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Evaluation Euro IV of effectiveness in transportation systems of Tehran on air quality: Application of IVE model

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ABSTRACT: The quick growth of vehicles is due to fast urbanization in mega cities during last decades. This phenomenon has serious impacts on air quality, as emission from mobile vehicles is the major source of air pollution. As a result, any attempt to reduce the emitted air pollutants is needed. This study aims at improving the fuel quality in transporting system with particular emphasis on taxis in Tehran in 2014. As a clean fuel, Euro IV is being used to reduce the emission of pollution, toxic substances, and greenhouse gases. A bottom-up approach to evaluate vehicular emission, using IVE (International Vehicle Emission) model in Tehran, has been presented, which employs the local vehicle technology and its distributions, vehicle soak distributions, power based driving factors, and meteorological parameters to evaluate the emission, itself. Results show that the most abundant air pollutant (CO) has been reduced by 87.6% due to the clean fuel consumption (Euro IV). Also, the emission rates of the predominant toxic pollutant (Benzene) decreased by 98.7%. As a clean fuel, Euro IV managed to increase the emitted amount of CO_2 and NH_3. It can be concluded that upgrading transportation system with updated fuel quality is an essential step to improve air quality in Tehran.

Keywords: air pollution, fuel quality, public transportation, taxis.

INTRODUCTION

One of the serious concerns of developing countries, such as Iran, is Air quality. There has been a considerable increase in respiratory and cardiovascular diseases and mortality, due to air pollution, with a huge number of people suffering from heart and respiratory illnesses due to this type of pollution, all around the world (Rashidi et al., 2012; Katsura, 2012; Lee et al., 2012; Sekhavatjou & Zangeneh, 2011; Quesada-Rubio et al., 2011; Wang et al., 2011; Zou et al., 2011). An average 70 kg adult person inhales about 20 m^3 of air per day, taking about 15 breaths per minute (Curtis, et al., 2006). Sensitive groups of people, such as atopic patients, asthmatics, patients who have experienced heart and brain stroke, people with bronchitis and emphysema, the elderly, children, and pregnant women, are most vulnerable to air pollution and toxicants (ALA, 2005). Population growth and

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urbanization are main causes of exponential growth of vehicles, especially in mega cities. Transportation greatly contributes in the release of hazardous air pollution emission, with vehicles being predominantly responsible for the emission of many air pollutants in urban areas (Zhang et al., 2011). The economic charges of diseases, related to the air pollution, in Iranian mega-cities exceed 8 billion dollars per year (World-Bank report, 2005).

Thus, governments need an accurate and comprehensive emission inventory to adopt efficient air-pollution-related strategies, letting them plan cost effective strategies (Cass & McRae, 1981). Besides, emission inventories are the main data for air quality forecasting simulators (Houyoux et al., 2000). Population and vehicle technologies, types of industry, processes of production, and metropolitan infrastructure are constantly changing. As a result, an emission inventory should be upgraded regularly to address the current conditions (Miller et al., 2006). The exhausted emissions from automobile sources are the main sources of air pollution in urban areas (Pant & Harrison, 2013).

Various emission inventory tools have been used previously to calculate the emissions of automobile source in urban areas (Franco et al., 2013). An economic and quick method to calculate vehicular emission is to use emission models, like COPERT, MOVES (Motor Vehicle Emission Simulator), and IVE (International Vehicle Emissions) simulators (Zhao & Sadek, 2013; Wu et al., 2014; Wallace et al., 2012).

COPERT was first developed by the European Environment Agency (EEA, 2002), and is widely used in Europe to calculate the emission of air pollutants and greenhouse gases from road transport (Soylu, 2007; Kassomenos et al., 2006; Fameli & Assimakopoulos, 2015).

The MOVES model, developed by EPA (Environmental Protection Agency), estimates the emissions from mobile sources, including a wide range of pollutants and allowing multiple-scale analysis (EPA, 2004).

Another model to calculate the mean emission rates from different vehicle categories and facility types is IVE model, which is especially designed to be flexible in order to deal with mobile source emissions needed by developing nations in their efforts (Guo et al., 2007). This model has been applied in different countries around the globe, such as Iran (Shafie-pour & Tavakoli, 2013; Shahbazi et al., 2016), China (Guo et al., 2007; Zhang et al., 2013; Wang et al., 2008), Vietnam (Kim et al., 2012), Nepal (Shrestha et al., 2013), and India (Mishra & Goyal, 2014; Nagpure et al., 2011). The advantage of IVE is its sensitivity to existing vehicle technologies in developing countries and driving behavior, quantified by vehicle-specific power and engine stress, having a significant effect on the emission of vehicle exhaust (Zhang et al., 2013). The calculated emission inventory for Delhi, India, from 2003 to 2012, by IVE model (Mishra & Goyal, 2014) showed that the emission of carbon monoxide (CO), nitrogen oxide (NOx), and particulate matter (PM) increased by 46%, 69%, and 18%, between 2003 and 2012, respectively.

To develop the emission inventory, IVE has been used in Kathmandu Valley, Nepal, for the fleet vehicle, including taxis, buses, motorcycles, vans, and three wheelers (MC) in 2010 (Shrestha et al., 2013). Results indicated that the lion's share of NOx (91%), black carbon (99%), and PM (93%) release belonged to buses, while motorcycles were the main source of CO and VOC (50%–79%). Results from IVE model implementation in Tehran, Iran, illustrated that hourly carbon monoxide (CO) emission, weighing 244.45 tons, during the rush hours was the most abundant criteria pollutant, about 25% of which was emitted during start-up periods. What is more, light vehicles were responsible for more than 82% of hourly carbon dioxide (CO_2) emissions, weighing 1744.22 tons during the study period. Based on IVE model, about 25% of the total vehicular emissions were from districts 2, 4, and 6 of Tehran municipality, respectively (Shafie-pour & Tavakoli, 2013).

