IPA
INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

8

WORKPLACE MONITORING

CONTENTS

SUMMARY

- This chapter will assist the reader in designing a comprehensive, well-executed workplace monitoring programme that will help to reduce the risk of exposure of workers to PGMs and other related workplace contaminants.

- Workplace monitoring entails understanding applicable occupational exposure limits and standards; and implementing air and surface monitoring programmes that allow for collection of exposure data and comparison of worker exposures to these values.

- The main components of such a programme are: development of a sampling strategy; selection of equipment; establishing standardised sampling techniques; analysis of samples; interpreting exposure results, including assessment of conformance to norms; notifying employees of results; and record keeping.

- Sampling strategies should align with prior qualitative chemical risk assessments (see also Chapter 10) and sampling campaigns; the purpose of sampling; and the manner in which the results will be used. Other considerations include the areas to sample; which employees or occupational groups to monitor; what activities to assess; the duration of the sampling period; the number of samples necessary; and the time periods or shift patterns to be monitored.

- Preference should normally be given to personal air sampling over static (background/area) sampling as it more accurately reflects individual exposure. Assessment of skin exposure potential and surface contamination levels may also be considered.

- Air monitoring programmes for PGMs focus on measuring airborne solid and liquid particulates of elemental metal or soluble metal compounds for which exposure limits are commonly set in most jurisdictions.

SUMMARY

No validated techniques currently exist to differentiate soluble Pt from complex halogenated platinum salts (CHPS) including chloroplatinates; hence measurements of soluble platinum are commonly used as a surrogate for CHPS.

- Repeat monitoring should be conducted when changes are made to processes, equipment, or work practices; in the event of exposure-related health complaints; and when activities of high exposure variance (such as maintenance work) are undertaken.

- The use of an inhalable (IOM) sampler when collecting samples of airborne PGMs is recommended. Suitable pumps and filters are described, along with care and usage.

- Conformance to standard sampling techniques promotes accurate and reproducible sampling results. Attention should be given to preparation of sampling trains; placement of equipment on the wearer; instructions to the wearer; periodic checking of equipment and of worker activity; record keeping; and secure transport of samples for analysis.

- Samples should be sent to an accredited laboratory. The analytical method recommended for PGMs is inductively coupled plasma-mass spectrometry (ICP-MS).

- It is important in all stages of workplace exposure monitoring that good records are kept, both to enable accurate interpretation of results and to provide an historical database. Recording the identity of PGM compounds handled during the sampling period is essential.

- It is best practice to inform individuals of the results and implications of samples collected on them and any remedial actions planned. This should extend to other workers whose exposures are likely to be similar to those monitored.

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SAMPLING STRATEGY

Prior to commencing any monitoring survey, consideration must be given to the purpose of the sampling and the manner in which the results will be used. The sampling strategy adopted will vary depending on its purpose: *i.e.*, for compliance monitoring; routine monitoring; or for determining a relationship between exposure and health outcome. Issues to consider include: is this an initial study to assess worker exposure; is it a follow up to previous monitoring; is it an assessment of specific tasks; is sampling required to evaluate control effectiveness; consideration of worst case scenarios; sampling for an epidemiology study? Since sampling is often used to provide comparison over time then, as far as possible, the conditions during the sampling periods should be the same.

The issues which should be considered to determine whether the selected sampling strategy will address the aims of the survey include:

- Which employees/ occupational groups are to be monitored.
- What processes or activities are to be assessed.
- The duration of the activities and therefore the sampling period.
- How many samples are required for each activity/ occupational group to enable a valid conclusion.
- What periods of time or shift patterns should be monitored, and when to sample.

Should there be uncertainty about the effectiveness of the proposed sampling strategy it is good practice to conduct some preliminary sampling first, to assess the suitability of the strategy and enable refinement where appropriate.

For monitoring, the approach will often be based on sampling within a HEG (Homogeneous Exposure Group) / SEG (Similar Exposure Group); *i.e.*, those individuals exposed to the same substances, within the same area, and who we think are conducting similar tasks in the same way—the premise being that their exposures will be very similar. While knowledge and experience of the site will help define the SEG, monitoring results must be reviewed to determine whether the groups of individuals selected are truly part of a SEG or whether the basis on which they have been selected is unsound.

If an individual's exposure measurement is less than half, or greater than twice the group average, then it is likely that the worker's exposure is different from the SEG selected and should be reclassified into another SEG. Although individuals within a defined SEG are expected to have similar average exposures, they may conduct different tasks within a shift and these should be monitored separately; or they may conduct the same tasks in a different manner and may benefit from observation and intervention followed by repeat sampling.

The aim of the employer is to provide each employee with a safe work environment, *i.e.*, where exposure to contaminants is reduced to an acceptable risk level. The sampling strategy applied should be designed to enable this assessment to be made. It is standard practice to collect samples based on HEGs/ SEGs, as previously discussed. The European standard for exposure assessment adopted by the Comité Européen de Normalisation (CEN, 1995) is based on the HEG concept. The CEN acknowledges that, within an HEG, exposures are subject to both "random and systematic" variation and provides a scheme for assessing group homogeneity.

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The standard contains simple decision rules for classifying each exposure measurement collected from an HEG.

A similar approach is described in BOHS/NVvA (2011). The method has five stages: selection of HEGs/SEGs (Section 3.2), a screening test (3.3), a group compliance test (3.4) and an individual compliance test (3.6) if an analysis of variance (3.5) shows that differences between individual exposure patterns makes this desirable. The HEG group thus determined is in compliance with standards if, with 70% confidence, 5% or less of exposures exceed the OEL.

