INTERNATIONAL JOURNAL OF ENVIRONMENT

Volume-3, Issue-4, Sep-Nov 2014 **ISSN 2091-2854**

Received:30 August *Revised:7 September* *Accepted:19 November*

EMPLOYEES' EXPOSURE TO CARBON MONOXIDE IN PAKISTAN STEEL MILLS

Kanza Abid[1] and Zafar Iqbal Shams[2]*

[1,2] Institute of Environmental Studies, University of Karachi, Karachi, Pakistan

*Corresponding author: zishams@uok.edu.pk

Abstract

Many processes in the iron and steel making industries emit carbon monoxide, which causes a variety of toxic effects on human health, such as fatigue, impaired memory, headache, and nausea. At elevated exposure, carbon monoxide poisoning may lead to loss of consciousness and death. Therefore, the current study has been carried out to investigate the occupational exposure of randomly selected fifty-eight employees of Pakistan Steel Mills to the carbon monoxide. The selected employees were from 10 different facilities of the Pakistan Steel Mills, who were working in two different shifts viz. nightshift and dayshift, each of twelve hours. Thirty employees from nightshift and twenty-eight employees from dayshift were monitored for their exposure to carbon monoxide. The instrument was logged to measure the employee's exposure to carbon monoxide with 1-minute interval. The study reveals that the employees, working in the Raw Materials Production Plant during nightshift were exposed to the highest mean concentration of carbon monoxide while those working in Oxygen Plant during nightshift were exposed to the lowest mean concentration of carbon monoxide. According to study, the highest recorded exposure was found near Blast Furnace during dayshift. The employees' exposure to 98th percentile concentration of carbon monoxide in different facilities of the steel mills has also been analyzed. The employees' exposure to carbon monoxide during commuting from home to their workplace has also been investigated.

Keywords: Carbon monoxide, Exposure, Coking, Furnace, Iron and Steel Making

Introduction

Pakistan Steel Mills (PSM) is the only integrated iron and steel making industry in Pakistan. It has a workforce of over 16,000 employees and is located at a distance of 40km south east of Karachi near seaport Bin Qasim (Coordinates 24°48'20"N 67°20'47"E). It spread over an area of 18,600 acres. It has a capacity of producing 1.1 million tons of steel per year. It has one of the largest conveyer systems and the industrial water reservoirs (about 110 MGD) in the world. The details of its main units are presented in Table 1.

Table 1: Main Units of PSM, their Products, Equipments, Number of Employees Monitored

Sr #	Main units	Products	Number of Equipments	Employees Monitored
1	Steel Making Department	Cast bloom, cast billet, cast slab	2 L.D converters, 1 bloom caster, 1 billet caster, 2 slab casters	12
2	Coke Oven	Coke	2 batteries, 49 ovens in each battery	10
3	Iron Making Department	Pig iron	2 blast furnaces	9
4	Thermal Power Plant	Electricity	3 generators, each produces 55MW	8
5	Hot Strip Mill	H.R coil and plate	2 reheating furnaces, 1700 mm universal stand	5
6	Iron Ore & Coal Jetty	Unloading and lifting iron ore and coal	2 unloaders, 7 km conveyer belt, universal machine	4
7	Oxygen Plant	Oxygen and nitrogen	2 air compressors, 2 cold boxes, 2 air turbines	3
8	Cold Rolling Mill	C.R coil/sheet, galvanized coil/ sheet, H.R sheet	4 high reversible machines, 1 bell type annealing furnace	3
9	Raw Material Production Plant	Sinter	2 sinter machines	2
10	Refractories	Fire day bricks, tar, bonded dolomite brick	Lime rotatory kiln, hydraulic bricks, power press	2
Total employees studied				58

Brief description of Raw Materials, Processes and Products of PSM

The coal and the ore of iron and manganese are imported and unloaded on ore and coal jetty at seaport Bin Qasim by two mechanized unit-orders with a capacity of 1000 tons hour^{-1} each and transferred directly to the plant site through two berth conveyor and two mill feed conveyers (4.5km long). The conveyer has a width of 1200 MM and a capacity of transporting 1200 tons of iron ore or coal per hour. The iron ore and coal are stored in separate stockyard at plant. In addition, the stockyard stores indigenous raw materials e.g., limestone, dolomite and quartzite. They are transferred by stacking, reclaiming machine and a network of conveyer belts.

The fine iron ore (< 6mm in size) is mixed and homogenized with limestone, dolomite, manganese ore and coke breeze in sintering section. The balling process is carried out in balling mixer drums. The sinter is then ignited at 1200 ˚C in sintering machine. The process of fusion is carried out by 'Down draft method'. The hot sinter is then crushed, cooled and sorted to separate the sinter of different sizes. The sinter of greater than 16mm in size is directly sent to blast furnace. The sinter fractions of 6mm-16mm in size are used as bed layer at sintering machine. While fractions of less than 6mm in size are recycled.

The coke is produced by thermal destruction of ordinary coal, which yields about 750-800kg of coke, 300-350 cu m of coke gases, 30-40kg of coal tar and many other by-products like benzene, naphthalene, and hydrogen sulfide. The produced coke contains 96.5-97.5% of carbon, 0.5-0.8% of hydrogen and 0.3-0.4% of oxygen, while the coke oven gas contains about 60% hydrogen, 25% methane, 4.1% nitrogen, 2.1% carbon dioxide and 5% carbon monoxide. Nitrogen is used for dry quenching of the coke.

