International Journal of Hygiene and Environmental Health 221 (2018) 868–875

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

# Urinary excretion of platinum (Pt) following skin and respiratory exposure to soluble Pt at South African precious metals refineries

Stephanus J.L. Linde*, Anja Franken, Johannes L. du Plessis

*Occupational Hygiene and Health Research Initiative, North-West University, Potchefstroom 2520, South Africa*

ARTICLE INFO

*Keywords:*
Urinary platinum
Platinum group metals
Dermal exposure
Platinum body burden
Ghostwipes™
MDHS 46/2

ABSTRACT

Adverse respiratory and skin health effects have been associated with occupational exposure to soluble platinum (Pt). However, the relationship between skin exposure and urinary Pt excretion has not yet been investigated. In this study we examined the relationship between skin and respiratory exposure to soluble Pt and urinary Pt excretion at two South African precious metals refineries.

The skin and respiratory exposure to soluble Pt as well as the urinary Pt excretion of forty precious metals refinery workers was assessed simultaneously using Ghostwipes™, Methods for the Determination of Hazardous Substances method 46/2 and spot urine tests, respectively.

The geometric mean for skin exposure to soluble Pt on four anatomical positions (palm, wrist, neck and forehead) was 0.008 µg/cm$^2$ [95% confidence interval (CI): 0.005-0.013 µg/cm$^2$], while the geometric mean for respiratory exposure was 0.301 µg/m$^3$ (95%CI: 0.151-0.601 µg/m$^3$) and the geometric mean for urinary Pt excretion was 0.212 µg/g creatinine (95%CI: 0.169-0.265 µg/g creatinine). Partial correlations identified significant positive correlations between skin exposure, respiratory exposure and urinary Pt excretion ($r = 0.580$ to 0.754).

Skin and respiratory exposures to soluble Pt were both positively correlated with urinary Pt excretion, and both exposure routes should be considered when investigating occupational exposure to soluble Pt.

## 1. Introduction

South Africa is the world's largest producer of platinum (Pt) (Johnson Matthey, 2017) and respiratory exposure to water-soluble Pt at precious metals refineries has been reported to frequently exceed the occupational exposure limit (OEL) of 2 µg/m$^3$, especially in production areas (Calverley et al., 1995; Maynard et al., 1997; Linnett and Hughes, 1999; Heederik et al., 2016). Soluble Pt salts, are potent sensitisers and Pt salt sensitisation is mainly associated with the intensity of respiratory exposure to water-soluble Pt compounds (Calverley et al., 1995; Merget et al., 2000; Heederik et al., 2016). Soluble Pt refers to Pt compounds that are soluble in water and includes, amongst others, halide-containing coordination complexes such as ammonium tetrachloroplatinate [$(NH_4)_2PtCl_4$] and ammonium hexachloroplatinate [$(NH_4)_2PtCl_6$] (WHO, 2000; DECOS, 2008).

While the majority of soluble Pt salts are powerful sensitisers, the metallic form of Pt is considered non-allergenic (Ravindra et al., 2004). The allergy symptoms observed in workers sensitised to soluble Pt indicate a type I reaction mediated by Immunoglobulin (Ig) E (Heederik et al., 2016). Following sensitisation, workers are usually removed from areas where they could be exposed further, yet this does not exclude the possibility of developing chronic asthma later in life (Merget et al., 2017). Occupational exposure to soluble Pt has been associated with several adverse skin reactions (dermatitis, eczema and urticaria) and respiratory health effects (asthma, rhinitis and shortness of breath) (Hunter et al., 1945; Roberts, 1951; Niezborala and Garnier, 1996; Cristaudo et al., 2005). Soluble Pt compounds have been classified as respiratory sensitisers in South Africa and the United Kingdom (HSE, 2011; DOL, 2017), and as both respiratory and skin sensitisers in Germany and Japan because it may cause allergic reactions of the skin and the airways (JSOH, 2013; DFG, 2016).

With reference to occupational exposure, both Maynard et al. (1997) and Heederik et al. (2016) stated that monitoring respiratory exposure alone might not be sufficient, particularly at low concentrations because of the possible contribution of skin exposure to soluble Pt sensitisation. During *in vitro* skin permeation studies, very low levels of soluble Pt permeated through full thickness human skin while high levels of Pt was retained within the skin (Franken et al., 2014, 2015). However, the skin exposure of precious metals refinery workers to soluble Pt has not yet been investigated.

* Corresponding author at: Occupational Hygiene and Health Research Initiative, North-West University, Private Bag X6001, Potchefstroom, 2520, South Africa.
*E-mail address:* Stefan.Linde@nwu.ac.za (S.J.L. Linde).

https://doi.org/10.1016/j.ijheh.2018.05.016
Received 1 February 2018; Received in revised form 27 May 2018; Accepted 31 May 2018
1438-4639/ 

Biological monitoring can be useful since it measures the total absorbed dose from all routes of exposure (Deubner et al., 2001). Urinary Pt excretion is a reliable biomarker of short-term exposure (Petrucci et al., 2005; Cristaudo et al., 2007) and has been used in various occupational settings (Schaller et al., 1992; Farago et al., 1998; Schierl et al., 1998; Petrucci et al., 2005; Cristaudo et al., 2007). It reflects total body burden of workers exposed to Pt and can characterise the extent of exposure in different areas (high versus low) (Petrucci et al., 2005; Cristaudo et al., 2007).

This study aims to: (1) quantify the skin and respiratory exposure to soluble Pt at two South African precious metals refineries; and (2) determine the relationship between workers' exposure and their urinary Pt excretion.

