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Short communication

Monitoring mercury in two South African herbaria

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ABSTRACT

Mercury [Hg] emissions from old plant collections treated with mercuric chloride ($HgCl_2$) may present a high health risk for staff working in certain herbaria. The present study evaluated Hg concentrations in ambient air, plant specimens and biological samples from staff working in the Pretoria National Herbarium (PRE) and the H.G.W.J. Schweickerdt Herbarium (PRU), University of Pretoria. Biological samples from a group of 15 people exposed to $HgCl_2$ in herbaria and a non-exposed control group of five people were studied. Additionally, plant samples from herbarium specimens treated and non-treated with $HgCl_2$ were analysed. Plant materials treated with $HgCl_2$ had persistent high concentrations of Hg in the range of 114–432 $\mu g\ g^{-1}$, whereas untreated materials were in the range of 0.20–0.45 $\mu g\ g^{-1}$. The $HgCl_2$-treated plant specimens induced elevated concentrations of Hg into the herbarium rooms near storage cabinets, where up to 1 $\mu g\ m^{-3}$ of Hg was measured in the air of both herbaria. However, no significant difference in mean Hg concentrations in hair was found between herbarium workers and members of the control group, 0.46 and 0.64 $\mu g\ g^{-1}$ respectively ($p<0.05$, Student's t-test). For both groups, Hg concentrations were lower than that indicated by the World Health Organization [WHO] for non-exposed adults, namely 2 $\mu g\ g^{-1}$. The mean concentration of total Hg in urine from the mercury-exposed herbarium group, 2.28 $\mu g\ g^{-1}$ creatinine, was significantly higher than in the control group, 1.05 $\mu g\ g^{-1}$ of creatinine. For both populations, the concentrations of Hg in their urine were below the threshold Hg values set by the WHO, i.e., 5 $\mu g\ g^{-1}$ creatinine. We concluded that there was no strong response by individual herbarium staff from long-term exposure to Hg concentrations in the range of 0.28–1.1 $\mu g\ m^{-3}$.

1. Introduction

Until the early 1980s, mercury (II) chloride ($HgCl_2$) was widely used by herbaria and museums to preserve dried plant specimens against attack from insects and fungi (Clark, 1986; Purewall et al., 2008). Because $HgCl_2$ is a slowly sublimating compound, institutions that have a long history of $HgCl_2$ application use may have significant amounts of its poisonous vapor in the air, especially in storage cabinets. Poisoning can result from inhalation, ingestion, or absorption through the skin during regular contact with materials containing $HgCl_2$. Despite isolated studies involving the determination of mercury levels in the air of herbarium storage rooms, little attention has hitherto been paid to the Hg-derived health risks

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in these workplaces (Bauer and Fuortes, 1999; Oyarzun et al., 2007). It is well known that exposure to organic and inorganic Hg may lead to multiple disorders in humans, including serious neurological and cardiovascular defects (Mergler et al., 2007). The potential health risks of exposure to gaseous Hg are poorly studied in herbaria and may well be underestimated. Plant specimens treated with $HgCl_2$ comprise a large proportion of the holdings in the Pretoria National Herbarium (PRE) and the H.G.W.J. Schweickerdt Herbarium (PRU), Pretoria. To date, no studies addressing the effects of Hg exposure on human health at these two institutions have been undertaken.

