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Review Article

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SOURCE IDENTIFICATION AND APPORTIONMENT OF AIR POLLUTANTS IN IRAN

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ABSTRACT:

Air pollution can adversely affect human health, vegetation growth, buildings and monuments throughout the world, especially in developing countries. There is an increasing concern about the various air pollutants including particulate matter (PM), volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) in ambient air of Iran. VOCs and PAHs are important types of air pollutants which are generated from human activities (e.g. transportation and industrial activities) in cites with high population density, whereas PM is formed from a variety of natural and anthropogenic sources. Iran, like most other countries in the Middle East, is affected annually by multiple dust storms. In general, the level of ambient PM originated from natural sources in some of Iranian cities such as Ahvaz and Zabol has been reported as the highest value throughout the world. When PM are associated with pollutants such as VOCs and PAHs in the lower atmosphere lead to the buildup of multiple pollutants and have the longest atmospheric lifetime and more readily penetrate into the lungs and consequently increase the mortality rate. Therefore, reliable source identification and apportionment of air pollutants is necessary and can be a useful tool for management and implementation of associated control strategies. This review has been focused on the source identification and apportionment of PM, VOCs and PAHs in some cities of Iran.

REVIEW

Environmental problems (e.g. water shortage and crisis, air pollution, deforestation, soil erosion) are major challenges of developing countries such as Iran [1]. Among them air pollution has been considered mostly in metropolitan cities because of its effect on public health. Air pollutants are typically carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), particulate matter (PM), volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) which may be released into the atmosphere due to natural and anthropogenic processes. Although a number of natural processes may release various pollutants into the air, anthropogenic activities are known as one of the main source of air pollution. During the last decade, high population growth, increasing urban-

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ization and industrialization in Asian countries lead to increase the atmospheric pollutions [2]. In these countries the environmental performance is lower than population growth and urbanization [3-5]. The concentrations of ambient PM in Asia's cities are generally twice the world average and more than five times of industrial countries [3, 6]. As a result, increasing human activity and fossil fuel consumption cause increasing release of pollutants into the atmosphere and also reduce urban air quality. In recent years, air pollution as a global problem has a high negative impact on human health and in general on the environment. World Health Organization reported that about 2.4 million people perish every year due to air pollution [7]. Among major air pollutants, PM, VOC and PAH_s are important air pollutants with significant effects on economic and human health, especially in those urban areas with low ventilation rate, undesirable geographical position and uncontrolled emission sources [8, 9].

VOCs are an important type of air pollutants which are generated in each urban and industrial area. VOCs play an important role in the formation of ozone and other photochemical oxidants such as peroxyacetyl nitrates (PAN) that leading to urban smog in troposphere [10, 11]. In general, the VOCs are pollutants released by both natural and anthropogenic sources and often associated with human activities, found indoors as well as outdoors [12]. VOCs are main contributors to O_3 formation and other photochemical oxidants in ambient air which can build up during several days [13].

PAHs are also a diverse group of organic compounds containing two or more fused aromatic rings of carbon and hydrogen atoms which are generated from a variety of anthropogenic sources [14, 15]. In general, PAHs compounds are a class of complex organic chemicals which may be generated by different processes such as high-temperature pyrolysis of organic materials, low to moderate temperature diagenesis of sedimentary organic material to form fossil fuels and direct biosynthesis by microbes and plants [16]. According to previous publications vehicle exhaust identified as a major source of PAHs which can be widely distributed in the atmosphere [17]. However, concentrations and profiles of PAHs from different sources in ambient air can change with environmental variables [17 - 19]. Numerous studies reported that PAHs have caused great concern specially when associated with PM [15]. In general, due to the variety of emission sources involved, it is necessary and important to identify the sources of PM emitted into the air. PM play an important role in human health effects, visibility degradation, and global climate change [20 - 22]. It has been shown that enhanced levels of PM associated with adverse environmental impacts, such as changes in the troposphere's chemical composition, radiation budget of the earth and troposphere's thermal structure [5]. The size of PM is from a few nm to tens of µm. Studies showed that particulates with aerodynamic diameter < 10 µm (PM_{10}) and particularly finer particles with aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$) can more readily penetrate into the lungs and increases the mortality rate [23, 24]. Particle size, source and composition are important determinant factors for deposition of PM at different regions of the pulmonary system [9, 25, 26]. In fact, particles with aerodynamic diameter of 0.01 µm to 10 µm, smaller than the diameter of a human hair, have a high risk potential to human health. Therefore, in recent years $PM_{2.5}$ have received more attentions in developing countries [9, 27]. Several of epidemiological studies indicated that PM concentration in urban areas has a clear correlation with the number of cardiovascular and respiratory disorders diseases [28 - 30]. Besides, several studies demonstrated that PM has most adverse impact for little children and the elderly people [31 - 33]. However, process involved in these health effects remains is highly uncertain and the pathogenic component of particles have not been plainly identified [32]. PM also can act as a potential carrier of harmful components such as organic and inorganic carbon as well as heavy metals which are known to cause inflammation in cultured lung cells [34 - 36]. Particulate matter is formed of a variety of solid and liquid substances derived from natural and anthropogenic sources. Many studies have demonstrated that sources of PM can be anthropogenic activities (e.g. road traffic, combustion of fossil fuels, power plants and various industrial processes) or natural sources occurrence from dust storm events, forest and grassland fires, living vegetation and marine salts [32, 37]. Dust storms, as a major source of mineral aerosols that usually occur in semi-arid and arid regions with low or no vegetation have a significant impact on the environment [33, 38, 39]. In the arid areas, each year several billion tons of dust are emitted to the atmosphere, which play an important role in dust aerosols transportation to the downwind regions located hundreds of kilometers away [33, 40, 41]. Arabian Peninsula and surrounding deserts are two major dust source area in the south-west Asia and Middle East and have been most active during the period of April to July [33, 42]. However, it has been reported that only 5 - 7% of total dust release into atmosphere is from natural sources [33]. This demonstrated that in both developed and less developed countries PM emissions due to road traffic that include emissions from motor vehicles and wear and tear of vehicle parts are known as a major source to total PM concentrations in urban atmosphere [35, 43-50]. It has been reported that motor vehicles emission particles mainly accumulated to fine PM (i.e $PM_{2.5}$), while with increasing distance to emission sources due to emissions of vehicle various parts (e.g., tires, brakes, and pavement abrasion) particle size is changed rapidly and lead to formation of coarse particles with size range of $PM_{2.5\text{-}10\mu m}$ [25, 51].

