NERC GUIDANCE ON EXPOSURE CONTROL APPROACHES FOR LABORATORY USES OF HAZARDOUS CHEMICALS

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Introduction

This guidance describes four **exposure control approaches** (ECAs) that specify different levels of laboratory precautions for work with hazardous chemicals based on health hazards. It also describes a methodology to allow an assessment of **exposure potential** for laboratory work with hazardous chemicals. A matrix table is given which maps the exposure potential against the **hazard group** of the chemical(s) being handled to allow selection of the most suitable exposure control approach.

Background

The basis of any COSHH assessment will be making a judgment on the likely levels of exposure to a particular chemical by a relevant route and, taking into account the hazardous properties of the chemical, whether or not this level of exposure represents a hazard that requires further control. The exposure control approach is not a complete risk assessment of itself, not least since it does not fully take into account: (a) the justification for the hazardous use; (b) the consideration of elimination or choosing safer alternatives (substitution); (c) applying the COSHH Hierarchy of Controls in their entirety and (d) following the COSHH Principles of Good Control Practice. However, it supports the risk assessment approach and makes the selection of suitable controls and facilities for the laboratory activities much easier. The hazard group classification, assessment of exposure potential and ECA used here are closely based on those in the HSE Technical Basis for COSHH Essentials[1], although the systems suggested there have been developed and amended to specifically suit the laboratory situation.

HSE Hazard Groups

The classification system for hazardous chemicals suggested here is broken into five hazard groups (also known as 'bands') and is based on the HSE Technical Basis for COSHH Essentials system. The five main groups are named, in ascending order of hazard, A to E - see Appendices B, C & D for the classification and examples of chemicals. This system uses the European Risk Phrases or GHS Hazard Statements under the harmonised classification of the EC Classification Labeling and Packaging (CLP) Regulation[2] to determine hazard group. It should be noted the HSE Hazard Group classification only applies to 'health' hazards - other methods should be used to assign precautions for non-health hazards. In addition a Hazard Group S for skin / eye health effects is assigned. Chemicals in Hazard Group S will also have one of the five main hazard groups A – E assigned since exposure to a material which may harm skin / eye is also likely to have an effect by other routes of exposure.

Assessment of Exposure Potential

The HSE Technical Basis for COSHH Essentials gives a system that helps identify the exposure potential for an activity. This is based on aspects of the work which are the airborne generation properties of the chemical (volatility / dustiness) and the quantities handled. The NERC Exposure Potential assessment method adds the nature of the operation, the duration of the task and the number of people involved to this.

To obtain an estimate of exposure potential, each aspect of the hazardous chemical and the activity in which it is being used is considered and assigned into either high, medium or low (H / M / L). Taking into account the H / M / L scores assigned across all aspects, a judgment on the final overall exposure potential of the laboratory work into H / M / L can be made. Completing a 'traffic light' visual chart may help in judging the impact of the individual scores towards giving a final overall exposure potential score (see Appendix A).

The assessment of exposure also needs to take into account the relevant route for the hazardous chemical as, even if the exposure potential is high, if it cannot reach a target organ via a relevant route of exposure, the exposure may not be important or significant. The assumption here is that the inhaled route is usually the most relevant and that exposure potential is closely linked to the airborne level. Skin may also be a relevant route of entry to the body hence an awareness of materials given a 'Sk' (Skin) notation (may be absorbed through intact skin thus contributing to systemic toxicity) by HSE publication EH40/2005 'Workplace Exposure Limits'[3] is important. Also, a solvent which can cross the intact skin barrier may also carry hazardous material which is dissolved in it. Ingestion and traumatic inoculation are less likely to give significant exposure if safe laboratory chemical practice is being followed (see NERC 20 Standard Controls[4]).

