Simulation of atmospheric mercury dispersion and depositions in Tehran city using modeling

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Outline

- Introduction
- Literature Review
- Sources Estimation
- Modeling & Evaluation
- Conclusion

Introduction

- Mercury is one of the most toxic heavy metals that can accumulate in biotic tissues and endanger the human health, wildlife and the environment.
- Mercury enters the body through digestion, breathing, skin absorption and eye contact which causes damage to the kidney, brain, respiratory and central nervous system.
- Mercury exists in the atmosphere in three important species including Gaseous Elemental Mercury (GEM), Reactive Gaseous Mercury (RGM) and Particulate Bounded Mercury (PBM).
- Mercury in atmosphere is mostly in form of elemental gaseous by more than 95 percent which remains in the atmosphere for several months to one year.

Literature Review

- A study of mercury emissions from industrial sources in India and its effects on the environment was done and as a result, the atmospheric mercury emissions have been estimated for 2000 and 2004 to be 321.49 Mg and 253.36 Mg, respectively (Mukherjee et al. 2009).
- Zhang et al. (2015) estimated the total anthropogenic Hg emissions in China to be continuously increasing from 356 ton in 2000 to 538 ton in 2010 with an average annual increase rate of 4.2% (China is the largest emitter of atmospheric mercury in the world).
- EPA (2016) estimated the mercury emission in the USA for 2014 sum to 55 tons, with 54 tons from stationary sources and 1 ton from mobile sources.
- Bullock and Brehme (2002) simulated the total mercury wet deposition for a month of spring and summer seasons using CMAQ model in east of USA.
- Gbor et al. (2007) simulated the daily average of total gaseous mercury (TGM=GEM+GOM) concentration in the surface layer and daily dry and wet deposition of different mercury species for 2002 in a domain that covered the continental United States and major parts of Canada and Mexico.
- Holloway et al. (2012) simulated the concentration of different forms of atmospheric mercury in the Great Lakes Region of North America using WRF/CMAQ models and compared the results with measurements data at two urban and rural stations.

Sources Estimation

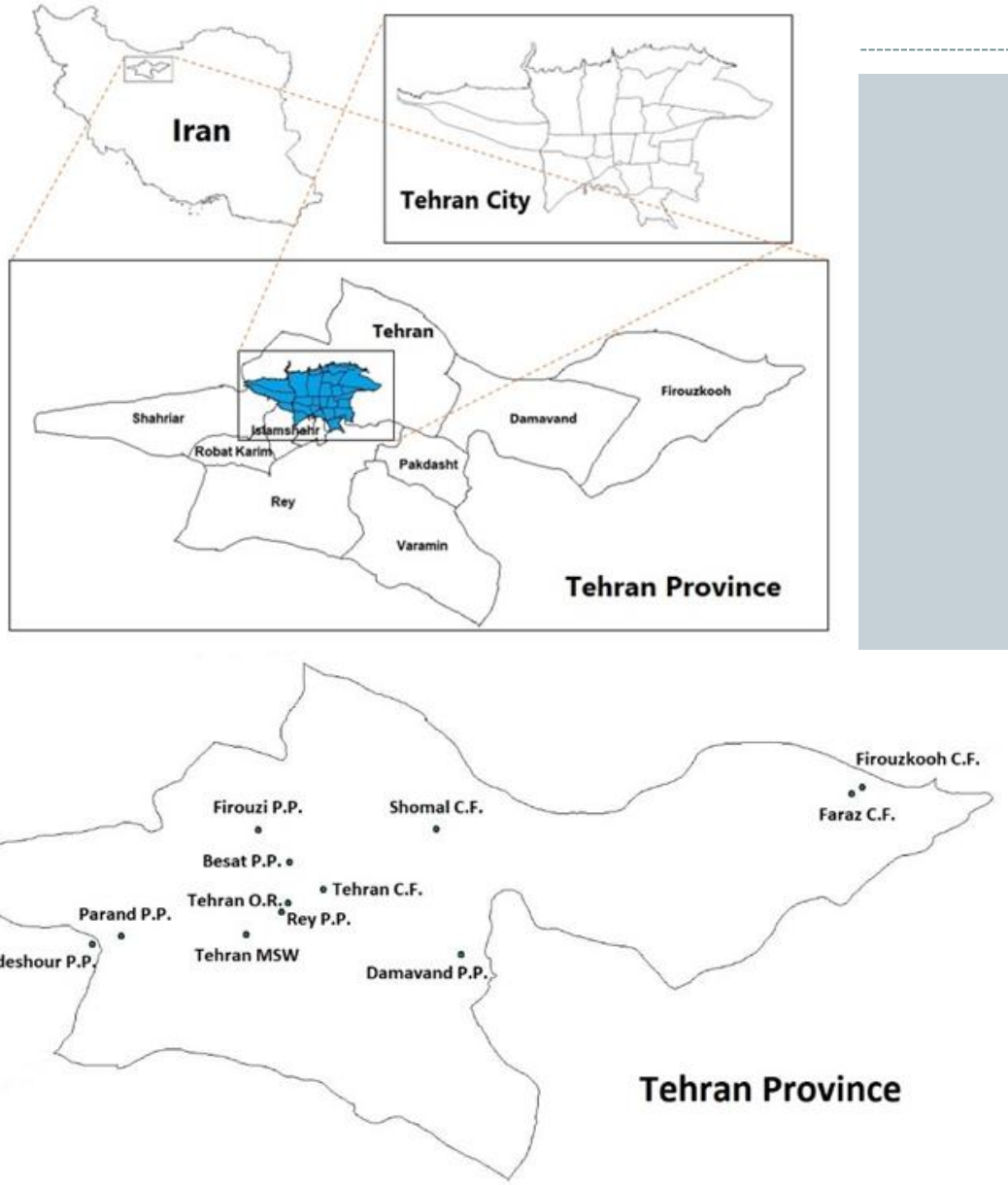
Stationary Sources

- There are six power plants in the Tehran province that use natural gas and gas-oil as fuels**.** In addition, there is an oil refinery in Tehran province that uses natural gas, gas-oil and fuel-oil as fuels. In order to estimate the atmospheric mercury emissions from these plants and oil refinery, the emission factors of the US-EPA AP-42 were used (EPA 1998a, 1998b).
- The amount of fuel consumed by the power plants and oil refinery is based on the data from Iran Statistics of Consumption of Energy (20 March 2016 - 20 March 2017), Iran Energy Balance sheet and Tehran Province Statistical Yearbook.
- There are four cement factories in Tehran province which annual production rate was taken from the Iran Cement Industry Employers Association.
- Another stationary source in Tehran city is the municipal solid waste (MSW) which include both landfill and waste incinerator. According to the amount of landfill gas produced, the US-EPA AP-42 estimates the atmospheric mercury emission factor (EPA 1997). The waste incinerator operating at a nominal capacity of 200 t/day. Considering the atmospheric mercury emission factor using (UNEP 2017) and the period of activity throughout the year (about 340 days), the amount of atmospheric mercury was estimated.

Atmospheric mercury emission factors based on type of fuel or Industry

Type of Fuel or Industry	Hg Emission Factor	Unit	Reference
Natural Gas	0.00416 E-06	kg/m^3 natural gas combusted	**(EPA 1998a)**
Fuel-Oil	0.01354 E-03	kg/m^3 fuel oil combusted	**(EPA 1998b)**
Gas-Oil	0.04982 E-03	kg/m^3 gas oil combusted	**(EPA 1998b)**
Kerosene	0.04982 E-03	kg/m^3 kerosene combusted	**(EPA 1998b)**
Cement Factory	0.1	g/t cement produced	**(Pacyna et al. 2006; Wang 2006)**
Municipal Waste Landfill Gas	2.92 E-04	concentration in landfill gas (ppm volume)	**(EPA 1997)**
Municipal Waste Incinerator	1	g/t waste incinerated	**(Pacyna et al. 2006; Mukherjee 2009)**

Location map showing Tehran city and location of stationary point sources in Tehran province. P.P. indicates the location of power plant, C.F. indicates the location of the cement factory and O.R. indicates the location of the oil refinery



The annual fuel consumption by the power plants and oil refinery in Tehran province and Production rate of Cement factories

Industry	Natural Gas (m^3/year)	Gas-Oil (m^3/year)	Fuel-Oil (m^3/year)
Besat Power Plant	563165000	422	0
Rey Power Plant	387406000	22525	0
Parand Power Plant	896902000	150989	0
Damavand Power Plant	2459134000	577629	0
Rudeshour Power Plant	915744000	202743	0
Firouzi Power Plant	117723000	0	0
Tehran Oil Refinery	608100000	21055	67580
Total	5948174000	975363	67580

Cement Factory's Name	Production Rate (t/year)
Firouzkooh	754917
Faraz	750288
Tehran	2294830
Shomal	792075
Total	4592110

Stationary Area and Mobile Sources

- In addition to the main stationary sources indicated, there are the minor mercury production sources that consume fuel. These sources include small industries, domestic and residential power houses, industrial cities, etc. The amount of fuel used in the cement factories, power plants and oil refinery were subtracted from the total fuel consumption in Tehran province and allocated to the minor mercury production sources which is referred to “Stationary Area Sources”.
- The amount of atmospheric mercury emission from mobile sources from all types of vehicles including cars, buses, motorcycles and trucks in Tehran city was estimated using the Motor Vehicle Emission Simulator (MOVES) model. Atmospheric mercury emissions from mobile sources for the other cities of Tehran province were estimated based on the demographic distribution of each city due to the lack of information on the number of vehicles and their average daily driven mileage.