Details and examples of monitoring strategies can be found in publications such as *'Monitoring Strategies for Toxic Substances'*, (HSE, 2006); *'Testing Compliance with Occupational Exposure Limits for Airborne Substances'*, (BOHS/NVvA, 2011); *'Quantitative Exposure Assessment'*, (Rappaport, SM and Kupper LL, 2008); *'Assessment of Long-Term Exposures to Toxic Substances in Air'*, *Annals of Occupational Hygiene* 35: 61-122, (Rappaport, SM, 1991); *'A Strategy for Monitoring and Assessing Occupational Exposures',* (AIHA, 2015); the *'South African Mines Occupational Hygiene Programme Codebook' / 'SAMOHP'*, (Department of Mineral Resources / 'DMR', 2002); and *Health Risk Assessment Guidance for Metals*, ICMM, Eurometaux and Eurofer, 2007.

Anyone involved in the collection of occupational hygiene samples must have an understanding of the techniques to be used and the strategies to be applied. They will require skill, knowledge and practical experience of the techniques and the information which must be collected to enable interpretation of the results. If using in-house personnel to carry out the monitoring, an agreed training programme should be in place requiring new surveyors to demonstrate their understanding and capabilities for each stage of the process. If an external organisation is engaged to conduct monitoring, it should have acknowledged accreditations to demonstrate competency. Regardless of who does the sampling, training and competency must meet local legal requirements.

MONITORING FREQUENCY

Sampling collection frequency will to some extent be determined by the sampling strategy. However, the results obtained from any initial sampling will help define the monitoring frequency. As a rule of thumb, when sampling to demonstrate compliance, the lower the result in comparison with an OEL or internal standard, the less frequently an occupational group or activity will be required to be monitored; with the proviso that sufficient sample results are available to provide a valid conclusion in terms of low exposure risk or statistical analysis. Note, however, that this rule of thumb does not apply when monitoring is conducted for epidemiological purposes *e.g.*, to establish a lowest observable adverse effects level (LOAEL).

If samples are being collected to determine a baseline concentration for an occupational group or an activity, then sufficient samples must be collected over a representative period of time, taking account of production differences and seasonal variations. Where these parameters vary significantly, or where uncertainties are present, an increased sampling frequency will be required.

All organisations must adhere to the health and safety legislation relevant to their country (see Chapter 10). In many instances such legislation will require, as a minimum, the assessment of risk of exposure to hazardous substances, and many require actual exposure monitoring to confirm risk assessment findings. In some countries, and within the platinum mining industry, there is a requirement to collect samples according to a defined regime and to provide the results for review by an authoritative body.

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The requirements of such schemes are often based on a quarterly sampling programme, the number of samples required for each SEG being specified, *e.g.*, 5% every quarter, or a specified minimum, *e.g.*, 5 persons. The frequency of the monitoring and requirements for repeat monitoring are based on the measured concentrations of the substance, *e.g.*, soluble Pt, in relation to the OEL. Where concentrations are found to exceed the OEL then monitoring should be repeated promptly to determine whether exposure at such concentrations is a regular occurrence; and to enable a review of the control measures in place.

Where the measured concentrations are below the exposure limit but in excess of 50% of it, repeat monitoring should again be carried out within a relatively short period. Results indicating that concentrations are less than 50% of the exposure limit should also be repeated but an annual basis will normally be sufficient.

For example, in the UK, HSE (2006) states that the frequency of routine surveys will vary; the closer the measured exposure is to the OEL, the more frequently monitoring should be undertaken. One scheme for setting monitoring frequency is given in BS EN 689 (BS EN, 1996). It is good practice to assign an in-house action level at approximately one third of the OEL, upon which appropriate actions will be investigated.

As an example of a regulatory scheme from South Africa, the SAMOHP (South African Mines Occupational Hygiene Programme Codebook) identifies three exposure concentration ranges or 'classification bands' (Table 8-1), and specifies the number of samples to be taken and the sampling frequency (by SEG) to be used for each of these 'bands' (Table 8-2).

Band	Personal Exposure Level Single substance	Mixture (mix)
A B C	Exposure conc. ≥ OEL 1 > Exposure conc. ≥ 0.5 OEL 0.5 OEL > Exposure conc. ≥ 0.1 OEL	Exposure conc. for mix ≥ 1 1 > Exposure conc. for mix ≥ 0.5 0.5 > Exposure conc. for mix ≥ 0.1

Table 8-1: Definition of the classification bands

Band	Minimum frequency	
A B C	3 monthly basis 6 monthly basis annual basis	*Sample 5% of employees within a HEG on a <minimum frequency> basis with a minimum of 5 samples per HEG, whichever is the greater.*

Table 8-2: Mandatory frequency of sampling by classification bands

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SAMPLING STRATEGY

SAMOHP presents a 'sequential methodology' to assign these classification bands as HEGs (Table 8-1) and to standardise industry's measurement approach.

- As a first step, a 'Sampling Area' is assigned.
- Then the relevant 'Activity Areas' are selected. Note that an 'Activity Area', is *not* synonymous with an HEG.
- A hazard assessment of these 'Activity Areas' is then carried out to identify all 'significant airborne pollutants' to which the workers are potentially exposed. A screening (exposure) assessment is then carried out using historical exposure data, professional judgement and, if necessary, personal exposure monitoring based on a recognised sampling approach.
- The exposure measurement data is then compared to the OEL in order to assign an appropriate classification band (Table 8-1) and sampling strategy (Table 8-2) for future monitoring surveys.
- If the personal exposure is found to be less than one tenth of the OEL then it is assumed no regular or routine monitoring is required.

