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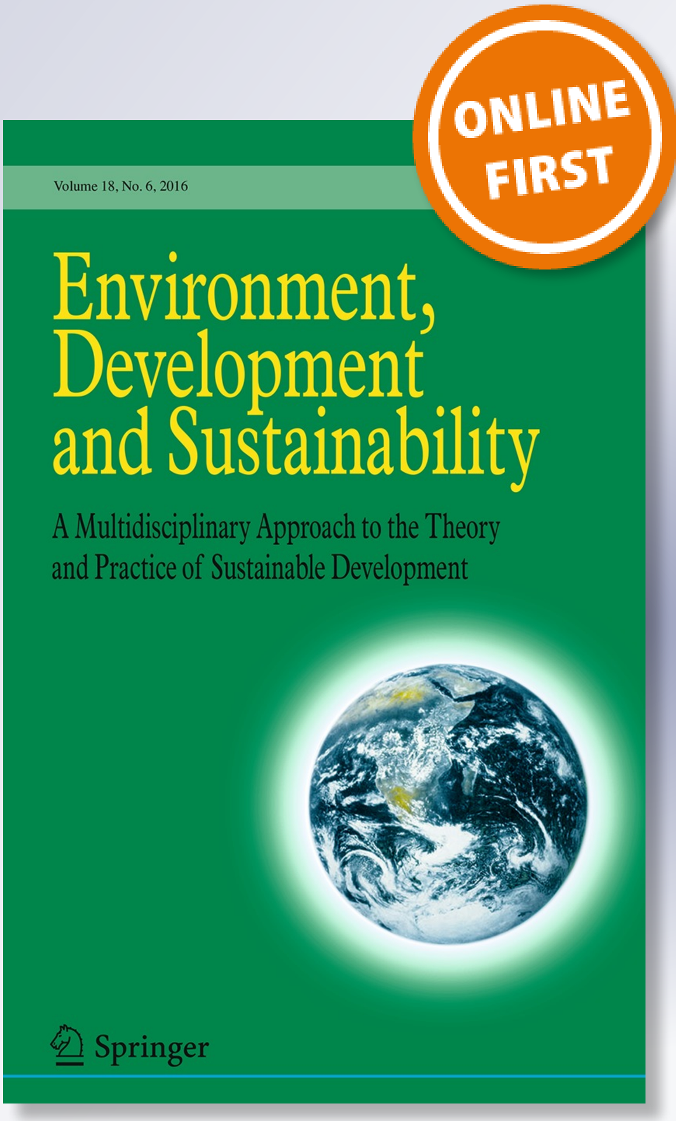

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Traffic and outdoor air pollution levels near highways in Baghdad, Iraq

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Abstract In Iraq, the number of passenger cars, trucks and buses, local generators, and heavy construction equipment rose to a considerable extent since 2003, causing high environmental problems. Many types of pollutants were monitored and recorded for 24 h during March 2016. The study attempts to explore and establish a relationship between the volume of activity and the movement of motor vehicles of various compounds and contaminants resulting from their exhaust pipes, such as sulfur dioxide, particulate matters, oxides of nitrogen, VOCs, and unburned hydrocarbons. The study focused in and around Mohammad Al-Qasim highway adjacent to the University of Technology, Baghdad. The results showed the need for urgent treatments addressed by the environmental authorities in the city. The study results demonstrated that these contaminants are increased during periods of the beginning and end of working hours for government departments. Some types of sulfur compounds (H_2S and SO_2) concentrations were at serious health-threatening levels, which is a result of the high sulfur content in the Iraqi fuel. The concentrations of NOx and VOC were high, also, which could make the studied area vulnerable to the risk of smog formation. The Iraqi government should make greater efforts to protect the environment and human in this country from the transportation pollution risks.

