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Occupational Exposure in the Transport, Handling and Storage of Hazardous Liquid Waste

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In NSW, many hazardous wastes are also classified as Dangerous Goods and Hazardous Substances. Occupational exposure assessment may be used to differentiate between acceptable and unacceptable exposures, to control unacceptable exposures, demonstrate compliance with legal or other guidelines or all three (AIHA 1991). One major challenge when dealing with hazardous waste is that its composition is not always known, making the utilisation of occupational exposure assessment strategies difficult. Ultimately however, the goal must be to ensure employee health and safety in the working environment, through eliminating or controlling exposures. A search of the NSW Department of Environment and Climate Change's (DECC) Public Register realised seventy eight (78) facilities with Environment Protection Licenses under the category of "Waste storage - Hazardous, restricted solid, liquid, clinical & related waste & Asbestos waste".

This paper outlines some of the relevant issues for assessing occupational exposures to hazardous waste and suggests an effective approach is to focus resources on the elimination or control of exposures, and using exposure monitoring to ensure controls are effective.

Introduction

The management of hazardous waste typically involves one or more of the collection, transport, storage, handling, transfer, treatment and processing of bulk or packaged materials. Figure 1 illustrates the various activities involved in the management of hazardous waste. However there appears to be little information in the public domain on worker exposure to "hazardous waste" during its transport, handling, storage and processing. For instance, a search in the Annals of Occupational Hygiene using the phrase "hazardous waste" in the abstract/title field did not yield any results and a search of the Journal Occupational and Environmental Hygiene yielded sixty two (62) results. Of these results only twelve (12) contained "hazardous waste "in the title, with most referring to hazardous waste site cleanup which is not considered relevant here.

The purpose of this paper is to discuss some of the challenges in assessing occupational exposure to hazardous waste and to suggest some approaches to controlling risks. The term "hazardous waste" can have different definitions and connotations. From an environmental perspective, hazardous waste in NSW has until the recent past, included wastes meeting the criteria for assessment as Dangerous Goods under the 'Australian Code for the Transport of Dangerous Goods by Road and Rail, 2007' . The NSW Department of Environment and Climate Change's (DECC) waste classification scheme is concerned with managing waste with contaminants in the context of landfill disposal and environmental risk. The DECC licenses various types of waste facilities such as storage, transfer, treatment and processing operations. Relatively recent amendments in 2008, aimed at simplifying waste classification, have resulted in hazardous waste (in liquid form) being classified as simply, liquid waste.

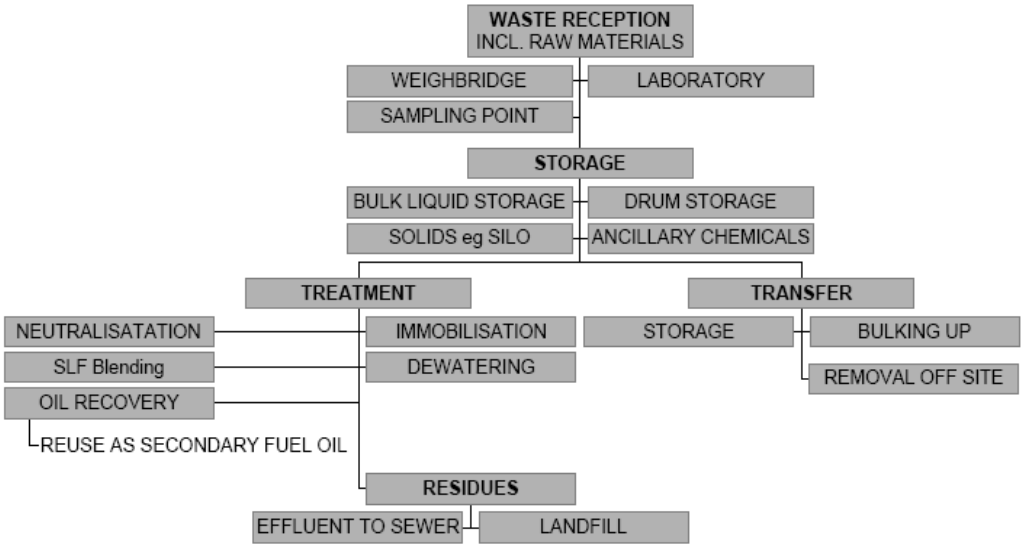

Figure 1. Processes undertaken in the management of hazardous waste (Environment Agency – UK 2002).

