# COMAH Guidance for the Surface Engineering Sector

## COMAH MAJOR ACCIDENT SCENARIOS AND RISK REDUCTION

### Introduction

1. This guidance will assist surface engineering sites which came within the scope of COMAH (Control of Major Accident Hazards Regulations 1999 as amended) in October 2005 as a result of holding threshold quantities of very toxic and toxic substances (including cyanides, dichromates and chromium trioxide) above certain quantities. It discusses the identification and assessment of major accident hazard scenarios at lower and top tier sites. Also, some prevention, control and mitigation measures which constitute good practice to inform the MAPP, safety report and on-site emergency plan.

2. Further information on assessing whether a site comes within the scope of COMAH, at lower or top tier, and the duties for each of these, is available on the HSE website at Surface Engineering webpages - **Live issues** and **COMAH - General background information.** General guidance on COMAH is also available in **A guide to the Control of Major Accident Hazards Regulations 1999 (as amended)**.

3. The key COMAH duty on operators is to "take all measures necessary" to prevent major accidents and limit their consequences to persons and the environment.

4. **Lower tier** sites need to produce a **Major Accident Prevention** Policy (MAPP) which describes:
   - the management systems;
   - the approach for identifying and evaluating major accident hazards;
   - the safe operation and maintenance of plant;
   - how changes are managed, and
   - how foreseeable emergencies are managed.

5. **Top tier** sites must prepare a safety report within one year of COMAH first applying (i.e. by 31 October 2006). This should contain information:
   - on management systems;
   - on the surrounding environment;
   - describing the installation, processes and dangerous substances;
   - identifying major accident scenarios, risks, and controls, including emergency response;
   - demonstrating that all necessary measures to reduce risk have been implemented.

6. Further guidance on the safety report assessment process and judgement criteria can be found in the COMAH **Safety Report Assessment Manual**. Top tier sites are also required to produce an on-site emergency plan to mitigate the consequences of possible major accidents. Further guidance can be found in the Emergency Planning for Major Accidents booklet (HSG191). Lower tier site also need an on site emergency plan (a general duty under the Health and Safety at Work Act 1974 and the Management of Health and Safety At Work Regulations 1999).

7. Both lower and top tier COMAH sites need to identify and assess their potential major accident hazard scenarios. Guidance specific to the **assessment of risks** for **TOP TIER** sites in the surface engineering sector is given below.

**Relationship to the Pollution Prevention and Control (PPC) regulations**

8. Some surface treatment sites are subject to both COMAH and PPC. While PPC seeks to prevent and control emissions to the environment, it also addresses the prevention of accidents which may cause environmental damage. This creates a potential overlap and possible duplication of regulation, which is to be avoided.

9. COMAH by definition only addresses major hazards, while PPC addresses the consequences of all accidents. PPC therefore addresses a range of accidents the consequence of which would fall below the MATTE thresholds.

10. For the risk zone which both PPC and COMAH addresses, the PPC risk assessment and measures may be satisfactory for COMAH. However COMAH deals with a higher magnitude of hazard and so must take precedence over PPC. COMAH does allow (regulation 7(11)) the use in safety reports of information generated for other legal regimes, such as PPC. The COMAH SR should still summarise the content and text of such information and the application to COMAH. These summaries can be brief, but are essential to the demonstration and the ability of assessors to reach a conclusion.

11. Implementation of Best Available Techniques (BAT) for PPC should require the same level of risk prevention and control measures required by COMAH. Because COMAH deals with major hazard there may be, proportionate to the risk, a requirement for additional risk assessment and a higher level of rigour in site inspection. This means that components of the Safety Management System would be inspected in some detail

**IDENTIFICATION OF MAJOR ACCIDENT HAZARD SCENARIOS**

12. COMAH defines a major accident as "an occurrence (including, in particular, a major emission, fire or explosion) resulting from **uncontrolled developments** in the course of the operation of any establishment (i.e. site) and leading to **serious danger** to human health or the environment, immediate or delayed, inside or outside the establishment, and involving one or more **dangerous substances**". The Guide to COMAH (L111) states that 'The occurrence must have the potential to cause serious danger, but it is not necessary for the danger to result in harm or injury' for the incident to be deemed a major accident.

13. For risks to people, serious danger means a risk of death, physical injury or harm for health. A Major Accident to the Environment (MATTE) is an event with the potential to cause severe, widespread, long term or even permanent damage to ecosystems. Further guidance on the definition of MATTE is provided by "Guidance on the Interpretation of Major Accident to the Environment for the Purposes of the COMAH Regulations" Department of the Environment, Transport and the Regions -ISBN 0 11 753501 X June 1999".

