 1995).

Carbon monoxide is a highly toxic gas but it is not easily detected by olfactory senses. It can seriously affect human aerobic metabolism owing to its high affinity for haemoglobin, forming carboxy haemoglobin (COHb), reducing the capability of the blood to carry the oxygen to body tissues such as heart and brain. Reactivity of CO with haemoglobin is 240 times greater than that of oxygen (Harrop, 2002; WHO, 1999). The effects of CO depend on its concentration, exposure time and health status of people, their age and activities. Long-term exposure to low concentrations of CO can have effects similar to short-term exposure to high concen-trations. The symptoms of exposure to CO include headache, tiredness, dizziness, nausea, vomiting and drowsiness and in very acute situations, unconsciousness and even death (Malakootian and Yaghmaeian, 2004).

The present study was focused on examining the status of CO pollution due to traffic congestions in Karachi city with some specific significance for urban planners. The main objective of this study was collection of data relating to CO concentrations at heavy traffic locations of Karachi, and assessment of human blood carboxy-haemoglobin (COHb) concentrations at these locations showing the spatial clusters and patterns of CO with its impact on respiratory and heart diseases and evaluating potential risk areas. Such a study was not made earlier.

Materials and Methods

Sampling map. Sampling of CO was carried out at 36 identified locations in different towns of Karachi, selected on main traffic congested areas as shown in Fig. 1 with town boundaries.

Sampling. Concentration of carbon monoxide was measured by Snift CO analyzer (Model 50). The analyzer

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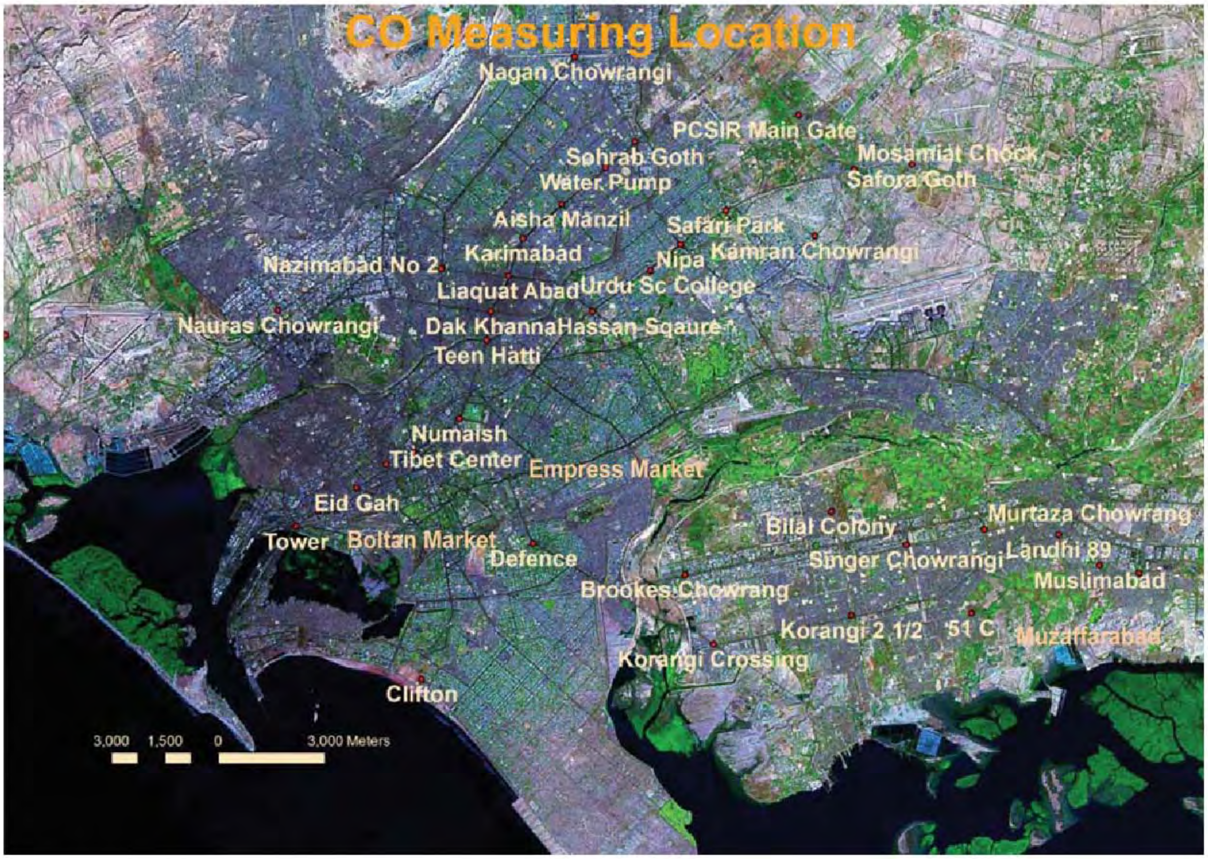

