COMPARISON OF CARBON MONOXIDE FOR METROPOLITAN CITY AT TRAFFIC STRESSED SITES – A CASE STUDY OF KARACHI 2002 –2018

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Abstract

The concentration of carbon monoxide (CO) gas was measured at different traffic stressed areas. This study aims to find out the air quality CO concentration in the city of Karachi, Pakistan from 2002 to 2018. More than 300 sites were observed in the year 2002 and 2018. Those observations were segregated with respect of type of the day, time of the day and, at different elevations. Type of the day is then categories on weekdays and weekends. Time of the day considered as morning, afternoon and, evening. Elevations of observation were taken as 3.0 feet and 4.5 feet above the ground. A CO Index was also checked for every combination. Geographic Information System (GIS) maps were also crafted for every combination of days, times and, heights to visualize the situation. At, 3.0 feet height for both cases of working and weekdays it is observed that CO concentration is nearly half of that of 2002. At the elevation of 4.5 feet it is also going down but about 10% as compared to 2002. Even after having a decrement trend the area under study is unhealthy for living. CO concentration was then predicted for years 2020, 2022 and 2025. Even have a decrement trend, the living condition was not good for any of the projected year for time of the day and type of the day. The main reason for having a decrement pattern is changing fuel type and removal of old carriage buses.

Keywords: CO Concentration; Karachi Metropolis; Air Quality Index; Traffic-related air Pollution.
I. Introduction

The physical and mental health of any human settlement is highly depended on air quality [II]. Vehicular emission is one of the greatest cause of air quality decrement VI]. Major pollutants emitted by motor vehicles are oxides of carbon and nitrogen (CO, NOx) along with Particulate Matters [XVII]. Karachi is one of the megacities of Pakistan [XVIII]. The location of the city Karachi is at the shore of Arabian Sea with latitude and longitude of 24.86° N, 67.00° E. Karachi is facing serious issues regarding air quality. It has 40% higher air pollution than other cities of the country. It is due to vehicular traffic, industries, and open garbage burning. These activities generate thousands of tons of toxic gases and particulate matters [XXI]. A normal person breaths 14 to 18 kg of this polluted air per day. Toxic gases and particulate matters in such high quantities and of such long duration are liable to cause harm to human. In Karachi, the sun never comes out to its full strength because of the atmospheric pollution [IV]. Besides industrial emissions, burning of solid waste, and natural dust, vehicular emissions are only just one big source of air pollution in monoxide is included in gaseous pollutants [XIV]. Because of short atmospheric lifetime[X], the atmospheric concentration of CO exhibits significant spatial and temporal variability [XII].

Carbon Oxide is inflammable which exits in 2nd oxidation degree. It oxidizes to CO$_2$, results in the formation of ozone. Carbon monoxide is toxic, colorless and odorless. It spreads in air quickly due to low density. The main sources of CO are traffic emission specifically gasoline-driven automobiles. Whereas, CO produce upon incomplete combustion of carbon. So, the anthropogenic emission is first of all-cause by combustion of fuel. The volume of emission is highly depended upon type of vehicle, its operating speed and working principle [V].

CO forms when carbon in fuels is not burned completely [XXII]. In an urban environment, vehicular exhaust can cause about 95 percent of all CO emissions [VII]. These emissions can result in high concentrations of CO, particularly in local areas with heavy traffic congestion [XVIII]. Other sources of CO emissions include industrial processes and fuel combustion in sources such as boilers and incinerators. This criteria pollutant results from incomplete combustion of fuel and are emitted directly from vehicle tailpipes[XIII]. Incomplete combustion is most likely to occur at low air to fuel ratios, during vehicle starting when air supply is restricted, when cars are not tuned properly, and at altitude. The effect of weather has also observed. Therefore, Carbon monoxide (CO) emissions from automobiles increase dramatically in cold weather. This is because cars need more fuel to start at cold temperatures and because some emission control devices operate less efficiently when they are cold.

Carbon monoxide is a sneaky poison, as it is colorless, non-irritating and without any odor. it approaches without warning. Apart from other effects on non-living things, biological effects of air pollutants directly upon humans are more significant [IX].
Table 1: Physical Properties of Carbon monoxide

| Property               | Value                        |
|------------------------|------------------------------|
| IUPAC ID               | Carbon monoxide              |
| Formula                | CO                           |
| Molecular Weight       | 28.01 g/mol                  |
| Boiling Point          | -191.5 °C                    |
| Melting point          | 205 °C                       |
| Density                | 0.968 air = 1.0              |
| Auto Ignition          | 606 °C                       |
| Solubility (H2O)       | 3.3 ml 100 ml⁻¹ @ 0 °C       |
|                        | 2.3 ml 100 ml⁻¹ @ 20 °C      |
| Specific Gravity       | 1.250 g L⁻¹ @ 0 °C           |
| Conversion Factor      | 1 ppm = 1.25 mg m⁻³ @ 25 °C   |

