

# Guide to the safe handling of solvents in a bituminous products laboratory

Manual 29 September 2010



## **Manual 29**

Published by Sabita  
Postnet Suite 56  
Private Bag X21  
Howard Place 7450  
South Africa

ISBN 978-1-874968-41-2

### **DISCLAIMER**

Considerable effort has been made to ensure the accuracy and reliability of the information contained in this publication. However, neither Sabita nor any of its members can accept any liability whatsoever for any loss, damage or injury resulting from the use of this information. The contents of this publication do not necessarily represent the views of all members of Sabita.

This document is provided to the reader as a service by Sabita and is intended for the sole use of the reader. It remains the property of Sabita. It may not be given to any third party, or copied and given to a third party, in part or in whole, without the express written permission of Sabita.

## Manuals published by Sabita

<b>Manual 1</b>	Construction of bitumen rubber seals
<b>Manual 2</b>	Bituminous products for road construction
<b>Manual 3*</b>	Test methods for bitumen rubber
<b>Manual 4*</b>	Specifications for rubber in binders
<b>Manual 5</b>	Manufacture and construction of hot mix asphalt
<b>Manual 6*</b>	Interim specifications for bitumen rubber
<b>Manual 7</b>	SuperSurf: Economic warrants for surfacing unpaved roads
<b>Manual 8</b>	Safe and responsible handling of bituminous products
<b>Manual 9</b>	Bituminous surfacings for temporary deviations
<b>Manual 10</b>	Appropriate standards for bituminous surfacings
<b>Manual 11</b>	Labour enhanced construction for bituminous surfacings
<b>Manual 12</b>	Methods and procedures - Labour enhanced construction for bituminous surfacings
<b>Manual 13</b>	LAMBS - The design and use of large aggregate mixes for bases
<b>Manual 14***</b>	GEMS - The design and use of granular emulsion mixes
<b>Manual 15*</b>	Technical guidelines for seals using homogeneous modified binders
<b>Manual 16**</b>	REACT - Economic analysis of short-term rehabilitation actions
<b>Manual 17</b>	The design and use of porous asphalt mixes
<b>Manual 18</b>	Appropriate standards for the use of sand asphalt
<b>Manual 19</b>	Technical guidelines for bitumen-rubber asphalt
<b>Manual 20</b>	Sealing of active cracks in road pavements
<b>Manual 21***</b>	ETB: The design and use of emulsion treated bases
<b>Manual 22</b>	Hot mix paving in adverse weather
<b>Manual 23</b>	Code of Practice: Loading bitumen at refineries
<b>Manual 24</b>	User guide for the design of hot mix asphalt
<b>Manual 25</b>	Quality management in the handling and transport of bituminous binders
<b>Manual 26</b>	Interim guidelines for primes and stone precoating fluids
<b>Manual 27</b>	Guideline for thin layer hot mix asphalt wearing courses on residential streets
<b>Manual 28</b>	Best practice for the design and construction of slurry seals

\* These manuals have been withdrawn and their contents have been incorporated in a manual entitled: *The use of modified binders in road construction* published as Technical Guideline 1 by the Asphalt Academy.

\*\* This manual has been withdrawn and its software programme incorporated in TRH12: *Flexible pavement rehabilitation investigation and design*.

\*\*\* These manuals have been withdrawn and their contents have been incorporated in a manual entitled: *Bitumen stabilised materials* published as Technical Guideline 2 by the Asphalt Academy.

## Sabita DVD Series

- DVD100**    **Testing of bituminous products**
- Penetration bitumen tests
  - Bitumen emulsion tests
  - Hot mix asphalt tests
  - Bitumen rubber tests
- DVD200**    **Repair of blacktop roads**
- Training guide for the construction and repair of bituminous surfacings by hand
- DVD300**    **Hot mix asphalt**
- Manufacture, paving and compaction of HMA
- DVD410**    **The safe handling of bitumen**
- DVD420**    **Treatment of bitumen burns**
- DVD430**    **Working safely with bitumen**
- DVD440**    **Firefighting in the bituminous products industry**

## ACKNOWLEDGEMENT AND DISCLAIMER

This publication is an extract of the original Contract Report: CSIR/BE/IE/ER/2009/ 0030/C April 2009, (authors J O'Connell and G Mturi), prepared for Sabita by the CSIR under Project 59E2084: *A Guide to the safe use of solvents in a bituminous products laboratory*.

The content of the original CSIR report is duplicated in this extract without alteration except for the content of Appendix C, which has been revised and edited to replace reference to foreign MSDS sheets and legislation with links to local South African information as applicable.

Appendix D has been omitted from the extract mainly due to extensive revision, and imminent promulgation, of local legislation (OHS Act and Regulations) that would soon render this publication out-of-date if published as is.

This document is prepared as a reference to assist Sabita members in making informed decisions related to the use of solvents in bituminous products laboratories.

While every effort has been made to ensure the accuracy of the information contained in this publication, neither the CSIR nor Sabita, or any of its members past present or future, warrants its accuracy or will, regardless of its or their negligence, assume liability for any foreseeable or unforeseeable use made thereof, which liability is hereby excluded. Consequently, such use is at the recipient's own risk on the basis that any use by the recipient constitutes agreement to the terms of this disclaimer. The recipient is obliged to inform any subsequent recipient of such terms.

# CONTENTS

- 1. Introduction**
- 2. Solvent specific test methods**
  - 2.1. Determination of the binder content of a hot mix asphalt sample and/or recovery of the binder
  - 2.2. Determination of the solubility of bitumen
  - 2.3. The xylene/heptane spot test (AASHTO T102)
  - 2.4. Determination of the binder content of emulsions (ASTM D244)
  - 2.5. Determination of the softening point of binder (where the softening point is expected to exceed 85°C - ASTM D36)
  - 2.6. The use of high performance liquid chromatography, gas chromatography or thin layer chromatography to characterise binders
- 3. Cleaning and maintenance**
  - 3.1. New developments
  - 3.2. Solvent cleaning
- 4. Evaluating the cost-effectiveness of a process**
- 5. General approach to the safe handling of solvents**
- 6. Conclusions and recommendations**
- 7. References**
- 8. Appendix A** - General laboratory safety rules
- 9. Appendix B** - Recommendations for solvent storage
- 10. Appendix C** - The Management and interpretation of Material Safety Data Sheets (MSDS)

## 1. Introduction

There are many disadvantages associated with the use of solvents in a bituminous laboratory. Chiefly, they can be categorised as follows:

- **Health and Safety Hazards** - Solvents are potentially harmful to laboratory operators and represent significant health risks when the solvent liquid or vapours are absorbed through inhalation or through exposure of the skin. Most solvents also present a significant explosion or fire risk;
- **Environmental Hazards** - Solvents in general have a high carbon footprint, i.e. their manufacture and disposal may be energy intensive, resulting in a direct or indirect contribution to the carbon dioxide concentration in the atmosphere. In addition some chlorinated solvents, such as the commonly used trichloroethylene (TCE), have been shown to be linked to damage of the ozone layer, and their use has become increasingly restricted under the Montreal Protocol and the US Clean Air Act;
- **Cost Implications** - The costs of solvents have increased significantly in the past number of years, and the costs are generally related to the cost of crude oil. However, other factors such as supply and demand, stricter environmental and safety regulations, and more costly manufacturing processes (to reduce carbon emissions and process pollutants) also play important roles. Moreover, not only has the cost of procurement increased significantly, but the cost of disposal and/or recycling has also increased.

Generally, the use of solvents in a bituminous products laboratory is limited to reagents for specific test methods and to cleaning agents for glassware and equipment. However, samples under test may also contain solvents such as paraffin (eg cut-back bitumen).

The specific test methods where solvents are used as reagents are:

- The determination of the binder content of a hot mix asphalt sample;
- The recovery of the binder of a hot mix asphalt sample;
- The determination of the solubility of bitumen;
- The xylene/heptane spot test;

- The use of High Performance Liquid Chromatography (HPLC), Gas Chromatography (GC) or Thin Layer Chromatography (TLC) to characterise the chemical composition of bitumen;
- The Dean and Starke test for the determination of binder content of bitumen emulsions or water content of bituminous mixtures;
- The determination of the softening point of bitumen where the softening point is expected to exceed 85°C.

Best practice for any bituminous laboratory would be to eliminate the use of solvents altogether for all test methods, as well as for cleaning purposes. Advances in laboratory equipment over the last decade have made this a viable option for some test methods, such as the determination of binder content, as well as for certain cleaning requirements.

However, it is not always possible to eliminate the use of solvents altogether. Under these circumstances, the following approach is recommended:

- **The substitution of more hazardous solvents with less hazardous solvents** - A number of test method developments over the last decade have allowed for the validation of existing test methods by replacing unsafe solvents such as trichloroethylene (TCE) with "safer" solvent combinations such as toluene/ethanol (85/15) or blends of n-propylbromide (1-bormopropane). The word "safer" is placed in quotation marks as it is important for any operator in a laboratory to understand that no solvent is completely safe. Even for "safe" solvents, there will always be some laboratory operators who would be sensitised to such solvents, whether through a medical or genetic predisposition;
- **The substitution of more hazardous solvents with one of the new generation "non-toxic", environmentally friendly solvents** - These new generation solvents, based on blends of naturally occurring compounds (eg limonene blends of oils derived from lemon peels) are easier to dispose of and are generally biodegradable;
- **Minimising risk exposure** - Where it is not practical to replace a hazardous solvent, it is important, depending on the toxicity of the solvent as well as legislative requirements, that the required measures to minimise risk exposure for a laboratory operator be undertaken. Such risk management (even for less toxic solvents) would entail:

- A set of general laboratory safety rules to minimise the exposure of a laboratory operator to any solvent as well as minimising the risk of fire and explosion. These general laboratory rules are discussed in detail in Appendix A. These general safety rules include details regarding Personal Protective Equipment (PPE), safety training, laboratory signage, maintenance and validation of safety equipment such as fire extinguishers, fume cupboards and extractor fans, etc. The requirements for fume cupboards and air flow through the laboratory for the various toxic solvents are also listed. Specific storage procedures and recommendations are listed separately in Appendix B;
- Management and interpretation of Material and Safety Data Sheets (MSDS). The MSDS for all possible solvents to be found in bituminous products laboratories in southern Africa are listed in Appendix C. The interpretation of the various properties and their relation to toxicity and fire/explosion risk are discussed in detail. Tables ranking the various solvents with regard to risk are also listed in Appendix C;
- Compliance with the legislative requirements of South Africa in terms of the Occupation Health and Safety Act of 1993 (with Amendments), the General Safety Regulations of 1986 as per Government Gazette Notice R1031, as well as the Hazardous Chemical Substances Regulations of 1995 as per Government Gazette Notice R1179. The requirements for monitoring of laboratory personnel in terms of exposure to those toxic solvents defined in the legislation as well the monitoring of the health of those laboratory personnel exposed to such defined toxic solvents are also discussed in these documents.

Overall, when working with solvents in a bituminous products laboratory, a balance between the safety and environmental requirements, technical accuracy and correctness, and cost-effectiveness needs to be attained. A short chapter on the assessment of the cost-effectiveness of a solvent is also included in the report.

All non-solvent options (i.e. solvent elimination), as well as possible solvent substitutions (and their implications) are discussed at length for each test method (under the chapter heading **Solvent specific test methods**). A similar discussion is held for the chapter headed **Cleaning and maintenance**.

## 2. Solvent specific test methods

### 2.1. Determination of the binder content of a hot mix asphalt sample and/or recovery of the binder

The determination of binder content and the recovery of the binder are discussed under the same heading, since the recovery of the binder is just an extension of the determination of binder content in those cases where solvents are used. When considering recovery of the binder, the choice of solvent becomes more limited compared to the determination of binder content only. This is due to the fact that an additional requirement, namely the effect of the solvent on the recovered binder properties, comes into consideration.

#### 2.1.1 Historical developments

Extraction and recovery of bitumen have been practiced in some form or other since the early twentieth century. In 1903 Dow<sup>1</sup> extracted hot mix asphalt with carbon disulphide (CS<sub>2</sub>) and recovered the binder using simple distillation. Although many solvents and recovery methods were used and developed after this, none gained widespread acceptance until the use of benzene as a solvent, along with the development of the Abson method in the 1930s. However, once the toxicity of benzene was understood, it was replaced in the 1950s and 1960s by a range of mostly chlorinated solvents still widely used today. These are:

- Trichloroethylene (TCE);
- 1,1,1-trichloroethane (TCA);
- Methylene chloride (or dichloromethane (DCM));
- Chloroform (or trichloromethane (TCM));
- Carbon tetrachloride;
- Toluene (methylbenzene).

Until recently (the 1990s) binder content determination and binder recovery have been limited to these solvents. The most popular extraction and recovery methods that have been established and used in conjunction with these solvents are<sup>2</sup>:

**Extraction Methods:** ASTM D2172 (Method A) - A cold extraction process followed by centrifuge ASTM D2172 (Method B) - A hot reflux (Soxhlet) extraction process.

**Recovery Methods:** ASTM D1856 - The Abson distillation recovery at atmospheric pressure and using a carbon dioxide carrier gas ASTM D5404 - Distillation recovery under reduced pressure using the Rotavapor Apparatus.

### 2.1.2 Recent developments

The late 1990s and early 2000s have seen the development of new and safer solvent systems, an improvement in the effectiveness of existing solvent systems as well as the development of new extraction methods. It has also seen the development of the ignition oven for the determination of binder contents of HMA mixes - a revolutionary step towards solvent-free testing.

**2.1.2.1 Ignition oven:** The ignition oven employs the principle of a decrease in mass of hot mix asphalt, after combustion of the binder, to determine the binder content of that particular hot mix asphalt. The cost savings in terms of solvents and HSE considerations make this a most cost-effective method.

Research<sup>3,4</sup> has indicated that the optimum temperature for ignition testing for most aggregates is 538°C (1000°F). A number of correction factors may be required to improve the accuracy of ignition testing:

- Most aggregates experience a mass loss of up to 0.4%<sup>5</sup> during the ignition process. A correction factor for aggregate mass loss can be obtained by putting the original aggregate through the ignition process;
- In some exceptional circumstances it may be necessary to obtain a correction factor for the hot mix asphalt by comparing the ignition result with an especially manufactured standard sample of known binder content;

- A mass balance requires a temperature compensation correction factor, which can be determined using a blank. Most commercial ovens today have an automatic correction factor built into the apparatus;
- A correction factor for moisture within the hot mix asphalt can be obtained by determining the moisture content of a sample of hot mix asphalt.

The ignition test has been formalised in AASHTO T308. The method is cost- effective and preferable from an HSE point of view. The method also results in substantial time saving compared to the solvent extraction method. Proficiency testing conducted in the USA has found that ignition oven testing results in greater repeatability and accuracy than solvent extraction testing<sup>5</sup>. This applies to both the grading of the recovered aggregate as well as the binder content. Coefficients of variation of less than 2% are obtained for the proficiency testing.

Although the growing acceptance of the ignition oven has resulted in a marked decline for the need for solvent extraction methods when determining the binder content of HMA mixes, there are still circumstances where solvent extractions are necessary:

- In cases where aggregates degrade substantially during ignition oven testing and the aggregate after ignition testing cannot be used for a grading determination;
- In cases where HMA samples are removed from a site some time after construction and no samples are available to determine the appropriate correction factors;
- In circumstances where the binder of the hot mix asphalt needs to be recovered and tested.

**2.1.2.2 SHRP extraction and recovery method:** As part of the SUPERPAVE process, an enhanced solvent extraction and binder recovery method has been developed and designated as AASHTO T319. The method, developed by Burr *et al*<sup>6</sup> has been designed to minimise solvent hardening of the binder and to maximise the quantitative extraction of the binder. Extraction is accomplished by using a rotating cylinder, with interior flights to facilitate mixing of the HMA and solvent. A vacuum line with

an in-line woven polypropylene filter is used to remove the effluent, before it passes through a second finer filter system. Any remaining fines in the solution are removed by centrifuge prior to recovery of the binder.

This method results in improved repeatability of binder extractions. A coefficient of variation of 6% was obtained for recovered viscosities compared with a value of 30%<sup>6</sup> attained by the AASHTO materials reference laboratory proficiency sample programme.

**2.1.2.3 New solvent developments:** In the search for safer and more environmentally friendly solvents, a number of new solvents have been developed, or alternatively, such solvents have been introduced into the bituminous products industry from other sectors in the economy.

Solvent developments include:

- **D-limonene** - This is a hydrocarbon (cyclic terpene) obtained by distilling the oil from orange peels (a by-product from the orange juice processing industry). It is a natural product used in a variety of applications, including the cosmetics, food and pharmaceutical industry. Limited amounts can be disposed of via the water drainage system. Care should be taken when interpreting some of the MSDS from Appendix C for these new solvents. The MSDS for D-limonene, for example, classifies it as a major skin irritant (See Appendix C) and highly poisonous if ingested, yet no toxicity data is available. The classification is harsh for a product that is used in medicine, food and make-up! It is the author's opinion that recent MSDS tend to over-classify (overstate any possible threat, no matter how remote) in order to protect those authors of the MSDS from any future litigation. With a flash point of 50°C, D-limonene has a higher fire/explosion risk than the other new solvents that have entered the market (even a higher risk than diesel: fp:75°C).
- **Florasolvs solvent range** - These consist of a range of products ranging from ethoxylated macadamia nut oil to ethoxylated jojoba\* oil, which not only serve as solvents, but also as non-ionic surfactants (ie soaps/cleaning agents). They have high boiling points/flash points, resulting in lower fire/explosion-risk materials.

*\*Jojoba oil (pronounced "ho-HO-bah") is the liquid unsaturated wax produced from the seed of the jojoba plant (Simmondsia Chinensis), a shrub native to southern Arizona, southern California and northwestern Mexico.*

- **N-propyl bromide solvents (nPB):** Various studies<sup>7</sup> have shown that nPB is a safe solvent in comparison with chlorinated solvents. However, others maintain that the nPB appears to be safe because a lack of research into side-effects have resulted in an illusion of safety. (More recently, the Californian Department of Health Services has raised a health hazard alert regarding the use of nPB in the bituminous products industry. nPB is suspected of damaging the reproductive systems in male and females, but no definitive proof has been established).

nPB has been reported<sup>8</sup> to work well technically when comparing the properties of the recovered binder with those of the original binder. The use of nPB also leads to a significant reduction in extraction and recovery times (30-40% less). Furthermore, nPB has been shown to be amenable to recycling and reusing in the extraction/recovery process<sup>8</sup>. These advantages have resulted in a number of states in the USA adopting nPB as their solvent of choice for the determination of binder content as well as binder recovery.

Chlorinated solvents widely used in the industry have been supplied by three large companies using similar manufacturing processes, resulting in a relatively consistent product. Unfortunately, the same does not apply to nPB. Different suppliers (with different brand names) may differ in terms of:

- Purity;
- Moisture content;
- Non-volatile residue

A number of brand names are available on the market, including but not limited to:

- En Tron-AE (Reliance Speciality Products Inc.);
- Lenium;
- Leksol;

- Hypersolve;
- Ensolv.