Population and net fuel consumption of stationary area sources in the cities of Tehran province

City	Population	Kerosene (m^3/year)	Gas-Oil (m^3/year)	Fuel-Oil (m^3/year)	Natural Gas (m^3/year)
Tehran	8953849	9743	235571.14	28856.5	10327773554
Firouzkooh	33558	3093	882.89	108.15	83922093.67
Varamin	639481	711	16824.43	2060.92	594520319.1
Shahriar	1438138	2884	37836.7	4634.84	1178715750
Islamshahr	548620	1340	14433.92	1768.1	478413981.8
Robat Karim	827845	1019	21780.19	2667.98	455656163.2
Damavand	125480	4110	3301.317	404.4	206860789.7
Pakdasht	350966	1970	9233.74	1131.1	663100729.9
Rey	349700	4532	9200.44	1127.02	1059262849
Total	13267637	29402	349065	42759	15048226230

Other Stationary Area Sources

- Mercury is produced and emitted into the air from other stationary area sources in Tehran province such as brick manufacturing, lamps production and usage, mercury used in dentistry and mercury emissions from thermometers.
- The total number of bricks produced per year in Tehran province was obtained from the Iran Ministry of Industry, Mining and Commerce to estimate their atmospheric mercury emission. Based on the US-EPA AP-42 factors (EPA 1998a, 1998b), the atmospheric mercury emission from the fuel consumption of brick manufacturing was determined.
- To estimate atmospheric mercury emission from mercury-containing thermometers, the number of mercury-containing thermometers imported into the country was calculated using the information from Tehran Chamber of Commerce, Industries, Mines and Agriculture data and deducted from the number of mercury-containing thermometers exported. Two types of medical and non-medical mercury-containing thermometers were considered.

Mercury content and rate of import, export and production/consumption of mercury-containing thermometers and brick manufacturing

Mercury-containing thermometer type	Import to the country (kg/year)	Export from the country (kg/year)	Production in the country (pcs/year)	consumption in the province (pcs/year)	Mercury content (g/item)
Medical	60028	0	0	332151	1
Non-medical	47681	900	0	38828	10
Total	647709	900	0	370979	-

Source	Mercury emission factor	Unit	Rate of production (Pcs/year)
Push brick	7.5 E-06	lb/ton	1486394800
Machine brick	7.5 E-06	lb/ton	959000000
Total	-	-	2445394800

Other Stationary Area Sources

- To calculate the atmospheric mercury emission from the production and breakage of mercury-containing lamps during use, the total statistics of mercury-containing lamps produced in the country were obtained from the Ministry of Industry, Mines and Commerce and adjusted to the Tehran province using population ratio. UNEP (2017) estimates mercury content for fluorescent tubes, compact fluorescent lamps (CFL), high-pressure sodium lamps and UV lights. Also, some of these types of lamps are imported/exported annually through the country which the statistical information was obtained from the Tehran Chamber of Commerce, Industries, Mines and Agriculture. The amount of each type of mercury-containing lamp produced inside the country was added to the number of bulbs imported and then deducted from the number of bulbs exported. The amount of atmospheric mercury emission from mercury-containing lamps was adjusted to Tehran province using population ratio.
- UNEP (2017) information was used to estimate atmospheric mercury emission from dental mercury-amalgam fillings during preparations and procedures at the dental offices.

Mercury content and rate of import, export and production/consumption of mercury-containing lamps and dental amalgam

Lamp type	Mercury content (mg/item)	Import to the country (kg/year)	Export from the country (kg/year)	Production in the country (pcs/year)	Production in the province (pcs/year)	Total Production/ consumption in the province (pcs/year)
Fluorescent tubes	25	476409	558	31525000	25000	5653039
Compact fluorescent	10	37606	149833	112550000	25000000	43589928
High-pressure sodium	20	1734	0	0	0	959
UV lights	15	3946	156	0	0	2097
Total	-	519695	150547	144075000	25025000	49246023

Population of Tehran province	g mercury consumed per inhabitant per year	Emission factor to air
13267637	0.1	0.02

Natural Sources

- Mercury is emitted into the air from natural sources. Urban surfaces usually include impervious surfaces such as pavements and permeable surfaces such as soil and green areas. The estimated amount of atmospheric mercury emission from impervious and permeable surfaces is 0.15 ng/m^2-hr and 2.3 ng/m^2-hr, respectively. It was assumed that the surrounding areas of Tehran province are pastures, with an estimated atmospheric mercury emission rate of 1.6 ng/m^2-hr (Denkenberger et al. 2012; Akbari et al. 2003).

Atmospheric mercury emission from power plants, oil refinery, cement factories, mercury-contained lamps and thermometers in Tehran province

Industry	Mercury Emission (Kg/year)	Industry	Mercury Emission (Kg/year)
Besat Power Plant	2.4	Tehran Oil Refinery	4.5
Rey Power Plant	2.7	Firouzkooh Cement Factory	49.8
Parand Power Plant	11.3	Faraz Cement Factory	49.5
Damavand Power Plant	39	Tehran Cement Factory	151.5
Rudeshour Power Plant	13.9	Shomal Cement Factory	52.3
Firouzi Power Plant	0.5	Total of cement factories	303.1
Total of power plants	69.8		

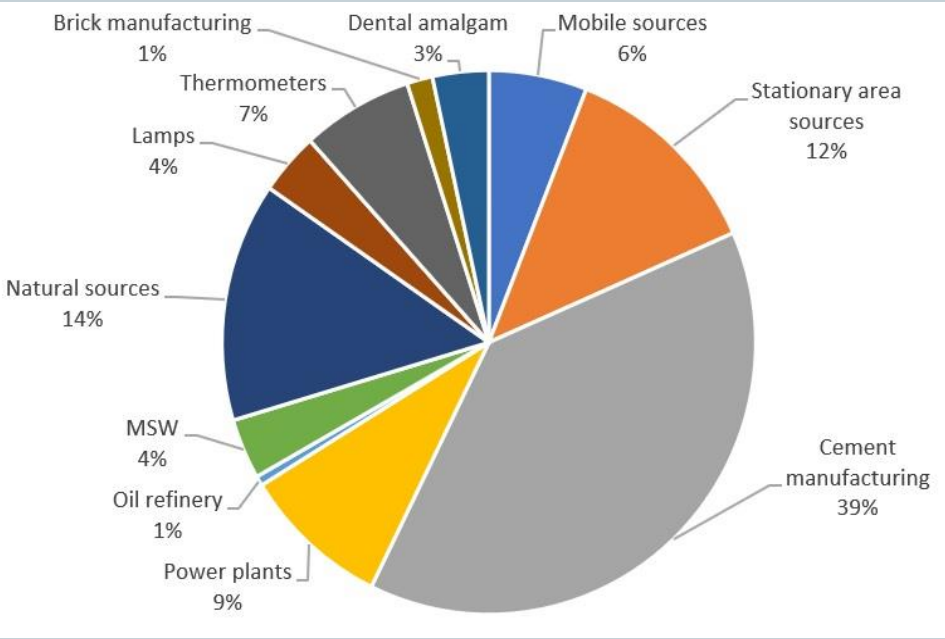
Mercury-containing lamp type	Mercury emission (kg/year)	Mercury-containing thermometer type	Mercury emission (kg/year)
Fluorescent tubes	7.1	Medical	33.2
Compact fluorescent	21.8	Non-medical	19.4
High-pressure sodium	0.001	-	-
UV lights	0.002	-	-
Total	28.9	Total	52.6

Atmospheric mercury emission of stationary area sources from different fuel types, mobile sources and brick manufacturing in the cities of Tehran province

City Name	Kerosene (Kg/year)	Gas Oil (Kg /year)	Fuel Oil (Kg /year)	Natural Gas (Kg /year)	Total from stationary area sources (Kg/year)	Mobile sources (Kg /year)
Tehran	0.49	11.74	0.391	43.01	55.6	31.3
Firouzkooh	0.15	0.04	0.001	0.35	0.7	0.1
Varamin	0.04	0.84	0.028	2.48	5.6	2.2
Shahriar	0.14	1.89	0.063	4.91	12	5.0
Islamshahr	0.07	0.72	0.024	1.99	4.7	1.9
Robat Karim	0.05	1.09	0.036	1.9	6.0	2.9
Damavand	0.2	0.16	0.005	0.86	1.7	0.4
Pakdasht	0.1	0.46	0.015	2.76	4.6	1.2
Rey	0.23	0.46	0.015	4.41	6.3	1.2
Total (Kg/year)	1.46	17.4	0.578	62.67	97.2	46.4

Source	Mercury emission from production (kg/year)	Mercury emission from fuel consumption (kg/year)	Net Mercury emission (kg/year)
Push brick	10.1	0.9	9.2
Machine brick	3.3	0.4	2.9
Total	13.4	1.3	12.1

Atmospheric mercury emission based on each emission sources and percentage of atmospheric mercury emission from each source in Tehran province



