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Transferring of Hg Concentration from Ambient Air to Rain Water and Surface Soil in an Industrial urban Area

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ABSRACT: Mercury is a dangerous and an extremely toxic element, which can transfer to the food chain. Presence of this element in the atmosphere particularly during the rainy seasons cause soil and environmental pollution, therefore this research will evaluate the transformation of mercury vapor from the atmosphere through precipitation into the soil. In the present study, mercury concentrations were determined during two seasons (winter and summer 2011) with 6 air, 14 rainwater and 6 soil, sampling stations. Collection, preparation and analysis of the air, rain, soil samples were based on NIOSH 6009, EPA1631 and EPA 7000 methods, respectively. Mercury concentration was determined by using cold vapor atomic absorption after sample preparation. The results show that the mean mercury vapour concentration in the air samples of Ahvaz city in winter and summer were 3.749± 2.625 ng/m^3 and 2.379± 0.984 ng/m^3, respectively. Further, the range of this pollutant in the air of studied area during the summer and winter seasons were 1.83-3.962 ng/m^3 and 1.394-5.00 ng/m^3, respectively. The highest value of Hg concentration in the rainwater sample was 0.77±0.0019 ppb and the mean concentration of mercury in the surface soil samples of the city was 0.511µg/g in winter. Finally, Mercury comparison between results of air and soil samples as well as air and precipitation samples at the winter season ($p<0.01$) showed a significant relationship.

Key words: Urban atmospheric pollution, Hg, Receptive environment, Rain chemistry, Soil pollution

INTRODCTION

Human exposure to heavy metals and their uptake it into the body through air, water and food can cause dangerous chronic and acute poisoning (Lorraine *et al.*, 1978). Also, some of the pollutants are extremely dangerous for the world's ecosystems (Burger *et al.*, 1993; Wolf *et al.*, 2000), due to accumulation and transformation of heavy metal through the food change (Castelle *et al.*, 2008; Sekhavatjou *et al.*, 2010; Hasan, M.A.A., 2010). Long term exposure to mercury can harm the environment (WHO, 2011). Several studies have been conducted concerning the measuring of the mercury vapor in the air. Nguyen et al. (2008), reported the Total Gas Mercury(TGM) concentration in the industrial area of South Korea, the value was determined at 6.32±8.56 ng/m^3 (Nguyen *et al.*, 2008). Lyman, S.N. et al. (2009), measured the mercury gas, oxidized gaseous mercury and particulate mercury at 9 km east of Reno, Nevada, USA, from November 2006 to March 2009. The results showed that the mean concentration of particulate mercury, oxidized gaseous and mercury gas was 37 ± 0.2 ng/m^3, 322 ± 18 ng/m^3 and 37 ± 7 ng/m^3, respectively.

Therefore, this research is an attempt to determine the mercury concentration in the precipitation and soil as well as total vapor concentration in the ambient air of Ahvaz city. Ahvaz is a city and the capital of Khouzestan Province in Iran (Sekhavatjou *et al.*, 2011; Sekhavatjou & Zangeneh, 2011). Owing to its rich resources of oil, gas, petrochemical, metal, cellulose and electrical industries coupled with a warm climate, it has become a source for the emission of air pollutants, particularly mercury vapor (Sekhavatjou *et al.*, 2008). The other aims of this study are comparing the results with permissible limits, examining the relationship between different matrixes, and finally identifying the possible emission sources of mercury emission in the studied area.

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MATERIAL & METHODS

In this research, the study period was from the summer to winter 2011 at 6 air, 14 rain water and 6 soil sampling stations. Precipitation and soil samples were collected at the predetermined stations, air samples were collected by using pump with a flow rate of 1 L/min in one hour. Water and soil samples were prepared based on EPA1631 and EPA 7000 methods, respectively and air samples were analyzed based on NIOSH 6009 method (NIOSH, 1994). The samples were determined by using cold vapour atomic absorption (hybrid system Hg 3000, EHG3000 & MC 3000 model). Statistical analyses in terms of T-test and ANOVA were applied to identify the correlation between data.