Nevertheless, the transport of Dangerous Goods remains under the jurisdiction of the DECC. Yet, the safe handling and storage of hazardous wastes which meet the criteria for assessment as Dangerous Goods falls under the jurisdiction of the OHS Regulatory Authority (Workcover NSW). Finally, a hazardous waste may also be hazardous substance as defined by workplace Hazardous Substances Regulation. Therefore in many cases employers are required to identify, assess and control any risks to workers from exposure to hazardous waste. Hereafter, the term liquid or hazardous liquid wastes is used to describe wastes, which in many instances are likely to meet the criteria for Dangerous Goods and/or Hazardous Substances under NSW OHS legislation; rather than any "environmental" definition.

In terms of occupational exposure to hazardous waste, the scope of this paper is limited to liquids and aspects of transfer such as transport, storage and bulking up. In addition, the focus is on the occupational hygiene aspects of exposure to hazardous waste rather than safety hazards such as fire and explosion.

Methods

A search of the NSW DECC public register was undertaken to identify facilities with Environment Protection Licenses for activities relating to hazardous liquid waste. A number of license holder activities were identified which have the potential to involve occupational exposure to hazardous liquid waste. These included "Waste Storage - Hazardous, Restricted Solid, Liquid, Clinical and Related Waste and Asbestos Waste", "Transport of Hazardous and other Waste", "Chemical Production – Waste Generation". The search of licenses was limited to the category of "Waste Storage - Hazardous, Restricted Solid, Liquid, Clinical and Related Waste and Asbestos Waste", because it is most likely to contain facilities primarily involved with hazardous waste. Such facilities are likely to handle the types of waste encountered in the occupational environment on a regular basis. The search identified different seventy-eight (78) facilities with this category. Each facility's license was read to identify the types of hazardous liquid waste the facility was permitted to store or process.

Results

Figure 2 illustrates the number of facilities storing or processing twenty (26) different types of liquid waste or waste streams identified by the relevant NSW DECC waste code. The DECC website lists these codes and descriptions (http://www.environment.nsw.gov.au/owt/wclist.htm).

Table 1 lists thirteen (13) liquid waste codes/ descriptions which appear on the licenses of ten (10) or more facilities in NSW. Of course, a facility may only accept one liquid waste while another facility may receive the entire range of wastes. Referring to Table 1; the four (4) highest frequency waste types received at facilities are J120 - Waste oil/water, hydrocarbons/water mixtures or emulsions , J100 - Waste mineral oils unfit for their original intended use, B100 - Acidic solutions or acids in solid form and C100 - Basic solutions or bases in solid form. It is likely that significant quantities of these waste types will be handled in bulk quantities, given their extensive use in industry. Acidic and basic solutions may be classified as Class 8 Corrosive Dangerous Goods. Hazardous wastes meeting the criteria of Class 8 are allocated to Class 6.1 if their inhalation toxicity (dust and mists) leads to Packaging Group I and their oral or dermal toxicity is at least in the range of Packaging Group I or II (Australian Code for the Transport of Dangerous Gods by Road and Rail, 2007). Therefore Class 8 wastes should not generally present a significant inhalation hazard; unless having a subsidiary risk of Class 6.1 (e.g. sulphuric acid fuming).

The potential for a solvent to create unacceptable inhalation exposures can be evaluated by the ratio of its volatility (vapour pressure) and its 8 hr occupational exposure standard (Debia et al 2009.) This index is known as the “Vapor Hazard Ratio” (VHR) which was described by Popendorf (1984). It was proposed as a tool to assess the substitution of one solvent with another, for example in a degreasing process, to ensure the replacement solvent was “less hazardous”. Therefore a highly volatile solvent with a low occupational exposure standard will have a much higher VHR than a less volatile solvent with a similar exposure standard. While a relatively simple concept for pure solvents it does become more theoretically complex for mixtures of solvents or chemicals. The boiling point of a chemical has also been used as an indication of the exposure potential of hazardous substances (Firth et al 2006).

