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Evaluation of Exhaust Pollutants in Iskenderpasa Underground Parking Garage

Case Study

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Abstract *— Parking garages which has pure indoor air quality should be evaluated in terms of environmental aspects, by considering different exhaust gas concentrations. In this study SO_2, NO_2, CO, O_3 and PM_{10} parameters were measured in specific points of a triplex parking garage which is in a high traffic location of Istanbul. Then, measurement results were compared with national and international emission limits, over limit pollutants were determined and air quality indexes were identified. Finally efficiency of current and possible measures of air pollution of the parking garage was discussed.*

Keywords—underground parking garage; primary air pollutants, indoor air quality

I. INTRODUCTION

The number of personal vehicles increases day by day because of improving technology, increasing purchasing power and transport flexibility. This situation causes traffic jam and car park requirement. It is luxury to park at lands -especially in Istanbul because of very expensive land prices- and parking on the road increases traffic jam. So, modern and organized car parks which respond the driver's requests became a requirement in the light of all these factors. However, exhaust gases, which are unburned Hydrocarbons (HC), Nitrous oxides (NO_x), Carbon monoxide (CO), Particulate Matter (PM), Sulphur oxides (SO_x), Lead (Pb), cause poor air quality in closed areas under poor ventilation.

According to EPA [1], oil powered lights duty and later than 1980 model vehicle which has more than 80,000 km roadway produces approximately 9.9 g CO per km where a diesel vehicle produces 0.8 g CO/km. Additionally same vehicle produces 0.9 g NO_x/km if oil powered and 0.6 g NO_x/km if diesel powered. Concentration of hydrocarbon (HC) emitted are generally lower in diesel engines (0.9 g CO/km for the same vehicle) when compared to oil vehicles (0.3 g HC/km). The major concerns of diesel engine emission are NO_2 (might come from nitric oxide NO), carbon dioxide (CO_2), dust particulates and sulphur dioxide (SO_2), on the contrary, the major concern of exhaust from spark-ignited engines is CO [2].

Some studies were conducted in order to explore mobile vehicles caused and concentrated air pollution in closed areas such as tunnel [2], parking areas [3], [4]. In the study of Chow et al. [3], correlation relationships between CO concentration (both instantaneous 1-minute average and other averages over longer periods) with the number of vehicles, mean air speed, and turbulent intensity were investigated. It was found that both mean air speed and turbulent intensity are good flow parameters that can be used for correlating with the CO concentration. However, the mean air speed and turbulent intensity depend on the design of the ventilation system and are difficult to estimate. Additionally control systems such as ventilation strategies [5], numerical approaches for dispersion of pollutant concentrations [6], and simulations on the distribution of temperature and CO concentration [7], numerical simulations on fire spread and smoke movement [8] investigated for enclosed garages by different researchers. Especially CO was investigated in the studies about air quality in parking garages; however PM was also investigated [9]. Results of those studies were evaluated with results of this study in the following pages.

Ho et al. [10] conducted a study on determination of carbon monoxide level and thermal environment in an underground car park. As a result, it was founded that, hourly average temperature is correlated with engine operating time fraction, ambient temperature, and historic effect for thermal environment. Both correlations are achieved with the R^2 value exceeding 90%.

According to Fig. 1, in Turkey, spark-ignited engines fuelled by oil are common in most passenger cars and compression-ignited engines, which are diesel engines, are being substituted with oil fuelled vehicles. Generally, the major differences between petrol and diesel engines are in the quantity of carbon monoxide (CO), particulate, and nitrogen dioxide (NO_2) produced.

