An exposure assessment of a laboratory assistant to hazardous chemical substances

ABSTRACT

A survey was conducted to measure exposure to hazardous chemical substances of a laboratory assistant working in a university laboratory, who complained of symptoms that could be indicative of chemical absorption. This case study describes the survey to quantify the exposure in order to determine whether it exceeded safety limits and recommend preventative measures if indicated. Exposure was sampled using a direct reading photo-ionization detector and coconut charcoal sorbent tubes. An additive effect between the different hazardous chemicals was identified. The 8-hour TWA exposure to acetone and dichloromethane was well below the occupational exposure limits, but was more than double the OEL-RL for chloroform. It was also likely that the OEL-STEL for dichloromethane (methylene chloride) was exceeded. Immediate removal for medical assessment and improved preventative measures were recommended.

Key words: exposure assessment, hazardous chemical substances, laboratory assistant

INTRODUCTION

A laboratory assistant complained of headaches and dizziness. This person has been an employee of a South African university for the past 12 years, and is responsible for the collection, decanting and distribution of various hazardous chemical substances (HCS) from a chemical storeroom to a number of laboratories on campus. An HCS may present a hazard as a result of contact with the body or absorption into the body through the skin, by ingestion or inhalation.1 HCSs can be classified as carcinogens, haematopoietic system toxins, hepatotoxins, nephrotoxins, neurotoxins and agents that damage the skin, eyes or mucus membranes.2

After receiving the complaints, a health and safety audit was conducted which noted inadequate and incorrect use of personal protective equipment when distributing the chemicals. These events led to a survey to measure exposure to HCSs in an individual who complained of symptoms that could be indicative of chemical absorption. Exposure was sampled using a direct reading photo-ionization detector (PID) and coconut charcoal sorbent tubes. The purpose of this case study is to describe the survey that was conducted to quantify the exposure of the laboratory assistant to multiple HCSs, in order to determine whether this exposure exceeded safety limits and recommend preventative measures if indicated.

CASE DESCRIPTION

Chemical storeroom

The storeroom has a volume of approximately 22.5 m³. The floor is a steel grid with a spillage sand pit 1m below floor level. It has an extraction fan which is not operational, one door and no windows.

Task description

A number of chemicals are purchased in large quantities (up to
25 ℓ), and stored in the storeroom. Twice a week the laboratory assistant opens these large containers and, using a small funnel, he pours the chemical into smaller glass bottles (2.5 ℓ). This method is repeated for every glass bottle. The number of bottles and type of chemical he decants depends on the laboratory requests, and this differs every day. The bottles are then distributed to the laboratories. During the decanting, large volumes of the chemical are spilled, and this unavoidably releases vapours into the atmosphere of the store room. The laboratory assistant then wipes the spilled chemical from the bottles with a cloth, and leaves the cloth on a shelf in the storeroom. The personal protective equipment issued to the employee consisted of a laboratory overcoat, household cleaning gloves and an FFP1 particulate dust mask.

"The results emphasise the importance of not only TWA-8h exposure sampling but also short-term exposures sampling."

**Personal exposure**

As noted above, a direct reading PID and coconut charcoal sorbent tubes were used to measure the laboratory assistant’s exposure. The PID instrument (EntryRAE, RAE Systems Inc.) recorded the total number of volatile organic compounds present in the breathing zone as personal exposure as well as area exposure in the storeroom atmosphere during the measurements. A VOC can be defined as any chemical compound based on carbon chains or rings and contains hydrogen, with a vapour pressure greater than 2 mm of mercury at 25°C. This PID for VOC broadband detection uses a 10.6 eV lamp to detect a wide variety of gases. Any compound with ionization energy lower than that of the lamp photons can be measured. The detector can detect just a few parts per million of these compounds.

The sorbent tubes (SKC International, product code 226-01) provided the specific concentrations of personal exposure to acetone, dichloromethane and chloroform. This was determined by following the NIOSH method 1500 and subsequent analysis by an accredited laboratory. Sampling was conducted for the duration of the laboratory assistant’s tasks in the storeroom, which was 38 minutes. TWA for an eight-hour shift was calculated with the understanding that the laboratory assistant was not exposed to any HCS for the remainder of the workday.

No detectible background levels of VOCs were recorded outside the chemical storeroom on the direct reading PID. In this case the source of VOC emissions were from storage and use of solvents. Once the employee entered the storeroom, readings started to increase, even prior to him performing his task. The door of the storeroom was kept open for the duration of the task. This particular day was chosen based on the large amount of chemical bottles that had to be filled. The particular chemicals transferred (in total 25 bottles of 2.5 ℓ each) were dichloromethane (13), ethanol (2), acetone (2), ethyl acetate (7) and chloroform (1). Figure 1 illustrates the employee’s personal and area exposure to HCS while performing his tasks. Personal exposure (black) was measured in the breathing zone of the laboratory assistant. Area sampling (grey) was measured in the storeroom where the task was performed 1.5 m above floor level. During this time there was a period of 7 minutes where personal exposure was very high with an average of 2258.4 ppm (maximum exposure of 3423.8 ppm).