Also, Shahbazi et al. (2016) showed that the main emission sources of carbon monoxide (CO), nitrogen oxide (NO_x), Volatile Organic Compound (VOC), and sulfur oxide (SO_x) were private cars. The IVE model's results indicated that the contribution of CO, VOCs, and PM emissions from motorcycles to the total traffic emissions was more than 15%, 31%, and 12%. Despite the fact that medium and heavy-duty vehicles comprised only 2.4% of Tehran's fleet vehicle, they were responsible for more than 41%, 64%, and 85% of NO_x, SO_x, and PM emissions. This study aims at evaluating the effectiveness of Euro IV in transportation system, with emphasis on taxis. The IVE model has been implemented in order to evaluate emissions from mobile sources, mainly taxis, in Tehran metropolis in 2014. Certainly, results will guide authorities to upgrade the transportation system by updated fuel quality as an essential step in improvement of Tehran's air quality.

MATERIAL AND METHODS

Tehran, the capital city of Iran, had a population of more than 8.5 million in 2011, with an annual average precipitation of about 230 mm, and annual average temperature of 17 °C (Hassanzadeh et al., 2009). The maximum and minimum temperature experienced in Tehran was 39 °C and was −6 °C, respectively (Ashrafi, 2012). Tehran is the 19th mega city of the world by population, also being one the largest cities in western Asia (Naddafi et al., 2012), occupying an area of more than 700 km^2, which is located between 35° 34′ and 35° 50′. Air pollution as a major problem (Bidokhti & Shariepour, 2010) in the mega city of Tehran has several influencing factors during recent years, such as rapid population growth, limited public transportation alternatives, and numerous private cars (Naddafi et al., 2012). The complex terrain conditions of Tehran intensify the air pollution problem in the city. The city is surrounded by Alborz mountain range on northern and northeastern sides, influencing the winds on the eastern side of Tehran as well as the pattern of pollution dispersion (Ashrafi, 2012; Sohrabinia & Korshiddoust, 2007). As it can be seen, the vehicle population in Tehran grows rapidly, with the total number of registered vehicles in the city increasing eight times in a span of 13 years. Today, 71.9% of registered vehicles constitute private light-duty ones, while 18% are motorcycles, with the rest belonging to taxis, buses, minibuses, pickups, and trucks.

IVE (International Vehicle Emissions) Model, version 2.0, has been designed by International Affairs Office, U.S. Environmental Protection Agency, to calculate mobile source air emissions. It aims at providing a background to assess the effectiveness and control strategies of various transportation planning. This model can predict the impact of different scenarios on local emissions as a bottom-up approach (Wang et al., 2008). Moreover, it is capable of not only measuring the progresses of emission reduction over time (ISSRC, 2008) but predicting toxic pollutants from various mobile sources of local air pollutants as well as greenhouse gas emissions. The emission is estimated, using vehicle emission rates, vehicle activity, and fleet vehicle distribution. The fleet file is prepared, using six types of data, namely fleet classification, fuel type (Petrol, NG, Propane, Ethanol, Diesel, CNG/LPG, and special), system of fuel delivery (Carbureted, Single Point Fuel Injection, Multi Point Fuel Injection, Pre-Injection, Direct Injection, 2-cycle, and 4-cycle), type of vehicle and its feature, distribution percentage of the desired vehicle, and air condition system distribution. According to these data, IVE model included 1417 technologies, 1372 of which are predefined and the remaining can be defined by the user.

In order to prepare fleet files, the first step was to select the appropriate classification. The present study selected light vehicles as fleet groups. Among different types of fuel in the IVE model, the desired fuel type for light vehicles was petrol. As for the desired group, the classes of fueling system were defined. Carburettor, Fuel Injection, Multi Point Fuel Injection, and Carburettor/ Mixer were selected for Light Duty vehicles and vans, mostly used in Tehran.

The second step was to insert the details of each group among the 1372 proposed technologies in IVE model, which included: vehicle type description, weight, system of air/fuel control, system of exhaust control, system of evaporative control, and age. Vehicles' age was defined in terms of odometer reading in thousands of kilometers travel (K km). The fraction of travel for each type of technology and the fraction of the technology, equipped with air conditioning, were required in IVE model, too. Table 1 shows the results of this assessment for Tehran. It should be mentioned that some light vehicles are capable of using both petrol and CNG simultaneously; however, due to lack of information about the traveled distance by CNG as a fuel, these systems were ignored. Location file was a further requirement of IVE model, being a representation of status and driving patterns. It included the information about driving behavior, starting patterns, environmental variables, and fuel characteristics, with each parameter having a considerable impact on the amount of emissions. It is necessity to consider specific locations, based on common characteristics of each district, when calculating the emission rate of mobile sources via IVE.