14. Other key MATTE principles are:-
    - The hazard contains the following components:
        - a "source" (that is the dangerous substance(s),
        - a "pathway" (means of release into the environment, for example sewers, drains, boreholes and flow along roadways) and
        - a "receptor" (part of the environment which may be damaged – bearing in mind that the environment can be both pathway and receptor).

- Without one of the components a MATTE is not possible. However if measures are needed to, for example, prevent a spillage entering the sewer system by means of a shut off valve or diversion tank, then there exists the potential for a MATTE. It is then incumbent on the COMAH duty holder to demonstrate that the risks associated with the implementation, operation and maintenance of these measures are “As Low As Reasonably Practical” (ALARP)

15. A small team of people, who understand the processes operated on site and who are competent to recognise the hazards, should use a suitable structured hazard identification procedure to establish which major accident hazard scenarios are created by the site’s activities. A number of major accident scenarios which may be relevant to the surface engineering sector are discussed below (but are not exhaustive). The hazard identification procedure should (i) determine whether the major accident scenarios discussed below are relevant for the site; and (ii) whether there are any additional major accident hazards. The dangerous substances can be considered in turn, using a brainstorming approach to consider whether any potential event could give rise to a major accident, e.g.
    - fire;
    - equipment and control system failures;
    - human error;
    - external events, such as flooding;
    - management system failures.

## MAJOR ACCIDENT HAZARD SCENARIOS AND RELEVANT GOOD PRACTICE

16. Identification of the major accidents which could arise is an essential part of developing the MAPP and determining suitable measures to reduce the risk. For top tier sites, identification of the major accident hazard scenarios is one of the first steps in preparing a safety report.

17. Some major accident hazard scenarios, which have been identified as being relevant to the surface engineering sector, are discussed below. Risk reduction measures which comprise relevant good practice are also discussed.

### (1) Inadvertent mixing of incompatible chemicals

### Identification

18. Surface engineering factories typically include a number of tanks or vats for different treatment processes and containing different chemicals. The compatibility of all chemicals used or stored on site should be assessed, in order to identify reactions which could generate dangerous substances, particularly in the gas/vapour phase. Some examples of inadvertent reactions which produce toxic gases are:
    - Cyanide + acid produces hydrogen cyanide (HCN)
    - Hypochlorite + acid produces chlorine
    - Bifluoride + acid produces hydrogen fluoride (HF)

19. Sources of information for such chemical incompatibilities include the material safety data sheet (SDS) and references such as Sax’s Dangerous Properties of Industrial Materials and **HSG 143** - Designing and operating safe chemical reaction processes.

20. Possible means of inadvertent mixing which should be considered include:
    - Mischarging, e.g. when making up a new vat; topping up etc.
    - Spills, particularly events that cause spills or rupture of several containers (containing different chemicals), e.g. collision by a fork-lift truck or other vehicle; fire.
    - Drainage of plant, e.g. during maintenance, etc., temporary connections, etc.

**Example scenarios**

21. An indication of the consequences of inadvertent mixing can be seen from the following examples.

    a) During the make-up of a new cyanide vat at a factory, a drum of 96% sulphuric acid was mistakenly charged to the vat which already contained cyanide, creating an inadvertent mixing event. This was estimated to liberate approximately 50 kg of very toxic hydrogen cyanide (HCN) vapour inside the building. (The reaction is exothermic and would liberate enough heat to vaporise the HCN formed.) The toxic cloud would fill the entire building (unless it was specially designed to prevent air movement from one part of the building to another). Multiple fatalities could be expected, particularly as high concentrations of HCN rapidly cause collapse and so would impair escape. HCN is not necessarily detectable by smell. The building will slow the release to the outside such that there is no major accident potential outside the building.

    b) A less severe but more likely variant of the above scenario is inadvertent topping up with acid instead of cyanide. This would lead to a much smaller release of HCN, less than 1 kg. With good ventilation, the distance to a 50% probability of death would be less than 1 metre. Therefore the main effect would be to the individual carrying out the topping up, unless there were others present in a small room with poor ventilation. Harm to others could also result from attempting to rescue an individual who had been overcome without suitable equipment and training.

    c) Other inadvertent mixing events, due to mistakenly charging a drum of acid during make-up of a vat, could cause a cloud of toxic chlorine or very toxic hydrofluoric acid (HF). In either case, a toxic cloud would form throughout the building and multiple fatalities would be expected. For HF, fatalities would be expected to be limited to persons within the building. For chlorine, a toxic cloud would extend outside the building from openings such as open doors. The distance until the concentration falls to that equivalent to a 50% probability of death is discussed in the **Appendix**.