Waste streams from Table 1. which standout as having higher inhalation exposure potential include: G110 - Organic solvents excluding halogenated solvents, R120 Waste pharmaceuticals, drugs and medicines, G150 - Halogenated organic solvents, G160 - Waste from the production, formulation and use of organic solvents. Solvents with relatively high VHR which may be found in these waste streams include: methanol, n-hexane, toluene, methylene chloride (dichloromethane), chloroform, trichloroethylene, carbon tetrachloride, perchloroethylene, methyl ethyl ketone, and tetrahydrofuran (Debia et al 2009). These waste streams would be a high priority in terms of occupational exposure assessment.

Figure 2. Facilities with an Environmental Protection License to store or process liquid waste.

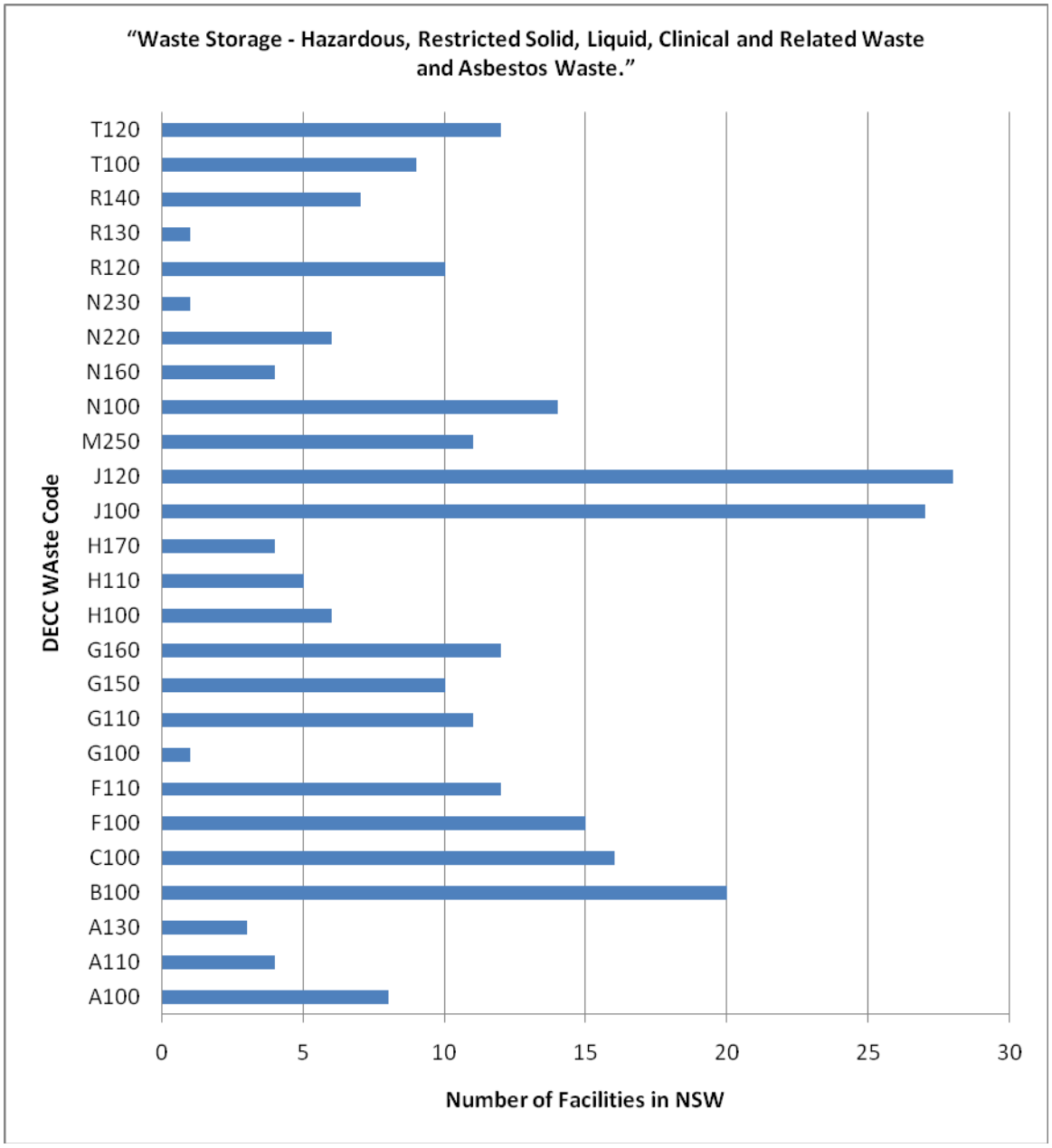

Table 1. DECC waste codes/descriptions for those liquid wastes/waste streams accepted by ten (10) or more facilities.

Waste Code	Waste Description	Number of Facilities
J120	Waste oil/water, hydrocarbons/water mixtures or emulsions	28
J100	Waste mineral oils unfit for their original intended use	27
B100	Acidic solutions or acids in solid form	20
C100	Basic solutions or bases in solid form	16
F100	Waste from the production, formulation and use of inks, dyes, paints, lacquers, pigments and varnish	15
N100	Containers and drums that are contaminated with residues of waste	14
T120	Waste from the production, formulation and use of photographic chemicals and processing	12
G160	Waste from the production, formulation and use of organic solvents	12
F110	Waste from the production, use , formulation of resins, latex,plasticisers,glues and adhesives	12
M250	Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials	11
G110	Organic solvents excluding halogenated solvents	11
R120	Waste pharmaceuticals, drugs and medicines	10
G150	Halogenated organic solvents	10

Discussion

Waste Characterisation