## 2. Materials and methods

### 2.1. Study description

The study was conducted at two South African precious metals refineries between October 2015 and November 2016. Forty workers (32 men and eight women) who were employed at the refineries for longer than one year participated in the study. The average age of the workers was 34.6 ± 7.9 years (range, 22–56 years) and the average number of years of employment at the refineries was 7.7 ± 6.3 years (range, 1–27 years). Ten persons, who lived > 100 km from the nearest Pt industry were included as a control group for the biological monitoring portion of the study. All participants were informed of the details prior to the start of the study and were asked to sign a written consent form. Ethics approval for the study was obtained from the Health Research Ethics Committee of the North-West University (NWU-00128-14-A1).

All workers used personal protective equipment (PPE) such as standard polycotton overalls, hard hats, respiratory protective equipment (RPE) (full-face respirators, half-face respirators or half-face paper dust masks), disposable coveralls and gloves (rubber or latex),as per the requirements of each refinery. As part of the refineries' health surveillance programme, all the workers were screened for soluble Pt sensitisation with skin prick tests before employment. They also underwent regular medical screening and were removed from possible exposure areas if they became sensitised to soluble Pt. In this study, one of the workers was included although he had previously experienced minor eczema-type symptoms. None of the participating workers were sensitised to soluble Pt at the time of data collection.

### 2.2. Distribution of participants

Following a workplace inspection and before sample collection, workers were grouped according to their working areas in the refineries and whether they performed production or non-production activities. The work areas are listed in Table 1 and included: concentrate handling, platinum group metals (PGM) separation, crushing and ignition, precious metals, other precious metals, other production activities (melting and packaging), other non-production activities (laundry, laboratory and maintenance), security, and health clinic. During data analysis, workers were further grouped according to whether they were directly or indirectly exposed to Pt, as well as their age and years of employment at the refineries. Workers directly exposed to Pt were directly involved in the Pt refining process and came into direct contact with Pt compounds. These areas included concentrate handling, PGM separation, crushing and ignition and precious metals areas. Those who were indirectly exposed to Pt worked in the other precious metals, other production and non-production, security and health clinic areas. For example, security workers conducted searches on directly exposed workers whose clothing was contaminated, laboratory workers handled PGM samples, health clinic workers consulted workers who wore contaminated clothing and laundry workers washed contaminated clothing. Work areas were chosen in such a way that a variety of tasks and exposure scenarios were included and not only high exposure tasks.

**Table 1**
Description of the study population and groupings used for statistical analyses.

| Groups | Sub-groupings | Number of workers | % |
|---|---|---|---|
| **Work areas** | Concentrate handling | 6 | 15 |
| | PGM separation | 5 | 12.5 |
| | Crushing and ignition | 4 | 10 |
| | Precious metals | 6 | 15 |
| | Other precious metals | 4 | 10 |
| | Other production activities | 3 | 7.5 |
| | Other non-production activities | 5 | 12.5 |
| | Security | 4 | 10 |
| | Health clinic | 3 | 7.5 |
| **Exposure categories** | Direct exposure | 30 | 75 |
| | Indirect exposure | 10 | 25 |
| **Years employed categories** | 1-4 | 15 | 37.5 |
| | 5-10 | 15 | 37.5 |
| | 10-20 | 7 | 17.5 |
| | ≥20 | 3 | 7.5 |
| **Age categories** | 20-29 | 9 | 22.5 |
| | 30-39 | 22 | 55 |
| | 40-49 | 7 | 17.5 |
| | ≥50 | 2 | 5 |
| **Sex** | Male | 32 | 80 |
| | Female | 8 | 20 |
| **Total** | | 40 | 100 |

%, percent of total group of participants.

### 2.3. Exposure monitoring

The urinary Pt excretion and skin and respiratory exposure of workers were measured concurrently over two consecutive work shifts. These shifts were not limited to specific work days (e.g. Mondays and Tuesdays) since many workers were shift workers who worked during weekends. Skin and respiratory exposures were measured over the two full work shifts. For biological monitoring, three spot urine samples were collected from each worker. The first and second samples were collected prior to the start of the first and second day of exposure monitoring, respectively and the third was collected before the start of the following day's shift (Linde et al., 2018). Schierl et al. (1998) exposed previously non-exposed volunteers to $[(NH_4)_2PtCl_6]$ dust and reported that their urinary Pt excretions reached the maximum approximately 10 h after the termination of exposure. Therefore, during our study, the spot urine samples collected on the following morning, approximately 16 h after the termination of exposure, and represented the change in urinary Pt excretion as a result of the previous day's exposure. In this study, we adapted Schierl et al. (1998)'s approach as a guideline for biological monitoring since the exposure scenario was similar to our study where workers mainly handled $[(NH_4)_2PtCl_6]$. No regulatory guidelines exist for the biological monitoring of Pt following occupational exposure (HSE, 2011; DOL, 2017; OSHA, 2017). Finally, surface contamination was assessed on workplace surfaces that workers come into contact with during their routine work activities.

#### 2.3.1. Skin wipe sampling

Skin exposure to soluble Pt was assessed using Ghostwipes™ (SKC, Eighty Four, Pennsylvania, USA). They are individually sealed robust wipes which are moistened with deionised water and have been used successfully for metals such as nickel (Ni), lead (Pb) and cobalt (Co) (OSHA, 2002; Du Plessis et al., 2010). Prior to the start of the shift, the areas of interest on the skin (palm, wrist, neck and forehead on the dominant side of the body) were cleaned with a wetted wipe, which was discarded (not analysed). After that, workers performed their normal work activities and were instructed not to wash their hands