**Preventative and Mitigatory Measures - Good practice**

22. The following are considered to be good practice for the prevention and mitigation of inadvertent mixing:

    - At delivery:
        - Check container integrity on receipt;
        - Check pallet security before unloading;
        - Unload in designated areas;
        - Specific incompatible substances to be on separate pallets;
        - Drains sealed before chemicals moved.
    - Storage:
        - Suitable location
        - Separate individual storage areas for non-compatible materials, such that a collision event or localised fire would not result in spillage and inadvertent mixing of non-compatible materials.
        - Separate acid and cyanide storage areas with separating bunds
    - Process:
        - Use dedicated tanks for acids and cyanides.
        - Clearly label all plant (e.g. tanks, piping, connections,etc.)..

- Use procedural controls for making up vats and topping up. This would include identification of the correct chemicals and amounts and checking of this before charging.
  - Make additions under supervision or by auto-dosing.
  - Train all operatives (including hazard awareness)
  - Written instructions for making additions.
  - Give attention to human factors issues. For example, different packaging for chemicals to make it difficult to mistake one for another; storage in different places.
- Limit consequences:
  - Limit the size of containers, (e.g. 45 litre drums of acids; 50kg kegs of cyanide) to limit the maximum quantity that could be inadvertently mixed and thereby limit the consequences.
  - Housekeeping following spillages so that a second spillage of non-compatible chemicals cannot result in inadvertent mixing.
  - Control of chemicals to drain to prevent mixing of non-compatible chemicals in the drains.
  - Control of chemicals to water treatment units to prevent uncontrolled mixing of non-compatible chemicals.
- Emergency response:
  - Provide supplies of cyanide antidote
  - Make plans for raising alarm, evacuating building
  - Rescue requires suitable protective equipment/breathing apparatus

**(2) Fire involving stored chromium trioxide or cyanides**

**Identification**

23. The major accident hazard from such a fire is that dangerous substances could be entrained into the smoke plume giving rise to a hazard from toxic smoke. There is also the potential for a fire to cause loss of containment of dangerous substances and the potential for mixing of non-compatible substances (see above).

24. Modelling suggests that:

- there would be no major accident hazard due to entrainment into the smoke plume which issues from the building provided that less than about 50 tonnes of chromium trioxide and/or cyanides were involved in a fire.
- If more than 50 tonnes of chromium trioxide and/or cyanide are held, or if dangerous substances which are more toxic than these are held, modelling would be required to determine whether toxic smoke from a fire would constitute a major accident hazard. **Further information** on the assessment of the consequences is given below.

25. In any case, if there is the potential for dangerous substances such as cyanides or chromium trioxide to be involved in a fire, there will be the potential for major accident to persons inside the building. This should be mitigated by emergency response

(evacuation). Liaison with the emergency services will be required to ensure that they attend any fire using breathing apparatus.

**Preventative and Mitigatory Measures - Good practice**

26. The following are considered to be good practice for the prevention and mitigation of toxic smoke from fires:
    - General fire precautions to prevent/minimise fires.
    - Minimise inventories of dangerous substances.
    - Segregate, and maximise separation of, toxics from flammables and/or combustibles. Flammables/ combustibles include fuels and other flammable/highly flammable liquids; and combustible solids, including any plastic components which are to be surface engineered, and the building if constructed using combustible materials such as timber.
    - Store dangerous substances in as inherently safe a form as possible, taking into account the needs of the process. It is finely divided solid cyanides and chromium trioxide which have the potential for entrainment into a smoke plume; storage as a solution in water is safer in this respect (but not necessarily for the environment). Use toxic solids with as large a particle size as possible since this mitigates against entrainment into a smoke plume.
    - Store dangerous substances at low level, preferably ground level, rather than high in a racking system. Use non-pressurisable containers.
    - Further guidance on storage is given in **HS(G)71** Chemical warehousing – The storage of packaged dangerous substances
    - The hazards to operators from breathing toxic dusts should also be considered.

**(3) Loss of dangerous substance inventory e.g. loss of thermostatic control on a plating bath**

**Identification**

27. Loss of process liquid level lowering the solution level will expose the hot surfaces of the immersion heater producing high temperatures sufficient to ignite the tank walls and spread fire to the fume extraction system.

28. If the tank is charged with process solution, the ignition and/or melting of the tank walls will release the process chemicals. This has the potential to impact the environment.

**Good practice**

29. The following are considered to be good practice for the prevention of fires caused by electrical process heaters:
    - replacement of electrical immersion heaters with indirect heating by heat exchangers

    For immersion heaters:

    - proper selection of equipment
    - installation and positioning of heaters
    - arrangement and integrity of control and sensor circuits, and
    - effective maintenance of the system
    - firm and suitable fixing of the heater with defined clearances
    - automatic fluid make-up to maintain the process liquid level
    - a low level cut-out in the event of catastrophic loss of process fluid
    - built in overtemperature device for the heater
    - construction of process tanks from fire retardant polypropylene

Further guidance can be found in:

- Fires in metal finishing premises from electric process heaters

- the British Surface Treatment Suppliers Association (BSTSA) and the Loss Prevention Council (LPC) – Joint Code of Practice: Electrical Process Heating Fire Safety in the Metal Finishing Industry.