In recent years, due to development of various industries and also increase in the number of vehicles in urban areas, air pollution has become an important environmental issue in Iran. Therefore, in recent years many studies focusing on concentration, particles size distribution, effects on human health, chemical composition and source identification of PM and also dust in some cities of Iran [9, 33, 37, 38]. However, when PM is associated with other air pollutants in the lower atmosphere lead to the buildup of multiple pollutants and have the longest atmospheric lifetime. Therefore, source apportionment as a technique which is used for identifying and qualifying the various sources of air pollution, is very important in various cities of Iran. In this regard, the United Nations Education, Scientific and Cultural Organization (UNESCO), report of air pollution in Isfahan and Tehran, two main cities of Iran, could be one of the oldest study addressed this issue [52]. This review focuses on source identification and apportionment of PM, VOCs and PAHs in some cities of Iran.

Source identification and apportionment methods

Identification and apportionment of air pollutants can be implemented using various approaches such as emission inventories, receptor-oriented models and source-oriented models. Source apportionment methods mainly include evaluation of numerical data, detailed emission inventories and receptor models such as principal component analysis (PCA) [53], positive matrix factorization (PMF) [5], multiple linear regression (MLR) [54], chemical mass balance (CMB) [55] and UNMIX models [56] that have been widely used in various studies. Methods based on the treatment and evaluation of numerical data are used to identify pollution sources. For example, source identification of PM emitted from natural sources such as dust storm could be done using correlation between wind direction and levels of measured pollutant [57, 58]. However, this method is very simple and may not be precise. Emission inventories provide total emissions from all source categories in a certain geographical area and within a specified time span, usually a specific year. Furthermore, they can be used for evaluate the emission decreasing strategies impacts of anthropogenic sources. However, they are not applicable when natural emissions are important. Source-oriented models (e.g AERMOD and CALPUFF) can predict the distribution of air pollutants but they need the detail information of pollution sources as well as meteorological and geological data. Receptor models are mathematical methods based on statistical evaluation and concentration measurements of ambient samples at receptors and have been widely used to identify emission sources. Practically, CMB and multivariate receptor models such as UNMIX and PMF are often applied to identify the contribution of various sources in air pollution [58, 59].

Study area

Iran is a Middle East country and is located between Turkey and Iraq on the west and Afghanistan and Pakistan on the east; Persian Gulf and Gulf of Oman in the south and Armenia, Azerbaijan, Turkmenistan and the Caspian Sea in the north (Fig. 1). In general, about 60 % of Iran is mountainous and the remaining part is desert and arid lands. Its climate is mainly arid and semi-arid and it's subdivided into 31 provinces. In this study, source identification and apportionment of PM, VOCs and PAHs in 8 cities of Iran belong to 7 provinces are investigated. The cities are Ahvaz, Isfahan, Khorramabad, Mashhad, Tabriz, Tehran, Zabol and Zahedan (Fig. 1).

• **Ahvaz,** capital city of Khuzestan province, with an area of 220 km^2 and population of 1 million approximately is located in an arid area in southwest of Iran and vicinity of Iraq, Saudi Arabia, and Kuwait, which are the major sources of dust [60 - 63].