Table 1. Technology distribution in the transport system of Tehran

Vehicle type	Fuel type	Weight	Air/Fuel system	Emission control	Evaporative	Age	Index
Auto/Truck	Petrol	Light	Carburetor	None	PCV	<79K km	0
Auto/Truck	Petrol	Light	Carburetor	None	PCV	80- 161K km	1
Auto/Truck	Petrol	Light	Carburetor	None	PCV	>161K km	2
Auto/Truck	Petrol	Light	Multi- Port FI	None	PCV	<79K km	99
Auto/Truck	Petrol	Light	Multi- Port FI	None	PCV	80- 161K km	100
Auto/Truck	Petrol	Light	Multi- Port FI	None	PCV	>161K km	101
Auto/Truck	Petrol	Light	Multi- Port FI	3- Way	PCV	<79K km	117
Auto/Truck	Petrol	Light	Multi- Port FI	3- Way	PCV	80- 161K km	118
Auto/Truck	Petrol	Light	Multi- Port FI	3- Way	PCV	>161K km	119
Auto/Truck	Petrol	Light	Multi- Port FI	3- Way/EGR	PCV	<79K km	126
Auto/Truck	Petrol	Light	Multi- Port FI	3- Way/EGR	PCV	80- 161K km	127
Auto/Truck	Petrol	Light	Multi- Port FI	3- Way/EGR	PCV	>161K km	128

This study divided Tehran into twenty two districts and considered the rural surrounding areas as a separate one, thus having 23 districts in total (Fig. 1). For the first location, the required information included altitude, date, base adjustment, I&M class, and percentage of time that the fleet equipped with air conditioning, would take at a temperature of 27 °C or higher. The study focused its activities on taxis and vans as transportation vehicle in 2014. The percentage of vehicles, using Air Conditioning, was considered to be zero. Table 2 summarizes fuel characteristics that point to the amount of contaminants and additives, such as overall fuel quality, sulfur content, lead, benzene, and oxygenate levels. Other required parameters are environmental parameters (temperature and humidity), Distance/Time which describes the total traveled distance by the fleet of interest, the total number of starts for the fleet including both warm and cold starts, mean velocity, and driving characteristics.

In this study, these data were calculated for every fleet in the studied period. There were two concepts in IVE model to monitor the driving patterns, which included Vehicle Specific Power (VSP) and Engine Stress. They can be defined in Equations (1) and (2) (ISSRC, 2008):

$$\mathrm{VSP}=\mathrm{v}\left\lfloor 1.1\mathrm{a}+9.81\left(\mathrm{a}\ \tan\left(\sin\left(\mathrm{grade}\right)\right)\right)+0.132\right\rfloor+0.000302\mathrm{v}^{3} \qquad (1)$$

where, grade: $(h_{t=0} - h_{t=-1})/\ v_{\ (t=-1\ \text{to}\ 0\ \text{seconds})}$, h: altitude (m)
v: velocity (m/s),
a: acceleration (m/s^2), and

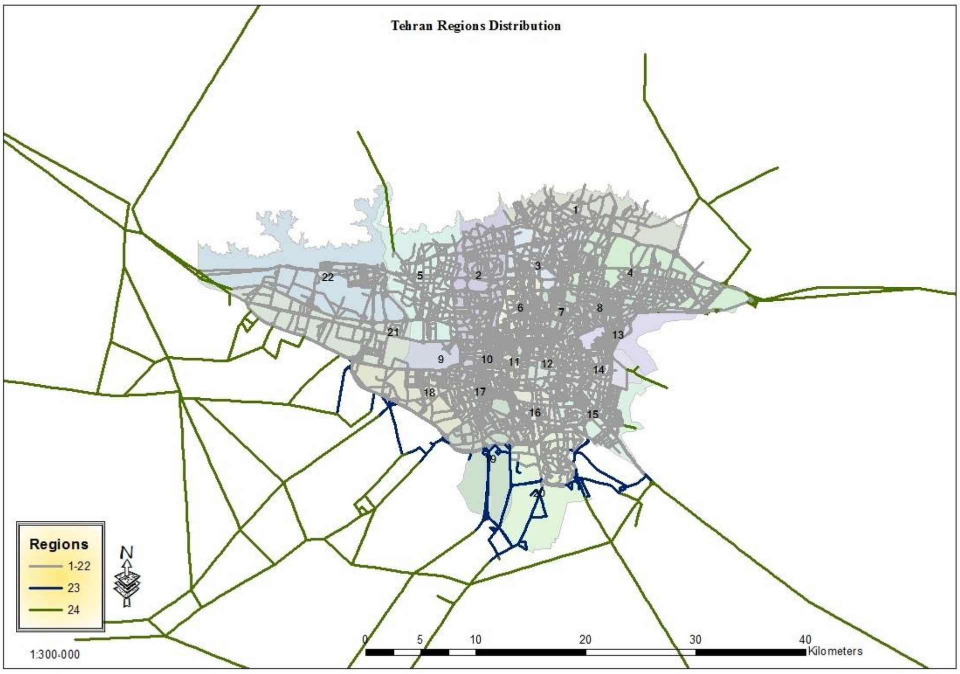


Fig. 1. Districts' locations in the city of Tehran

Table 2. Fuel characterization, used in IVE model in this study

Fuel characterization	Sulfur content (ppm)	Lead content (ppm)	Benzene content (%)	Oxygenate content (%)
Euro carb, I, II	300	0	3	2.5
Euro IV	50	0	0.5	2.5

$$\text{Engine Stress}\left(\text{unitless}\right)=\text{RPM Index}+\left(0.08\ \text{ton}/\text{kW}\right)*\ \text{Pre average Power} \tag{2}$$

where, Pre average Power: Average (VSP $_{t=-5\text{ to }-25\text{ sec}}$) (kW/ton), and

RPM Index: velocity $_{t=0}$/Speed Divider (unit less)

For the studied vehicle type, the GPS data was broken into one of the 3 STR bins and one of the 20 VSP ones. As such, the driving route could belong to one of the 60 driving bins. Table 3 illustrates the driving bin's distribution in this study. It should be mentioned that the STR bin was set Low in the current study. Power Bins 1-11 represented the negative power case (when the vehicle was moving downhill, slowing down, or combination of these two). Power Bin 12 represented the zero or very low power situation, like waiting at a traffic light. And Power Bins 13 and above represented positive power case (when the vehicle was driving at a constant speed, accelerating, moving uphill, or a combination of these).