Every year, Karachi faces a serious threat to public health because of air pollution, especially in urban areas. This degradation of air quality is mainly because of vehicular exhaust and industrialization in urban premises. The air quality of the city is more than seven times the World Health Organization (WHO) Guidelines for Total Suspended Solid (TSS) Concentration. The study area has the highest figure of mortality. It has also the greatest number of annual average concentration of TSP, Suspended Solids (TSP) among all of the megacities. CO rapidly absorbed in the lungs and is taken up in the blood where 80 – 90 percent of CO binds to hemoglobin (Hb) with the formation of carboxyhaemoglobin (COHb), which impairs the oxygen-carrying capacity of blood, which may result as fatal. CO at very low concentrations in the blood (i.e. 0.1%) will combine with over half of the haemoglobin and immediately reduce the O₂ carrying capacity by a similar proportion. The affinity of CO for human foetal haemoglobin is higher than that for normal haemoglobin. This means that unborn babies are especially susceptible to CO poisoning. In ambient air, CO rapidly diffused but its concentration approaches an alarming stage at proximity of source especially, in open window low height vehicles. The major factor for acceptance of CO is its concentration are endogenous production of CO, the intensity of physical effort, body size, the condition of the lungs and the barometric pressure whereas alcoholism, obesity, old age, heart conditions, and lung diseases worsen the intensity of effect.

The major consequence of CO is to reduce the oxygen transport to the tissues. Organs, which are dependent on large oxygen supply, are the most vulnerable, particularly the heart and the central nervous system. Four types of health effects are described to be associated with CO exposure: neurobehavioral effects, cardiovascular effects, fibrinolysis effects and Perinatal effects. Carbon monoxide leads to a decreased oxygen uptake capacity with a resultant decreased work capacity.
II. Methodology

The city Karachi is the largest city in the country. It is continuously and rapidly growing in terms of population. Due to better industrialization, economy and educational facilities, this city attracts people around the country. The city Karachi as shown in figure 1 is most industrialized, urbanized, and affluent city in Pakistan. The city is divided into 18 administrative units termed as Town. It has 06 cantonments as well, with a population of 18 million, about 10 percent of the total population of the country. Nearly 40% population of the city lives in “Kachi Abadis” with low-income groups. The climate of the city is subtropical, with short rainfall averagely 256 mm annually. The rains are normally during the months of July–August. Humidity is high during summer season and it is relatively dry in the winter season. 85% humidity in August and 58% in December the wettest and driest month respectively. The average monthly temperature varies between 13°C and 34°C. Karachi has the biggest industrial infrastructure in and around it. The city has no proper solid waste management system.

This city is the most populated city of Pakistan having very high traffic volume. It is confronting the situation of increasing traffic every day [XXIV]. This increase in traffic is primarily due to uncontrolled population growth rate and rapid urbanization of the city. Karachi is facing a growth rate of vehicles about 7.60% per annum [XV]. Due to this traffic, Karachi has one of the most polluted urban environments in-country along with high air and noise pollution contributed by traffic [I].

Traffic in Karachi is increasing day by day. Six percent of total vehicles of Pakistan are in Karachi[XV]. More than 2.6 million vehicles are registered in Karachi. There is an increase of more than sixteen thousand vehicles each month in Karachi in the year 2005[XVI]. This increase is in all modes of vehicles such as motorcycles/scooters, rickshaws, cars/jeeps/vans/taxis, buses, trucks/trailers, and pickups. Karachi has a total road length of more than 9500 kilometers that accommodates 1.81 million vehicles. The average speed at most arterials is 30-40 kilometers per hour and in core areas peak speed is 15 kilometers per hour or lower. High traffic volumes and low operational speed led to air quality degradation, especially on roads. Pakistan has yet not developed any model to compute concentration of gases in an automated manner. Therefore, carbon monoxide emissions were measured manually at the field using handheld CO meter.
A total of 308 sites were selected. These sites were the same as the study in 2002 in a Ph.D. thesis [XXIX]. All selected sites were at major intersection as in figure 2 for measuring CO emissions due to traffic. The CO concentration was observed on weekdays and weekends. Time of the day was selected as morning, afternoon and evening with an elevation of 3.0 feet and 4.5 feet from the ground.