The literature has not revealed any requirements/specifications for nPB in the bituminous products industry. It has been suggested that the ASTM D6368 standard specification for Vapour-Degreasing Grade normal-Propyl Bromide be used as basis for specification for the bituminous products industry<sup>9</sup>. However, ASTM D6368 does not address any limits on isopropyl bromide (iPB), an impurity believed to have the potential for asphalt-solvent interactions and a cause for reproducibility toxicity at low concentrations. It has been proposed to limit the iPB impurity to a maximum of 0,1 %, which is likely to be the limit set by the EPA as stated in its Advance Notice of Proposed Rulemaking for nPB.

The effects of different stabilisers used by the different nPB suppliers have not yet been determined. The literature indicates that at least one state, namely Minnesota has evaluated En Tron-AE with regards to its stabiliser, and has approved its exclusive use for their asphalt extraction applications within the Minnesota DoT.

A number of patented safety solvents characterised by low toxicity fire and explosion risk - These include, but are not limited to:

- Oil-Flo (water-soluble) from TITAN Laboratories;
- Bind-off from Chemical Solutions Inc.;
- X-it from Pantheon Chemical.

Although all of the aforementioned solvents have been used in the determination of binder content, only the nPBs have been used in the recovery of binder.

In recent years, ethanol blending with existing solvent systems has led to an improvement in the effectiveness of those solvent systems in extracting binder from hot mix asphalt, resulting in an overall improvement in the accuracy and repeatability of the

properties of the recovered binder. Generally, the addition of 15% ethanol<sup>10</sup> has been found to be most effective.

**2.1.3 Solvents and their technical performance pertaining to the determination of binder content and the determination of the recovered binder properties** - In order to replace an existing solvent with a safer, more environmentally friendly alternative, it is necessary to evaluate the technical performance of the alternative solvent. The technical performance of a particular solvent can be defined as a measure of the accuracy (a reflection how close the properties of the recovered binder compare with the properties of the binder prior to recovery) and repeatability of the measurements obtained on a recovered binder using that solvent or the accuracy and repeatability of the binder content determination by that solvent. The technical performance of any particular solvent is often determined by comparing the properties of a binder, recovered with that solvent, to the properties of the same binder recovered by TCE (considered by some to be an asphalt industry standard in the USA).

**2.1.3.1 Variations in technical performance:** The technical performance of any particular solvent may vary according to:

- The type and age of the binder - some solvents may display an excellent technical performance with regards to one type of binder (e.g. aromatic high molecular weight bitumen) but poor technical performance with another type of binder (e.g. a waxy-type bitumen). The technical performance of a solvent towards a particular binder may change as the binder ages.
- The type of aggregate - Some absorptive limestone aggregates can affect the technical performance of a particular solvent.
- The specific property defined by the measurement on the recovered binder - it could well be, for example, that a specific solvent such as a commercial n-propyl bromide blend, may produce accurate, repeatable softening point measurements for specific binder/aggregate systems, but may not produce acceptable stiffness measurements, using a dynamic shear rheometer, for the same system.
- The extraction and recovery method used - Researchers<sup>6</sup> have, for example, established that the repeatability for the ASTM D1856 (Abson distillation recovery at atmospheric pressure) is significantly

superior to ASTM D5404 (Distillation recovery under reduced pressure using the Rotavapor Apparatus).

**2.1.3.2 The effect of coefficient of variation on determination of technical performance:** One major impediment to establishing the technical performance of a particular solvent is the generally poor repeatability of many of the tests performed on recovered binders. The coefficient of variation (standard deviation/mean x 100) of a particular test performed on recovered binders does not only reflect the inherent variation of that particular test method/test equipment combination, but also includes the variation inherent in the particular binder extraction and recovery method that was used. A coefficient of variation of 25% implies that the standard deviation equates to a value of 25% of the mean and for a normal distribution. This implies that 95% of the experimental values are distributed over a range within 50% of the mean ( $2\delta$ ). Such high coefficients of variation make it very difficult to statistically differentiate between results obtained on recovered binders using different solvents and extraction/recovery methods, especially when using statistical methods employing 95% confidence levels. It is, therefore, difficult to establish the technical performance of a solvent (by means of comparison) when evaluating binder properties that have high coefficients of variation.

RILEM Technical Committee TC56 has carried out a range of inter-laboratory testing<sup>11</sup> across Europe during 1986, using various extraction methods/solvents and a specified RILEM recovery procedure involving a Rotavapor at specified reduced pressure and temperature. Their results for using DCM as solvent can be summarised as follows:

**Table 1. Coefficients of variation**

Method	Coefficient of variation for dichloromethane		
	For binder prior to extraction	For recovered binder after extraction and recovery	General proficiency testing in Europe until that time for non-recovered binder
Penetration	5,4%	15%	
Softening point	2,9%	3,6%	
Viscosity	19%	30%	24% <sup>15</sup>

By combining the results for different solvents used in this exercise, the various coefficients of variation increase significantly.

AASHTO laboratory proficiency testing scheme has reported inter-laboratory coefficients of variation ranging from 25 - 42% from 1986 to 1991 for recovered viscosities<sup>6,12</sup> (an improvement on earlier years).

### 2.1.3.3 Experimental errors contributing to poor technical performance as well as poor coefficients of variation:

Poor technical performance (as well as poor coefficients of variation) may be attributed to errors that stem from four main areas:

- The hardening effect of the solvent on the recovered binder;
- Incomplete removal of the solvent from the recovered binder;
- Incomplete removal of all the binder from the aggregate;
- Incomplete separation of aggregate fines from the binder .

#### **The hardening effect of the solvent on the recovered binder:**

Binder hardening is a factor that affects the technical performance of all solvents<sup>2, 13</sup>. It can be defined as the process whereby a binder dissolved in a solvent exhibits stiffer properties after recovery from that solvent compared to its properties before it was dissolved in that solvent. Burr *et al*<sup>2</sup> have studied chemical changes within bitumen during binder hardening using a combination of gel permeation chromatography and infra-red

spectrometry. They established that two types of chemical processes occur during hardening, one being the "oxidative" process associated with normal ageing of bitumen, and the other being an unfamiliar process associated with an increase in molecular weight but not polarity. The "oxidative" ageing process can be suppressed by a reduction in light and a reduction in the partial pressure of oxygen.

Binder hardening can result in an increase of 5 - 300% in the properties depicting the stiffness of a recovered binder, depending on the conditions of extraction and recovery, the solvent used, the binder-aggregate system as well as the specific property being measured to depict binder stiffness. For example, properties such as rotational viscosity values and complex shear values determined by a dynamic shear rheometer may show much larger increases than properties such as Ring and Ball softening point or penetration.

Factors that affect the extent of hardening include:

- Solvent type - Researchers<sup>2, 14, 16</sup> have found that the hardening effect for commonly used solvents are:

carbon tetrachloride >> other chlorinated solvents > toluene > benzene.

The addition of ethanol to benzene to improve its solvency power results in an increase in the hardening effect of benzene, but not to such an extent that it exceeds the hardening effect of the chlorinated solvents.

- Time - A longer contact time between the binder and the solvent results in a greater hardening effect<sup>1, 2, 17</sup>. Extraction method ASTM D2172 (Method B) - hot reflux extraction - employs a longer time than ASTM D2172 (Method A) - cold centrifuge extraction. RILEM Technical Committee TC 5611 has recommended that recoveries be completed within 18 hours after extraction. ASTM D 1856 (Absorbent distillation recovery at atmospheric pressure), however, requires that the recovery process, (from the start of the extraction to the end of the recovery) must be completed within 8 hours;

- Temperature - Although binder hardening occurs at room temperature<sup>2, 14</sup>, a higher temperature during contact between the binder and the solvent results in a greater hardening effect<sup>2, 10, 17</sup>. Extraction method ASTM D2172 (Method B) employs a higher temperature than ASTM D2172 (Method A);
- Light - The absence of light during contact between the binder and the solvent reduces the hardening effect<sup>2, 18</sup>. RILEM Technical Committee TC 5611 has recommended that extracted binder solution be kept in the dark until the recovery is completed;
- Oxygen - A lower partial pressure of oxygen during contact between the binder and the solvent reduces the hardening effect<sup>2</sup>;
- Different binder-aggregate types exhibit different extents of binder hardening for the same extraction and recovery conditions<sup>2</sup>.

Conclusions regarding the effects of binder hardening imply that

- The lowest possible temperature should be employed during the extraction-recovery phase, i.e. the hot extraction method, ASTM D2172 (Method B), and the high temperature Abson recovery distillation, ASTM D1856, would be disadvantageous from a binder hardening perspective;
- The time of contact between solvent and binder should be limited to the shortest possible time that allows for effective extraction of the binder from the hot mix asphalt.

### **Incomplete removal of the solvent from the recovered binder**

Residual solvent remaining in the recovered binder after solvent recovery results in a reduced stiffness for the recovered binder.

The presence and concentration of residual solvent in the binder can be monitored using:

- Infrared spectroscopy<sup>9, 19</sup>;
- Gas chromatography<sup>20</sup>;
- High performance liquid chromatography.

Some researchers<sup>14, 21</sup> have shown that the Abson distillation (ASTM D1856) results in greater quantities of residual solvent present in the recovered binder compared to the Rotavapor

method (ASTM D5404). Other researchers<sup>22</sup>, however, using different solvent/binder systems, have found no difference regarding residual solvents between the two methods. The initial perception has resulted in the Rotavapor method becoming the method of choice since the 1970s, regardless of the fact that this method has also been shown to have lower repeatability. (The ease of the method and the lower recovery temperature have also played a role in the popularity of this method.)

### **Incomplete removal of all the binder from the aggregate**

A number of researchers<sup>9, 10, 21, 23</sup> have shown that the binder is never completely removed from the aggregate, regardless of the solvent used for extraction.

The solvent most widely recognised as having the highest solvency power (especially for aged binder) is pyridine<sup>10</sup>, which is highly toxic. An estimate of the binder retained by the aggregate during extraction by any specific solvent can be ascertained by comparing the results obtained for that solvent with results obtained for pyridine. Incomplete extraction causes the binder content of hot mix asphalt to be underestimated by 0,1 to 1,0%<sup>2, 21, 23</sup>.

Extraction method ASTM D2172 (Method B) - hot reflux extraction - has been associated with less complete removal of the binder from the aggregate compared to ASTM D2172 (Method A) - cold centrifuge extraction.

The binder retained by the aggregate (after extraction) can either be highly oxidised (aged) resulting in the polar fractions being strongly associated with the aggregate<sup>10</sup> (adsorbed), or the retained binder can be of low viscosity, having been absorbed by a porous aggregate<sup>23</sup>. Depending on the nature of the retained binder, incorporation of this fraction into the recovered binder can have a significant effect on the recovered binder properties<sup>10, 23</sup>. It appears that not much work has been done to determine the effects of adding strongly ad/absorbed material back to the recovered binder. However, there are some<sup>23</sup> who argue that the ad/absorbed binder remaining after extraction should not be regarded as part of the binder because of its close association with

the aggregate, but should rather be regarded as an integral part of the aggregate in terms of function and effect.

Innovations<sup>10</sup> discussed earlier include the addition of alcohols, especially ethanol (EtOH), to existing solvents to improve binder extraction. Cipione *et al*<sup>10</sup> have shown that 15% ethanol is the optimum level for improving solvency towards the fraction adsorbed to the aggregate. TCE/EtOH was found to be equivalent to pyridine with regards to its solvency power. Toluene/EtOH was also evaluated and found to have superior performance compared to toluene alone, but inferior performance compared to TCE/EtOH. However, considerable improvement can be achieved by increasing the volume of Toluene/EtOH by 50% compared to the volume of TCE/EtOH for extraction. Safety and legislative considerations make Toluene/EtOH a more attractive consideration than TCE/EtOH.

#### **Incomplete separation of aggregate fines from the binder:**

Test methods address this problem in various ways:

- ASTM D 1856 (Absorbent distillation recovery at atmospheric pressure) specifies centrifuging the extracted binder solution prior to distillation;
- California Test 362 (California DOT) specifies the addition of Celite (diatomaceous earth) to the extracted binder solution prior to distillation in order to bind the fines;
- AASHTO T319 (developed as part of the SUPERPAVE process) specifies two filtration steps of the extracted binder solution prior to centrifuge and distillation.

One way of determining the extent of fines present in the recovered binder, is to do an ash content analysis on the recovered binder.

#### **2.1.3.4 Using the physical properties of solvents to predict their technical performance:** Some of the physical properties of a solvent, obtained from the MSDS, that may be used to predict its technical performance include:

- Density - In general, a solvent with a higher density would tend to retain more fines, which would contaminate the recovered binder, resulting in stiffer properties being attained;
- Boiling point - A solvent with a higher boiling point tends to result in the less efficient removal of the solvent from the binder during the recovery process, resulting in softer properties being measured.

**2.1.4 Experimental case studies:** Peterson *et al*<sup>21</sup> studied the effects of solvent on recovered binder properties using a modified AASHTO T319/Rotavapor (ASTM D5405) as extraction/recovery process. They could find no differences between the technical performances for TCE, EnSolv and toluene/ethanol using  $G^*/\text{Sin}\delta$  as the defining parameter. The intra-laboratory coefficient of variation for  $G^*/\text{Sin}\delta$  was 26%. Such a relatively high value would limit the validity of any conclusions drawn from the study.

Collins-Garcia *et al*<sup>8, 24</sup> studied the effects of solvent on recovered binder properties using a modified Reflux (ASTM D2172 (Method B))/Rotavapor (ASTM D5405) as extraction/recovery process. They could find no differences between the technical performances for TCE and EnSolv using Brookfield viscosity at 60°C and penetration as the defining parameters. Stroup-Gardiner *et al*<sup>9</sup> studied the effects of solvent on recovered binder properties using the centrifuge method (ASTM D2172 (Method A))/Rotavapor (ASTM D5405) as extraction/recovery process. They used six combinations of different grades of binders (including a SBS-modified binder) and aggregates. They could find no differences between the technical performances for TCE and four nPBs (Lenium, Leksol, Hypersolve, Ensolv) using  $G^*/\text{Sin}\delta$  and BBR Stiffness as the defining parameters. When the Hypersolve solvent was used, the SBS polymer separated from the binder in solution. Intra-laboratory coefficient of variation for  $G^*/\text{Sin}\delta$  varied from 25% to 65%, severely compromising the validity of conclusions drawn from the study.

Van Assen<sup>20</sup> studied the effects of solvent on recovered binder properties using the centrifuge method (ASTM D2172 (Method A))/Abson distillation recovery (ASTM D1856). Results indicated that for South African binders and aggregates, good technical performance was obtained when using benzene and toluene as solvents. However, results for very aged asphalt

tended to display poorer repeatability. Chlorinated solvents displayed poorer technical performance.

## **2.2. The determination of the solubility of bitumen**

The solubility of bitumen is defined by a specific solvent as determined by a particular national/state standard or specification. Depending on which particular specification or standard is being followed, the solvent cannot be changed until that particular specification or standard is amended. Nevertheless, some researchers<sup>8</sup> have successfully replaced various solvents specified in ASTM D2042 with nPB. Although the results for a limited number of binder-aggregate systems show some statistically significant difference between the original solvents and the nPB, these differences are usually small enough not to affect compliance with a specification requirement of minimum solubility of 99,5% or even 99,9%.

## **2.3. The xylene/heptane spot test (AASHTO T102)**

No evidence of attempts at solvent replacement has been found in the literature. However, the relatively low toxicity of the solvents (xylene, heptane) and the small volumes of solvent used in this test, make the task of finding solvent replacements a low priority. In any event, a test such as this is an international test method, and any changes to the method would necessarily be driven internationally. Safety procedures, as laid down in Appendices A, B and C should be adhered to.

## **2.4. The determination of the binder content of emulsions (ASTM D244)**

No evidence for attempts at solvent replacement has been found in the literature. However, the relative toxicity of the solvents (xylene, toluene) is low compared to chlorinated solvents and the associated risks are small, especially when the required safety procedures as laid down in Appendices A, B and C are followed.

## **2.5. The determination of the softening point of binder (where the softening point is expected to exceed 85°C - ASTM D36)**

No evidence for attempts at solvent replacement has been found in the literature. The relative toxicity of the solvent (glycerine) is low and the associated risks are small, especially when the required safety procedures are followed as laid down in Appendices A, B and C. Also, this is an international test method, and any changes to the method would necessarily be driven internationally.

## **2.6. The use of high performance liquid chromatography, gas chromatography or thin layer chromatography to characterise binders**

Solvents for such procedures can vary widely from laboratory to laboratory, depending on the solvent cost/availability, the type of equipment and the nature of the binder.

## 3. Cleaning and maintenance

### 3.1. New developments

Just as the ignition oven (See 2.1.2.1) used for the determination of binder content of hot mix asphalt has reduced the need for solvents in the industry, so the development of high temperature oven cleaning of laboratory glassware and equipment can lead to decreased dependency on solvents. This would lead to decreased cost of laboratory operation and decreased exposure of laboratory workers to the hazards of solvents. An example of such ovens is the PYRO-CLEAN series of ovens from M&L Testing Equipment (Inc).

### 3.2. Solvent cleaning:

Typical solvents used for cleaning in South Africa include:

- Paraffin;
- Diesel;
- Toluene;
- Xylene;
- Hexane.

These solvents vary in their toxicity and risk of fire/explosion (See Appendix C), and if a laboratory should use one of them they should adopt the necessary precautionary procedures as outlined in Appendix A, B and C. The alternative "safety solvents" adopted by the industry as discussed in 2.1.2.3, have been adopted by many laboratories internationally for cleaning purposes. As previously mentioned these include:

- D-limonene;
- Florasolvs solvents;
- N-propyl bromide solvents (nPBs);
- Oil-Flo;
- Bind-off;
- X-it.

## 4. Evaluating the cost-effectiveness of a process

Many traditional cost analyses consider only capital, operational and maintenance costs associated with a process. Costs such as waste disposal, solvent reclamation, electrical usage, regulatory compliance, worker compensation, etc. are often lumped into general overheads and are not allocated to specific processes.

Behrens *et al*<sup>25</sup> carried out traditional cost analyses for various solvent based processes involving the determination of the binder content of hot mix asphalt, as well as for the ignition oven-based process. They found that the traditional analyses showed that the ignition oven process was only marginally more economical than the solvent-based processes.

Behrens *et al*<sup>25</sup> repeated the procedure by using a total cost analysis approach (TCA), which they developed by combining traditional costs with hidden costs. Some of the hidden costs included:

- Compliance with regulatory requirements (record keeping, testing of exposure values);
- Cost of safety equipment;
- Reporting of results;
- Training of new personnel;
- Monitoring of processes;
- Recycling of solvents;
- Insurance/financial assurance;
- Accidental release/spillage costs;
- Long term liability with regards to exposure of personnel to solvent fumes, possible spillage and environmental damage (legal costs, fines, property damage, productivity of the workforce).

As a result of considerable uncertainty about the true value of some of the hidden costs, fuzzy set theory was used to circumvent the problem. The final assessment showed that the ignition oven process was now by far the most cost-effective method due to its superior health, safety and environmental aspects. It is the authors' opinion that during this exercise, insufficient stress was placed on the fact that the ignition oven process requires less time compared to the solvent process, which allows for a potential increase in the productivity of the workforce.