Keywords Pollutants · Greenhouse gasses · Sulfur dioxide · PM · Ozone · Baghdad

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1 Introduction

Exposure to air pollutants in the open air is a source of great danger to the whole world; various studies showed the persistence of high air pollutants to levels exceeding the acceptable values. Several recent studies linked between the acute respiratory and cardiovascular diseases and the air pollutants resulting from traffic by accurate measurements (Eeftens et al. 2015; Delfino et al. 2009; Jansen et al. 2005; McCreanor et al. 2007; Meng et al. 2007). Many researchers have found a direct relationship between air pollution and respiratory diseases, especially among children (Rancière et al. 2016; Shams et al. 2014; D'Amato et al. 2015; Ma et al. 2016). Pollutants like nitrogen dioxide (NO_2) and particulate matters (PM2.5 and PM10) are measured because it is the most hallmarks of ambient air pollution and are associated with many health risks in the long term (Lv et al. 2013; Zhang et al. 2015). These criteria air pollutants are monitored and measured on continuous basis in many countries around the world (Rückerl et al. 2011; Luong et al. 2016; Cirach et al. 2012).

The coarse particulate matters called PM2.5 and PM10 are produced mostly from fossil fuel burning in internal combustion engines and industrial burners. The other ultra-low-diameter particles, which have a partially different composition and with more dangerous called PM1, are found in high concentrations in vehicle exhaust (Heal et al. 2012). These tiny particles penetrate deep into the respiratory tract and may reach directly the blood and brain. Fossil fuels contains amounts of sulfur which may be oxidized to sulfuric acid that is being diluted by cold ambient air, and with the presence of organic gasses, the sulfuric acid becomes the nuclei at which the large molecules condense to form the ultra-fine particles (Hassanvand et al. 2015; Cao et al. 2012; Liati et al. 2016; Duan et al. 2006). Both the ultra-fine and coarse particles (PM2.5 and more) have buoyancy lifetimes relatively short ranging from several minutes to a few hours after it is being emitted or after the formation of ultra-fine particles (UP) (Cao et al. 2013; Hinds 2001). Those particles accumulate on the surfaces due to gravity, and its accumulation rate is affected by the wind movement. In the other hand, the ultra-fine particles can flow with the currents and remain suspended in the air for several days up to one week (Al-Katheeri et al. 2012; Cao et al. 2011).

Volatile organic compounds (VOC) consist of gaseous unburned or partially burnt hydrocarbons in the ambient temperatures. VOCs are also emitted from the petrol tanks and crankcase of vehicles as well as from other stationary sources (Wang et al. 2013). It is a large group of complex organic chemicals that consist mostly of the burning process of fossil fuels (Wang and Li 2011; Wu et al. 2014). VOC mostly consisted of alkenes, alkanes, cycloalkanes, aromatics, and oxygenates (Sun et al. 2016). Most of these compounds are highly toxic environmental pollutants. High concentrations of VOC are found in the major cities and the atmosphere of urban areas because of the increasing traffic (Jamhari et al. 2014; Liaud et al. 2015). The volatile organic compounds in the ambient air affect the air quality over long distances (Derstroff et al. 2016). Many of these VOCs are carcinogenic, mutagenic, and teratogenic (Wu et al. 2016; Franciscoa et al. 2016).

The greenhouse gas emission is one of the most significant results of the excessive use of cars and vehicles. These gasses produce from the burning of fossil fuels in the automotive and car engines. Greenhouse gasses include (carbon dioxide (CO_2), water vapor (H_2O), ozone (O_3), methane (CH_4), and nitrous oxide (N_2O) (Chaichan et al. 2016).

