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Mercury Contamination in Ambient Air – A Review Focus on PM2.5 and PM10”

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Abstract: Mercury is a toxic element that can be found in air, water, and soil. It was said to be a highly potent neurotoxin that influences the central nervous system in both human and wildlife. Mercury is a naturally occurring element, but the level of mercury in the environment is becoming an alarming problem due to the growth of industrialization. Due to its properties, mercury can existed in particulate matter PM2.5 and PM10, therefore it can transport and remain in a long time in the ambient air. The deposition of particulate mercury together with particulate matter PM2.5 and PM10 have made the air pollution become more serious and put human health under high risk. This paper reports the current state of mercury contamination in the ambient air with a focus on the existence of mercury in the particulate matter PM2.5 and PM10. The toxic effects of mercury on human health and some control technology for decontamination of mercury in the ambient are also discussed.

Index Terms: Hg, toxicity, contamination, global production, management

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I. INTRODUCTION

Mercury (Hg) is a chemical element with atomic number 80 and belongs to group 12 of the periodic table of elements. The most common mineral form of Hg in the nature is mercuric sulfide (cinnabar). Hg was known and used from at least as far back as 1500 BC in Egypt [1]. To date, Hg has still been being used in various devices in household such as thermostats, thermometers, light switches, auto switches, appliance switches, batteries, fluorescent lamps (Figure 1). During a long time, Hg was used in dental amalgams. It represents up to 21% of total household uses of mercury. Among applications of Hg, the percentage of Hg used in thermostats was the highest. It contributed up to nearly 47% of total household uses of Hg.

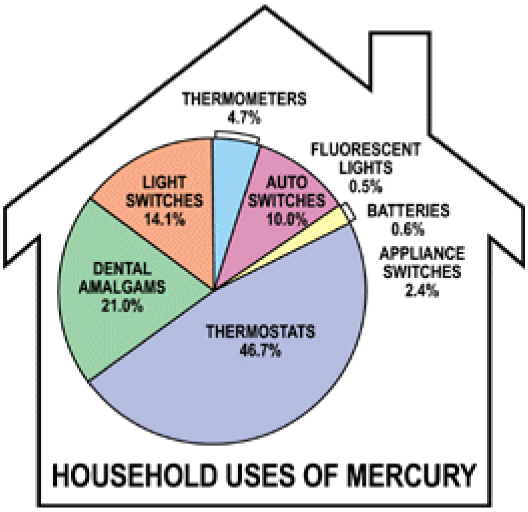


Figure 1. Application of Hg in household [2]

Although Hg was used in many devices in household, the main emission source of Hg which contributed to Hg contamination in the environment is from industrial activities and natural emission (Figure 2). It was reckoned that natural emission accounts for up to 70% of total Hg emitted globally [3]. According to the statistical data in 2008, the natural emission from ocean contributes 2682 tons of Hg annually. Other natural processes such as biomass burning, volcanoes, desert, and forest are also significant parts which release a big amount of Hg.

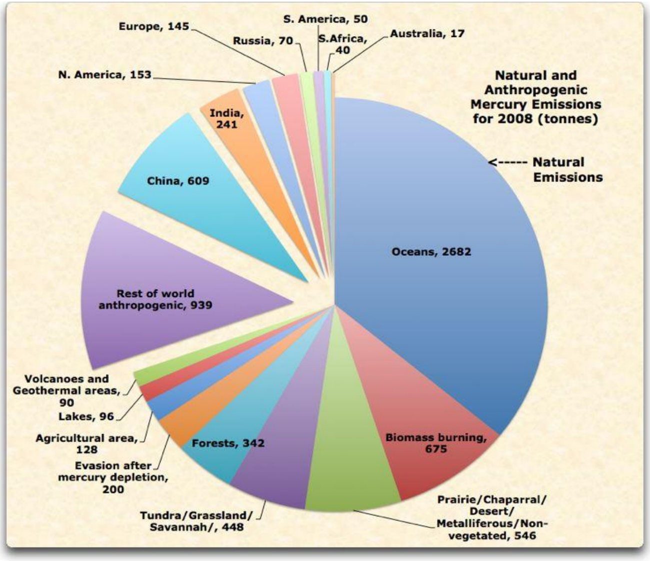
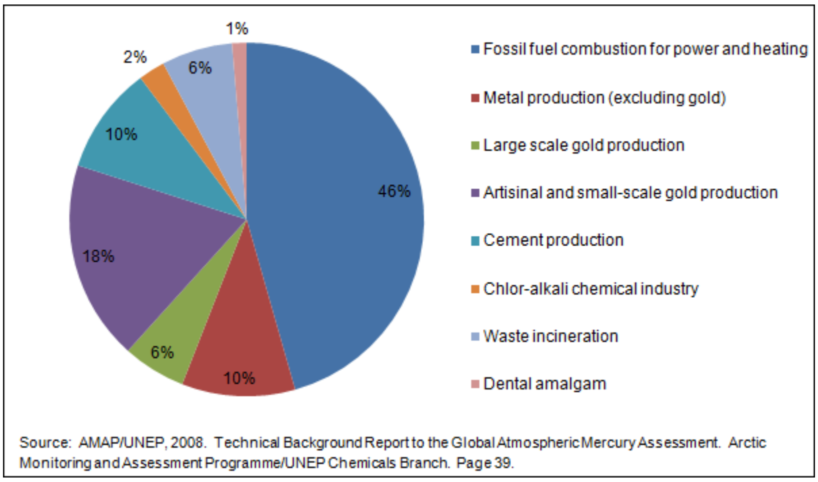


