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Full Length Research Paper

Seasonal variation of mercury vapor concentrations in industrial, residential, and traffic areas of Ahvaz city, Southwest Iran

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Mercury has been known as a toxic substance that could raise potential risks to human health. The main anthropogenic sources of mercury pollution in air include combustion of fossil fuel, metal smelting and processing, and vehicle transportation all of which exist in Ahvaz city in Southwestern Iran. Ambient air mercury vapor concentrations were measured in summer and winter in industrial, residential and traffic areas in five sampling points. Results show that mercury level was high in sampling point near steel companies and it was lowest in the residential zone. Also, the average amounts of mercury vapor were 19.9 and 20.7 ng/m^3 in summer and winter, respectively.

Key words: Air pollution, mercury vapor, urban area, emission source, Ahvaz city, Iran.

INTRODUCTION

Mercury is a naturally-occurring heavy metal that is a leading concern among air toxic metals because of its volatility and persistence (Pavlish et al., 2003; Holmes et al., 2009). Furthermore, mercury can be converted to methyl mercury (Me-Hg) and accumulated in the food chain, posing a potential threat to human health (Clarkson, 1993; Pirrone and Wichmann-Fiebig, 2003). Also, mercury interacts and interferes with the body's biochemical processes (Rooney, 2007). It can be released into the atmosphere from a variety of natural and anthropogenic sources (Lin et al., 2006; Hissler and Probst, 2006). Waste incineration/disposal, coal combustion, metal smelting, paper/pulp production, refining and manufacturing and chlorine-alkali production are currently major global anthropogenic mercury emission source categories (Alvim-Ferraz and Afonso, 2003; Mukherjee et al., 2004; Streets et al., 2005; Wang et al., 2000; Feng et al., 2002; Hassett et al., 2004; Bullock, 2000; Feng et al., 2004). The atmosphere is the main pathway for the distribution of mercury in the global environment (Camargo, 2002) and numerous studies have shown this important subject. Particulate mercury in ambient air of Shanghai was measured by Xiu et al. (2005). Golubeva et al. (2002) reported that the levels of mercury in Murmansk, and over Kola and Motovsky Bays were associated with a primary direction of a near-surface wind from the nearest sources of mercury emission located in the Russian North region. Atmospheric mercury is deposited on the earth or water bodies mainly through dry deposition or washout of particle or water-soluble gaseous divalent mercury (Hedgecock and Pirrone, 2001). Also, Hissler and Probst (2006) concluded that most of the atmospheric mercury deposition is trapped by the organic matter contained in the soils and in the stream sediments.

The main aims of this study involved the determination of mercury vapor levels in urban ambient air in warm and cold seasons, and investigation of different concentration levels of mercury vapors due to various land uses (for example, residential, traffic, and industrial area).

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Table 1. Description of sampling stations in Ahvaz city, Southwest of Iran.

Description of station	Name of station	Code of sampling station
Located in industrial zone such as steel factory	Foolad industry	1
Located in traffic zone with high traffic	Amaniyeh	2
Located in traffic zone with high traffic	Mosala	3
Located in industrial zone	Sarbandar road	4
Located in residential zone	Kiyanpars	5