The sinter, iron ore, coke and other fluxes such as limestone, dolomite, and quartzite are added under high temperature and pressure into the blast furnace for charging them by 14 tuyers at the bottom of furnace. The hot blast travels in upward direction and converts them into molten state. The molten metal (pig iron) and slag are separated at the bottom of the furnace. The hot blast produces many gases like carbon monoxide, carbon dioxide, hydrogen and nitrogen, which are collected at the top of the furnace as by-products.

The pig iron along with steel scrap, lime and fluorite are charged in basic oxygen furnace (converter). After charging, a calculated volume of oxygen is blown into the converter at controlled flow rate. In PSM, the oxygen is produced by Linde's method. The PSM has two converters, each having a capacity to convert 130 tons of iron into steel. During this process, the carbon, which is dissolved in the metal, is initially oxidized into carbon monoxide. The carbon monoxide along with hot waste gases, before discharging into the atmosphere, are burnt with excess air to recover energy by a steam producing boiler. The cooling steel produces hydrogen, nitrogen, carbon monoxide, carbon dioxide and methane. The PSM has three steam turbines, each of them produces 55 megawatt of electricity.

Toxicity of Carbon Monoxide

Many units in iron and steel making industry, such as coke oven batteries, sintering plant, blast furnace, basic oxygen furnace and thermal power plant emit carbon monoxide (Streets, et al., 2006), which is one of the most lethal gases. Carbon monoxide is often referred to as silent killer since it is a colorless, odorless and tasteless gas. It cannot be sensed by human if it is around even at very high concentration. Nonetheless, the gas is harmful even at its lower ambient concentration if exposed to longer span of time. Its elevated level is often poisonous and fatal. However, its toxicity depends upon its ambient level, duration of exposure, exercise (which increase the amount of air inhaled and exhaled per unit time), ambient pressure, health status and the specific metabolism of exposed persons (Raub, 1999; Hampson, 2002; Omaye 2002; Hampson and Hampson, 2002; Guzman, 2012; Iqbal, et al., 2012; Braubach, et al., 2013; Kushwaha, et al. 2013).

As a consequence, human exposure to carbon monoxide has extensively been measured across the world (Haflidson and Figueira, 1997; Roberge, 1998; Lofgren, 2002; Erdogan, et al., 2004; Marco, et al., 2005; Carolyn, et al., 2010; Reboul, et. al., 2012) to mitigate its concentration in the human environment. Therefore, the present study has been conducted to divulge the exposure of the selected employees working in the different departments of PSM to the carbon monoxide since such study has never been carried out to investigate the exposure of the employees of PSM to carbon monoxide.

Materials and Method

Currently, in Pakistan Steel Mills, over 16,000 employees are working in two different shifts, viz., dayshift and nightshift, each of twelve hours. The dayshift starts from 9:00 a.m. and terminates at 9:00 p.m. while the nightshift commences at 9:00 p.m. and ends at 9:00 a.m. Fifty-eight employees were randomly selected from ten different departments (Table 1) of the Steel Mills to study their exposure to carbon monoxide. The entire data for employees' exposure to carbon monoxide were collected during March to August 2013. During the study period, the PSM was working at an average efficiency of 13.93-32.2%, which was one of the lowest production periods. The employees' exposure to carbon monoxide was also recorded while they were commuting from home to PSM and from PSM to home since the commuting is an essential part of the service

In this study, the employees' exposure to carbon monoxide was monitored by the data logger EL-USB-CO300, which was made in Lascar Electronics Ltd., United Kingdom. The device consists of electrochemical sensor and a data logger, which measures continuously the concentration of carbon monoxide in the air ranging from 0-300 ppm with a resolution of 0.5 ppm. It operates with an accuracy of ±4%. Its operating temperature range is from -10 to 40 ^{o}C. The logger was logged by an EasyLog software through a computer to record the employee's exposure to carbon monoxide with 1-minute interval.

The selected employees were asked to clip the data logger in their collar close to the nose once they enter the vehicle to travel to the PSM and remove the logger when they return home after completion of their 12-hour shift. In this way, 720 readings were recorded for each 12-hour shift of the employees, while number of readings were varied for commuting from home to PSM or vice versa mainly due to traffic congestion in the evening during heavy traffic flow. The data were then transferred to computer for statistical analysis and graphic presentation.

Results

Employees’ Exposure to Mean Concentration of Carbon Monoxide

The employees’ exposures to the mean concentration of carbon monoxide during nightshift in different locations of Pakistan Steel Mills are presented in Figure 1 while those exposed during dayshift are presented in Figure 2. Thirty employees of nightshift from 22 different locations while twenty-eight employees of dayshift from 19 different locations were monitored for their exposure to carbon monoxide. One employee each from 27 designated locations while two employees each from 11 designated locations were monitored for CO exposure. However, three employees were taken for the study from each designated location of tapping site of Blast Furnace, gas cutting section of Steel Making Department and Mechanical Department of Coke Oven Batteries since these departments are the larger and main units of Pakistan Steel Mills.

