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Assessment of Air Pollution Levels in Automobile Parking – Lots

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Abstract

The indoor air quality is deteriorating day by day. A lot of studies are done on outdoor air pollution due to vehicles and industrial sources, but, very few studies are done on indoor air pollution. This study focuses on the indoor air pollution inside automobile parking – lots due to vehicles and vehicular movements. The major pollutants that emit from the vehicles are CO, VOC, particulate matter, Sox, NOx. This paper focuses on the pollution due to CO and VOC inside car parking. These pollutants are very toxic and have very harmful health effects. Some of the VOCs are known to be carcinogenic. High levels of CO can even cause death. There are some techniques such as bio filtration and photo catalytic oxidation are also discussed.

Keywords: *CO, VOC, parking, Indoor air pollution, health risk assessment, Bio filtration, Photo catalytic oxidation*

INTRODUCTION

Parking especially the underground parking are potentially a ''hot-spot'' microenvironment (i.e. where high levels of mobile source-related air pollutants intersect with communities).There is rapid growth of automobile population is observed in the past few years. According to a report shared under national data sharing policy, vehicular population is increasing at a rate of 130% per year (NDSAP,India report). But the land is scarce and also an expensive resource which should be utilized to its full value. Due to this increased automobile population, not only the air & noise pollution, traffic congestion, such problems are created but also the parking space demand has also increased. An as alternative to the ground level parking, underground and multi-level parking has been introduced as an solution to the parking problems due to increased automobile population. Automobiles are a major source of Volatile Organic Compounds (VOCs)and CO along with other pollutants. VOCs are a part of tailpipe exhaust emissions along with evaporative emissions from the automobiles. Carbon Monoxide is a product of incomplete combustion of the fuel. Underground and multilevel parking are a microenvironment that is of concern but has not been characterized yet (Kim et al. 2015). These pollutants have a serious health impacts on the person(s) exposed to it. Some of the VOCs are carcinogenic and the carbon monoxide has a strong binding affinity with hemoglobin and results in the formation of carboxyhaemoglobin (COHb), which is poisonous for blood as it decreases the oxygen carrying capacityof the blood. The COHb levels are represented in percentage in the blood, and the presence of carbon monoxide in blood may vary depending upon the concentration of pollutant in the air, amount of work being done, time of exposure, all of these are required for the health risk assessment of the presence being exposed to the pollutant. Whereas VOC can be carcinogenic and non-carcinogenic both, there are so many VOCs present in the air, not all of them are lethal, some of them are dangerous but not life threatening under normal exposure. Carcinogenic and non – carcinogenic risk can be calculated using the required information such as age, body weight, chronic daily intake (CDI), average life span, etc. for calculating the risk to the person exposed to pollutants.

LITERATURE AT A GLANCE

Baltrenaset al.(2004) found that streets located in the vicinity of parking – lots had the highest influence on pollutant concentrations; higher concentrations of pollutants were observed in areas where heavy or special vehicles are parked.

Demir(2015) concluded that in the construction and management of car parks the human health and safety must be taken into the consideration. As there are dense movements of motor vehicles in car parks, the harmful exhaust emission concentrations caused by the motor vehicles may reach to the dangerous levels.

Amodioet al. 2011 indicates that BTEX represent the greater part of VOC monitored suggesting the vehicular traffic as the main source of air pollution. He also confirmed that there is high correlation between benzene and toluene concentrations emitted from vehicles.

Catroet al. (2015) study done in confined parking spaces in rio de janeiro, brazil reveals that the light vehicles evaporative emissions contribute to increase in BTEX concentrations, being the most important source of these compounds. Toluene was the most abundant in among the monoaromatic compounds.

Tsai et al. 2002 study done on three different tollbooths reveal that the VOC content in different type of tollbooth were quite comparable associated with engine exhaust emissions, but were much lower than those associated with vapor emissions. ()

Residential parking garages were also assessed for the VOC emission associated with vehicles and it was found that the cold – start tailpipe emissions were significantly higher than the corresponding hot – start tailpipe emissions, the cold – start profile is dominated byproducts of incomplete combustion. (Graham et al, 2004).