Figure 2. Annual total Hg emitted globally from both natural and anthropogenic sources [3].
Among national regions, China and India are two countries which released the biggest amount of Hg to cause Hg pollution. China released 609 tons of Hg to environment annually, and India is followed with 241 tons of Hg every year. Whereas, the total Hg released by other regions including North America, Europe, Russia, South America, South Africa, and Australia is only 475 tons per year.

The constitution of globally anthropogenic Hg contamination sources in 2008 was demonstrated in Figure 3. It was note that fossil fuel combustion for power and heating contributed up to nearly half of Hg contamination sources (46%). It was followed by the artisanal and small-scale gold production (18%). Industrial activities such as metal production (excluding gold) and cement production released around 10% of total Hg emitted to the environment. Other sources like large-scale gold production, waste incineration, chlor-alkali chemical industry, and dental amalgam shared the remaining percentage of around 15% of total Hg emission.



Source: AMAP/UNEP, 2008. Technical Background Report to the Global Atmospheric Mercury Assessment. Arctic Monitoring and Assessment Programme/UNEP Chemicals Branch. Page 39.

Figure 3. The percentage of Hg contamination sources in total anthropogenic Hg emission [4]

At the early stage of industrialization, the toxicity of Hg and its effects on human and wildlife were not appropriately understandable. Therefore, the application and management of Hg have resulted in a variety of damage and disaster. The Minamata disease is an example of the disaster caused by Hg contamination which was said to affect more than 3000 people in Japan. This was caused by the industrial discharge of Hg compounds into Minamata Bay. The effects of Hg in this incident were mainly through food chain. Fish and shellfish tend to accumulate Hg in their body through bio magnification process. The fish species are high on the food chain accumulated higher Hg concentration in their viscera and muscle tissues.

The toxicity effects of Hg on human vary with the uptake pathway of Hg into human body. Chronic exposure to Hg even at very low concentrations of Hg in the range 0.7–42 µg/m^3 air can cause some symptoms such as tremors, impaired cognitive skills, and sleep disturbance in human [5]. At higher elemental Hg levels of 1.1 to 44 mg/m^3 with acute exposure (4 – 8 h), it can result in various symptoms such as chest pain, dyspnea, cough, hemoptysis, and impairment of pulmonary function [6]. Based on the toxicological calculations, WHO has set the limit value of inorganic Hg concentration in drinking water is 6 µg/L[7].

II. MERCURY CONTAMINATION IN THE AMBIENT AIR

Mercury is the toxic metal can be volatile at ordinary temperature. Therefore, the contamination of Hg in atmosphere or in the ambient air as the gaseous phase is one of the biggest concerns. In addition, Hg emission from anthropogenic combustion such as municipal waste incinerator and heat power plant is continuously increasing. This form of Hg can transport and retain in the atmosphere for many months. They can also be converted to a more water soluble form Hg (II) or bind with particulate matter or aerosol. The conceptual pathway and transport of Hg (Mercury cycle) in the atmosphere and in the environment are summarized in Figure 4.

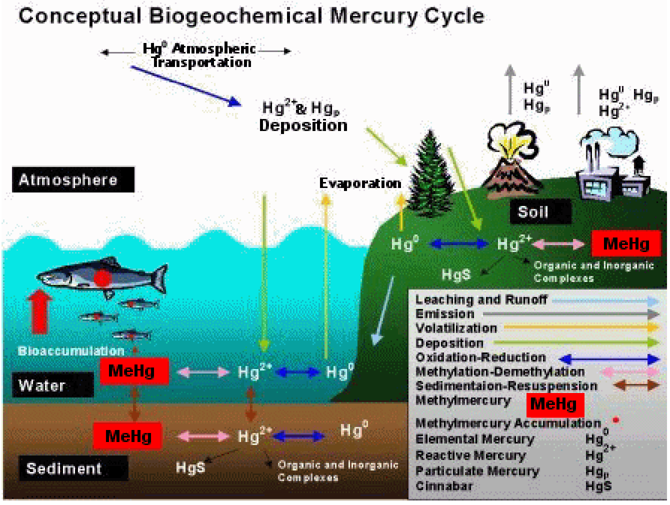


Figure 4. The sources and pathway of Hg in the environment [8].