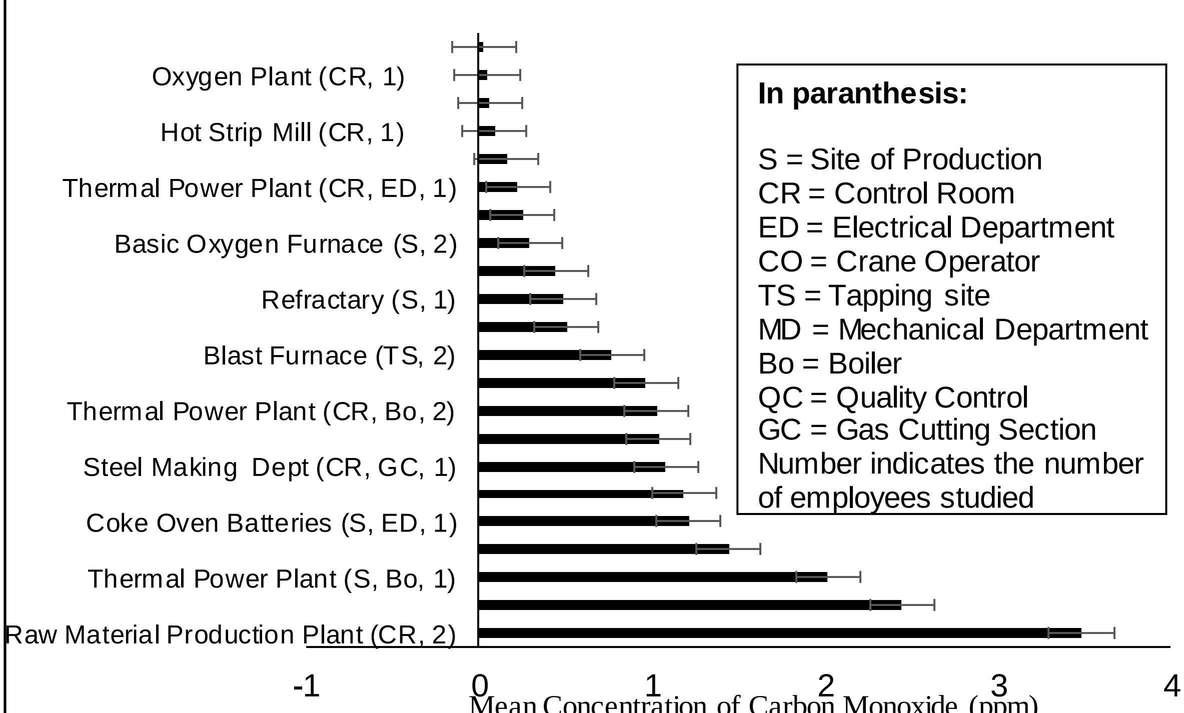

Figure 1: Employees' Exposure to Mean Concentration of CO During Nightshift in Different Facilities of PSM