CO emissions were measured in normal traffic volume as the survey was not conducted on special occasions like public holidays and strikes etc. CO emissions are characterized as abnormal and non-continuous phenomena because it depends on traffic type and behavior. Both vary from time to time and place to place. Therefore, gas concentration map for each time period, height, and day type for both years 2002 and 2018 were developed using ArcGIS 10.6. Morning, afternoon and evening were referred to as mor, noon and eve respectively. While weekday and weekend were referred as W.D and W.E. Timing for the data collection in morning, afternoon and evening were 06:30-10:30, 12:00-15:00 and 16:30-24:00 respectively. Air Quality Index (AQI) was also found for not only 2002 and 2018. The concentration of CO gas was forecasted for year 2020, 2022 and 2025. These predictive concentrations were on the basis of AAA version of the Exponential Smoothing algorithm. It calculates/predicts a future concentration on existing values.
III. Results and Discussion

GIS maps were developed on the basis of time of day, elevation, and type of the day. CO concentration was mapped on working days at an elevation of 3.0 feet. It is observed from Fig 2. CO concentration measured in working days at height of 3 ft.: (a) morning 2002, (b) afternoon 2002, (c) evening 2002, (d) morning 2018, (e) afternoon 2018, (f) evening 2018. CO concentration has a decreasing trend spatially for every time of the day. In 2002 condition was worse comparatively especially in evening. However, condition was better in 2018. Same is the trend of weekends at 3.0 feet as shown in Fig 3. CO concentration measured in weekends at height of 3 ft.: (a) morning 2002, (b) afternoon 2002, (c) evening 2002, (d) morning 2018, (e) afternoon 2018, (f) evening 2018. While some points in the morning have a higher concentration. The rest of all have comparative decrement trend. The conditions were worse during evening timing in 2002. However, if compare within 2018 evening is the most vulnerable time still. Fig 3 & Fig 4 suggest that the CO concentration is more or less same for both 2002 and 2018. However, minor decrease can be observed in 2018 as compared to 2002. This decrease is because of fuel type change in the region. Gasoline was used in 2002 while Compressed Natural Gas (CNG) replaced it by 2018. This is one of the foremost reasons. CNG is more environmentally friendly as compared to gasoline. One more reason is that
the minibuses now vanish, Chigchi (a little bigger rickshaw) has completely replaced it. These mini buses used diesel fuel. While chigchi uses CNG. A drastic change in 3.0 feet elevation can be observed. This change is about 50% of the 2002 concentration. This is because of the removal of minibuses. Those minibuses have tail at about 3.5 feet.

Fig2. co concentration measured in working days at height of 3 ft.: (a) morning 2002, (b) afternoon 2002, (c) evening 2002, (d) morning 2018, (e) afternoon 2018, (f) evening 2018.
Fig 3. CO concentration measured in weekends at height of 3 ft.: (a) morning 2002, (b) afternoon 2002, (c) evening 2002, (d) morning 2018, (e) afternoon 2018, (f) evening 2018.
Fig4. CO concentration measured in working days at height of 4.5 ft.: (a) morning 2002, (b) afternoon 2002, (c) evening 2002, (d) morning 2018, (e) afternoon 2018, (f) evening 2018.

Fig5. CO concentration measured in weekends at height of 4.5 ft.: (a) morning 2002, (b) afternoon 2002, (c) evening 2002, (d) morning 2018, (e) afternoon 2018, (f) evening 2018.
A detailed comparison between emissions of 2002 and 2018 is presented on the basis of mean and mode. This descriptive statistic was for every time of the day i.e.; morning, afternoon and evening and for every elevation i.e. 3 ft. and 4.5 ft. for weekends and working days. The data were presented in Figure 6. Line 1 shows the global background concentration of CO emission in ppm. Global background concentrations of carbon monoxide range between 0.06 mg/m$^3$ and 0.14 mg/m$^3$ (0.05 ppm – 0.12 ppm). Line L1 shows the average global background concentration of CO gas. In working day (W.D), at an elevation of 3.0 ft. concentration was decreased to about 50% more or less for every time of the day. This trend is the same for weekends (W.E) as well. At an elevation of 4.5 ft. trend of decrement continue but the magnitude of decrement is very low. This is because high exhaust tailpipe buses are same on their routes. While slight decrement could be because of a change in fuel type. From gasoline to CNG as discussed in previous section. The most repeated number in 2002 is 10 ppm while in 2018 it as high as 19 ppm and as low as 7 ppm.

![Graph showing comparison between 2002 & 2018 CO concentration measured in weekdays and weekends of 2002 and 2018 in morning, afternoon and evening at the height of 3 ft. and 4.5 ft.](image)

Air Quality Index (AQI) was done for past, 2018 and future data. Exponential smoothing method was used for predicting values. No of the time in the past, 2018 and in future the study area in Good Rating. It is moving around Hazardous to Moderate. However, it is moving in a good direction.