**DISCUSSION**

As indicated in Table 1, the 8 hour TWA exposure to acetone and dichloromethane was well below the occupational exposure limits, but was more than double the OEL-RL for chloroform. Although short-term exposure was measured for 38 minutes the OEL-STEL for dichloromethane (methylene chloride) is in all likelihood exceeded during the sampling period. The Regulations for Hazardous Chemical Substances do not list an OEL-STEL for chloroform, however the exposure to chloroform exceeded the NIOSH OEL-STEL of 2 ppm. If the South African TWA OEL is multiplied by three to give an indication of the OEL-STEL (6 ppm), the short-term exposure to chloroform is 8.36 times above the OEL-STEL.

According to the ACGIH both chloroform and dichloromethane are confirmed animal carcinogens with unknown relevance to humans. Both chloroform and dichloromethane cause central nervous system depression with symptoms of headache, dizziness, nausea and reduced coordination. Consequently the results of exposure to both chloroform and dichloromethane simultaneously and their possible additive effect would explain the employee’s complaints of headaches and dizziness.

<table>
<thead>
<tr>
<th>Employee’s exposure</th>
<th>OEL-TWA</th>
<th>Employee’s exposure</th>
<th>OEL-STEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>1.23</td>
<td>750</td>
<td>14.04</td>
</tr>
<tr>
<td>Chloroform</td>
<td>4.39</td>
<td>2</td>
<td>50.13</td>
</tr>
<tr>
<td>Dichloromethane*</td>
<td>33.93</td>
<td>100</td>
<td>387.79</td>
</tr>
</tbody>
</table>

* Control limit. Also indicated as methylene chloride with a recommended limit (Table II) of OEL-TWA of 100 ppm and an OEL-STEL of 250 ppm.

# TWA for an eight-hour shift was calculated with the understanding that the laboratory assistant was not exposed to any HCS for the remainder of the workday.

Table 1. Personal exposure to HCS and occupational exposure limits according to the Regulations for Hazardous Chemical Substances of South Africa.®

---

"The results emphasise the importance of not only TWA-8h exposure sampling but also short-term exposures sampling."

**Personal exposure**

As noted above, a direct reading PID and coconut charcoal sorbent tubes were used to measure the laboratory assistant’s exposure. The PID instrument (EntryRAE, RAE Systems Inc.) recorded the total number of volatile organic compounds present in the breathing zone as personal exposure as well as area exposure in the storeroom atmosphere during the measurement. A VOC can be defined as any chemical compound based on carbon chains or rings and contains hydrogen, with a vapour pressure greater than 2 mm of mercury at 25°C. The PID for VOC broadband detection uses a 10.6 eV lamp to detect a wide variety of gases. Any compound with ionization energy lower than that of the lamp photons can be measured. The detector can detect just a few parts per million of these compounds.

The sorbent tubes (SKC International, product code 226-01) provided the specific concentrations of personal exposure to acetone, dichloromethane and chloroform. This was determined by following the NIOSH method 1500 and subsequent analysis by an accredited laboratory. Sampling was conducted for the duration of the laboratory assistant’s tasks in the storeroom, which was 38 minutes. TWA for an eight-hour shift was calculated with the understanding that the laboratory assistant was not exposed to any HCS for the remainder of the workday.

No detectible background levels of VOCs were recorded outside the chemical storeroom on the direct reading PID. In this case the source of VOC emissions were from storage and use of solvents. Once the employee entered the storeroom, readings started to increase, even prior to him performing his task. The door of the storeroom was kept open for the duration of the task. This particular day was chosen based on the large amount of chemical bottles that had to be filled. The particular chemicals transferred (in total 25 bottles of 2.5 ℓ each) were dichloromethane (13), ethanol (2), acetone (2), ethyl acetate (7) and chloroform (1). Figure 1 illustrates the employee’s personal and area exposure to HCS while performing his tasks. Personal exposure (black) was measured in the breathing zone of the laboratory assistant. Area sampling (grey) was measured in the storeroom where the task was performed 1.5 m above floor level. During this time there was a period of 7 minutes where personal exposure was very high with an average of 2258.4 ppm (maximum exposure of 3423.8 ppm).

**DISCUSSION**

As indicated in Table 1, the 8 hour TWA exposure to acetone and dichloromethane was well below the occupational exposure limits, but was more than double the OEL-RL for chloroform. Although short-term exposure was measured for 38 minutes the OEL-STEL for dichloromethane (methylene chloride) is in all likelihood exceeded during the sampling period. The Regulations for Hazardous Chemical Substances do not list an OEL-STEL for chloroform, however the exposure to chloroform exceeded the NIOSH OEL-STEL of 2 ppm. If the South African TWA OEL is multiplied by three to give an indication of the OEL-STEL (6 ppm), the short-term exposure to chloroform is 8.36 times above the OEL-STEL.