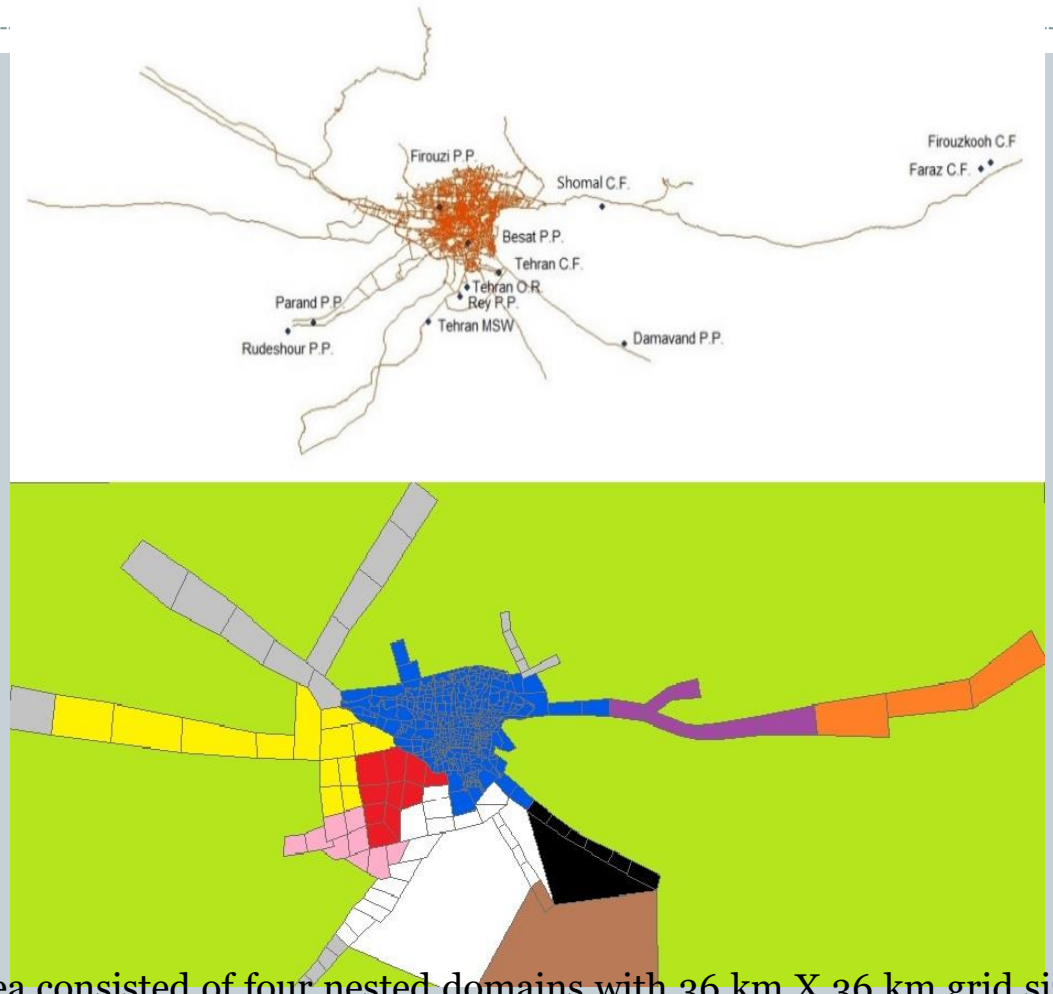
Type of emission sources	Atmospheric mercury emission (Kg/Year)
Cement factories	303.1
Natural sources	111.0
Stationary area sources	97.2
Power plants	69.8
Thermometers	52.6
Mobile sources	46.4
Lamps	28.9
Waste disposal	28.0
Dental amalgam preparation	26.5
Brick manufacturing	12.1
Oil refinery	4.5
Total	780.1

Modeling & Evaluation

Models

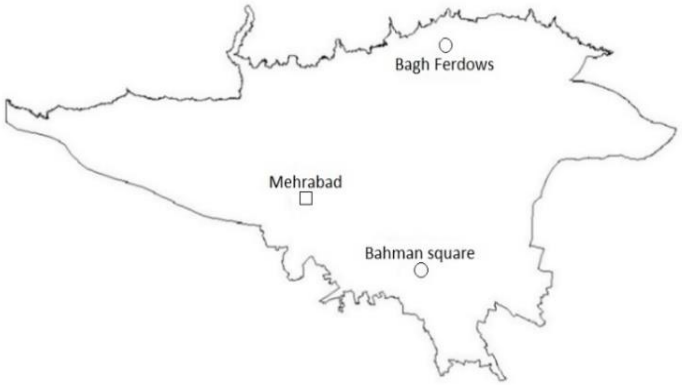
- WRF version 3.9 (Weather Research and Forecasting)
- SMOKE version 3.5.1 (Sparse Matrix Operator Kernel Emissions)
- CMAQ version 5.1 (Community Multiscale Air Quality)

The modeling domain consist of 493 zones. Each color represents a city, roads around and Green color represents the pastures surrounding the Tehran province



The modeling area consisted of four nested domains with 36 km X 36 km grid size at the outermost domain which decreased by one third proportions and reached an innermost domain with the grid size of 1.3 km X 1.3 km including Tehran city. The domain grid consists of a network of 100 x 76 cells.

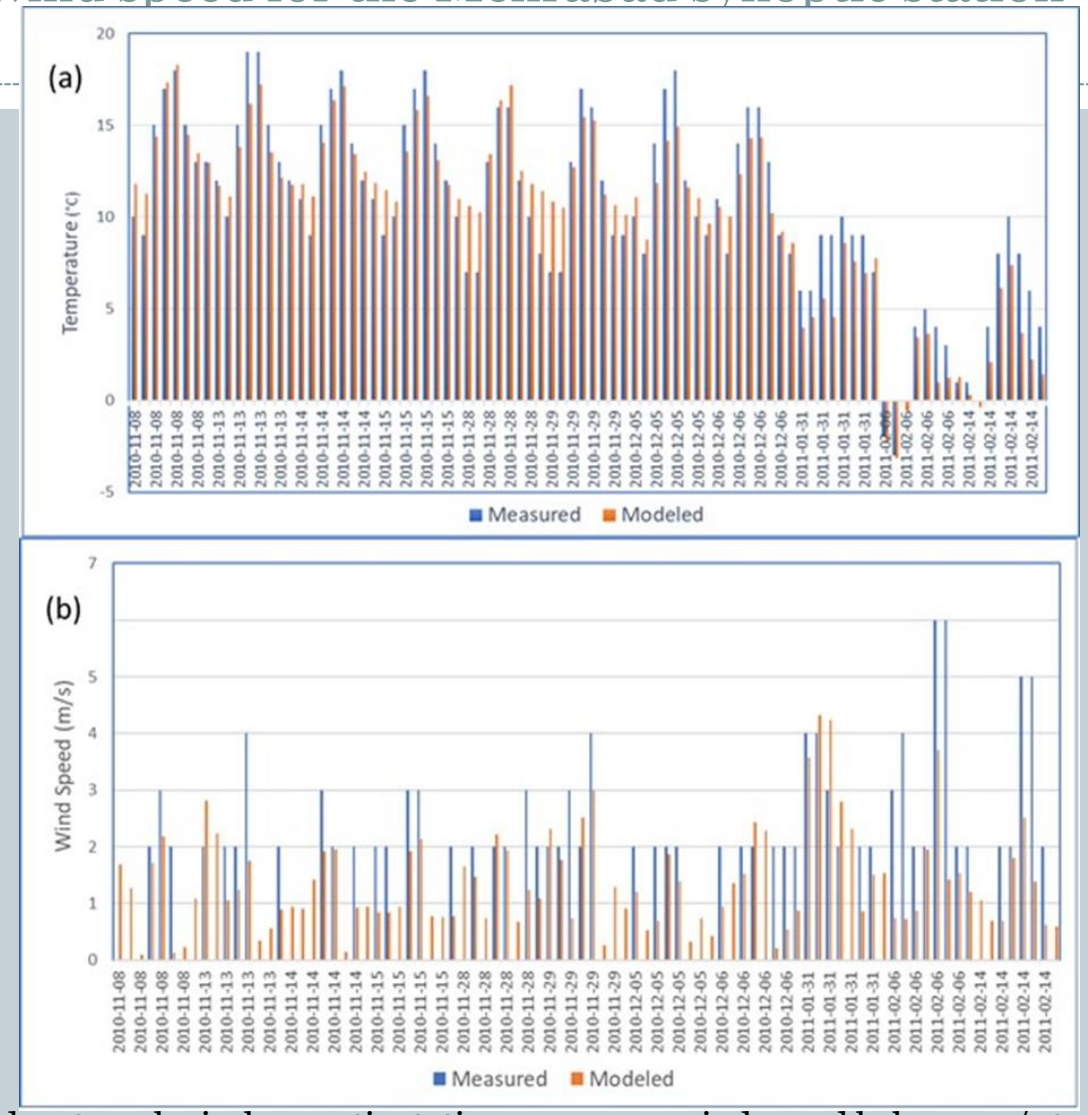
Locations of stations in Tehran city, a circle represents the particulate mercury measuring stations and square represents the meteorological synoptic station and measured atmospheric PHg concentrations



Date	Station	Concentration (ng/m³)	Station	Concentration (ng/m³)
08.11.2010	Bagh Ferdows	-	Bahman square	0.1
13.11.2010		0.1		0.3
14.11.2010		0.06		0.2
15.11.2010		-		0.2
28.11.2010		0.1		0.2
29.11.2010		0.1		0.1
05.12.2010		0.1		0.03
06.12.2010		0.03		0.07
31.01.2011		0.59		0.93
06.02.2011		0.29		0.78
14.02.2011		0.65		1.25
Average		0.22		0.38