The aspects to be considered in judging exposure potential and assigning H / M / L are:

- **Quantity** (this is total volume being handled i.e. in stock bottle / container not just quantity being weighed out or dispensed): Low is less than 1g / ml; Medium is less than 100g / ml and High is more than 100g / ml.
- **Duration**: Low (Short) is less than 1 minute in a day; Medium is between 1 minute and 15 minutes in a day and High (Long) is more than 15 minutes in a day.
- **Numbers involved / exposed**: Low is one or two persons; Medium is three or four persons and High is five or more persons.
- **Airborne Generation Properties:**
  - **Volatility** (at Normal Temperature and Pressure) - Low is a boiling point of 150ºC or above; Medium is a boiling point between 50 – 150ºC and High is a boiling point at or below 50 ºC. This may also be expressed in vapour pressure where low is 500 Pa (3.75 mmHg) or less; Medium is between 500 and 25,000 Pa (3.75 to 187.5 mmHg) and High is 25,000 Pa or more (≥187.5 mmHg).
    Note: if the material is handled at elevated temperature or pressure this gives increased potential for airborne exposure which equates to increased volatility.

- **Dustiness -** Low = pellets and non-dusty solids, Medium = granular or crystalline (coarse dusts), High = fine solids and light powder.

- **Nature of operation**: Low = operation conducted with low energy where risk of generating significant airborne concentrations / aerosols or mists is minimal e.g. liquids being handled/poured/dispensed carefully with no splashing or spray; Medium:= operation where some energy is involved e.g. pouring from height with some splashing, stirring/mixing carefully by hand or solids dispensed from low heights; High = highly energetic operations such as ultra-sonication, vortexers, mixing with shakers/vibrators or high speed stirrers, spraying, grinding etc.

Table to show Exposure Potential aspects and criteria for Low / Medium / High

	SCORES		
ASPECTS	**Low**	**Medium**	**High**
Quantity	≤ 1g or ml	> 1 - 100g or ml	> 100g or ml
Duration	≤ 1 min per day	> 1- 15 min per day	> 15 min per day
Number of persons	1 to 2	3 to 4	5 or more
Volatility (liquids)	BP ≥ 150ºC or VP ≤ 500 Pa / 3.75 mmHg	BP 50 – 150ºC or VP 500 – 25000 Pa / 3.75 – 187.5 mmHg	BP ≤ 50ºC or VP ≥ 25,000 Pa/ 187.5 mmHg
Dustiness (particulates)	Pellets and non-dusty solids	Granular or crystalline (coarse dusts)	Fine solids and light powder
Nature of operation	Low energy e.g. careful handling	Medium energy e.g. pouring from low heights or stirring, use of hand tools	High energy, e.g. spraying, grinding, high speed stirring, ultra-sonication etc

A quantitative method for assigning an overall score to exposure potential is not attempted. The H / M / L method used applies the same volatility / dustiness measures as the HSE but different values to its divisions on quantity (reduced to reflect the smaller scale of laboratory operations compared to industrial processes). These are supplemented by consideration of duration (using the COSHH Essentials 15 minute per day figure), number of persons exposed and nature of work operation. This guides the assessor in making a qualitative judgment to give H / M / L exposure potentials.

This Exposure Potential assessment method is a replacement for the technique described in Appendix IV of NERC Procedure No 19, which was derived from a former Royal Society of Chemistry technique that is no longer in place.

NERC Laboratory Exposure Control Approaches

Taking into account the Exposure Potential and the Hazard Group using the matrix below, it is possible to assign one of four levels of control to the proposed laboratory activity.

Matrix linking Hazard Group and Exposure Potential to select NERC ECA

Hazard Group of Substance *(see Appendices B & C)*	***E***	ECA3*	ECA4*	ECA4
	D	ECA3*	ECA3*	ECA4*
	C	ECA2*	ECA3*	ECA3
	B	ECA1	ECA2*	ECA 2
	A	ECA1	ECA1	ECA 2*
** These approaches may be varied or relaxed (e.g. the next lower ECA used) as justified by risk assessment*		***Low***	***Medium***	***High***
		Exposure Potential		

The NERC laboratory **Exposure Control Approaches** or **ECAs** consist of different levels of controls from **1 to 4** in ascending order of control. These are similar to the approaches in the HSE Technical Basis for COSHH Essentials but modified specifically for laboratory activities. The * asterix assigned for certain combinations allows the

assessor to ‘derogate’ a lower level of exposure control approach for part or all of an activity where it can be justified by the risk assessment. Examples of this could be where lower concentrations are used or the form of the original chemical has been altered to reduce the risk of exposure e.g. by dissolving a flyaway solid into a solution. Another factor allowing derogation may be low ‘potency’ as the hazard group system does not always take into account the level of exposure necessary to produce the hazardous effect, although this is reflected in the Workplace Exposure Level (WEL) as assigned in the HSE publication EH40.