• **Isfahan,** is a city in central Iran with an area of 494 km^2 and population of 1.6 million [64]. Although the city is famous as a historical place in Iran, however it's one of the major industrialized region in the country where the city's air quality has been adversely affected by various industrial activities (e.g. steel and iron plants, cement factories, power plants, oil refinery and petrochemical industries, brick and gypsum industries, etc.) and transportation as well as dust storms.

• **Khorramabad** is the capital city of the Lorestan province with a population about 0.5 million people and the area of 25 km^2 approximately, is one of the most important cities in southwestern Iran [65].

• **Mashhad** is the capital city of Razavi Khorasan Province that known as the second most populous city in Iran (population is up to 2.8 million). This city with an area of 850 km^2 is located in the northeast of the country closed to the borders of Turkmenistan and Afghanistan [66].

• **Tabriz** is the megacity of Eastern-Azerbaijan Province in northwest of Iran. Its area and population are 324 km^2 and 1.7 million, respectively. Industries such as oil refinery, thermal power plant, petrochemical complex and a cement factory are the main sources of air pollution in this region [9].

• **Tehran**, the capital city of Iran is and as one of the largest cities in the world having about 730 km^2 area and more than 8 million population. The city is located in a valley at the foot of the Alborz Mountains in northern Iran and has generally a moderate to dry climate [56].

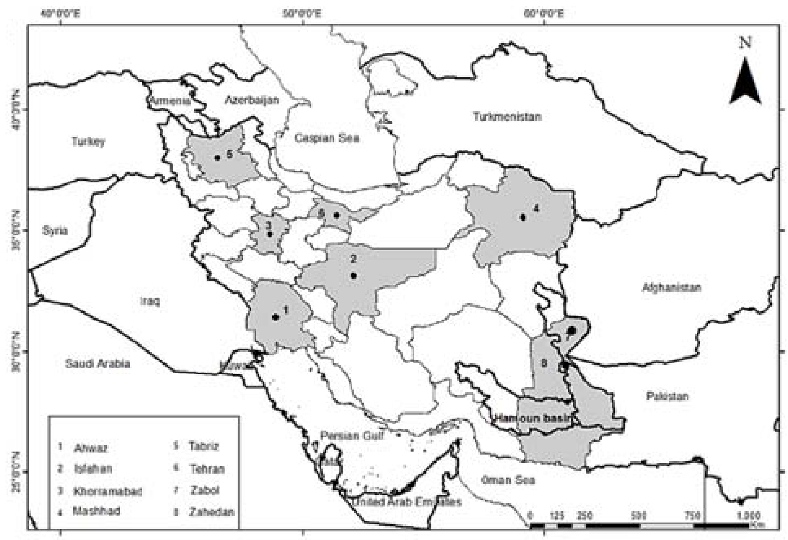

Fig. 1. Location of the Iranian cities investigated in the current study

• **Zahedan,** is the capital city of Sistan and Baluchestan Province with population of 0.8 million and is located in southeast Iran closed to the Iranian border with Pakistan and Afghanistan. It is considered as one of the most active dust source regions in southwest Asia [33].

• **Zabol**, is one of the cities of Sistan and Baluchestan Province, located in southeast Iran with population of 0.1 million, approximately. It has been introduced by WHO as the world's most polluted city mainly because of dust storms in the region (http://www.worldatlas.com). However, it was challenged by Iran's Department of Environment implying that WHO's report was based on projection models which were only reliable as much as a model. By the way, it is acceptable that this region is one of the highest polluted area with airborne dusts throughout the world.

Source identification and apportionment of PM

Source of PM in Iran like most of the other area throughout the world is categorized into natural and anthropogenic sources. Recent studies showed that main dust source in Iran, similar to the other countries in the Middle East, is desert dust storms originated from Arabian Peninsula, Kuwait, Iraq, and parts of Iran [61], which have significantly increased PM concentration in the ambient air [33, 38, 67].

World Health Organization reported Ahvaz city as one of the most polluted cities in the world because of increased PM_{10} concentration in air [5, 68]. Average annual precipitation is 250 mm in this city [69]. One of the main reason for increasing PM_{10} level in this region could be the occurrence of the Middle Eastern dust storms [61]. As a result, the daily medium PM_{10} concentrations in Ahvaz reached to about 5013 µg/m^3 [70]. In addition, a four years study showed that the maximum concentration of PM_{10} in Ahvaz was higher in summer in comparison to the other seasons [69]. Sowlat et al. (2013) identified the potential sources of PM_{10} in ambient air of Ahvaz city using the PMF receptor model. They considered eight factors including crustal dust, marine aerosol, road dust, metallurgical plants, secondary aerosols, motor vehicles, petrochemical industries as well as fossil fuel combustion and vegetative burning as the potential sources of PM_{10}. Their results revealed the high relative contribution of the crustal dust which was about 41%, while vegetative burning and road dust showed the minimum contribution (Fig. 2) [5].