Table 3. Distribution of driving into IVE power bins for vehicles Taxis, operating in Tehran with Low Stress bin

Distribution of Driving at Each Power (VSP) Bin for Low Stress Bin				
Hour	**Velocity**	**Average age VSP**	**Bin**	**Percent**
8	63	90.1	19	100
9	40.5	60.02	19	50
		14.03	15	25
		11.3	14	25
10	41.33	5.65	13	33.33
		60.65	19	66.66
11	42.1	2.93	12	7.7
		7.1	13	15.38
		13.08	14	7.7
		18.44	16	7.7
		25.31	17	7.7
		75.08	19	53.85
12	33.42	0	11	28.57
		8.9	13	14.28
		13.72	14	14.28
		88.175	19	42.86
13	37.5	6.44	13	16.66
		11.77	14	33.33
		17.25	15	16.66
		81.47	19	33.33
14	38.75	53.08	19	50
		5.4	13	25
		23.81	17	25
15	39.4	6.44	13	20
		25.31	17	20
		42.03	19	60
16	25.66	8.27	13	33.33
		2.6	12	33.33
		37.87	19	33.33
17	37.38	19.69	16	12.5
		130.915	19	25
		16.15	15	25
		8.9	13	12.5
		3.28	12	12.5
		9.7	14	12.5
18	42.5	3.28	12	50
		134.28	19	50
19	43.5	57.15	19	100
20	44.5	18.44	16	50
		65.92	19	50
21	65	97.9	19	100
22	67	106.24	19	100

Different kinds of starts can have a severe impact on tailpipe emissions, similar to driving patterns. For instance the engine soak period has the most important influence on emissions. In contrast, cold start, when the engine is completely cold and there is a period of more than 18 hours between the last operations to the next start, usually releases the most emissions, since the engine needs to warm up and the catalyst, if there is any, needs longer time to heat up to the operating conditions (Schifter et al., 2010; ISSRC, 2008). A warm start, when a warm engine is shut off for five minutes or less, before starting again, has the least amount of emissions from start-up. In order to evaluate emission, the current study assumed that each vehicle started only once with a soak period of 8 hours. The considered emission rates for Tehran were based on particular studies and dynamometer testing on a particular cycle at standard conditions in the IVE. This model is capable of using correction factors in order to compute the real emission rates in each location, corresponding to desired technologies. The base emission rates were calculated, based on US Federal Test Procedure (FTP) driving cycle (Zervas & Bikas, 2008; ISSRC, 2008) and running emissions were from the LA4 cycle (Enns & Brzezinski, 2001) in IVE model. Based on sulfur content of fuel as well as existing quantities in the fuel characteristics table, sulfur dioxide concentration needs to be multiplied in an adequate correction factor to run IVE for Tehran.

RESULTS AND DISCUSSION

The current study aims at evaluating the effect of using Euro IV as fuel in transport system of Tehran on vehicle emissions for three groups of criteria: pollutants, global warming components, and air toxins in Tehran. To do so, driving patterns for various classes of taxis, measured by GPS (Global Positioning Satellite) technology, were used providing their hourly driving pattern information. Based on the provided data from Tehran Air Quality Control Company, there were 77,949 active registered taxis in the city. Figure 2 demonstrates the distribution of different types of taxis with their various age intervals, showing that about 45% of taxis were less than 5 years old, 46% between 5 and 10 years old, and the rest were older than 10 years. The common technology of each vehicle type, driving patterns, traveled distance by desired fleet, soak times, and other effective parameters on the emission rates, were investigated.