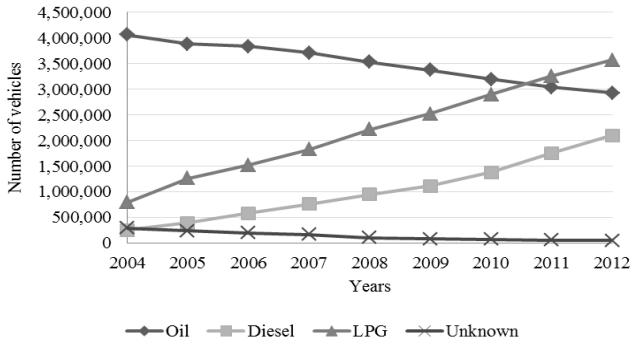

Fig. 1. Change in number of vehicles in Turkey according to years and vehicle types [11]

In Turkey, investment in underground parking garages is a new trend for both private and public initiatives. Of course, required precautions are taken, however due to technical problems such as establishment in wrong location causes concentrated exhaust pollutants which have adverse effects in human health. In this study, SO_2, NO_2, CO, O_3 and PM_{10} parameters were measured in specific points of a triplex parking garage which is in a high traffic location of Istanbul. Then, measurement results were compared with national and international emission limits, over limit pollutants were determined and air quality indexes were identified. Finally efficiency of current and possible measures of air pollution of the parking garage was discussed.

II. METHODOLOGY

In this study, SO_2, NO_2, CO, O_3 and PM_{10} parameters were measured in specific points of a triplex parking garage. The methodology used to select measurement technique and a brief presentation of a study location was given in the following part.

A. A brief information about the sampling site

Iskenderpasa storey car park was selected due to high number of parking cars in it, and high traffic location where it is located. Location of Iskenderpasa underground parking Garage in Istanbul was given in Fig. 2.

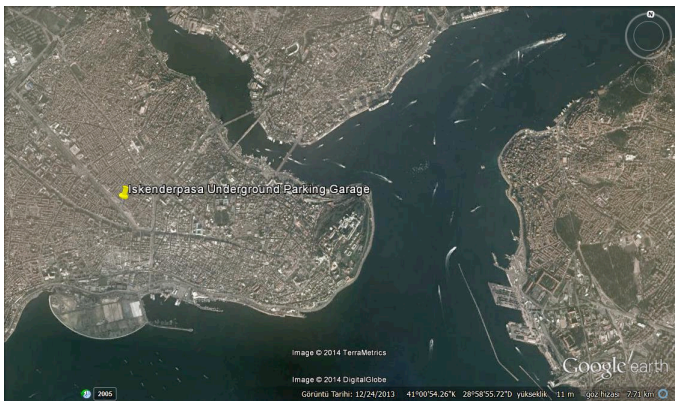

Fig. 2. Location of Iskenderpasa underground parking garage in Istanbul

It is located in historical peninsula of Istanbul, which is close to institutional facilities, historical places, shopping malls, high amount of residential areas, transfer points of different transportation means and routes. Therefore traffic load and parking garage requirements are very high in this area throughout the day.

Fig. 3. Inside and outside view of the subjected underground storey carpark [12].

The parking garage is available for 230 vehicles in three floors. Only one of these floors is adjacent to the ground. The remaining two floors are underground. Furthermore a jet fan system with a CO detector exists **Error! Reference source not found.**. Floor plan of the parking garage is given in Fig. 4. There are three floors; ground floor was named as “Blue Car Park”, a bottom of the ground floor was named as “Red Car Park” and two bottom of the ground floor was named as “Green Car Park”. Each of the floors have same plan as indicated in Fig. 4. There are two side by side twin parking garage and they were named as “CarPark 1” and “CarPark 2”

B. Measurement technique

Air quality measurements were conducted for exhaust gases (SO_2, NO_2, CO, O_3 and PM) which are the pollutants have greatest impact on human health. Entrance and exit of the triplex car park has different doors as in Figure 1, entrance is in Carpark-1 and exit is in Carpark-2, colors were identified according to floor numbers. Two different measurement locations were identified and instant gas measurements were conducted for each of the gas. Also five different measurement locations were identified for instant PM measurements when jet fans were deactivated for inhibition of ventilation during measurement. Used measurement devices were PDR 1500- UDCN 0931037956 for PM measurements with TS EN 2361:1976 and KITAGAWA Model AP-20 Aspirating Pump/083808 for other gas measurements with TS EN 1231:2000.