According to the results of the PMF model, it was found that contribution of natural sources was higher than anthropogenic sources most probably due to the occurrence of dust storms in the region [5]. Moreover, the presence of petro-

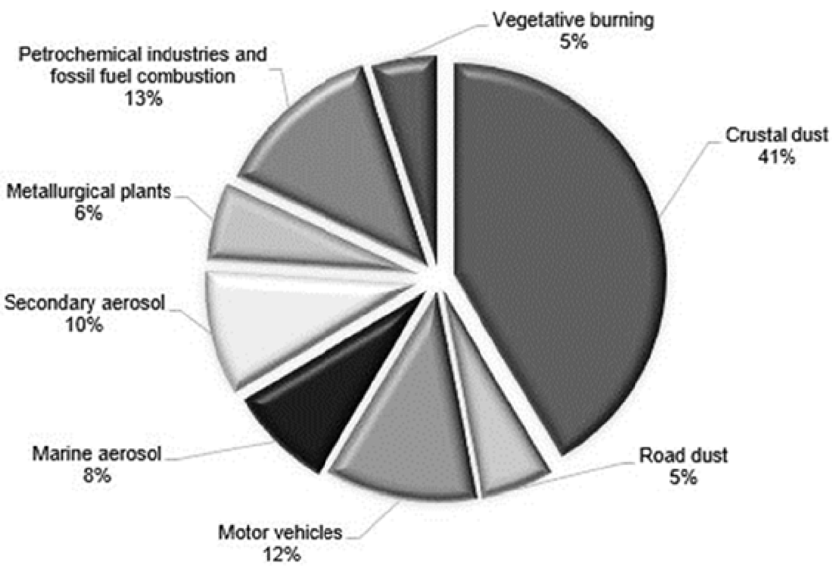

Fig. 2. Mean relative contributions of various sources of PM_{10} obtained from PMF model in Ahvaz city, Iran [5].

chemical industries, combustion of fossil fuels, motor vehicles, traffic and agricultural activities are known as other sources of air pollutants in the region. Shahsavani et al. (2012a) investigated PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ concentrations to extract the patterns of diurnal variation of PM concentrations and define the temporal trends of PM ratios from April to September 2010 in Ahvaz. The results indicated that the longest dust event occurred during June and had a peak concentration of 2028 μg/m^3. Fig. 3 shows the mean concentrations of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ from April to September 2010 in the region [62].

Fig. 3 illustrates the temporal trends in the mean values of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ concentrations over the period of April to September 2010. It is apparent that the highest monthly averages values of PM concentrations were observed in lasted May and early June, when the wind speeds were also the highest. These findings highlighted the important of Shamal wind (i.e. a hot northwesterly wind that is dominant during spring) in the dust events of Ahvaz area which brings large amount of dust from southern areas of Iraq. These results were consistent with the results of other studies in Kuwait, Iraq, and Saudi Arabia [71]. Broomandi et al. (2017) reported that the main origins of dust particles of Ahvaz city were northwest Iraq and east Syria which were identified by HYSPLIT

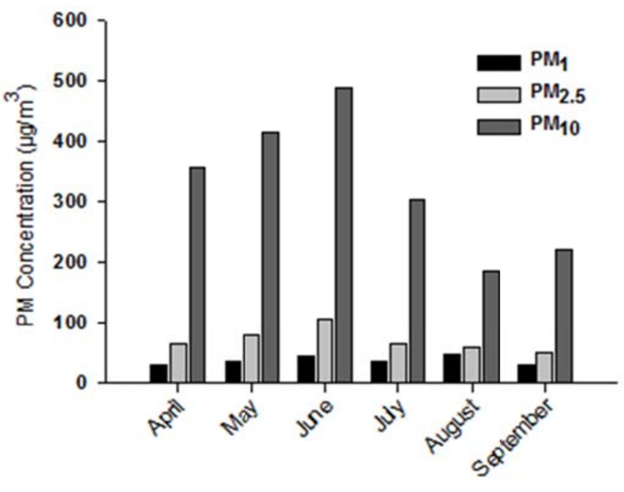

Fig. 3. Mean concentrations of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ from April to September 2010 in Ahvaz city, Iran [62].

model. In this regard, an eroded sedimentary environment outside Iran has been introduced as the origin of airborne dusts in Khuzestan province [72].