Examples of tasks within the PGM refining industry which may merit specific monitoring:

- Grading and preparation of incoming PGM-containing feedstocks particularly for toll refining *e.g.*, homogenising (milling and blending), pelletising, 'burning'/drying, and to a lesser extent, smelting.
- Dissolution of bullion, salts, pellets, etc. in chloride-based solutions during oxidative leaching of PGM.
- Separation by solvent extraction and/or precipitation of Pt-containing streams as a hexachloroplatinate solution and of other PGM streams with potential hexachloroplatinate contamination.
- Isolation of solid chloroplatinates from chloroplatinate solutions.
- Recovery (filtration and packaging) of chloroplatinate salts.
- Reduction of chloroplatinate salt solids and solutions.
- Sampling during all of the above or similar processes where chloroplatinate contamination may occur.
- Laboratory operations involved in preparing and analysing samples.
- Cleaning of PPE and laundering of work clothing.
- Routine blockage clearance, and cleaning up after spillage and leaks.
- Maintenance of plant *e.g.*, pumping gear, transfer systems, change-out of scrubber solutions and dust collection filters.

NON-ROUTINE MONITORING

Sampling strategies should also consider evaluation of those specific tasks and activities which are not carried out on a daily or routine basis, *e.g.*, stock-take, dismantling, deep cleaning and other non-routine maintenance activities, shut-down activities, etc.

In addition to initial and frequency-based sampling, qualitative or quantitative re-evaluation of exposure is recommended for assurance of exposure control when any of the following events occur:

- A worker health complaint is received that could be exposure-related.
- Initial monitoring triggered an engineering control change proposal and the control has been installed.
- Initial monitoring resulted in specifying respiratory protection. Follow up periodically to ensure protection remains adequate, and after engineering controls are installed.
- A process change occurs.
- An occupational illness occurs.
- Activities that are highly variable in exposure and may otherwise be difficult to capture or schedule are planned, *e.g.*, construction work or 'stock take'.

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AIR MONITORING

Air monitoring can be used to measure airborne concentrations of PGM substances to determine personal exposure, general background concentrations, and the effectiveness of control measures (refer to Chapter 9 of this Guide for coverage of the latter). In terms of monitoring priorities, an important group of PGMs are CHPS[1]—most notably those compounds that cause sensitivity (PSS or Platinum Salt Sensitivity).

The sampling strategy may direct the manner in which sampling is conducted, *e.g.*, the position of the sampler, the duration of the sample period and activities conducted during the sampling period. It is therefore important to consider the reason for sampling, and how the results will be used, before embarking on the sampling survey.

In most instances the reason for air monitoring will be to compare the exposure of employees against government-mandated occupational exposure limits (OELs), authoritative body consensus standards or internal or trade organisation targets[2].

Personal samples will generally be collected over a full shift, enabling a shift average to be compared against the relevant OEL or target, expressed as an 8-hour time-weighted average (TWA). If airborne concentrations are to be determined for a specific activity, then it is important to define not only the activity to be monitored but also the sample volume necessary to enable interpretation of the results. If too small a sample volume is collected the analysis may not yield results above the limit of detection (LOD) or the limit of quantitation (LOQ), precluding meaningful comparison with the exposure limit or other threshold value. Qualified laboratories may have different reporting limits based on instrumentation, quality control and experience; it is important to obtain and agree the reporting limits of the laboratory to be used in advance of sampling, in order to calculate sample volume needed.

Although personal samples are collected on individuals, the results may be used to provide information on the potential exposure of all persons conducting the activities monitored, *i.e.*, for a homogenous group (BSI EN, 1996), homogenous exposure group [HEG] (SAMOHP, 2002), or a similarly-exposed group (SEG). SEGs are defined as groups of workers who have the same general exposure profile for the substances of interest, due to the similarity and frequency of the tasks performed, the materials being used, processes being run, and controls in place. In determining whether a truly homogenous group of workers has been sampled not only must workers be selected appropriately before sampling, but the results obtained must be reviewed statistically to confirm that the group selected can be called a homogenous group (see Section 8.1 Sampling Strategy).

Static samples, also known as "area" or "background" samples, can be collected to provide information on the concentration of substances in the general work environment. These samples are useful when determining the exposure of employees who may not be directly involved in a process, or who are simply passing through an area where airborne PGMs may be present. Static samples are also useful in determining the effectiveness of control measures as they can be collected under precise, repeatable conditions, enabling comparison of results.

Both personal and static samples can be collected over a long period of time, increasing the detection limit; or over a number

[1] Complex halogenated platinum salts (CHPS) are compounds where the halide is directly coordinated to a central Pt atom.
[2] Following recognition by US OSHA that some established Permissible Exposure Limits (PELs) are inadequate for ensuring protection of worker health, OSHA suggested alternate exposure standards (OSHA, 2015a).

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of discrete time periods, giving more accurate information on the fluctuation of airborne concentrations over time.