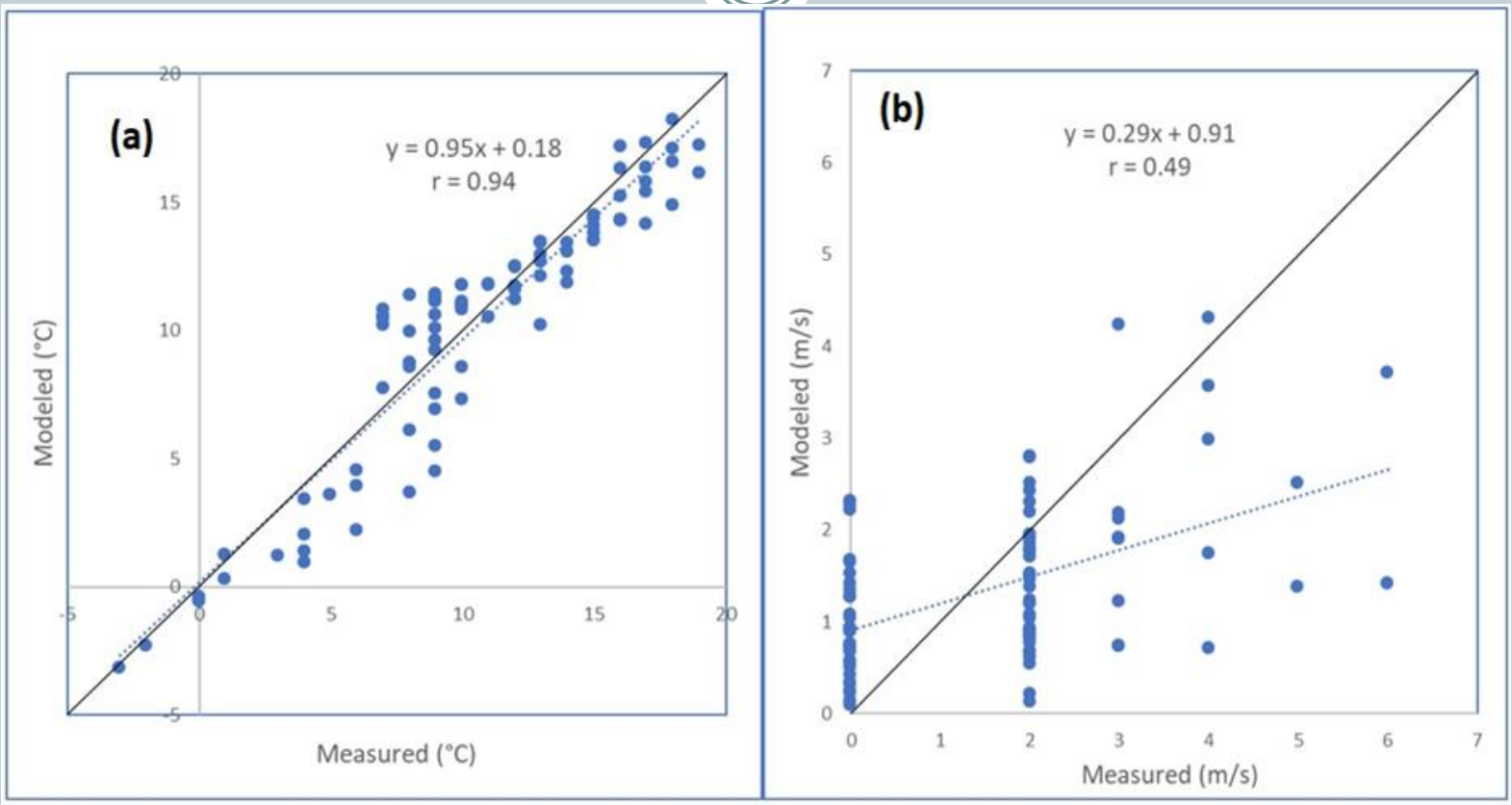
The Tehran Air Quality Control Company report (AQCC 2011) for two stations, that measured the particulate mercury using high volume samplers for 24 hours was used to validate the results obtained from the model.

Daily comparison between modeled and measured (a) temperature, (b) wind speed for the Mehrabad synoptic station



- Since the Mehrabad meteorological synoptic station assumes a wind speed below 2 m/s to be equal to 0, the difference between the modeled and measured wind speed is greater.

Daily correlation between modeled and measured (a) temperature, (b) wind speed

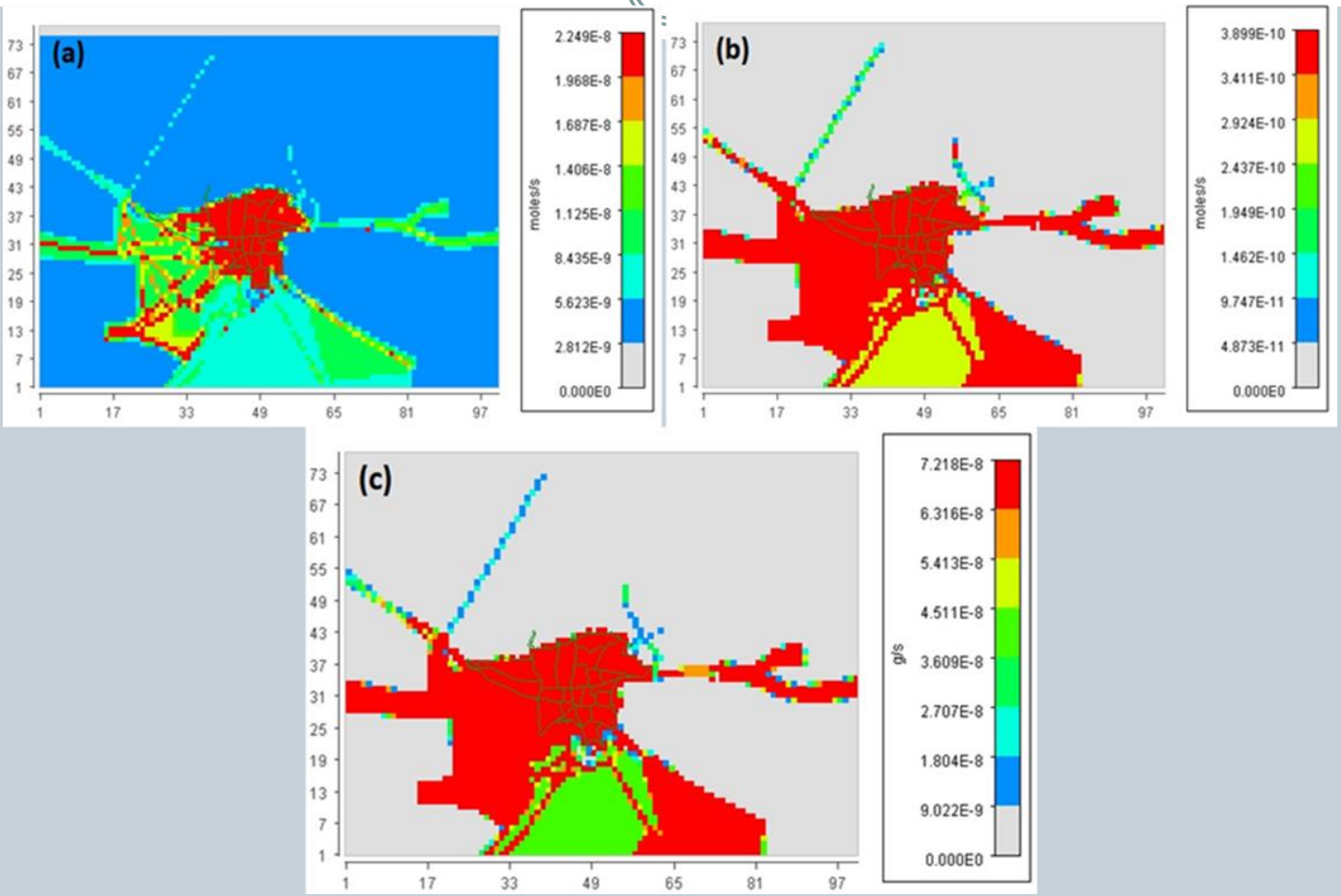


- The results for the temperature parameter show a good agreement between the model and the measurements values with a correlation coefficient equal to 0.94. The correlation between the measured data and the modeled data for wind speed are not good, with a correlation coefficient of 0.49.