Kim et al. (2007) reported that in the present study the vehicular effect is contributing to the overall concentration of the pollutants is slightly less than revealed by dynamometer testing.

Mann et al.(2001) conducted a study on the concentration of benzene in houses with attached parking garage, the study revealed that the concentration of benzene from fuel vapor and exhaust emissions were quite higher and it can easily transmit to the personal living spaces and the pollutant concentration indoors is quite higher as compared to outdoors.

Chaloulakou et al. (2002) research on enclosed multi-level parking shows that the concentration of Carbon Monoxide on the entrance/exit of the parking are highest because of the activity pattern, design of the parking, whereas the concentration inside the parking at different sites varies according to the no of vehicles in the vicinity. It doesn’t show a regular trend as parking behavior is always random.

Papakonstantinou et al. (2003)done a similar study as done by chaloukalou, but in this study the more emphasis was on the numerical prediction of the levels of CO in enclosed underground garage, the results show that under proper ventilation condition, the levels of CO was below the occupational health hazard levels.

Chen et al. 2012 measured VOCs upto C10 using carbotrapmultibed thermal adsorption tubes during the morning and afternoon rush hours in three tunnels Taiwan, and found that the concentration of VOCs increase with increase in traffic flow and emission profiles in three tunnels are in range of C2 – C6

Topacoglu et al. (2014) research on the effect of CO levels on the persons health and calculated the associated COHb levels of the affected person, and the results were unexpectedly higher as the vehicles exhaust emissions pose a health risk problem on to the persons exposed to it.

Ho et al. (2004)had done a field study to investigate the traffic pattern and carbon monoxide level in an underground car park. The study was conducted over a period of 6 days; traffic volume, hourly engine operation time, and parking lot occupancy were measured initially. Then these are correlated with CO levels and thermal environment of the car park. Both Correlations, CO and thermal environment with hourly engine operation are achieved with R2 value exceeding 90%.

VOCs

Some of the VOCs are known carcinogenic such as benzene, formaldehyde. VOCs are associated with long term and short term health effects depending upon the time of exposure of the person. The employees working at the underground and multi-level parking are always exposed to the contaminants such as VOCs, CO, NOx, but the health effects of VOCs have not been discussed in respect of the carparking employees. The major potential health effects include acute and chronic respiratory effects, neurological toxicity, lung cancer and eye and throat irritation (Burton, 1997; Hodgson et al. 1991). Fatigue, headaches, dizziness, nausea, lethargy and depression are classical neurological symptoms associated with VOCs (Godish, 1990). Using traffic volume and proximity as a surrogate for exposure, studies have reported associations between mobile sources and acute (Nicolai et al. 2003; Peters et al. 2005) and chronic disease

(Lwebuga-Mukasaet al. 2004). The public health threat from mobile sources has the potential to be particularly severe due to their growing intensity (vehicle miles traveled), known toxic emissions, and close integration. It also has been found that the upper bound lifetime cancer risk from VOCs is quite comparable to the estimates of risk from radon and environmental tobacco smoke among 800 Americans investigated (Wallace, 1991).

In a risk assessment, the extent to which a group of people has been or may be exposed to a certain chemical is determined, and the extent of exposure is then considered in relation to the kind and degree of hazard posed by the chemical, thereby permitting an estimate to be made of the present or potential health risk to the group of people involved (USEPA, 1985).

This study is aimed to learn about the possible sources of VOCs from automobiles and health risk assessment of the employees exposed to the contaminants in parking.

CO

Breathing CO can cause headache, dizziness, vomiting and nausea. If CO levels are high enough, it can cause unconsciousness, or sometimes even death. Exposure to moderate and high levels of CO over long periods of time has also been linked with increased rate of heart disease (Glaberet al. 2007).

VOCS FROM VEHICLES

The emissions from motor vehicles are categorized as “fuel vapour or evaporative emissions” and “exhaust emissions” from tailpipe (Pierson et al. 1999). The evaporative emissions were classified as hot – soak emissions, diurnal emissions, running losses and resting losses (mannet al. 2001). Hot – soak emissions result from the heating of the fuel system after engine shutdown.