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Index \ Value = \frac{CO \ concentration}{CO \ goal \ Concentration \ 9 \ ppm} \times 100 \tag{1}
\]
AQI Guidelines were:

Table 2: Air quality guidelines

| Air Pollution Index (API) | Rating | Remarks |
|--------------------------|--------|---------|
| 0-50                     | Good   |         |
| 51-100                   | Moderate|        |
| 101-199                  | Unhealthy|       |
| 200-299                  | Very Unhealthy| Alert |
| 300-399                  | Hazardous| Warning |
| 400-499                  | Hazardous|         |

AQI rating for the weekend was hazardous to unhealthy in 2002 and 2018. While it has a better rating in future years that is unhealthy to moderate as shown in table 3. The trend has towards betterment in every coming year. AQI for the weekend has better rating even one data set 2025 in morning and 3.0 ft. elevation reaches up to Good.

Table 4: AQI Rating for weekends

Weekend

| Elevation | Mornings | Afternoon | Evening |
|-----------|----------|-----------|---------|
| 3'        |          |           |         |
| Year      | Index Value | Rating | Index Value | Rating | Index Value | Rating |
| 2002      | 193      | Unhealthy | 235 | Very Unhealthy | 335 | Hazardous |
| 2018      | 108      | Unhealthy | 114 | Unhealthy | 139 | Unhealthy |
| 2020      | 97       | Moderate | 99  | Unhealthy | 114 | Unhealthy |
| 2022      | 87       | Moderate | 84  | Moderate | 89  | Moderate |
| 2025      | 71       | Moderate | 62  | Moderate | 53  | Moderate |

| Elevation | Mornings | Afternoon | Evening |
|-----------|----------|-----------|---------|
| 4.5'      |          |           |         |
| Year      | Index Value | Rating | Index Value | Rating | Index Value | Rating |
| 2002      | 136      | Unhealthy | 161 | Unhealthy | 213 | Very Unhealthy |
| 2018      | 125      | Unhealthy | 143 | Unhealthy | 178 | Unhealthy |
Table 5: AQI Rating for weekends

| Year | Elevation | Mornings | Afternoon | Evening |
|------|-----------|----------|-----------|---------|
| 2020 | 3'        | Unhealthy| Unhealthy | Unhealthy|
| 2022 | 3'        | Unhealthy| Unhealthy | Unhealthy|
| 2025 | 3'        | Unhealthy| Unhealthy | Unhealthy|

| Elevation | Mornings | Afternoon | Evening |
|-----------|----------|-----------|---------|
| Year      | Index Value | Rating | Index Value | Rating | Index Value | Rating |
| 2002      | 332       | Hazardous| 347       | Hazardous| 417       | Hazardous|
| 2018      | 112       | Unhealthy| 142       | Unhealthy| 155       | Unhealthy|
| 2020      | 84        | Moderate | 116       | Unhealthy| 122       | Unhealthy|
| 2022      | 56        | Moderate | 91        | Moderate | 90        | Moderate |
| 2025      | 29        | Good     | 65        | Moderate | 57        | Moderate |

| Elevation | Mornings | Afternoon | Evening |
|-----------|----------|-----------|---------|
| Year      | Index Value | Rating | Index Value | Rating | Index Value | Rating |
| 2002      | 201       | Very Unhealthy| 209 | Very Unhealthy| 254 | Very Unhealthy|
| 2018      | 141       | Unhealthy | 174       | Unhealthy | 202 | Very Unhealthy|
| 2020      | 134       | Unhealthy | 170       | Unhealthy | 195 | Unhealthy |
| 2022      | 126       | Unhealthy | 165       | Unhealthy | 189 | Unhealthy |
| 2025      | 115       | Unhealthy | 159       | Unhealthy | 179 | Unhealthy |

IV. Conclusions

This article describes the CO concentration of more than 300 sites in morning, afternoon and evening at an elevation of 3.0 feet and 4.5 feet at traffic stressed sites. The air quality of metropolitan is showing better trend. It shows the following results:

1. Changing fuel form gasoline/diesel to CNG has a positive effect on the over city air quality.
2. Mini-buses change to small rickshaw, have also help to reduces the Co concentration in the city.
3. Evening, working days have the worst air quality conditions, the trend is more or less the same but visible reduction in CO concentration could be observed.
4. AQI shows that the air quality never goes to betterment except unhealthy. For the predicted data 2025 in the morning, some good AQI were observed.

V. Recommendation

1. Health conditions should also have observed through hospital data or on-site interview. It could give an understanding about the human exposure to CO gas and its effect.
2. GIS-based contour map could also give a better understanding about the missing points.

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