Gaseous Elemental Mercury Emissions from Selected E-Waste Processing Facilities in Turkey

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Abstract

The amount of mercury contained in each unit of electrical and electronic waste (WEEE) is low (about 2-10 mg per equipment). However, it is estimated that all the mercury in the annually produced WEEE accounts for about 22% of the world mercury consumption. Facilities focusing on WEEE recycling have grown enormously in recent years and unfortunately some of this e-waste contains mercury or mercury compounds. The mercury may be released into the environment from consumer products during the recycling processes. Additionally, the recyclers themselves face the possibility of mercury exposure. Environmentally sound management of WEEE needs to involve the informal recycling industry which plays an important part in waste management. The global Minamata Convention on Mercury (Hg), created recently through the United Nations Environmental Programme, requires its signatories to perform improved atmospheric Hg monitoring and characterization of Hg sources. In this study, we evaluate the gaseous mercury emissions from selected licensed WEEE facilities to the atmosphere in different provinces of Turkey by employing a passive air sampling technique.

Keywords: waste electric and electronic equipment (WEEE), e-waste processing, mercury, air, passive sampling

1. INTRODUCTION

Discarded computers, electronic office equipment, electronic entertainment gadgets, mobile phones, television sets, and refrigerators are all examples of electrical and electronic waste, or e-waste (WEEE) (Wikipedia, 2022). Every year, an estimated 50 million tons of e-waste are produced (Sthiannopkao and Wong, 2013). Epoxy resins, fiberglass, polychlorinated biphenyls, polyvinyl chlorides, thermosetting polymers, lead, tin, copper, silicon, beryllium, carbon, iron, aluminum, cadmium, mercury, and thallium are among the substances present in WEEE (Chan et al., 2007). Mercury can be found in flat-screen monitors, tilt
switches such as mechanical doorbells and thermostats and especially in fluorescent tubes having various applications in our living and working environments (USEPA, 2012). Such toxic compounds in WEEE can enter the environment through the waste stream and end up in surface water, groundwater, soil and air. Consequently, such chemicals may have a negative impact on the biotic and abiotic environment as well as humans (Puckett et al., 2012; Chen et al., 2011; Frazzoli et al., 2010; Needhidasan et al., 2014). The Minamata Convention on Mercury was recently ratified as a global treaty to protect human health and the environment from anthropogenic mercury emissions and releases (Mishima and Brown, 1992; Jesty, 2011; MEJ, 2013). As of 2022, 128 countries became signatories of the Convention whereas 137 countries became a party to it (https://www.mercuryconvention.org/en/parties). Turkey signed the treaty in 2014. Signatory countries are obliged to ban new mercury mines, phase out existing ones, control air emissions, and regulate the informal sector of artisanal and small-scale gold mining. Moreover, the Convention requests that “parties endeavor to cooperate to develop and improve geographically representative monitoring of mercury (Hg) levels in environmental media (UNEP, 2013). Gaseous elemental mercury (GEM) is one of three atmospheric mercury (Hg) forms and typically makes up >95% of total Hg. The long atmospheric residence time of GEM implies that its long-range atmospheric transport is the primary environmental distribution mechanism (Driscoll et al., 2013; Lin et al, 2006). Due to high purchasing and operational costs of the instruments in addition to technical training requirements for automated Hg monitoring techniques, gaseous Hg monitoring data in Turkey and in many other parts of the world are limited. As in the case for persistent organic pollutants (POPs), passive air samplers (PASs) have the potential to overcome the limitations of existing techniques for monitoring atmospheric Hg. Such sampling devices require no electrical energy, are low cost, and are easy to deploy concurrently at multiple locations (McLagan et al., 2019). The aim of the current study is to investigate concentrations of GEM at sites in the vicinity of selected WEEE processing facilities in Turkey and compare them to levels at background sites.