All samples must be collected and analysed using a validated method. For superior detection and measurement of platinum substances, IPA have co-developed a "Harmonised Methodology for the Sampling of Platinum in Workplace Atmospheres" [http://ipa-news.com/samplingmethod] (IPA and University of Wisconsin, 2015). This method broadly follows that of MDHS 46/2 "*Platinum Metal and Soluble Platinum Compounds in Air —Laboratory method using electrothermal atomic absorption spectrometry (ET-AAS) or inductively coupled plasma-mass spectrometry (ICP-MS)*" (HSE, 1996). It incorporates the use of sensitive sample preparation and analytical techniques and includes comprehensive data on method validation (WIS, 2015).

It should be noted that neither method—as discussed in detail below—enables chemical species discrimination between CHPS (*i.e.*, fluoro-, chloro-, bromo-, and iodo-platinates) and other soluble platinum compounds. Where there is mixed exposure which includes fractional exposure to chloro- or other halogenoplatinates, the results are interpreted in a conservative manner assuming that all Pt measured in the samples is derived from CHPS. The hygienist or other person determining the sampling strategy must be aware of this limitation when interpreting related exposure datasets.

The IPA method indicates use of ICP-MS for the analysis of sample solutions with low platinum concentrations. Research by Maynard *et al.* (1997) has shown that ICP-MS can increase the sensitivity of the analysis by up to three orders of magnitude over the ET-AAS method.

Nevertheless, even these improved methods will not necessarily provide the level of detection required to assess PGM concentrations in areas of low exposure, particularly for short-term samples. It is also important to understand the potential for metals and their compounds to interact with sampling media, and to ensure that appropriate sampling and analytical procedures are followed in order to obtain accurate and meaningful results.

Particular issues to consider when sampling CHPS include the following:

- Location.
- Activities.
- The lack of speciation of the samples by chemical analyses. The assumption is that all exposure is to chloroplatinates where CHPS are being used or produced.
- Identification of any changes (and proposed changes) in the process *e.g.*, introduction of new plant or risk management measures (RMM), automation, introduction of new product streams, increased production on an existing production line.
- Opportunities for dermal exposure to occur.
- Opportunities to introduce wipe sampling to track the spread of CHPS through the factory premises (OSHA, 2015b).

Opportunities for further characterisation of inhalation exposure may be considered. These include size-resolved personal sampling using cascade impactors, direct reading instruments (DRI) *e.g.*, DiscMini™ and static/fixed point sampling using DRI *e.g.*, DustTrak™, fast mobility particle sizer (FMPS), and aerodynamic particle sizer (APS).

Although, as previously stated, a number of methods including MDHS 46/2 (HSE, 1996), NIOSH 7303 (NIOSH, 2003), and ID130SG (OSHA, 1985) have been used in the past for monitoring airborne soluble platinum, the IPA recommends depending on the applicable legal requirements in the respective jurisdiction its "*Harmonised Methodology for the Sampling of Platinum in Workplace Atmospheres*" (IPA and University of Wisconsin, 2015).

For other PGMs the analytical methods listed in the previous paragraph can be used.

EQUIPMENT

The information provided in this and the following section incorporates guidance from the IPA "*Harmonised Methodology for the Sampling of Platinum in Workplace Atmospheres*" (IPA and University of Wisconsin, 2015). This should be used as the reference for further details on all aspects of sample collection.

During air sampling for platinum metal and soluble platinum compounds, a measured volume of air is drawn through an MCE (mixed cellulose ester) filter mounted in an inhalable dust sampler to capture airborne dust and mist. The filter is subsequently analysed to determine the amount of platinum group metals, *e.g.* platinum metal or soluble platinum compounds captured and the airborne concentration of the PGM material.

The IPA-recommended 'sampling train' is comprised of:

- An MCE filter with mean pore diameter of 0.8um (Note: The filters must be of a 'low metal' grade which preferably give blanks of <50 picogram (pg) platinum from a 10 ml leach test.
- Filter holder – inhalable IOM sampler head.
- Sampling pump – complying with the provisions of European Standard (BS EN ISO, 2013).
- Tubing.
- A means of connecting sampler to the wearer, *e.g.*, belt or harness.

Flat-tipped tweezers are needed for handling the filters, and a room with no PGMs present to prepare the sampling head (and later remove the filter holder) is important. Also needed is a flowmeter capable of measuring the flow rate to ±1% and calibrated against a primary standard at the flow rates of interest, with a measurement uncertainty of less than ±2.5%. This is used to measure, as a minimum, the flow rate before, during and after the sampling period.

The IOM sampling head meets the following international standards (SKC, 2016):

- Preferred sampler for HSE Method MDHS 14/4 (HSE, 2014).
- ACGIH sampling criteria for inhalable particulate.
- ISO/CEN health-related fractions of bio-aerosols.
- Australian standard for inhalable particulate.
- OSHA equivalent method for particulates not otherwise regulated (PNOR).

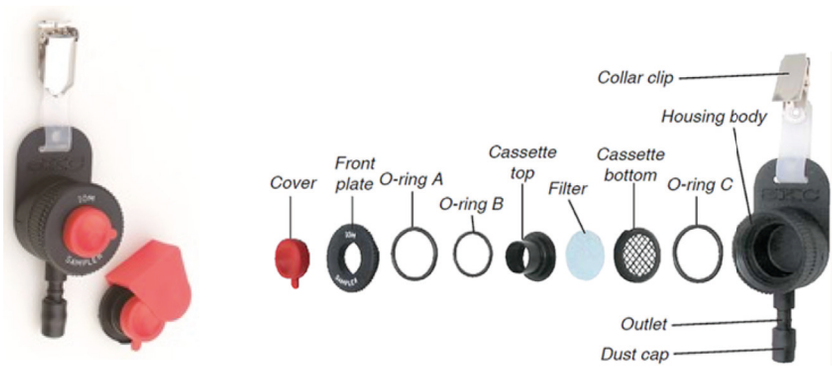

Figure 8-1: IOM sampling head and cassette (left), exploded diagram (right) [SKC, 2016]

