We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

5,500
Open access books available

136,000
International authors and editors

170M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Chapter

Characterization of Atmospheric Mercury in the High-Altitude Background Station and Coastal Urban City in South Asia

Manikanda Bharath Karuppasamy, Srinivasalu Seshachalam, Usha Natesan and Karthik Ramasamy

Abstract

This study is performed to evaluate the potential sources and seasonal variation of atmospheric mercury (Hg) emissions from regional sources and other influences in India. To achieve this, using the gold amalgam technique with an automated continuous mercury vapour analyzer (TekranTM 2537B). To assess the total gaseous mercury in high altitude mountain peak station at Kodaikanal & coastal/urban air in Chennai region, the impact of changing weather conditions is also evaluated. To compare the past and recent reports of mercury at different locations in the world. The average total gaseous mercury value in Chennai is 4.68 ng/m^3, which is higher as compared to Kodaikanal, where it is 1.53 ng/m^3. The association between TGM with meteorological parameters in ambient air such as temperature, relative humidity, rainfall intensity, the direction of wind and velocity of was studied. The TGM concentration in India are compared with other nations, the TGM levels are similar to the east and Southeast Asian countries, and also Europe, Sub-Saharan Africa and North America are the averages and maximum concentration generally smaller. This research will help to establish more effective management approaches to mitigate the impacts of atmospheric mercury on the rural and urban environment.

Keywords: ambient total gaseous mercury, meteorological parameters, high-altitude station, coastal urban city, global perspective

1. Introduction

The Atmosphere hosts almost all emissions from every source on the Earth's surface, freshwater bodies, oceanic surface and anthropogenic emissions. In the atmosphere, mercury occurs in the following three primary forms: The gaseous elemental mercury (GEM), reactive elemental mercury or divalent mercury (RGM) and particulate mercury (PHg) [1, 2]. There is a significant quantity of research which indicates that these elements in the environment, water and marine environments via a dynamic mixture of transport and transformation in natural and human (anthropogenic) [1, 3–5]. Mercury (Hg) stays as a natural substance with the biogeochemical cycle, which is involved in the Earth and is considered as a contaminant because of its long-range transport in the atmosphere [6, 7].

At World level, about 50 to 70% of total mercury discharge is through anthropogenic exercises, including petroleum product ignition, smelting of metals, burning of urban waste, the release of smoke from coal-burning power plants [8, 9]. In nature, mercury occurs in three unmistakable structures, GEM, RGM and PHg [10–13]. Among these three structures, RGM and PHg shift rapidly because of their characteristics such as high-water dissolvability and reactivity [14, 15]. The lifetime of GEM is 0.5 to 2 years, which is sufficient for its transportation worldwide level [16–18]. It is reported that East Asian Nations are a standout amongst the most critical patrons of worldwide anthropogenic mercury discharge [19–21]. Total gaseous mercury (Hg0) evasion is approximated to be 2900 mg/year (range 1900–4200 mg/yr) from the ocean [22, 23]. The ocean is therefore known to be the primary terrestrial Hg source worldwide, contrasted with approximately 2000 mg/yr from direct anthropogenic emissions. Hg usually occurs in geochemical reserves, but for several years human activities including mining and more recent burning of fossil fuels have increased the emission of Hg from the mineral source into the atmosphere [24, 25]. The background means the concentration of TGM in the northern hemisphere (1.3–1.6 ng m^{-3}), southern hemisphere (1.1–1.3 ng m^{-3}) and tropic regions (0.8–1.1 ng m^{-3}) respectively [26–28]. Various investigations have been completed worldwide on GEM mainly centred on the urban and rural locales, including mining and mechanical territories [29–34]. A thorough investigation of the air fluctuation, adding up to vaporous mercury and their relationship at the high-altitude station (Kodaikanal) of Southern India has been reported [35]. However, there is no complete investigation of the developed and developing urban regions of India and their contribution to TGM. This is the first research in India with a comparative and continuous observation of the temporal variations in TGM and its relationship to other meteorological parameters in urban and rural high-altitude stations. In general, the variation in mean seasonal concentration of TGM depends largely on meteorological variables. The study aims to investigate that during the day concentration of TGM is strongly change by solar radiation, evaporation and weather patterns. The main objectives of this study are to assess the Seasonal variability of atmospheric Total Gaseous Mercury (TGM) in high-altitude background station (Kodaikanal) and coastal urban city (Chennai) in India, to identify the potential sources and sinks of atmospheric mercury in the study areas and the influence of changing weather conditions on the atmospheric mercury distribution. Further, to compare the concentration of mercury in the past and recent findings of mercury at different locations around the world.

2. Materials and methods

In this study, monitoring sites are centrally located in high-altitude background station (Kodaikanal) and coastal urban city (Chennai) in South India (**Figure 1**). Kodaikanal is situated on a plateau on the southern ridge of upper Palani hill, at 2133 m (6998 ft) between the valleys of Parappar and Gundar. Such hills surround the Western Ghats mountains on the western side of South India. Kodaikanal region covering the whole of Kodaikanal taluk is located between 10° 7'56" N latitude and 10°26' and 77°15' East and 77°42' East longitude. Such hills shape the western Ghats on the west portion of South India's eastward slope. Kodaikanal is located on the east coast of the Western Ghats, at the southern end of the elevated hills of Palani of Dindigul district, in the state of Tamil Nadu. For a long time in Kodaikanal, despite reports of extensive mercury contamination, the closure of a mercury factory owned by the Indian Unilever company Hindustan Unilever became a big concern. There are 35,021 residents in Kodaikanal.

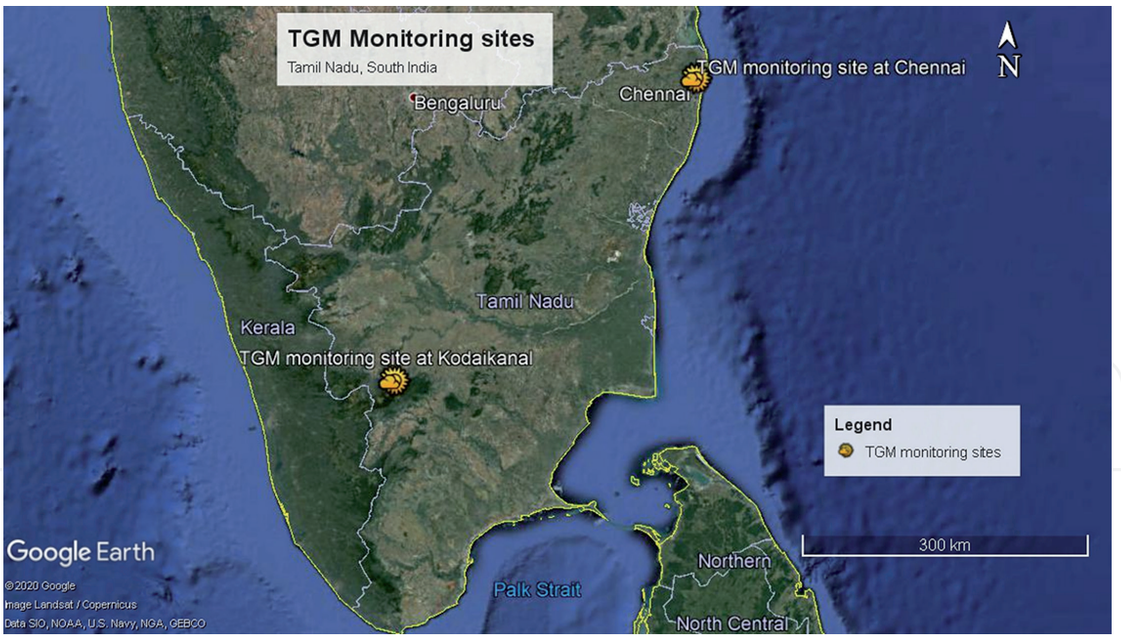

Figure 1.
Atmospheric Total Gaseous Mercury (TGM) monitoring sites in high-altitude background station (Kodaikanal) and coastal urban city (Chennai) in South India.