Fossil fuels combustion emits several pollutant gasses; one of it is sulfur dioxide (SO_2). Transportation as power generation is the source of this gas. Sulfur dioxide affects human health when it is inhaled during the respiration process. This pollutant can cause severe corrosion problems at the presence of water. Besides, if it is deposited in the soil, it may cause many adverse effects to the ground and the underground water (Goos et al. 2011; Bolourinejad et al. 2014). Also, H_2S and SO_2 can cause health problems even when they are emitted in little quantities (ppm level) (Gersen et al. 2014). Sulfur dioxide accompanied with nitrogen oxides is the primary source for acid rain formation (Chaichan 2015a, b). Acid rain causes soil futile and groundwater acidity, accelerates the corrosion of buildings and monuments, and reduces visibility (Jegal and Kim 2015). Sulfur dioxide can be very harmful to people who suffer from asthma or have breathing problems at a concentration of 0.5 ppm. If its levels exceeded 20 ppm, it could cause permanent damage in the lung. This gas is pungent and irritating and has a smell at concentrations of 3 ppm, making it easier to be detected (Zhang et al. 2016).

Ozone is not a primary pollutant emitted from car's engine exhausts. It is a secondary pollutant formed in the atmosphere by photochemical reactions between NOx, VOC, and sunlight (Chaichan 2016). Inhaling ozone can affect human health, especially children. It also causes adverse effects on plants and ecosystems (Chaichan 2015a, b; Voskampa et al. 2016).

In Iraq, the locomotives run by gasoline increased largely since 2003. Its numbers exceeded more than 4.5 million cars. The increments level for gasoline cars is about 17.5% yearly since 2003 (Essays 2013; Kgabaar net 2015). About 38% of gasoline locomotives are concentrated in the Iraqi Capital, Baghdad, with about 1.75 million cars (Alaalem report 2013). The diesel-fueled trucks, buses, heavy-duty construction equipment, and about 15,000 shared electricity generators all are emitting vast masses of pollutants in the Iraqi environment (Al-Waeely et al. 2014). Besides, hundreds of thousands of small wattage electric generators are used in the Iraqi citizen houses (Chaichan and Kazem 2012). Heavy fuel oils are used in the power generation in Iraq profoundly. The burning of heavy fuel oils emits massive levels of soot, carbon depositions, and sulfur oxides (Chaichan and Faris 2015).

The Iraqi diesel fuel has high levels of sulfur contents that exceed 10,000 ppm which can be considered the worst in the world (Atiku et al. 2016; Ahmed and Chaichan 2012). On the other hand, the Iraqi gasoline has a sulfur content of about 500 ppm which is considered a very high concentration level (Chaichan 2012). The great interest in the sulfur content in any fuel is not only to focus on what is produced from sulfur oxides or sulfur hydroxide but because it reduces the cetane number for diesel and the gasoline octane number. In addition to that, it helps dramatically in increasing the formation of PM.

Noise levels are associated with the road network, the traffic flow, the speed and load conditions, and city weather (Zuo et al. 2014). Bell and Galatioto (2013) indicated that noise levels in the towns ranging from about 54 dB in high-density residential streets up to 74 dB on high-traffic roads.

The recent study aims to evaluate the effect of traffics in Baghdad City, Iraq. The taken sample was Mohammed Al-Qasim highway near the University of Technology. The study monitored and recorded the air quality in this area. The principal goal of this study is to collect data and information on the levels of some criteria air pollutants to raise an alarm to the Iraqi authorities and stakeholders in preserving the environment and public health in Iraq.

2 Materials and methods

2.1 The study location

The area of study is Mohammed Al-Qasem highway section in front of the University of Technology. This highway road was selected because it is, as all Baghdadi highways, crowded with cars, heavy trucks, and construction equipment. The vehicular traffic was recorded using an internet camera fixed on the top of the university main gate facing the highway. The recording timing lasted for all March 2016. The traffic volume was determined from the recorded videos. The traffic volume was calculated for intervals of 15 min. Two categories selected to describe the traffic, small vehicles, and heavy vehicles.

2.2 Measuring devices

The practical measurements of pollutant emission rates vary considerably as a result of different methods of measuring devices, fuels, operating cycles, test procedures, and natural dilution. Fuel is the key factor in determining the emissions that must be measured, which facilitates the accurate measuring of the concentrations of many different combustion sources (Nussbaum et al. 2009).

Several instruments were used to measure the variable pollutants. Table 1 represents the measuring instruments specifications and details. All the measuring instruments were calibrated at the Central Organization for Standardization and Quality Control, Baghdad/Iraq.