### (4) Environmental impact of fire control

**Identification**

30. Application of water and/or foam to a fire may result in large volumes of water or foam which may contain dangerous substances which were either part of the COMAH inventory or may have been produced during the fire.

31. There is no legal duty on Fire & Rescue Authorities to extinguish fires. Without risk to life or other property, a controlled burn may be the most practical option. Foreseeable scenarios where this option may apply should be identified and justified.

32. Due to the unpredictable nature of a fire, worst case assumptions should be made regarding the volume of water which may be applied. The key issues for a COMAH duty holder are:-

- What is the retention volume and time for holding firewater on site?
- What pathways exist for firewater to leave the site? This should include not only the obvious ones such as sewer or the surface water system, but also the unexpected such as overflows onto roadways or boreholes and soakaways.

**Good practice**

33. The following are considered to be good practice for the prevention and mitigation of environmental impact from fire control:

- Limit the number of pathways e.g. by bunding
- Restrict the flows e.g. fit penstock valves to sewer connections
- Construct firewater retention tanks (subject to space)
- Discuss with the Fire Service likely fire fighting scenarios and potential volumes of firewater which may be produced.
- Discuss with the sewerage undertaker the fate of firewaters entering the foul system. It is possible that retention capacity is available within the system

### (5) Spillage

**Identification**

34. Spillages of liquids, which enter the drainage system either resulting in a release to sewer and/or watercourse, give rise to the potential for a MATTE.

35. Plating shops maintain an inventory of dangerous substances. The greatest risk of spillage occurs during delivery and transfer of dangerous substances, during normal operation and maintenance.

**Good practice**

36. Further guidance can be found in:

- **HS(G)71** Chemical warehousing – The storage of packaged dangerous substances
- Surface Engineering Association - Health, Safety & Environment Code of Best Practice for the Surface Finishing Industry 2001

**(6) Scenarios caused by other dangerous substances**

37. There may be other major accident scenarios as a result of other dangerous substances held at the site. Once a site qualifies as coming under COMAH, **all** dangerous substances, regardless of the quantities held, must be considered for their potential to give rise to a major accident (either directly or through escalation of events).

38. Natural gas and LPG are dangerous substances which are commonly used for space and/or process heating. Major accidents scenarios involving these must therefore be considered, i.e. fires and explosions. The worst case gas explosion, for example, will have the potential to demolish the building and multiple fatalities to those inside. An LPG cylinder or tank, if involved in a fire, has the potential to undergo a BLEVE (boiling liquid expanding vapour explosion), causing a large fireball and multiple fatalities of those in the vicinity. Such scenarios are common to most industrial premises and, utilising relevant good practice, the risk is suitably low. Such good practice is covered in guidance such as the **LPGA Codes of practice**. It includes:

- Segregation of LPG storage from combustibles and other dangerous substances.
- Burner controls which isolate the fuel if ignition is lost.
- Inspection programmes for pressure vessels and piping.
- Protection of vessels and piping from impact.

## COMAH RISK ASSESSMENT

### Introduction

39. Top tier COMAH sites are required to produce a safety report, which will include a risk assessment. Most sites in the surface engineering sector are expected to give rise to relatively low risk from major accident hazards. The level of demonstration expected in a COMAH safety report will also be proportionately low.

40. The risk assessment (predictive) aspects required in a safety report for the surface treatment sector include the following:

- Identification of the major accident hazards (MAH). The following are discussed **above**:
  - Inadvertent mixing of incompatible materials.
  - If large quantities (> 50 tonnes) of chromium trioxide and/or cyanides are stored as solids, then there may be a major accident hazard from toxic smoke in the event of a fire.
  - Environmental major accident scenarios, e.g. due to failure of the plating bath; water or foam from fire-fighting; or spillage of plating solutions.
  - There may also be other major accident hazard scenarios due to other dangerous substances such as natural gas or LPG, if present.

- Information on the **extent** and **severity** of the major accident hazards. Further information is given below.

- A risk assessment. Risk assessments can be done to different levels of detail, as given below in order of increasing rigour:
  - Qualitative (Q), in which frequency and severity are determined purely qualitatively.
  - Semi-quantitative (SQ), in which frequency and severity are approximately quantified within ranges.
  - Quantified risk assessment (QRA), in which full quantification occurs.

Qualitative assessment is likely to be sufficient and **further information** is given below.