Chennai, situated on the South East Coast of India is the capital of Tamil Nadu. The Chennai city houses large scale enterprises like Petrochemical businesses, Thermal power plants, Rubber Factories and also many small-scale industries are prospering in and around the city. Chennai Metropolitan falls in the tropical wet and dry climatic condition, with the average barometrical temperature of around 25 to 40°C. The normal yearly precipitation of the city is approximately 140 cm. Because of its varied industrial and domestic setting, Chennai Metropolitan is a suitable site for studying the variations in the concentration of TGM in the air. The computerized mercury vapour analyzer (Model No - Tekran 2537B) placed at Anna University, Guindy Campus, Chennai (13° 0'45.05" N - 80° 14'2.66" E; MSL – 49 ft) was used for TGM measurements. TGM measurement and dataset were collected from the top of the Institute for ocean management, building in the Guindy campus of Anna University. The sampling height is about 50 m above the ground level, and the sample inlet was fixed in 1m above the floor of the sampling site. Many significant roads crossed in the nearby observation sites it creating vehicular pollution, with no significant sources of massive industrial pollution within 10 km radius.

3. Sampling methods and materials

The Total Gaseous Mercury (TGM) estimation was carried out using a Tekran™ 2537B utilizing an in-situ automated ambient mercury vapour analyzer. Tekran mercury vapour analyzer (2537B) continuously measured the TGM every 5-minutes from January 2015 to December 2016 at high-altitude background station (Kodaikanal) and coastal urban city (Chennai) in South India. The meteorological information was acquired from computerized weather stations such as the Central Pollution Control Board (CPCB) Chennai station, Indian Meteorological Department and World weather online. Consistent informational collections of the above said parameters were recorded for each 15-minute interim and per day averages. Using a Mercury Vapor Automated Analyzer (Model No–Tekran 2537B), the addition of total gaseous mercury (TGM) was studied. To this achieve, using cold vapour atomic fluorescence spectroscopy (CVAFS) techniques and the minimum

detection limit 0.1 ng/m^3, which are described. When the ambient air was analyzed, a 47 mm Teflon filter was inserted in the whole measurement method of usage of the experiment. The flow rate is constant 1 L min^{-1} during all sampling periods. The implicit two gold cartridges, on the other hand, gather and thermally desorb mercury. The analyzer measured the Hg concentrations with intervals of 5 minutes automatically every 24 hours, and it was calibrated with its internal permeation sources. Present measurements at atmospheric TGM concentrations include other parameters, temperature, relative humidity, density, rainfall intensity, the direction of wind and velocity of the wind. The analyzer is automatically adjusted every 24 hours for each cartridge utilizing the internal ZERO and SPAN Permeation Processes. The peak areas for both cartridges during the calibration cycle are ensured during the ZERO process and under an error of less than ± 10% during the SPAN process. Computerized day-to-day alignments were performed every 24 hours (3.10 p.m. and 3.40 p.m.) using the instrument's internal adjustment source [35, 36]. The periodical inner alignment expels both in traverse and zero that are caused for the most part by temperature and maturing of the fluorimeter light. The tested air was estimated in each five-minute time interim at a stream rate of 5 L min^{-1}. The detail of the inspecting air and the precision status of the instrument is clarified by Mao et al. The recognition furthest reaches of the TGM are< 0.1 ng m^{-3}. The precision of the estimation and the task is ± 5 %. Zero air was utilized as straightforward for the instrument. Airstream was gathered through PFA Teflon tube, which was tried with an aftereffect of around 100 % RGM passing proficiency (vacillation of RGM is once in a while < 2 %). However, this method is still the most accurate to date and is widely used for the observation of speciated Hg in ambient air.

4. Results and discussion

4.1 Characteristics of TGM in the high-altitude background station in South India

In the meteorological variables at the high-altitude ground station at Kodaikanal, India continued measurement of total gaseous mercury (TGM= Gaseous Elemental Mercury (GEM) + Reactive Gaseous Mercury (RGM) was performed from Jan 2015 to December 2015). The mean concentration for TGM was 1.49 ng m^{-3} with a range of 1.1–2.10 ng m^{-3} is shown in **Figure 2**. The Global Mercury Observation System (GMOS) ground-based monitoring sites in India are also the highest altitude monitoring location in the GMOS network at Kodaikanal (South India). Such measurement positions constitute a major addition to the GMOS network and improve the understanding of atmospheric Hg species in this world region. The statistical summary of TGM concentration along with the meteorological parameters in the ambient air of Kodaikanal during the study period provided in **Table 1**. **Figure 2** shows the hourly average, daily average, monthly variation of TGM concentration in high-altitude background station (Kodaikanal) in South India. The maximum hourly and daily average concentrations were 2.55 ng/m^3 and 1.95 ng/m^3, respectively. The TGM concentration was occurring at every day for a month, evening time (3.00 am to 6.00 pm; the maximum concentration within the whole-time frame) it is shown in **Figure 2**. This finding was identical to previous observations of [37], at high altitude, remote area of the region of Mt. Changbai, northeast China. Mean annual TGM concentrations at the site of Kodaikanal were recorded at 1.52 ± 0.24 ng/m^3; between 0.77 ng/m^3 and 3.35 ng/m^3. These observable values of mean TGM concentrations were strongly linked to previous observations [35]. The average TGM values in the study

area have also been compared with those reported from the high-altitude rural areas, but lower than in the Asian coastal regions [30, 38]. The highest monthly average TGM was reported in April 2015 (2.07 ng/m^3), while in July 2015 the lowest monthly average was 1.08 ng/m^3. The TGM concentrations range from 0.7 to 2.0 ng/m^3, accounted for approximately 96% of the overall TGM. The annual mean TGM values were usually higher during the day time (1.57 ng/m^3) compared tonight (1.08 ng/m^3) it shows in **Figure 2**. The day-night fluctuations in the TGM level may be induced by temperature variations and thus condensation levels and soil volatilization. A rural site with a similar altitude (~2800 m) in the south of France, where the estimation of TGM in the Pic du Midi Observatory [39], with equivalent techniques, recorded an average of 1.86 ± 0.27 ng/m^3. The geogenic mercury emissions are almost ~0.5 kilotonnes per year (kt y^{-1}) and re-emission of Hg ~1.6 kt y^{-1} from the sources of plants and biomass burning [40]. The mercury deposition can be influenced by organic substances complexation, binding to Fe-Mn oxides, hydrothermal pollutants, sulfide interaction and methylation, as well as world proximities such as river drainage, waste sources, etc. [9, 10, 19, 41]. Meteorological conditions of high-altitude background station (Kodaikanal) in South India studied during the period under report are presented in **Figure 3**. The rose diagram graphically displays wind speed, and wind direction graph indicates that West, ENE direction has the maximum value of frequency fall in 20% with a wind speed range of 4–5 m/s at December to March. The minimum wind speed ranges 2–3 m/s falls in during May to November in Kodaikanal site (**Figure 3**). The relative humidity values increased from June to November; also, the TGM