In theory, each ascending level of exposure control is designed to lead to a 10 times reduction in exposure. The aim is to have control of the hazardous chemical to within its WEL. Column 3 of the table in Appendix C entitled ‘concentration range’ shows the range of exposure aimed at for each hazard group, although this does not always exactly conform to the assigned WEL. The ultimate measure of success in achieving ‘adequate control’, which is the aim of any COSHH assessment, is to control exposure to within any assigned WEL, and for asthmagens, carcinogens and mutagens (which by definition will be in Hazard Groups D and E), to as low as is reasonably practicable. It should be noted that not all hazardous chemicals have been assigned a WEL. Just because a hazardous chemical does not have a WEL does not mean that any level of exposure is acceptable, it must still be controlled so that the risk is reduced to an acceptable level, if necessary assigning an in-house Occupational Exposure Level.

The four NERC Laboratory ECAs should be used in conjunction with well designed laboratories and safe laboratory chemical practice (see the NERC Guidance on Standard Controls for Laboratory Uses of Hazardous Chemicals).

Description of NERC Laboratory Exposure Control Approaches

ECA1: Work in a well designed laboratory with good general ventilation (an air change rate in excess of 5x per hour) using good working practices to minimise spread / generation of high airborne concentrations of hazardous contaminants.

ECA2: Work undertaken as above but with the application of engineering controls using LEV devices such as extract grilles, captor hoods or nozzles, partial enclosures with extraction and re-circulating single HEPA filtered enclosures.

ECA1 and 2 are approaches which are generally applicable to Hazard Group A and B materials but may be applicable for work of low exposure potential with materials from higher hazard groups e.g. with liquids of low volatility or solids which have low dustiness. If high hazard solids are dissolved in aqueous solutions (i.e. risk of exposure via the airborne route is minimised,) significantly diluted and the skin/splashing or aerosol generation risk is low, then relaxation to these lower ECAs may be appropriate.

ECA3: As ECA 1 plus use of high efficiency partial containment devices such as NERC Class 1 fume cupboards which are ducted to external atmosphere or, for solids or aerosols, double HEPA filtered powder handling enclosures / safety cabinets.

ECA4: Specially devised precautions applied after seeking specialist advice and writing a detailed risk assessment. The precautions applied will involve the highest levels of engineered controls and, although fume cupboards may be appropriate, consideration should be given to using total enclosure devices such as isolators or glove boxes. Working within specially designed facilities such as a dedicated laboratory or containment suite may also be appropriate.

ECA 3 and 4 are approaches which are applicable to work with hazard group D & E chemicals. ECA3 is also applicable for high exposure potential work with hazard group C chemicals. ECA3 will provide a very high level of protection. If steps are taken to reduce the exposure potential, e.g. by dilution, this could justify using a lower ECA.

In addition to following an ECA, the following must also be taken into account:

Skin (Sk) notation (as specified in EH40 - risk of absorption through intact skin) and **Hazard Group S** (see Appendices B & C)**:** use gloves which offer the relevant degree of chemical resistance to the materials handled and physical strength for the nature of operations being undertaken. It may be that no single glove type gives the requisite long term protection in which case regular changes if they become contaminated and/or double gloving may be needed. In addition, these materials will require eye protection.

Personal Protective Equipment (PPE): Wearing of lab coats & eye protection is a standard precaution and is not an onerous precaution, albeit the least preferred option. However, for certain work this PPE may need to be supplemented to offer additional/improved protection e.g. by wearing gloves with extended cuffs, over-arm protection, aprons, head covering, goggles or full face protection and special footwear.