Mercury contamination sources emits into the atmosphere as three difference forms including gaseous elemental mercury (Hg^0), mercury binding to particulate matter (Hg_p), and divalent mercury (Hg^{2+}). Natural sources like volcanoes mainly emit Hg^0 and Hg_p whereas the industrial sources usually emit all both of three atmospheric Hg forms. These Hg forms can travel a long distance in the air and retain a long time up to several months in the atmosphere. At this stage, Hg can directly enter into human body through inhalation and cause various chronic and acute symptoms. According to a report by Environment America Research and Policy Center, power plants in the United States have emitted 66, 050 pounds of Hg into the air in total [9].

During the transportation in the atmosphere, Hg^0 can be converted into Hg^{2+} and/or Hg_p. These two forms are the main deposit forms of Hg in water and soil environment. Under anaerobic condition, Hg can be transformed into methylmercury (MeHg) by microorganisms. This compound is the common forms which can be bioaccumulated through food chain. The food chain, especially Hg-contaminated fishes become a big hazard to human health when they are consumed. Scientists have indicated that Hg contamination has affected a tenth of American women in the childbearing age, and this could be a direct damage to their children's brain development [9].

III. MERCURY CONCENTRATION with PM 2.5 AND PM 10

Particulate Hg is only a part of Hg contamination source in the ambient air but it has attracted much attention because the air contamination with particulate matter is now increasing. The increases in particulate matter such as PM2.5 and PM10 will be correlated with the increasing potential of Hg^0 binding to particulate matter and transformed into Hg_p. This process simultaneously induces the deposition of Hg and inhalation by human. The fate processes of Hg with the focus on atmospheric transformation are illustrated in Figure 5.

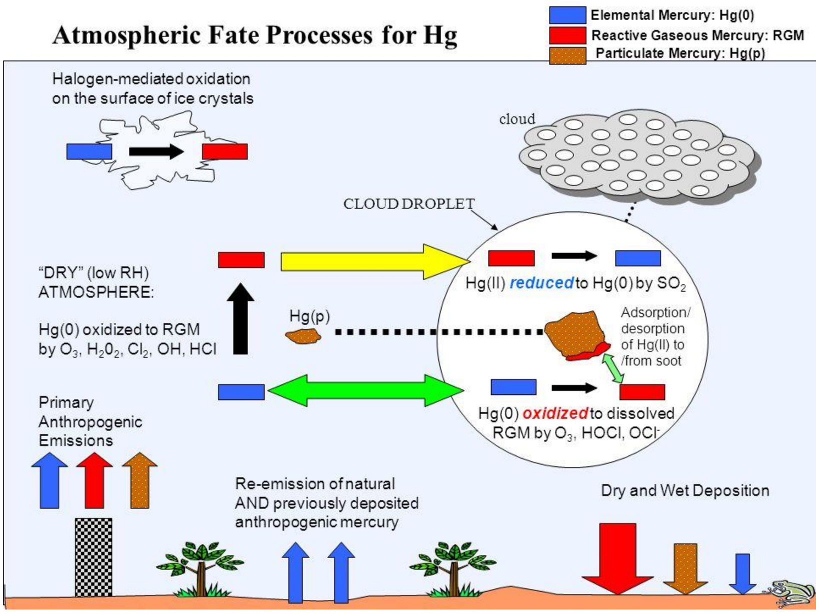


Figure 5. Atmospheric fate process for Hg [10]

It was reported that the concentrations of Hg in PM aerosol at the urban site were always higher than that at the rural site [11]. The adsorption of Hg onto fine particulate matter is much more than coarse particulate matter during winter due to the low temperature. This was also confirmed by another study on the air quality of a coastal city in China which recommended the control of PM2.5 to reduce particulate Hg [12]. The measurement data also indicated that the presence of Hg in fine particulate matter (PM2.5) in winter is dominated (65%) whereas the presence of Hg in coarse particle (PM10) is dominated (50-60%) in summer [13]. Another study in China [14] reported that the concentration of particulate Hg during the heating season in urban air is much more than that during non-heating season (0.461 ng/m^3 vs. 0.145 ng/m^3). Coal burning and wind-blown soil material was mentioned to be the two main sources of particulate Hg which contributes up to 24.1% of total Hg emission in urban areas. With a more detail monitoring program during 2009 – 2010, Feddersen and co-workers [13] have calculated that the dry deposition rate of particulate Hg was 1.7 – 2.8 ng/m^2/d in the summer, 4.6 ng/m^2/d in the winter, and 2.5 ng/m^2/d in the spring.

IV. CONCLUSION

Understanding the distribution of particulate Hg in the air and its binding to particulate matter PM2.5 and PM10 in each season of a year would be useful to decide a more effective control technology for reduction of Hg pollution in the air. Due to its toxicity, Hg in the air should be control under a limit that is set by the WHO, the US EPA, or the national environmental protection agency. Any incident leading to the emission of Hg should be managed in a correct way that is widely disseminated by governmental agency. Many researches have indicated that the enrichment of Hg on PM2.5 followed by the reduction of PM2.5 is recommended as the key process to remediate the Hg contamination in the ambient air.

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