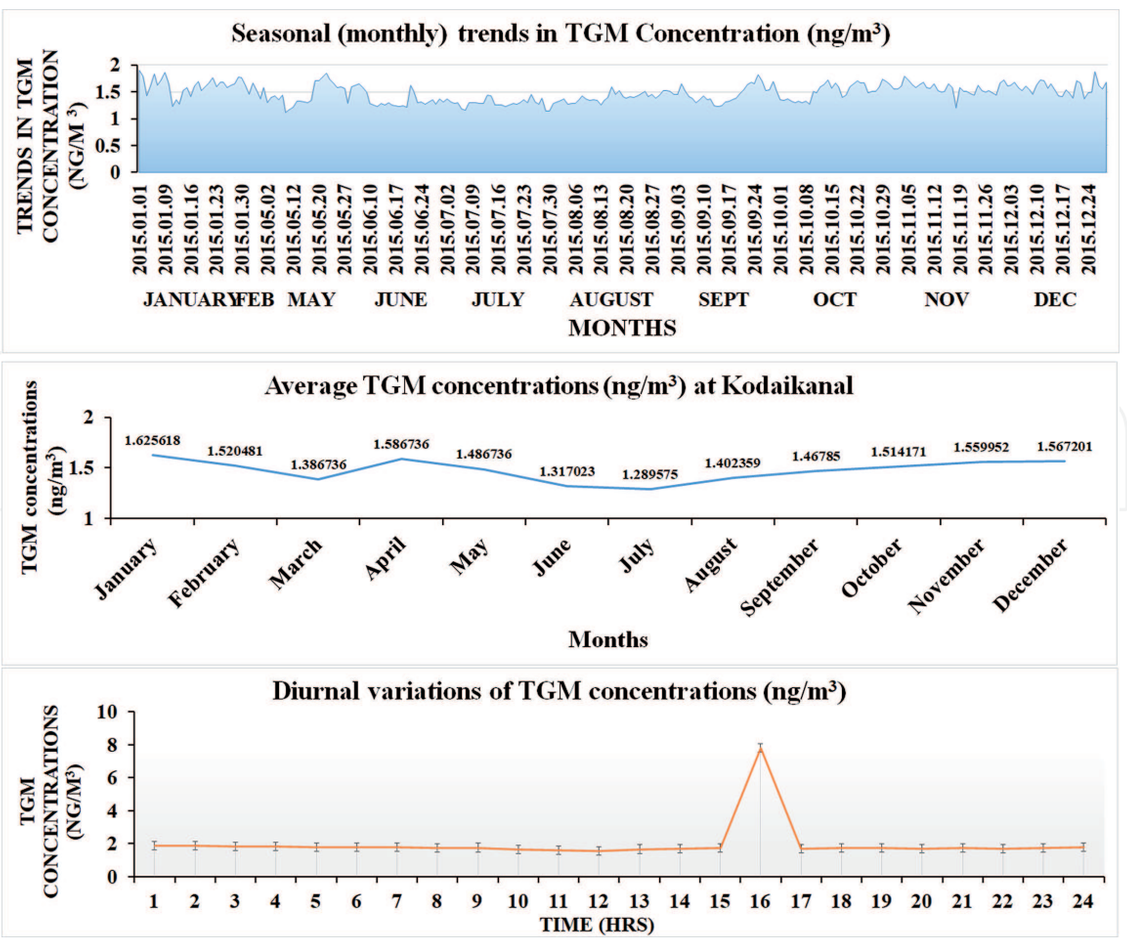

Figure 2.
Diurnal and monthly variation of TGM concentration in high-altitude background station (Kodaikanal) in South India.

Sites	Air Quality Parameters	Seasons			
		Autumn	**Spring**	**Summer**	**Winter**
Chennai	Wind Speed (m/s)	1.13	1.38	1.41	1.11
	Wind Dir (Deg)	198	131	157	187
	Temp (Â°C)	29	30	31	27
	RH (%)	71	73	67	73
	SR (W/sq.m)	199	254	213	198
	TGM (ng/m^3)	4.69	5.40	3.62	5.39
Kodaikanal	Wind Speed (m/s)	8.60	6.70	8.40	9.20
	Wind Dir (Deg)	177	258	129	150
	Temp (Â°C)	17.6	17.4	20.5	18.1
	RH (%)	92.2	91.1	82.6	80.3
	SR (W/sq.m)	290	304	346	322
	TGM (ng/m^3)	1.54	1.38	1.62	1.59

Table 1.
Statistical summary and Seasonal variations of ambient air quality parameters sites in high-altitude background station (Kodaikanal) and coastal urban city (Chennai) in South India.

concentrations were decreased. But relative humidity values decreased from December to May; similarly, the TGM concentrations were increased. Between November and May (dry season), the TGM concentration difference was relatively higher than between June and August (wet season). The Correlation trends of TGM concentration and meteorological parameters in high-altitude background station (Kodaikanal) in South India it shows in **Figure 3**. There were major differences in the mean seasonal concentration of TGM, which mainly depends on weather conditions, and found to be the following: Summer > Winter > Northeast monsoon or Autumn > South-West monsoon or Spring it is given in **Table 1**. This research also showed that solar radiation, evaporation and rainfall strongly changed the daytime TGM concentration. The seasonal variation is influenced by meteorological conditions and other external sources [4, 14]. The gaseous elemental mercury is an important pathway from soil to atmosphere at the forest and to the environment [19]. Also, in the Kodaikanal region, the mean annual TGM value in the Northern Hemisphere in Kodaikanal is well within the ranges of the recorded TGM background for the area (1.5–1.7 ng/m^3). These ground stations mainly track the remote background at high altitude sites and sea levels. The meteorological conditions are significantly influenced by the topsoils and vegetation to release mercury in nature environments [8, 26]. The findings were also significantly affected by long- transport of improved Hg air masses from the eastern part of Gansu, the west of Shanxi, the west of Ningxia as well as northern India [37]. Furthermore, these studies have shown that natural source emissions in summer are higher than in winter.

4.2 Temporal variability of atmospheric mercury in Chennai coastal and urban region

Diurnal and monthly variation of TGM concentration and meteorological parameters in the coastal urban city (Chennai) in South India were estimated in-situ. In the overall monitoring period, day by day, TGM esteem ranges from 0.07 to 638.74 with a mean estimation of 4.68 ng/m^3. The highest concentration of total