Biological effects of mercury are determined by the toxicity of its principal chemical forms, namely elemental mercury (Hg^0), mercury (II) (Hg^{2+}) and methylmercury (CH_3Hg^+). Mercury vapor has the ability to penetrate cell membranes and so invade all cells in the body, including those of the brain, where it is oxidized to the biologically active form (Hg^{2+}). The high affinity of methylmercury for sulfhydryl groups (SH^-) leads to its accumulation in blood and hair (Stopford, 1979; U.S. EPA, 1997). Methylmercury readily distributes throughout the body and is able to penetrate the blood-brain and placental barriers, causing neurological damage. While CH_3Hg^+ causes neurological damage, Hg^{2+} does not penetrate the blood-brain or placental barriers easily. However, it is highly toxic to the kidneys (WHO, 2003). Since a portion of methylmercury is taken up from the blood circulation by hair protein (Berglund et al., 2005), mercury in human hair is an excellent marker for exposure to methylmercury. Exposure to inorganic compounds of mercury, on the other hand, has been found to correlate with mercury concentrations in urine (WHO, 2003). Occupational exposure and effects of Hg on organisms, e.g. neurotoxicity and genotoxicity, have been studied in chlor-alkali plants, mines and in dental clinics (WHO, 1991, 2003; U.S. EPA, 1997). Studies indicate that the major portion of inhaled mercury vapor or inorganic mercury is retained in the human body and is mainly deposited in the kidneys, with urine being its main pathway for elimination (Stopford, 1979; WHO, 1991). Urine is the most commonly used biological sample for monitoring levels of mercury exposure as it reflects the cumulative dose (Clarkson, 2002) and represents a more appropriate indicator of long-term exposure than blood (U.S. EPA, 1997). The risk assessment of human exposure to inorganic mercury compounds at low concentration is needed in order to understand the relationship between the dose–effect response, and this topic has been recommended for future research by the WHO (WHO, 1991).

The treatment of herbarium specimens with $HgCl_2$ was traditionally used in various herbaria in South Africa to protect plants against insect and fungi (Hall, 1988). Recent studies in Spain confirmed that old plant collections in herbaria represent the source of Hg vapor in the air (Oyarzun et al., 2007). Founded in 1903, the Pretoria National Herbarium (PRE), currently houses about 1.2 million plant specimens, making it the largest herbarium in Africa. The H.G.W.J. Schweickerdt Herbarium [PRU], University of Pretoria, is a smaller university herbarium with about 120 000 specimens. It is important to study the long-term effects of Hg exposure from sources such as air inhalation and direct contact with specimens on human health of herbarium workers. The principal objectives of this study were to determine the levels of total Hg in these two herbarium buildings, including that of the indoor air, dust and wall plaster, and to determine the concentrations of Hg in hair and urine samples from staff members who regularly work in the herbarium storage area and handle specimens treated with mercuric chloride. Results for this population of workers were to be compared with those arising from a non-exposed control group.

2. Materials and methods

2.1. *Collecting of samples*

Samples of hair and urine were collected from 20 consenting staff of the Pretoria National Herbarium (PRE) in October 2006 and February 2007. The first group of 15 staff members was employed for an average of 19.5 ± 11.4 years, in the range from 1 to 36 years in enclosed areas containing $HgCl_2$-treated herbarium specimens stored in metallic and wooden cupboards. Similar samples were collected from a second group of five people consisting of staff members working outside the herbarium (in the associated Pretoria National Botanical Garden), all of which have not been exposed to the poisoned specimens. Each sample of hair was preserved in a labeled paper envelope and was digested and analysed on the next day after sample collection. Urine samples were collected towards the end of the five day working week (Friday) to ensure the longest level of regular exposure. To assess the concentrations of Hg in the herbarium environment, samples of dust and non-painted wall plaster material from different points inside the various herbarium wings and outside the herbarium building were collected in plastic vials and kept in the refrigerator before analysis.

The Pretoria National Herbarium building (Fig. 1) consists of four wings A, B, C, and D with a central staircase area inside.

Herbarium specimens from the Pretoria National Herbarium (PRE) and the H.G.W.J. Schweickerdt Herbarium (PRU) were analysed for total Hg content in the dried plant material. The concentration of Hg in the herbarium samples (leaves) treated with $HgCl_2$ was compared with that in control samples of the same plant collected from live plants in the vicinity of Pretoria. For the determination of total Hg in ambient air, samples were collected by bubbling air through HNO_3 (1:1) for 1.5 h at 28 °C at a flow rate of 1.1 l/min. The concentrations of Hg in the air of the two herbaria were examined from three different positions: near cabinets with plant specimens, in the herbarium rooms, but away from cabinets and in rooms outside the herbarium which served as controls. To assess the precision and accuracy of the measurement procedure, CRM 397 “Human hair-Trace elements” and SRM 2584 “Indoor dust-Trace elements”, were used.

2.2. *Sample preparation*

Hair samples were washed with de-ionized water (resistivity 18.2 MΩ cm) obtained from a Milli-Q-water system and were cut into sections about 1 cm long. Samples were digested in a Microwave Accelerated Reaction System Model MARS® (CEM