

Commonly asked Questions about the CDOIF Guideline

Understanding Major Hazard Human Harm Risk Assessment (MHHRA) for COMAH

Q *What is the current status of the HSE document 'Reducing risks, protecting people'(sometimes known as R2P2) ?*

A The HSE 2001 publication *'Reducing risks, protecting people: HSE's decision-making process'* (R2P2), set down the general approach used by the HSE for making regulatory decisions. The document made it clear that R2P2 was not intended as guidance for Operators. R2P2 explained that Operators who want to emulate the regulators' approach, first need to recognise how the different contexts in which HSE applies its framework differ; taking this into account when applying it to their own sectors of industry. One such differing context is the COMAH regulatory framework to which the MHHRA guidance applies. HSE have placed R2P2 into the National Archive, as many Operators have used it as guidance, or still refer to this document; its previous use is therefore referenced in this guideline. This CDOIF guideline outlines an appropriate approach for COMAH Operators to adopt when applying these principles, including when undertaking a tolerability of risk assessment (see section 5.5 of the CDOIF guideline).

Q *How should the tolerability of risk framework in R2P2 be interpreted by Control of Major Accident Hazards (COMAH) Operators?*

A The CDOIF guideline outlines the general principles that need to be included in any assessment of human harm. However, it is for each sector of industry, including the onshore major hazard sector, to produce its own good practice guidance on how a suitable and sufficient tolerability of risk assessment can be carried out. This should take into account issues such as the legal context, the people exposed, and the Major Accident Hazard Scenario(s) MAHS(s) a person could be exposed to.

Section 5 of the CDOIF guideline outlines CDOIF's view on how COMAH Operators should undertake a tolerability of risk assessment for COMAH. CDOIF notes Operators can adopt other appropriate equivalent approaches, providing the current good practice principles it contains are followed. However, it should be noted that CDOIF did not identify any alternative principles and risk criteria when creating this guideline.

Q *The CDOIF guideline recommends that the focus of a MHHRA be at the unit operation level. What is a unit operation?*

A This guideline's primary focus is to assess the risk of human harm from the major accident hazards associated with a COMAH establishment's unit operation(s). A unit operation is a defined physical change, and/or defined chemical transformation, performed within a fixed defined system. A [process] system is a fixed arrangement of process equipment whose boundaries are defined. it may be used to perform a particular process, or a number of defined processes. It is normally designed to be operated either continuously, or to produce single batches. For more detail please see **Technical Note 1**, appended.

Q *The new CDOIF guideline on major hazard human harm risk assessment (MHHHRA) for COMAH is very different from what we are used to. The law, however, has not changed. How is it that many Operators and specialist inspectors have misinterpreted the law for so long?*

A There are a range of reasons, including the lack of available guides to current good practice principles and approaches. In addition, as the chemicals industry matured and fewer new plants were built, there has been a move towards outsourcing risk assessment and loss prevention, progressively reducing experience and knowledge among Operators. This led to a move towards simple, generic and rapid assessment methodologies for existing facilities. However, these are sometimes based on techniques which work well in most cases for early design, but are inappropriate for MHHHRA, particularly when determining cumulative risk. Good practice in MHHHRA has also evolved over the last twenty-five years. Historically, the COMAH Competent Authority (CA) has carried out sample inspections on COMAH establishments, including targeted risk controls against particular standards or initiatives, such as ageing plant. MHHHRA sample inspections have been conducted less frequently.

Q *There are guidance documents and standards which use fractional time at risk for calculating individual risk. Can you explain why the approach taken in the CDOIF guideline is different when undertaking a MHHHRA?*

A The cumulative risk to the person is the summation of the risks from the MAHS(s) that the person is exposed to.

Some Operators suggested that once the maximum cumulative individual risk of a person is determined, this could be divided by the numbers of shifts (for example, three) or teams on site (for example, five), as a specific person was only there for a fraction of the time. Their argument was that the establishment's major accident hazard risk to workers at any one time should be divided to represent the risk to any one worker on a shift.

This is not appropriate as the COMAH Regulations and the Health and Safety at Work etc. Act 1974 do not focus on the individual but harm to 'people', 'employees' and 'persons other than employees'. The cumulative risk is determined for serious danger to these people, both singularly and collectively, both onsite and offsite. CDOIF concluded that the risk fractionation approach suggested by some Operators was not appropriate. This is because risks arising from occupational hazards, such as toxic dusts, are proportionate to the time a particular individual is present, the dose being accumulated over hours or days. If a major hazard scenario occurs, the dose of thermal harm, toxic dose or blast occurs over a few seconds or minutes, so whoever is present receives the full dose; this is not divided by the number of shifts (**see Technical Notes 2 and 3 below**).