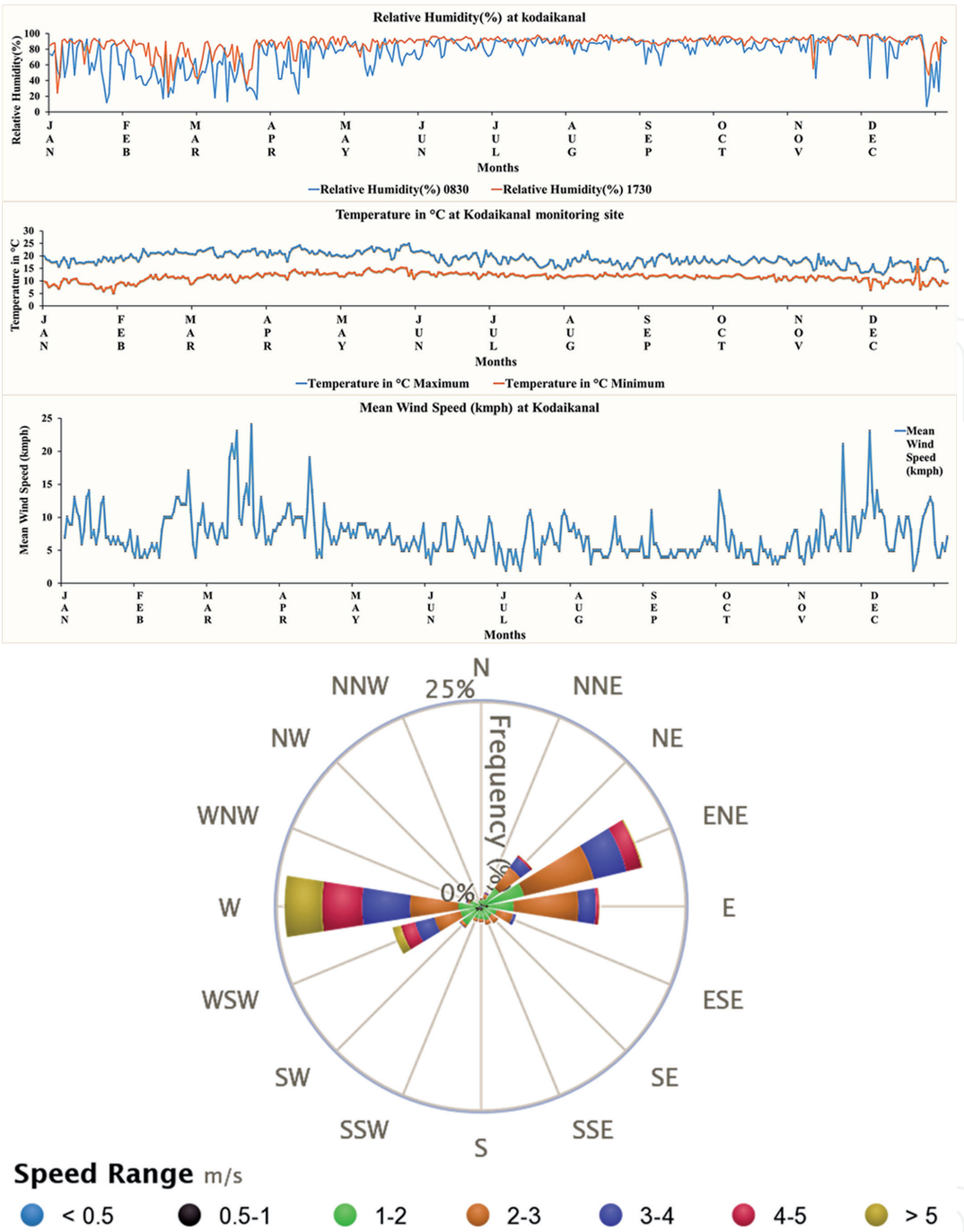

Figure 3.
Trends of TGM concentration and meteorological parameters in high-altitude background station (Kodaikanal) in South India.

gaseous mercury was recorded in June 2016 (638.74 ng/m^3), and lowest concentration was recorded in August 2016 (0.07 ng/m^3) at the coastal urban city (Chennai) in South India (**Figure 4**). The measured values of TGM are having a higher range than the Northern Hemisphere foundation concentration (1.50–1.75 ng/m^3) [9, 42]. TGM concentration occurring at every day, night or early morning (2.00 am to 7.00 am; the maximum concentration within the whole-time frame) is shown in **Figure 4**. Similarly, TGM concentrations were higher in the early in the morning and midnight times reported by Schmolke et al. [36]. Such night-time maximums of TGM concentration [33, 36, 43, 44] have been due to mercury releases in the night-time inversion layer from surface accumulations. The potential sources of TGM in the investigation ground are from coal-based power plants, vehicular discharge, and

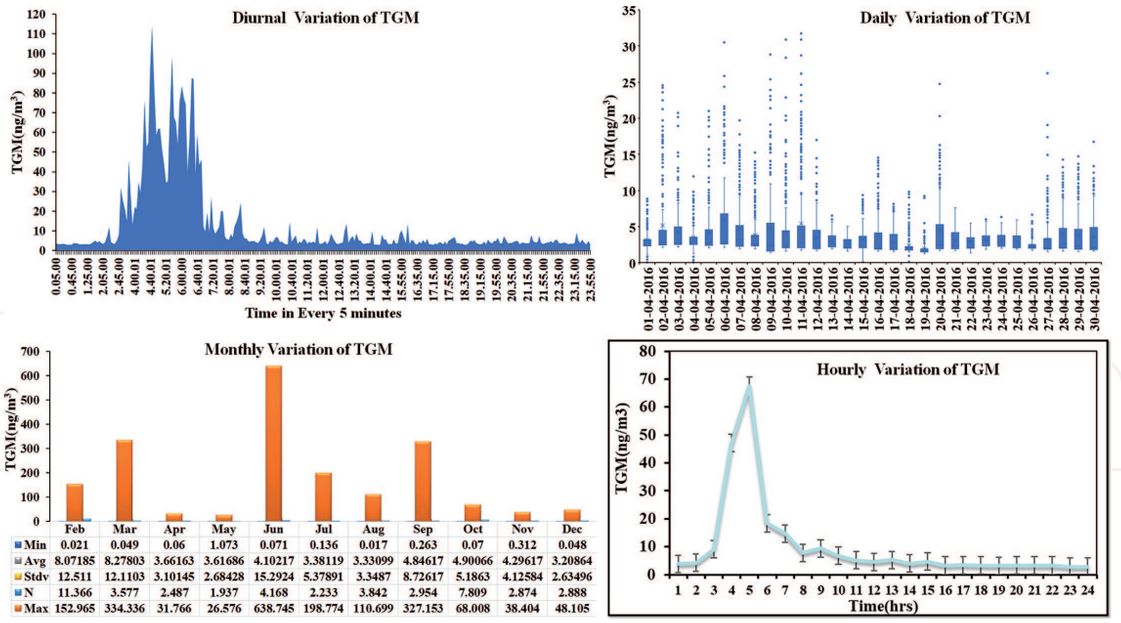

Figure 4.
Diurnal and monthly variation of TGM concentration in the coastal urban city (Chennai) in South India.

squander burning [11, 12, 43]. The short-term measurements of TGM in china report recommend that the TGM ranges from 2.5 to 3.5 ng/m^3 for east beach front territories of China, 1.94 to 3.22 ng m^{-3} for Indochina peninsular regions [29]. Ci et al. [45] revealed that sea occasions are effectively engaged with the conveyance of the GEM along with the beachfront territories. Globally an average of 1.5 ng/m^3 of gaseous mercury is found in the atmosphere and Chennai; the average is 4.68 ng/m^3. The present-day a large source of atmospheric mercury obtains from the ocean the mostly in Hg0 (approximately ranges 1900–4200 Mg/year). The datasets of meteorological parameters versus TGM were plotted in **Figure 5**. Amidst the whole investigation time frame, the most extreme aggregate recurrence of wind rose was seen between 35 to 65° (NE) and 195 to 275° (SSE to WSW), and this focus is around 39% of the aggregate TGM outflow from the coastal urban city (Chennai) in South India **Figure 5**. TGM fluctuations were observed seasonally and diurnally, which suggested differences in source intensity, deposition processes and meteorological influences. The meteorological data set observed used to compare total gaseous mercury variation in the coastal urban city (Chennai) in South India, and it shows in **Figure 5**. The annual rose diagram graphically displays wind speed, and wind direction graph indicates that NE direction has the maximum value of frequency fall in 14% with a wind speed range of more than 5 m/s at Chennai urban environments. It is observed that when the temperature (27 centigrade) is low, the total gaseous mercury is found to be maximum (8.07 ng/m^3) for February (**Figure 5**). olar radiation, temperature, relative humidity and the wind speed increased a month of April, but the TGM concentration was in declined it shows in **Figure 5**. The TGM concentration was in positively correlated in barometric pressure and wind direction. The TGM concentrations continuously decreased in the following months, April to August; similarly, the barometric pressure and relative humidity also decreased (**Figure 5**). The meteorological parameters play a vital role in regulating atmospheric total gaseous mercury concentrations [15, 46]. The leading cause of pollution in megacities India is affected by the coal-fired power plants, transportation, industrial activity and also urban solid waste [47]. The peak concentration of total gaseous mercury was observed in Chennai urban environments during Winter as 5.64 ng/m^3, and the lowest concentration occurred during South-West