Diurnal emissions result from the cyclic heating and cooling of the fuel tank during the day and night, as fuel and fuel vapour warm and expand, emissions leave the tank. Running losses occurs when fuel is heated to the point at which it boils in the fuel tank, once the fuel boils, the evaporative emission control system is overwhelmed and the engine may even be incapable of burning the vaporized fuel. And resting losses result from the diffusion of fuel through plastic and rubber fuel system components, these emission rates are less but occur continuously and in total can be significant. CO_2, NO_x, CO, HC, etc. are considered to be the constituents of the exhaust emissions from tailpipe. But the studies have revealed that the VOCs are also a part of tailpipe emissions. Study done by Singh et al. 2010 indicates that BTEX are a part of vehicular exhaust emissions.

Table 1: Table of contamination level of CO and VOCs

Study area	Contaminants detected	Level of contamination	Reference
Area Of bari, Italy	VOCs	27.3 – 37.5 µg/m^3	Amodio*et al.* 2011
Zurich Airport	TVOCs NOx CO CO_2	7140 – 780608 ppbv BDL – 61.1 µg/m^3 77 – 205 ppbv -	Schurmann*et al.* 2007
Traffic Tunnels, Taiwan	TVOCs	200–1074 µg/m^3	Chen *et al.* 2012
Parking Lot, Vilnius	VOCs CO NOx PM	3.12 – 3.56 mg/m^3 4.5 - 5.1 mg/m^3 0.068 – 0.084 mg/m^3 0.07 – 0.11 mg/m^3	Baltrenas*et al.*2004
Parking garage, Baltimore	CO pPAH MTBE Benzene	0.31 ppm 1.17 ppm 0.47 ppm 0.51 ppm	Kim *et al.* 2007

	Toluene Ethylbenzene m+p-xylene 0-xylene	0.37 ppm 0.37 ppm 0.49 ppm 0.42 ppm	
Attached parking Garage	Benzene Aromatic hydrocarbons (except benzene)	4.1 – 101.3 µg/m^3 31.4 – 208.9 µg/m^3	Mann *et al.* 2001
Car fleet emissions	CO NOx Benzene	10.6 – 26.4 g/km 0.9 – 26.1 g/km 0.04 – 0.42 g/km	Palmgren*et al.* 1999
Air basins (AQMD)	Ozone NOx CO PM_{10} VOCs	31 – 85 ppb 10 – 212 ppb 215 – 2505 ppb 25 – 72 ppb 146 – 315 ppb	Qin *et al.* 2004
Petrol station, Delhi & Mumbai	VOCs	14.8 –33.8 µg/m^3	Srivastava*et al.* 2005
Tollbooth, Baltimore	VOCs PAH	0.04 – 95.7 µg/m^3 15.4 – 50 ng/m^3	Sapkota*et al.* 2005
Inside new cars	VOCs	1.5 – 28.4 ppm	Chien, 2007
Parking	VOCs (evaporative vapor generation)	2.6 g (Max.)	Dong *et al.*2015

	VOCs (Diurnal)	0.69 g (Avg.)	
Parking	VOCs	4.0 – 14.7 µg/m^3	Jo *et al.* 2001
Automobile cabin	BTEX n – butane i – pentene	0.5 – 4.3 ppb 3.5 – 24.2 ppb 3.5 – 26.8 ppb	Kim *et al.* 2016
Parking, Rio de janeiro	Benzene Toluene Ethyl benzene Xylene	15.90 – 102.40 µg/m^3 90 – 327.80 µg/m^3 12.80 – 100.20 µg/m^3 8 – 199.60 µg/m^3	Castro *et al.* 2015
Underground garage, greece	CO	41.3 -163.6 ppm	Papakonstantinou*et al.* 2003

HEALTH RISK ASSOCIATED WITH VOCS

Health risk assessments are necessary for determining the non – cancer hazards and cancer risks associated with the site contaminated. Calculations of the cancer risk related to VOCs require the carcinogenic potencies of VOCs and the exposures of the target group of people. Risks are calculated as a simple multiple of the intakes and potency factors.