2. MATERIALS AND METHODS

2.1. Sampling, Sample Analysis and Air Concentration Calculation

Sampling was conducted using a passive gaseous Hg sampler (Hg-PAS), which was described in detail by McLagan et al. (2016). Briefly, GEM was sorbed on a sulfur-impregnated activated carbon (HGR-AC, Calgon Carbon) which was placed in a stainless-steel mesh cylinder. The HGR-AC filled mesh cylinder was placed in a porous polyethylene diffusive barrier (white diffusive body, Radiello®) which controlled the rate of diffusion from the atmosphere to the sorbent. Finally, the sampler was housed inside a polypropylene container to protect the sampler from wind and rain during the course of the sampling. Previous studies reported (McLagan et al., 2017; 2018) that meteorological parameters such as wind speed and temperature have a minor and quantifiable impact on the rate of mercury uptake in the Hg-PAS. Samples were collected in the vicinity (5-20 m) of 20 WEEE facilities located in 8 different provinces of Turkey from June 2021 to May 2022. Additionally, samples were collected from background sites in each province.

A Direct Mercury Analyzer (DMA-1) (Milestone Inc.), which operates based on thermal decomposition, amalgamation, and atomic absorption spectroscopy (USEPA Method 7473) was used to determine the GEM concentrations in the HGR-AC. The measured mass of Hg (m in ng) sorbed to the HGR-AC, a sampling rate (SR in m³/day), and the sampling duration (t in day, in the current study: 92-101 days) were used to estimate gaseous Hg concentration (C in ng/m³ = m / (SR×t)). Details are given by McLagan et al. (2016).

3. RESULTS AND DISCUSSION

Preliminary results from the first seasonal sampling campaign are shown in Figure 1. GEM level in blank samples was 0.082±0.026 ng/m³ (0.05-0.12 ng/m³; n=12). At background sites, the average GEM concentration was 2.31±0.73 ng/m³ (1.23-3.63 ng/m³) while the average value at WEEE sites was 29.1±63.9 ng/m³ (1.87-271 ng/m³). Mean annual GEM concentrations at remote background sites range from 1.5 to 1.7 ng/m³ in the Northern hemisphere and from 1.1 to 1.3 ng/m³ in the Southern hemisphere (Gustin et al., 2011; Pirrone et al., 2013). McLagan et al. (2019) reported GEM levels between 4.47 and 6700 ng/m³ in the Abbadia San Salvatore mine (ASSM) area in central Italy, historically the third largest site of Hg production globally behind Almadén (Spain) and Idrija (Slovenia). The same researchers found the GEM concentrations to be between 1.26 and 166 ng/m³ in the district of Monte Amiata surrounding the ASSM. In the current study, atmospheric GEM concentrations at sampling sites in proximity to e-waste recycling facilities were 0.73-142 times (18±37) higher than at the background sites.
Concentration levels at background sites observed in the current study were in the range of, or slightly higher than, remote background sites in the Northern and Southern hemispheres. Some of the sites in the proximity of WEEE processing sites showed elevated GEM levels, with one site in Ankara showing particularly high concentrations (site A6, 270 ng/m^3), not unlike those in the vicinity of the ASSM.

Figure 2 compares ambient air average GEM concentrations detected in background and WEEE sites in the current study to the levels detected in other parts of the world. Although sampling methods in these studies vary, as the concentration levels are expressed in ng/m^3, still they are comparable. Average ∑Hg concentration at WEEE sites in the current study (29.1 ng/m^3) was higher compared to levels detected at a WEEE site in Norway (5 ng/m^3, geometric mean, Snow et al., 2021) but lower compared to concentration level detected by personal passive sampler (500 ng/m^3, Snow et al., 2021) at the same WEEE site in Norway.

Results of the current research clearly show that WEEE sites act as point sources of gaseous elemental mercury to the atmosphere in the areas where these facilities are located. As a signatory to the Minamata Convention, Turkey is obliged to reduce Hg emissions to the environment. In this context, monitoring studies are needed to reveal the current status of Hg emissions across the country and Hg-PAS samplers can be used effectively in such an effort.
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