Respiratory Protective Equipment (RPE): Use of RPE should not normally be necessary and should only be used after justification by risk assessment when control by other more preferred controls are not considered adequate. The type of RPE applied will require careful selection and may also require fit testing of the user. This does not to prevent users choosing to wear RPE if they wish but this is not the same as it being a requirement of the risk assessment.

Care is required to avoid applying the ECA approach too strictly and common sense must always be used. Two examples can be drawn from the chemicals listed in Appendix D. Ethyl mercaptan is a Hazard Group B chemical so according to this scheme does not require use of a fume cupboard. This would be very unwise due to its extremely noxious smell rather than its health hazard. Osmium tetroxide, a Hazard Group D chemical, should always be handed with extreme care due to its toxicity and corrosivity but also because it has the lowest assigned WEL at 0.2 parts per billion. In addition, the hazard classification may alter under the Annex VI of the EU Classification, Labeling and Packaging Regulation (CLP) according to its concentration. One example is formaldehyde where a 4% solution (also known as 10% formalin) is Hazard Group C whereas the saturated 38% solution (also known as formalin) is Hazard Group D. Even if CLP does not show a changed classification for lower concentrations, the conclusion of a risk assessment may choose to allow such derogation.

The four NERC ECAs are very similar but not identical to the four HSE Control Approaches from the Basis of COSHH Essentials document. There is no attempt to create 'exposure predictor bands' and the assessment remains at 'Exposure Potential' which takes into account the nature of the operation.

The NERC ECAs reflect the specific nature of laboratory operations which generally involves smaller quantities, shorter duration of work and smaller numbers of persons exposed, albeit often with higher risk materials. They also reflect the effectiveness of fume cupboards in containing smaller scale operations, especially when tested to meet the NERC class 1 containment criteria.

References:

1. 'The technical Basis for COSHH essentials: Easy steps to control Chemicals', HSE (revised), 2009: http://www.coshh-essentials.org.uk/assets/live/CETB.pdf
2. Annex VI of European Regulation (EC) No 1272/2008 – Classification, Labeling and Packaging of Substances and Mixtures, Tables 3.1 and 3.2.
   Note: these replace the former Approved Supply List to the Classification (Hazard Information and Packaging for Supply) Regulations 2002 (CHIP3) which was repealed when CHIP4 came into force in 2009 and give the official classifications to hazardous substances). The harmonized classification of substances and its officially assigned GHS or risk phrases used to determine hazard group may be searched at the ECHA C&L inventory database at http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database.
   It should be noted this C&L inventory database also includes supplier notified classifications which must be treated with care and do not necessarily represent an accurate classification of hazard.
3. HSE Guidance EH40/2005, 'Workplace Exposure Limits', 2nd Edition issued 2011 ISBN978 0 7176 6446 7: http://www.hse.gov.uk/pubns/priced/eh40.pdf
4. NERC Guidance on standard controls for laboratory uses of hazardous chemicals http://www.nerc.ac.uk/about/policy/safety/procedures/guidance_hazardous_chemical_use.pdf

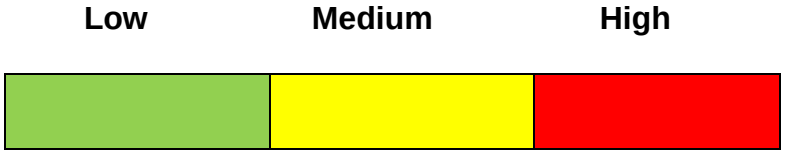
Appendix A: Traffic light chart to help assess Exposure Potential

To obtain an estimate of exposure potential, each aspect of the hazardous chemical and the activity in which it is being used is considered and assigned into either high, medium or low (H / M / L). Taking into account the H / M / L scores assigned across all aspects, a judgment on the final overall exposure potential of the laboratory work into H / M / L can be made.

Completing a 'traffic light' visual chart as shown below may help in judging the impact of individual scores towards giving a final overall exposure potential score.