It has been reported that about 78% of air pollution in Isfahan city is due to on-road vehicles and non-road vehicles and engines which cause respiratory disease in this region (Rashidi et al., 2013). Transboundary dust storm, probably originating from Iraqi arid land introduced as the major source of atmospheric deposition in the Zagros area and central Iran which may reduce the contribution of local soils and sediments to aerosols [73]. Industrial and urban activities may also affect PM level in the air of Isfahan city, however there is no published document in our knowledge. PM may be associated with other pollutants such as heavy metals. Norouzi et al., (2016) used Platanus orientalis L. leave as a bioindicator for identification of heavy metals in atmospheric dusts of Isfahan Province. Their results showed that according to the enrichment factor (i.e. the ratio of each element and reference element in the sample and in the crust or soil) and principal component analyses some metals in the dust such as Zn originated from vehicular emissions, oil combustion as well as wear and tear of vehicle tires, while the potential sources of Cu were industrial processes, traffic and combustion of fossil fuels [74]. They also introduced the polluted soils in Isfahan Province as the main natural source of Mn and Ni in dust followed by anthropogenic activities. Norouzi et al. (2017) in a case study of atmospheric dusts of Isfahan introduced biomagnetic approach as a rapid and inexpensive method for identification of heavy metals related to anthropogenic and other traffic related sources. The annual atmospheric dust deposition rate of lands around the Isfahan city was recorded about 61 ton / km^2 which was found to be the highest in the summer in comparison to other seasons [75]. However, the most problematic season was winter because of the maximum concentration of heavy metals which was related to meteorological conditions, specially the wind speed.

Considering the urban structure unsuitable for vehicular traffic and geographical location of Khorramabad, this city has a great potential to increase the concentration of PM. Mirhosseini et al. (2013) measured PM_{10} and $PM_{2.5}$ concentrations during the period of April 2010 - March 2011 in the ambient air of the city. Their results showed a significant difference between the mean values of PM_{10} concentration in the season of summer comparing to other seasons. However, the results showed that the annual means of PM_{10} and $PM_{2.5}$ concentrations in Khorramabad city were lower than the standard amount of Table 1Iran. indicates the average PM_{10} and $PM_{2.5}$ concentrations in different season of Khorramabad city. In general, the average concentration of PM_{10} and $PM_{2.5}$ in summer season was higher than the national standard. The main reason could be the occurrence of very severe dust storms in Iraq in the summer which might have a significant impact on the air quality of the region [65].

It has been reported that development of industries and also increase in the number of vehicles are the main reasons of reducing air quality in Tabriz, especially in winter season [76]. Therefore, Tabriz known as one of the seven polluted Iranian metropolitan cities [77]. In general, atmospheric thermal inversion in cold season and Middle East dust storm from Iraq in the warm season are two important factors affecting air quality of the city [77]. In order to evaluate the PM concentrations two urban and industrial suburban sites in Tabriz were selected during period of September 2012-June 2013 [9]. Table 2 illustrates average concentrations of PM_1, $PM_{2.5}$ and PM_{10} during different months in the selected sites. The results revealed that the highest and lowest concentrations of PM were observed during cold and warm months, respectively. In general, the annual average concentrations of PM_1, $PM_{2.5}$ and PM_{10} in industrial suburban sites was more than urban sites. In fact, PM concentrations mainly affected by the type of industries and their quantity of production along

Table 1. Mean concentrations of PM_{10} and $PM_{2.5}$ ($\mu g/m^3$) of Khorramabad city in different seasons [65].

	Standard concentration (NAAQS – 24h)†	Winter	Spring	Summer	Autumn
$PM_{2.5}$	35	39	94	157	50
PM_{10}	150	44	108	177	62

Table 2. Mean concentrations ($\mu g/m^3$) of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} in two urban and industrial suburban sites in Tabriz [9].

Month	Urban sampling site			Suburban sampling site		
	$PM_{1.0}$	$PM_{2.5}$	PM_{10}	$PM_{1.0}$	$PM_{2.5}$	PM_{10}
September	24	39	85	-	-	-
October	31	56	130	-	-	-
November	15	23	44	37	44	142
December	33	41	84	35	45	115
January	40	48	110	30	39	106
February	41	53	106	38	47	111
March	28	40	95	17	22	53
April	18	24	44	37	49	134
May	13	20	43	26	35	107
June	22	24	47	-	-	-

with the duration of their activities. On this basis, it was observed that the PM concentrations could not be related to the monthly trend. The average of $PM_{2.5}$ / PM_{10} ratio in the urban site was more than suburban sites. This high portion of $PM_{2.5}$ than PM_{10} in the urban site might be due to the higher traffic in Tabriz city which could be mixed with the emission from the nearby residential area. It should be noted that the sometimes local dust occurred in urban and suburban areas which can be led to increasing PM concentrations in ambient air [9].

Tehran air pollution is affected by stationary and mobile sources and also its geographical location and topography [3]. Tehran is one of the worst cities in the world in terms of air pollution, mainly because of mobile sources rather than stationary sources. The source apportionment of PM_{10} in Tehran city revealed that the relative contributions of mobile and stationary sources were 83% and 17%, respectively (Fig. 4) [78]. In fact, many studies confirmed that mobile sources are the main reason of increasing air pollution in Tehran which mostly focused on PM concentration and size [79, 80].