## 5. General approach to the safe handling of solvents

As mentioned in the introduction, the general principles in our approach to solvents in laboratories should be:

- **Eliminate** - a solvent if it is practical to do so (e.g. ignition oven);
- **Replace** - dangerous/environmentally unfriendly solvents with safer/more environmentally friendly solvents. Solvents can be evaluated by means of their MSDS. Appendix C lists the MSDS for commonly used solvents and explains how the data on the MSDS should be interpreted. A laboratory operator may not handle a solvent in a laboratory without the operator having familiarised him/herself with the MSDS for that solvent;
- **Safe handling** - where it is not practical to replace a hazardous solvent, it is important, depending on the toxicity of the solvent, as well as legislative requirements, that the measures required to minimise exposure to risk be undertaken. Such risk management (even for less toxic solvents) would entail:
  - Ensure the general laboratory safety rules in Appendix A are obeyed;
  - Ensure that the specified storage procedures in Appendix B are followed;
  - Before working with a solvent, familiarise yourself with its MSDS with regards to its fire/explosion risk, health risks and procedures to be followed in case of spillage;
  - Ensure compliance with the legislative requirements of South Africa in terms of the Occupation Health and Safety Act of 1993 (with Amendments), the General Safety Regulations of 1986 as per Government Gazette Notice R1031, as well as the Hazardous Chemical Substances Regulations of 1995 as per Government Gazette Notice R1179.

Overall, when working with solvents in a bituminous products laboratory, a balance between the safety and environmental requirements, technical accuracy and correctness, and cost-effectiveness needs to be attained.

## 6. Conclusions and recommendations

The ignition oven has proven to be a safe, cost-effective, environmentally friendly and time-saving method for binder content determinations of hot mix asphalt. The ignition oven also displays a higher degree of accuracy and repeatability compared to traditional solvent-based methods. The author strongly recommends that the ignition oven test method becomes the specified standard test method for routine quality assurance testing in South Africa.

In circumstances where it is required that the binder be recovered from the hot mix asphalt, or where the ignition oven would not be suitable for binder content determination, the use of solvent would still be required. In such circumstances the use of benzene and chlorinated solvents are no longer acceptable and should be phased out in South Africa. This recommendation is justifiable in terms of:

- Health and safety considerations (benzene and the chlorinated solvents are all carcinogens - Appendix C);
- Environmental considerations;
- International legislative requirements (Montreal Protocol).

Any number of solvents can be proposed as replacement for those currently used nationally, but such a replacement/s must conform to the HSE/legislative requirements of South Africa as well as the requirements for technical performance as defined in chapter 2.1.3.

It has been established through the AASHTO laboratory proficiency testing scheme, and other international bodies, that test results obtained from binders recovered from hot mix asphalt, exhibit poor repeatability (i.e. the results have high coefficients of variation). This poor repeatability has a direct effect on the reliability of the results obtained. In order to limit the coefficient of variation, it is recommended that one single extraction procedure be prescribed for South Africa. The authors propose that the new SUPERPAVE-developed method, as set forth in AASHTO T319, be considered. It would have the advantage of being an internationally-accepted test method. Alternatively, from a more cost-effective point of view, the current extraction method as described in TMH 1, Method C7b may be amended to include such improvements as decreased lighting

through the use of closed containers, decreased partial oxygen pressure, etc.

Furthermore, for enhanced repeatability, only one specific solvent should be prescribed in South Africa. It is the authors' recommendation that toluene/ethanol should be considered for South African conditions, based on:

- The acceptable technical performance of this solvent combination as seen in the literature review (Chapter 2.1.4);
- The low health and safety risks associated with these solvents (Appendix C).

Alternatively, nPB, may be considered as the national standard solvent based on the fact that, internationally, the trend seems to be in this direction. However, the more recent health alert (Appendix A) is of concern.

It is also recommended that one single recovery/distillation procedure be prescribed for South Africa. Possible choices include the SUPERPAVE-developed method as described in AASHTO T319, or alternatively, ASTM D5404 (rotary evaporator method), but amended to include a two-flask system for lower binder hardening.

Based on international experience as reported in the literature<sup>9</sup>, it is important to note that should a specific solvent be chosen as a national standard for the recovery of binders, it would be necessary to subject that solvent to a full investigative procedure, in order to verify the technical performance of that solvent. The investigative procedure should include:

- The recovery of a number of binders of known properties from different refineries (prior to mixing), as well as a number of polymer-modified binders of known properties, using the proposed solvent in conjunction with reference solvents such as benzene and TCE. This would establish the technical performance of the proposed solvent in the absence of any aggregate effects. It is recommended that un-aged binder as well as long-term aged binder be used to determine the effects of binder ageing on the recovery process;
- A repeat of the process above, but using relatively older pavement samples encompassing at least six of the more common aggregate types and at least one aggregate predicted to give problems (e.g.

absorptive limestone). In this way aggregate effects can be established. For comparisons, pyridine can be used to establish the "true" binder content of the mixes;

- The identification of those test values obtained from the recovered binders that would best reflect the performance characteristics of the binder prior to recovery (performance characteristics such as stiffness, elasticity, adhesion/cohesion). Internationally there is a tendency to use the test values obtained from the dynamic shear rheometer to reflect the stiffness of the binder prior to recovery. Historically, the coefficients of variation for these test values have been high, and it may be that some other test value, with a lower coefficient of variation, would be more useful as the primary indicator for defining the properties of the recovered binder;
- The determination of the effect of background lighting and time constraints at the various stages of extraction/recovery.

Irrespective of the processes that would be followed, it is vital that sufficient experimental repetitions be carried out to establish the statistical repeatability with confidence. The repeatability would have a direct effect on the quality of the conclusions drawn from the work.

In conclusion, the authors believe that the current *status quo* in South Africa with regards to the determination of binder content, as well as to the recovery of binders cannot be maintained. South Africa is trailing Europe and the USA in the formulation of a cohesive national binder recovery philosophy, and the necessary investigative data is inadequate to show that our current test methods and practices:

- have been validated;
- are acceptable with regards to the coefficient of variation; and
- involve properties chosen to characterise the binder that reflect the binder performance correctly.

In the absence of such evidence, published journal articles from South Africa that involve recovered binder properties may yield findings and conclusions based on data that has not been statistically validated.

## 7. References

1. **Abson, G, 1933:** *Method and apparatus for the recovery of asphalt.* Proc. ASTM II, pp 704-714.
2. **Burr, BL, Davison, RR, Jemison, HB, Glover, CJ and Bullin, JA, 1991:** *Asphalt hardening in extraction solvents.* Transportation Research Record 1323, pp 70-76.
3. **Murphy, NE, 1994.** *Asphalt content determination by the ignition methods.* M.S. thesis, Auburn University, Alabama, USA.
4. **Brown, ER, Murphy, N and Mager, S, 1995:** *Historical development of asphalt content determination by the ignition method.* Journal of Asphalt Paving Technologists, Vol64.
5. **Brown, ER and Mager, S, 1996:** *Round-robin study of asphalt-concrete content by ignition.* Transportation Research Record 1543, pp 132-138.
6. **Burr, BL, HB, Glover, CJ, Davison, RR, and Bullin, JA, 1993:** *New apparatus and procedure for the extraction and recovery of asphalt binder from pavement mixtures.* Transportation Research Record 1391, pp 20-29.
7. **Clark, L, 1998:** *Ensolve vapour degreasing and cleaning solvent.* EnviroTech International, Melrose Park, Ill.
8. **Collins-Garcia,H, Tia, M, Roque, R and Choubane, B, 2000:** *Alternative solvent for reducing health and environmental hazards in extracting asphalt.* Transportation Research Record 1712, pp 79-85.
9. **Stroup-Gardiner, M and Nelson, JW, 2000:** *Use of normal propyl bromide solvents for extraction and recovery of asphalt cements.* NCAT Report 00-06, National Centre for Asphalt Technology, Auburn University, Al.
10. **Cipione, CA, Davison, RR, Burr, HB, Glover, CJ and Bullin, JA, 1991:** *Evaluation of solvents for extraction of residual asphalt from aggregates.* Transportation Research Record 1323, pp 47-23.
11. **Huet, J, 1988, Rilem Technical Committees, TC56-MHM:** *Hydrocarbon materials, recovery method with rotary evaporator of the soluble binder from bituminous mixes: interlaboratory test comparisons and test procedure recommendation.* Materials and Structures, Vol 21, No.2, pp 151-160.
12. **AASHTO:** *Materials reference laboratory report for bituminous concrete proficiency samples:* Reports from 1987, 1988, 1989, National Bureau of Standards, Gaithersburg, Md.

13. **Peterson, GD, Davison, RR, Glover, CJ and Bullin, JA, 1994:** *Effect of composition on asphalt recycling agent performance.* Transportation Research Record 1436, pp 38-46.
14. **Abson, G and Burton, C, 1960:** *The use of chlorinated solvents in the Abson recovery process.* Proc., Association of Asphalt Paving Technologists, 29, pp 246-252.
15. **Isacsson, U, 1983:** *Comparative analysis of the viscosity of bitumen.* Proc. Third International RILEM Symposium on Testing of Hydrocarbon Binders and Materials, Vol I, pp 105-118.
16. **Abu-Elgehit, MA, Hancock, CK and Traxler, RN, 1969:** *Effect of selected solvents on the viscosities and oxygen contents of asphalts.* Analytical Chemistry, 41.
17. **Noureldin, MS and Manke, PG, 1978:** *Study of transverse cracking in flexible highway pavements.* Transportation Research Record 695, pp 28-32.
18. **Bussow, C, 1936:** *Notes on a method of recovering bitumen from paving materials.* Proc. Association of Asphalt Paving Technologists, Vol 7, pp 160-164.
19. **Farrar, MJ, Harnsberger, PM, Thomas, KP, Wisner, W, 2006:** *Evaluation of oxidation in asphalt pavement test sections after four years of service.* Proc. International Conference on Perpetual Pavement.
20. **Van Assen, E, 1997:** *Assessment of binder extraction methodologies.* Contract Report CR-97/092, Transportek, CSIR, South Africa.
21. **Peterson, RL, Soleymani, HR, Anderson, RM and McDaniel, RS, 1999:** *Recovery and testing of RAP binders from recycled asphalt pavement.* Research Paper, the Asphalt Institute.
22. **Burr, BL, Davison, HB, Glover, CJ and Bullin, JA, 1990:** *Solvent removal from asphalt.* Transportation Research Record 1269, pp 1-8.
23. **Stroup-Gardiner, M, Newcomb D and Savage, D, 1994:** *Defining specification limits with respect to testing variability.* Association of Asphalt Paving Technologists, Vol 63.
24. **Collins-Garcia, H, Mang, T, Roque, R and Choubane, B, 2000:** *An evaluation of alternative solvent for reducing health and environmental hazards.* Proc. Annual Transportation Research Board Meeting, Washington DC.
25. **Behrens, ML, Dvorak, BI and Woldt, WE, 2000:** *Implications of hidden costs: Comparison of bitumen testing procedures.* Environmental Technology, Vol 21, pp 243-255.

## Appendix A - General laboratory safety rules

### 1. Introduction

The original intention was to limit the scope of Appendix A to the use of solvents only. However, it was later decided that all aspects of safety in a laboratory should be included as a limited edition might leave the rules open to misinterpretation and expose the authors to liability.

Many of the guidelines/rules set out in this Appendix are further circumscribed in statutory requirements.

The first step in establishing laboratory safety rules is to conduct a risk assessment. Thereafter the rules are established based on the risks identified from the hazards present in the laboratory. The risk assessment should cover the following areas:

- Hazard communication;
- Chemical storage;
- Personal Protective Equipment (PPE);
- Handling and use of chemicals;
- Fire and gas safety;
- Hazardous waste management;
- Ventilation and fume hoods;
- Physical hazards, ergonomics, safe conduct and housekeeping;
- Equipment safety;
- Emergency procedures.

### 2. Hazard communication

It is important that all laboratory workers and visitors have access to and are exposed to all information on hazardous materials. This information is provided by means of product labels, MSDS as discussed in Appendix C, warning signs as well as training by appropriate professionals so that workers are able to interpret hazard warning information. HSE/HSEQ policy documents must contain an approved list of acceptable laboratory abbreviations. This permits laboratories to use abbreviations on labels etc. However, a list of abbreviations must be posted in the laboratory, preferably

in a location close to where the products are stored; and a list must be included with the MSDS file. Hazard communication occurs via:

- **Labelling** - Labels identify as well as alert people to the dangers of the product and basic safety precautions when handling the product. A label may be a mark, sign, stamp, device, sticker, ticket, tag, or wrapper and must be attached to, imprinted, stencilled or embossed on the container of the controlled product.

There are two types of labels: supplier labels and workplace labels.

- **Supplier labels:** Suppliers are responsible for making sure their products are clearly labelled. A supplier label generally contains the following information:
  - .. Product identifier (name of product);
  - .. Supplier identifier (name of company that sold it);
  - .. Impurities, other components;
  - .. Flash point (where applicable);
  - .. Storage colour code;
  - .. Hazard warning/rating/class;
  - .. Risk descriptor (danger, warning, caution, etc);
  - .. Risk descriptive statement;
  - .. Handling advice (how to work with the product safely);
  - .. First aid measures (what to do in an emergency);
  - .. Reference to the MSDS.

Supplier labels may also contain additional information such as:

- .. Identification numbers (i.e. CAS number, UN number and barcodes);
- .. Recommended PPE;
- .. Recommended fire extinguisher class.

These supplier labels must be provided in the official language of the users.

**Workplace labels:**

Appropriate labels must be present when:

- .. controlled products are produced, manufactured or prepared (e.g., stock solutions) in the laboratory;
- .. the controlled product is transferred from the original container into another container; and
- .. the original supplier label becomes illegible or damaged or when it is removed.

The authors also recommend that a workplace label contain the following information:

- .. Product identifier (product name) - including the full name of the product/solution as it appears on the MSDS as well as its purity and concentration;
- .. Information for the safe handling of the product and reference to the MSDS;
- .. Date of transfer/manufacture and expiry date.

• **Laboratory sample labels:**

Laboratory samples are samples intended solely to be tested in a laboratory. These would include recovered binders and separated binder components. The requirements for laboratory samples that are intended to be used in a laboratory immediately and solely by that person who prepared them include:

- the samples must be clearly identified;
- a description of sample's contents must be readily available (e.g. noted in a laboratory book or similar electronic system); and
- MSDS for the sample must be readily available.

Laboratory samples that must be transported outside of a laboratory (e.g. sent elsewhere for analysis), including within the institution, must have a label affixed to them containing the following information:

- product identifier (product name);
- owner's name (name of Principal Investigator who prepared the sample);
- laboratory number and building;
- emergency telephone number.

When samples are greater than 10kg, the label affixed to the container must meet the requirements of a supplier label. Laboratory samples should not be sent via internal mail.

- **Material Safety Data Sheets** - See Appendix C (**The management and interpretation of material and safety data sheets** - for binder and asphalt laboratories);
- **Education and training** - Training and education provides more detailed instruction on the specific procedures necessary to carry out work safely. Training can be divided into two parts: general training and job-specific training:
  - General training:** This is basic training that an organisation is required to conduct so that all personnel whose work function may result in health, safety or environmental incidents undergo appropriate training. This training should provide instruction on the classification of products; include risks and precautions, (hazard register) and the content, purpose and interpretation of information found on labels and in MSDS;
  - Job-specific training:** This refers to training in the procedures and test methods employed by a particular laboratory, and would include training on the safe handling and storage of products specific to that laboratory (including spill and leak training, waste disposal and basic first aid instructions). Job-specific training is usually the responsibility of the laboratory supervisor. Training requirements shall be established, taking the following into account:
    - .. New employees during their induction period in the organisation;
    - .. New employees during their job-specific training;
    - .. Existing employees when there is a change in their duties;
    - .. When new equipment or materials are introduced (change management procedure);

- When emergency procedures are revised;
- When a drill indicates a need for improvement.

### 3. Chemical storage

See Appendix B (**Recommendations for solvent storage**).

### 4. Personal Protective Equipment (PPE)

A wide variety of PPE is available which, with proper use and care, will minimise or eliminate exposure to hazardous materials. Every laboratory worker should be familiar with the location, types, and uses of the PPE available for the job. The laboratory supervisor should have sufficient quantities of equipment to protect everyone who will work with hazardous materials. All laboratory workers should at all times wear the appropriate PPE such as eye and face protection, protective clothing, hand protection, foot protection and respirators where circumstances require their use. It should be noted that PPE should only be used as a control measure when other measures are inappropriate or are inadequate by themselves. However, there is growing evidence that the levels of protection offered by PPE, as indicated by laboratory-based tests, may not be achieved in real use situations. Additionally, studies of workplace protection suggest that the spread of contaminants inside protective clothing, including gloves, is commonplace and significant.

#### 4.1 Eye and face protection

Eye and/or facial protection should be required for all personnel (staff and visitors) at:

- All areas where hazardous materials, or substances of an unknown nature, are stored, used or handled;
- All areas where the possibility of splash, flying objects, moving particles and/or rupture exist;
- All areas where there are other eye hazards (e.g. UV or laser light). It is recommended that:
  - goggles/safety glasses and face shields be worn when handling, pouring or transferring any chemical in order to avoid eye damage;

- eye wash bottles and safety showers be installed where corrosive and toxic chemicals are being handled and where there is a risk of exposure;
- contact lenses be discouraged strongly since gases and vapours can be concentrated under the lens and cause permanent eye damage. In the event of a splash, the involuntary eyelid spasm makes removal of the lens nearly impossible and the eye could not be irrigated satisfactorily.
- Protective eyewear for employees who wear prescription eyeglasses must be one of the following:
  - eyeglasses with protective lenses that also provide optical correction;
  - goggles to be worn over glasses;
  - a face shield to fit over eyeglasses.

Instructions for selection and use of protective eyewear are as follows:

- **Light-to-moderate work:** certified safety glasses with side shields;
- **Work with significant risk of splash of chemicals, or projectiles:** goggles;
- **Work with significant risk of splash on face, or possible explosion:** full face shield, plus goggles;
- If safety glasses with correction lenses are needed, an optometrist or ophthalmologist should be consulted.

## 4.2 Protective clothing

All laboratory workers should wear fully buttoned laboratory coats or appropriate protective clothing, such as aprons and coveralls, at all experimental areas where hazardous materials are handled. Instructions for selection and use of protective laboratory clothing are as follows:

- select knee-length laboratory coats with button or snap closures;
- wear a solid-front laboratory coat or gown with back closures and knitted cuffs when working with highly toxic or infectious agents;
- wear protective aprons for special procedures such as transferring large volumes of corrosive material;
- remove protective clothing when leaving the laboratory;

- remove protective clothing in the event of visible or suspected contamination. Laboratory coats should be able to absorb even large spills and if removed promptly may not contaminate the skin. In some cases, disposable synthetic materials are used for protective clothing where maximum impermeability is desired.

### 4.3 Foot protection

Open-toed shoes, sandals, or other shoes that do not fully enclose the foot pose a significant potential for foot injuries in the laboratory. Small pieces of glass from broken pipettes or test tubes can be trapped easily between the foot and open shoe causing serious lacerations. A full shoe can protect the foot from spilled chemicals for enough time to get to a sink or safety shower. An open shoe affords no protection. Special rubber boots or plastic shoes may be needed where large quantities of solvents might penetrate normal foot gear (e.g. during spill clean-up operations). However, where specific laboratory safety rules call for the use of safety shoes, these must be worn in accordance with those safety rules.