RESULTS & DISCUSSION

Tables 1 and 2 show the means of total mercury vapor concentration and mean Hg concentration at the air sampling stations in Ahvaz city. The range of the total Mercury vapor at the study area stations in the winter and summer seasons were 1.33- 4.56 ng/m^3 and 2.15-5.72 ng/m^3, respectively. The highest value belonged to the metal industry and traffic points in the study area.Table 3. shows the range of mercury concentration is 0.0-0.77 ng/m^3 in the rainwater samples. The highest concentrations was reported at the stations which were near the metal industry area, further, in all samples the mean concentration are 0.3207 ±0.31929 µg/ lit (Table 4).

Table 5 shows the mean Hg concentration in the soil samples in the study areas. Table 6 shows the range of concentrations in winter is 0.013 – 0.681 µg/g .The lowest value was reported in the residential area that is far from industrial one, whereas the highest value was recorded at the metal industry. It should be considered that due to the high temperatures in the Khuzestan province and volatilization of mercury, this element could not be detected during the summer season. The results show that the mean concentration of Hg vapor in the air samples of Ahvaz were higher than the mean world value during the winter and summer seasons. However, the values at the different air samples were in the range of the mercury concentration of the urban area. The highest value of Hg in the air samples due to the metal fusion industry was recorded in the winter and summer season 4.56 ng/m^3 and 5.72 ng/m^3, respectively. In the case of the rainwater samples the highest value of mercury was recorded 0.77 ±0.0019 µg/lit at the metal fusion industries area, whereas the lowest value recorded at the residential area that doesn't have any emission

Table 1. Average total mercury vapor concentration in ambient air of the studied area, 2011

Station	Average mercury concentration in summer (ng/m^3)	Average mercury concentrationin winter (ng/m^3)
Industrial zone (Foolad Kavyan)	5.72	4.56
Traffic zone(Nakhl Circle)	4.53	3.74
Industrial zone (Oil & Gas)	2.15	2.03
Industrial zone (Tubing)	2.37	1.33
Residential zone (Kiyanpars)	2.42	2.47
Beach park	3.23	2.34

Table 2. The range of average total mercury vapor concentration in ambient air of the Ahvaz city, 2011

Average concentration of total mercury vapor (ng/m^3)	Number of Samples seasonaly	Summer	Winter
	18	**3.3847± 1.21365**	**2.7826±1.0033825**
The global mean concentration of mercury	2.5(ng/m^3)		
Range of mercury concentrations in urban area	5-15 (ng/m^3)		

Table 3. Average concentration of mercury in rain water of the studied area, 2011 (µg/lit)

No.	Sampling stations	Mean	No.	Sampling stations	Average
1	Foolad Kavyan	0.770	8	Modaress Blv.	0.160
2	Meli group	0.757	9	Golestan	0.025
3	Tubing	0.640	10	Naft shahrak	0.015
4	Steel industry	0.633	11	Kiyanpars	0.003
5	Navard pipe	0.617	12	6th Reagion	ND
6	Naderi street	0.543	13	Padadshahr	ND
7	Saat circle	0.340	14	Lashgar	ND

sources. With respect to the nature of the activity- hot metal operations- of the Foolad Kaviyan Company, the above result is acceptable. The mean mercury concentrations of rain water samples were compared to the US EPA standard, in which the maximum permissible value is 0.002 mg/lit. The annual mean concentration of Hg of precipitation was less than permissible limit. Furthermore, according to the EPA standard, the permissible limit for air is 0.1 mg/ m^3, whereas the annual Hg value in the air of Ahvaz is less than it. The highest value of the mercury at the soil sample stations was 0.10 µg/g in winter that is seems due to presence of steel industry. In the summer, there was not detected, probably due to the high volatilization properties of mercury in the soil and effect of the temperature on Hg concentration in the environment.In this research the mercury concentration in the soil samples were compared with the standard of the soil in the urban area. The results show the Hg concentration in the study area was higher than the soil of urban area. Table 6. compare the results of the present study with the air, rain and soil samples which were taken from other places around the world. Comparison between present research and the study which has been done by Sekhavatjou et al. (2011) reported that the stations which are near to the metal industries have a high value of Mercury. Table 7. indicates the relationship between mercury concentration in the ambient air, precipitation and soil in the summer and winter by using the Pearson correlation method.