Fig. 1. CO measuring locations.

is ideal for measuring (in ppm) the level of carbon monoxide in ambient air. During all the measurements, the meter was kept at about 1.2 m above the ground level. At each site, level of CO in the ambient air was taken at intervals of 10 min and a set of ten readings was recorded during a period of about 2 min with repetition after every 8 min. The data was generated from 08 AM to 18 PM, at each site. Thus 60 CO spot readings were taken at each location, making a total of 2160 readings. From these readings, 8 h TWA average values were calculated.

GIS techniques. GIS is a computer system capable of assembling, storing, manipulating and displaying geographically referenced information, identified according to their locations.

GEO reference. Geo refers to the process of assigning map coordinates to image and non-image data (met data). The geo referenced map can be used as a planimetric map, for on-screening digitization with GIS. Fig. 2 shows interpolated surface of CO.

Digitization. In the broadest sense, digitization refers to any process that converts non-digital data into the numbers. There are two types of digitization namely tablet digitization and screen digitization. In the present study, screen digitization method was used wherein vector data are drawn in the viewer with a mouse using the displayed image as a reference. These data are then written on to the vector layer.

Cartographic techniques. With the help of cartographic and geographical information system (GIS) techniques, town boundaries were demarcated and record of CO at different locations of Karachi was made. Locations having different potential of CO and areas of different towns were computed; GIS technique was used for plotting and mapping the information retrieved.

Results and Discussion

Table 1 shows the time weighted everage values of CO. The time weighted average (TWA) values of carbon