### 4.4 Hand protection

In the laboratory, gloves are used for protecting hands from radiation, chemical products, hazardous material and physical hazards such as abrasion, tearing, puncture and exposure to temperature extremes.

**Latex gloves and skin reactions:** Natural latex is derived from the sap of the rubber tree and contains rubber polymers, carbohydrates, lipids, phospholipids and proteins. During the manufacturing process additional chemical agents are added to impart elasticity, flexibility and durability to the latex. Because of these properties, and because of their high tactile strength and low cost, latex gloves are used for many laboratory procedures. Unfortunately, for some people, wearing latex gloves can cause skin reactions of either an irritant or allergic nature, and can be caused by:

- chronic irritation from sweating of hands inside gloves or from gloves rubbing against the skin;
- sensitisation to the chemical additives used in the manufacturing process;

- reaction to naturally-occurring latex proteins.

Frequent hand-washing, as well as residues from scrubs, soaps, cleaning agents and disinfectants may further irritate the skin. Using one of the following alternatives may reduce the risk of skin problems associated with the use of latex rubber gloves:

- non-latex gloves;
- “hypo-allergenic”, non-powdered or low-protein latex gloves;
- polyethylene, PVC or cloth liners under latex gloves;
- non-latex gloves under latex gloves.

Occurrences of skin problems (e.g., rash, itching, peeling, red, blistering skin or dry flaking skin with cracks and sores) that seem to be associated with the wearing of latex gloves should be reported to a physician when symptoms first appear.

**Glove selection guidelines:** Base selection of glove material on:

- identification of the work procedures requiring hand protection;
- flexibility and touch sensitivity required: a need for high tactile sensitivity, for example, would restrict glove thickness, and some protocols may require the use of gloves with non-slip or textured surfaces;
- type and length of contact (e.g. occasional or splash vs. prolonged or immersion contact);
- whether disposable or reusable gloves are more appropriate.

**Table 1. Recommended glove materials for a variety of laboratory hazards**

Hazard	Degree of hazard	Recommended material
Abrasion	Severe	Reinforced heavy rubber, staple-reinforced leather
	Less severe	Rubber, plastic, leather, polyester, nylon, cotton
Sharp edges	Severe	Metal mesh, staple-reinforced heavy leather, aramid steel
	Less severe	Leather, terry cloth (aramid steel)
	Mild with delicate work	Lightweight leather, polyester, nylon, cotton
Chemicals and liquids	Varies depending on the concentration, contact time etc. Consult MSDS, manufacturer or permeation chart	Choice depends on chemical. Examples: natural nitrite or butyl rubber, neoprene, PTFE (polytetrafluoroethylene), polyvinyl chloride, polyvinyl alcohol
Cold		Leather, insulated plastic or rubber, wool, cotton
Heat	Above 350°C	Asbestos types
	Up to 350°C	Neoprene-coated asbestos, heat resistant leather with linings, Nomex
	Up to 200°C	Heat resistant leather, terry cloth (aramid fibre)
	Up to 100°C	Chrome-tanned leather, terry cloth
General duty		Cotton, terry cloth, leather
Product contamination		Thin-film plastic, lightweight leather, cotton, polyester, nylon
Radiation	Low to moderate radiotoxicity	Any disposable rubber or plastic gloves

*\*Gloves not listed here may also be suitable; refer to the MSDS, glove manufacturer or permeation chart.*

No single glove material is resistant to all chemicals, nor will most gloves remain resistant to a specific chemical for longer than a few hours. Determine which gloves will provide an acceptable degree of resistance by

consulting the MSDS for the product, contacting glove manufacturers or by referring to a compatibility chart or table for permeation data. These resources may use the following terms:

- “permeation rate” refers to how quickly the chemical seeps through the intact material: the higher the permeation rate the faster the chemical will permeate the material;
- “breakthrough time” refers to how long it takes the chemical to seep through to the other side of the material; and
- “degradation” is a measure of the physical deterioration (for example, glove material may actually dissolve or become harder, softer or weaker) following contact with the chemical;
- selection, use and care of protective gloves.

**Guidelines for glove use include the following:**

- choose a glove that provides adequate protection from the specific hazard(s);
- be aware that some glove materials may cause adverse skin reactions in some individuals and investigate alternatives;
- inspect gloves for leakage before using; test rubber and synthetic gloves by inflating them;
- make sure that the gloves fit properly;
- ensure that the gloves are long enough to cover the skin between the top of the glove and the sleeve of the lab coat;
- discard worn or torn gloves;
- discard disposable gloves that are, or may have become, contaminated;
- avoid contaminating “clean” equipment: remove gloves and wash hands before carrying out tasks such as using the telephone;
- always wash your hands after removing gloves, even if they appear not to be contaminated;
- do not reuse disposable gloves;
- follow the manufacturer’s instructions for cleaning and maintenance of reusable gloves;
- before using gloves, learn how to remove them without touching the contaminated outer surface with your hands.

## 4.5 Respirators

Respirators should be used only in emergency situations (e.g. hazardous spills or leaks) or when other measures, such as ventilation, cannot adequately control exposures. There are two classes of respirators: air-purifying and supplied-air. The latter supply clean air from a compressed air tank or through an air line outside the work area, and are used in oxygen-deficient atmospheres or when gases or vapours with poor warning properties are present in dangerous concentrations. Air-purifying respirators are suitable for many laboratory applications and remove particulates (dusts, mists, metal fumes, etc.) or gases and vapours from the surrounding air.

**Selection, use and care of respirators:** Follow proper procedures for selecting and using respiratory protective equipment. Correct use of a respirator is as vital as choosing the right respirator. An effective programme for respiratory protection should include the following:

- written standard operating procedures and training;
- selecting a respirator that is suitable for the application. Consult the MSDS or the environmental safety officer before purchasing and using a respirator;
- assigning respirators to individuals for their exclusive use, whenever possible;
- fit-testing: evaluation of facial fit for all users of respirators; beards, long sideburns, glasses or the wrong size of respirator may prevent an effective seal between the wearer's face and the respirator;
- protocols for using, cleaning and sanitary storage of respirators;
- regular inspection of the respirator, and replacement of defective parts;
- medical surveillance, before an individual is assigned to work in an area where respirators are required, to verify the person's ability to function under increased breathing resistance.

It is essential to assess the health status of the wearer and to have their medical status reviewed periodically. It has been determined that persons with certain medical disorders and conditions may be at risk when wearing a respiratory protective device. The following clinical conditions are among

those which could compromise an individual's ability to wear a respirator without risk:

- Chronic obstructive and restrictive lung disease: chronic bronchitis, emphysema, pneumoconiosis, fibro thorax, asthma, etc.;
- Ischemic heart disease: coronary insufficiency and myocardial infarction;
- Benign and accelerated hypertension;
- Hemorrhagic disorders: vascular haemophilia, hypersplenism, thrombocytopenia, purpura, etc.;
- Thyroid disorders or cystic fibrosis;
- Epilepsy: grand mal, focal, etc.;
- Diabetes mellitus;
- Cerebrovascular accidents;
- Facial abnormalities;
- Kidney diseases;
- Conductive and sensorineural hearing loss;
- Serious defects in visual acuity;
- Ruptured eardrum.

The importance of claustrophobia, anxiety, and other psychological factors during the wearing of a respirator should not be overlooked in a medical assessment. Without such screening, persons psychologically unsuited to wearing respirators may be placed in situations in which they become a danger to themselves and others. Therefore, prospective respirator users must show evidence that the wearing of respiratory protective devices will not produce undue physical or psychological stress or risk.

## 5. Handling and use of chemicals

Laboratory personnel work in a potentially extremely hazardous and unforgiving environment. The substances with which they work may be toxic, flammable, explosive or carcinogenic, to mention a few unpleasant possibilities. It is therefore important that all personnel in the laboratory learn the potential hazard of the chemicals they are handling and using everyday.

- **Toxic chemicals and the four routes of entry:** Chemicals can gain entry into the body by:

- Inhalation** of gases, vapours and particulate material (e.g. mists, dusts, smoke, fumes);
  - Absorption** through skin of liquids, solids, gases and vapours;
  - Ingestion** of chemicals directly or indirectly via contaminated foods and beverages and contact between mouth and contaminated hands (nail-biting, smoking);
  - Injection** of chemicals through needles and other contaminated laboratory sharps.
  
- **Flammable chemicals:** Flammable and combustible liquids, solids or gases will ignite when exposed to heat, sparks or flame. Flammable materials burn readily at room temperature, while combustible materials must be heated before they will burn. Flammable liquids or their vapours are the most common fire hazards in laboratories.
  
- **Oxidising chemicals:** Oxidisers provide oxidising elements such as oxygen or chlorine, and are capable of igniting flammable and combustible material even in an oxygen-deficient atmosphere. Oxidising chemicals can increase the speed and intensity of a fire by adding to the oxygen supply, causing materials that would normally not burn to ignite and burn rapidly. Oxidisers can also:
  - React with other chemicals, resulting in release of toxic gases;
  - Decompose and liberate toxic gases when heated;
  - Burn or irritate skin, eyes, breathing passages and other tissues
 Precautions to follow when using and storing oxidisers in the laboratory include the following:
  - .. Keep away from flammable and combustible materials;
  - .. Keep containers tightly closed unless otherwise indicated by the supplier;
  - .. Mix and dilute according to the supplier's instructions;
  - .. To prevent release of corrosive dusts, purchase in liquid instead of dry form;
  - .. Reduce reactivity of solutions by diluting with water;
  - .. Wear appropriate skin and eye protection;
  - .. Ensure that oxidisers are compatible with other oxidisers in the same storage area.

- **Reactive chemicals**

- May be sensitive to jarring, compression, heat or light;
- May react dangerously with water or air;
- May burn, explode or yield flammable or toxic gases when mixed with incompatible materials;
- Can vigorously decompose, polymerise or condense;
- Can also be toxic, corrosive, oxidising or flammable;
- Some chemicals may not be dangerous when purchased but may develop hazardous properties over time (e.g. diethyl ether and solutions of picric acid).

**Precautions when working with dangerously reactive chemicals:**

- Understand the hazards associated with these chemicals and use them under conditions which keep them stable;
- Store and handle away from incompatible chemicals;
- Keep water-reactive chemicals away from potential contact with water, such as plumbing, fire sprinkler heads and water baths;
- Handle in a chemical fume hood;
- Wear the appropriate skin and eye protection;
- Work with small quantities;
- Use up or dispose of these chemicals before they attain their expiry date.

- **Corrosive chemicals:** Corrosives are materials, such as acids and bases (caustics, alkalis) which can damage body tissues as a result of splashing, inhalation or ingestion. Also:

- They may damage metals, releasing flammable hydrogen gas;
- They may damage some plastics;
- Some corrosives, such as sulphuric, nitric and perchloric acids, are also oxidisers; thus they are incompatible with flammable or combustible material;
- They may release toxic or explosive products when reacting with other chemicals;
- They may liberate heat when mixed with water.

**Precautions for handling corrosive materials include:**

- Wear appropriate skin and eye protection;
- Use in the weakest concentration possible;
- Handle in a chemical fume hood;
- Use secondary containers when transporting and storing corrosives;
- Always dilute by adding acids to water;
- Dilute and mix slowly;
- Store acids separately from gases.

**Chemical spill response:**

- **Spill response contingencies:** Laboratory heads are responsible for predetermining procedures for response to the types of spill situations that may be anticipated for their operations. Individuals requiring assistance in preparing spill response plans should contact their environmental health and safety department.
- **Development of spill response plans:**
  - Communications:** All laboratories housing hazardous materials are required to provide means of contacting appropriately trained people who may be summoned in the event of emergencies involving their laboratories, especially for after-hours situations. This may involve posting the relevant telephone number(s) and/or providing them to the security services, who operate the emergency telephone number. Building directors are also required to provide to the security services telephone numbers where they, or alternate contact persons, may be reached during after-hours crises.
  - General guidelines:** The following factors are to be considered when developing spill response procedures:
    - .. Categories of chemicals (e.g. oxidisers, flammable solvents) and their chemical, physical and toxicological properties;
    - .. The quantities that may be released;
    - .. Possible locations of release (e.g. laboratory, corridor);
    - .. PPE needed;
    - .. Types and quantities of neutralising or absorbing material needed.

**The following guidelines should be followed when initially responding to a spill situation:**

- Determine appropriate clean up method by referring to the Material Safety Data Sheet (MSDS). If you are unsure how to proceed, or if you do not have the necessary protective equipment, do not attempt to clean up the spill;
- If the spill is minor and of known limited danger, clean up immediately;
- If the spill is of unknown composition, or potentially dangerous (explosive, toxic vapours), alert everyone present and evacuate the room;
- If the spill cannot be safely handled using the equipment and personnel present, call the emergency telephone number to request assistance.

**Guidelines for specific types of spills:** This section describes how to clean up some of the chemical spills that may occur in the laboratory. Refer to sub-section on waste management for details on how to dispose of the absorbed chemical.

- **Flammable and toxic liquids:**

- If you can do so without putting yourself at risk, immediately shut off all potential ignition sources;
- If fire occurs, alert everyone present and extinguish all flames. If the fire cannot be controlled immediately activate the nearest fire alarm;
- If no flames are evident, pour adsorbent material around the perimeter of the spill and then cover the rest of the material. Wear an appropriate respirator if toxic vapours are involved;
- Wear gloves resistant to the chemical being handled. Using a plastic utensil (to avoid creating sparks), scoop up the absorbed spill, place it in a plastic bag, seal it, and place in a labelled container.

- **Corrosive liquids:**

- Alert everyone present. If vapours are being released, clear the area;
- Do not attempt to wipe up a corrosive liquid unless it is very dilute;

- Gloves, boots, apron and eye protection must be used when neutralising an extensive corrosive spill. Respiratory protection is required if the liquid releases corrosive vapour or gas;
  - Pour the required neutralising or adsorbing material around the perimeter of the spill, and then carefully add water and more neutralising material to the contained area. Carefully agitate to promote neutralisation;
  - Use pH paper to verify that all contaminated areas are neutralised and safe to wipe up;
  - If an adsorbent (e.g. spill control pillows) material is used instead of a neutraliser, scoop up the absorbed spill, place it in a plastic bag, seal it, and then place in a labelled box. If neutralised material contains no toxic heavy metals (e.g. chromium), flush down the drain with plenty of water.
- **Corrosive solids:** Small spills can be cleaned up mechanically with a dustpan and brush. Larger spills should be cleaned up using a High Efficiency Particulate Air (HEPA) filter vacuum. For spills containing fine dusts, an air-purifying respirator with dust filters is recommended, as are gloves, protective goggles, and a laboratory coat.
  - **Toxic solids:** Avoid disturbing such solids (e.g. asbestos) which may release toxic dust. Wet the material thoroughly, then place it in a plastic bag and label it appropriately. If wet removal is not possible, a vacuum equipped with a HEPA filter is required.
  - **Gases:** In the event of the release of a corrosive gas (e.g. chlorine) or gases that are absorbed through the skin (e.g. hydrogen cyanide), a complete chemical resistant suit and a self-contained breathing apparatus are required. There are no practical means of absorbing or neutralising a gas - the leak must be corrected at the source.
  - **Mercury:** If a small amount of mercury is spilled (e.g. broken thermometer), use an aspirator bulb or a mercury sponge to pick up droplets, place the mercury in a container, cover with water, seal it, and label the bottle appropriately. To clean up the residual micro-droplets that may have worked into cracks and other hard-to-clean areas, sprinkle sulphur powder or other commercially available product for mercury decontamination. Leave the material for several hours and sweep up solid into a plastic bag, seal it and label it appropriately. Contact the appropriate organisation for monitoring of

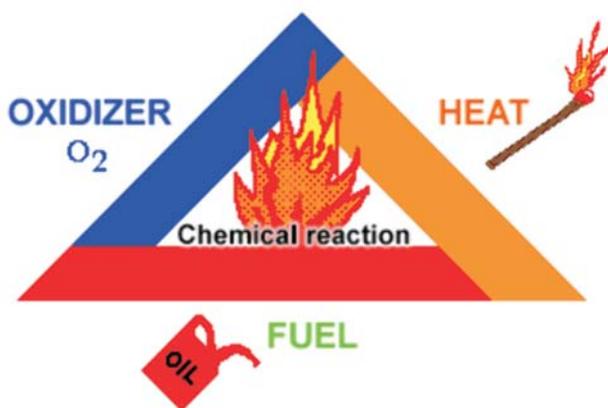
mercury air concentrations. If a large spill of mercury is involved, the area should be closed off, and a mercury respirator worn during the clean-up. A mercury vacuum is available from the appropriate organisation for large mercury spills.

- **Special categories:** For further information on responses to other categories consult Appendix C: **The management and interpretation of Material Safety Data Sheets.**

## 6. Fire and gas safety

- **Fire Safety:** Laboratory fires can be caused by Bunsen burners, runaway chemical reactions, electrical heating units, failure of unattended or defective equipment, or overloaded electrical circuits. Laboratory personnel should familiarise themselves with the operation of the fire extinguishers and the location of pull stations, emergency exits and evacuation routes in their workplaces. In the event that the general alarm is sounded, use the evacuation routes established for your area and follow the instructions of the evacuation monitors. Once outside the building, move away from the doors to enable others to exit.

Fire cannot occur without an ignition source, fuel and an oxidising atmosphere (usually air), the three elements that comprise what is called the “fire triangle” shown here.



Fire will not be initiated if any one of these elements is absent, and will not be sustained if one of these elements is removed.

This concept is useful in understanding prevention and control of fires. For example, the coexistence of flammable vapours and ignition sources should be avoided, but when flammable vapours cannot be controlled elimination of ignition sources is essential.

- **Classes of Fire:** The National Fire Protection Association (NFPA - USA) has defined four classes of fire, according to the type of fuel involved. These are:
  - Class A fires involve combustibles such as paper, wood, cloth, rubber and many plastics;
  - Class B fires entail burning of liquid fuels like oil-based paints, greases, solvents, oil and gasoline;
  - Class C fires are of electrical origin (fuse boxes, electric motors, wiring);
  - Class D fires encompass combustible metals such as magnesium, sodium, potassium and phosphorus.
  
- **Fire extinguishers:** Fire extinguishers are rated as A, B, C or D (or combinations of A, B, C and D) for use against the different classes of fires. Personnel should familiarise themselves with the fire class ratings of the extinguishers in their work areas so that they know what types of fire they can attempt to extinguish with each particular extinguisher. They should learn how to use each type of extinguisher, as there will be no time to read instructions during an emergency. They should attempt to fight small fires only, and only if there is an escape route available. It is important to have the extinguisher recharged after every use. If the necessity does arise to fight a fire, personnel should remember the acronym “PASS” when using the extinguisher:
  - **P:** Pull and twist the locking pin to break the seal;
  - **A:** Aim low, and point the nozzle at the base of the fire;
  - **S:** Squeeze the handle to release the extinguishing agent;
  - **S:** Sweep from side to side until the fire is out;

Be prepared to repeat the process if the fire breaks out again.