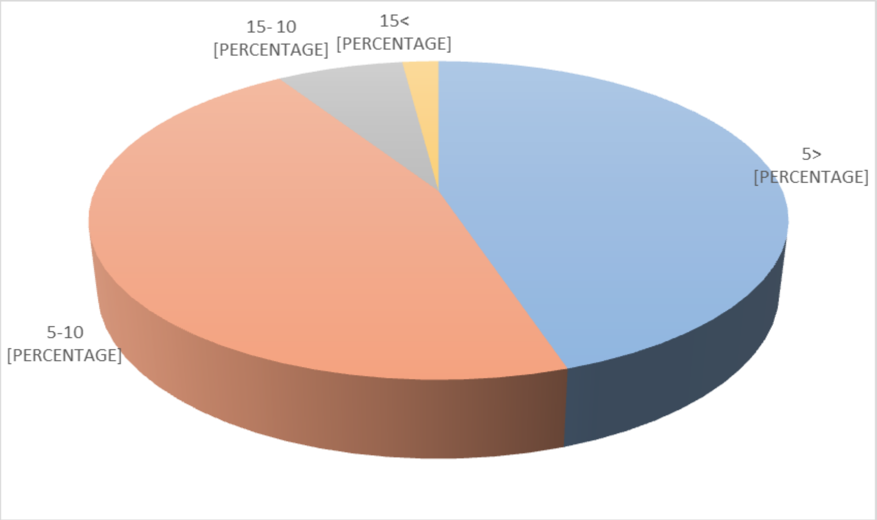


Fig. 2. Tehran vehicle fleet age distribution with emphasis on taxis

Results from this study show a considerable reduction in criteria pollutants, air toxins, and greenhouse gases. To better understand the emission reduction, as a result of using Euro IV fuel in transportation system of Tehran, Tables 4, 5, and 6 illustrate the daily emissions showing that during the evaluation period, carbon monoxide with daily amount of 9690 tones enjoyed the lion's share amongst criteria pollutants, being responsible for about 96.5% of total emissions, which plummeted to 1199.3 tones, due to using Euro IV. From a general analysis, it can be seen that the main contributor to toxic emissions by weight was Benzene with about 31% of total toxic emissions, which witnessed a notable reduction to the value of 0.16 tones after using Euro IV. According to the results, it should be mentioned that Euro IV increased CO_2 and NH_3. The combustion process was incomplete, when using Euro I and II as fuel in vehicles, but in case of Euro IV it happened completely. The complete combustion process produces more CO_2 than the incomplete one.

Also, Euro IV increased the catalytic convertor efficiency, thus raising the amount of NH_3 emissions. Using Euro I and II, CO_2 with a daily emission of 16,158.8 tons, played the main role in air pollution while, SO_X with 1.76 tons per day, was the least air pollutant. With Euro IV, CO_2 remained the main air pollutant, with a daily emission of 17,092.46 tons, whereas it was Benzene to become the least air pollutant, with a daily amount of 0.16 tons. Table 7 shows the reduction percentage of air pollutants, due to using Euro IV as fuel in transportation system (taxis) in Tehran.

According to Table 7, there was a remarkable decrease in Benzene with a percentage of 98.7%. Breathing large amount of Benzene as a toxic pollutant causes dizziness, drowsiness, rapid heart rate, tremors, headache, confusion, and unconsciousness. Figures 3, 4, and 5 show the hourly comparison between two used fuel type scenarios. Results indicate a notable amount of reduction in daily pollutant's emissions, especially during the rush hours. As it can be seen, most of the recorded emissions were released during morning and evening rush hours (i.e. 8-10 AM and 5- 8 PM).

Table 4. The estimated vehicle criteria pollutant emissions) tones/day(, using IVE model in Tehran

Total emission	Euro I,II	%	Euro IV	%
CO	9690	96.5	1199.30	96
VOC	121	1	9.48	0.8
VOC $_{evap.}$	8.98	0.1	8.82	1
NO_X	150.60	2	32.30	3.1
SO_X	1.76	0.02	0.31	0.01
PM	1.96	0.02	0.75	0.06

Table 5. The estimated vehicle toxic emissions (tones/day), using IVE model in Tehran

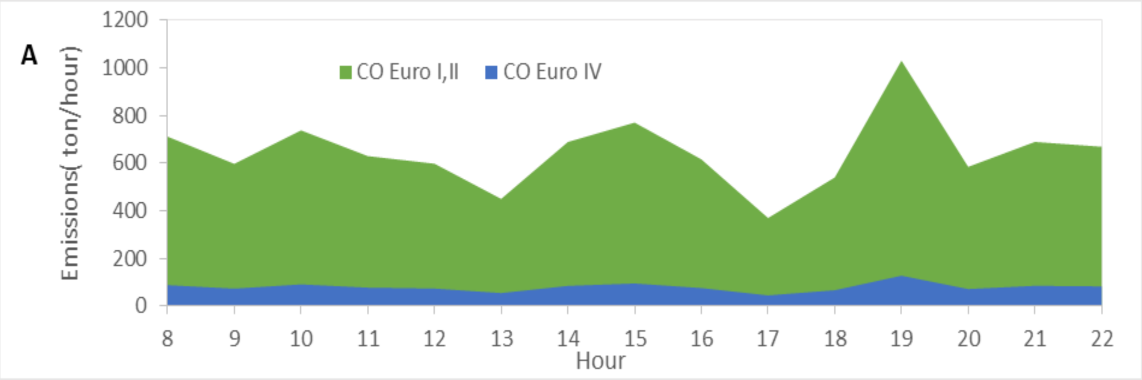
Total emission	Euro I,II	%	Euro IV	%
1,3 Butadiene	2.15	5	0.19	1
Acetaldehydes	4.43	11	0.35	3
Formaldehydes	11.60	27	0.93	7
Benzene	12.76	31	0.16	1
NH_3	11.26	26	11.54	88

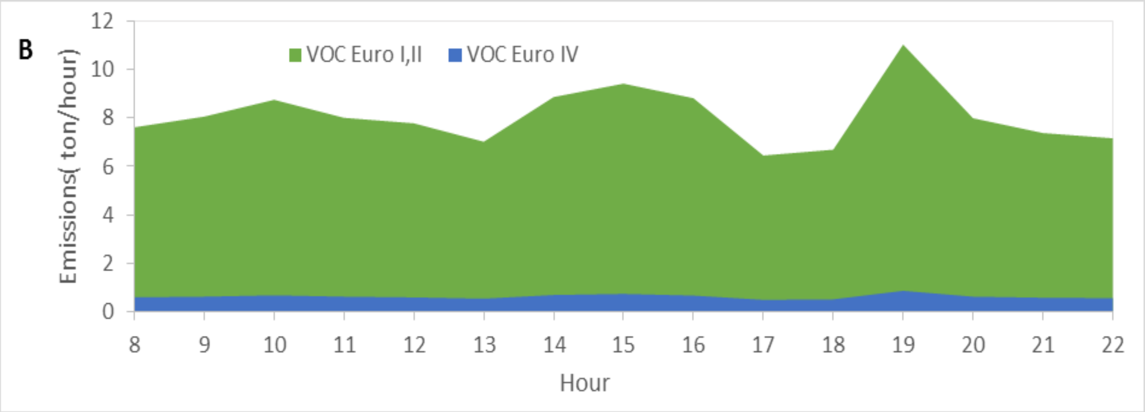
Table 6. The estimated vehicle-related greenhouse gas emissions (tones/day), using IVE model in Tehran