GC is the preferred method for researchers to identify VOC, ozone, and NOx due to its high sensitivity. There are several techniques suitable for this purpose, such as static headspace (Serrano et al. 2013; Kovacs et al. 2011; Boczkaj et al. 2016; Rui and Shengzhuo 2015). At present, lots of specialized devices measure the concentrations of particulate matters, and most of the devices used to measure particle size. Sometimes they are divided into several categories each of which uses some of the properties related to the size of particles, such as the viability of electric mobility, molecule diameter, the effect of inertial force and mass, and the block spectrum. The use of different principles based on various properties leads to the difficulty of relying on the measurement result, and direct comparison between specifications.

2.3 Tests procedure

The measuring devices have been installed close to the Muhammad al-Qasim Street just at 1 m from it. The pollutants data were measured at 4 weeks, throughout the working day, and sometimes at holidays to ensure that it contained all the traffic conditions along this route. These measurements represent curbside or roadside emissions as a large number of students exist in this area especially at the beginning and end of the working hours. It can be considered that minute population will be exposed to these high levels of air pollution, whereas the majority of the population will be exposed to much lesser concentrations of air

Table 1 Technical specifications of the measuring instruments

No.	Device name	The measured pollutant	Made in	Range	Uncertainty (%)
1	G460	CO, CO_2, H_2S, NO_2, SO_2, O_3	Germany	0–55 ppm	0.14
2	G460	Ozone, VOC	Germany	0–500 ppm	0.12
3	AEROCET	PM1, PM2.5, PM7, PM10, TSP	USA	5–250 $\mu g/m^3$	0.20
4	Sound level meter	Sound level	Japan	0–120 dB	0.23

pollutants. The measuring readings were not taken from a fixed point but from variable points on the street, as there are two exists on the road before and after the University.

3 Results and discussion

The sharp increase in the number of cars in Baghdad city after 2003 has intensified traffic in highways and within the sub-routes, also. So, the work to reduce the use of cars would reduce the environmental impact of the movement of transport. In spite of the use of European countries emission standards Euro-6, these cities are, to this day, lacing effective contribution to the reduction of PM2.5 near the streets where traffic is dense (Tobollik et al. 2016).

The traffic data analysis is illustrated in Fig. 1. The figure shows that the traffic began to increase after 6:30 AM because most people start to go to work at that time. The figure indicates the presence of two peaks with high traffic volumes (104,764 cars/day) in the morning and a reverse trend in the afternoon, and these flows of traffic show approximately similar pattern throughout the day. The heavy truck movements begin at almost the same as the small vehicles; their numbers increased in the morning at 7:00 AM and last almost same in size to the middle of the day and continue to some extent in the late afternoon. The number of vehicles went down after the 6:00 PM at lower rates. The figure reveals the number of heavy vehicles at night, which is equal to the small cars' number and outdone sometimes, as many of these vehicles' drivers prefer driving at night away from roads congestion. The recorded car number passing through the highway is a large number reminding us cities as Beijing, Delhi, New York.

3.1 Suspended particles

The European Agency for the Environment (EEA 2005) considered that the PM concentration in the indoor and outdoor air is the most important environmental factor that has a significant impact on health in Europe. These levels are responsible for most of the environment-related diseases. When the concentration of PM2.5 is increased in the outdoor, it causes cardiovascular and cardiopulmonary disease. The WHO (2004) estimated that air pollution with PM was the responsible for 100,000–725,000 deaths each year in Europe (Borrego et al. 2007). Liati et al. (2016) clarified that new gasoline and diesel