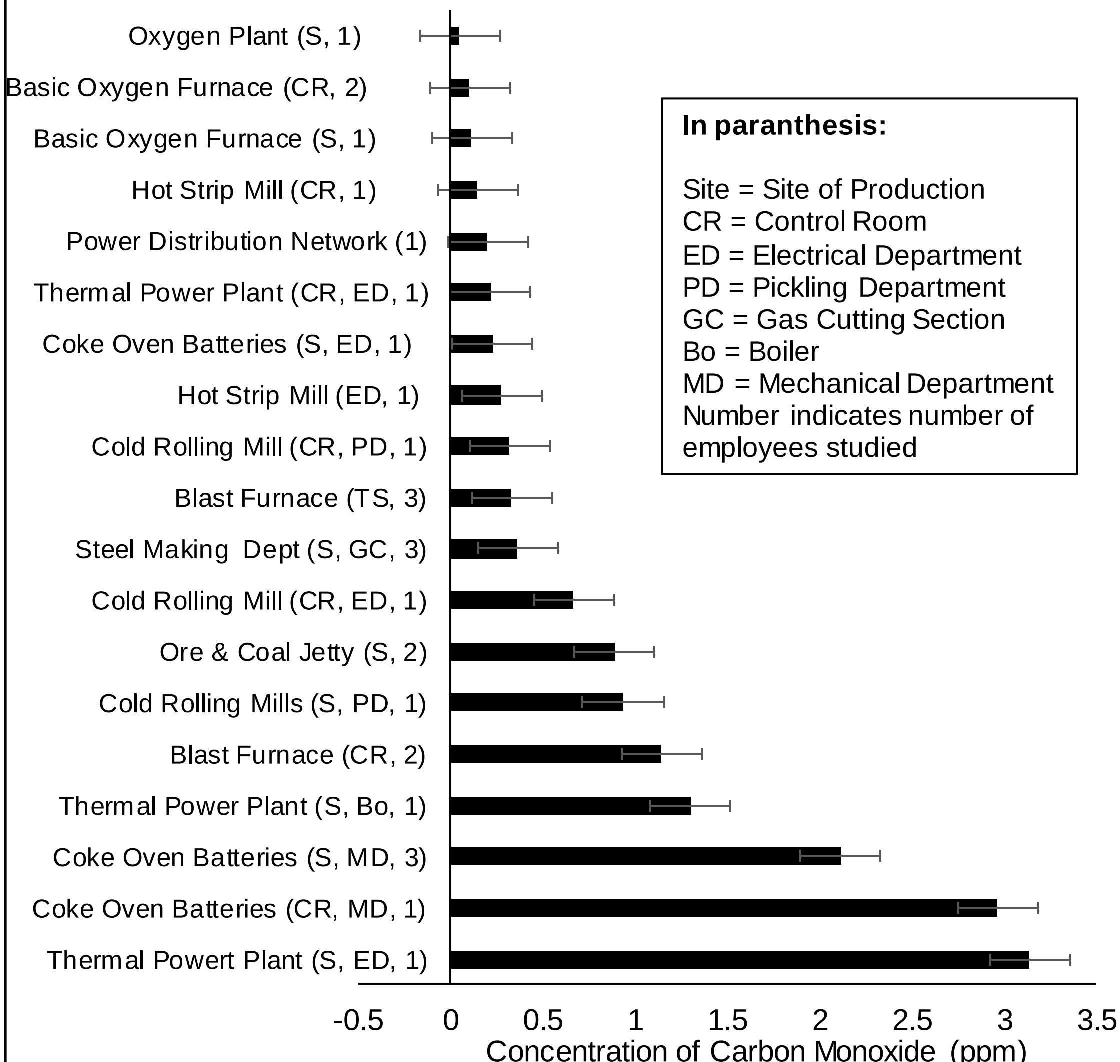

Figure 2: Employees' Exposure to Mean Concentration of CO During Dayshift in Different Locations of PSM

Out of 41 total locations, the mean concentration of carbon monoxide remained within 1 ppm in 27 locations. The mean concentration of carbon monoxide exceeded 2 ppm in six locations and 3 ppm in two locations. The employees working on the site of Raw Material Production Plant during nightshift were found to be exposed to the greatest mean concentration of carbon monoxide (3.5 ppm), while the employee working in the site of Oxygen Plant during nightshift was exposed to the lowest mean concentration of carbon monoxide (0.03 ppm).

Employees' Exposure to 98 percentile CO Concentration

The concentrations of carbon monoxide remained within 1 ppm in most of the locations of PSM during 12-hour shift of the employees. However, there were infrequent peaks during both the day and the night shifts, which was primarily due to the employee's performance of duty in different areas within a department. For instance, an employee of control room of Blast Furnace was found to be exposed to the highest recorded peak concentration (295.5 ppm) of carbon monoxide, when he went through the oven gas inlet while the coke oven gas was being leaked.

For that reason, the 98 percentile of 720 recorded readings of carbon monoxide are calculated for all the designated employees working in different locations of PSM. The analysis of nightshift is presented in Figure 3, while those of dayshift are presented in Figure 4. The employee working in the control room of mechanical department of Coke Oven Batteries during dayshift was found to be exposed to the greatest 98 percentile of CO concentrations (18.5) while the employees, working in the control room of Basic Oxygen Furnace and both in the control room and the site of the Oxygen Plant during nightshift are exposed to the lowest 98 percentile CO concentrations. Out of 41 total locations, the 98 percentile CO concentration exceeded 5 ppm in 14 locations, 10 ppm in 6 locations and 15 ppm in one location only.

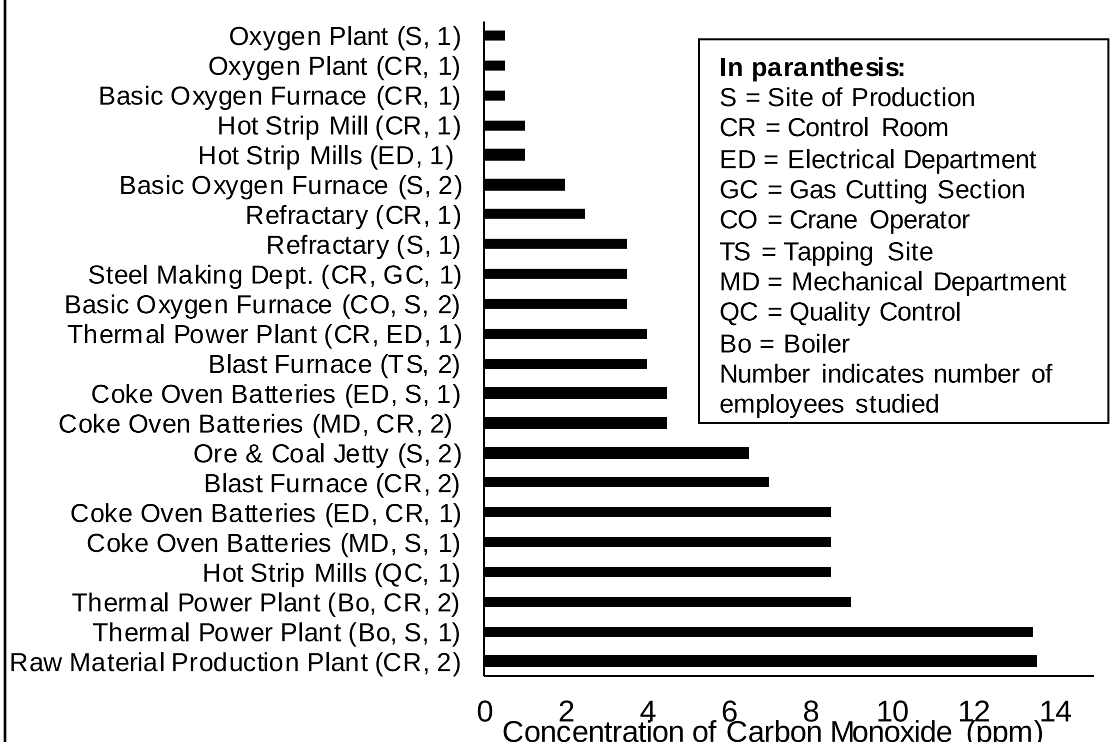

Figure 3: Employees' Exposure to 98 percentile CO Concentration During Nightshift in Different Facilities of PSM