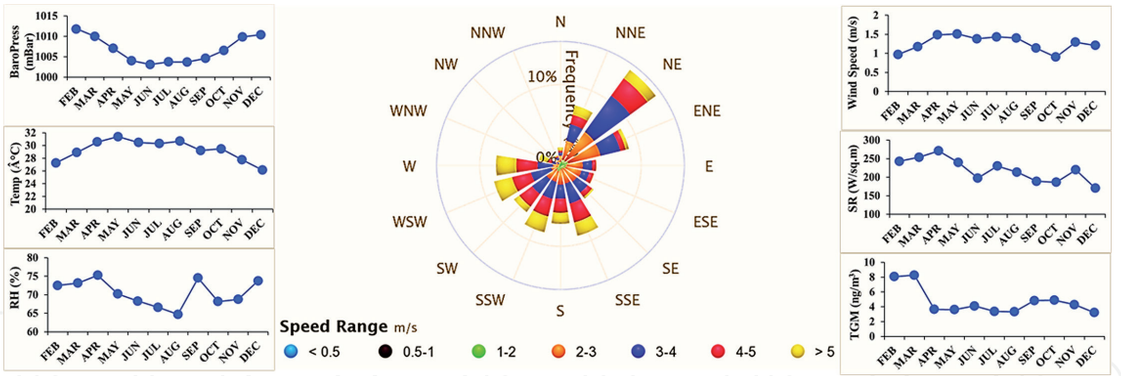

Figure 5.
Trends of TGM concentration and meteorological parameters in the coastal urban city (Chennai) in South India.

Monsoon, which is 3.91 ng/m^3. The highest concentration is observed during Winter and Summer due to long-range transportation of total gaseous mercury compared to autumn and spring seasons. The concentration of total gaseous mercury for the four seasons are arranged in the following order: Winter > Summer > Autumn > Spring for the coastal urban city (Chennai) in South India it is given in **Table 1**.

4.3 Mercury assessment of South Asia and global perspective

The influence of seasonal shift is very predominant in high-altitude background station (Kodaikanal) and coastal urban city (Chennai) in South India. The meteorological parameters (Wind speed, wind direction, solar radiation, Atmospheric temperature, Relative humidity) and TGM focus were connected to decide the relationship connection between the informational indices of the monitoring sites. Total gaseous mercury concentration varies significantly with wind speed and wind direction and other meteorological parameters, a concentration which changes with the seasons as given in **Table 1**. China and India where less attention of recycling the waste and increased production of coal combustion, metals, chlorine, and cement production. In India imported mercury users of Chlor-alkali plants, thermometers, batteries, Hg-Zinc, Zn-Carbon, fluorescent lamps, thermostat switches, alarm clocks, and hearing aids a total mercury user of 129.32 (Mg) reported by Mukherjee et al. [47]. A total of 6500 tones year^{-1}, adapted from, was measured for mercury emissions from biomass combustion, geogenic activities, and soil/vegetation/ocean emissions. The atmospheric mercury emissions approximately one-third from the sources of anthropogenic emissions similarly, natural emissions 70% and Oceanic emissions from 36% [31]. The primary anthropogenic sources such as combustion of fossil fuels for 24% and coal-burning (21%) at worldwide estimated emissions [5]. The approximately 2320 Mg of mercury is released yearly to the worldwide atmosphere (31%) for the primary sources of anthropogenic emission [8]. The world's leading mercury reservoirs, a unit of the Earth's measurement system and still an ecosystem suffering from anthropogenic activity, encompass the atmosphere (4.4 to 5.3 Gt), the terrestrial environment (in particular soils: 250 to 1000 Gg) and aquatic ecosystems (e.g. oceans: 270 to 450 Gg) [48]. The sustainability of mercury monitoring networks is an essential factor affecting the effectiveness of monitoring efforts.

In a global mercury assessment in 2013, mercury reported to dental usage measured at roughly 270-341 tons in 2010 [49], which represents 10% of global consumption of mercury **Figure 6**. Recently, the United Nations Environment Programme (UNEP) report 2018 to estimate the anthropogenic sources of

anthropogenic sources in 2015 were about 2220 tons. Such sources constitute respectively 25 to 37 percentages of overall worldwide mercury emissions, measured at approximately 2000 tons. The TGM concentration in South Asia (India) are compared with other nations, the TGM levels are similar to the east, and southeast Asian countries and also Europe, Sub-Saharan Africa and North America are the averages and maximum concentration generally smaller. Mercury emission estimated (kg) in global in south Asia was in the second-largest nation in the worldwide it shows **Figure 6** [49]. Recent assessments of emissions of mercury into the environment (the 2010 targets) indicate that the primary anthropogenic sources of mercury pollution into the environment are artisanal and small-scale gold mining and fossil fuels (primarily coal) for power plants and industrial boilers for the generation of heat and electricity. In India majority of mercury releases from coal-burning (89,444 kg) followed by non-ferrous metal production (22,536 kg), waste from products (13,692 kg), cement production (13,421 kg) non-ferrous metal production, combustion of fossil fuels and artisanal small scale gold mining was in less than 1000 kg etc. it shows in **Figure 6** [49]. The most important natural sources and sources of re-emissions assessed within the GMOS project are oceans, which contribute 36% of the emission of mercury, followed by biomass (9%), deserts, metal and non-vegetation areas (7%), tundra and grassland (6%), forest (5%) and evasion after the events of mercury depletion (3%) [25, 40]. The majority of mercury releases worldwide estimated by fossil fuel combustion (11%), small-scale gold mining (5%), non-ferrous metal production (4%), cement production (3%),