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The pumps used in sample collection should meet BS EN ISO (2013) and have:

- An automatic flow control which keeps the volumetric flow-rate (set at 2 L min-1 within ±0.1 L min-1 in case of changing back pressure caused by filter loading.
- Either a malfunction indicator, which following the completion of sampling indicates that the air flow has been reduced or interrupted during sampling, or an automatic cut-out which stops the pump flow if it is reduced or interrupted.
- A facility for adjustment of the flow rate that prevents inadvertent adjustment during use.
- Pulsation damped flow.
- Preferably, flow-stabilised pumps.

The pumps should be maintained and serviced on a regular basis in line with the manufacturer's requirements, normally annually, and records kept.

All equipment should be thoroughly cleaned prior to use and the filters loaded into the cassettes in a clean environment. Setting up of equipment on site should be conducted within a clean area where samples and equipment can be handled without the risk of PGM contamination.

SAMPLING TECHNIQUE

Following a standard air sampling procedure will ensure that results from repeat monitoring exercises will be comparable.

All equipment required should be gathered prior to the survey and checked to ensure it is operating correctly and that all required calibration and servicing requirements are within date.

When preparing the sampling heads additional sample heads should be set aside as field controls; these samples are handled in the same manner as the actual samples, except that no air is drawn through them. They serve to demonstrate that no contamination of the actual samples occurred during the preparation and handling of the sample heads. Two field controls should be set aside for every batch of 10 samples collected.

Sampling heads should be clearly labelled with the filter number, and sampling pumps should also be numbered, to aid identification when in use. The flow-rate should be set at the start of the sampling period to the desired flow-rate (normally 2.0 L min-1) within ±0.1 L min-1of the prescribed flow-rate.

An exposure sample record should include the following information, as a minimum:

- The name and job title of the person being sampled (personal samples) and plant/ site identification.
- A description of the location, including the height and distance of any static sample, with respect to the source (area samples).
- A description of the tasks undertaken during the sample period.
- Identity of chemicals of interest in the work area during the sample period (especially important as soluble platinum analysis does not identify individual metal compound(s)).
- The date, time and duration of the sample period and calculated sample volume.
- Record of calibration.
- Details of the control measures in use.
- Details of workplace environment and process, including any conditions which may result in the environment being atypical.
- Sample method, lab analytical method and laboratory used.

Information recommended for a more complete sample record includes, as applicable, the items below. These are especially relevant if records may later be queried for occupational health or epidemiology studies:

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- Task information in an agreed, consistent format.
- Exposure control information in an agreed, consistent format.
- Unique sample number and campaign number or ID.
- Sample strategy involved (worst case, random, repeat).
- Details of the equipment used, model number, serial number, lot number, etc.
- Weather conditions if outdoors or if room temperature and atmospheric pressure differs from calibration conditions.

After the sampling train has been assembled it should be checked to ensure that there are no leaks. This can be performed by covering the sampler's inlet or 'kinking' the tubing. The pump should stall. If this does not occur there may be a leak in the train, which should be re-examined and rectified. Once the sampling equipment has been confirmed as functioning correctly, the pump should be turned off and the sampling head recapped.

When placing the sampling equipment onto the wearer, time should be taken to explain to the person the reason for the monitoring and, in particular, what is required of the worker during the sampling period. In most instances this will simply be to conduct work practices in the normal manner; however, specific instructions may be required *e.g.*, what to do at break times, avoidance of inadvertently covering the sampling head, and what to do if the worker becomes aware of any problems with the sampling equipment.

The sampling head should be placed in the breathing zone of the wearer, *i.e.* within 300 mm (12 inches) of the nose and mouth, on the upper chest or lapel. Consideration must be given as to whether there may be a concentration gradient across the wearer with respect to the airborne concentration of the substances being measured. If such a gradient exists, the sampling head should be positioned on the lapel which will receive the greatest concentration. This should be noted on the sample record form.

Personal samples should be collected over the entire shift if the results are to be compared with the 8hr TWA. However, where the tasks being carried out within a shift are repetitive and there is a high degree of confidence that sample results from any period will be very similar to any other period, the sample time may be reduced to as short a period as four hours or 24% of the shift. Task-specific sampling should cover only the period during which the task is being performed.

Where static samples are collected the equipment will normally be placed at a height equivalent to the breathing zone. This is defined in BS EN as 1.5m (1996). Height may also be determined empirically, *e.g.*, from the average height of workers or the height of their breathing zone if exposures occur in a stooping, sitting, elevated or other non-standing position. Note that the results obtained from static samples cannot be compared directly with those of personal exposures. Note also that when collecting static samples in areas believed to have very low concentrations of PGMs, use of higher flow-rate sampling pumps and/or longer collection periods may be advised in order to obtain results greater than the laboratory's LOD and LOQ.

Wearers should be asked to keep a note of the activities they carry out during the sampling period and the control measures they use, in particular the use and type of any respiratory protective equipment (RPE). This may require formal note-taking or may simply require confirmation from the wearer that they conducted the tasks according to standard operating procedures, with no upsets or variations occurring.

During the sampling period it is important to check the sampling equipment to ensure that the sample head remains within the breathing zone and has not inadvertently been covered, and to check the flow rate. It is also important to observe and document the work being carried out.