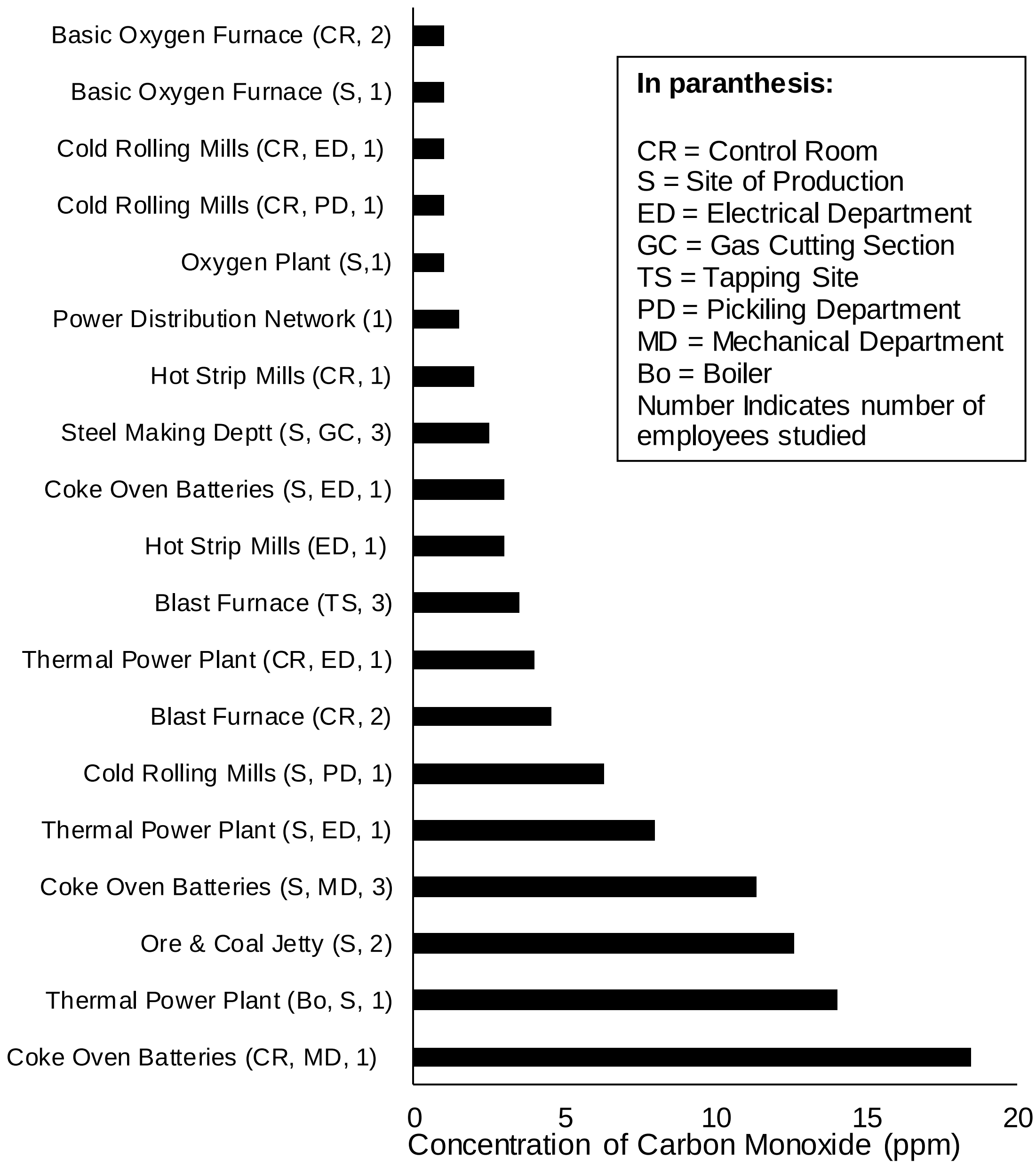

Figure 4: Employees' Exposure to 98 percentile CO Concentration During Dayshift in Different Facilities of PSM

Employees' Exposure to Recorded Peak Concentration of Carbon Monoxide

Figures 5 and 6 demonstrate the employees' exposure to the highest recorded peak concentration of carbon monoxide at various locations of Pakistan Steel Mills during nightshift and dayshift respectively. The employee, working in the control room of Blast Furnace during dayshift, has experienced the highest recorded peak concentration of carbon monoxide (295.5 ppm). While the employee working in the site of Oxygen Plant during nightshift is exposed to the lowest recorded peak concentration of carbon monoxide (1 ppm). Out of 41 total locations, the peak concentration of carbon monoxide exceeded 25 ppm in 15 locations, 50 ppm in 5 locations and 75 ppm in 2 locations.