## Extent

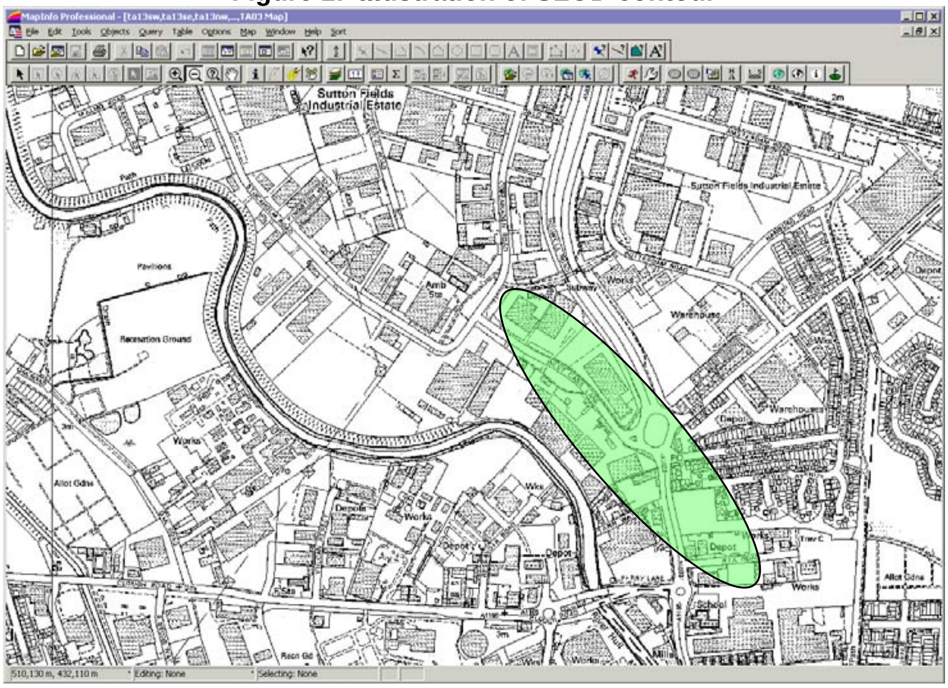
41. ‘Extent’ is a measure of the distance affected (hazard range) of a major accident scenario. For example, whether the hazard extends only within the building, or whether there is also an off-site hazard and, if so, for what distance. Extent can be quoted to different effect levels. For major accident hazard safety risks, an appropriate level to use is significant likelihood of death (**SLOD**), which is equivalent to a 50% probability of death.

42. Some further information on hazard ranges for typical scenarios are given in the **Appendix**.

## Severity

43. For safety risks, it is a requirement of Schedule 4 part 2 of COMAH to estimate the potential number of fatalities and injuries that could result for the major accident hazards. These will be specific to the particular site and the number of people employed on-site and the number in the surrounding area.

**Figure 1: Illustration of SLOD contour**




44. A rough estimate of the number of potential fatalities can be obtained by:
    - plotting the SLOD contour (50% probability of fatality) onto a map (see Figure 1 above),
    - finding the direction in which it covers the highest population, and
    - counting the number of people affected.

45. This rough estimate effectively balances the number of people who are within the SLOD contour and survive, with the number who are outside the contour but are killed.

46. An example estimation of severity is as follows. An inadvertent mixing scenario can liberate 36 kg of chlorine and create a SLOD contour including the inside of the factory itself, which has 18 employees, and an external cloud with a downwind

distance shown in **Figure 4** (for those outside) and **Table 2** (for those inside). In the worst case, F2 weather (stable, low turbulence, conditions with low wind speed) has been assumed although this is more likely at night when the factory would be closed and not be making up new tanks. For the worst case wind direction (assessed by looking at a map and finding the direction in which the cloud covers the most houses), the cloud given by Table 2 could encompass 12 houses, which are assumed to have an average number of occupants of 2.5. People are assumed to be at home and to be indoors 90% of the time.

47. The potential severity of this example scenario would be:

    a. 8 people in the factory
    b. 12 x 2.5 x 0.9 = 27 people inside houses
    c. 2 people caught by the cloud outside
    d. Total = 8 + 27 + 3 = 38

**Risk assessment**

48. A risk assessment considers both the consequence (severity) and the likelihood or frequency of each of the major accident hazards. The depth of the analysis in the risk assessment should be proportionate to (a) the scale and nature of the major accident hazards (MAHs) presented by the site and the installations and activities on it, and (b) the risks posed to neighbouring populations and the environment. The risks referred to here include both those to the individual at most risk and the risk of causing multiple fatalities. It is expected that most surface engineering sites are likely to be of relatively low proportionality and that qualitative risk assessment will be sufficient.