However, one important sources of PM_{10} in south of Tehran is heavy traffic and wind erosion of desert areas located in the region. Halek et al. (2004) reported that high dependency on private passenger cars in Tehran, low price of fuel, shortage of public transport facilities particularly during the peak hours are some of the main contributors to PM_{10} emission in Tehran and suburban areas. Moreover, their results indicated the increasing of PM concentration during the evening rush hours (15:00 – 20:00) and morning rush hours (06:00 – 09:30), whereas, traffic levels and pollutant concentrations were significantly lower on Fridays. It has been reported that the monthly average of PM_{10} in Tehran is high in autumn and low in spring [81]. Bidhendi et al. (2007) measured PM concentration and particles size distribution of twenty sites during period of January 2004 - January 2005 in Tehran. The substantial difference in mean total suspended particulate in twenty sites highlighted the importance of motor vehicles as a major source of PM in the ambient air [79]. These findings are consistent with the results of previous studies [82]. Furthermore, Halek et al. (2010b) investigated season variation of PM_1, $PM_{2.5}$ and PM_{10} concentration in five stations of Tehran. In general, it was found that the average concentrations of PM_{10}, $PM_{2.5}$, and PM_1 in the cold seasons were higher than the warm seasons (Table 3). Besides, it was revealed that increasing PM_1 concentration was much higher than the PM_{10} and $PM_{2.5}$ concentrations [80]. The main reason of increasing PM concentrations in the cold season in Tehran can be due to city's geographic position which led to increasing the volume of trapped particles. As a consequence, thermal inversion that traps Tehran polluted air is often observed in the cold seasons [80]. Givehchi et al. (2013) identified the dust emission from desert region as a natural source contributed to PM_{10} in Tehran air pollution. They reported that the deserts area in Iraq and a part of eastern Syria

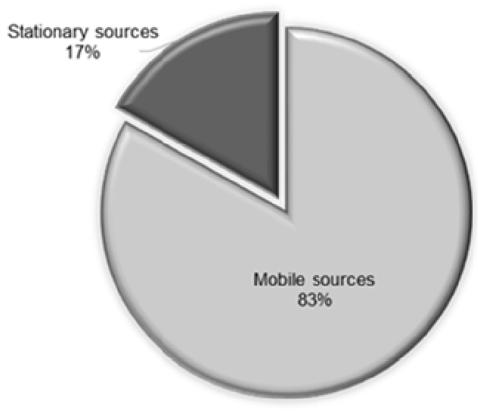

Fig. 4. Mobile and stationary sources relative contribution of PM_{10} in Tehran city [79].

Table 3. Average concentrations (µg / m^3) of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ in warm and cold seasons in Tehran [81].

Particulate matter	Warm seasons	Cold seasons
$PM_{1.0}$	16	54
$PM_{2.5}$	25	42
PM_{10}	98	184

are the major sources of dust in Tehran and more than 90% of the dust consisted of PM_{10} [38].

Zahedan and Zabol are considered as the main cities of Sistan and Baluchestam Province. This region has an arid climate with an annual average precipitation of 55 mm occurring mainly in winter. In recent years, several studies investigated concentration of $PM_{2.5}$ and PM_{10} in this region. Rashki et al., (2011) measured PM_1, $PM_{2.5}$ and PM_{10} concentrations during the period of July 2008 - March 2010 in Zahedan city. The results indicated that the monthly mean PM_{10} concentrations during the summer was higher than the winter, probably because of dust storms emitted from the nearby deserts [83]. It was reported that annual variation of monthly mean $PM_{2.5}$ and PM_{10} concentration was somewhat similar but this was in contrast with annual variation of monthly mean $PM_{1.0}$ concentration which was higher in winter in comparison to other seasons [83]. The difference in the annual variation between PM_{10} and PM_1 could be due to differences in soil properties of source regions. It was also demonstrated that main anthropogenic source of PM in Zahedan urban ambient air could be related to fossil fuel combustions, vehicular traffic and industrial activities that release a major value of near-surface anthropogenic aerosols. However, one reason for increasing $PM_{2.5}$ and PM_{10} concentration during summer months, can be thermal heating at the surface and the increase of the mixing layer height favors buoyancy and the dilution of anthropogenic aerosols (PM_1). But another reason can be decreasing rainfall in summer which credit accumulation of road dust. However, as a consequence, wind speed over Zahedan in summer acts as a supplemental tool for increasing PM concentration and deteriorating the air quality [83]. Furthermore, Rashki et al., (2012) measured PM_{10} concentrations over Zabol city during September 2010 to July 2011. Their results indicated dust storms which occurred during summer present larger grain sizes and as a consequence, a smaller fraction of particles was under 10.0 and 2.5 µm [33]. Table 4 show monthly mean $PM_{2.5}$ and PM_{10} concentrations in Zahedan and Zabol. There was a similar pattern of PM_{10} concentration in different seasons of Zahedan and Zabol cities, but with much higher values in the former site [33]. These major differences in PM_{10} concentrations between the two adjacent cities are attributed to severe dust storms that originated from Hamoun basin which directly affect Zabol. In general, Hamoun basin is known as an intense dust source region which cause a further increase in PM_{10} concentrations in Zabol rather than Zahedan city.