- **Preventing fires:** Use the following precautions when working with or using flammable chemicals in a laboratory, and keep in mind that these precautions also apply to flammable chemical waste:
  - Minimise the quantities of flammable liquids kept in the laboratory;
  - Do not exceed the maximum container sizes specified by the National Fire Protection Association (NFPA);
  - Except for the quantities needed for the work at hand, keep all flammable liquids in NFPA or UL (underwriters' laboratories) approved flammable liquid storage cabinets. Keep cabinet doors closed and latched at all times. Do not store other materials in these cabinets;
  - Use and store flammable liquids and gases only in well-ventilated areas. Use a fume hood when working with products that release flammable vapours;
  - Keep flammable solvent containers, including those for collecting waste, well capped. Place open reservoirs or collection vessels for organic procedures like HPLC inside vented chambers;
  - Store flammable chemicals that require refrigeration in "explosion-safe" (non-sparking) laboratory refrigerators;
  - Keep flammable chemicals away from ignition sources, such as heat, sparks, flames and direct sunlight. Avoid welding or soldering in the vicinity of flammables;
  - Bond and ground large metal containers of flammable liquids in storage. To avoid the build-up of static charges, bond containers to each other when dispensing;
  - Use portable safety cans for storing, dispensing and transporting flammable liquids;
  - Clean spills of flammable liquids promptly.
- **Evacuations:** In the event that the general alarm is sounded, follow the evacuation routes established for your area; do not use the elevators. Follow the instructions of the evacuation monitors. Once outside the building, move away from the doors to allow others to exit;
- **Gas Safety - hazards of compressed gases:** Compressed gases are hazardous due to the high pressure inside cylinders. Knocking over an unsecured, uncapped cylinder of compressed gas can break the cylinder valve, and the resulting rapid escape of high pressure gas can turn a cylinder into an uncontrolled rocket or pinwheel,

causing serious injury and damage. Poorly controlled release of compressed gas in the laboratory can burst reaction vessels, cause leaks in equipment and hoses or result in runaway chemical reactions. Compressed gases may also have flammable, oxidising, dangerously reactive, corrosive or toxic properties. Inert gases such as nitrogen, argon, helium and neon can displace air, reducing oxygen levels in poorly ventilated areas and causing asphyxiation.

- **Safe handling, storage and transport of compressed gas cylinders:**

- All gas cylinders, full or empty, should be securely supported using suitable racks, straps, chains or stands to prevent tipping or damage to the neck, valve and regulator;
- Compressed gas cylinders containing toxic gases should be used only in an operating chemical fume hood;
- When cylinders are not in use or are being transported, remove the regulator and attach the protective cap;
- An appropriate cylinder cart should be used for transporting cylinders. Chain or strap the cylinder to the cart;
- Verify that the regulator is appropriate for the gas being used and the pressure being delivered. Do not rely on the pressure gauge to indicate the maximum pressure ratings; check the regulator's specifications;
- Do not use adaptors or teflon tape to attach regulators to gas cylinders;
- Never bleed a cylinder completely empty; leave a residual pressure;
- Do not lubricate the high-pressure side of an oxygen regulator;
- Do not expose cylinders to temperature extremes;
- Store incompatible classes of gases separately;
- Compressed gas cylinders should not be stored in unventilated locations such as cupboards or lockers, but should be stored in a location where they will not be tampered with by unauthorised persons, and which is dry, well-protected and well-ventilated (at least 20 feet from highly combustible materials);
- Cylinders must not be dropped or struck or allowed to hit one other violently;
- Cylinder valves not equipped with fixed hand wheels shall have keys or handles on valve spindles or stems while cylinders are in service. If multiple cylinders are connected to a manifold, only one key or handle is required;

- Leaking regulators, cylinder valves, hose, piping systems, apparatus or fittings shall not be used. Do not attempt to repair or fix cylinder valves,
- Cylinders shall not be used as rollers or supports, whether full or empty;
- Cylinders must not be placed where they might form part of an electrical circuit;
- Never use a cylinder's contents for purposes other than those intended by the supplier;
- Never allow acetylene to come in contact with unalloyed copper, except in a blowpipe or torch;
- When flammable lines or other parts of equipment are being purged of air or gas, open lights or other ignition sources must not be allowed near uncapped openings;
- All compressed gas cylinders must be legibly marked with their contents;
- Cylinders shall not be stored on their sides, unless approved for that use.

## 7. Hazardous waste management

All laboratory operations with chemicals result in the production of chemical wastes. These wastes may pose potential harm, both short and long term, to human health or to the environment, unless the disposal is properly handled. There are now regulations and guidelines governing all areas of waste management from creation, transportation to disposing of hazardous waste. The following guidelines are specifically given for laboratories to be able to manage hazardous waste.

- **Waste minimisation:** In order to minimise the amount of hazardous waste presented for disposal, it is important to follow these guidelines:
  - Avoid overstocking: one of the main sources of laboratory waste is surplus stock - the result of over buying. Recent pricing arrangements with suppliers have greatly reduced the benefits of purchasing chemicals in large volumes. Also, there is little need to store large quantities of chemicals, as orders are generally shipped the day after an order is received;
  - Do not accept donations of materials that you don't plan to use. Many companies have traditionally unloaded unwanted reagents

by donating them to laboratories, which eventually transfers the cost of disposal to the university;

- Substitute hazardous experimental materials for non-hazardous ones. For example, use aqueous-based, biodegradable scintillation fluids whenever possible;
- If laboratory personnel employ good waste separation practices, the quantity of waste (solid and liquid chemicals, contaminated protective clothing, pipettes, etc) can be kept to a minimum.

- **Hazardous waste disposal guidelines:**

- Label all waste materials completely and legibly, using labels available from an **appropriate organisation**. Inadequately labelled containers will not be accepted;
- Package waste materials in approved containers;
- Overfilled and/or leaking containers cannot be accepted for disposal;
- Never discharge wastes into the sewer unless you have verified that hazardous wastes regulations permit you to do so. For information, contact an **appropriate organisation**.

- **Waste preparation procedures:**

**Organic solvents and oils:**

- Collect in the containers provided by an appropriate organisation;
- Indicate the composition of the contents as accurately as possible on the attached label.

**Miscellaneous chemicals and cylinders;**

- Complete a laboratory chemical inventory form and send to an appropriate organisation;
- Await instructions.

**Chemicals of unknown composition:**

- Unknown chemicals cannot be accepted;
- Analyse or contact an appropriate organisation to arrange for analysis (at the expense of the waste generator).

**Peroxide-forming (e.g. ether) and explosive (e.g. dry picric acid) chemicals:**

- Do not mix with solvents or other waste;
- If the material is older than one year, do not attempt to open or move the container. Contact an appropriate organisation for advice.

**Corrosives (acids and bases):**

- Collect acids (pH) and bases (pH7) separately in the plastic containers provided by an appropriate organisation. Do not mix acids with bases;
- Indicate the composition of the contents, as accurately as possible, on the attached label.

**Broken glassware (uncontaminated):**

- Designate a cardboard box for broken glass; label it "*BROKEN GLASS*", and place glass inside. When the box is full, seal it with tape and place it next to the garbage receptacle for pickup by the cleaning staff.

**Empty chemical reagent bottles:**

- Remove the cap from the empty bottle and allow volatile materials to evaporate into the fume hood;
- Rinse the bottle three times with tap water and let dry;
- Remove or obliterate the label;
- Place the uncapped bottle next to the garbage receptacle.

## 8. Ventilation and fume hoods

General ventilation, also called dilution ventilation, involves dilution of inside air with fresh outside air, and is used to:

- maintain comfortable temperature, humidity and air movement for room occupants;
- dilute indoor air contaminants;

- replace air as it is exhausted to the outside via local ventilation devices such as fume hoods;
- provide a controlled environment for specialised areas such as surgery or computer rooms.

General ventilation systems comprise an air supply and an air exhaust. The air may be supplied via a central HVAC (Heating, Ventilation and Air Conditioning) system or, especially in older buildings, via opening windows. Laboratory air may be exhausted through either local exhaust devices or air returns connected to the HVAC system. Local exhaust ventilation systems capture and discharge air contaminants or heat from points of release. Common local exhaust ventilation devices found in laboratories include:

- chemical fume hoods;
- canopy hoods;
- slotted hoods;
- biological safety cabinets;
- direct connections.

Chemical hoods, canopy hoods and direct connections exhaust devices can be used for binder and asphalt laboratories:

- **Chemical fume hoods:** Chemical fume hoods are enclosed units with a sliding sash for opening or closing the hood. They are able to capture and exhaust even heavy vapours, and are preferred for all laboratory procedures that require manual handling of hazardous chemical material. (Refer to sub-section on safe use of chemical fume hoods below for information on the safe use of chemical fume hoods).
- **Canopy hoods:** Canopy hoods are designed to capture heat from processes or equipment, such as atomic absorption spectrophotometers or autoclaves; a canopy or bonnet is suspended over a process and connected to an exhaust vent. The following limitations make canopy hoods poor substitutes for chemical fume hoods, because they:
  - draw contaminated air through the user's breathing zone;
  - do not capture heavy vapours;
  - provide less containment than chemical fume hoods, and are more affected by air turbulence;
  - do not provide adequate suction more than a few inches away from the hood opening.

- **Direct connections:** Direct connections provide direct exhausting of contaminants to the outdoors and are used for venting:
  - flammable liquid storage cabinets;
  - other toxic chemical storage cabinets;
  - solvent and waste reservoirs, such as for HPLC solvent systems;
  - reaction vessels, sample analysers, ovens, dryers and vacuum pump outlets.
  
- **Ventilation balancing and containment:** By regulation, more air is exhausted from a laboratory than is supplied to it, resulting in a net negative pressure (vacuum) in the laboratory. Negative pressure draws air into the laboratory from surrounding areas, and serves to prevent airborne hazardous chemicals from spreading outside the laboratory in the event of an accidental release inside the laboratory. Balancing of laboratory ventilation must take into consideration the amount of air exhausted by local ventilation devices such as fume hoods. Modern laboratories do not have opening windows, as opening of windows tends to pressurise a room, pushing air from the laboratory into adjacent non-laboratory areas.
  - Safe use of chemical fume hoods:** Fume hoods properly used and maintained will render substantial protection, provided the user is aware of its capabilities and limitations. The recommended performance standard for fume hoods is the delivery of a minimum face velocity of 100 linear feet per minute (0,5 m/s) at half sash height. An anemometer for determining a fume hood's face velocity should be available from Environmental Health and Safety (SHE/SHEQ). To ensure your fume hood provides the highest degree of protection observe the following guidelines:
    - .. Only materials being used in an ongoing experiment should be kept in the fume hood. Cluttering the hood will create air flow disturbances;
    - .. When it is necessary to keep a large apparatus inside a hood, it should be placed upon blocks or legs to allow air to flow underneath;
    - .. Operate the hood with the sash as low as practical. Reducing the open face will increase the face velocity;
    - .. Work as far into the hood as possible. At least six inches is recommended;

- Do not lean into the hood. This disturbs the air flow, and also places your head into the contaminated air inside the hood;
- Do not make quick motions into or out of the hood, or create cross drafts by walking rapidly past the hood. Opening doors or windows can sometimes cause strong air currents which will disturb the air flow into the hood;
- Heating devices should be placed at the rear of the hood;
- Do not use a hood for any function it was not specifically designed;
- Keep hood door closed when not attended;
- Remember that sinks inside fume hoods are not designed for disposing of chemical wastes.

**Additional information on Local Exhaust Ventilation design, operation and maintenance standards:**

Reference to local regulatory standards related to ventilation may be found in the following OHS Act regulations:

- Environmental Regulations for Workplaces, 1987: Regulation 5 (1): *General ventilation requirements for all workplaces*;
- Hazardous chemical substances regulations, 1995: Regulation 10 (1): *Control of exposure to HCS* (reference to engineering control measures where exposure to HCS is above Occupational Exposure Limits).

However, the above regulations are not sufficient to provide guidance and specific design, operation and maintenance standards for the control of airborne contaminants in the workplace.

In the absence of suitable local (SA) standards, Sabita therefore recommends that, for the purpose of following and illustrating good practice, the following guide is adopted as the standard for demonstrating legal compliance and implementing *best available techniques* as required by the Sabita HSE Charter.

- *Controlling airborne contaminants at work - A guide to local exhaust ventilation.*

This guide is available on the UK Health and Safety Executive website, and is made available as a free download under the terms of the Click-use PSE Licence number C2010002170 (Sabita), end date 22 August 2015 at the following link:

<http://books.hse.gov.uk/hse/public/saleproduct.jsf?catalogueCode=9780717662982>.

## **9. Physical hazards, ergonomics, safe conduct and housekeeping**

There are other hazards present in the laboratory environment that may or may not be linked to hazardous chemicals but worth bearing in mind for the general safety of all laboratory staff.

### **9.1 Electrical safety**

- Purchase and use only approved electrical equipment;
- All electrical outlets should carry a grounding connection requiring a three-pronged plug;
- Never remove the ground pin of a three-pronged plug;
- Remove cords by grasping the plug, not the cord;
- All electrical equipment should be wired with a grounding plug;
- All wiring should be done by, or under the approval of, a licensed electrician;
- Electrical equipment that has come into contact with water should be disconnected at the main switch or breaker before being handled. Laboratory personnel should familiarise themselves with the location of such devices;
- Know how to cut off the electrical supply to the laboratory in the event of an emergency;
- Maintain free access to panels; breaker panels should be clearly labelled to identify the equipment they control;
- Ensure that all wires are dry before plugging into circuits;
- Electrical equipment with frayed wires should be repaired before being put into operation;
- Tag and disconnect defective equipment;
- Be sure that all electrical potential has been discharged before commencing repair work on any equipment containing high voltage power supplies or capacitors;
- Minimise the use of extension cords and avoid placing them across areas of pedestrian traffic;

- Use only CO<sub>2</sub>, halon, or dry chemical fire extinguishers for electrical fires.

## 9.2 High pressure and vacuum work

Pressure differences between equipment and the atmosphere cause many laboratory accidents. Glass vessels under vacuum or pressure can implode or explode, resulting in cuts from projectiles and splashes to the skin and eyes. Glass can rupture even under small pressure differences. Rapid temperature changes can lead to pressure differences, as can carrying out chemical reactions inside sealed containers.

The hazards associated with pressure work can be reduced by:

- checking for flaws such as cracks, scratches and etching marks before using vacuum apparatus;
- using vessels specifically designed for vacuum work. Thin-walled or round-bottomed flasks larger than 1ℓ should never be evacuated;
- assembling vacuum apparatus so as to avoid strain. Heavy apparatus should be supported from below as well as by the neck;
- taping glass vacuum apparatus to minimise projectiles due to implosion;
- using adequate shielding when conducting pressure and vacuum operations;
- allowing pressure to return to atmospheric before opening vacuum desiccators or after removal of a sample container from cryogenics;
- wearing eye and face protection when handling vacuum or pressure apparatus.

## 9.3 Repetitive work and ergonomics

Ergonomics is concerned with how the workplace “fits” the worker. Performing certain work tasks without regard for ergonomic principles can result in:

- fatigue;
- repetitive motion injuries;
- strains, aches and injuries from biomechanical stresses;
- eyestrain from video display terminals (VDTs);
- decreased morale.

## Factors that can increase the risk of musculoskeletal injury are:

- awkward positions or movements;
- repetitive movements;
- application of force.

In a laboratory setting, look for the following when addressing ergonomic concerns:

- Laboratory bench and workbench heights are suitable for all personnel;
- Laboratory chairs are on wheels or castors, are sturdy (5-legged), and are adjustable (seat height, angle, backrest height);
- VDTs are positioned at or slightly below eye level, and are positioned so as to avoid glare from lights or windows;
- Computer keyboards and pointing devices are positioned so that wrists are kept in a neutral position and forearms are horizontal;
- Colour, lettering size and contrast of equipment display monitors are optimised to minimise eye strain;
- Work station design does not necessitate excessive bending, reaching, stretching or twisting;
- Vibration-producing equipment, such as vortex mixers and pump-type pipettes are not used for extended periods of time;
- Buttons and knobs on equipment are accessible and of a good size;
- Heavy items are not carried or handled;
- Laboratory workers are using proper techniques when lifting or moving materials;
- Indoor air quality parameters, such as temperature, humidity and air supply are comfortable;
- Floors are slip-resistant;
- Noise levels are not excessive.

### 9.4 Glassware safety

- Use a dustpan and brush, not your hands, to pick up broken glass;
- Discard broken glass in a rigid container separate from regular garbage and label it appropriately (see **Hazardous Waste Management**, page 55 - 56);

- Protect glass that is subject to high pressure or vacuum. Wrapping glass vessels with cloth tape will minimise the possibility of projectiles;
- Glass is weakened by everyday stresses such as heating and bumping. Handle used glassware with extra care;
- Discard or repair all damaged glassware, as chipped, cracked or star-cracked vessels cannot handle the normal stresses.

### **When handling glass rods or tubes:**

- fire polish the ends;
- lubricate with water or glycerine when inserting through stopper;
- ensure stopper holes are properly sized, and not too small;
- insert stoppers carefully, with a slight twisting motion, keeping hands close together; and
- use gloves or a cloth towel to protect your hands.

## **9.5 Safe laboratory conduct and housekeeping**

To minimise the potential for eating/drinking hazardous materials, the following procedures are recommended in all laboratories. No eating, drinking, smoking, gum chewing, or application of cosmetics should take place in areas where chemicals are stored or used.

- Wash hands and face after working with or around chemicals and before eating, drinking, smoking, using the restroom, applying cosmetics, or leaving the facility;
- Do not store, handle, or prepare food or beverages in refrigerators, glassware, utensils, microwaves, ovens, cabinets, sinks, countertops, tables, or other locations which are also used for laboratory operations. Food and drink is permitted only in designated eating, preparation, and food storage locations within the laboratory;
- Do not enter designated eating, preparation and food storage areas wearing contaminated clothing or with contaminated laboratory tools or equipment. If in doubt, remove or clean equipment and clothing before bringing it into these areas;
- Do not leave cigarettes lying in a laboratory or near fumes which can be absorbed by the cigarettes;
- To minimise the hazard of residual chemicals, always clean the work area after completing test procedures or laboratory work. Wipe up any spills or waste material and dispose of properly. Clean tools and

containers that may be contaminated before putting them away. Clean any protective equipment that may have been contaminated and store properly. After protective equipment has been removed, check personal clothing for contamination. Remove or neutralise contamination or contaminated clothing before leaving the laboratory or going home. Always wash face and hands before leaving;

- Avoid practical jokes or other behavior that might confuse, startle or distract another worker. Never use laboratory chemicals, materials, or equipment for practical jokes or horseplay;
- Do not use mouth suction for pipettes or starting a siphon;
- To minimise the hazards of entanglement or chemical contamination the following personal apparel rules are recommended:
  - Confine long hair, necklaces, neckties, and other loose clothing that could get caught in moving equipment or be contaminated with chemicals;
  - Remove jewelry, rings, earrings, watches, and other personal items that will interfere with the use of protective equipment or could get caught in equipment;
  - Appropriate shoes should be worn at all times in the chemical and materials handling and storage areas of the laboratory. Sandals, flip-flops, or open toed shoes are not allowed;
- Personal housekeeping:
  - Keep the work area clean and uncluttered;
  - Keep chemicals and equipment properly labeled and stored;
  - Clean the area on completion of an operation or at the end of the day.