CDOIF did consider other approaches (for example, adopting some fractionation for a period of time). However, as there is no logical argument or evidence to support the use of risk fractionation, and adopting such an approach could undermine assurance in the MHHHRA guideline and CDOIF's reputation, this approach was not included. Instead, CDOIF adopted the principle that Operators calculate the maximum cumulative individual risk, based on the time that the job/activity is being carried out at that installation/establishment. CDOIF recognised the COMAH CA's commitment to give Operators reasonable time to change their practices if they currently adopt risk fractionation.

CDOIF recognised that, in some cases, using risk fractionation made it appear that the risks from the establishment were tolerable if ALARP, when in fact, they were not. However, it should be noted that, in many cases, intolerable risks may arise if the Operator's MHHHRA is not of a sufficient resolution; but when MAHS risks are adequately assessed the cumulative individual risks are then shown to be tolerable if ALARP.

If the cumulative individual risk is still intolerable after the resolution has been increased, the Operator will need to consider replacing or modifying the main contributors to their risk profile (e.g. checking all appropriate measures are in place, ensuring all reasonably practicable further measures have been evaluated and implemented as necessary, or changing the unit operation).

Q *Are there times when fractionation is appropriate?*

A CDOIF noted that it is appropriate to consider the fractional time exposed when a person carrying out a particular job function moves from one part of an establishment to another, and in doing so is not exposed to all of the MAHS(s) all of the time. **Table 3 of the CDOIF guideline** gives an example of how to consider the fractional time a job function is exposed to a MAHS. In addition, sometimes similar job functions share a range of tasks within a team on the same shift. Provided that the tasks are in an area which is subject to the same MAHS(s) and that the tasks are randomly allocated rather than permanently assigned, the cumulative individual risk can be averaged among that team to produce a profile, which includes a fraction of time a job function is exposed to a MAHS (**see section 5.4.4 of the CDOIF guideline**).

Q *To undertake a tolerability of risk assessment an Operator must determine the maximum cumulative individual risk to the person from the establishment. How should this be done?*

A CDOIF considered how you could determine the maximum cumulative risk to the person from the establishment's MAH risks and noted the following good practice principles (**see section 5.4 of the CDOIF guideline**):

- People both inside and outside the establishment are exposed to a wide variety of risks. As a person moves location, they often move in and out of the hazard ranges of the various MAHS(s) on the establishment. It is only the cumulative risks from the MAHS(s) to which people are exposed which are considered when carrying out a MHHRA for COMAH. The risks from everyday life or occupational risks such as slips, trips or falls are not considered.
- If a major accident was to occur, the exposure to a person is over a few minutes or seconds. So, if they are present, they receive the full dose, not a fraction based on the number of shifts.
- There is no consistently cited definition because it is used in different forms for different circumstances. For example, cumulative individual risk could refer to a hypothetical person, job function or a named person. However, sometimes the use of a particular form of cumulative individual risk is inappropriate.
- For COMAH, cumulative individual risk (most often referred to simply as 'individual risk') is for a MAHS that can result in serious danger. This is a range from serious injury to death, so the ends of this range are calculated separately. It is the sum of the MAHS consequence frequencies that a person is exposed to for both death and serious injury, respectively.

CDOIF concluded that a person's total risk of both death and also serious injury could be determined by considering the geographical location of the person with time, whether outside or inside as this modifies the risk, and the opportunity to escape should an MAHS occur (**see section 5.4 of the CDOIF guideline**). CDOIF concluded that Operators could use these principles to select the most appropriate approach to determining the maximum cumulative risk to the person.

These principles mean that the form of cumulative individual risk selected must be appropriate for the particular person being considered under the MHHRA. For example, as it may not always be possible to account for the movements of people offsite, or onsite where a particular onsite job function is static. For example, for a dedicated control room operator who rarely goes to the production plant, and only works from a particular control room, adopting cumulative individual risk (hypothetical person) may be appropriate. Another example is if the person performs a set of tasks that take them inside and outside, and to several areas of the plant. In these cases, cumulative individual risk (job function) may be appropriate. It is the operator's responsibility to adopt the appropriate approach based on the working group's principles.

Q *If HSE is rejecting arguments from the current (2001) R2P2 surrounding individual risk, then why is it quoting the risk tolerability values from the same document?*

A R2P2 set down the general approach used by the HSE for making regulatory decisions, it was not Operator guidance on undertaking a tolerability of risk assessment for COMAH. The CDOIF guideline develops the risk criteria outlined in R2P2 to include MAHS(s) and incorporate serious danger. CDOIF considered the good practice principles that a COMAH Operator can adopt to undertake a suitable and sufficient tolerability of risk assessment for COMAH (**see section 5.4 of the CDOIF guideline**). It concluded that one way to meet this requirement was to adapt the risk criteria in R2P2 for MAHS(s), in order to include serious injury (an element of the COMAH definition of major accident). The CDOIF guidelines stress that Operators could adopt other appropriate and equivalent approaches, providing these good practice principles are followed; however it should be noted that CDOIF did not identify any alternative principles and risk criteria when creating this guideline.