Source apportionment of VOCs

In general, industrial activities in the metropolitan cities of the world lead to the enhancement of VOCs level in the atmosphere. In order to devise effective air quality control, Iranian Department of Environment has limited release of benzene, toluene, ethyl benzene and xylenes (BTEX) into the air of some Iranian cities. Despite, in some cities such as Tehran so far it has been failed to effectively control the excess BTEX emissions [84]. Therefore, it is necessary that identify VOCs sources and to evaluate the individual

Table 4. Monthly mean $PM_{2.5}$ and PM_{10} concentrations (µg / m^3) in Zahedan and Zabol cities, Iran [33, 84].

	July 2008 to March 2010				September 2010 to July 2011			
	Zahedan				Zabol			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
$PM_{2.5}$	32	32	38	29	-	-	-	-
PM_{10}	107	121	172	114	273	289	683	484

contribution of VOCs sources in Iran. In order to identify VOC sources in Tehran city, Dehghani et al. (2016) identified the various source contributions of BTEX at an industrial site in the western Tehran during the winter and spring seasons using UNMIX as a multivariate receptor model. Among the various major anthropogenic sources for VOCs, three main groups of sources were identified including solvent and painting sources (e.g. vehicle manufacturing), vehicular emissions and fuel evaporation and mixed origin sources (e.g. rubber and plastic manufacturing, leather industries and miscellaneous sources (Table 5). It was observed that the mixed sources compared to another sources had the highest contribution of total BTEX [56]. However, results indicated a distinct seasonal variation, whereas the concentrations of total BTEX were significantly higher in the winter than in the spring season. There are two reasons leading to increase concentration of BTEX in winter season. Firstly, high stability of the atmosphere leading to accumulation of traffic rush hour and industrial emissions nearby road level in winter. Secondly, use of cleaner fuel which was replaced to dirty fuels in Tehran from February to March 2015 leading to reduction of BTEX concentration in Spring season.

Table 5. Sources contribution of BTEX in Tehran city obtained by UNMIX model [56].

Source categories	Sources contribution (%)
Solvent and painting	8
Motor vehicle exhaust	33
Mixed sources	59

Increasing the growth population and industrial activities in Mashhad city has introduced this city as the second air polluted city in Iran. In addition to thermal inversion, air stability and decrees of rain value led to in the accumulation of pollutants in the city air. Sarkhosh et al., (2015) investigated the contributions of various sources of ambient VOCs during the period of December 2012 - March 2013 at the center of the Mashhad city using the UNMIX model. Source apportionment results showed a good correlation between measured and predicted values by the UNMIX model and main source of VOCs was road traffic [66]. Fig. 5 presented various sources contribution of VOCs in Mashhad city.

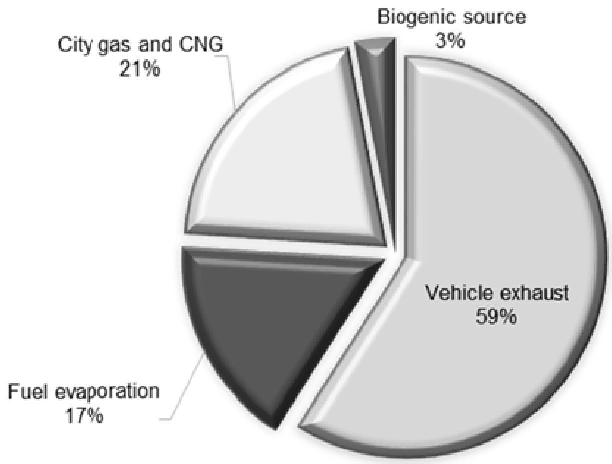

Fig. 5. Contribution of various sources to ambient VOCs in Mashhad city obtained from UNMIX model [66].

Recently, there was a tendency toward source identifications and apportionment of BTEX in Ahvaz city due to wide use of BTEX compounds in many industries especially petroleum industries and increasing the number of motor vehicles and their harmful effects on human health. Rad et al., (2014) measured ambient concentrations of BTEX at 12 points in Ahvaz from July to September 2012 and January to March 2013. Their results showed that atmospheric concentrations of BTEX in Ahvaz were influenced by seasonal and spatial variability. A comparison between BTEX level in four different parts of the city as residential areas, industrial areas, high-density traffic area and entrances and exits of the city revealed that the highest levels of BTEX were observed in the high-density traffic area at both sampling periods (Table 6). Besides, the lowest and highest levels of BTEX were observed in summer and winter, respectively. This is probably due to increases in solar radiation and photochemical reactions in summer season [11].