49. In a qualitative risk assessment, both the consequence and likelihood aspects are given descriptors. However, since it is a requirement of COMAH to quantify severity, the consequences can be quantified in terms of ranges of numbers of potential fatalities.

50. The risk can be presented in terms of a risk matrix, which has the dimensions of severity and likelihood. Further information on risk matrices and potential pitfalls is given in a paper by Mark Middleton & Andy Franks "Using Risk Matrices", The Chemical Engineer, September 2001, pp 34 – 37, which is based on work done for HSE.

51. Risk matrices often indicate the magnitude of the risk, usually in terms of three bands:
    - Risks that are so high as to be intolerable
    - Risks that are tolerable if they have been reduced as low as reasonably practicable (ALARP)
    - Risks that are broadly acceptable.

52. For risks that are broadly acceptable or at the low end of the tolerable region, it will usually be sufficient to demonstrate that **relevant good practice** has been used to prevent, control and mitigate the risk.

53. Some qualitative descriptors which have been used to express quantified ranges of frequency are given in Table 1 and some frequencies of unusual events are given in Table 2. These could be used to decide likelihood for particular events, although independence and experience are important when assessing likelihood categories.

**Table 1   Benchmarking of likelihood descriptors**

| Frequency | Description |
|---|---|
| $10^{-2}$ – 1 per year | Expected.  Known to occur during the process |
| $10^{-2}$ – $10^{-4}$ per year | Known to occur occasionally, perhaps in another company, but not normally anticipated |
| $10^{-4}$ – $10^{-6}$ per year | Conceivable that it could occur but no evidence available that it ever has |
| < $10^{-6}$ per year | Virtually inconceivable.  Extremely unlikely to ever occur. |

**Table 2   Frequencies of some unusual events**

| Event | Frequency per year |
|---|---|
| Risk of death from 5 hours solo rock climbing per weekend | $10^{-2}$ |
| Death from a traffic accident | $10^{-4}$ |
| Death from a fire or gas explosion at home | $10^{-6}$ |
| Struck by lightning | $10^{-7}$ |
| Hit by fallen aircraft | $2x10^{-8}$ |
| Rupture of a pipe on a pressurised storage system | $10^{-5}$ |
| Sudden catastrophic failure of pressure vessels | $3x10^{-6}$ |
| Average frequency of a warehouse fire, across all industry sectors | $10^{-2}$ |

54. The likelihood of the particular severity outcome should be used (e.g. the likelihood of a particular mischarging event occurring and causing x fatalities, which will depend on how many people are exposed in particular circumstances), rather than the likelihood of the scenario (e.g. the likelihood of any mischarging event occurring).

55. An example risk matrix is shown in Figure 2 for illustrative purposes.  The colours have the following meanings:

- Red      intolerable risk;
- Orange  risk may be intolerable at the higher end of the likelihood range;
- Yellow   tolerable if ALARP;
- Green    broadly acceptable risk.

56. Any risk matrix should be reviewed to ensure it is suitable for the risk assessment, e.g. that it covers the necessary range of potential severity.

**Figure 2        Example risk matrix**

| Likelihood | Severity | | |
|---|---|---|---|
| | Single fatality | 2-10 fatalities | 11-50 fatalities |
| Likely<br>> $10^{-2}$ per year | Red | Red | Red |
| Unlikely<br>$10^{-4}$ – $10^{-2}$ per year | Orange | Orange | Red |
| Very unlikely<br>$10^{-6}$ – $10^{-4}$ per year | Yellow | Yellow | Yellow |
| Remote<br>$10^{-8}$ – $10^{-6}$ per year | Green | Green | Yellow |

57. The following events will be used as an example:

    a. Mischarging during routine topping up of a cyanide bath liberating a small amount of HCN

b. Mischarging a drum of acid during tank make-up producing HCN
c. Mischarging a drum of acid during tank make-up producing chlorine

58. The estimated severities for these events are as follows:
    a. 1 fatality to the person topping up
    b. All the 8 persons in the factory are fatalities
    c. 38 fatalities as estimated in the example **above**

59. The estimated likelihoods are as follows:
    a. Mistakes topping up are conceivable although a mistake with such serious consequences is very unlikely, as the operator would have opportunity to notice a reaction taking place and would probably have opportunity to escape. From Table 1 the range $10^{-4}$ – $10^{-6}$ per year is selected. This is 'very unlikely' in Figure 2.
    b. Mistakes during make-up of a new tank are considered to be virtually inconceivable given the administrative controls in place and the infrequency with which new tanks are made up. 'Remote' is selected in Figure 2.
    c. This event would require both a mistake during make-up of a new tank, and for the weather to be F2 (inversion with low wind) and for the wind to be in the worst direction. This reduces the likelihood compared with b although the category remains 'Remote' in Figure 2.