Emission profiles for atmospheric mercury from all sources in SMOKE

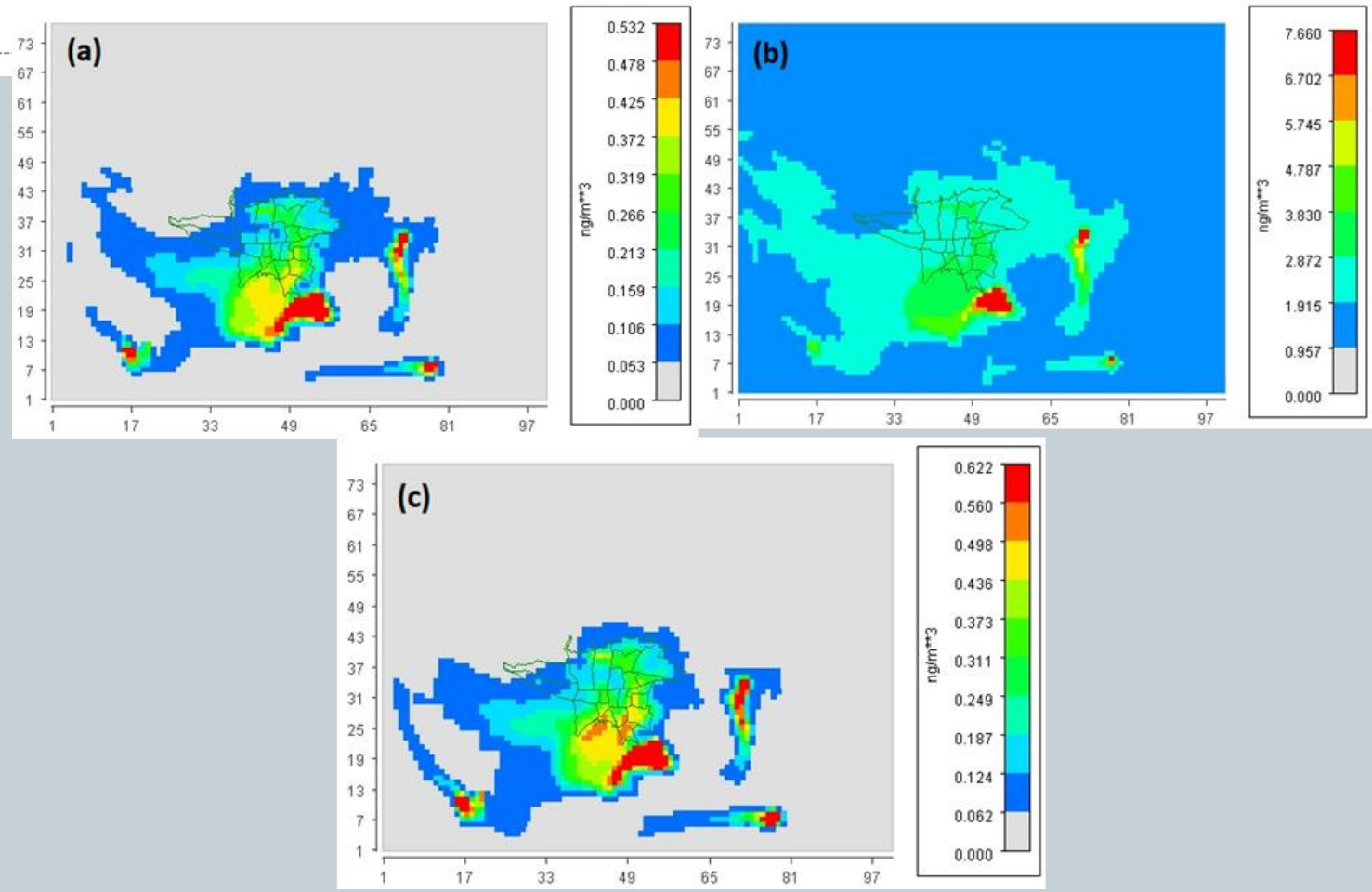
Emission Source	GEM	GOM	PHg	Reference
Fuels Combustion	0.5	0.3	0.2	(Walcek et al. 2003)
Cement Manufacturing	0.75	0.13	0.12	(SMOKE User's Manual 2013)
Municipal Landfill	0.8	0.1	0.1	(Walcek et al. 2003)
Mobile Sources - Diesel	0.56	0.29	0.15	(SMOKE User's Manual 2013)
Mobile Sources - Gasoline	0.91	0.086	0.004	(SMOKE User's Manual 2013)
Other Stationary Area Sources	0.8	0.1	0.1	(Walcek et al. 2003)
Natural Sources	1.0	0.0	0.0	(Travnikov 2005; Ryaboshapko et al. 2007a)
Average	0.76	0.15	0.09	-

Atmospheric emissions of (a) GEM, (b) GOM and (c) PHg in the total domain for 08.11.2010 at 13:00 UTC



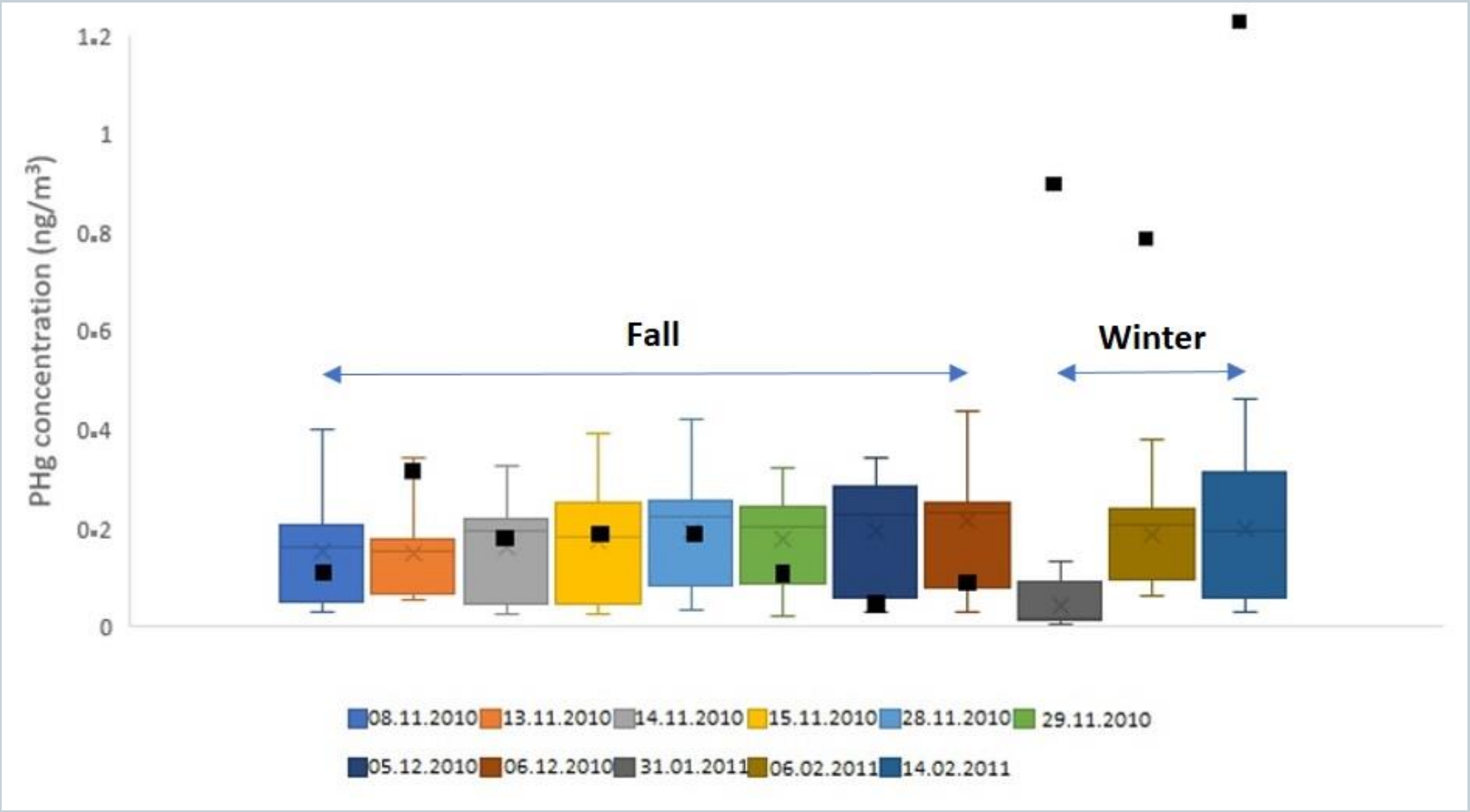
- The SMOKE model provides the emission rates per hour for each form of mercury during the day that GEM emissions being the highest and PHg is the lowest.

Atmospheric concentrations of (a) PHg, (b) GEM and (c) GOM in the total domain for 28.11.2010 at 19:00 UTC