	Low	Medium	High
Quantity			
Duration			
Numbers involved			
Volatility / Dustiness			
Nature operation			

Overall Exposure Potential:



Appendix B: HSE Technical Basis for COSHH Essentials allocation of EU Risk phrases or GHS Hazard Statements to Hazard Group giving target concentration ranges for exposure

Hazard Group	Type	Concentration range	Units	R-phrases	H-statements
A	Dust	>1 to 10	mg/m^3	R36, R38 and all R-numbers not otherwise listed	H303, H304, H305, H313, H315, H316, H318, H319, H320, H333, H336 and all H-numbers not otherwise listed
	Vapour	>50 to 500	ppm		
B	Dust	>0.1 to 1	mg/m^3	R20/21/22 and R68/20/21/22	H302, H312, H332, H371
	Vapour	>5 to 50	ppm		
C	Dust	>0.01 to 0.1	mg/m^3	R23/24/25, R34, R35, R37, R39/23/24/25, R41, R43, R48/20/21/22, R68/23/24/25	H301, H311, H314, H317, H318, H331, H335, H370, H373
	Vapour	>0.5 to 5	ppm		
D	Dust	<0.01	mg/m^3	R26/27/28, R39/26/27/28, R40, R48/23/24/25, R60, R61, R62, R63, R64	H300,H310,H330,H351, H360, H361, H362, H372
	Vapour	<0.5	ppm		
E	Dust	-		R42, R45, R46, R49, R68	H334, H340, H341, H350
	Vapour	-			

Hazard Group S

This is a special hazard group for skin and eye effects and consists of hazardous chemicals assigned:

EU Risk Phrases - R21 ‘Harmful in contact with skin’ (Hazard Group B); R24 ‘Toxic in contact with skin’ (Hazard Group C); R27 ‘Very toxic in contact with skin’ (Hazard Group D); R34 ‘Causes burns’ (Hazard Group C); R35 ‘Causes severe burns’ (Hazard Group C); R38 ‘Irritating to skin’ (Hazard Group A); R41 ‘Risk of serious damage to the eyes’ (Hazard Group C); R43 May cause sensitisation by skin contact (Hazard Group C); R66 ‘Repeated exposure may cause skin dryness or cracking’ (Hazard Group A) and R21, R24 or R27 in combination with R39 ‘Danger of very serious irreversible effects’; R48 ‘Danger of serious damage to health by prolonged exposure’ or R68 ‘Possible risk of irreversible effects’

or

GHS Hazard Statements - H310 ‘Fatal in contact with skin’ (Hazard Group D); H311 ‘Toxic in contact with skin’ (Hazard Group C); H312 ‘Harmful in contact with skin’ (Hazard Group B); H314 ‘Causes severe burns and eye damage’ (Hazard Group C); H315 ‘Causes skin irritation’ (Hazard Group A); H317 ‘May cause an allergic skin reaction’ (Hazard Group C); ; H318 ‘Causes serious eye damage’ (Hazard Group C); H319 ‘Causes serious eye irritation’ (Hazard Group A); EU66 (see R66 above) and EU70 ‘Toxic by eye contact’ (Hazard Group E).

Appendix C: EU Risk Phrases / GHS Hazard Statements with Hazard Groups

EU Risk Phrase	Wording	Hazard Group
20	Harmful by inhalation	B
21	Harmful in contact with skin	B & S
22	Harmful if swallowed	B
23	Toxic by inhalation	C
24	Toxic in contact with skin	C & S
25	Toxic if swallowed	C
26	Very toxic by inhalation	D
27	Very toxic in contact with skin	D & S
28	Very toxic if swallowed	D
34	Causes burns	C & S
35	Causes severe burns	C & S
37	Irritating to respiratory system	C[1]
38	Irritating to skin	A & S
39	Danger of very serious irreversible effects	-[2]
40	Limited evidence of a carcinogenic effect	D[3]
41	Risk of serious damage to the eyes	C & S
42	May cause sensitisation by inhalation	E
43	May cause sensitisation by skin contact	C[4] & S
45	May cause cancer	E
46	May cause heritable genetic damage	E
48	Danger of serious damage to health by prolonged exposure	+1[5]
49	May cause cancer by inhalation	E
60	May impair fertility	D[1]
61	May cause harm to the unborn child	D[1]
62	Risk of impaired fertility	D[1]
63	Possible risk of harm to the unborn child	D[1]
64	May cause harm to breastfed babies	D[1]
65	Harmful: may cause lung damage if swallowed	A
66	Repeated exposure may cause skin dryness or cracking	A & S
67	Vapours may cause drowsiness and dizziness	A
68	Possible risk of irreversible effects	E

Notes:

[1] Based on evidence, experts can reduce Group from D to C or from C to B.