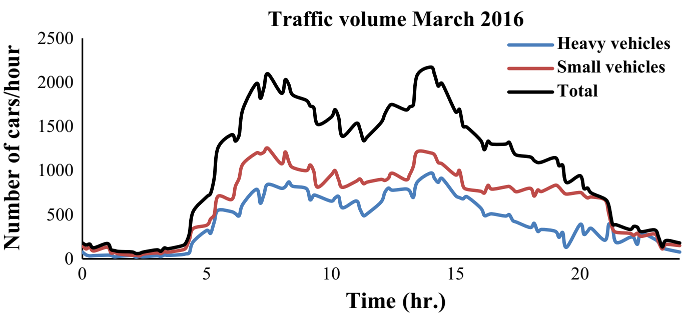

Fig. 1 Traffic volume data

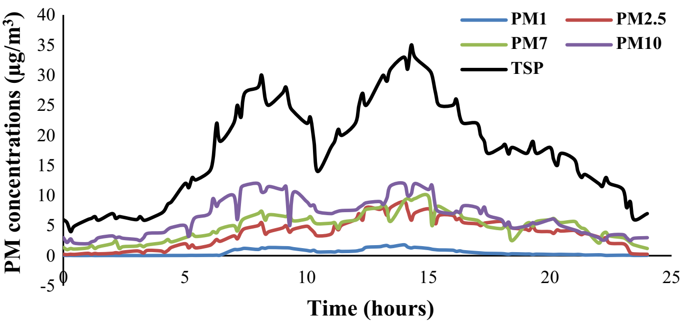

Fig. 2 Suspended particles concentration data

engines which operate on direct injection procedure produce higher PM concentrations than conventional port fuel petrol and diesel engine equipped with particle filter.

Figure 2 illustrates the suspended particle concentrations during the day. These concentrations are also related to the increased traffic that occurred at the start and end of the working day, which means around 8 AM to 2 PM. The suspended particle reached levels that may cause diseases for the university students who crowded at the peak time around the studied area. Some particulate matters which are considered very dangerous as PM1, PM2.5, PM7 and PM10 were measured with levels that call for a stop and to study how to get rid of it, or at least reduce them to the lowest values. PM1 levels exceeded the WHO maximum level by 112%; the measured PM2.5 level exceeded the WHO maximum level by 44%, as Table 2 indicates.

3.2 Carbon monoxide

Figure 3 represents the recorded levels for CO pollutant during the day. The levels of CO recorded in the studied area may display the risk to the university students and staffs near the studied area. Table 3 shows the comparison between the recorded concentrations and the limits of other standards. The results reveal that the CO levels for the exposure duration lie near the maximum limits adopted by EPA, WHO, and UAE. The high CO levels can be the result of many parameters such as bad maintenance and old engines, and the major cause is the lack of environmental legislations determining the accepted engine pollutant levels in Iraq (UAE 2015, WHO 2005).

3.3 Concentration of sulfur pollutants

Sulfur dioxide (SO_2) is one of the air pollutants that is dispersed widely, especially in the industrial areas. SO_2 is one of the factors that can aggravate asthma; cause asthma; allergy sufferers are suffering from the effects of SO_2 (Reno et al. 2015).

The results in Table 3 represent high measured concentration of H_2S and SO_2 which exceeded the WHO maximum limit with 32%, representing a danger to public health and the environment, as Fig. 4 reveals. Iraqi fuel that contains elevated levels of sulfur can be considered as a fundamental reason for such concentrations.

Table 2 A comparison between the ambient air quality standards for EPA, UAE, and the WHO guidelines and the recent study measurements for suspended PM

No.	Pollutant	EPA	WHO	UAE	Iraq
1	PM1	0.20	0.25	0.30	0.53
2	PM2.5	35	25	22	36
3	PM10	150	150	125	163
4	TSP	300	300	300	317

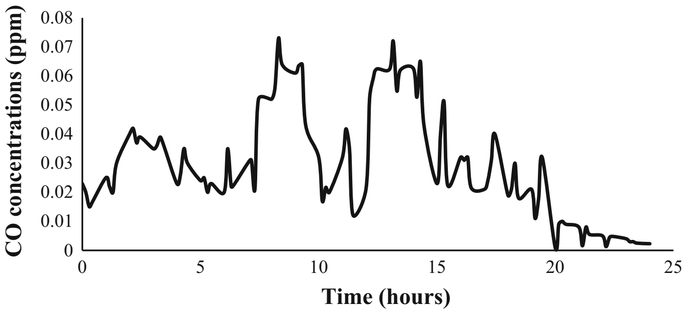

Fig. 3 CO concentration in the studied area

Table 3 Comparison between the accepted EPA, WHO, and UAE pollutants limits and the recent study measurements