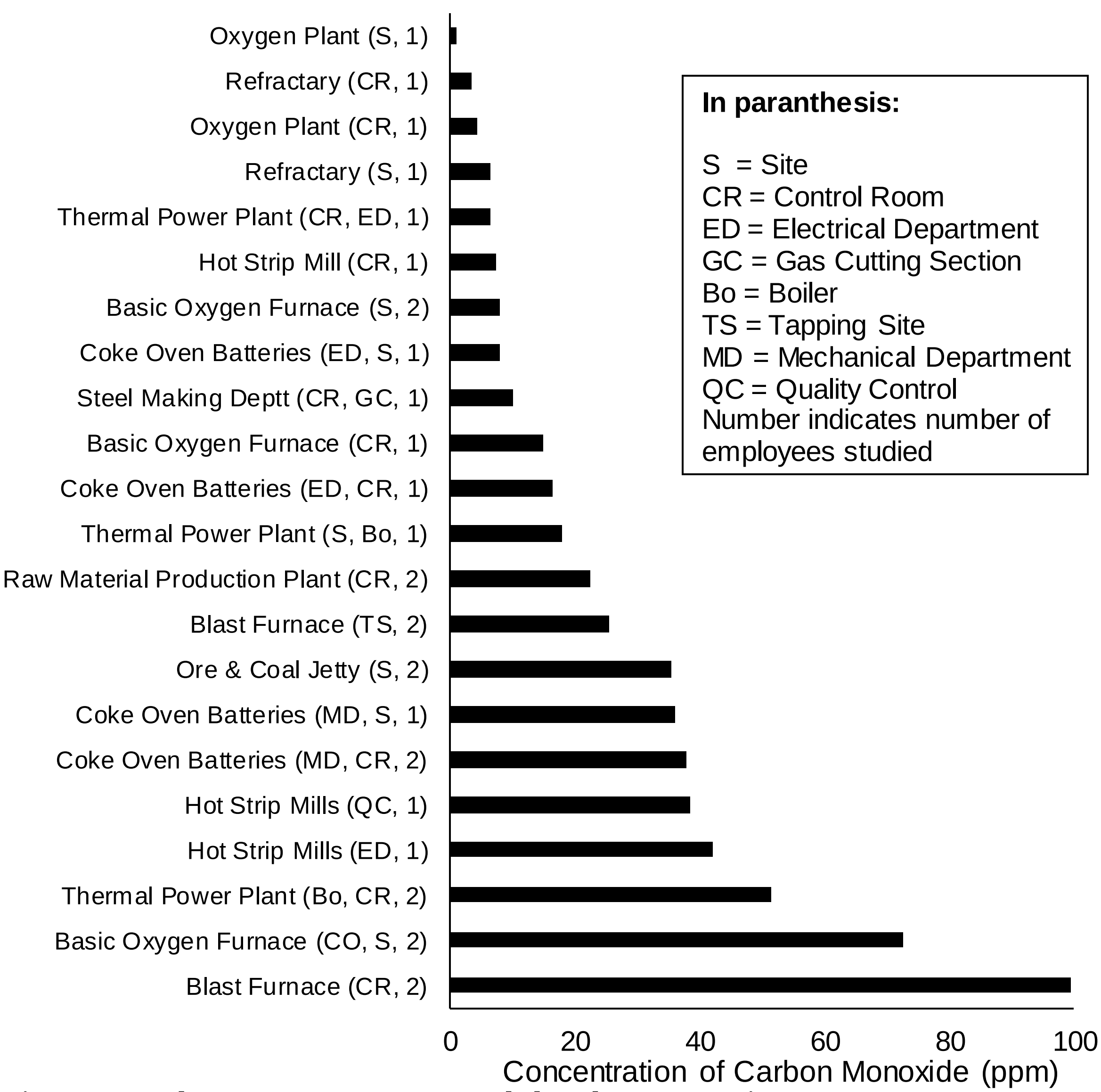

Figure 5: Employees's Exposure to Recorded Peak Concentration to CO During Nightshift in Different Locations of PSM