Total emission	Euro I,II	%	Euro IV	%
CO_2	16158.85	99.69	17092.46	99.95
N_2O	1.47	0.01	0.66	0.04
CH_4	26.40	0.3	2.01	0.01

Table 7. Comparison of reduction percentages in air pollutants' daily emissions) tons/day(, using Euro I, II, and Euro IV as fuel in transport system (taxis) in Tehran

Air Pollutant	Euro I,II	Euro IV	Reduction (%)
CO	9690	1199.3	87.6
VOC	121	9.48	92.2
VOC_{evap}	8.98	8.82	1.8
NO_X	150.6	32.3	78.6
SO_X	1.76	0.31	82.2
PM	1.96	0.75	61.7
1,3 Butadiene	2.15	0.19	91.4
Acetaldehydes	4.43	0.35	92.1
Formaldehydes	11.6	0.93	92
Benzene	12.76	0.16	98.7
N_2O	1.47	0.66	55
CH_4	26.4	2.01	92.4





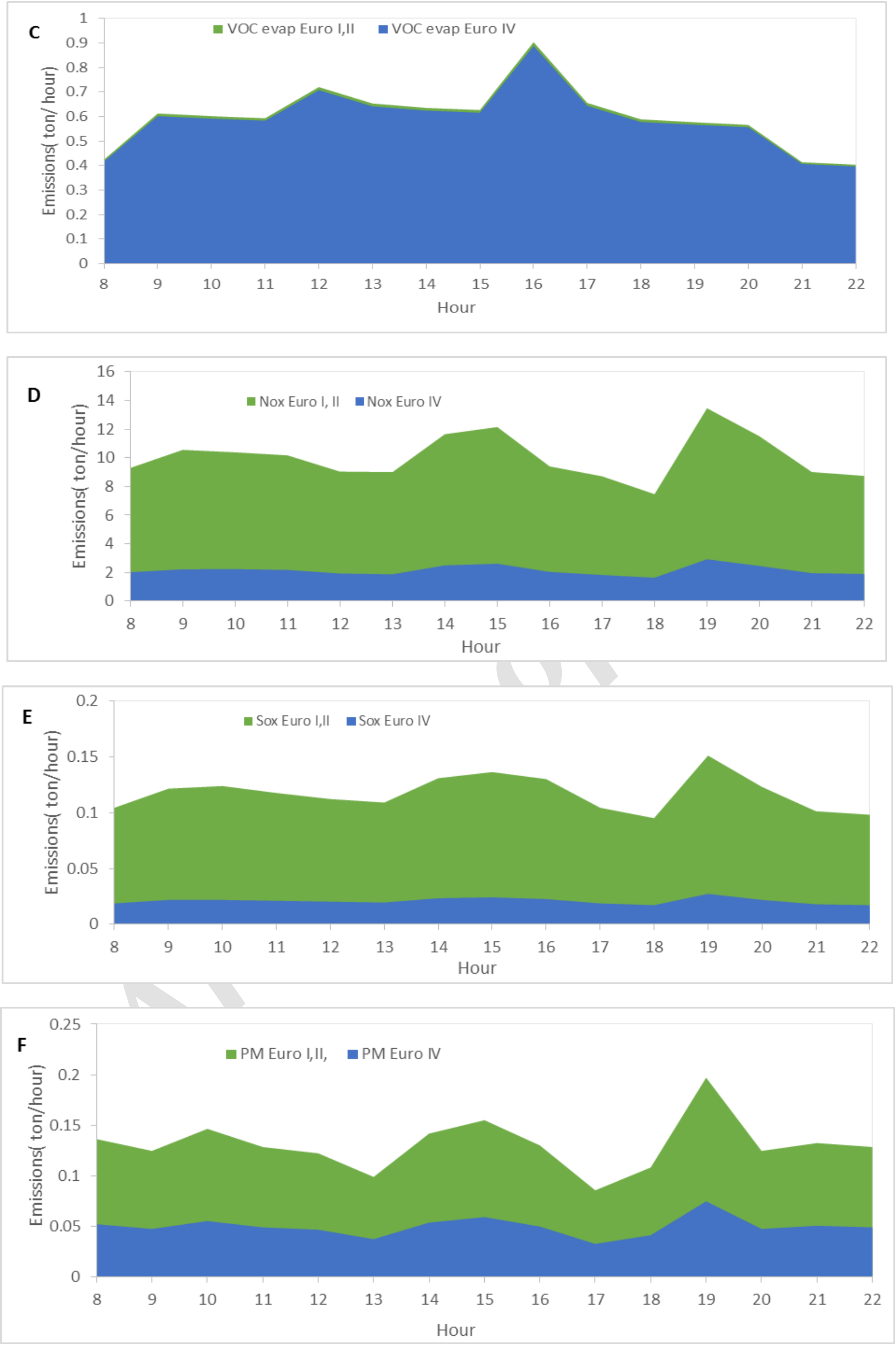


Fig. 3. Daily temporal distribution of running criteria pollutants emissions: (A) CO, (B) VOC, (C) VOC$_{evap}$, (D) NOX, (E) SOX, and (F) PM, released by taxis in Tehran in 2014