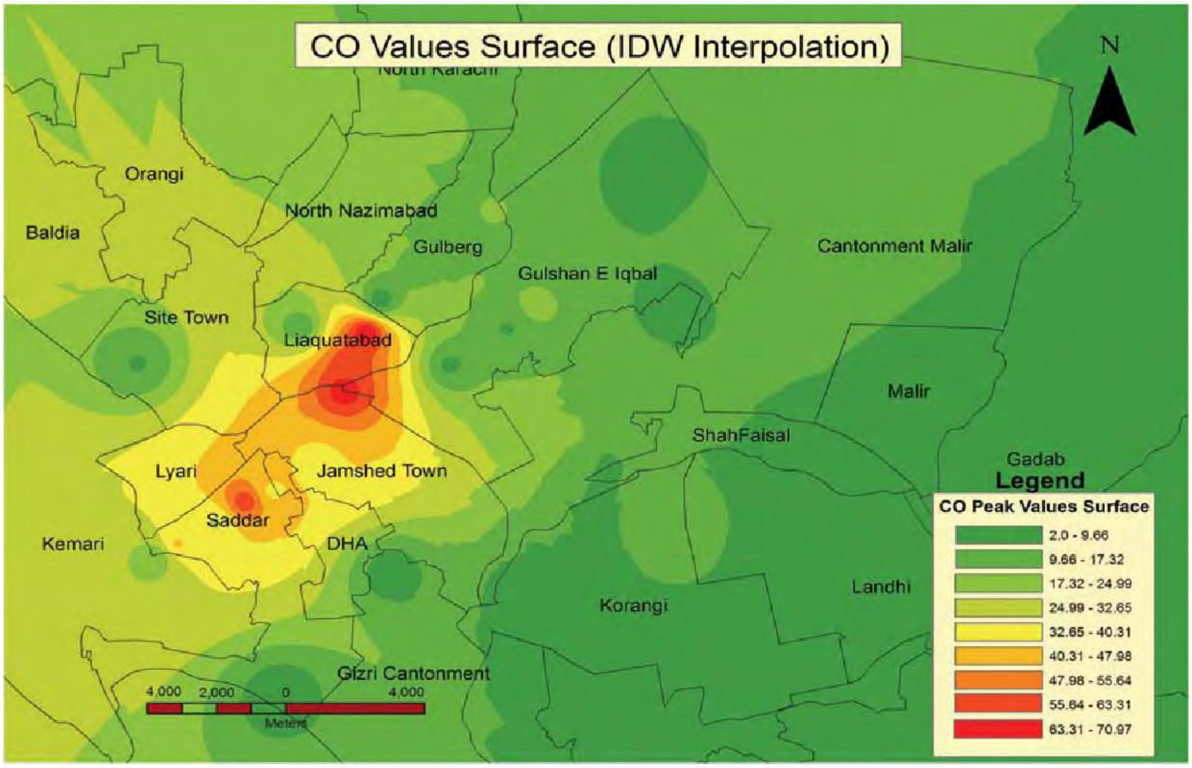

Fig. 2. Interpolated surface of CO

monoxide for 8 h average ranged from 3 to 71 ppm, whereas equilibrium concentration of blood COHb - air CO level (%), varied from 0.7 to 15.8% (Table 1). The results suggest that TWA 8 h average concentration of CO at 20 locations (location no. 1-17, 23,33 and 35) out of thirty six locations was very high and much above the permissible limit of 9 ppm (10 mg/m^3) recommended by the WHO (1999, 1998). The reasons of high concentration of carbon monoxide pollution on the streets include old vehicles with poor maintenance, narrow roads with uneven surfaces, rash driving, lake of education of vehicle drivers, especially commercial vehicle drivers, frequent traffic jams and congestion.

During traffic jams, the concentration of carbon monoxide shoots up abruptly within fraction of a minute becoming health hazard for human beings. Similarly the concentration of carbon monoxide varies with traffic density and types and condition of vehicles in the given traffic stream. Other factors such as wind velocity, wind direction, humidity and temperature are also important. Higher wind velocity and more open area around the location lower the concentration of carbon monoxide, whereas high temperature along with higher wind velocity would increase the rate of diffusion, which could enhance the dissipation of carbon monoxide soon after the emission.

Locations No.5, 6,7,12,14,15,16 and 17 (Table 1) are highly congested areas having narrow roads, slow moving traffic and high traffic density as compared to the rest of locations, resulting in high concentration of CO. Generally, the concentration of carbon monoxide increases between 8:00 and 9:00 h local time, at the time when people go to their offices and students to their institutions. Commercial activities reach their peak leves between 11:00-15:00 h; the traffic density gets lower at 16:00 h thus reducing the CO emission. After 16:00 h, the traffic density again increases subsequently raising the CO level.

When carbon monoxide is inhaled, it combines with the blood haemoglobin forming carboxy haemoglobin. Normal or background level of blood carboxy haemoglobin (COHb) is about 0.5% originating from the destructive metabolism of haem, a component of haemoglobin and ambient air CO (Khan *et al.,* 1996).

The equilibrium percentage of COHb in blood stream of a person exposed to less than 100 ppm can be estimated by the equation:

COHb in blood (%) = 0.16 (CO conc. in ppm + 0.5); (0.5% is the normal background COHb concentration in blood).