Under the Protection of the Environment Operations Act (POEO Act 1997); waste codes and descriptions are applied to various waste streams (e.g. wastes resulting from surface treatment of metals and plastics) and wastes (e.g. lead and lead compounds) for correct processing and/or disposal. If the waste is also a Dangerous Good, it is required to be transported and stored in accordance with Dangerous Goods legislation (e.g. the placarding of vehicles and stores indicating the class of Dangerous Good). Typically hazardous liquid waste will be characterized by its waste code/description and Dangerous Goods class for compliance purposes. In these cases, public safety and environmental risk are key considerations, with good reason.

Occupational Exposure Assessment

Assessment of occupational exposures to hazardous substances may be used to differentiate between acceptable and unacceptable exposures, to control unacceptable exposures, demonstrate compliance with legislated or other guidelines or all three (AIHA 1991). Assessment usually involves estimation, either qualitative or quantitative, of the degree of exposure to one or more hazardous substances. This requires knowledge of the potential routes of exposure, such as inhalation of vapours or skin contact. If inhalation is a significant route of exposure, air sampling in the breathing zone of workers may be undertaken. This requires knowledge of the work environment, process, tasks and chemicals involved to be effective (Grantham 2001). In the case of sampling the breathing zone of workers, a sample result may be compared against an Occupational Exposure Standard (OES). However there are significant challenges involving hazardous waste in the context of occupational exposure assessment. These include:

- Dangerous Goods classification will generally be too broad. For instance Class 6.1 Toxic is very relevant with respect to occupational exposure assessment, however many Dangerous Goods classified as Class 3 Flammable will also be hazardous

substances e.g. toluene and styrene. The classification criteria for Class 6.1 Toxic addresses acute toxicity criteria rather than the chronic effects of exposure to lower levels of chemicals; however assignment to Packaging Groups I, II or III is also a function of vapour pressure (Australian Code for the Transport of Dangerous Goods by Road and Rail, 2007).