60. The three example events can then be plotted on the example risk matrix as shown in Figure 3:

**Figure 3 Worked example using example risk matrix**

| Likelihood | Severity | | |
|---|---|---|---|
| | Single fatality | 2-10 fatalities | 11-50 fatalities |
| Likely $> 10^{-2}$ per year | | | |
| Unlikely $10^{-4}$ – $10^{-2}$ per year | | | |
| Very unlikely $10^{-6}$ – $10^{-4}$ per year | a | | |
| Remote $10^{-8}$ – $10^{-6}$ per year | | b | c |

61. For these examples, the risk matrix suggests that the risks are either broadly acceptable or towards the lower end of the 'tolerable if ALARP' band. It is however emphasised that such conclusions can only be drawn if a risk matrix has been suitably calibrated.

## ALARP demonstration

62. An important function of the safety report is to demonstrate that all measures necessary have been implemented to prevent, control and mitigate major accident hazards. This is equated by HSE to the demonstration that the risk is as low as reasonably practicable (ALARP).

63. If the risks are found to be broadly acceptable or low in the 'tolerable if ALARP' region, it would be expected that demonstration that **relevant good practice** has been implemented will be sufficient to demonstrate ALARP.

64. Alternatively an ALARP demonstration would comprise answering the questions:
    - What more could I do to reduce risk? and
    - Why have I not done it?

65. It would be expected that any low cost risk reduction measures which were identified would be implemented anyway. Further information on **ALARP** is given on HSE's COMAH web pages.

66. A good demonstration should show the link between identified major accident hazard scenarios and the specific applied necessary measures in place to address those hazards.

## APPENDIX: FURTHER INFORMATION ON HAZARD RANGES

### Typical hazard ranges for inadvertent mixing events

### Generation of chlorine

67. Mischarging a 45 litre drum of 96% sulphuric acid to a tank containing hypochlorite is estimated to liberate approximately 36 kg of chlorine. The toxic cloud would fill the entire building, causing multiple fatalities.

68. If the chlorine was released via an open door in the factory building, it would give rise to a toxic cloud outside the factory. A high release rate from the building was assumed (equivalent to 10 air changes per hour). The volume of the factory was assumed to be 2800 $m^3$ but the toxic cloud dimensions were found to be very insensitive to the volume of the building assumed. The toxic cloud dimensions for different quantities of chlorine are as shown in the graphs below. These are for weather conditions F2 (this is equivalent to a still night) and D5 (this is equivalent to a blustery day).

**Figure 4 Distances to 50% fatality (SLOD) for releases of different quantities of chlorine for people outside in F2 conditions**

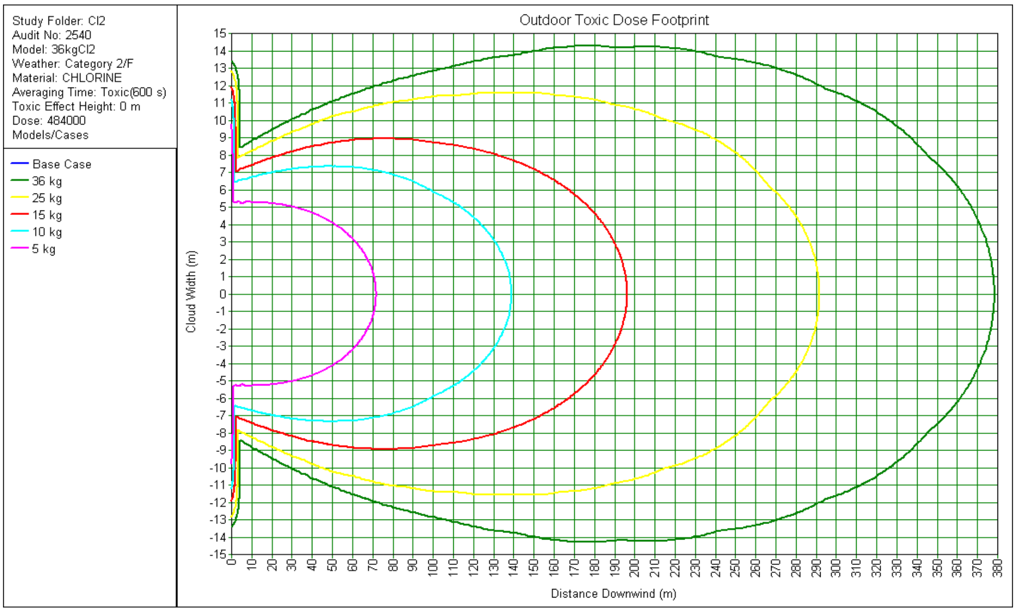
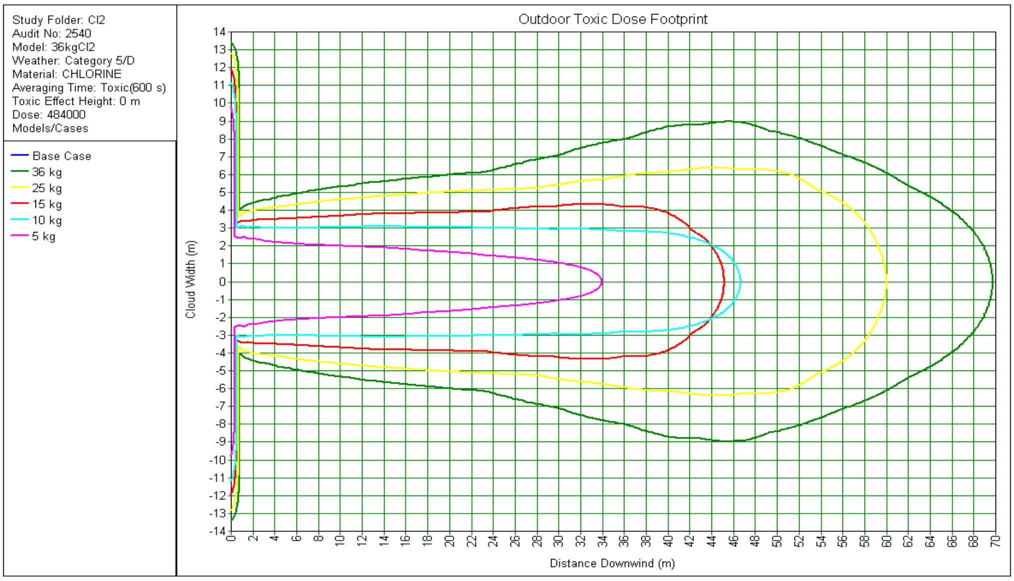


