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Biological monitoring involving children exposed to mercury from a barometer in a private residence

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HIGHLIGHTS

- A spill from a broken barometer caused a mercury spill of a few milliliter.
- Removal of the spill using a vacuum cleaner caused a widely dispersed contamination.
- Blood analysis confirmed uptake of mercury in one adult and two children.
- A strategy for human biological monitoring was presented.

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ABSTRACT

A small spill of approximately 3 mL of mercury from a broken barometer in a residential setting resulted in blood values of 32 μg/L in a boy of 9 months and 26 μg/L in a girl of 2.5 years in samples collected within 6 h after the start of the incident. A nanny who attempted to remove the spill had a blood mercury value of 20 μg/L at the same time point. These elevated blood values were attributed to inhalation rather than dermal uptake or ingestion. Exposure was aggravated by the use of a vacuum cleaner in an early attempt to remove the spill and incomplete decontamination of involved persons, leading to a continuation of exposure. Over a period of three months general cleaning was followed by targeted cleaning of hot spots until the indoor air mercury levels reached a median value of 0.090 μg/m^3 with a range of 0.032–0.140 μg/m^3. Meanwhile the family was staying in a shelter home. Human biological monitoring (HBM) was motivated by the complex exposure situation and the involvement of young children. Initially high blood values triggered alertness for clinical signs of intoxication, that (as it turned out) were not observed in any of the exposed individuals. Despite continued exposure from hair and clothes, within six weeks after the incident, blood levels returned to a background level normally seen in children. HBM contributed to reassurance of the parents of the young children that quick elimination of the mercury did not require medical treatment.

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1. Introduction

In many residences there are potential sources of exposure to elemental mercury. Private residences made up 16.7% of 406 elemental mercury spills recorded in 14 states in the US over a period of 6 years (Zeitz et al., 2002). In homes mercury can evaporate from broken objects such as antique or replica silvered mirrors, lamps and vases, technical appliances such as electrical switches, mercury discharge lamps, gas regulators and measurement instruments such as thermometers, thermostats, barometers, blood-pressure gauges and pendulum clocks (CDC, 2007; Hryhorczuk et al., 2006). In the US 42% of the residential spills were related to dropped or spilled mercury containers. Some intoxications are described related to use of elemental mercury in cosmetics (Lauwerys et al., 1987; Li et al., 2000; Tang et al., 2013). Mercury is also used for spiritual purposes in certain Afro-Caribbean and Latino cultures (Baughman, 2006). Use of mercury in such rituals resulted in cases of intoxications involving children (Ozuah, 2000, 2001; Wu et al., 2013). In other cases of residential exposures the liquid mercury was brought into the home from an unattended industrial facility (Azziz-Baumgartner et al., 2007) or school (Schwartz et al.,

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1992; Risher et al., 2003). Sometimes the origin of the mercury remained unknown (Cherry et al., 2002). More serious cases resulted in fatalities involving children and were related to the melting of mercury on a kitchen stove (Campbell, 1948; Moutinho et al., 1981; Rowens et al., 1991).

Elemental mercury is primarily taken up by inhalation due to an efficient absorption into the blood. The median (range) absorption was estimated to be 69% (57–73%) in a study involving nine human volunteers (Sandborgh-Englund et al., 1988) and 79% (75–84%) in four volunteers (calculated from data by Kudsk, 1965). A third study reported an average of 74% for five volunteers (Hursh et al., 1976) and a fourth more recent study reported an absorptions of 77 and 81% for two volunteers (Pogarev et al., 2002). Some clinical toxicology handbooks report higher values for inhalation exposure (Ellenhorn and Barceloux, 1988; Haddad and Winchester, 1990; Friberg et al., 1986; Baselt, 2004). Dermal absorption of elemental mercury vapor contributed only 2.2% of pulmonary uptake in human volunteers (Hursh et al., 1989) but for direct skin contact with the liquid phase there are no experimental data to support a quantitative estimate. The uptake from ingestion is estimated to be very low due to the limited absorption of mercury from the gastrointestinal tract (WHO, 2003; Sandborgh-Englund et al., 2004). Even when elemental mercury was ingested in suicide attempts, the patients survived and clinical symptoms of intoxication were explained by inhalation (Lech and Goszcz, 2006).

Before redistribution into the tissues a considerable fraction is eliminated via exhalation, with half-lives of 13–25 h (Hursh et al., 1976). Cherian et al. (1978) studied toxicokinetics in human volunteers inhaling radioactive mercury and estimated the elimination corresponding to 7% of the dose within three days. Within 7 days 9.2% of the dose appears in feces and 2.4% in urine. In another study volunteers were exposed to 400 $\mu g/m^3$ for 15 min. Elimination during light exercise resulted in loss of 7.5–12% during the first three days. Only 1% of the dose was excreted in urine after 3 days and 8–40% after 30 days (Sandborgh-Englund et al., 1988; Jonsson et al., 1999).