Table 4. Average concentration of mercury in the different period of the precipitation, 2011(µg/lit)

Average concentration of mercury	No. of samples	Winter season
First period	14	0.32194±0.3186
Second period	14	0.32426±0.3229
Third period	14	0.33573±0.3207
Total	42	0.31929± 0.3207

Table 5. Average mercury concentration in soil samples of the Ahvaz city, 2011 (µg/g)

Stations	Average mercury concentration
Foolad Kavyan	0.681
Tubing	0.222
6th Region	0.013
The area around airport	0.050
Kiyanpars (residential area)	0.511
Beach park (Traffic zone)	0.070

Table 6. Comparison the value of mercury concentration in air, precipitation and soil of the studied area with other locations around the world

Matrix	Researcher	Location	Mercury values
Air	(Sekhavatjou *et al*., 2011)	Ahvaz – Iran	20.7 ng/m^3 in the winter 19.9 ng/m^3 in the summer
	(Cheng Fang *et al.*, 2010)	Traffic zone - Taiwan	2270 ng/m^3
	(Thi Nguyen *et al.*, 2008)	Industrial area- san city in Korea	6.32 ng/m^3
	(Lyman, S.N. *et al.*, 2009)	Reno, Nevada, United States	Particulate mercury 37 ± 0.2 ng/m^3 Oxidized gaseous 322 ± 18 ng/m^3 Mercury gas 37 ± 7 ng/m^3
	This study, 2011	Ahvaz city	Winter: 3.749± 2.625 ng/m^3 Summer: 2.379± 0.984 ng/m^3
Precipitation	(Poissant, L., 2000)	Canada	0.00698 µg/lit
	(Glass *et al.*, 2009)	Minnesota	0.17-3.4 µg/lit
	(Mitchell, G.J., 2003)	Maine river	(1.80± 1.29) × 10^{-3} µg/lit
	(Ferrara, R., 2003)	Italy	0.017-.0079 µg/lit
	This study, 2011	Ahvaz city	0.77±0.0019 µg/lit
Soil	(Giulio, RTD. & Ryan, EA., 1987)	North Carolina Island	0.025-0.032µg/g
	(Rodrigues *et al*., 2006)	Europe	0.015-6.3 µg/g
	(Chen *et al*., 2009)	Beijing – China	0.26 µg/g
	(Oppong, S.O.B. *et al.*, 2010)	South west of Ghana	0.042-0.145 µg/g
	This study, 2011	Ahvaz city	Winter: 0.511 µg/g

Table 7. Statistical analysis of Correlation between parameters in the studied area

Mercury concentration	season	Correlation	P value
Precipitation and air	Winter and winter	Significant relationship	p<0/01
Air and soil	Winter and winter	Significant relationship	p<0/01
Air and soil	Summer and summer	No significant relationship	p>0/01
Precipitation and soil	Winter and winter	Significant relationship	p<0/01
Air	Winter and summer	No significant relationship	p>0/05

CONCLUSION

The results show a significant difference between different matrixes in the study area. According to the results, it is concluded that the studied area affected mutually and mercury pollutants were transferred from one matrix to another one. Comparison between sampling sites show, there is a significant correlation between air and soil samples, as well as soil and precipitation. Furthermore, there is no significant correlation between air and soil samples in the summer due to lack of measurement and high evaporation from the soil samples in the summer. There was no significant correlation between air samples in the winter and summer season. This was probably due to the presence of the permanent emission sources in the study area. Based on the results of this research, the variation of mercury concentration in the different regions is concluded as follows:

-Based on the type of land uses, mercury vapor concentration variation in air samples is in the order of: Metal industries Ã traffic Ã residential and barren land.

-Based on the type of land uses, mercury vapor concentration variation in rain samples is in the order of: Metal industries Ã traffic Ã residential and barren land.

-Based on the type of land uses, mercury vapor concentration variation in soil samples is in the order of: Metal industries Ã residential area Ã traffic Ã barren land.

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