Using this equation, blood COHb -air CO equilibrium data for different locations were estimated in the range of 0.7 to 15.8 % (Table 1).

Table 1. Time weighted average of carbon monoxide and calculated values of carboxyhaemoglobin (COHb) at the selected sites for 8 hours.

ID	Location	TWA CO values (ppm)	Calculated values of COHb (%)
1	NIPA	24.5	4.4
2	Sohrab Goth	20	4.0
3	Water Pump	13	2.6
4	Aisha Manzil	15	3.0
5	Teen Hatti	69	11.5
6	Dak Khana	63	10.6
7	Liaquatabad	71	12.0
8	Karimabad	11	2.2
9	Mosamiat Chock	14	3.0
10	Safora Goth	15	3.0
11	Safari Park	13	2.6
12	Numaish	37	6.4
13	Tower	20	4
14	Empress Market	39	6.7
15	Eid Gah	32	5.6
16	Bolton Market	41	7.1
17	Tibet Center	61	10.3
18	Korangi 51 C	4	1.1
19	Korangi 2 1/2	4	1.1
20	Korangi Crossing	7	1.6
21	Singer Chowrangi	3	0.9
22	Murtaza Chowrangi	5	1.3
23	Bilal Colony	16	3.1
24	Landhi 89	4	1.1
25	Muslimabad	7	1.6
26	Muzaffarabad	4	1.1
27	Brookes Chowrangi	3	0.9
28	PCSIR Main Gate	3	0.9
29	Defence	2.5	0.9
30	Clifton	3	0.9
31	Hassan Sqaure	8	1.8
32	Urdu Sci. College	9	2
33	Nagan Chowrangi	20	4
34	Kamran Chowrangi	5	1.3
35	Nazimabad No. 2	11	2.2
36	Nauras Chowrangi	9	2

Table 2 shows adverse effects of CO on human health, (Wolf, 1971). It is obvious that upto 1% CO in the haemoglobin may be considered ideal whereas above 1% is detrimental. However, it is the level above 2% where physiological effects become evident.Thus 2-5% blood COHb level may affect the central nervous system, impair time interval discrimination, cause visual acuity, affect discrimi-nation of brightness and may change certain other psychomotor functions. When this situation is supplemented with other gaseous pollutants of automobile exhaust like hydrocarbons, oxides of sulphur and nitrogen dust, etc., a bleak picture can be visualized.

Table 3 shows town-wise sites selected for CO measurement and also presents minimum, maximum, range, mean, standard deviation and sum values of CO through GIS interpolation technique. The results suggest that Liquatabad, Jamshed Town, Gulshan-e-Iqbal and Saddar (Table 3) are the highly vulnerable areas where people are at great risk of developing respiratory and heart related diseases.

Table 4 shows town-wise risk areas with reference to health effect of COHb. Exposure to elevated CO level is associated with impairment of visual perception, working capacity, manual dexterity, learning ability and performance of work task (Aziz and Qureshi, 2003).

Table 2. Effect of COHb blood level on humn health

COHb blood level (%)	Demonstrated effects
Less than 1.0	No apparent effects
1.0 to 2.0	Some evidence of effect on behavioral performance
2.0 to 5.0	Central Nervous System effects impairment of time interval discrimination, visual acuity, brightness discrimination and certain other psychomotor function.
> 5.0	Cardiac and pulmonary functional change
10.0 to 80.0	Headache, fatigue, drowsiness, coma, respiratory failure, death

Table 3. Town wise area and CO concentration through GIS interpolation techniques