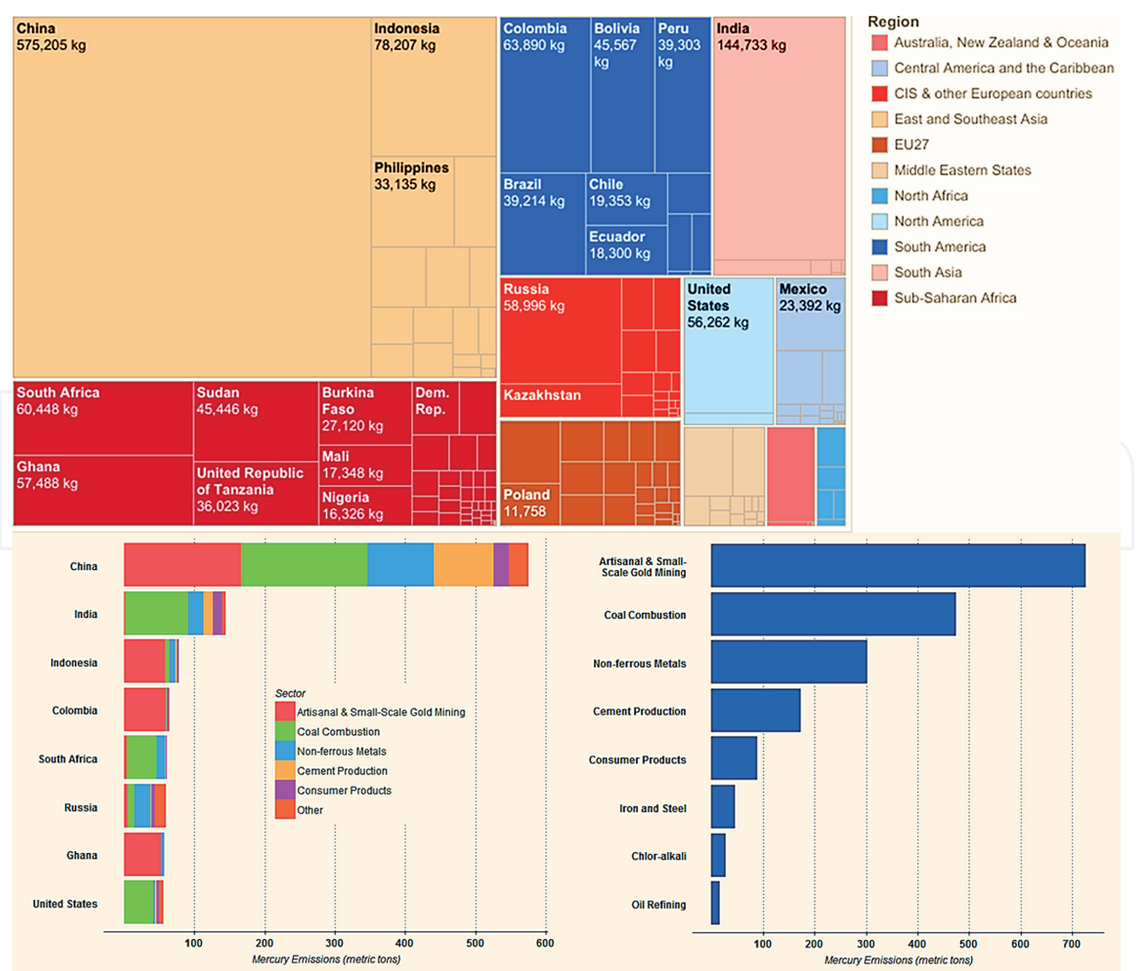

Figure 6.
Country and sector-wise mercury emission and sources of emission sectors in India and global (data source: UNEP [49]).

caustic soda production (2%), waste incineration (2%) and pig iron production (1%) [8]. Total mercury emissions are dominant in Asian countries, particularly China and India, and this information on the above factors and detailed estimates for mercury can be found in AMAP/UNEP [49].

Mukherjee et al. [47] reported the mercury contamination in India its mainly from industrial mercury emissions from coal combustion, the iron and steel industry, non-ferrous metallurgical plants, chloralkali plants, cement industry, waste disposal and other minor sources (i.e. brick production). The largest contributors to the source categories are coal combustion (52%) and waste incineration (32%) as shown in **Figure 6**. In general, TGM concentrations in urban and suburban areas are higher than in rural areas [49]. Mercury emission estimated (kg) in global in south Asia was in the second-largest nation in the worldwide [49]. However, measurements from global urban sites, which are also situated in the same region Asia, showed less than half of the mean concentration from our site. One of the main reasons for our study area is located in the coastal region was that episodically diluting with cleaner marine air and TGM with oceanic bromine will reduce pollution [50]. The possible sources of TGM in India are coal-fired power plants, vehicular emission, manufacture of ferrous and non-ferrous metals, waste incinerating sites, domestic fuel use from residents within the Informal villages around the Landward side, and ocean origin sources. Also, The Asian countries emissions are dominated in the global anthropogenic mercury emissions [21]. Current estimations on mercury emissions and re-emissions of primary natural mercury, including, mercury leakage cases, were measured at 5207 tonnes year^{-1}, which accounts for approximately 70% of the GMOS programme [5]. This pollution estimate is accurately compared to the information given by Cohen et al. Various additional lines of study and measurement are necessary to improve inventories of mercury and improve the ability to assess control options.

5. Conclusions

India is known to be the second-highest mercury (Hg) contributor to the global Hg budget for the environment. The present study is focused on the hourly, daily, and seasonal variations of the TGM concentration and meteorological parameters investigated at high-altitude background station (Kodaikanal) and coastal urban city (Chennai) in India. The mean total gaseous mercury concentration in Chennai is 4.68 ng/m^3, which is higher when compared to Kodaikanal, where it's approximately 1.53 ng/m^3. TGM concentrations exhibit an obvious diurnal pattern at Chennai urban region. All peak values appear between 3:00 am, and 8:00 am in all the seasons. This is probably the result of the change in the height of the atmospheric boundary layer that occurs between day and night. This is in large relation to global averages, but slightly less than in semi-industrial/urban areas in India.

The reason behind the higher concentration of total gaseous mercury in Chennai region is the high pollution due to anthropogenic sources, for example, industrial and vehicular emissions, which essentially improves vaporous mercury and also significantly enhances the atmospheric mercury level. Among the seasons, concentrations of TGM were higher during winter season both in Chennai and Kodaikanal indicating dry air with lower humidity aggregates higher pollutants in an urban environment. Total gaseous mercury concentration during the winter season is observed to be maximum in both regions. The average TGM concentrations during four monitoring seasons were ordered as Winter > Summer > Autumn > Spring. The average TGM concentrations in Chennai during the four monitoring seasons were ordered as Winter (5.64 ng/m^3) > Summer (5.16 ng/m^3) > Autumn (4.59 ng/m^3)

> Spring (3.92 ng/m^3). The average concentration of total gaseous mercury in the high-altitude background station (Kodaikanal) for the four seasons are arranged in the following order: Winter (1.61 ng/m^3) > Autumn (1.53 ng/m^3) > Summer (1.51 ng/m^3) > Spring (1.36 ng/m^3). From the results, it is clear that meteorological parameters play a vital role in the variation of total gaseous mercury. Factors such as the re-emission of concentrated mercury through Earth soils, vertical mixing and long-range transport influenced the seasonal variability of TGM at the monitoring sites. Moreover, it is clear that in the future if these meteorological parameters changes, it will change the concentration of total gaseous mercury in the observation regions. The present study can be extended by quantifying the total mercury emission from the earth systems and its impact on environments and human health in the Chennai urban region. There is a shortage of essential information and pollution factors for Asian countries to complete this analysis to address this situation. Recent work has used TGM and meteorological parameters, although the impact of wind speed, wind direction, and solar radiation on pollutant behaviour are well known, and these factors can be more easily approached in future research.

Acknowledgements

The authors express their gratitude towards The Global Mercury Observation System (GMOS), European Commission, for providing instrumental (Grant Agreement no. 265113) and technical support and Central Pollution Control Board (CPCB), Chennai, for providing meteorological data.