## 9.6 Equipment safety

Whenever laboratory equipment is purchased, preference should be given to equipment that:

- limits contact between the operator and hazardous material, and mechanical and electrical energy;
- is corrosion-resistant, easy to decontaminate and impermeable to liquids;
- has no sharp edges or burrs.

Every effort should be made to prevent equipment from becoming contaminated. To reduce the likelihood of equipment malfunction that could result in leakage or spill:

- Review the manufacturer's documentation, and keep that documentation for future reference;
- Use and service equipment according to the manufacturer's instructions;
- Ensure that anyone who uses a specific instrument or piece of equipment is properly trained in setup, use and cleaning of the item.

The following sections outline some of the precautions and procedures to be observed with some commonly used laboratory equipment.

- **Centrifuges:** Improperly used or maintained centrifuges can present significant hazards to users. Failed mechanical parts can result in release of flying objects and hazardous chemicals. The high speed spins generated by centrifuges can create large amounts of aerosol if a spill, leak or tube breakage occurs. To avoid contaminating your centrifuge:
  - Check glass and plastic centrifuge tubes for stress lines, hairline cracks and chipped rims before use. Use unbreakable tubes whenever possible;
  - Avoid filling tubes to the rim;
  - Use caps or stoppers on centrifuge tubes. Avoid using lightweight materials such as aluminium foil as caps;
  - Use sealed centrifuge buckets (safety cups) or rotors that can be loaded and unloaded in a biological safety cabinet. Decontaminate the outside of the cups or buckets before and after centrifugation. Inspect o-rings regularly and replace if cracked or dry;
  - Ensure that the centrifuge is properly balanced;
  - Do not open the lid during or immediately after operation, or attempt to stop a spinning rotor by hand or with an object, or interfere with the interlock safety device;
  - Decant supernatants carefully and avoid vigorous shaking when re-suspending.

When using high-speed or ultra centrifuges, additional practices should include:

- Connect the vacuum pump exhaust to a trap;

- Record each run in a logbook: keep a record of speed and run time for each rotor;
- Never exceed the specified speed limitations of the rotor.
- **Heating baths, water baths:** Heating baths keep immersed materials at a constant temperature. They may be filled with a variety of materials, depending on the bath temperature required; they may contain water, mineral oil, glycerine, paraffin or silicone oils, with bath temperatures ranging up to 300°C. The following precautions are appropriate for heating baths:

  - set up on a stable surface, away from flammable and combustible materials including wood and paper;
  - relocate only after the liquid inside has cooled;
  - ensure baths are equipped with redundant heat controls or automatic cut-offs that will turn off the power if the temperature exceeds a preset limit;
  - use with the thermostat set well below the flash point of the heating liquid in use;
  - equip with a thermometer to allow a visual check of the bath temperature. The most common heating bath used in laboratories is the water bath. When using a water bath:
    - .. clean regularly; a disinfectant, such as a phenolic detergent, can be added to the water;
    - .. avoid using sodium azide to prevent growth of micro-organisms; sodium azide forms explosive compounds with some metals;
    - .. raise the temperature to 90°C or higher for 30 minutes once a week for decontamination purposes;
    - .. unplug the unit before filling or emptying, and have the continuity-to-ground checked regularly.
- **Shakers, blenders and sonicators:** When used with infectious agents, mixing equipment such as shakers, blenders, sonicators, grinders and homogenisers can release significant amounts of hazardous aerosols, and should be operated inside a biological safety cabinet whenever possible. Equipment such as blenders and stirrers can also produce large amounts of flammable vapours. The hazards associated with this type of equipment can be minimised by:

- selecting and purchasing equipment with safety features that minimise leaking;
  - selecting and purchasing mixing apparatus with non-sparking motors;
  - checking integrity of gaskets, caps and bottles before using. Discard damaged items;
  - allowing aerosols to settle for at least one minute before opening containers;
  - when using a sonicator, immersing the tip deeply enough into the solution to avoid creation of aerosols;
  - decontaminating exposed surfaces after use.
- **Ovens and hot plates:** Laboratory ovens are useful for baking or curing material, off-gassing, dehydrating samples and drying glassware. However, care should be taken to:
    - Select and purchase an oven whose design prevents contact between flammable vapours and heating elements or spark-producing components;
    - Discontinue use of any oven whose backup thermostat, pilot light or temperature controller has failed;
    - Avoid heating toxic materials in an oven unless it is vented outdoors (via a canopy hood, for example);
    - Never use laboratory ovens for preparation of food for human consumption;
    - Glassware that has been rinsed with an organic solvent should be rinsed with distilled water before it is placed in a drying oven.
- **Analytical equipment:** The following instructions for safe use of analytical equipment are general guidelines; consult the users' manual for more detailed information on the specific hazards:
    - Ensure that installation, modification and repairs of analytical equipment are carried out by authorised service personnel;
    - Read and understand the manufacturer's instructions before using this equipment;
    - Make sure that preventive maintenance procedures are performed as required;
    - Do not attempt to defeat safety interlocks;
    - Wear safety glasses and laboratory coats (and other appropriate PPE as specified) for all procedures.

- **Gas chromatographs (GC):** Gas chromatography requires handling compressed gases (nitrogen, hydrogen, argon, helium), and flammable and toxic chemicals. Consult product MSDS before using such hazardous products. Specific precautions for working with gas chromatographs include:
  - Perform periodic visual inspections and pressure leak tests of the sampling systems, plumbing, fittings and valves;
  - Follow the manufacturer's instructions when installing columns. Glass or fused capillary columns are fragile: handle them with care and wear safety glasses to protect eyes from flying particles while handling, cutting or installing capillary columns;
  - Turn off and allow heated areas such as the oven, inlet and detector, as well as connected hardware, to cool down before touching them;
  - To avoid electrical shock, turn off the instrument and disconnect the power cord at its receptacle whenever the access panel is removed;
  - Turn off the hydrogen gas supply at its source when changing columns or servicing the instrument;
  - When using hydrogen as fuel (flame ionisation FID and nitrogen-phosphorus detectors NPD), ensure that a column or cap is connected to the inlet fitting whenever hydrogen is supplied to the instrument to avoid build-up of explosive hydrogen gas in the oven;
  - Measure hydrogen gas and air separately when determining gas flow rates;
  - Perform a radioactive leak test (wipe test) on electron capture detectors (ECDs) at least every six months for sources of 50MBq (1,35 mCi) or greater;
  - Ensure that the exhaust from ECDs is vented to the outside;
  - When performing split sampling, connect the split vent to an exhaust ventilation system or appropriate chemical trap if toxic materials are analysed or hydrogen is used as the carrier gas;
  - Use only helium or nitrogen gas, never hydrogen, to condition a chemical trap.
  
- **High-pressure liquid chromatography (HPLC) equipment:** HPLC procedures may require handling of compressed gas (helium) and flammable and toxic chemicals. Familiarise yourself with the

hazardous properties of these products, as well as recommended precautionary measures, by referring to MSDS, and:

- Inspect the drain system regularly; empty the waste container frequently when using organic solvents;
- Ensure that waste collection vessels are vented;
- Never use solvents with auto-ignition temperatures below 110°C;
- Be sure to use a heavy walled flask if you plan to use vacuum to degas the solvent;
- Never clean a flow-cell by forcing solvents through a syringe: syringes under pressure can leak or rupture, resulting in sudden release of syringe contents;
- High voltage and internal moving parts are present in the pump. Switch off the electrical power and disconnect the line cord when performing routine maintenance of the pump;
- Shut down and allow the system to return to atmospheric pressure before carrying out maintenance procedures.

## 10. Emergency processes

Every laboratory will experience an accident, minor or major, involving hazardous agents or conditions at some time during its operation. During these incidents, laboratory personnel may be placed at high risk. Many laboratories may be ill-prepared to meet and control these emergencies because they have not integrated safety as an essential part of each laboratory operation. This involves creating emergency contingency plans based on the potential emergencies identified, and periodically undergoing training in preparation for possible emergencies. This section outlines guidelines for various emergencies that could happen in a laboratory. It is also recommended there be a laboratory representative for each of the emergencies outlined below, who has been properly trained to handle/co-ordinate the emergency procedure on behalf of the laboratory.

- **First aid:** Know how to handle emergency situations before they occur:
  - Become familiar with the properties of the hazardous products used in your area;
  - Familiarise yourself with the contents of the first aid kit and learn how to use each item. Ensure that instructions are readily available and easy to understand;

- Locate and know how to test and operate emergency equipment, such as showers and eyewashes, in your area;
  - Learn first aid: Contact an appropriate organisation for first aid training. The emergency first aid procedures described below should be followed by a consultation with a physician for medical treatment.
- **Burns:** In the laboratory, thermal burns may be caused by intense heat, flames, molten metal, steam, etc. Corrosive liquids or solids such as bases and acids can cause chemical burns; first aid treatment for chemical burns is described in sub-section: *Chemical splashes to the skin or eyes*, below. In electrical burns, electrical current passing through the body generates heat.
  - Burns to the skin: First aid treatment of skin burns encompasses the following:
    - .. If the burn is electrical in origin, ascertain that the victim is not in contact with the power supply before touching him/her. If the victim remains in contact with a power source, unplug the device or shut off the main power switch at the electrical distribution panel;
    - .. Dial the emergency number if the burn is serious. Seek immediate medical treatment for all electrical burns, even if they don't appear to be serious;
    - .. Remove jewellery, including watches, from the burned area;
    - .. Expose the burnt area, but avoid removing clothes that are stuck to the skin;
    - .. If possible, immerse burnt surfaces in cold water for at least 10 minutes, or apply cold wet packs;
    - .. Avoid applying lotions, ointments or disinfectants to a burn. First and second degree burns can be washed with soap and water after the cool down period;
    - .. Cover first and second degree burns with a moist bandage; apply dry compresses to third degree burns and to entry and exit wounds of electrical burns;
    - .. Do not burst blisters, as they form a natural barrier against infection.
  - Burns to the eyes: Burns to the eyes may be caused by chemical substances, heat (hot liquids, steam, open flames, molten metal, etc.), or radiation from welding procedures, laboratory lamps and lasers. Burns caused by ultraviolet, visible or near-infrared radiation may not produce symptoms until 6-8 hours after

exposure. First aid procedures for chemical burns to the eyes are described in sub-section *Chemical splashes to the skin or eyes*, below. General first aid procedures for thermal and radiation burns to the eyes are as follows:

- .. Prevent the victim from rubbing or touching the eyes;
  - .. For heat burns, flush the eyes with cool water until the pain subsides;
  - .. Cover the eyes with dry sterile gauze pads; apply a wet compress to the eyes if it is too painful to close them;
  - .. Send the victim for medical care. If the burn is the result of exposure to a laser beam, advise emergency medical personnel of the characteristics of the laser and the distance between the victim and the laser.
- **Cuts:** First aid treatment for minor scrapes, scratches, cuts, lacerations or puncture wounds include the following:
    - wash the wound and surrounding area with mild soap and running water;
    - remove any dirt around the wound;
    - cover with an adhesive dressing or gauze square taped on all sides with adhesive tape;
    - wounds caused by dirty, soiled or grimy objects should be examined by a physician, who will determine whether a tetanus immunisation is needed;
    - if the wound was caused by an object that has contacted human blood or body fluids, the victim must be seen by a physician immediately, as immunisation or post-exposure prophylaxis may be required;
    - If a wound is bleeding profusely, the first aider should attempt to stop the bleeding as quickly as possible;
    - Elevate the injured area above the level of the heart, if possible, in order to reduce the blood pressure to the area of the wound;
    - Apply direct pressure to the wound unless an object is protruding from it (in this situation, apply pressure around the injury). Direct pressure can be applied with the fingers of the hand, the palm of the hand or with a pressure dressing;
    - If bleeding cannot be controlled with direct pressure, apply pressure to the arteries supplying the injured area. This involves compressing the artery between the wound and the heart, against a bone;

- Do not remove a dressing that has become soaked with blood, as this may interrupt the clotting process; apply an additional dressing on top of the first;
  - Avoid over-tightening of the dressing; i.e. do not cut off the blood circulation to limbs;
  - As a tourniquet completely stops the flow of blood to beyond the point of application, it should be applied only as a last resort, as in the case of a severed limb.
- **Chemical splashes to the skin or eyes:**
    - For splashes to the skin:
      - .. If the splash affects a large area of skin, go to the nearest shower and rinse thoroughly for at least 20 minutes; remove contaminated clothing while in the shower;
      - .. For splashes involving a small skin area, proceed to the nearest drench hose, remove contaminated clothing and jewellery and rinse for 15 minutes.
    - For splashes to the eyes:
      - .. Go to the nearest eyewash and rinse for at least 20 minutes;
      - .. If you are wearing contact lenses, remove them as quickly as possible, while continuing to flush;
      - .. Hold your eyelids open with your fingers;
      - .. Roll your eyeballs so that water can flow over the entire surface of the eye;
      - .. Lift your eyelids frequently to ensure complete flushing;
      - .. Cover the injured eye with dry sterile gauze pads while waiting for medical attention.
  - **Poisoning:** As described in Section on the *Handling and use of chemicals*, toxic substances can enter and poison the body by inhalation, absorption through the skin, ingestion or injection. When assisting a victim of poisoning:
    - if serious poisoning occurs, call an ambulance ;
    - ensure that the area is safe to enter before attempting to aid the victim;
    - move the victim away from the contaminated area and provide first aid as required;

- do not induce vomiting unless advised to do so by a reliable authority;
  - provide emergency medical personnel with the MSDS for the poisonous product. If the victim was overcome by an unknown poison and has vomited, provide the ambulance technicians with a sample of the vomit;
  - always ensure that the victim receives medical attention, even if the exposure seems minor.
- **Fires:** The immediate response depends on the size of the fire. Laboratory personnel should attempt to extinguish a fire only if it is clearly safe to do so.
    - Suspected fires: All staff should familiarise themselves with the locations of the fire alarms and evacuation routes in the areas that they occupy. Anyone discovering smoke, a strong smell of burning or any smell of an unusual nature, should immediately:
      - .. Inform security personnel;
      - .. Alert the building emergency warden, building service person or building director.
    - Known fires:
      - .. Shout "FIRE!" loudly and repeatedly to give the alert;
      - .. Activate the fire alarm;
      - .. Telephone the nearest fire department from a safe location by dialling the national emergency number;
      - .. Evacuate the premises in a swift, orderly fashion using the stairways and/or fire escapes, but NOT the elevators, and follow the instructions of evacuation monitors;
      - .. Inform the building emergency warden of the location, magnitude and nature (e.g. electrical) of the fire, the open evacuation routes, individuals requiring assistance, and other pertinent details. Once outside the building, move away from the doors to enable others to exit.
    - Clothing fires: If your clothing should catch fire, it is important not to run, as this would provide additional air to support the flames. Remember the "Stop, Drop and Roll" rule:
      - .. **Stop** where you are;
      - .. **Drop** to the floor; and
      - .. **Roll** to smother the flames.
-

As soon as the flames are extinguished, go to the nearest emergency shower to cool burned areas with copious amounts of water. If someone else is on fire:

- .. Immediately immobilise the victim and force him/her to roll on the ground to extinguish the flames;
  - .. Assist in smothering the flames, using whatever is immediately available, such as a fireproof blanket or clothing;
  - .. Give appropriate first aid (refer to sub-section on first aid above).
- **Hazardous chemical spills:** In the event of a spill of a hazardous (volatile, toxic, corrosive, reactive or flammable) chemical, the following procedures should be followed:
    - If there is fire, pull the nearest alarm. If you are unable to control or extinguish a fire, follow the fire evacuation procedures, as described in section **Fire and Gas Safety** (sub-section Evacuations);
    - If you attempt to stop the spillage from continuing, make sure it is safe to do so and make sure you are wearing the appropriate PPE;
    - If the spill is in a laboratory or chemical storeroom:
      - .. Evacuate all personnel from the room;
      - .. Be sure the hood/local exhaust is turned on;
      - .. If flammable liquids are spilled, disconnect the electricity to sources of ignition if possible;
      - .. Call the building emergency telephone number to request additional assistance if you cannot manage the clean-up yourself;
    - If the spill is in a corridor or other public passageway:
      - .. Evacuate all people from the area and close off the area to keep others out;
      - .. Call the emergency telephone number to have the air system in the area shut down (to prevent contamination of other areas) and to request additional assistance.

*Note: More detailed information on spill clean-up action is available in Appendix C - The management and interpretation of Material Safety Data Sheets.*

- Natural gas leaks: Have the natural gas valves closed if the gas is not in use. If gas is in use, and a natural gas smell is detected:
  - .. Check that all gas valves have been turned off;
  - .. Call the local emergency number if the odour persists;
  - .. Dial the local /national emergency number if proven that there is a confirmed gas leak.
- Practise drills: All emergency drills should be tested periodically. The objectives of a drill shall include evaluation of the following:
  - .. Practicality of the plan (structure and organisation);
  - .. Adequacy of communications and interactions among parties;
  - .. Emergency equipment effectiveness;
  - .. Adequacy of first aid and rescue procedure;
  - .. Adequacy of emergency personnel response and training;
  - .. Public relations skills;
  - .. Evacuation and personnel count procedures. Note that the complexity of the drill may be increased as the response team gains efficiency.

## 11. References

1. [http://www.mcgill.ca/ehs/laboratory/labsafety/#cli\\_5.1](http://www.mcgill.ca/ehs/laboratory/labsafety/#cli_5.1).
2. Handbook of laboratory safety (3rd Edition, CRC Pres).
3. CSIR Built Environment (Building 2): BBUILTENV/BLDG 2/T/OP/001/2005.
4. **Nemchin RG and Brusick DJ**, 1985, *Basic principles of laboratory safety*, Environmental Mutagenesis 7, pp 947-971.
5. **Evans PG, McAlinden, JJ and Griffin P**, 2001, *Personal Protective Equipment and dermal exposure*, Applied Occupational and Environmental Hygiene, Volume 16 (2), pp 334-337.
6. *Laboratory safety manual Part C: Physical Testing*, April 2005.
7. *Laboratory safety manual*: California Department of Transportation, April 2005.
8. The University of Queensland Australia, Occupational Health & Safety Unit, *Guidelines for the safe storage of chemicals*, Revised June 2007, pp 1-5.
9. J. Hazardous Material, 1, 334, 1975.

## Appendix B - Recommendations for solvent storage

### 1. Introduction

Many of the guidelines/rules set out in Appendix B, are further circumscribed or superseded by the legislative requirements as set out in the OHS Act and Regulations as applicable.

Operations involving the handling of solvents or chemicals in general, whether they are small quantities of pure or concentrated substances or large quantities of more dilute materials, provide the setting for accidental release into the environment. Laboratory storage practices may enhance or diminish overall laboratory safety. There are many factors to be considered during storage of chemicals such as the amount, location and organisation of the stored chemicals as well as packaging and labelling. However there are general guidelines when it comes to laboratory storage.