- It is not certain that the composition of the hazardous liquid waste will be characterised correctly or that once a waste has been characterised it will not be inadvertently or intentionally contaminated or substituted with other waste. Furthermore as Table 1. indicates, most waste codes and descriptions will not identify specific hazardous substances and the waste may also be a mixture of substances. According to the Environment Agency (2002) proper waste characterization is essential to waste storage, transfer, storage, bulking up and treatment operations. Problems arising from inadequate waste characterization include inappropriate storage and mixing of incompatible substances, accumulation of wastes and unexpected treatment characteristics. This requires a system that has as an initial stage, a screening step or pre-acceptance procedure, involving the provision of information and representative samples of the waste.
- Assuming that wastes are well characterised, the types of hazardous liquid waste handled on a routine basis will vary from day to day. Daily average exposures may vary considerably from day to day in a workplace even if a worker is exposed to the same hazardous substances doing the same job (Kumagai and Matsunaga 1992). Of the seventy eight (78) licenses read, fifteen (15) waste facilities are licensed to receive 5 or more different waste codes and descriptions.
- When workers are exposed to more than one hazardous substance which has the potential to affect the same target organ; the effect may be additive, synergistic or potentiating as in the case of methyl ethyl ketone and n-hexane. This makes interpretation of air sampling results quite complex with respect to occupational exposure standards; especially when various liquid waste streams are involved.
- Workers involved in the collection and transport of hazardous liquid waste are required to collect waste from various locations such that it is difficult to characterise their workplace and environment e.g. a collection point may be changed from a well ventilated area to a poorly ventilated one when loading a vehicle tanker.
- Resources required for meaningful sampling for occupational exposure assessment are limited to larger organisations and beyond the means of ordinary workplaces (Grantham 2001).

In occupational hygiene, it is critical to have a clear understanding of the purpose for undertaking any assessment, but particularly for quantitative assessment such as air sampling, as there can be numerous limitations. Considerations for a waste facility will include many macro-factors, such as the size and layout of the facility, the types and amount of waste it receives, how it is stored, handled, transferred, transported or processed. Therefore it is recommended that the overall objective should be to identify and focus attention on those situations with potential significant or unacceptable exposures of workers to hazardous liquid waste, for further evaluation or control. A basic characterisation of the waste facility is required to achieve this aim. According to the AIHA (1991) this basic characterisation includes the following three elements, which are briefly discussed below in the current context.

a) Workplace characterisation

This is a description of the various processes and operations conducted at a facility. Figure 1.0 is such a description of the types of processes which can be carried out at

waste facilities. A facility may only conduct *storage and transfer* operations in which waste may be transported to the site in tankers and/or by vehicles in drums, unloaded and stored. The site may have bulk storage tanks and/ or packaged stores, conduct bulking up operations and removal off site. In this case bulking up operations include combining smaller quantities of waste into drums or Intermediate Bulk Containers (IBC's) for transport off site, for further processing or treatment. A picture can be constructed of the activities causing exposure which is a key consideration from an occupational hygiene perspective. For instance what types of vehicles are used to transport waste? Is there manual or more automated transfer of waste, are waste transfers conducted in buildings or in the open; if inside are there local exhaust ventilation controls? Do internal bulk storage areas have adequate natural or mechanical ventilation?

b) Workforce characterisation

To understand the potential for occupational exposure to hazardous liquid waste, it is necessary to identify in more detail how workers interact with the various processes, as discussed above. For instance how many tanker loads of waste does a bulk tanker driver handle, how often is the driver required to be positioned near the source of waste or handle the transfer hose? During bulking up operations, how often do the operators empty or fill drums or IBC's? What is the range of volumes of waste handled? Are operators in the vicinity of sources of exposure such as open drums or vessels? Is cleaning of transfer equipment, such as hoses, necessary?

A further very important consideration is the length of work shift, as occupational exposures standards are usually expressed as eight (8) hour time weighted averages for a work shift. These may need to be altered if the worker works ten (10) or twelve (12) hour shifts or longer work weeks.

c) Agent (waste) characterisation

The preceding two sections were aimed at obtaining an understanding of the nature of the work environment and activities to: a) identify those groups of employees who may have the greatest potential for exposure and b) resultant potential health effects. The former can be mostly achieved with workplace and workforce characterisation; however the latter can only be achieved in conjunction with reliable waste characterisation. The difficulties of this have been discussed above with the recognition that each facility storing or handling hazardous waste will be somewhat different.