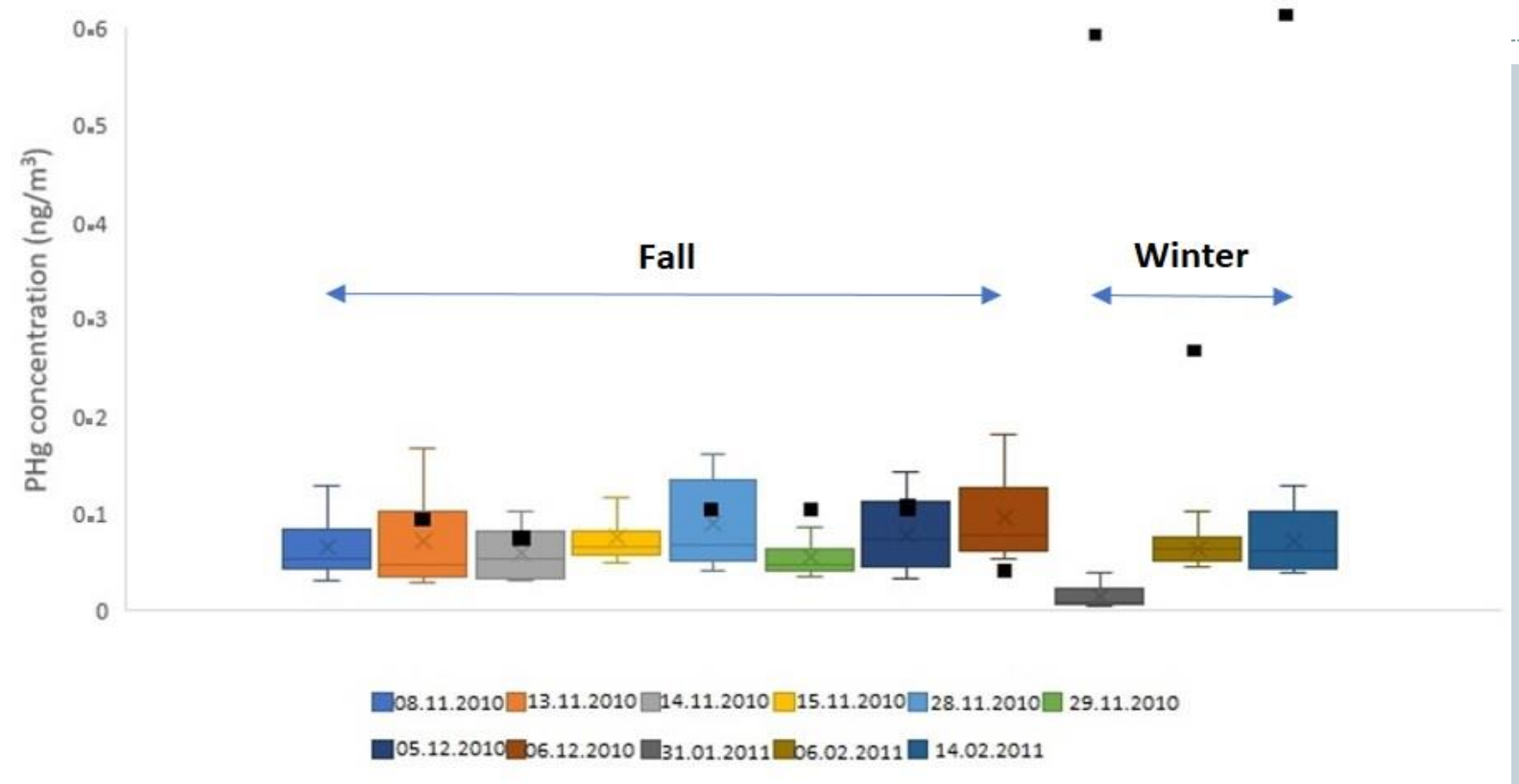


Atmospheric mercury concentrations in the southeastern part of Tehran city are higher than in the other areas. This is due to the presence of the Tehran Cement Factory in that area indicating it is the most polluting source of atmospheric mercury in Tehran city.

Daily modeled concentration of PHg in Bahman Square station. The multiplication sign represents the mean, the box plots are the 25th and 75th percentiles, the square is measured data and the line is median



Daily modeled concentration of PHg in Bagh Ferdows station. The multiplication sign represents the mean, the box plots are the 25th and 75th percentiles, the square is measured data and the line is median

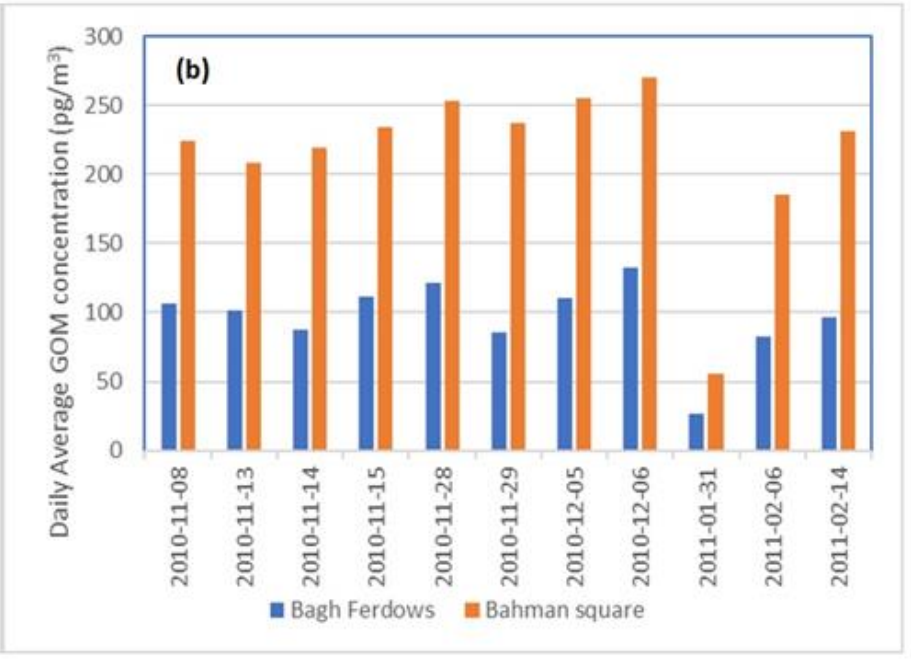


The model results for almost all days except 31.01.2011 at both measuring stations are within the same range. The measurement results at both stations in the last three days of the simulation period, are higher than the other days corresponding with the model results.

Evaluation

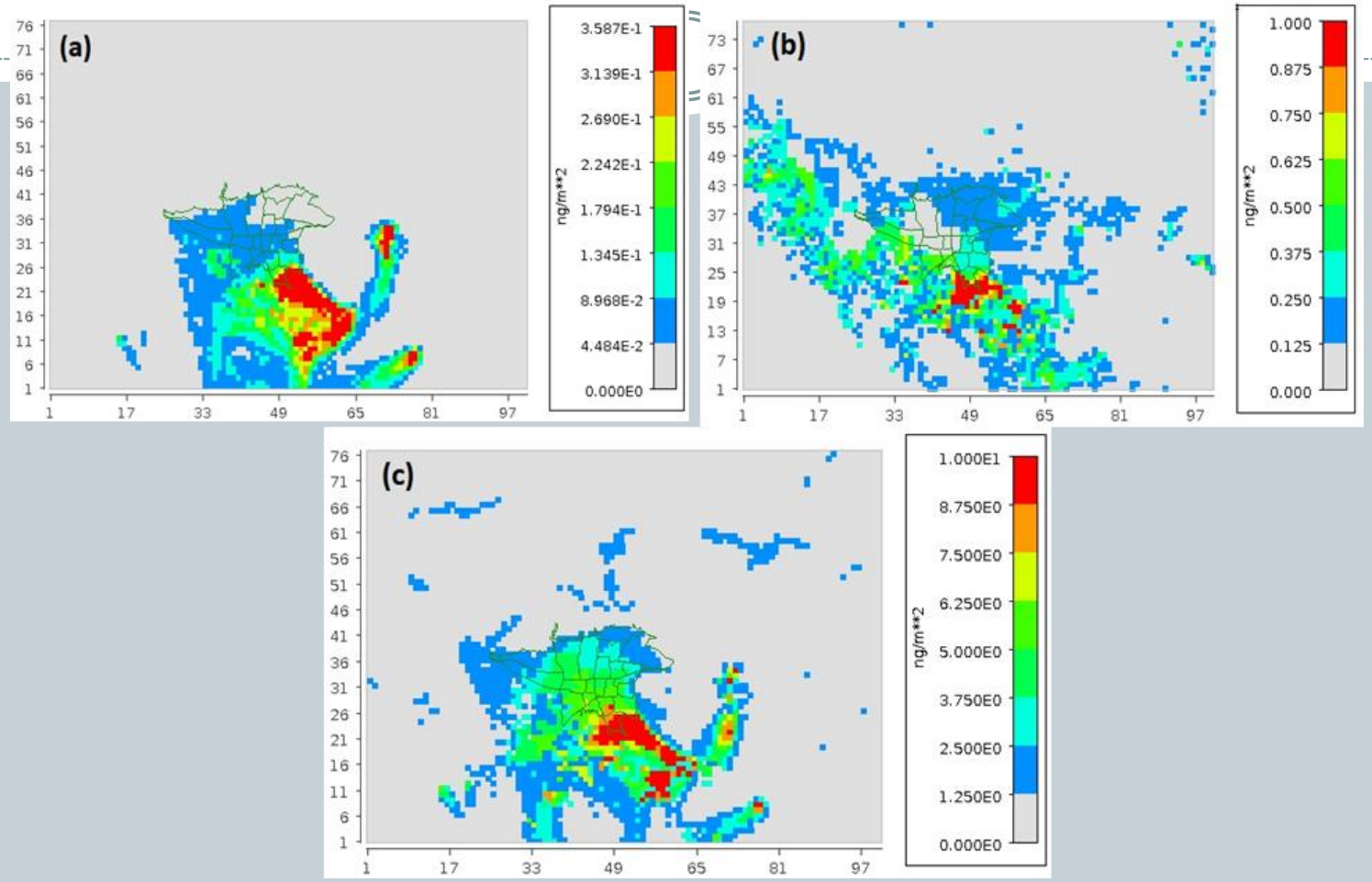
- $RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_i - M_i)^2}$
- The RMSE was calculated as 0.28 ng/m^3 and 0.46 ng/m^3 for Bagh Ferdows and Bahman Square, respectively indicating that the model performs better for the Bagh Ferdows station since to the values of RMSE are closer to 0.
- The RMSE was calculated as 0.08 ng/m^3 and 0.7 ng/m^3 for fall and winter days, respectively indicating that the model performs better for fall than winter season.