[2] Combination phrase. No impact of header number - use the Group for the other R-numbers.

[3] Old data sheets have R40 as a combination phrase. If so, treat as (2).

[4] As [1] but retain skin sensitisation in mixtures to a concentration of 0.1%.

[5] Combination phrase. Group for R-numbers in combination rises from B to C or from C to D.

[6] If a combination phrase, as [2]; otherwise Group E.

GHS Hazard Statement	Wording	Hazard Group
300	Fatal if swallowed	D
301	Toxic if swallowed	C
302	Harmful if swallowed	B
304	May be fatal if swallowed and enters airways	A
310	Fatal in contact with skin	D & S
311	Toxic in contact with skin	C & S
312	Harmful in contact with skin	B & S
314	Causes severe burns and eye damage	C & S
315	Causes skin irritation	A & S
317	May cause an allergic skin reaction	C & S
318	Causes serious eye damage	C & S
319	Causes serious eye irritation	A & S
330	Fatal if inhaled	D
331	Toxic if inhaled	C
332	Harmful if inhaled	B
334	May cause allergy or asthma symptoms or breathing difficulties if inhaled	E
335	May cause respiratory irritation	C
336	May cause dizziness or drowsiness	A
340	May cause genetic defects [1]	E
341	Suspected of causing genetic defects [1]	E
350	May cause cancer [1]	E
351	Suspected of causing cancer [1]	D
360	May damage fertility or the unborn child [1, 2]	D
361	Suspected of damaging fertility or the unborn child [2.4]	D
362	May cause harm to breast-fed children	D
370	Causes damage to organs [3,4]	D
371	May cause damage to organs [3,4]	B
372	Causes damage to organs through prolonged or repeated exposure [3,4]	D
373	May cause damage to organs through prolonged or repeated exposure [3,1]	C
EUH066	Repeated exposure may cause skin dryness or cracking	A & S
EUH070	Toxic by eye contact	E & S
EUH071	Corrosive to the respiratory tract	C

Notes:
[1] route if relevant
[2] effect if known
[3] organ if known
[4] route if relevant

Appendix D: Examples of Chemicals from different Hazard Groups

1. **Ethanol** 95% - not classified as health hazard. Flammable. Workplace Exposure Limit (WEL) 1000 parts per million (ppm) / 1920 milligrammes per cubic metre (mg/m^3) 8 hr Time Weighted Average (TWA) long term exposure limit only. Medium volatility, Boiling Point (BP) 78º C, Vapour Pressure (VP) 5,950 Pascal (Pa).

2. **Acetone** – **Hazard Group A** by virtue of R36 and H319 & H336. Irritant and Flammable. WEL: 500ppm / 1210 mg/m^3 8 hr TWA / 1500ppm/3620 mg/m^3 15 min Short Term Exposure Limit (STEL). Medium volatility but close to high (BP 56.1º C, VP 182 millimetres of mercury (mmHg).

3. **Ethyl mercaptan** (ethanethiol) – **Hazard Group B** by virtue of R20 and H332. Harmful and Flammable. WEL: 0.5ppm / 1.3 mg/m^3 8 hr TWA / 2ppm/5.2 mg/m^3 15 min Short Term Exposure Limit (STEL). High volatility (BP 35º C, VP 442 mmHg). *Note: Must be handled in a fume cupboard due to its noxious smell with an extremely low odour detection threshold. Is used as the stenching agent in natural gas and in very low concentrations may erroneously suggest presence of a gas leak.*
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4. **Sulphuric Acid** ≥15% concentration – **Hazard Group C** by virtue of R35 and H314. Corrosive. WEL: (mist) 0.05 mg/m^3 8 hr TWA long term exposure limit only. Low volatility.