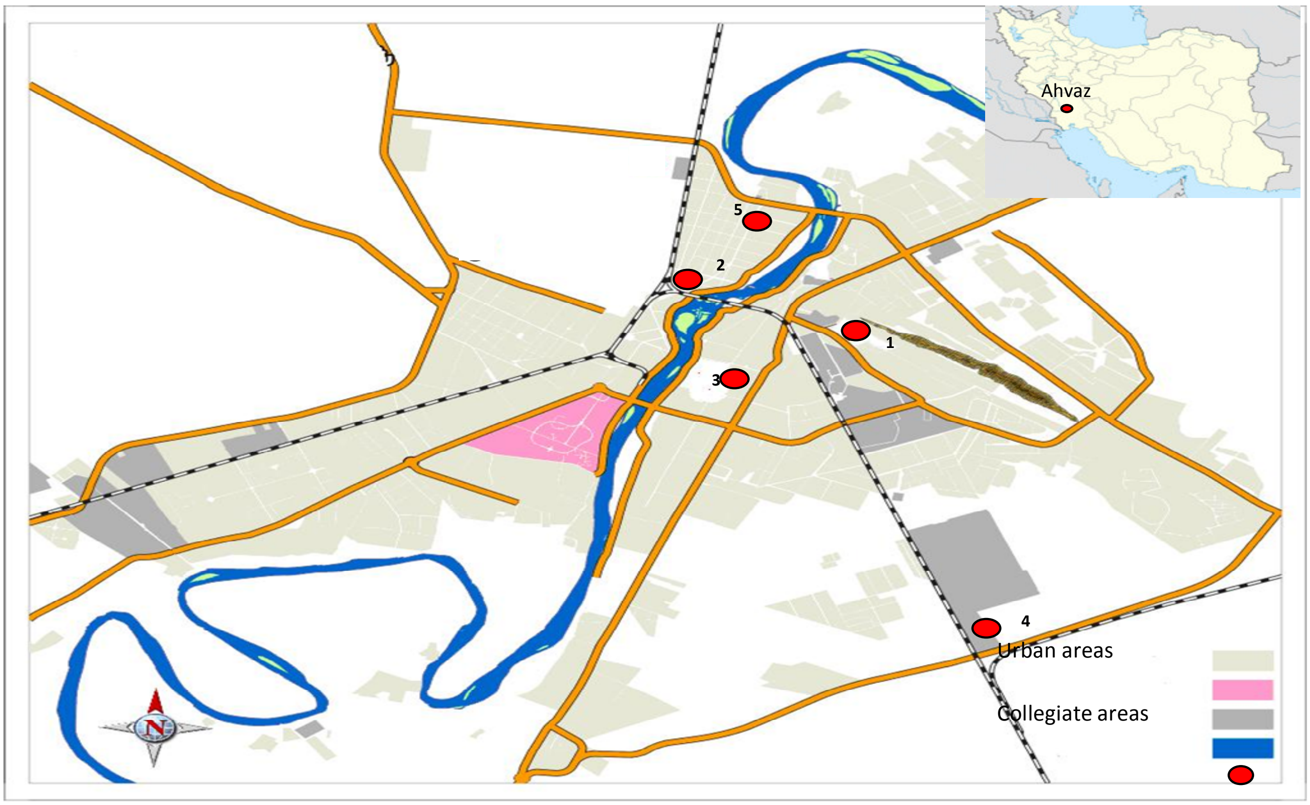

Figure 1. Situation of sampling stations in Ahvaz city, southwest of Iran.

MATERIALS AND METHODS

Study area

The city of Ahvaz is the capital of the Iranian province of Khouzestan. It is built on the banks of the Karun River and is situated in the middle of Khouzestan Province (31°19'45" N and 48°41'28" E). The city has an average elevation of 20 m above sea level. The city had a population of 1,338,126 in 2006. Ahvaz has a desert climate with long, extremely hot summers and mild, short winters.

Ahvaz is an industrialized city and the major parts of oil industries are located there. Also, some other industries such as steel and pipe processing companies, and carbon black manufacturing are adjacent the city. Due to this, we selected three types of sampling stations including, industrial, traffic, and residential areas. The name and description of all the stations are provided in Table 1. Also, the situation of sampling points in Ahvaz city, are illustrated in Figure 1.

Sampling

The sampling campaign was in accordance to NIOSH (1994). The flow rate was controlled at 0.25 to 5 L/min. A cellulose–fiber filter and Hopcalite sorbent was used. Sampling was performed during the summer and winter of 2010 in five stations in Ahvaz city. Generally, sample collection period was 6 h and 40 min in each station. The temperature, relative humidity and wind speed were recorded during the sampling period. All the sorbent tubes were caped and covered by aluminum foil and packed securely for shipment to the laboratory to prevent contamination (NOISH, 1994).

Chemical analysis

The concentration of mercury was determined by atomic adsorption, cold vapor following wet digestion. The sampled filter was treated by concentrated HNO_3/HCl at 25°C and diluted to 50 ml.

Table 2. Average of measured meteorological parameters during sampling period.

Station code	Wind speed (m/s)		Humidity (%)		Temperature (°C)	
	Winter	Summer	Winter	Summer	Winter	Summer
1	7	7.7	46	21.3	27.5	41.5
2	3	6	38.3	20.3	25.2	46.4
3	5.6	5.3	30.6	21.6	26.4	48.6
4	4.7	6.7	36.3	22	23.9	48.2
5	4.7	8.7	35.3	21.3	25.6	43.8

Table 3. Hg concentration levels in different stations in summer and winter 2010.

Station		Number of sample	Statistical parameter	Total Hg concentration (ng/m^3)	
Name	code			Winter	Summer
Foolad industries	1	10	Average	43.12	42.05
			Range	39.55 - 45.02	36.22 - 45.21
			S.D.	3.09	5.06
Amaniyeh	2	10	Average	41.43	40.95
			Range	35.93 - 48.62	35.69 - 47.76
			S.D.	6.51	6.18
Mosala	3	10	Average	36.83	35.64
			Range	27.71 - 39.54	29.11 - 37.22
			S.D.	5.32	4.11
Sarbandar road	4	10	Average	37.71	36.05
			Range	34.45 -39.43	29.55 - 39.96
			S.D.	2.82	5.66
Kiyanpars	5	10	Average	2.66	2.05
			Range	0.0 - 3.76	0.0 - 2.38
			S.D.	0.138	0.0

Calculation and statistical analysis

To calculate the concentration of mercury vapor in the air volume sampled, the following equation was used:

$$C = \frac{W \cdot \frac{V_s}{V_a} - B}{V} \quad 1.$$

Where, C = concentration (mg/m^3), W = amount of mercury in the sample aliquot (µg), Vs = original sample volume (ml), Va = aliquot volume (ml), B = average amount of mercury present in the media blanks (µg), and V = air volume sampled (L).