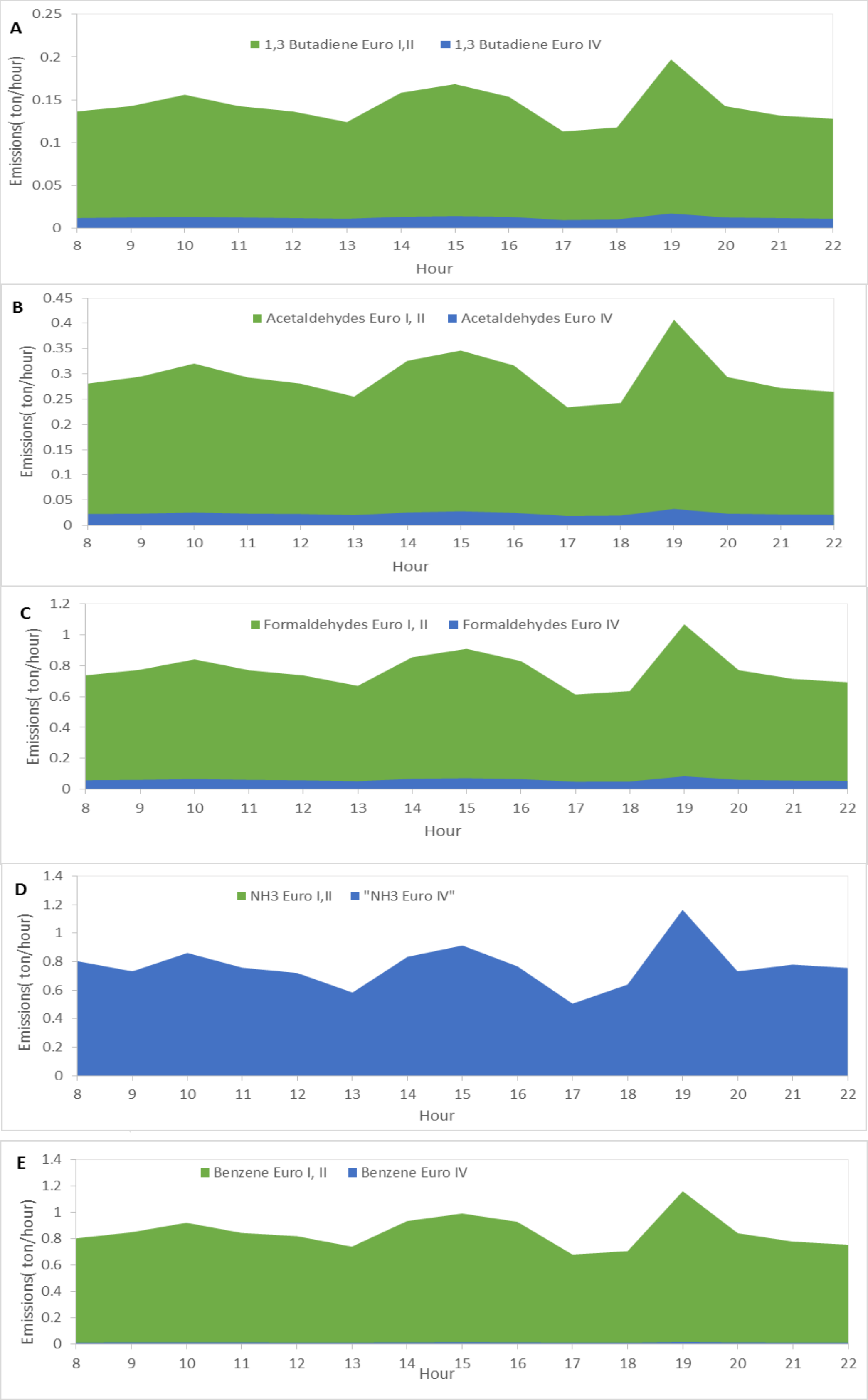


Fig. 4. Daily temporal distribution of running toxic emissions: (A) 1,3 Butadiene, (B) Acetaldehydes, (C) Formaldehydes, (D) NH_3, and (E) Benzene ,released by Taxis in Tehran in 2014