According to the ACGIH both chloroform and dichloromethane are confirmed animal carcinogens with unknown relevance to humans. Both chloroform and dichloromethane cause central nervous system depression with symptoms of headache, dizziness, nausea and reduced coordination. Consequently the results of exposure to both chloroform and dichloromethane simultaneously and their possible additive effect would explain the employee’s complaints of headaches and dizziness.

<table>
<thead>
<tr>
<th>Employee’s exposure</th>
<th>OEL-TWA</th>
<th>Employee’s exposure</th>
<th>OEL-STEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>1.23</td>
<td>750</td>
<td>14.04</td>
</tr>
<tr>
<td>Chloroform</td>
<td>4.39</td>
<td>2</td>
<td>50.13</td>
</tr>
<tr>
<td>Dichloromethane*</td>
<td>33.93</td>
<td>100</td>
<td>387.79</td>
</tr>
</tbody>
</table>

* Control limit. Also indicated as methylene chloride with a recommended limit (Table II) of OEL-TWA of 100 ppm and an OEL-STEL of 250 ppm.

# TWA for an eight-hour shift was calculated with the understanding that the laboratory assistant was not exposed to any HCS for the remainder of the workday.
dichloromethane is a moderate to severe irritant when it comes in contact with skin. Long-term exposure to dichloromethane may lead to dermatitis and neurological effects as well as liver impairment.9 Chronic exposure to chloroform by inhalation is associated with effects on the liver and central nervous system, such as depression and irritability, and effects on the heart.10

The additive effect of mixed exposure to various HCS can be calculated according to C1/T1 + C2/T2 + C3/T3, where C is the observed concentration, and T is the corresponding threshold limit.6 The calculated additive effect of the laboratory assistant’s exposure to hazardous chemical substances exceeded 1 (2.54) which indicates that there was an additive effect between the different hazardous chemicals. Additive effect refers to the combined effect of two or more hazardous substances that have a similar toxicological effect on the same target organ or system.7

The laboratory assistant was not adequately equipped with PPE, as the FFP1 dust mask he was issued is not suitable for use with chemicals, and provided no protection against the vapours. The household cleaning gloves also did not provide sufficient protection against spillages of chemicals. The ventilation system in the storeroom was not functional, and the only method of ventilation was provided by the open door. The decanting method was not suitable, as large volumes of chemicals were spilled which increased the laboratory assistant’s exposure.

As this survey was only conducted on one day, his exposure to other chemicals in the storeroom was not measured. Measurement should be repeated to include all possible exposures.

CONCLUSION AND RECOMMENDATIONS

The short-term exposure of the laboratory assistant to chloroform and dichloromethane probably exceeded the OEL-STEL concentrations. The TWA exposure to chloroform exceeded the OEL-TWA concentration. Additive effects of exposure to a mixture of chemicals, in this case acetone, chloroform and dichloromethane, are indicated.

The results emphasise the importance of not only TWA-8h exposure sampling but also short-term exposures sampling. These clarify the extent and duration of peak exposures when planning and assessing exposures of workers to HCS, as well as the effects of exposure to various hazardous chemicals simultaneously.

In the Regulations for Hazardous Chemical Substances of 1995, dichloromethane is listed in Table I with a control limit, but methylene chloride is listed in Table II with a recommended limit.5 These are synonyms for the same chemical. As dichloromethane is a suspected human carcinogen, it should therefore only be listed in Table I and methylene chloride should be removed from Table II.

This study led to valuable information provided to the laboratory assistant’s supervisor in order to improve his working conditions. The laboratory assistant was issued with new PPE, and further recommendations were made to improve the working environment of the worker. Due to the absence of any assessments or monitoring, and the presence of possible symptoms related to long-term exposure to solvents, it was recommended that the employee be withdrawn immediately and referred to an occupational health practitioner for a physical evaluation and other tests necessary to determine his health status. The employee was also occasionally exposed to HCS listed in Table III, such as methanol and should also be placed under medical surveillance for this exposure. Spillages can be prevented by using appropriate siphoning equipment. The extraction fan should be repaired and the adequacy of its operation verified. The employee should be supplied with the appropriate personal protective equipment (PPE), such as gloves and correct respiratory protection to reduce his exposure to HCS. The employee should receive training and education on the correct use, maintenance and replacement of PPE.4,5

LESSONS LEARNED

• Simultaneous exposure to various chemicals with similar toxicological effects may have an additive effect.
• The importance of short-term exposure cannot be over emphasised to determine peak exposures.
• TWA-8h exposure sampling together with short-term exposures sampling clarify the extent and duration of peak exposures when planning and assessing exposures of workers to HCS, as well as the effects of exposure to various hazardous chemicals simultaneously.

REFERENCES

7. ACGIH. 2008 TLVs and BEIs based on the documentation of the threshold limit values for chemical substances and physical agents & biological exposure indices. Cincinnati, USA: ACGIH; 2008.