Author details

Manikanda Bharath Karuppasamy[1*], Srinivasalu Seshachalam[1], Usha Natesan[2] and Karthik Ramasamy[3]

1 Institute for Ocean Management, Anna University, Chennai 600025, Tamil Nadu, India

2 Centre for Water Resource, Anna University, Chennai 600025, Tamil Nadu, India

3 National Centre for Sustainable Coastal Management, Ministry of Environment, Forest and Climate Change, Chennai 600025, Tamil Nadu, India

*Address all correspondence to: krmanibharath93@gmail.com

IntechOpen

© 2020 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. CC BY

References

[1] Johannes, Bieser., Hélène, Angot., Franz, Slemr., Lynwill, Martin.: Atmospheric mercury in the Southern Hemisphere – Part 2: Source apportionment analysis at Cape Point station, South Africa. Atmos. Chem. Phys. 63 (2020). https://doi.org/10.5194/acp-2020-63

[2] Lyman, S.N., Cheng, I., Gratz, L.E., Peter, Weiss-Penzias., Leiming, Zhang.: An updated review of atmospheric mercury, Sci. Total Environ. (2019). https://doi.org/10.1016/j.scitotenv.2019.135575.

[3] Fitzgerald WF, Engstrom DR, Mason RP, Nater EA. The case for atmospheric mercury contamination in remote areas. Environ. Sci. Technol. 1998;**32**(1):1-7. DOI: 10.1021/es970284w

[4] Tripathee Lekhendra., Guo Junming., Kang Shichang., Paudyal Rukumesh., Sharma Chhatra Mani., Huang Jie., Chen Pengfei., Sharma Ghimire Prakriti., Sigdel Madan., Sillanpää Mika.: "Measurement of mercury, other trace elements and major ions in wet deposition at Jomsom: The semi-arid mountain valley of the Central Himalaya". Atmos. Res. Volume 234, article id. 104691 (2020). DOI:10.1016/j.atmosres.2019.104691

[5] UNEP.: Global Mercury Assessment. United Nations Environment Programme, Geneva (2018).

[6] Liuwei, Wang., Deyi, Hou., Yining, Cao., Yong, Sik OK., Filip, M.G., Tack Jörg, Rinklebe., David O'Connor.: "Remediation of mercury contaminated soil, water, and air: A review of emerging materials and innovative technologies". Environ. Int. 134, 105281 (2020). https://doi.org/10.1016/j.envint.2019.105281

[7] Slemr, F., Weigelt, A., Ebinghaus, R., Bieser, J., Brenninkmeijer, C.A., Rauthe-Schöch, A., Hermann, M., Martinsson, B.G., van Velthoven, P., Bönisch, H., Neumeier, M., Zahn, A., Ziereis, H.: Mercury distribution in the upper troposphere and lowermost stratosphere according to measurements by the IAGOS-CARIBIC observatory: 2014-2016. Atmos. Chem. Phys. 18, 12329-12343 (2018)

[8] Pirrone N, Stracher GB, Cinnirella S, Feng X, Finkelman RB, Friedli HR, et al. Global mercury emissions to the atmosphere from anthropogenic and natural sources. Atmos. Chem. Phys. 2010;**10**:5951-5964

[9] Yi, Hui., Tong, Lei., Lin, Jia-mei., Cai, Qiu-liang., Wang, Ke-qiang., Dai, Xiao-rong., Li, Jian- rong., Chen, Jin-sheng., Xiao, Hang.: "Temporal variation and long–range transport of gaseous elemental mercury (GEM) over a coastal site of East China". Atmos. Res. Volume 233, article id. 104699 (2020). DOI:10.1016/j.atmosres.2019.104699

[10] Cooke, C.A., Martínez-Cortizas, A., Bindler, R., Sexauer Gustin, M.: Environmental archives of atmospheric Hg deposition – A review. Sci. Total Environ. (2019). DOI: https://doi.org/10.1016/j.scitotenv.2019.134800

[11] Huan, Zhang., Zhangwei, Wang., Chunjie, Wang., Xiaoshan, Zhang.: Concentrations and gas-particle partitioning of atmospheric reactive mercury at an urban site in Beijing, China. Environ. Pollut.Vol: 249, Page: 13-23 (2019). https://doi.org/10.1016/j.envpol.2019.02.064

[12] Jiaoyan, Huang., Matthieu, Miller B., Eric, Edgerton., and Mae Sexauer, Gustin.: "Deciphering potential chemical compounds of gaseous oxidized mercury in Florida, USA". Atmos. Chem. Phys. 17, 1689-1698 (2017). DOI:10.5194/acp-17-1689-2017.

[13] Poissant L, Pilote M, Beauvais C, Constant P, Zhang HH. A year of continuous measurements of three atmospheric mercury species (GEM, RGM and Hgp) in southern Québec, Canada. Atmos. Environ. 2005;**39**:1275-1287

[14] Cheng, Z., Tang, Y., Li, E., Wu, Q., Wang, L., Liu, K., Wang, S., Yongmei Huang., Lei Duan.: Mercury accumulation in soil from atmospheric deposition in temperate steppe of Inner Mongolia, China. Environ. Pollut. Vol: 258, Page: 113692 (2019). https://doi.org/10.1016/j.envpol.2019.113692

[15] Guor-Cheng Fang, Kai-Hsiang Tsai, Chao-Yang Huang, Kuang-Pu OuYang, You-Fu Xiao, Wen-Chuan Huang, Yuan-Jie Zhuang.: "Seasonal variations of ambient air mercury species nearby an airport". Atmos. Res. 202, Pages 96-104 (2018). https://doi.org/10.1016/j.atmosres.2017.11.008

[16] Fang F, Wang Q, Li J. Urban environmental mercury in Changchun, a metropolitan city in Northeastern China: source, cycle, and fate. Sci. Total Environ. vol. 2004;**330**:159-170

[17] Syed, Abdul Rehman Khan., Yu, Zhang., Anil, Kumar., Edmundas, Zavadskas., Dalia, Streimikiene., "Measuring the impact of renewable energy, public health expenditure, logistics, and environmental performance on sustainable economic growth," Sustainable Development, John Wiley & Sons, Ltd., vol. 28(4), pages 833-843, (2020), DOI: 10.1002/sd.2034.

[18] Weiss-Penzias P, Jaffe D, Swartzendruber P, Hafner W, Chand D, Prestbo E. Quantifying Asian and biomass burning sources of mercury using the Hg/ CO ratio in pollution plumes observed at the Mount Bachelor Observatory. Atmos. Environ. 2007;**41**:4366-4379

[19] Jun, Zhou., Buyun, Du., Lihai, Shang., Zhangwei, Wang., Hongbiao, Cui., Xingjun, Fan., & Jing, Zhou.: Mercury fluxes, budgets, and pools in forest ecosystems of China, A review. Crit. Rev. Eng., Sci. Technol. (2019). DOI: 10.1080/10643389.2019.1661176

[20] Liu L, Zhang W, Lu Q, et al. Variations in the Sensible Heating of Tibetan Plateau and Related Effects on Atmospheric Circulation Over South Asia. Asia-Pacific. J. Atmos. Sci. 2020. DOI: https://doi.org/10.1007/s13143-020-00207-0

[21] Pacyna EG, Pacyna JM, Sundseth K, Munthe J, Kindbom K, Wilson S, et al. Global emission of mercury to the atmosphere from anthropogenic sources in 2005 and projections to 2020. Atmos. Environ. 2010;**44**:2487-2499

[22] Horowitz HM, Jacob DJ, Zhang Y, Dibble TS, Slemr F, Amos HM, et al. A new mechanism for atmospheric mercury redox chemistry: Implications for the global mercury budget. Atmos. Chem. Phys. 2017;**17**:6353-6371