Table 6. Mean concentrations of BTEX in different parts of Ahvaz city [11].

Sampling point	Concentration (μg / m^3)
Residential areas	4.37
Industrial areas	14.58
High-density traffic area	13.72
Entrances and exits of the city	0.92

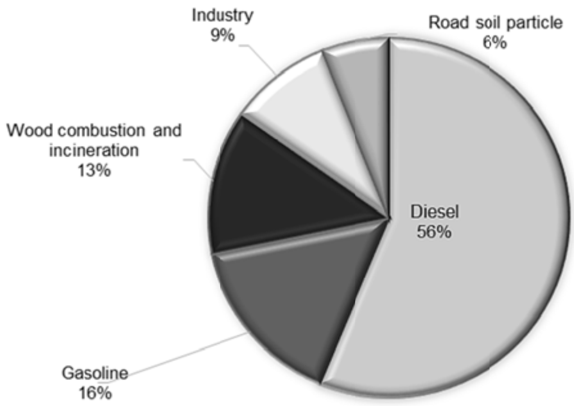

Fig. 6. Contribution of different sources of PAHs in Tehran [86].

Source apportionment of PAHs

Moeinaddini et al. (2014) identified vertical concentration profiles in different altitudes (10, 100, 200 and 300 m) and source contributions of PAHs in particle samples with the size of 4 μm which were collected from the Milad Tower of Tehran metropolitan area, during the period of fall and winter. They used PMF model and five sources including diesel, gasoline, wood combustion and incineration, industry, and road soil particle were apportioned [85]. The highest average concentrations of PAHs were obtained in the 10 and 100 m samples, which highlighted the contributions of local sources, specially the fuel combustion of vehicles (Fig.6). In general, the most abundant PAHs component during the October 2011 to March 2012 in Tehran city were: Naphthalene, acenaphthylene, benzo[a]anthracene, fluorine, benzo[e]pyrene, phenanthrene, acenaphthene. As a result the higher contribution of diesel source was probably due to one large train station and three bus terminals in Tehran. It was also found that with increasing altitude, the contributions of gasoline and road soil particles were reduced which was similar to the result of [86]. PAHs from diesel sources could be originated in the lowest altitude (10 m) and rather from the traffic and industrial activities in vicinity areas, while PAHs from industry sources might be originated in the highest altitude (300 m) [85]. According to previous studies, gasoline-fueled cars and motorcycles are important sources of hydrocarbons in Tehran [78].

Investigation of PAHs concentrations in the air of Isfahan city revealed that their concentrations in non-working days was lower than working days of a week revealing the anthropogenic sources such as transportation and industrial activities [87]. Their results also showed that the concentration of benzo[a]pyrene, as an index of aromatic hydrocarbons, was 2.72 ng/m^3. However, there is a lack of information about PAHs and VOCs apportionment in ambient air of most of Iranian cities.

CONCLUSIONS

In recent years, with rapid industrial and economic developments, Iran is facing with serious air pollution problems. Transportation, extensive use of fossil fuels, outdated urban fleets of gasoline and diesel vehicles, industrial sources within and close to the city boundaries and natural dust have been introduced as the major sources of large Iranian cities [88]. In general, in cities with high population density such as Tehran the main source of air pollution is anthropogenic sources especially mobile sources, while in cities such as Ahvaz, Zahedan and Zabol the main source of air pollution is particulate matter from natural sources. Ahvaz and Zabol have been mentioned by WHO as the most polluted cities throughout the world, mainly because of high concentration of PM in the air. Arid climate and drought together with mismanagement of water and ecosystems threaten the wetlands and rivers in various locations of Iran. Considering that these ecosystems are currently known as one of the main source of PM, they should be rehabilitated and retained to enhance air quality of neighboring cities. Furthermore, cooperation of neighboring countries including Iraq, Kuwait, Saudi Arabia and Syria to prevent desertification and soil erosion and thereafter to control the dust storms is a vital issue. In this regard, the role of countries such as Turkey and Afghanistan in water management of rivers originating from those countries for wetlands rehabilitation is very important and should not be neglected.

Source identification and apportionment of air pollutants in various locations of Iran is an important approach in environmental management and implementing the associated control strategies of air pollutants. Although various studies have been conducted throughout the country, however it seems that comprehensive studies are needed to be conducted to find the source and apportionment of different pollutants in ambient air. In this regard, investigation of pollutants which have a significant effects on human health such as persistent organic pollutants, PAHs and BTEX as well as gaseous pollutants (e.g. SO_2, NOx, O_3 and CO) are highly recommended.

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ETHICAL CONSIDERATIONS

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, redundancy, etc.) have been completely observed by the authors.

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