**Figure 5 Distances to 50% fatality (SLOD) for releases of different quantities of chlorine for people outside in D5 conditions**




69. If people are inside buildings rather than out in the open, the distance to 50% fatality is reduced, as shown in Table 2 below. The usual advice to people living close to a COMAH site with toxic hazards would be to go indoors and shut all doors and windows on hearing an alarm. Then to tune into a local radio station for instructions on when to go outside again.

**Table 2 Hazard ranges to 50% probability of fatality for those inside a building**

| Quantity of chlorine released (kg) | F2 weather conditions | | D5 weather conditions | |
|---|---|---|---|---|
| | Max down wind distance (m) | Max cloud width (m) | Max down wind distance (m) | Max cloud width (m) |
| 36 | 177 | 16.5 | 42 | 9 |
| 25 | 167 | 14 | 40 | 6.5 |
| 15 | 78 | 11 | 28 | 5.5 |
| 10 | 49 | 9.5 | 18 | 5 |
| 5 | 14 | 6 | 4.5 | 3.6 |

## <u>Generation of hydrogen cyanide (HCN) or Hydrofluoric acid (HF)</u>

70. Details have been given above for **HCN** and **HF**. In the worst case of mischarging of a complete drum of acid to a tank containing cyanide or bifluoride, a toxic cloud would form throughout the building and multiple fatalities would be expected. Fatalities would be expected to be limited to persons within the building.

## Assessing consequences from warehouse fires

71. The conclusion **above** that there is no external major accident hazard from a warehouse fire if less than about 50 tonnes of chromium trioxide or cyanides are held was obtained by making the following assumptions, all of which will tend to overestimate the hazards (i.e. are conservative):
- Materials stored as finely divided solid particles in pressurisable containers
- 10% of the dangerous substance is entrained into the toxic smoke plume
- The plume has a low buoyancy as a result of a small fire.
- 30 minutes exposure to the smoke, i.e. no account taken of escape

72. It is anticipated that most surface engineering companies will be storing less than this threshold amount. If not, modelling will be required and further information is available in HSE's guidance on safety report assessment for **chemical warehouses**.

### Assessing the consequences from LPG vessels

73. If an LPG vessel is involved in a fire or if a major rupture occurs, for example due to vehicle impact, a fireball can result.

74. Figure 6 shows hazard ranges for thermal radiation from such fireballs. The distance to SLOD corresponds to the distance within which there is a 50% probability of fatality to those outside. The distance to dangerous dose is also shown. Dangerous dose corresponds to 1-5% probability of fatality. People within a building are likely to survive a fireball, particularly if they keep away from windows. They may need to evacuate afterwards if the building catches fire.

75. Further information on assessing the consequences from LPG vessels is given in the **HSE safety report assessment guide for LPG**.

**Figure 6 Fireball hazard ranges for LPG tanks and cylinders**