[23] Streets DG, Horowitz HM, Jacob DJ, Lu Z, Levin L, TerSchure AFH, et al. Total mercury released to the environment by human activities. Environ. Sci. Technol. 2017;**51**:5969-5977

[24] Amos HM, Jacob DJ, Streets DG, Sunderland EM. Legacy impacts of all-time anthropogenic emissions on the global mercury cycle. Global Biogeochem. Cycles. 2013;**27**(2):410-421. DOI: 10.1002/gbc.20040

[25] Ghazvini MV, Ashrafi K, Shafiepour Motlagh M, et al. Simulation of atmospheric mercury dispersion and deposition in Tehran city. Air Qual. Atmos. Health. 2020;**13**:529-541 https://doi.org/10.1007/s11869-020-00813-x

[26] Lynam M, Dvonch JT, Barres J, et al. Atmospheric wet deposition of

mercury to the Athabasca Oil Sands Region, Alberta, Canada. Air. Qual. Atmos. Health. 2018;**11**:83-93 https://doi.org/10.1007/s11869-017-0524-6

[27] Slemr F, Brunke EG, Ebinghaus R, Kuss J. Worldwide trend of atmospheric mercury since 1995, Atmos. Chem. Phys. 2011;**11**:4779-4787

[28] Sprovieri F, Pirrone N, Bencardino M, D'Amore F, Carbone S, Cinnirella F, et al. Atmospheric mercury concentrations observed at ground-based monitoring sites globally distributed in the framework of the GMOS network. Atmos. Chem. Phys. 2016;**16**:11915-11935

[29] Fu XW, Feng XB, Dong ZQ, Yin RS, Wang JX, Yang ZR, et al. Atmospheric gaseous elemental mercury (GEM) concentrations and mercury depositions at a high-altitude mountain peak in south China. Atmos. Chem. Phys. 2010;**10**:2425-2437

[30] Nguyen HT, Kim KH, Kim MY, Kang CH, Shim SG. Mercury in air in an area impacted by strong industrial activities. Chemosphere. 2008;**71**:2017-2029

[31] Pacyna, J.M., Travnikov, O., Simone, F.D., Hedgecock, I.M., Sundseth, K., Pacyna, E.G., Steenhuisen, F., Pirrone, N., Munthe, J., Kindbom, K.: Current and future levels of mercury atmospheric pollution on a global scale. Atmos. Chem. Phys. 16, 12495-12511 (2016)

[32] Pandey SK, Kim KH, Yim UH, Jung MC, Kang CH. Airborne mercury pollution from a large oil spill accident on the west coast of Korea. J. Hazard. Mater. 2009;**164**:380-384

[33] Schiavo B, Morton-Bermea O, Salgado-Martinez E, et al. Evaluation of possible impact on human health of atmospheric mercury emanations from the Popocatépetl volcano. Environ. Geochem Health. 2020. DOI: https://doi.org/10.1007/s10653-020-00610-6

[34] Wang Z, Chen Z, Duan N, Zhang X. Gaseous elemental mercury concentration in atmosphere at urban and remote sites in China. J. Environ. Sci. 2007;**19**:176-180

[35] Karthik R, Paneerselvam A, Ganguly D, Hariharan G, Srinivasalu S, Purvaja R, et al. Temporal variability of atmospheric Total Gaseous Mercury and its correlation with meteorological parameters at a high-altitude station of the South India. Atmos. Pollut. Res. 2016;**8**(1):164-173

[36] Schmolke SR, Schroeder WH, Kock HH, Schneeberger D, Munthe J, EbinghausR.Simultaneousmeasurements of total gaseous mercury at four sites on an 800 km transect: spatial distribution and short-time variability of total gaseous mercury over central Europe. Atmos. Environ. 1999;**33**:1725-1733

[37] Fu, X.W., Feng, X., Shang, L.H., Wang, S.F., and Zhang, H.: Two years of measurements of atmospheric total gaseous mercury (TGM) at a remote site in Mt. Changbai area, Northeastern China. Atmos. Chem. Phys. 12, 4215-4226 (2012)

[38] Nguyen HL, Leemakers M, Kurunczi S, Bozo L, Baeyens W. Mercury distribution and speciation in Lake Balaton, Hungary. Sci. Total Environ. vol. 2005;**340**:231-246

[39] Fu, X., Marusczak, N., Heimburger, L.R., Sauvage, B., Gheusi, F., Prestbo, E.M., and Sonke J.E.: Atmospheric mercury speciation dynamics at the high-altitude Pic du Midi Observatory, Southern France. Atmos. Chem. Phys. 16, 5623-5639 (2016)

[40] Outridge, P.M., Mason, R.P., Wang, F., Guerrero, S., Heimbürger-Boavida,

L.E.: Updated Global and Oceanic Mercury Budgets for the United Nations Global Mercury Assessment. Environ. Sci. Technol. (2018). https://doi.org/10.1021/acs.est.8b01246.

[41] Lee DS, Dollard GJ, Pepler S. Gas-phase mercury in the atmosphere of the United Kingdom. Atmos. Environ. 1998;**32**:855-864

[42] Zhang, Y., Khan, S.A.R., Kumar, A., Golpîra, H., Sharif, A., Is tourism really affected by logistical operations and environmental degradation? An empirical study from the perspective of Thailand. J. Clean. Prod. 227, 158-166, 2019.

[43] Lee T, Shin U, Park S. Atmospheric Structure for Convective Development in the Events of Cloud Clusters over the Korean Peninsula. Asia-Pacific. J. Atmos. Sci. 2020. DOI: https://doi.org/10.1007/s13143-020-00211-4

[44] Syed Abdul Rehman Khan., Arshian, Sharif., Hêriş, Golpîra., Anil, Kumar., "A green ideology in Asian emerging economies: From environmental policy and sustainable development," Sustainable Development, John Wiley & Sons, Ltd., vol. 27(6), pages 1063-1075, (2019). DOI: 10.1002/sd.1958.

[45] Ci ZJ, Zhang XS, Wang ZW, Niu ZC, Diao XY, Wang SW. Distribution and air-sea exchange of mercury (Hg) in the Yellow Sea. Atmos. Chem. Phys. 2011;**11**:2881-2892

[46] Penuelas J, Sardans J. Developing holistic models of the structure and function of the soil/plant/atmosphere continuum. Plant Soil. 2020. DOI: https://doi.org/10.1007/s11104-020-04641-x

[47] Mukherjee, A.B., Bhattacharya, P., Sarkar, A., and Zevenhoven, R.: Mercury emissions from industrial sources in India and its effects in the environment, Springer, New York, USA, chap. 4, 81-112 (2009). DOI: 10.1007/978-0-387-93958-2_4

[48] Obrist D, Johnson DW, Edmonds RL. Effects of vegetation type on mercury concentrations and pools in two adjacent coniferous and deciduous forests. J. Plant Nutr. Soil Sci. 2012;**175**(1):68-77. DOI: 10.1002/jpln.201000415

[49] AMAP/UNEP.: Technical Background Report for the Global Mercury Assessment2013, Arctic Monitoring and Assessment Programme, Oslo, Norway/ UNEP Chemicals Branch, Geneva, Switzerland. vi + 263 pp, (2013).

[50] Zhu J, Wang T, Talbot R, Mao H, Hall CB, Yang X, et al. Characteristics of atmospheric Total Gaseous Mercury (TGM) observed in urban Nanjing. China. Atmos. Chem. Phys. 2012;**12**:12103-12118 https://doi.org/10.5194/acp-12-12103-2012