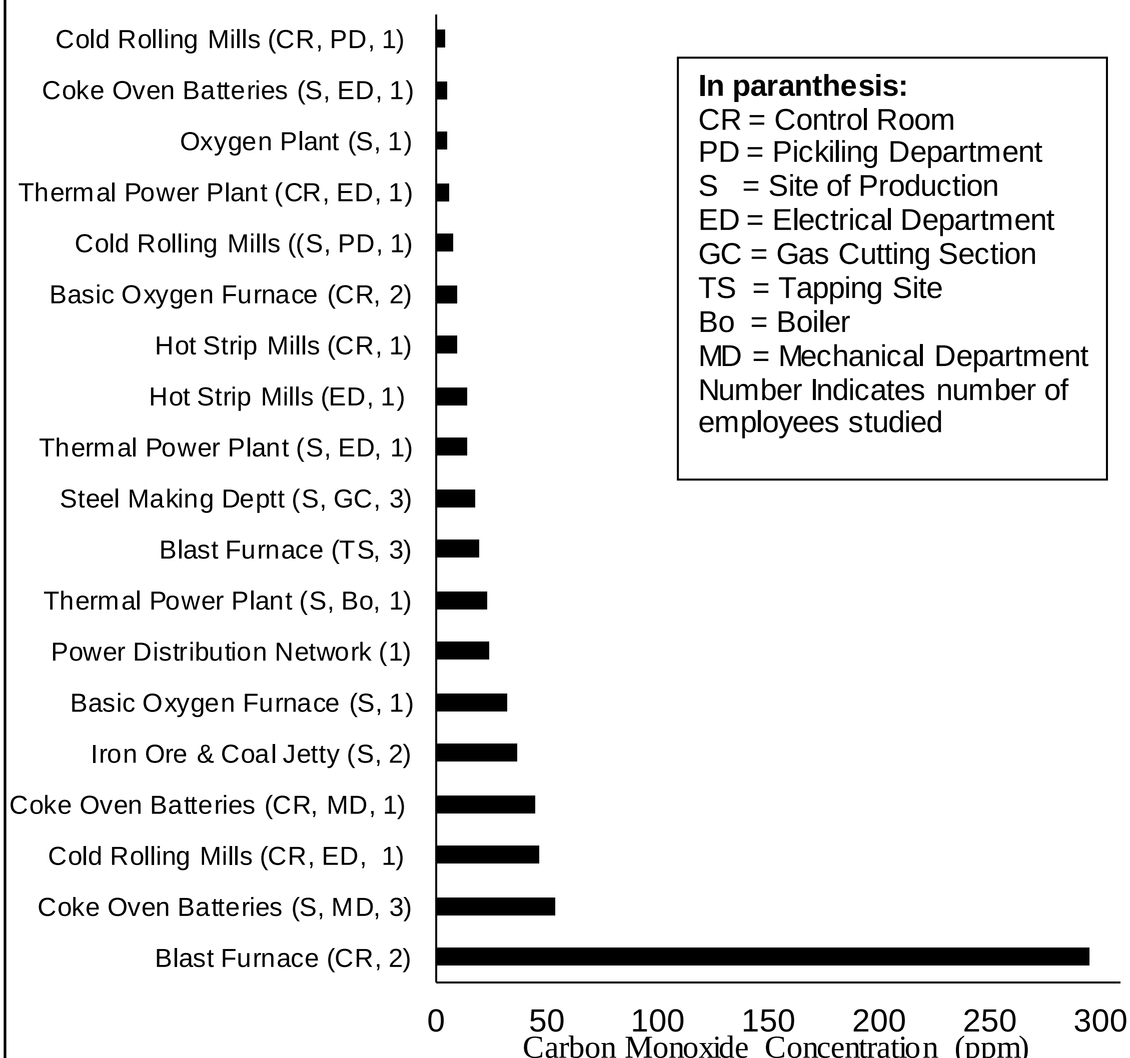

Figure 6: Employees's Exposure to Recorded Peak Concentration to CO During Dayshift in Diffrent Locations of PSM

Exposure to Carbon Monoxide while shuttling between Home and PSM

Table 2 demonstrates the exposure of fifty eight employees to the mean concentration, 98 percentile and peak values of carbon monoxide while commuting from home to Pakistan Steel Mills and vice versa during morning and evening. The results reveal that the employees were exposed to the higher mean concentrations, higher 98 percentile and higher peak of carbon monoxide while shuttling between home and PSM in the evening compared to that in the morning. The higher exposure in the evening was due to higher vehicular traffic, congestion and slow pace of traffic flow in the evening compared to those in the morning.

Table 2: Employees' Exposure to various attributes of carbon monoxide (ppm) while commuting between home and PSM			
Commuting Time	Mean ± SD	98 percentile	Peak
Morning	3.02 ± 3.19	11	48.5
Evening	4.86 ± 4.18	14.5	62.5

Discussion

The results demonstrate that the exposure of the employees of Pakistan Steel Mills to carbon monoxide has not exceeded the guidelines of World Health Organization (WHO) for carbon monoxide in any of its department. The exposure to mean concentrations of carbon monoxide in all the designated locations were well within the WHO guidelines for 8-hour (9 ppm) and even for 24-hour (6 ppm). The exposures to the low mean concentrations of carbon monoxide were mainly due to low production in the steel mills during the study period. The production of the steel mills during the study period ranged from 13.93% to 32.2%, which was one of the lowest production periods in its history. For instance, Pakistan Steel Mills have two blast furnaces, each one has a capacity of about 3,028 tons. Nevertheless, the furnaces produced merely from 261 to 873 tons during the study period. The low production in the steel mills was one of the main factors which corresponds the employees' exposure to low mean concentration of carbon monoxide.

However, an increase in the exposure to carbon monoxide was recorded, when a unit showed an increase in its production. For instance, when the production in the Raw Material Plant was 450 tons shift^{-1}, the employee was exposed to 6.2 ppm of mean concentration of carbon monoxide during his 12-hour shift. Nonetheless, when the production in the same plant was reduced to 100 tons shift^{-1}, the employee exposure also reduced to 0.77 ppm of mean concentration of carbon monoxide. The aforesaid plant is meant for the production of sinter and the grinding of coal and solid fuel coke, which are used as feed and fuel for the blast furnace.

The blast furnace gas, which normally contains 23% carbon monoxide (Xu and Cang, 2010) and is considered as an important occupational exposure in an integrated steel industry (Lewis, et al., 1992; Ghose, et al., 1999), demonstrated rather lower mean concentration of carbon monoxide in its tapping site compared to its control room. Tapping site is the place, where molten metal is taken out from the blast furnace. The tapping process is directly scheduled as that of the charging of the blast furnace. The tapping is done after three hours of operation in blast furnace. The control room of blast furnace showed higher mean concentration of carbon monoxide compared to the tapping site of the furnace during both the day and the night shifts. This may be due to the trap of the gas in both the shifts. Moreover, the employees of both the shifts of control room of blast furnace were exposed the highest recorded peak concentration of carbon monoxide, which was due to his exposure to the leakage in coke oven gas inlet. Carbon monoxide sometimes originates or leaks from the top or body of blast furnace or from the many gas pipelines inside the plant especially during repairs or inspection around the furnace (Masaitis, 2011)

Coke oven batteries are another important unit, which produces carbon monoxide in sufficient amount. For instance, one ton of coke production generates about $500m^3$ of coke oven gas, 5% of which is carbon monoxide (Streets, et al., 2006). In Pakistan Steel mills, some of the coke oven gas is used in blast furnace operation while the rest of the gas is released in the atmosphere without any treatment. In coke oven batteries also, the exposure to the mean concentration of carbon monoxide was higher in its control room compared to its site of production. This may be due the trap of the gas in the control room of coke oven batteries.