The US EPA developed IRIS to provide the value of potency factors for selected VOCs for risk assessment. The cancer potency factors for inhalation of the VOCs in IRIS system (US EPA, 1998) are adopted to calculate lifetime risk.

Concentration of VOCs in indoor air is more than the concentration of VOCs in outdoor air (USEPA). Underground parking can also be compared with the indoor scenario. In order to ease the process of risk assessment, several assumptions has to be made on the basis of the best professional judgment and questionnaire data.

The average body weight of the individuals can be computed from the questionnaires in which the employees working in the enclosed parking spaces were surveyed. The amount of the air breathed by the individual can be taken as 1.2 m3/h (Exposure factors handbook, 2011). An entire lifetime of 70 years can be applied for the carcinogenic assessment. The work lifetime can be assumed to be 30 years for non – carcinogenic assessment.

The inhaled toxicants is assumed to be totally absorbed for risk calculations in some studies (Hoddinott and Lee, 2000; Muller et al.2003). Hence, the absorption factor of VOCs for humans is assumed to be 100%. Inhalation exposure can always be related to exposure frequency, duration and activity pattern. The average number of hours spent in car parking can be computed from the survey that covers the employees working in enclosed car parking with similar activity pattern.

Table 2: Potency factors for selected VOCs according to the IRIS systema

Volatile organic compounds	Potency factor $(mg/kg/day)^{-1}$
1,1-Dichloroethene	1.16
Methylene chloride	0.014
chloroform	0.081
Benzene	0.029
Trichloroethene	0.013
Tetrachloroethene	0.0033
styrene	0.00057

aUSEPA(1998)

Exposure can be assessed by the amount of time they spend in the parking. No. of hours exposed (ET) = No. working hours/day ×No. of working days/week. Risk can be simply expressed as the product of the chronic daily intake (CDI) and potency factor (PF) for a specific cancer substance.

The inhalation intake or CDI is used to assess carcinogenic risk and non – carcinogenic effects from chronic exposure and is calculated by averaging daily intake over the exposure period.

CDI in mg/kg/day can be computed using following equation:

$$CDI = \frac{(C_a \times IH \times ET \times EF \times ED)}{(365 \times AT \times BW)}$$

$$CDI = Inhalation\ intake\ \left(\frac{mg}{kgday}\right)$$

$$C_a = conc. of\ chemical\ in\ ambient\ air\ (mg/m^3)$$

$$EF = Frequency\ of\ exposure$$

$$ED = Exposure\ duration\ (year)$$

$$AT = Averaging\ Time$$

$$IH = inhalation\ rate\ (m^3/h)$$

$$ET = Exposure\ time\ \left(\frac{h}{week}\right)$$

$$BW = body\ weight\ (kg)$$

CANCER RISK

Cancer risk is estimated as the probability of developing a cancer from a lifetime continuous exposure of VOCs.

The lifetime cancer risk can be estimated using equation:

$$R = CDI \times PF$$

$$R = Cancer\ hazard\ risk$$

$$PF = cancer\ slope\ factor\ or\ potency\ factor$$

NON CANCER RISK

Unlike cancer risk, non – cancer risk is expressed in terms of the hazard quotient (HQ), which is defined as the ratio of the estimated exposure of an individual to the reference dose. The RfD (mg/kg.day) is a numerical estimate of the daily exposure to the human population, including sensitive subgroup such as children, that is not likely to cause harmful effects during a lifetime (US EPA, 1989).

Hazard quotient can be calculated as:

$$HQ = {}^{CDI}/_{R_f D}$$

The non – cancer health impacts are expressed as the hazard index (HI), which is determined by calculating HQ for each contaminant and summing all the HQs at a specific location for which the assessment is to be done. For a given pollutant, exposures below the reference level (HI<1) are unlikely to be associated with adverse health effects. The potential for adverse effects increases when the exposure concentration starts to exceed the reference dose.