Modeled daily average atmospheric concentration of (a) GEM and (b) GOM in Bagh Ferdows and Bahman Square stations



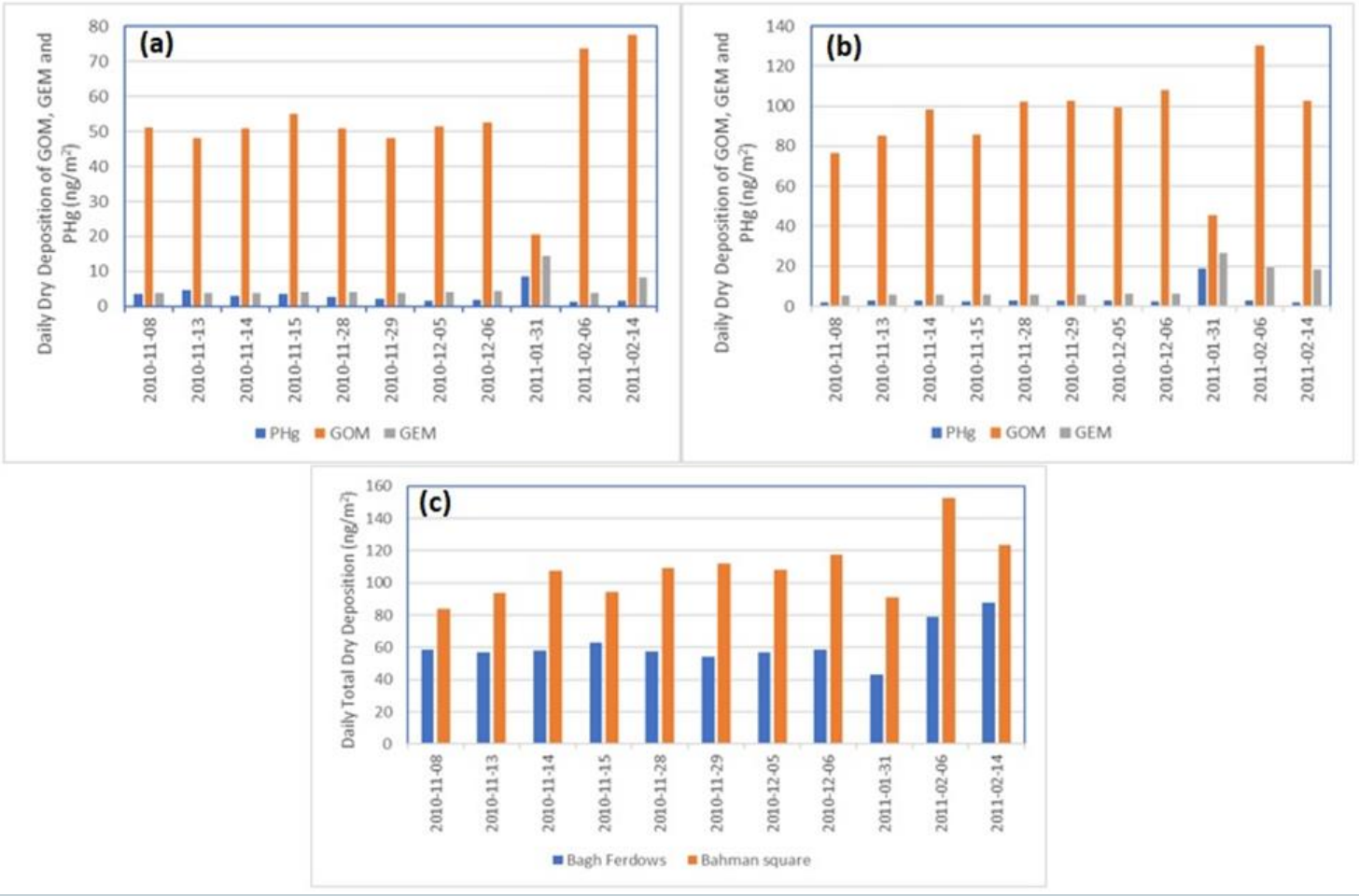
- Concentrations of modeled GEM and GOM at Bahman Square station are higher due to their proximity to emission sources. At 31.01.2011 the concentrations of GEM and GOM decreased due to precipitation and wet deposition.

Dry deposition of (a) PHg, (b) GEM and (c) GOM in the total domain for 13.11.2010 at 05:00 UTC



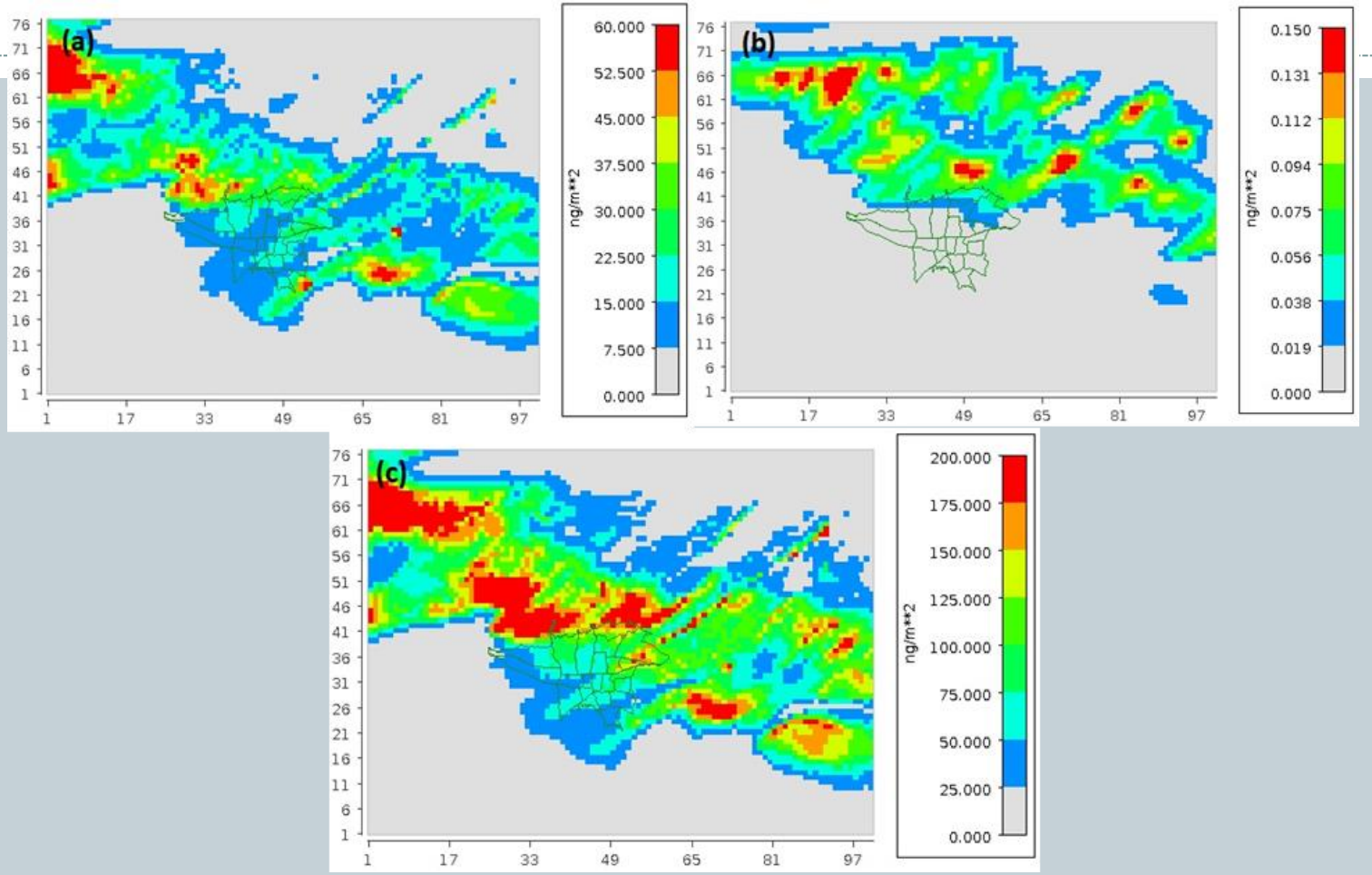
- The dry deposition of GOM is larger than for PHg and GEM. Mercury dry deposition is also larger closer to the mercury stationary emission sources. In the southeastern part of Tehran city, the highest dry deposition was observed due to the presence of Tehran cement factory.

Modeled daily dry deposition of GOM, GEM and PHg in (a) Bagh Ferdows station, (b) Bahman Square station and (c) Daily total dry deposition



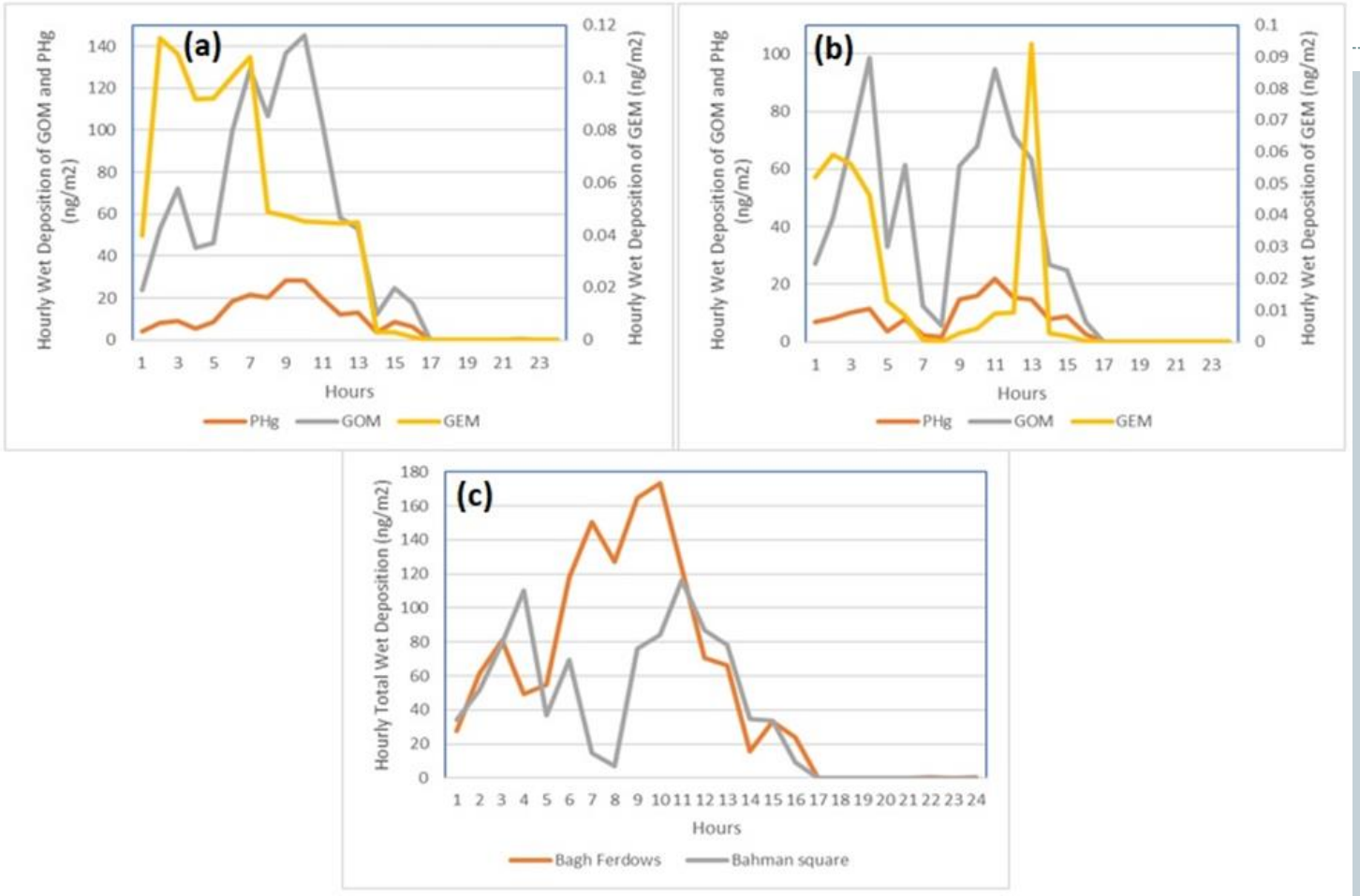
- Most dry deposition is in the GOM form. At 31.01.2011 due to the precipitation, GOM dry deposition decreased but GEM and PHg deposition increased at both stations. In the winter season, the total dry deposition appears to be higher than in the fall due to the lower temperatures. Total dry deposition at Bahman Square station is higher than Bagh Ferdows station due to the higher mercury concentrations.