However, the control room of basic oxygen furnace demonstrated lower exposure to the mean concentration of carbon monoxide, compared to its site of production. Nonetheless, the employee working in the control room of gas cutting section in steel making department was exposed to the higher mean concentration of carbon monoxide, compared to those who cut the slabs of steel on site. The crane operators, who work on site above ladle in steel making department, were exposed to the higher concentrations of carbon monoxide when the crane was right above the ladle in which ladle casting was taking place or the crane was carrying hot steel from basic oxygen furnace or the gas cutting was taking place.

The employees working in both the control room and on the site of production in oxygen plant are found to be exposed to the lowest mean concentration of carbon monoxide, which reveals its lowermost activity for the emission of carbon monoxide among the entire sampling locations.

References

Braubach, M., Algoet, A., Beaton, M., Lauriou, S., Heroux, M. E. and Krzyzanowski, M., 2013. Mortality associated with exposure to carbon monoxide in WHO European Member States. *Indoor Air*, 23, 115 – 125.

Carolyn K. Reeb-Whitaker, Bonauto, D. K., Whitaker, S.G. and Adams, D., 2010. Occupational carbon monoxide poisoning in Washington States, 2000-2005. *Journal of Occupational and Environmental Hygiene*, l 7(10), 547-556.

Environmental Health Criteria 213, Carbon Monoxide (second Edition), (1999), World Health Organization, Geneva,

Erdogan, M.S., Islam, S.S, Chaudhari, A. and Ducatman, A.M., 2004. Occupational carbon monoxide poisoning among West Virginia workers' compensation claims: Diagnosis, treatment duration and utilization. *Journal of Occupational and Environmental Medicine*, 46, 577-583.

Ghose, M.K., Majee, S.R. and Sinha, P.K., 1999. Monitoring and assessment of impact on air environment caused by coke plant operations in India. *International Journal of Environmental Studies*, 56, 475-482.

Guzman, J. A., 2012. Carbon monoxide poisoning. *Critical Care Clinics,* 28(4), 537-548.

Haflidson, W.O. and Figueira, C. S., 1997. Carbon monoxide exposure to concrete finishers. *Applied Occupational and Environmental Hygiene*, 12, 126-131.

Hampson, N. B. and Hampson, L. A., 2002. Characteristics of headache associated with acute carbon monoxide poisoning. *Headache*, 42, 220-223.

Iqbal, S., Law, H.Z., Clower, J. H., Yip, F.Y. and Elixhauser, A., 2012. Hospital burden of unintentional carbon monoxide poisoning in the United States, 2007. *The American Journal of Emergency Medicine*, 30(5), 657-664.

Kushwaha, R., Hazarika, N., Srivastava, A., 2013. Traffic related aerosol exposure and their risk assessment of associated metals in Delhi, India. *International Journal of Environment*, 2(1), 26-36.

Lewis, S., Mason, C., and Srna, J. 1992. Carbon monoxide exposure in blast furnace workers. *Australian Journal of Public Health*, 16(3), 262-268.

Lofgren, D.J., 2002. Occupational carbon monoxide poisoning in the state of Washington, 1994-1999. *Applied Occupational and Environmental Hygiene*, 17, 286-295.

Marco, G.S.D. Kephalopoulos, S., Ruuskanen, J. and Jantunen, M., 2005. Personal carbon monoxide exposure in Helsinki, Finland. *Atmospheric Environment*, 39(15), 2697-2707.

Masaitis, J. 2011. Iron and steel. Encyclopedia of Occupational Health and Safety. International Labor Organization, Geneva.

Omaye, S.T., 2002. Metabolic modulation of carbon monoxide toxicity. *Toxicology* 180, 139-150.

Raub, J. A., 1999. Health effects of exposure to ambient carbon monoxide. *Chemosphere – Global Change Science*, 1(1-3), 331-361.

Reboul, C., Thireau, J., Meyer, G., Andre, L., Obert, P., Cazorla, O., Richard, S., 2012. Carbon monoxide exposure in the urban environment: An insidious foe for the heart? *Respiratory Physiology & Neurobiology*, 184, 204-212.

Roberge, B., 1998. Evaluation and control of carbon monoxide exposure from propane-fueled forklifts. *Applied Occupational and Environmental Hygiene*, 13, 183-191.

Streets, D.G., Zhang, Q., Wang, L., He K., Hao, J., Wu, Y., Tang, Y. and Carmichael, G.R., 2006. Revisiting China's CO emissions after the transport and chemical evolution over the Pacific (trace-P) mission: synthesis of inventories, atmospheric modeling, and observations. *Journal of Geophysical Research*, 111, 1-16.

Xu, C.C. and Qiang, C.D., 2010. A brief overview of low CO_2 emission technologies for iron and steel making. *Journal of Iron and Steel Research, International,* 13(3), 1-7.