HEALTH RISK ASSOCIATED WITH CO

Health risk assessment is necessary in order to calculate the percentage content of carbon monoxide in blood. Carbon monoxide has 200-250 times more affinity for binding with hemoglobin than oxygen. So it attaches rapidly with the blood, and the assessment of health is done by calculating the percentage carboxy hemoglobin levels of blood. For non – smokers the % COHb levels should be less than 1.5 %, whereas in case of smokers the range increases to 3 – 15 %. (LightA.,et al.).

$$\%COHb = 0.005(CO)^{0.85}(\alpha t)^{0.63} where\ CO\ is\ in\ ppm$$

$$\alpha = 1\ for\ normal\ activity,\ 3\ for\ heavy\ work$$
$$t\ is\ in\ minutes$$

For NAAQS the percentage exposure level of the person exposed for 8 hours shift and normal activity for work is 0.293 % at maximum concentration of 4 ppm, whereas in case of OSHA standards the CO level range is 35 – 50 ppm for 8-hour time weighted average and the respective level of percentage carboxy haemoglobin is 5.01 % - 6.8%, which is very harmful for one’s health, as it should be less than 1.5 % for non – smokers

ABATEMENT TECHNIQUES

Indoor air pollution is a major concern nowadays. The concentration of pollutants present in the indoor air affects the health of the people who occupy space within it. Reduction of these compounds is a very important task. There is much work is being done in the reduction of these compounds. Techniques like Biofiltration, photocatalytic oxidation, phyto remediation are being used for the reduction of these pollutants.

BIOFILTRATION

Biological control of air pollution has many operational and cost advantages over the conventional physico-chemical methods in most of the chemical industries. Bio filtration have been used for almost 100 years for waste treatment and especially in treating highly concentrated effluents (Metcalf and Eddy 2003). In bio filtration, polluted air is blown through a porous media, typically a mixture of compost, soil or wood chips that supports a population of microbes.

Under optimum conditions, these microorganisms convert the absorbed biodegradable contaminants mostly into carbon dioxide, salt and water.(Detchanamurthyet al. 2012)

The concept of using microorganisms for the removal undesirable compounds has been well established in the field of wastewater treatment. But now this technique is also being used for the removal of undesirable compounds from contaminated air. It is a cost effective approach to volatile organic compound removal for large air flows and mostly low concentrations. In bio filteration, polluted air is blown through a porous media containing viable population of microorganisms. Under optimum conditions, the microbes convert the organic compounds into carbon dioxide, salt and water.(lesonet al.1991)

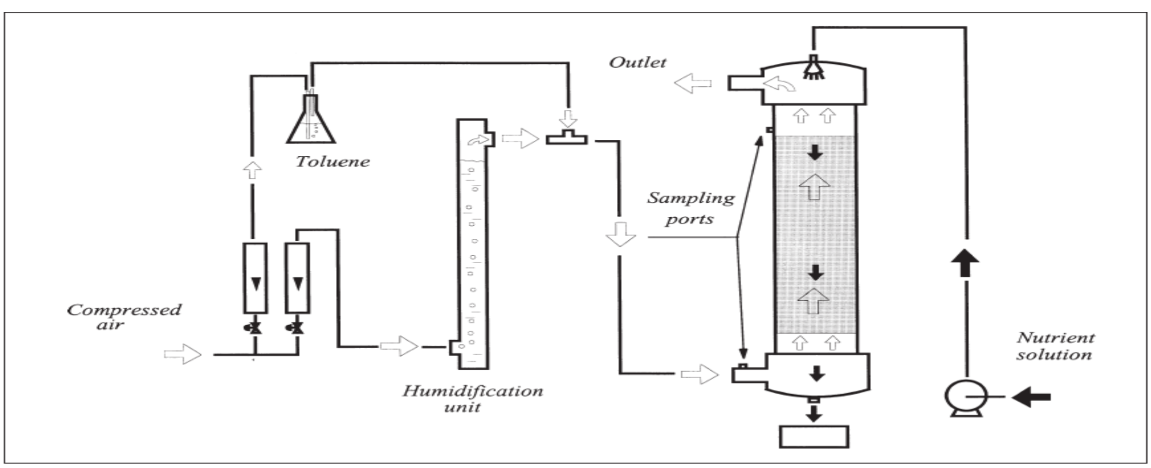

Fig 1: Experimental setup of biofilter (Wu et al.1999)

The biofilter system is a fixed bed of solid porous material in which microorganisms grow on solid particles and degrade the organic pollutants. The polluted air stream is fed into the biofilter and passes through the packed bed provided with micro-organisms and essential nutrients. (Gidaset al. 2001).