Elemental mercury readily passes through the blood–brain and placenta barrier and becomes trapped as divalent mercury. It accumulates in the head, chest and kidneys with clearance half-lives of 21, 43 and 64 days (Hursh et al., 1976). These are also the primary targets were effects occur. Acute elemental mercury inhalation can lead to the following symptoms, usually within hours of exposure: cough, chills, fever and shortness of breath, metallic taste, dysphagia, salivation, weakness, headaches and visual disturbances. Complaints of the gastrointestinal tract include nausea, vomiting and diarrhea. In severe intoxications chest radiography reveals interstitial pneumonitis, emphysema, pneumothorax that may resolve or progress to respiratory failure or cardiac arrest and death (Rowens et al., 1991; Jung and Aaronson, 1980; Moutinho et al., 1981). In many cases the respiratory distress that followed the initial symptoms is delayed for several days to a week (Jung and Aaronson, 1980; Moutinho et al., 1981).

This study describes an acute exposure of one adult and two young children who were involved in a residential mercury spill from a broken barometer. In the follow-up human biological monitoring (HBM) was used in addition to extensive air monitoring. The results are discussed and compared to other reported cases of mercury spills in private residences.

2. Methods

Air monitoring was used to assess the situation in terms of health risk and also to support effective cleaning of the house and furnishing. Mercury vapors were measured in a heated home (19–22 °C) with ventilation that was close to the normal situation during the cold season (all windows and doors closed but some of the ventilation grids opened). Mercury vapor measurements were performed using a Lumex mercury spectrometer type RA-915M (Lumex Instruments, Nicosia, Cyprus).

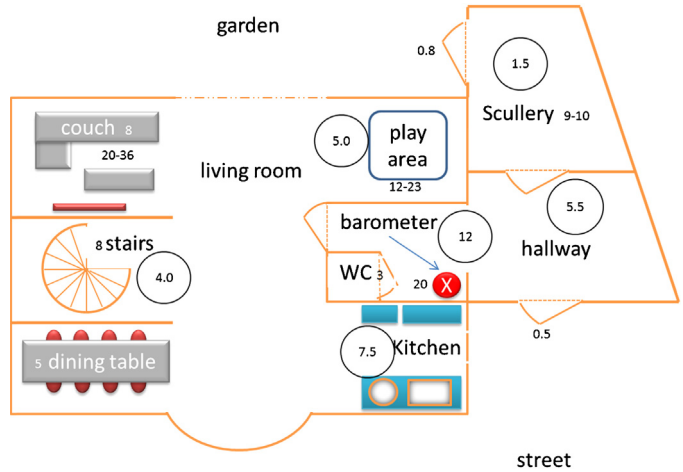

Fig. 1. Plan of the residence. Numbers indicate concentrations of mercury (in $\mu g/m^3$) measured at close range to floors and objects on December 6th (3 days after the incident). Numbers in circles indicate results of measurements performed at breathing height.

Two sampling strategies were used: building materials and objects were scanned at close range to search for hot spots of mercury evaporation. In a second sampling approach the air concentration at breathing height was determined (approximately 100 cm from the floor) central in the room. For the timeline day numbers were assigned, indicating day 1 as the day when the spill occurred. For the calculations of air concentrations multiple samples at the same location were combined by taking the average (to avoid the increase of the weight of such locations in the overall descriptive statistics). The parents approved the use of information from the medical files of the children. The nanny also approved use of her medical files. From the nanny and the children on the day of the incident a venous blood sample was collected and sent to the clinical laboratory of a hospital. In addition to mercury, also standard blood parameters were determined (including liver and kidney function). Blood collection was repeated on day 4, 39 and 122, following the day of the incident. Urine was collected on two occasions.

3. Results

3.1. Case description

On Monday, December 3rd, 2012 around 14:00 h the Office for Health, Environment & Safety, the Public Health Services Brabant/Zeeland in Tilburg, The Netherlands (public health service) received a phone call related to a mercury spill, involving young children. The caller was the nanny, a 52-years-old woman, who was taking care of two children on behalf of the parents who were at work. The incident involved a boy of 9 months and a girl of 2.5-years-of-age. The incident which caused the contamination occurred at around 10:00 h in the morning in the hallway of a private residence, a modern house built in 1996 with concrete floors. In Fig. 1 the plan of ground floor and second floor of the residence is presented. The mercury was released from the glass reservoir of a traditional barometer produced in The Netherlands. It is estimated that 30% of the volume of liquid mercury was spilled. This corresponds to a volume of approximately 3 mL. The nanny and the children were putting on their coats in the hallway to go out when the boy touched the glass of a barometer on the wall causing it to break and mercury to spill. Mercury was spilled on the boy's head, clothes and on the stroller and also on the hardwood floor. The stroller was contaminated with a stain of approximately 10 × 5 mm. The nanny put the boy on a rug on the floor and the girl in her own play area in the living room. In the meantime she cleaned the spill using a vacuum cleaner. The door between the hallway and the living room was left open for the nanny to keep an eye on the children. After cleaning she took the children outside for a walk. Upon return, several hours after the spill, the children were put to bed in their rooms on the first floor. Despite the indications

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