### 2. General storage guidelines

- Do not block access to emergency safety equipment such as fire extinguishers, eye wash bottles, showers, first aid kits or utility controls such as breaker boxes or gas shut-off valves;
- Avoid blocking exits or normal paths of travel: keep hallways, walkways and stairs clear of chemicals, boxes, equipment and shelf projections;
- Ensure that the weight of stored material does not exceed the load-bearing capacity of shelves or cabinets;
- Ensure that wall-mounted shelving has heavy-duty brackets and supports and is attached to studs or solid blocking. Regularly inspect clamps, supports, shelf brackets and other shelving hardware;
- Arrange items so that they do not overhang or project beyond the edges of shelves or counter tops;
- Do not stack materials so high that stability is compromised;
- Leave a minimum of 45,7 cm of clearance between sprinkler heads and the top of storage;

- Use a safety step or stepladder to access higher items; never stand on a stool or a chair;
- Store frequently used items between knee and shoulder height;
- Store heavy objects on lower shelves;
- Store hazardous chemicals in an area that is accessible only to authorised laboratory workers;
- Minimise quantities and container sizes kept in the laboratory commensurate with their usage and shelf-life;
- Do not store chemicals in aisles, under sinks or on floors, desks or bench tops;
- Store chemicals away from sources of heat (e.g. ovens or steam pipes) and direct sunlight - substances which are temperature sensitive may require storage in a controlled temperature environment with contingency plans in the event of power-failure;
- Never stack bottles on top of each other;
- Do not store chemicals above eye level/shoulder height;
- Store larger containers on lower shelves;
- Store liquids inside chemically-resistant secondary containers (such as trays or tubs) that are large enough to hold spills, and ensure that chemical containers and their seals or stoppers are appropriate for the type and quantity of chemical stored (as far as is practicable, chemicals should be stored in the containers in which they are supplied);
- Containers that have held hazardous chemicals should be treated as full, unless the receptacle or package has been rendered free from hazardous chemicals;
- Store chemicals inside closable cabinets or on sturdy shelving that has 12,7 mm - 19 mm edge guards to prevent containers from falling;
- Ensure that chemicals cannot fall off the rear of shelves;
- Store chemicals based on compatibility and not in alphabetical order (refer to Table 1, 2 and 3 below). If a chemical presents more than one hazard, segregate according to the primary hazard;
- Designate specific storage areas for each class of chemical, and return reagents to those locations after each use. The amounts stored in laboratory areas should be kept to a minimum;
- Store volatile toxic and odorous chemicals in a way that prevents release of vapours (e.g. inside closed secondary containers, ventilated cabinets, paraffin sealing);
- Store flammables requiring refrigeration in explosion-safe or laboratory-safe refrigerators;

- All packages in storage should be labelled to allow unmistakable identification of the contents (see Appendix A);
- Opening of packages, transferring of contents, dispensing of chemicals or sampling should not be conducted in or on top of a cabinet or a cupboard for storing chemicals unless it is specifically designed for this purpose and appropriate procedures and equipment are used;
- Label reactive or unstable chemicals (e.g. ethers) with the date of receipt and the date opened;
- Inspect chemicals weekly for signs of deterioration and for label integrity. Leaking or damaged packages should be removed to a safe area for repacking or disposal, labels should be reattached or replaced, as necessary, to clearly identify the contents of the package;
- Dispose of unwanted chemicals promptly through the waste management programme;
- Procedures must be established to deal with clean-up and safe disposal of spillages (spill-kit should be readily accessible);
- Keep inventory records of chemicals, and update annually.

### 3. Chemical compatibility

The storage scheme outlined in the sub-section **Chemical segregation** may not suffice to prevent mixing of incompatible chemicals. Certain hazardous combinations can occur even between chemicals of the same classifications. Tables 1 and 2 on the following pages give examples, respectively, of which chemical groups should not be stored together, and common examples of incompatible chemical combinations:

**Table 1. Compatible chemical groups**

Number	Chemical group	Do not store with group numbers:
1	Inorganic acids	2-8,10,11,13,14,16-19,21,22,23
2	Organic acids	1,3,4,7,14,16,17-19,22
3	Caustics	1,2,6,7,8,13-18,20,22,23
4	Amines and alkanolamines	1,2,5,7,8,13-18,23
5	Halogenated compounds	1,3,4,11,14,17
6	Alcohols, glycols and glycol ethers	1,7,14,16,20,23
7	Aldehydes	1-4,6,8,15-17,19,20,23
8	Ketones	1,3,4,7,19,20
9	Saturated hydrocarbons	20
10	Aromatic hydrocarbons	1,20
11	Olefins	1,5,20
12	Petroleum oils	20
13	Esters	1,3,4,19,20
14	Monomers, polymerisable esters	1-6,15,16,19-21,23
15	Phenols	3,4,7,14,16,19,20
16	Alkylene oxides	1-4,6,7,14,15,17-19,23
17	Cyanohydrins	1-5,7,16,19,23
18	Nitriles	1-4,16,23
19	Ammonia	1-2,7,8,13-17,20,23
20	Halogens	3,6-15,19,21,22
21	Ethers	1,14,20
22	Elemental phosphorous	1-3,20
23	Acid anhydrides	1,3,4,6,7,14,16-19

**Table 2. Examples of incompatible combinations of some commonly used chemicals**

Chemical	Ensure no contact with
Ascectic acid	chromic acid, nitric acid, hydroxyl compounds, perchloric acid, peroxides, permanganate
Acetylene	chlorine, bromine, copper, fluorine, silver, mercury
Alkali metals (e.g. sodium)	water, chlorinated hydrocarbons, carbon dioxide, halogens
Ammonia, anhydrous	mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium nitrate	acids, metal powders, flammable liquids, chlorates, nitrites, sulphur, finely divided combustible materials
Aniline	nitric acid, hydrogen peroxide
Bromine	same as chlorine
Carbon, activated	calcium hypochlorite, all oxidising agents
Chlorates	ammonium salts, acids, metal powders, sulphur, finely divided combustible materials
Chromic acid	ascetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids
Chlorine	ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Copper	acetylene, hydrogen peroxide
Flammable liquids	ammonium nitrate, inorganic acids, hydrogen peroxide, sodium peroxide, halogens
Hydrocarbons	fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydroflouric acid	anhydrous ammonia, ammonium hydroxide
Hydrogen peroxide	copper, chromium, iron, most metals or their salts, alcohols, acetone, aniline, nitromethane, flammable liquids, oxidising gases
Hydrogen sulphide	fuming nitric acid, oxidising gases
Iodine	acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	acetylene, fulminic acid, ammonia
Nitric acid	acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulphide, flammable liquids, flammable gases
Oxalic acid	silver, mercury
Perchloric acid	acetic anhydride, bismuth and its alloys, organic materials

Potassium	carbon tetrachloride, carbon dioxide, water
Potassium chlorate	sulphuric and other acids
Potassium permanganate	glycerin, ethylene glycol, benzaldehyde, sulphuric acid
Silver	acetylene, oxalic acid, tartaric acid, ammonia compounds
Sodium peroxide	alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulphide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulphuric acid	potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium, etc.)

- Read the label carefully before storing a chemical. More detailed storage information is usually provided by the MSDS;
- Ensure that incompatible chemicals are not stored in close proximity to each other. Separate certain chemicals from each other according to the segregation scheme in Table 3. Note that in some instances chemicals of the same category may be incompatible. The following storage recommendations are given to avoid the possibility of an explosion or the emission of toxic flammable or corrosive gases:
  - Store two incompatible goods at least 3m apart;
  - Store goods that could react violently at least 5m apart. For more detailed information refer to the reactivity section of the MSDS or a reference manual on reactive chemical hazards.

**Table 3. Suggested segregation for chemical storage**

<b>Flammables</b>	<b>Non-flammable solvents</b>
<p>Store in grounded flammable liquid storage cabinet Separate from oxidising materials</p> <p>Examples: Acetone Ethanol Glacial acetic acid</p>	<p>Store in cabinet Can be stored with flammable liquids Separate from oxidising materials</p> <p>Examples: Carbon tetrachloride Ethylene glycol Mineral oil</p>
<b>Acids</b>	<b>Caustics</b>
<p>Store in cabinet of non-combustible material Separate oxidising acids from organic acids Separate caustics, cyanides and sulphides</p> <p>Examples: Nitric acid Hydrochloric acid Sulphuric acid</p>	<p>Store in a dry area</p> <p>Separate from acids</p> <p>Examples: Ammonium hydroxide Sodium hydroxide Potassium hydroxide</p>
<b>Water reactive chemicals</b>	<b>Oxidisers</b>
<p>Store in a cool, dry location Separate from aqueous solutions Protect from fire sprinkler water</p> <p>Examples: Sodium Potassium Lithium</p>	<p>Store in cabinet of non-combustible material Separate from flammable and combustible materials</p> <p>Examples: Sodium hypochlorite Benzoyl peroxide Potassium permanganate</p>
<b>Non-oxidising compressed gases</b>	<b>Oxidising compressed gases</b>
<p>Store in well-ventilated area Separate physically from oxidising compressed gases</p> <p>Examples: Nitrogen Hydrogen Carbon dioxide</p>	<p>Separate physically from flammable compressed gases</p> <p>Examples: Oxygen Chlorine Nitrous oxide</p>

## 4. Unstable chemicals

Many chemicals (most notably ethers such as THF, dioxane, diethyl and isopropyl ether) are susceptible to decomposition resulting in explosive products. Ethers, liquid paraffins, and olefins form peroxides on exposure to air and light. Since most of these products have been packaged in an air atmosphere, peroxides can form even if the containers have not been opened.

- Discard unopened containers of ethers after one year;
- Discard containers of ethers within six months of opening;
- Never handle ethers beyond their expiry dates; contact your local waste disposal coordinator to arrange to have the material stabilised and removed.

The following are common examples of compounds prone to peroxide formation:

- Cyclohexene
- Dicyclopentadien
- Diethyl ether (ether)
- Dimethyl ether
- Dioxane
- Isopropyl ether
- Tetrahydrofuran (THF)

The label and MSDS will also indicate if a chemical is unstable.

## 5. Explosive chemicals

Many chemicals are susceptible to rapid decomposition or explosion when subjected to forces such as being struck, vibrated, agitated or heated. Some become increasingly shock sensitive with age. Picric acid becomes shock sensitive and explosive if it dries out.

- Refer to the label and the MSDS to determine if a chemical is explosive;
- Write the dates received and opened on all containers of explosive or shock-sensitive chemicals;
- Inspect all such containers every month;

- Keep picric acid solutions wet i.e. 30% or more water;
- Discard opened containers after six months and closed containers after one year, unless the material contains stabilisers;
- Wear appropriate PPE and perform experiments behind a face shield;
- Work with small quantities.

The following are atomic groupings that are associated with the possibility of explosion:

- |                                       |   |
|---------------------------------------|---|
| <input type="checkbox"/> acetylide;   | <input type="checkbox"/> hydroperoxide; |
| <input type="checkbox"/> amine oxide; | <input type="checkbox"/> nitrate;       |
| <input type="checkbox"/> azide        | <input type="checkbox"/> nitrite;       |
| <input type="checkbox"/> chlorate;    | <input type="checkbox"/> nitroso;       |
| <input type="checkbox"/> diazo;       | <input type="checkbox"/> nitro;         |
| <input type="checkbox"/> diazonium;   | <input type="checkbox"/> ozonide;       |
| <input type="checkbox"/> fulminate    | <input type="checkbox"/> perchlorate;   |
| <input type="checkbox"/> N-haloamine; | <input type="checkbox"/> peroxide;      |
| <input type="checkbox"/> hypohalite   | <input type="checkbox"/> picrate        |

The following are common examples of materials known to be shock-sensitive and explosive:

- |  |  |
|--|--|
| <input type="checkbox"/> ammonium nitrate;     | <input type="checkbox"/> lead azide;             |
| <input type="checkbox"/> ammonium perchlorate; | <input type="checkbox"/> nitroglycerine;         |
| <input type="checkbox"/> copper acetylide;     | <input type="checkbox"/> picric acid (when dry); |
| <input type="checkbox"/> dinitrotoluene;       | <input type="checkbox"/> trinitrotoluene.        |
| <input type="checkbox"/> fulminate of mercury; |  |

## 6. Chemical storage cabinets

Flammable chemicals should be stored inside flammable liquid storage cabinets. Only those flammables in use for the day should be outside the cabinet. Guidelines for cabinet use include:

- Use authority-approved flammable liquid storage cabinets;
- Keep cabinet doors of the cabinet closed and latched;
- Do not store other materials in these cabinets.

Areas containing flammable vapours or combustible dusts should be classified according to hazard zone assessment. Once classified, it is the organisation's responsibility to make sure the area is suitably equipped to handle the respective danger. The relevant requirements concerning avoidance of ignition sources are recommended depending on whether these flammables are part of the normal/abnormal operations and whether the ignition source is controlled.

Chemicals kept on shelves or racks shall be subject to the following conditions:

- Shelving and its fixtures shall be compatible with the goods stored, or shall be suitably protected from the goods;
- The maximum holding capacity of the shelving systems shall not be exceeded;
- Shelves used for chemical storage shall be restrained against lateral movement and shall have lips on them to prevent containers being pushed through to the other side.

Chemical storage cabinets are required for the storage of dangerous goods exceeding storage limit quantities. Chemicals kept in cabinets shall comply with the following requirements:

- When storing flammable substances, the contents of the cabinet shall not exceed 100ℓ. If a 250ℓ cabinet is used for the storage, it must be de-rated. This involves removing some of the shelving and placing a sticker over the manufacturer's capacity rating, so that it is clear that 100ℓ is the maximum cabinet capacity;
- All new installations of flammable solvent cabinets must be mechanically ventilated as per regulations. There is no requirement for venting of cabinets containing other classes of dangerous goods;
- The capacity of any chemical storage cabinet used in a laboratory to store chemicals that are either flammable solids, spontaneously combustible, dangerous when wet, oxidising agents and/or organic peroxides is recommended not to exceed 50ℓ;
- Within a radius of 10m, measured from any one cabinet, the cabinet storage capacity aggregated for all cabinets in that radius shall not exceed 250ℓ or 250kg, including no more than 10ℓ or 10kg each of dangerous goods that are either flammable solids, spontaneously combustible, dangerous when wet, oxidising agents and/or organic

peroxides. The radius shall be measured horizontally through intervening walls, unless those walls are able to prevent the spreading of a fire of the magnitude that could be expected to result from the contents of the cabinet(s);

- Cabinets shall not be located:
  - One above the other;
  - Where they can jeopardise emergency escape (minimum 3m);
  - Under stairs or in corridors;
  - The spill catchment/bund of cabinets must not be used to store chemicals;
  - Where possible, store chemicals on spill trays within cupboards or cabinets

Chemical storage rooms must be purpose built and comply with the requirements of regulations. This standard allows for the storage of chemicals in quantities that exceed the quantities permitted to be kept on laboratory shelves or in chemical storage cabinets in the laboratory.

## 7. Flammable solvent storage limits

When a fire or explosion occurs in a laboratory, a major concern is to reduce the amount of fuel available to support the fire. Many solvents commonly used in laboratories are highly flammable, and should even a small quantity become involved in the fire, it would have the capacity of significantly increasing the probability of the fire spreading. Consult the OHS Act (Occupational Health and Safety Act, General Safety Regulations 4: *Use and storage of flammable liquids* and; *Hazardous Chemical Substances Regulations*, 1995<sup>14</sup>.

**Labelling, packaging, transportation and storage:** Place restrictions on the maximum amounts of flammable liquids allowed to be stored, depending on class, in flammable material storage cabinets within a room and defines the maximum size of individual containers for the various classes of flammables.

## 8. References

Refer to page 76.

## Appendix C - The management and interpretation of MSDS (for bituminous products laboratories)

### 1. Introduction

Always review the chemical safety information, including the MSDS before starting to work with any new or unfamiliar cleaning product or chemical.

MSDS provide information about precautions for protection against known hazards associated with the material and often include useful information on chemical, physical, and toxicological and ecological properties, along with suggestions for storing, transporting, and disposing of chemicals. MSDS are a general source of information, and they should be consulted as a first step in assessing the risk associated with using a product or chemical. However, because there is currently no mandated international standard format for MSDS, their quality varies widely depending upon manufacturer, and the information they contain may be inappropriate for all applications. It should be noted, however, that there is a national standard for MSDS as outlined in the Hazardous Chemical Substances Regulations, 1995 9A, *Handling of hazardous chemical substances*.

Exercise caution, and utilise non-MSDS sources of information, such as the internet. (See also the list at the end of **Glossary of Terms** below). Never use a chemical product if there is doubt about how to handle or use it. You should always consult with your Health, Safety and Environmental (HSE) professionals if you have health, safety or environmental questions. Consult with your supplier when you have application questions.

### 2. Definitions of typical technical terms contained within an MSDS (local and international versions)

**action level** - exposure level at which any specified exposure limit takes effect;

**acute effect** - involves severe symptoms which develop rapidly and may quickly reach a crisis;

**acute exposure** - a short-term exposure usually occurring at high concentration;

**acute hazard** - a single exposure that may cause harm, but which is unlikely to lead to permanent damage;

**acute health effect** - an effect that develops either immediately or a short time after exposure;

**allergic contact dermatitis** - type of skin hypersensitivity. Its onset may be delayed by several days to as much as several years, for weaker sensitizers. Once sensitized, fresh exposure to the sensitizing material can trigger itching and dermatitis within a few hours;

**Ames test** - used to assess whether a chemical might be a carcinogen. It assumes that carcinogens possess mutagenic activity, and uses bacteria and mammalian microsomes to determine whether a chemical is a mutagen. Approximately 85% of known carcinogens are mutagens. The Ames test, therefore, is a helpful but not perfect predictor of carcinogenic potential;

**argyria or argyrisms** - an irreversible bluish-black discoloration of the skin, mucous membranes or internal organs caused by ingestion of, or contact with, various silver compounds;

**auto-ignition temperature (of a chemical)** - the lowest temperature at which the material will ignite without an external source of ignition;

**breakthrough time** - the time taken in standard tests for permeation of a chemical through a protective barrier (such as a rubber glove) to be detected;

**boiling point** - the temperature at which a liquid changes to a gas, at normal atmospheric pressure;

**carcinogen** - chemical known or believed to cause cancer in humans. The number of known carcinogens is comparatively small, but many more chemicals are suspected to be carcinogenic;

**CAS registry number** - a unique, identifying number assigned to a chemical by the Chemical Abstracts Service (CAS);

**chemical formula** - sometimes called the molecular formula, indicates the elements that make up a chemical;

**chemical name** - a proper scientific name for the active ingredient of a product;

**coefficient of oil/water distribution** - the ratio of the solubility of the chemical in an oil to its solubility in water;

**combustible liquid** - a liquid which has a flash point above 37,8C (100F);

**compressed gas** - a material which is a gas at normal room temperature (20°C) and pressure but is packaged as a pressurized gas, dissolved gas or gas liquefied by compression or refrigeration;

**condensation** - the process of reducing from one form to another denser form such as steam to water;

**corrosive material** - a material that can attack (corrode) metals or cause permanent damage to human tissues such as skin and eyes on contact;

**COSHH (Control of Substances Hazardous to Health - USA/UK)** - COSHH regulations impose a number of obligations on employers; the objective of the regulations is to promote safe working with potentially hazardous chemicals. (South Africa has its own version known as the Hazardous Chemical Substances Regulations);

**cryogenics** - materials that exist at extremely low temperatures, such as liquid nitrogen;

**cutaneous hazard** - a chemical that may cause harm to the skin, such as defatting, irritation, skin rashes or dermatitis;

**degradation** - term generally used to describe the loss of resilience of material used for protective gloves. Degradation may cause the material to soften, swell, become hard and brittle, or - in severe cases - disintegrate;

**density** - the weight of a material in a given volume. It is usually given in grams per millilitre (g/ml);

**dilution ventilation** - dilution of contaminated air with uncontaminated air in a general area, room or building for the purposes of health hazard or nuisance control, and/or for heating and cooling;

**dose** - amount of the agent that has entered the body through the various routes of entry;

**DoT** - Common abbreviation for the U.S. Department of Transportation, which regulates the transport of chemicals in the U.S.A.