Town name	Area (km^2)	Min (ppm)	Max (ppm)	Range (ppm)	Mean (ppm)	STD (ppm)	Sum (ppm)
Baldia	28595000	18.51	28.65	10.14	26.14	1.55	299040
Bin Qasim	114185000	2	7.74	5.74	5.4	0.97	246604
Cantonment Malir	119152000	6	24.63	18.63	11.47	2.53	546764
DHA	7650000	8.79	42.74	33.94	28.83	9.15	88221
Gadab	441369984	2	27.25	25.25	11.51	6.11	2032680
Gizri Cantonment	38302500	4	18.28	14.27	12.05	2.73	184639
Gulberg	13820000	4.07	32.75	28.68	16.88	3.03	93288
Gulshan-e-Iqbal	53690000	3.01	68.99	65.99	15.2	8.87	326507
Jamshed Town	23417500	7.94	68.93	60.99	33.26	12.97	311536
Kemari	113568000	2	35.83	33.83	24.11	5.7	1095140
Korangi	41472500	3	15.99	12.99	7.13	2.46	118290
Landhi	39160000	3	15.9	12.9	6.46	1.93	101145
Liaquatabad	10855000	11.02	70.98	59.95	39.3	14.85	170625
Lyari	7980000	27.48	46.63	19.15	37.04	3.58	118235
Malir	17792500	6.03	10.49	4.45	7.81	0.86	55605
North Karachi	20457500	11.5	19.6	8.1	16.16	1.87	132239
North Nazimabad	16702500	16.31	28.25	11.94	21.77	3.38	145467
Orangi	23475000	23.64	29.54	5.9	26.01	1.44	244227
Saddar	24155000	3.01	60.97	57.96	28.06	12.54	271083
ShahFaisal	11710000	6.11	11.73	5.63	8.61	1.49	40309

Table 4. Town wise risk areas on the basis of blood COHb level through GIS techniques

Town name	Blood COHb level (%)	Health effects of blood COHb level	Level of risk areas
Bin Qasim	1.364	Some affects on behavioural performance	Low risk areas
Landhi	1.5336	Some affects on behavioural performance	Low risk areas
Korangi	1.6408	Some affects on behavioural performance	Low risk areas
Malir	1.7496	Some affects on behavioural performance	Low risk areas
Shahfaisal	1.8776	Some affects on behavioural performance	Low risk areas
Cantonment Malir	2.3352	Some affects on behavioural performance	Medium risk areas
Gadap	2.3416	Some affects on behavioural performance	Medium risk areas
Gizri Cantonment	2.428	Some affects on behavioural performance	Medium risk areas
Gulshan-e-Iqbal	2.932	Some affects on behavioural performance	Medium risk areas
North Karachi	3.0856	Nervous and psychomotor function	Medium risk areas
Gulberg	3.2008	Nervous and psychomotor function	Medium risk areas
North Nazimabad	3.9832	Nervous and psychomotor function	Medium risk areas
Kemari	4.3576	Nervous and psychomotor function	Medium risk areas
Orangi	4.6616	Nervous and psychomotor function	Medium risk areas
Baldia	4.6824	Nervous and psychomotor function	Medium risk areas
Site Town	4.7048	Nervous and psychomotor function	Medium risk areas
Saddar	4.9896	Nervous and psychomotor function	Medium risk areas
DHA	5.1128	Cardiac and pulmonary functional change	High risk areas
Jamshed Town	5.8216	Cardiac and pulmonary functional change	High risk areas
Lyari	6.4264	Cardiac and pulmonary functional change	High risk areas
Liaquatabad	6.788	Cardiac and pulmonary functional change	High risk areas

Conclusion

GIS-based this study shows that the concentration of carbon monoxide in the ambient air on the busy roads of Karachi is very high and almost the entire pollution in the environment is being generated by automobile exhaust. Growing number of vehicles, used leaded gasoline, poor condition and maintenance of vehicles, use of defective silencers, poor road conditions, rash driving etc. are the major causes of high concentration of CO in the environment of Karachi.

Thus, there is a growing need to formulate proper regulatory laws to limit emission of gaseous pollutants from individual vehicles and to implement the regulations forcefully by on- the-spot checking. Traffic geometry also plays important role in avoiding congestion on the roads and local route modification could prevent major causes of pollution. Faulty and worn out vehicles should be removed from the roads.

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