d) Assessment and Controls

The preceding discussion covered some established occupational hygiene principles to characterise the workplace, workforce and types of hazardous waste. However the establishment of an occupational exposure profile is a "moving target" and resources are best allocated towards controlling or eliminating exposures. The UK Health and Safety Executive (HSE) has developed COSHH Essentials, to provide guidance to small and medium size employers on suitable controls for exposure to chemicals. Based on the chemical health hazard and exposure potential, a generic risk assessment is performed which defines an appropriate control approach. COSHH Essentials (for liquids) uses liquid volatility and quantity as a determinant of exposure potential. The Risk or R-phrases for the substances are used to signify the health hazard with substances grouped into five (5) hazard groups. The scheme is not intended for use as an exposure model, but rather to define adequate exposure controls for a range of workplace scenarios (HSE 2002). The information required can be obtained from a Material Safety Data Sheet.

An example of a suggested approach for defining priorities for control measures is given in Table 2 below, although the implementation needs to be facility specific. The intent is that the facility can prioritise action according to its highest risk exposure scenario. It is essentially based on the waste classification code (column c) and the inhalation exposure potential of the waste (column d). It is also considers the likelihood for the inhalation exposure to be realised, based on the workforce/workplace characterisation (column b). Monitoring (column f) can be used to ensure exposures are adequately controlled (column e). Two examples follow to highlight the use of the table for a facility that accepts the type of wastes listed.

Example 1.

Waste types listed in the first 2 rows of column (c), are likely to have a high inhalation exposure potential. However the driver/operator performs no manual transfer of waste (row 2). That is closed drums are loaded onto a vehicle for transport and subsequent storage prior to treatment. In this case it is considered that suitable respiratory protection can be provided while loading, unloading the vehicle and performing any vehicle checks. The adequacy of the level of respiratory protection afforded could be confirmed by use of a direct reading instrument and /or personal exposure monitoring.

Example 2.

A facility accepts large quantities of J100 waste (waste mineral oils) which is deemed a low inhalation exposure potential. Waste is handled by bulk vehicle tanker transfer of liquid in open, well ventilated areas (row 4). Therefore there should be no need for further additional controls.

Table 2. A suggested approach to controlling exposure to hazardous waste

Relative Risk Level for Facility (a)	Workforce/Workplace Characterisation (b)	Type of Hazardous Waste/DG Accepted at Facility (c)	Inhalation Potential (d)	Controls (e)	Monitoring (f)
HIGH  LOW	Operations requiring manual handling of medium to large quantities of waste such as transfers with open drums or containers (litres to cubic metres).	Waste Codes: G110, G150, G160, R120, D.G Class 3.0 – Flammables	High	Containment / Local Exhaust Ventilation with performance to be verified Respiratory Protection Equipment - Supplied Air Systems	Personal exposure monitoring and/or Direct Reading Instruments are warranted to ensure controls are effective in reducing exposure.
	Operations requiring no manual handling of large quantities of waste (cubic metres). Containers remain closed and no open transfer.	Waste Codes: G110, G150, G160, R120, D.G Class 3.0 –Flammables	High	Adequate natural or general ventilation Respiratory Protection Equipment	Personal exposure monitoring and/or Direct Reading Instruments are warranted to ensure adequate Respiratory Protection.
	Operations requiring manual handling of waste Transfers with open drums or containers (litres)	Waste Code : J 100	Low	Adequate natural or general ventilation Respiratory Protection Equipment	Direct Reading instruments may be used to ensure low exposure potential.
	Operations requiring no manual handling of waste (cubic metres). Bulk liquid transfer	Waste Code: J100	Low	Adequate natural or general ventilation Respiratory Protection Equipment	Monitoring may be considered.

Conclusion

Typically occupational exposure assessment will incorporate the quantitative aspect of exposure monitoring which can require significant resources, especially for complex exposure scenarios. Assessment of occupational exposure to hazardous liquid waste presents such a case. Resources should be directed towards the implementation of exposure controls or elimination of exposures, and exposure monitoring can be utilised to verify the effectiveness of controls. A suggested approach has been offered in accordance with occupational hygiene principles. Limitations in this paper, which must be considered in practice, include alternate routes of exposure such as skin contact and exposure to solid materials.

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