If the flow rate has altered from that set at the start of the

sampling period, then the new flow rate must be recorded. Whether the flow rate is altered back to the initial setting will depend on how much the rate has varied and whether it is likely to keep decreasing/increasing. If the flow rate increased or decreased by more than 10%, then the sample should be discarded. If the flow rate is changed back to the original setting, then these details must be recorded clearly on the sample record form enabling an accurate calculation of total sample volume to be made.

Ideally the flow rate should be checked every hour of sampling, but as a minimum it should be checked at least once during the sampling period. Checking the flow rate and the equipment within the first hour of sampling gives the opportunity to verify that the sampler is being worn correctly and to answer any questions the wearer may have. If any problems are identified at this early stage it gives the opportunity for a new sample to be collected. The flow rate must be checked at the end of the sampling period, before the pump is switched off.

In addition to checking the flow rate, other observations should be made throughout the sampling period. These can include noting the operator's conformance with standard procedures; the general conditions of the work environment and the tasks being carried out; and making notes about the use of control measures.

All samples must be adequately characterised at the time of collection, to help in interpreting the results. Precise and accurate exposure assessment records should be kept in an accessible manner, not only to inform the results at the time of sampling, but as a record should the results be queried in the future. Variation from the planned sampling programme should be recorded, with explanations documented.

On completion of the sampling period, when all checks have been carried out and records verified, the filter samples are ready to be prepared for transfer to the analytical laboratory. It is advised that a chain of custody be established to identify who has responsibility for the care and storage of the samples at each stage.

The samples and field blank filters (sometimes referred to as control samples) must be transported in a manner which will not result in any contamination or loss of any of the sample. Either the filter may be removed from the sample head and placed in a labelled container; or the internal cassette may be removed, capped, and placed in a suitable container for transport. The latter option is preferred.

All associated paper work including the sample record sheet should be transferred with the samples, with a copy kept on-site for reference. Signatures should be recorded at each stage of the transfer to provide a chain of custody.

ANALYSIS/ SPECIATION FOR SOLUBLE PLATINUM

The samples collected should be sent to an accredited laboratory for analysis. It is recommended, depending on the applicable legal requirements in the respective jurisdiction, that the selected laboratory follow the sample preparation and analytical methods provided in the IPA "*Harmonised Methodology for the Sampling of Platinum in Workplace Atmospheres*" (IPA and University of Wisconsin, 2015) and participates in an external quality assessment scheme, *e.g.*, Workplace Analysis Scheme for Proficiency [WASP] (HSL, 2013). Although there are currently no schemes specifically for Pt, laboratories may consider developing their own exchange schemes similar to WASP. Laboratories should consider meeting requirements of BS ENISO/IEC 17025:2005 *General requirements for the competence of testing and calibration laboratories*.

Even if the laboratory does not participate in an external scheme it should conduct internal quality

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control analyses to assess both the reliability of the preparation and analyses and the consistency of the analyst.

The samples analysed will contain inhalable dust and particulates; if using the IOM sampler which has an internal cassette the contents of the cassette itself should also be recovered and analysed as part of the sample.

On receipt of the samples the filters will be transferred into individual flasks; where appropriate the surfaces of the sampler or cassette will be washed to remove any particles adhering to the surfaces.

Samples may be analysed by electrothermal atomic absorption (ET-AAS) spectrometry or by ICP-MS depending on reporting limit desired. In both instances calibration solutions are prepared and are analysed together with the actual samples. Depending upon the quantity of platinum collected on the samples it may be necessary to dilute the samples to bring them within the calibration range.

Following analysis, the mean Pt concentration is calculated; details on the method of calculation and reporting limits can be found in the "*Harmonised Methodology for the Sampling of Platinum in Workplace Atmospheres*" (IPA and University of Wisconsin, 2015).

Solubility is a relative term and is defined by the conditions which are used in that particular industrial or analytical purpose. Some of the chloroplatinate salts are poorly (sparingly) soluble in water compared to the simple chlorides of the alkali metals. In the chemical analysis of soluble platinum compounds for the purposes of workplace monitoring, the term 'soluble' refers to a platinum species which after extraction with high-purity water (WIS, 2015) or 0.07 molar (M) hydrochloric acid (HCl) (HSE, 1996; WIS, 2015) will pass through a 0.45 µm filter (WIS, 2015). HCl solubilisation is used empirically to mimic certain acidic physiological conditions.

Note that analysis of IH/OH samples for soluble metals does not identify the particular metal compound(s) present. Results may indicate soluble PGM or insoluble PGM. Therefore, it is very important to describe in the sampling record the materials involved or handled.

SURFACE SAMPLING

Contact with CHPS and some of the other PGMs on the skin may cause ill-health effects including irritation and sensitisation. Therefore, an assessment of the potential for dermal exposure in the workplace should not be overlooked and incidents resulting in abnormal skin exposures should be recorded in both IH records and the employee's medical file. Monitoring of surfaces *e.g.*, door knobs, lab benchtops, and equipment by wipe sampling for settled dust levels or spilled material may be useful in further controlling exposures.

Before conducting surface sampling, it is important to consider the rationale for doing so, and the numeric benchmarks to use. If there are regulatory requirements these must be followed at a minimum.