Also, to understand the relationship amongst mercury vapor concentrations in various lands uses and seasons, the t-test and ANOVA analyses were used.

RESULTS AND DISCUSSION

The average amounts of temperature, relative humidity and wind speed are presented in Table 2. As this table indicates, the study area had high temperature in summer and also the wind speed was high. As shown in Table 3, generally in all the stations, the average concentrations of mercury were higher in winter. Also, the mean concentration of mercury vapors was highest in Foolad industries and the lowest belonged to Kiyanpars that is located in the residential zone. The range of measured levels was 2.38 to 47.76 and 3.76 to 48.62 ng/m^3 in summer and winter, respectively.

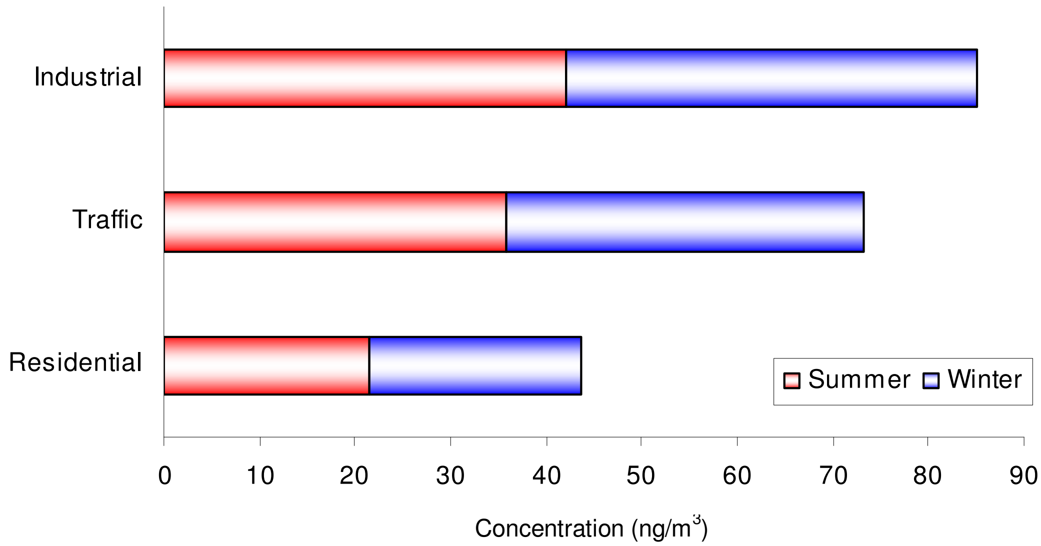

Figure 2. Hg concentration levels in different areas of the area of the study.

Table 4. Comparison of Hg concentration levels in different areas of the world.

Location	Reference	Total Hg concentration (ng/m^3)
Ahvaz/ summer	This study	19.9
Ahvaz/ winter	This study	20.7
Canada	Pilgrim et al. (2000)	4.47
Matsu/Japan	Lee et al. (2003)	41
Waste dump, Zagreb/ Croatia	Pehnec et al. (2010)	8.0-10.0
the Slovak Republic	Hladíkova et al. (2001)	2.63 (1.13-3.98); background area 3.64 (2.25-5.27); agriculture area 4.57 (1.73-20.53); urban area 5.28 (1.53-39.85); industrial area

The Hg concentration according to different land uses is presented in Figure 2. As this figure illustrates, the trend of mercury vapor decreased as: industrial area > traffic area > residential area, in both summer and winter, while the concentration in all the different areas was higher in winter than in summer.

To understand the relationships between different sites and seasons, ANOVA and t-tests analysis were used. The results show that mercury vapor concentrations in both summer and winter have significant differences ($P < 0.05$) as well as mercury vapors in residential and industrial areas ($P < 0.05$).

To compare the ambient mercury vapor in the study area and other sites of the world, Table 4 was prepared.

Mercury vapor concentration in Ahvaz city was much higher than those of other sites of the world (Table 4). According to Hladíkova et al. (2001), the average concentration of total mercury was 5.28 ng/m^3 in the industrial area of the Slovak Republic while this level (average of both summer and winter) in industrial area of the Ahvaz city was 42.55 ng/m^3. The highest mercury levels in the industrial area are related to metallurgical industry including steel and pipeline manufacturing. This subject is in accordance to Li et al. (2009) which concluded that metal smelting and coal combustion are considered as the most Hg emission categories in Asia.

The high levels of mercury vapor in winter can be justified by lower temperature and higher relative humidity. In addition, the less wind speed in winter avoids dispersion of mercury vapors in the atmosphere. Traffic areas also revealed high levels of Hg which can be due to fuel quality and vehicle types. So, to control the mercury vapor emission to the atmosphere, high quality fuel should be distributed. Also, for industrial sector, mercury emissions controls, particularly, closing and converting facilities to non-mercury technology are needed. The high amounts of mercury in air may cause chronic effects on human health and the environment so, more remedial actions and further studies and preparation of an emission inventory are needed.

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