Wet deposition of (a) PHg, (b) GEM and (c) GOM in the total domain for 31.01.2011 at 06:00 UTC



- The wet deposition of GOM is larger than PHg and GEM and is dependent on the precipitation patterns.

Modeled hourly wet deposition of GOM, GEM and PHg in (a) Bagh Ferdows station, (b) Bahman Square station and (c) Hourly total wet deposition



- Most of the wet deposition is in the GOM form and wet deposition of GEM is negligible. The total wet deposition of Bagh Ferdows station is larger than Bahman Square station due to more precipitation. Precipitation stopped at the end of the day therefore the wet deposition was 0 during those hours.

Conclusions

- Comparison of modeling and measuring results for atmospheric PHg concentration in winter season was not very good, which seems to be due to a problem with the measured data since it is highly variable compared to the measured data in the other days of this period.
- due to the low concentration of atmospheric PHg, these differences between measured and model values seems to be inevitable because a very small change in sampling or analysis can make a big difference in final concentrations.
- However, only 20 measured data during fall and winter appears to be inadequate to reach solid conclusion, therefore it is recommended that additional measurements of mercury for the entire year are made with a larger number of stations.
- It is possible that the differences of PHg concentrations in modeled and measured days, may be due to weaknesses in WRF simulation of stable conditions specially in winter season.
- Based on the modeling and measuring results, it appears that the average atmospheric PHg concentration at Bahman Square and Bagh Ferdows station is about 0.2 ng/m^3 and 0.1 ng/m^3, respectively.
- Concentrations and dry depositions of different forms of atmospheric mercury at Bahman Square station are higher than Bagh Ferdows station due to proximity to mercury stationary emission sources.
- Wet and dry deposition of GOM is more than other forms of atmospheric mercury due to its reactivity.

Papers

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ORIGINAL PAPER

Estimation of atmospheric mercury emission inventory in Tehran Province

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Abstract
In this study, atmospheric mercury emission inventory was estimated from various anthropogenic sources of emission in Tehran province, including stationary, mobile and also natural sources. The mercury emission factors from different sources were obtained using the United Nations Environment Programme, the United States Environmental Protection Agency AP-42 and related papers. Twelve mercury emission stationary point sources including power plants, cement factories, oil refinery and municipal solid waste in Tehran province were considered, as the total amount of mercury released into the air from these sources was estimated at 405.3 kg/year. To estimate the atmospheric mercury emissions from stationary area sources, the amount of fuel consumed by the activity of power plants, cement factories and oil refinery has been deducted from the total amount of fuel consumed in Tehran province, and according to the type of fuel consumed, this amount was estimated at 97.2 kg/year. Other stationary area sources considered in this study include the brick manufacturing, the use of mercury-containing lamps, the use of mercury in dental treatment and thermometers and the total atmospheric mercury emission from these sources was estimated at 120.1 kg/year. The amount of atmospheric mercury emission from mobile sources was estimated at 46.4 kg/year. The atmospheric mercury emission from natural sources are based on the surface type, which includes impervious surfaces such as pavements and permeable surfaces such as soils, was estimated at 434.1 kg/year of mercury emitted into the air. The total atmospheric mercury emission in Tehran province was estimated at 780.1 kg/year.

Keywords Atmospheric mercury · Emission's estimation · Emission factors · Mercury emission sources · Tehran province

Introduction

Mercury is one of the most toxic heavy metals that can accumulate in biotic tissues and endanger the human health, wildlife and the environment. Mercury enters the body through digestion, breathing, skin absorption and eye contact which causes damage to the kidney, brain, respiratory and central nervous system (Saturday 2018; Bernalte et al. 2015; Gupta and Nirwan 2015).

Mercury exists in the atmosphere in three important species including gaseous elemental mercury (GEM), reactive gaseous mercury (RGM) and particulate bounded mercury (PBM). Mercury in atmosphere is mostly in form of elemental gaseous by more than 95% (Zhou et al. 2019; Gbor et al. 2007). Bivalent compounds of mercury are more toxic than compounds of a single capacity, also mercury can be transported to places far away from its sources. Mercury is produced naturally and/or anthropogenically in the environment. The natural sources of mercury emission include volcanoes, forest fires, soil, plants and water. Some naturally emitted mercury includes re-emissions of deposited anthropogenic mercury (Gbor et al. 2006).

In 1997, the United States Environmental Protection Agency (EPA) presented a report named "Mercury Study Report to Congress" (MSRTC) about the anthropogenic mercury emissions in the USA. This report examined the mercury emissions from various sources. The total anthropogenic mercury emissions for 1994–1995 in the USA were estimated at 144 Mg/year (MSRTC 1997). Pacyna et al. (2001) estimated atmospheric mercury emissions from anthropogenic sources in Europe at 341.8 Mg/year during 1995. Pacyna and Pacyna (2002) estimated the global emissions of mercury from anthropogenic sources for 1990 and

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Simulation of atmospheric mercury dispersion and deposition in Tehran city

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Abstract
In this study, dispersion and deposition of atmospheric mercury (Hg) in Tehran city was simulated using WRF-SMOKE-CMAQ models. The Weather Research and Forecasting (WRF) model was used to simulate the meteorological parameters. For validation of WRF results, the simulated wind speeds and temperatures were compared with the parameters measured at a meteorological station in Tehran city for 11 days (8 days in fall and 3 days in winter) in 2010–2011. The correlation coefficient (r) for temperature and wind speed was 0.94 and 0.49, respectively, indicating there was good agreement between measured and modeled results. An atmospheric mercury emission inventory was developed using the United Nations Environment Programme (UNEP), the United States Environmental Protection Agency AP-42 (US-EPA AP-42), and related papers. Sparse Matrix Operator Kernel Emissions (SMOKE) was used to allocate the atmospheric mercury emissions to the modeling domain, and the Community Multiscale Air Quality (CMAQ) model was used to simulate the concentration and deposition of atmospheric mercury. To validate the results of the CMAQ model, the simulated atmospheric particulate mercury (PHg) concentrations for 11 days were compared with the measured results at two different stations (Bagh Ferdows and Bahman Square) where it was measured by the Tehran Air Quality Control Company (AQCC). Comparison between the results from the modeled and measurements of PHg in fall was better than winter. Concentrations and dry depositions of the various forms of atmospheric mercury were higher in areas closer to mercury stationary emission sources.

Keywords Atmospheric mercury · Tehran city · WRF-SMOKE-CMAQ models · Numerical simulation · Dispersion and deposition

Introduction

Mercury is one toxic pollutant among the numerous heavy metals that can accumulate in biotic tissues. Human exposure to mercury can be from exposure to contaminated soil, water, or food, particularly fish. Mercury has a variety of documented adverse impacts on human health and the environment (Wip et al. 2013). Mercury can accumulate in organs, such as the kidney, liver, and especially in the brain, and may interfere with digestive, immune, and nervous systems (Rice et al. 2014).

Mercury is present in the atmosphere in three main forms including gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and particulate mercury (PHg). The main component of mercury in the atmosphere is GEM (> 80%), which remains in the atmosphere several months to 1 year (Driscoll et al. 2013). GOM and PHg have a much shorter residence time in the atmosphere due to more efficient removal by wet and dry deposition (Marrugo-Negrete et al. 2014). Their atmospheric residence time is days to weeks (Zhou et al. 2019).

A number of studies have been carried out to simulate the dispersion and deposition of mercury in the atmosphere at various scales using Lagrangian (RELMAP and HYSPLIT) or Eulerian approaches (CMAQ). Since 2000, a number of

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Thank you!