- DOT hazard codes:
  - 1 Explosives;
  - 2.1 Flammable gas;
  - 2.2 Non-flammable gas;
  - 2.3 Poisonous gas;
  - 3 Flammable liquid;
  - 4.1 Flammable solid;
  - 4.2 Spontaneously combustible;
  - 4.3 Dangerous when wet;
  - 5.1 Oxidiser;
  - 5.2 Organic peroxide;
  - 6.1 Poison- keep away from food;
  - 6.2 Infectious material;
  - 7 Radioactive;

- 8 Corrosive;
- 9 Miscellaneous.

**ED50 (Effective Dose 50)** - the amount of material required to produce a specified effect in 50% of an animal population. (See qualification in the definition of LD50).

**EINECS** - acronym for European Inventory of Existing Commercial Chemical Substances.

**ELINCS** - acronym for European List of Notified Chemical Substances;  
**embryotoxins** - retard the growth or affect the development of the unborn child. In serious cases they can cause deformities or death. Mercury compounds and certain heavy metals, aflatoxin, formamide and radiation are known embryotoxins;

**etiologic agents** - microscopic organisms such as bacteria or viruses, which can cause disease;

**evaporation rate** - the rate at which a liquid changes to vapor at normal room temperature;

**explosive (flammable) limits** - the Lower Explosive Limit (LEL) is the lowest concentration of vapour in air which will burn or explode upon contact with a source of ignition. The Upper Explosive Limit (UEL) is the highest concentration of vapour in air which will burn or explode upon contact with a source of ignition;

**explosive (flammable) range** - the range between the LEL and the UEL;

**exposure limits** - established concentrations which, if not exceeded, will not generally cause adverse effects to the worker exposed. Exposure limits differ in name and meaning depending on origin. For example: Permissible Exposure Levels (PELs) are legally enforceable exposure limits, set by various OSH bodies including OSHA (USA). PELs are not available for all chemicals. Different exposure limits include:

- **Time-Weighted Average (TWA):** The average airborne concentration of a biological or chemical agent to which a worker may be exposed in a workday or a work week;
- **Short Term Exposure Level (STEL):** The maximum airborne concentration of a chemical or biological agent to which a worker may be exposed in any 15 minute period, provided the TWAEV is not exceeded;

- **Ceiling Exposure Level (CEILING):** The maximum airborne concentration of a biological or chemical agent to which a worker may be exposed at any time;
- **SKIN:** This notation indicates that direct or airborne contact with the product may result in significant absorption of the product through the skin, mucous membranes or eyes. Inclusion of this notation is intended to suggest that preventative action be taken against absorption of the agent through these routes of entry;
- **Threshold Limit Values (TLVs)** are exposure guidelines developed by the American Conference of Governmental Industrial Hygienists (ACGIH). They are not legally enforceable, but because they are updated regularly, they represent good professional practice. They are expressed as follows:
  - **TLV-TWA (Threshold Limit Value - Time-Weighted Average):**  
The time-weighted average concentration for a normal eight-hour work day and a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect;
  - **TLV-STEL (Threshold Limit Value - Short Term Exposure Limit):** A 15 minute time-weighted average exposure which should not be exceeded at any time during a work day even if the eight-hour TWA is within the TLV. Exposures at the STEL should not be repeated more than four times a day and there should be at least 60 minutes between successive exposures at the STEL;
  - **TLV-C (Threshold Limit Value - Ceiling):** the concentration that should not be exceeded during any part of the working exposure.

**f/cc** - fibres per cubic centimetre of air;

**FDA** - US Food and Drug Administration flammable limits - See "Explosive Limits";

**flashback** - occurs when the flame in a gas torch bums back into the torch or hose; this is often accompanied by a hissing or squealing sound, and a pointed or smoky flame;

**flash point** - the lowest temperature at which a flame will propagate through the vapour of a combustible material to the liquid surface. It is determined by the vapour pressure of the liquid, since only when a sufficiently high vapour concentration is reached, can it support combustion. It should be noted that the source of ignition need not be an open flame, but could equally be, for example, the surface of a hot plate, or a steam pipe;

**freezing point** - the temperature at which a liquid becomes a solid, at normal atmospheric pressure;

**hazard codes** - see UN hazard codes;

**hazardous decomposition products** - formed when a material decomposes (breaks down) because it is unstable, or reacts with materials such as water or oxygen in air;

**hazardous polymerisation** - polymerisation is a process of forming a polymer by combining large numbers of chemical units or monomers into long chains (polyethylene from ethylene or polystyrene from styrene). Uncontrolled polymerisation can be extremely hazardous. Some polymerisation processes can release considerable heat or can be explosive;

**hematopoietic agent** - chemical which interferes with the blood system by decreasing the oxygen-carrying ability of haemoglobin. This can lead to cyanosis and unconsciousness. Carbon monoxide is one such agent, familiar to smokers;

**hepatotoxin** - chemical capable of causing liver damage;

**hypoxia** - a condition defined by a low supply of oxygen;

**inhibitor** - material which is added to a chemical to prevent an unwanted reaction. For example, BHT (2,6-di-t-butyl-p-cresol) is often added to tetrahydrofuran to prevent potentially dangerous polymerisation;

**ingestion** - means taking a material into the body by mouth (swallowing);

**inhalation** - means taking a material into the body by breathing it in;

**IARC** - International Agency for Research in Cancer. The IARC home page is at <http://www.iarc.fr/>;

**irritant** - chemical which may cause reversible inflammation on contact;

**LC50 (Lethal Concentration 50)** - the concentration of a chemical which kills 50% of a sample population. This measure is generally used when exposure to a chemical is through the animal breathing it in, while the LD50 is the measure generally used when exposure is by swallowing, through skin contact, or by injection;

**LD50 (Lethal Dose 50)** - the dose of a chemical which kills 50% of a sample population. In full reporting, the dose, treatment and observation period should be given. Further, LD50, LC50, ED50 and similar figures are strictly only comparable when the age, sex and nutritional state of the animals is specified. Nevertheless, such values are widely reported and used as an effective measure of the potential toxicity of chemicals;

**LDLO** - Lethal Dose Low;

**LEL (Lower Explosive Limit)** - See Explosive Limits;

**local exhaust ventilation** - involves the capture of pollutants at the source;

**Median Lethal Dose (MLD)** - see LD50;

**MEL (Maximum Exposure Limit)** - the maximum permitted concentration of a chemical to which a worker may be exposed over an extended period of time. Typically, MELs are quoted in ppm for an 8-hour reference period, though shorter periods may be quoted for some materials. MELs are, in many countries, enforceable by law;

**melting point** - the temperature at which a solid material becomes a liquid;

**MSDS** - a widely used abbreviation for a Material Safety Data Sheet, which contains details of the hazards associated with a chemical, and gives information on its safe use;

**mutagen** - an agent that changes the hereditary genetic material which is a part of every living cell. Such a mutation is probably an early step in the sequence of events that ultimately leads to the development of cancer;

**NA Number** - See "UN Number";

**NIOSH (National Institute for Occupational Safety and Health)** - sets OELs and provides services in occupational health and safety investigations in the USA. The NIOSH home page is at <http://www.cdc.gov/niosh/>;

**nephrotoxin** - a chemical which may cause kidney damage. Common examples include antimony compounds, dimethyl sulphoxide, dimethylformamide and tetrahydrofuran;

**neurotoxin** - chemical whose primary action is on the CNS (Central Nervous System). Many neurotoxins, such as some mercury compounds, are highly toxic, and must only be used under carefully controlled conditions;

**nuisance material** - material that can cause transient irritation or discomfort, but which has no long-term or systemic effects;

**OEL (Occupational Exposure Limit)** - A (generally legally-enforceable) limit on the amount or concentration of a chemical to which workers may be exposed;

**Occupational exposure limits - control limits:** OEL-CL (Hazardous Chemical Substances Regulations). An OEL-CL is the maximum concentration of an airborne substance, averaged over a reference period, to which employees may be exposed by inhalation under any circumstances, and is specified together with the appropriate reference period in Table 1 of Annexure 1;

**Occupational exposure limit-recommended limit** - OEL-RL (Hazardous Chemical Substances Regulations). An OEL-RL is the concentration of an

airborne substance, averaged over a reference period, at which, according to current knowledge, there is no evidence that it is likely to be injurious to employees if they are exposed by inhalation, day after day, to that concentration;

**odour threshold** - the lowest airborne concentration, usually in part per million, of a vapour in air which can be detected by smell;

**OES - Occupational Exposure Standard oxidising material** - gives up oxygen easily or can readily oxidise other materials;

**PEL (Permissible Exposure Limit)** - a Time-Weighted Average (TWA) or absolute value (usually prescribed by regulation) setting out the maximum permitted exposure to a hazardous chemical (see "exposure limit");

**peroxidisable materials** - materials that can form peroxides in storage, generally when in contact with the air. These peroxides present their most serious risk when the peroxide-contaminated material is heated or distilled, but they may also be sensitive to mechanical shock. The quantity of peroxides in a sample may be determined using a simple peroxide test strip;

**pH** - a measure of the acidity or basicity (alkalinity) of a material when dissolved in water;

**photoallergic contact dermatitis** - a skin condition brought on by exposure to light following skin contact with certain types of chemicals, such as sulphonamides;

**pictographs** - widely-used pictorial representations of the hazards presented by chemicals;

**poison class A or B** - classified by the DOT into two classes. Those in Class A are highly toxic materials which, even in very small quantities, present a hazard to life. Examples of such gases are cyanogen, phosgene and hydrocyanic acid. Class B poisons, though less toxic, are presumed to present a serious threat to health during transportation;

**polymer** - a natural or man-made material formed by combining units, called monomers, into long chains;

**polymerisation** - a process of forming a polymer by combining large numbers of chemical units or monomers into long chains;

**PPB or ppb (Parts Per Billion)** - used to specify the concentration (by volume) of a gas or vapour at very low concentration, or a dissolved material at high dilution;

**PPM or ppm (Parts Per Million)** - used to specify the concentration (by volume) of a gas or vapour at low concentration, or a dissolved material at high dilution;

**pyrophoric materials** - materials that ignite spontaneously in air. Since a wide variety of chemicals will burn if heated sufficiently, it is usual to define a pyrophoric material as one which will ignite spontaneously at temperatures below about 45°C;

**reactive materials** - materials that may undergo vigorous condensation, decomposition or polymerisation. They may react violently under conditions of shock or increase in pressure or temperature. They may also react vigorously with water or water vapour to release a toxic gas;

**reproductive toxin** - (such as vinyl chloride or PCBs) - a chemical which may cause birth defects or sterility;

**sensitisation** - the development, over time, of an allergic reaction to a chemical;

**sensitiser** - a chemical which may lead to the development of allergic reactions after repeated exposure;

**solubility** - the ability of a material to dissolve in water or another liquid;

**solvent** - a material which is capable of dissolving another chemical;

**specific gravity** - the density of a liquid compared to the density of an equal amount of water;

**stability** - ability of a material to remain unchanged in the presence of heat, moisture or air;

**STEL (Short Term Exposure Limit)** - the maximum permissible concentration of a material, generally expressed in ppm in air, for a defined short period of time (typically 5 minutes). These values, which may differ from country to country, are often backed up by regulation and therefore may be legally enforceable (see "exposure limit");

**systemic poisons** - poisons that have an effect which is remote from the site of entry into the body;

**TD50** - May be defined as follows: for a given target site(s), if there are no tumours in control animals, then TD50 is that chronic dose-rate in mg/kg body wt/day which would induce tumours in half the test animals at the end of a standard lifespan for the species. Since the tumour(s) of interest often occur in control animals, TD50 is more precisely defined as: that dose-rate in mg/kg body wt/day which, if administered chronically for the standard lifespan of the species, will halve the probability of remaining tumourless throughout that period. A TD50 can be computed for any particular type of neoplasm, for any particular tissue, or for any combination of these. The range of statistically significant TD50 values for chemicals in the CPDB that are carcinogenic in rodents is more than 10 million-fold;

**teratogen** - chemical which may cause genetic mutations or malformations in the developing fetus. Agents or compounds that a pregnant woman takes into her body that generate defects in the foetus;

**TLV (Threshold Limit Value)** - the maximum permissible concentration of a material, generally expressed in parts per million in air for some defined period of time (often 8 hours). These values, which may differ from country to country, are often backed up by regulation and therefore may be legally enforceable (see "Exposure Limits");

**TLV-C (Threshold Limit Value - Ceiling)** - an exposure limit which should not be exceeded under any circumstances (see "Exposure Limits");

**toxicity** - ability of a substance to cause harmful effects;

**trade name** - the name under which a product is commercially known;

**TSCA (Toxic Substances Control Act)** - regulates the manufacture, transport and use of toxic substances in the USA;

**TWA (Time Weighted Average)** - term used in the specification of Occupational Exposure Limits (OELs) to define the average concentration of a chemical to which it is permissible to expose a worker over a period of time, typically 8 hours (see "Exposure Limits");

**UEL (Upper Explosive Limits)** - see "Explosive Limits";

**UN Hazard codes:**

- Class 1 Explosive Class;
- Class 2 Gases;
- Class 3.1 Flammable liquids, flash point below  $-18^{\circ}\text{C}$ ;
- Class 3.2 Flammable liquids, flash point between  $-18^{\circ}\text{C}$  and  $23^{\circ}\text{C}$ ;
- Class 3.3 Flammable liquids, flash point between  $23^{\circ}\text{C}$  and  $61^{\circ}\text{C}$ ;
- Class 4.1 Flammable solids;
- Class 5.1 Oxidising agents;
- Class 5.2 Organic peroxides;
- Class 6.1 Poisonous substances;
- Class 7 Radioactive substances;
- Class 8 Corrosive substances;
- Class 9 Miscellaneous dangerous substances;
- NR Non-regulated.

**UN Number** - a four-digit number assigned to a potentially hazardous material or class of materials. UN (United Nations) numbers are internationally recognised and are used by fire fighter and other emergency

response personnel for identification of materials during transportation emergencies. NA (North American) numbers are assigned by Transport Canada and the US Department of Transport to materials they consider hazardous and to which a UN number has not been assigned;

**vapour** - a gaseous form of a material which is normally solid or liquid at room temperature and pressure;

**vapour density** - the density of a vapour compared to the density of an equal amount of air;

**vapour pressure** - the pressure of a vapour in equilibrium with its liquid or solid form;

**ventilation** - the movement of air;

**vesicant** - a chemical which, if it can escape from the vein, causes extensive tissue damage, with vesicle formation or blistering;

**VOCs** - Volatile Organic Compounds;

**volatility** - the ability of a material to evaporate.

## List of Sources to Help Identify Hazards of Chemicals

### 1. EPA FACT Sheets:

[www.epa.gov/enviro/html/emci/chemref/index.html](http://www.epa.gov/enviro/html/emci/chemref/index.html)

### 2. ASTDR ToxFaqS:

[www.atsdr.cdc.gov/toxfaq.html](http://www.atsdr.cdc.gov/toxfaq.html)

### 3. EPCRA Overview:

[http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/ehs\\_2003.htm](http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/ehs_2003.htm)

### 4. Integrated RISK Information System:

[www.epa.gov/IRIS/](http://www.epa.gov/IRIS/)

### 5. Workplace Hazardous Materials Information System (WHMIS):

[www.hc-se.gc.ca/hecs-sesc/whmis/index.htm](http://www.hc-se.gc.ca/hecs-sesc/whmis/index.htm)

### 6. Occupational Health and Safety Administration (OSHA):

[www.osha.gov](http://www.osha.gov)

## 3. MSDS of solvents pertaining to the report

Please note:

- Paraffin in South Africa is known as kerosene in the USA;
- Glycerine or glycerol in South Africa is known as glycerin in the USA;

- Many of the occupation exposure limits in the MSDS sheet should be considered as guidelines - limits set by South African legislation are enforceable and will take precedence;
- TCE, chloroform, dichloromethane have been reported to be carcinogens;
- Ensolv (brand name for n-propyl bromide) causes irritation to the lungs where there is a pre-existing lung condition - some skin/eye irritation reported. Should be used in well ventilated area to avoid headaches, dizziness and nausea;
- When exposed to more than one chemical/agent, synergistic effects are often reported in the literature. That is, the combined effects of two or more agents are often worse the sum of the individual effects

#### 4. References and links to international MSDS sources

<http://www.sciencelab.com/msdsList.php>

<http://www.mallbaker.com/europe/msds/default.asp>

<http://www.elcosh.org/docs/d0800/d000828/d000828.html>

<http://www.albatross-usa.com/pdf/elecchemmsds/AlbatrossVDS3000MSDS.pdf> <http://www.coastwidelabs.com/MSDS.htm>

#### 5. Useful sources for local MSDS

**Note:** Suppliers of hazardous chemical substances have a duty to supply an up-to-date MSDS to the purchaser/user of the substance. Users must ensure that the MSDS is obtained and held on file and regular checks should be done to ensure that that MSDS are not outdated (in particular with regard to local emergency contact information).

<http://www.msdssearch.com/> <http://www.mycrochem.co.za/msds/>

[http://www.engen.co.za/home/apps/content/products\\_services/msds/CategoryList.aspx](http://www.engen.co.za/home/apps/content/products_services/msds/CategoryList.aspx)

<http://www.euapps.shell.com/MSDS/GotoMsds>

<https://cglapps.chevron.com/msdspds/HomePage.aspx>

<http://www.totaltec.co.za/drawmenu.php?guid=1>

<http://www.ikusasachemicals.co.za/www.ikusasachemicals.co.za/index.html>

## 6. Supplementary legal requirements

Appendix D of the original CSIR report contained text of the most pertinent SA legal requirements and has been omitted from this extract, mainly due to pending changes in legislation. To ensure that users have access to the most current legal requirements the links to the Department of Labour website have been included instead.

Users of this publication should regularly check this website to assure that the most current versions of the OHS Act and Regulations are referenced for compliance purposes.

Links to applicable SA legal requirements.

<http://www.labour.gov.za/legislation/acts/occupational-health-and-safety/read-online/amended-occupational-health-and-safety-act>

<http://www.labour.gov.za/legislation/regulations/occupational-health-and-safety/regulation-ohs-general-safety-regulations>

<http://www.labour.gov.za/legislation/regulations/occupational-health-and-safety/regulation-ohs-construction-regulations-2003>

<http://www.labour.gov.za/legislation/regulations/occupational-health-and-safety/regulation-ohs-hazardous-chemical-substances>