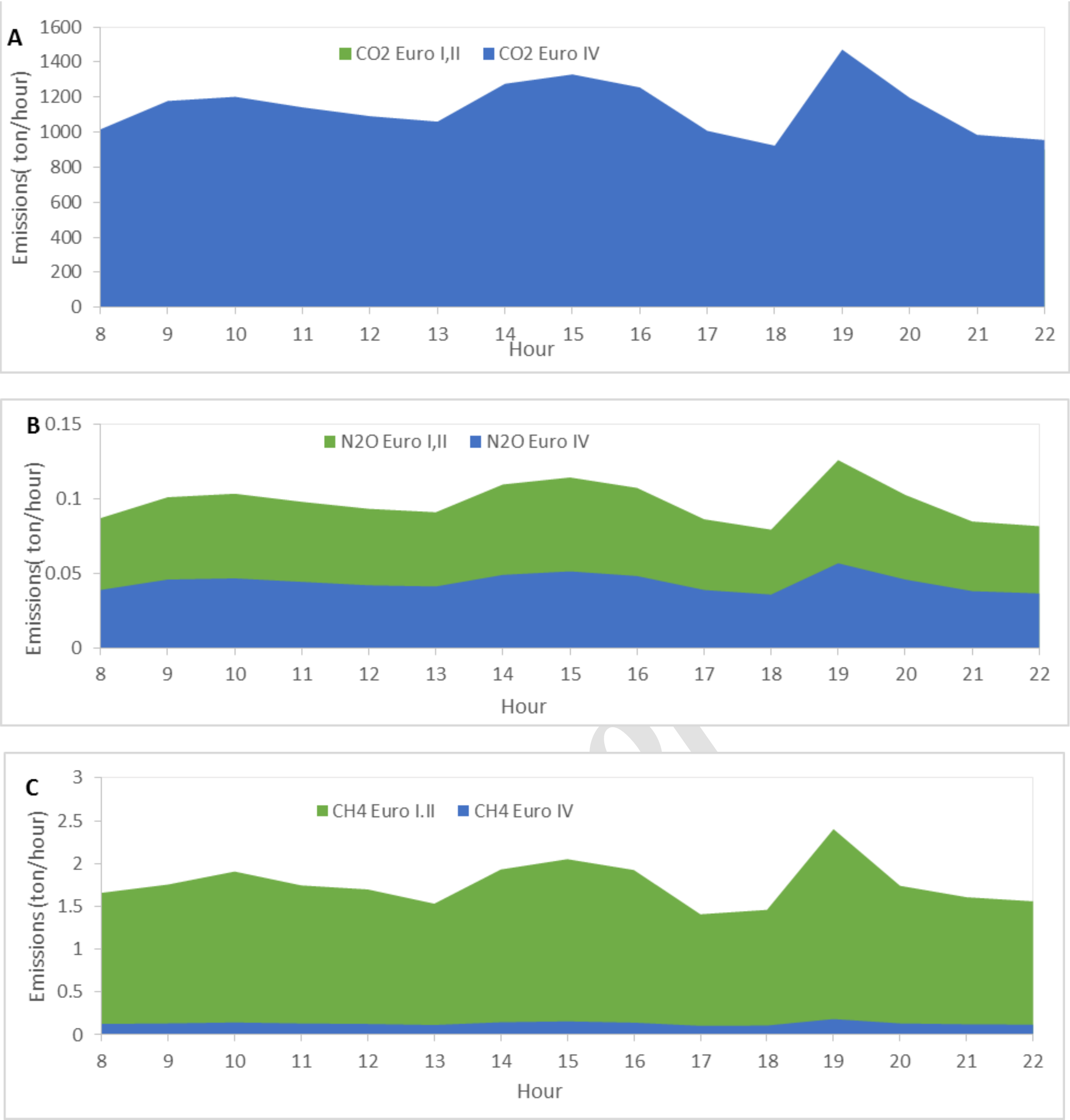


Fig. 5. Daily temporal distribution of running greenhouse gases emissions: (A) CO_2 (B) N_2O, and (C) H_4 released by Taxis in Tehran in 2014

According to the estimated health damages of total daily air pollution (Karimzadegan et al., 2008), it was evaluated about USD 16,224 for increasing each unit of PM10; USD 28,816 for each unit of CO; USD 1,927 for each unit of NO_2; and USD 7,739 for each unit of SO_2. The total cost will increase significantly if the chronic and indirect effects are added to the mentioned figure. Also, Naddafi et al. (2012) showed that, regarding the short-term impacts, PM10 had the highest health impact on Tehran inhabitants, having increased the total of 2194 out of 47,284 in a year.

Also, sulfur dioxide and nitrogen dioxide were responsible for about 1458 and 1050 cases of total mortality. In order to reduce the magnitude of health impacts from the estimated air pollution for the mega city of Tehran, it is needed to take urgent action to reduce the amount of the emitted air pollutants. In order to improve the air quality in Tehran city, studying the effectiveness of Euro IV as fuel in Tehran transportation system, it is recommended to consider other vehicle types and the start-up impacts on air pollutant's emissions in IVE model. The assessment of air pollutant's emission rates in different districts of Tehran can be used as the basis for management decisions by authorities; as a result, it is needed to study and determine the emission rate in each district separately. The quality of used fuel and vehicle technology, driver's behavior and driving cycle can be evaluated in each district.

CONCLUSION

This study focused on investigating the effectiveness of fuel quality improvement in Tehran's transportation system, using IVE model in 2014. Results show that about 45% of taxis were less than 5 years old, and were responsible for the production of three groups of criteria pollutants, global warming components, and air toxins in Tehran. Temporal variations of air pollutants' emissions show that during the rush hours (8-10 AM and 5-8 PM), the emitted air pollutants had their maximum values. Thanks to the clean fuel (Euro IV), there was a considerable reduction in criteria pollutants, air toxins, and greenhouse gases. The main contributor to emissions caused by taxis using moderate fuel (Euro I, II) was CO, having declined by 87.6%, due to Euro IV consumption in taxis. Also, Benzene as the predominant toxic emission, experienced a notable reduction of about 98.7%. Nonetheless, Euro IV consumption increased CO_2 (which was because of the complete combustion reaction instead of the incomplete one), and NH_3 (which was due to increased catalytic convertor efficiency). More expanded transportation system with more updated clean fuel can significantly reduce vehicular emissions, estimated by IVE.

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