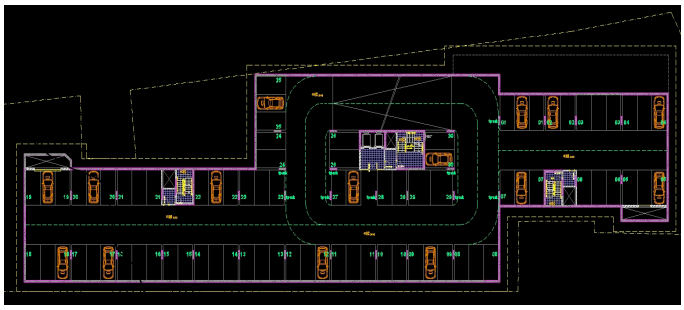

Fig. 4. Floor plan of the Iskenderpasa underground parking garage [13]

III. RESULTS AND DISCUSSION

In this study, SO_2, NO_2, CO, O_3 and PM_{10} parameters were measured in specific points of a triplex parking garage. Measurement results are averaged and given in Fig. 5. for each of the floors.

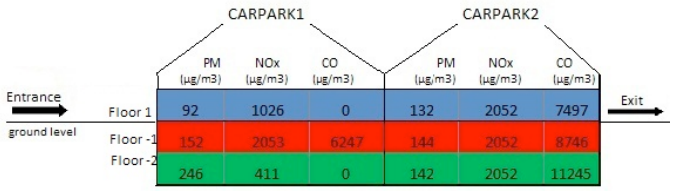

Fig. 5. Maximum PM and gas concentrations according to park floors.

According to results of this study, PM_{10} exceed limit values of United States Environmental Protection Agency (US-EPA) (150 µg/m^3 daily and 50 µg/m^3 yearly), and European Union (EU) and World Health Organization (WHO) (50 µg/m^3 hourly and 20 µg/m^3 yearly) limits, and also not exceeding Turkish legislation limit (140 µg/m^3 daily and 78 µg/m^3 annual). This car park needs abatement technologies in terms of PM_{10} concentrations. According to study of Li et al. [9], PM concentration was nearly duplicated in exit of an underground parking garage, when compared to entrance. Additionally, hourly PM_{10} concentration was weakly correlated with traffic flow, where it was reduced remarkably after wetting the road surface which shows suspended PM is dominant in underground parking garages.

NO_x results are extremely exceeding limit values of Turkish Legislation (300 µg/m^3 hourly and 63 µg/m^3 annual average). Also NO_x emissions are very high when compared to international limits such as EU (200 µg/m^3 hourly), US-EPA (100 µg/m^3 yearly), WHO (200 µg/m^3 hourly). Indoor air quality should be carefully investigated in terms of NO_x parameter and required measures should be taken.

CO parameter exceeding limit of Turkish legislation in the bottom floor of the second CarPark, which was (14,000 µg/m^3 for 8 hours and 10,000 µg/m^3 as annual average). Also it is hitting US-EPA, WHO, EU limit values (10,000 µg/m^3 for 8 hours). In this regard, CO measurements should be done carefully for entire of the floors and supplementary ventilation should be supplied for the bottom floors since CO level in an underground car park depends on three major factors [10]: ventilation, infiltration, and vehicle engine operating time. It is highly expected that the CO concentration in an underground car park should be correlated with the engine operating time. In a car park, engine operating time varies randomly and can be represented by a probability density function. It is closely related to number of cars entering/leaving car park, degree of congestion and level of occupancy of the parking lots.

O_3 and SO_2 parameters were also measured in this study; however no remarkable high concentration values were achieved.

IV. CONCLUSIONS

As traffic increases, car park requirements and also poor air quality in underground parking garages are increasing. From this regard, PM_{10}, NO_x and CO parameters are becoming larger amounts in air of underground parks which have no high ventilation possibilities and require extra measures to protect human health. However SO_2 and O_3 parameters are not in remarkable amounts in underground parking garage air.

In Turkey, investment in underground parking garages is a new trend for both private and public initiatives. Of course, required precautions are taken, however due to technical problems such as establishment of abatement technologies in wrong locations of parking garages causes concentrated exhaust pollutants which have adverse effects in human health. In order to solve such problems, literature should be investigated deeply; new studies should be performed and public should be informed for the possible health induced problems of poor air quality in parking garages.

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