5. **Methanol** 95% - **Hazard Group C** by virtue of R39/23/24/25 and H370. Flammable and Toxic. WEL: 200 ppm / 266 mg/m^3 8hr TWA / 250 ppm / 333 mg/m^3 15 min STEL, Sk notation. Medium volatility, BP 64º C, VP 13,020 Pa.

6. **Hydrochloric Acid** ≥25% concentration - **Hazard Group C** by virtue of R35 and H314. Corrosive. WEL (gas and mists): 1 ppm / 2 mg/m^3 8 hr TWA / 5ppm / 8 mg/m^3 15 min STEL. High volatility (BP 48º C, VP 28,300 Pa)

7. **Hydrogen peroxide solution** ≥50% – **Hazard Group C** by virtue of R35 and H314. Harmful and oxidiser. WEL: 1ppm / 1.4 mg/m^3 8 hr TWA / 2ppm/2.8 mg/m^3 15 min STEL. Low volatility, BP115º C – 157º C, VP 0.7 Pa @ 30º C.

8. **Formaldehyde** ≥0.2% to <5**%** aqueous solution – **Hazard Group C** by virtue of R43 and H317. Harmful. WEL 2ppm / 2.5 mg/m^3 both 8hr TWA and 15 min STEL consider as medium volatility.

9. **Formaldehyde** ≥25% aqueous solution – **Hazard Group D** by virtue of R40 and H351. Toxic and category 3 carcinogen. WEL 2ppm / 2.5 mg/m^3 both 8hr TWA and 15 min STEL. High volatility (Data not available but saturated solution in water which will evolve considerable quantities of gas).

10. **Paraformaldehyde** solid – **Hazard Group D** by virtue of R40 and H351 (although not listed in Annex VI of CLP). Toxic and category 3 carcinogen. Formaldehyde WEL 2ppm / 2.5 mg/m^3 both 8hr TWA and 15 min STEL. Consider low volatility as solid although slowly releases formaldehyde gas and de-polymerises on dissolution or heating.

11. **Hydrofluoric Acid** >7% - **Hazard Group D** by virtue of R26/27/28 and H300, H310 and H330. Very Toxic and Corrosive. WEL (HF gas as F): 1.8ppm / 1.5 mg/m^3 8hr TWA / 3ppm / 2.5 mg/m^3 15 min STEL. Consider to be High volatility (HF gas has boiling point of 19.5 ºC).

12. **Osmium tetroxide** solid – **Hazard Group D** by virtue of R26/27/28 and H300, H310 and H330. Very Toxic and Corrosive. WEL 0.0002 ppm and 0.002 mg/m^3 8 hr TWA / 0.0006 ppm and 0.006 mg/m^3 15 min STEL. Technically Medium volatility (BP 130 º C and VP 1,500 Pa @ 27 º C) but should treat as High volatility as, although a solid at room temperature, sublimes to produce appreciable vapour and with such a low WEL can even create hazardous concentrations at 20 º C.

13. **Chloroform** >5% – **Hazard Group D** by virtue of R40 and H351. Toxic and category 3 carcinogen. 2ppm / 9.9 mg/m 8 hr TWA long term exposure limit only Sk notation. High/Medium volatility, BP 61.2º C, VP about 180 mmHg at 20º C.

14. **n-Hexane** – **Hazard Group D** by virtue of R62 and H361. Harmful, Flammable and category 3 toxic for reproduction. WEL: 20ppm/72 mg/m^3 8hr TWA long term exposure limit only. Medium volatility - BP 68-69º C, VP 17,600 Pa.

15. **Phenol** >10% – **Hazard Group E** by virtue of R68 and H341. Toxic and category 3 mutagen. WEL: 2ppm / 7.8 mg/m^3 8 hr TWA / 4ppm/16 mg/m^3 15 min STEL. Low volatility (BP 181.7º C).

16. **Mercuric chloride** solid – **Hazard Group E** by virtue of R68 and H341. Very toxic and category 3 mutagen. WEL (as mercury): 0.02 mg/m^3 8 hr TWA long term exposure limit. Low or no volatility.