Three reasons for surface sampling are listed below. Further information on surface wipe strategies is available in ASTM D7659 Standard Guide for Strategies for *Surface Sampling of Metals and Metalloids for Worker Protection*.

a) **Housekeeping for contamination control:**
Wipe tests may be performed to ensure good housekeeping, *i.e.*, decontamination of equipment, containers and surfaces to avoid dermal exposures or re-entrainment of particulate into workplace air; or of PPE or work clothing to prevent exposures outside the work area.

b) **Direct skin exposure:**
If a skin / dermal OEL exists for a material, then sampling of dermal exposures including skin surface and surfaces employees may touch *e.g.*, door knobs, work surfaces and the inside of gloves or other PPE should be conducted.

As of this printing, the contribution of dermal exposure to CHPS sensitisation is not known; no dermal OEL or target has been established.

c) **Inhalation exposure:**
If the material is hazardous by inhalation only, then the reason for sampling is to assess risk of secondary entrainment of the material *i.e.*, to avoid accumulation of material that can later become airborne. While it is difficult to set a numerical target for this, the Pharmaceutical industry sometimes uses a rule of thumb of 10 times the airborne OEL to express a benchmark exposure in terms of mass/100 cm^2. A shortcoming is that this method fails to consider the form on the surface, how dusty it may be, ability to become airborne, etc. Such values are often determined by trial and error to form a reasonably effective hygiene benchmark.

The location of sampling should represent all potential sources of re-entrainment into the air and/or of direct dermal exposure. Sampling should be planned according to the conditions of concern. For example, to test cleaning to a benchmark, sampling would be conducted after the area or surface is cleaned. If determining effectiveness or improvement by cleaning, then samples would be collected both before and after cleaning. To ensure a room is kept clean, sampling of all horizontal surfaces should be scheduled regularly, *i.e.*, tops of piping and duct work near the ceiling, with frequently disturbed surfaces wipe-sampled more often (floors, desks, tables).

Sample sets should include blanks, typically one per 10 samples and at least one per lot of sample wipes/sample filters.

8.3

SURFACE SAMPLING

EQUIPMENT

Neoprene lab gloves, wipes with consistently low background metals detected (Ghost Wipes (SKC) or other wipe media such as Whatman filter paper, grades 40, 41 or 42) moistened with deionised water, individually sealed packets, and a 10 x 10-cm template as shown in Figure 8-2.

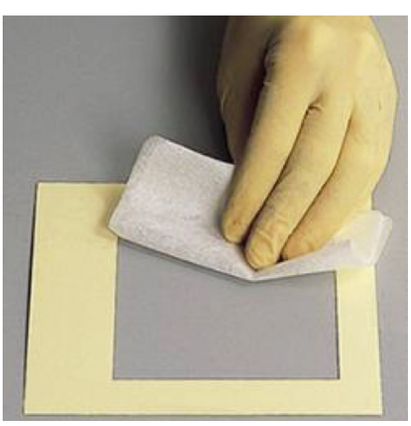

Figure 8-2: Surface wipe sampling

SAMPLING TECHNIQUE

Sampling is begun by first donning clean gloves, then carefully removing the wipe from its individual package.

Next, wipe the surface inside the template left to right as depicted in Figure 8-3 'a'. Fold the wipe in half, then wipe as in 'b'. Finally wipe the outer edge 'c'.

Place the wipe in the re-sealable package or a separate vial, close and seal the package and uniquely label the sample.

Finally, record pertinent data on a field sampling form noting:

- the sample location in detail, including the location conditions as appropriate.
- any unusual visible dust or changes in operating conditions.

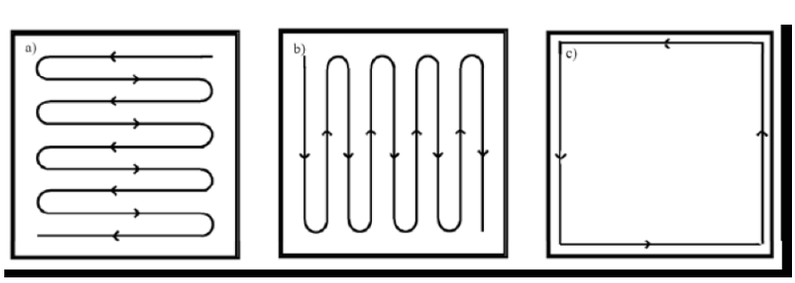

Figure 8-3: The sequence of the technique used in surface wipe sampling

Complete a laboratory transmittal form to deliver to the lab along with the wipe samples.

Further wipe sampling information is available in ASTM D6966 *Standard Practice for Collection of Settled Dust Samples Using Wipe Sampling; Methods for Subsequent Determination of Metals.*

ANALYSIS

Analysis is typically performed by ICP or ICP/MS, similar to the method above for air samples.

CALCULATING EXPOSURE RESULTS

The lab analysis will report results as total mass on the filter. Results of wipes should be recorded internally as mass/100 cm^2, and compared against the benchmark selected for the material.

Blanks should be recorded as mass per filter.

8.4

SOURCES OF IMPRECISION, UNCERTAINTY AND ERROR IN SAMPLING RESULTS

SOURCES OF IMPRECISION, UNCERTAINTY AND ERROR IN SAMPLING RESULTS

In all sampling and analysis there will be sources of error including those of systematic and random nature. Errors may occur in the collection of samples, *e.g.*, as to the appropriate time and place to sample, and in selection of the individual(s) representative of actual exposure.

Furthermore, aerosols are often non-uniform in the workplace and the concentration to which the sampler is exposed is not always the same as the concentration to which the person is exposed. This is often the main source of measurement error and one of the reasons why it is important to base exposure estimates on personal samples rather than static sample results.