PHOTOCATALYTIC OXIDATION

Common methods of controlling indoor air pollution include controlling pollution sources, increasing the air exchange rate and using air purifiers. Traditional air purifiers use filters to remove particulate matters or use sorption materials (e.g., granular activated carbon) to adsorb gases or odors. However, these techniques only transfer the contaminants to another phase rather than eliminating them, and additional disposal or handling steps are subsequently required. An alternative remediation technology, which offers a number of advantages over conventional technologies, is the use of heterogeneous photocatalytic oxidation (PCO). Operating at low or room temperature, the PCO can degrade a broad range of contaminants into innocuous final products such as CO2 and H2O without significant energy input.(Zhao et al. 2003)

In the PCO reaction, pure or doped metal oxide semiconductors (e.g., TiO2, ZnO, CdS, Fe(III)-doped TiO2) are commonly used as the photocatalysts. An important step of photoreaction is the formation of hole–electron pairs which need energy to overcome the band gap between valence band (VB) and conduction band (CB). When the energy provided (photon) is larger than the band gap, the pairsof electron-holes are created in the semiconductor, and the charge will transfer between electron–hole pairs and adsorbed species (reactants) on the semiconductor surface, then photo-oxidation happens. Common light sources used are the ultra-violet (UV) lights.

TiO2 suffers from the limited absorption of solar light as a result of its large band gap and low quantum yield because of the fast recombination of photo-generated charges.(Xu at al., 2016). Typical photocatalysts have been modified in order to enhance their solar photocatalytic activity, by doping, metal particle deposition or even by their combination with other materials to produce highly photoactive composites.

Graphene, a two-dimensional, single-layer sheet of carbon atoms that are closely packed into a hexagonal lattice structure, is a very promising candidate for high performance photocatalyst because of its excellent thermal conductivity, excellent mobility of charge carriers and large specific surface area. (Yadavet al. 2016)

CONCLUSION

Enclosed car parking can be a potential hot – spot for carcinogenic risks and non – carcinogenic hazards. Identification and characterization of VOCs in car parking hasn't been done yet as per the studies. The employees working in enclosed car parking are constantly exposed to the contaminants which can have acute and chronic health effects. Health risk assessment of employees working there should be done so as to assess the health risk they are being exposed to due to working there. Cancer risks and non – cancer hazards can be calculated as discussed above. It will help us in understanding the environment in enclosed car parking and the effect of ventilation in the retention of the contaminants inside the enclosed car parking. In case of the non – cancer risk, if the hazard quotient is less than 1, there will be no adverse health effects on the person exposed to it, but if it is greater than 1 then there will be adverse health effects due to the inhalation of the contaminants. In case of assessment of the percentage carboxy hemoglobin levels, the levels for non – smokers should be less than 1.5%, whereas for smokers 3 – 15% are considered depending upon the frequency of their smoking. New and promising technologies for APC (Air Pollution Control) are being studied and some of them has a potential for reducing air pollution and is studied widely. Bio filtration technology and photocatalytic oxidation, these technologies are not new candidates in the field of discovery but earlier they have been used only in the field of water treatment. But now these technologies are also being used for the treatment of air pollution due to their cost effective and simple by products are being produced.

CO and VOC are known contaminants and very harmful for health, their levels vary depending upon the type of establishment and the working hours. The health effects on the employees due to these contaminants can be mild to severe, depending upon the level of exposure, duration of exposure and the type of parking they are working in. health risk assessment is a tool which can help in assessing the pollution inside the parking in terms of the health of the employees. The air pollution control strategies are not installed anywhere until now, they are still new but effective technologies. In the time to come it may prove to be very helpful in reducing pollution.

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