No.	The pollutant	Exposure time (h)	Concentrations (ppm)			
			EPA	WHO	UAE	Recent study
1	CO	8	9	11	–	12
		1	20	–	20	19
2	SO_2	24	0.04	0.05	–	0.066
		1	0.25	0.75	0.13	0.33
3	NO_2	24	0.099	–	–	0.16
		1	0.18	0.21	0.13	0.339
4	O_3	8	0.80	0.60	0.80	0.99
		1	0.09	–	0.08	0.926

3.4 Concentration of NOx, VO, and Ozone

Zheng et al. (2015) findings suggested that the exposure to NOx presented in the environment at the first year causes severe breathing problems and dry cough with symptoms of rhinitis patterns. In the same time, one of the most significant interactions that result from human activities such as the combustion is the oxidation of volatile organic compounds by the nitrate radical (NO_3) (Ye et al. 2016). Many of the research works showed that this interaction for not less than three decades, which the reaction time for NO_3-VOC to affect

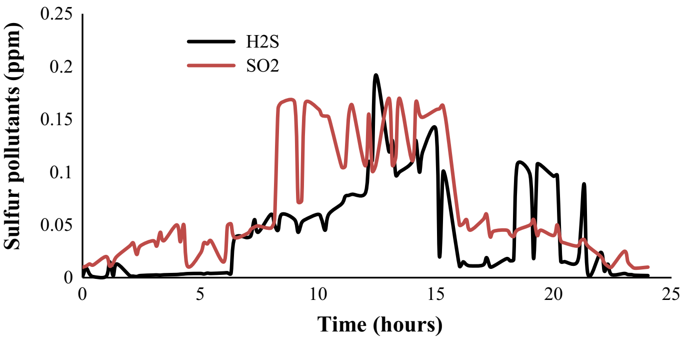

Fig. 4 Sulfur pollutants concentration data

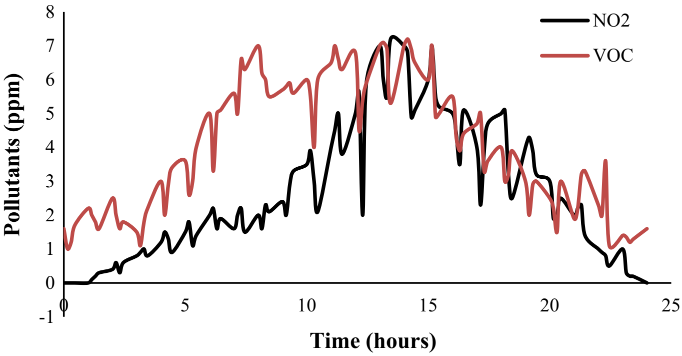

Fig. 5 NOx and VOC pollutants concentration data

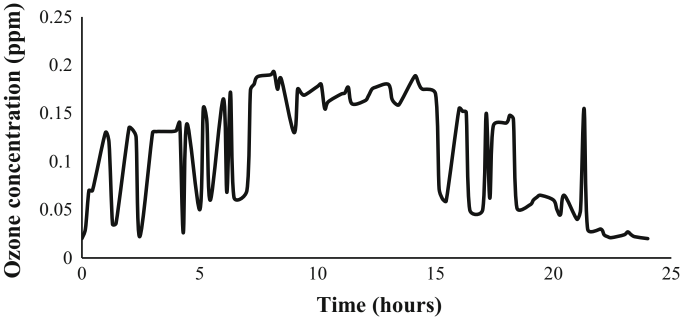

Fig. 6 O_3 pollutant concentration data

air quality and climate and vision through their interaction with ozone and organic aerosols (Hänninen et al. 2014; Fritschi et al. 2011; Basner et al. 2014).