Errors in sampling equipment and use may arise. The equipment, instruments, filters, reagents and other supplies used and the procedures followed in the collection and analysis of the samples may have inherent bias or may be imprecise.

The individuals involved in collecting and analysing the samples could introduce both systematic and random errors.

Errors which can be introduced on-site include:

- Incorrect flow measurements.
- Incorrect recording of sampling times.
- Errors in calculations.
- Overloading of filter media.
- Inappropriate placement of the sampler.
- Mis-labelling.
- Contamination.
- Poor storage and transfer techniques.

Errors which can be introduced in the laboratory include:

- Improper handling.
- Contamination.
- Use of uncalibrated instruments.
- Poor sample preparation.
- Calculation errors.
- Mis-labelling.

Care should be taken and checks made to avoid the above human sources of error. If not avoided, these errors may cause significant imprecision in the final results.

In practice, the errors presented by any analytical bias will commonly be much lower (in the order of 1% or less) than those introduced by sampling errors (*e.g.*, pump flow rate plus or minus 10%), or human errors.

Ultimately, the degree of imprecision, error and uncertainty in the estimation of exposure parameters is best determined and managed through statistical treatment of the results from the sampling and analytical measurements.

8.5

INTERPRETING RESULTS

Sample results should be reviewed against the sampling strategy as noted in Section 8.1. The results can be used for assessing regulatory compliance, comparison to OELs or target control levels, refinement of SEGs and/or adjustment of the sampling strategy.

OELs and other benchmarks provide a link between the risk assessment process and the practice of risk management. They are also a useful tool in risk communication. Once sample results are available it is essential that they are interpreted correctly. Results should be adjusted to the applicable exposure limit—calculated Time Weighted Average, Short Term Exposure limit, Ceiling or Target. Adjustment will be needed for longer work shifts.

At a minimum, the exposure limits applicable in each jurisdiction and to the pertinent material must be applied for determining legal compliance.

Many companies consider the latest toxicology and consensus standards for exposure control target comparison. Exposures in excess of these limits require immediate review and generally require remedial action. Even in well-controlled workplaces, measured airborne concentrations can sometimes exceed the exposure limit. Interpretation of such exception conditions is an important component in the science of industrial hygiene.

Further evaluation of the sampling data to account for the variability of your exposure results can be done by entering your data and target OEL level into a statistical analysis for determining risk for non-compliance.

The analysis should first test for fit to the statistic (lognormal or normal data for example) then provide a percentile estimate at a certain defined confidence level. For example, using the AIHA IH STAT tool (available from www.AIHA.org), the OEL target is added along with the sample data. Based on the data a “Yes” or “No” answer is provided for fit to the statistic desired. If the data does fit a statistic, then the calculations provided within that statistical test can be used. A common control level is keeping the likelihood of exceeding the target OEL at less than 5%. This percentage figure is calculated for you in the AIHA IH STAT tool. A similar approach is described in BOHS/NVvA (2011) as noted in the previous section on sampling strategy.

8.6

SAMPLE RESULTS / NOTIFICATION REPORTS

Regardless of whether any notification is mandatory, it is best practice both to inform persons who have been sampled of their results and to give them the opportunity to understand the significance of the results and have their questions answered. Other workers in that job or SEG should also be informed of pertinent results. This not only ensures that workers receive the information and understand the risks associated with their exposure, but also is likely to encourage future monitoring cooperation.

Where only background samples have been collected, the results should be shared with those who work in the area or who may routinely access the area.

Notification should be in compliance with the applicable laws, and normally in writing so that the operator has a record. Notification should be provided within a suitable time period. Typically, written notice is provided within 15 business days of receipt of the sample results.

Notification should be provided to the employee's supervisor and operations management both for their knowledge, and for the progression of workplace modifications or other actions such as changes in control measures (*e.g.*, RPE).

Where monitoring results show that exposure has been significant and workplace modifications are planned, further communication by appropriate management is advised. This may take place through meetings, training, or other direct means including involving workers in planning remedial actions. The objectives are to ensure that the consequences are fully explained and understood, and to promote acceptance of workplace modifications to be undertaken.

The mechanism of routine notification will vary across organisations and countries but may include:

- A confidential letter or email to each employee.
- A letter or email notification to the employee's supervisor and operations management.
- A report table of results and actions posted where those in the same job or HEG/SEG will see it.
- Discussion at safety meetings following written notification.

A copy of the employee's personal notification letter is usually provided to the site Occupational Health staff and/or Human Resources for filing in the employee's HR file. Alternatively, summary reports by HEG/SEG may be provided.

All notification letters or postings should be maintained, along with the survey record, in the EHS department files or computer system.

8.7

RECORD KEEPING

It is important in all aspects of occupational exposure monitoring that good records are prepared and preserved. This enables accurate interpretation of results and observations, and provides an historical record of the procedures applied and followed. It is recommended that the following documents are kept:

- Sampling strategy.
- Primary sampling and analytical records, and calculations.
- Sample transfer information with the analytical laboratory (chain of custody).
- Reports.
- Calibration certificates, sampling equipment maintenance records.
- Training records and presentations for those who conduct sampling.
- Sampling procedures.
- Changes to operations/ systems.

Such documents can be kept electronically or in paper form, but must be readily retrievable. Where personal details are contained within the documents these must be kept in a secure manner in accordance with applicable privacy law, with only appropriate authorised access.

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