The concentrations of nitrogen oxides (NOx) and volatile hydrocarbon compounds (VOC) are very high in the studied area, as Fig. 5 shows. Table 3 results reveal that the

NOx levels for the exposure duration exceeded the maximum limits adopted by EPA with about 18%. The presence of pollutants together with the presence of sunlight produces elevated levels of ozone, which appears in the form of high levels, as Fig. 6 shows. The proper maintenance and impose of limitations on the emitted pollutants from vehicles would reduce the extent of these contaminants and carry the Iraqi environment away from the danger zone.

3.5 Noise concentration

Many studies have shown that the health effects resulting from traffic noise cause many diseases, and therefore, noise is considered one of the air pollutants (Halonen et al. 2015). In best estimates, we can say the loss of about million human per year due to the noise output of traffic in Western Europe alone (Halonen et al. 2015). The noise can be linked to a series of audio and non-audio diseases (Babisch et al. 2014), and some of these diseases are what causes premature death (Halonen et al. 2015) and deaths due to heart disease and vascular (Babisch et al. 2014; Münzel et al. 2014). Also, noise causes annoyance and sleep disturbance (Ristovska et al. 2014), cognitive problems in children (Basner et al. 2014), and hypertension (Fritschi et al. 2011).

Figure 7 shows the noise in the studied area for 24 h. The noise source is the traffic whether from engines or cars movements. The recorded noise levels are high; it exceeded Bell and Galatioto (2013) levels (54–74 dP) at all times. This noise is causing a nuisance to the vehicles drivers nearby or to the surrounding residents to Muhammad Al-Qasim Street. The noise levels exceeded 90 decibels sometimes, which is considered to be high. Iraqi environmental authorities should put powerful noise determinants for the benefit of citizens.

3.6 The health hazards

Table 2 represents the National Ambient Air Quality Standards (NAAQS) adopted by United States Environment Protection Agency (USEPA) (2005) and the World Health Organization (WHO) Air Quality Guidelines (2004) compared to the recent study measurements. The comparison clarifies that the studied area's air quality is bad where the pollutant levels are near or exceeded the acceptable limits. PM pollutants, especially the ultra-fine ones, are the cause of many cancers and respiratory diseases.

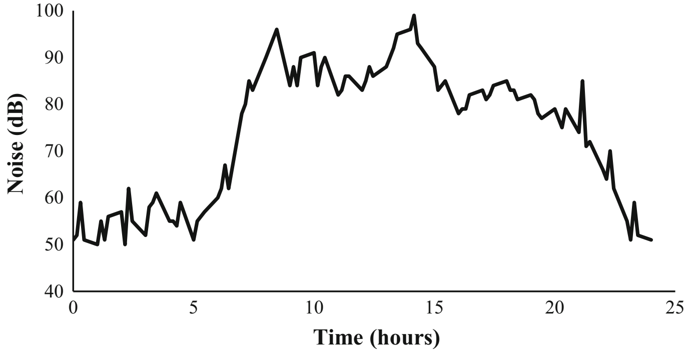

Fig. 7 Traffic noise levels in the studied area

Table 3 compares between the recorded concentrations of some pollutants (CO, SO_2, NO_2, and O_3) and the limits of EPA, WHO, and UAE. The results reveal that the CO levels for the exposure duration were near the maximum limits adopted by EPA, WHO, and UAE. The increments in CO concentrations can be referred to many parameters such as inadequate maintenance and old engines, and the primary cause is the lack of environmental legislations determining the accepted engine pollutants levels in Iraq. CO affects the human health especially the blood hemoglobin since as it has high susceptibility to union with the hemoglobin. It severely affects the breathing processes in the living organisms including humans, and causes a feeling of tiredness and difficulty in breathing and ringing in the ears. In the case of increase in its concentrations, it leads to a fall in blood pressure, lack of vision and hearing, relaxation the muscles of the body, unconsciousness, and death within 2 h.

The SO_2 concentrations exceeded the maximum limits for USEPA, WHO, and UAE. The source of this pollutant is well known; it is the high sulfur content in the Iraq diesel and gasoline. SO_2 has harmful effects in terms of turning the moisture in the air into sulfuric acid as a result of its oxidization to sulfur trioxide, and then it interacts with water vapor (Zhang et al. 2016). Each of sulfur dioxide and sulfuric acid severely affect the respiratory system (bronchitis, shortness of breath, chest pain and spasm of the vocal cords, and irritation of the eyes and skin, etc.). It will also lead to the creation of environmental problems such as acid rain.

The recorded NO_2 concentrations are high and reached an alarming limit especially for the exposure for 1 h. NO_2 with water vapor in the atmosphere poses to create a strong acid which is nitric acid. NO_2 contributes to a significant damage to human health, including (irritation of the mucous membranes of the airways, inflammation in the lung and eye irritation, etc.), and it is one of the causes of the acid rain, and it adversely affects the ozone layer.

The present results indicate that O_3 concentrations are high in the tested area and exceeded all the acceptable limits. The O_3 increase in the air causes the emergence of respiratory symptoms such as irritation of the throat and chest tightness, shortness of breath, deficiency in lung function, and increased asthma attacks.

3.7 Air quality management in Iraq

The reduction of air pollution levels of the ambient air requires scientific, technical, and extraordinary commitment efforts from both the government and society as a whole. The USA, China and European countries tried to develop strategies for air quality management (AQM) with the escalation of the economic development with the pollution resulting. The air quality management (AQM) is a major challenge in Iraq and requires significant efforts in which the issuance of laws and regulations to measure pollutants and control to keep the constant race between economic development and environmental pollution. Clean air management experiences have proven in the USA that the work to monitor, identify, and neutralize a single pollutant would not have a significant impact on air quality. The air quality management must work to achieve several goals, including:

1. Study of pollution areas in the long term and the sources of this contamination.
2. Assess the relationship between ambient air measurements and the adverse effects of pollution. For example, instead of focusing on reducing the PM at the local level, it should be concentrated on the rest of polluting gases such as sulfur dioxide, nitrogen oxides, and carbon monoxide, and the measures that aim to reduce them.

Till today, the Iraqi Government and the oil industry authorities have not taken a serious step to lessen the amount of sulfur in Iraqi diesel and gasoline, which is considered as the greatest source of danger. Reducing the sulfur content in diesel fuel from 10,000 to 34 ppm, as in Europe and the USA, will reduce environmental pollution in Iraq to an unimaginable proportion. The issuance of the determinants of pollutants emitted from motor vehicles and engines and putting lows and restricted legislations will help in reducing the high pollution levels that have been monitored in this study. The Iraqi government has issued instructions to evaluate the pollutants released by electrical generators; unfortunately, this legislation was not implemented out to this day.

4 Conclusions

A practical study was conducted near the University of Technology in Baghdad City, the Iraqi capital, to evaluate the pollution levels and to determine the share of traffics on this pollution. The study showed that a large number of cars (104,673 vehicles per day) are passing through Mohammad Al-Qasim highway every day. The population of heavy vehicles is close to the number of light cars making this road busy all hours of the day. This high crowding results in high environment pollution.

The study results revealed that the PM concentrations were high, and some types of particulate matters were at serious health-threatening levels for passers-by whether students or members of the university. The measured sulfur compound (H_2S and SO_2) concentrations were high revealing the harmful effect of the Iraqi fuel contents of sulfur. The levels of NOx, VOC, and ozone were also high. These emissions levels make this area to be actively exposed to smog danger. Also, the levels of the CO were colossal and alarming. The Iraqi government should make greater efforts to protect the environment and human in this country from pollution risks. The National Ambient Air Quality Standards in Iraq becomes a must.

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