Q *Our COMAH sector doesn't publish failure rate data - where can we find data?*

A It is most likely that an Operator will need to select from a range of techniques to determine a unit operation's MAHS frequencies. These consider the failure frequencies of components, equipment items and, in some cases, sub-assemblies. It may involve using a range of information sources to generate the MAHS frequencies required. **Annex 13 of the CDOIF guideline** highlights current failure rate data sources. **Annex 18** on human error probabilities has also been included. **Annex 14** gives advice on deriving failure rates from site data, which is encouraged.

It would be unusual to find the MAHS frequencies for a whole unit operation that uses the same process parameters; has an identical configuration; is controlled the same way; and also encompasses all scenario failure mechanisms leading to loss of containment. Any sources of equipment/component frequency should be reconciled against the establishment's experience when available.

Q *For sites which are upper tier, their COMAH risk assessment is assessed against the Predictive Aspects of HSE's safety report assessment manual (SRAM). This document allows for assessments to be qualitative, semi quantitative and fully quantitative. How does the CDOIF methodology fit in with qualitative assessments?*

A The SRAM is designed for the regulator (not the Operator) to consider if the minimum information required in a COMAH safety report has been provided. The SRAM states that it is not intended to provide guidance to operators on writing safety reports. However, it has been made publicly available via the HSE/COMAH Website to ensure transparency in respect of the HSE Safety Report assessment process. The SRAM clearly states it was not designed to consider if a suitable and sufficient MHHRA has been produced by the COMAH Operator. The SRAM is also not guidance on the use of qualitative, semi-quantitative and quantitative MHHRA approaches. **Section 4 of the CDOIF guideline**, with consideration

of **Annex 2** on proportionality (which makes it clear that all COMAH establishments are at least high proportionality), enables a COMAH Operator to consider the appropriate MHHHRA approaches to adopt.

Q *I am complying with my general arrangements, including those to meet PUWER and DSEAR, are these not sufficient to address MAHS(s)?*

The general requirements given in DSEAR and PUWER were mainly intended for dealing with site general arrangements, and were not focused on the public who may be impacted by a major accident. Therefore, compliance with such legislation is not sufficient to meet your MHHHRA requirements, including considering the initiating and propagating events that can lead to each MAHS, ensuring appropriate measures are in place, undertaking a tolerability of risk assessment and considering further measures.

Q *Do I really need to undertake both hazard identification (HAZID) and a hazard and operability study (HAZOP)?*

A It is an Operator's responsibility to consider current good practice and principles and determine what is necessary to undertake a suitable and sufficient MHHHRA. **Section 3 of the CDOIF guideline** outlines the key principles to consider when undertaking major accident hazard scenario identification. The principles in the CDOIF guideline make it clear that an Operator needs a combination of techniques which should include both top-down and bottom-up studies.

Q *Do I need to include fatality scenarios for non COMAH materials, for example, high-pressure carbon-dioxide (CO₂)?*

A It should be noted that if the material is not defined as a dangerous substance under COMAH but gives rise to a scenario that includes a COMAH dangerous substance, it still needs to be considered.

CO₂ is not a dangerous substance under COMAH, but some Operators have decided to include it in their assessments. This is because there is still a duty under The Management of Health and Safety at Work Regulations (MHSWR) to undertake a suitable and sufficient risk assessment.

Q *How long do we have to comply?*

A You need to continue to comply with the Health and Safety at Work etc. Act (HSWA) and relevant statutory provisions (like COMAH and the MHSWR) for as long as you are an employer, self-employed or an Operator under the legislation. This includes keeping your MHHHRA and related measures under review and revision (for example, when things change). If you feel that you are not following the current good practice principles in the CDOIF guideline, you should discuss this with your regulatory inspector and agree a reasonable time for you to comply.

Q *I am using a software quantitative risk assessment (QRA) tool, will that comply?*

A The CA's experience is that using a software QRA tool, alongside other appropriate techniques to implement MHHHRA good practice principles, can result in the Operator adopting a suitable and sufficient MHHHRA.

The key issues are that such software QRA tools by themselves often do not:

- make it transparent what all the identified MAHS(s) are;
- explain all the event combinations that can lead to each MAHS;

- explain what control measures are required;
- produce appropriate MAHS frequencies or consequences; and
- undertake an appropriate tolerability of risk assessment using maximum cumulative individual risk; or appropriately consider further measures.

Q *How do I justify the cost and time burden of the additional assessment to senior management? Will this make us safer?*

A It is recognised that many Operators have invested in inappropriate MHHHRA approaches. In setting out the good practice MHHHRA principles, the CDOIF guideline reduces the risk of this happening in the future. Also, if you have not adopted a suitable and sufficient MHHHRA approach, then you are unable to say with confidence that all measures necessary are in place, and/or that the risk from the establishment to the person is as low as reasonably practicable (ALARP). By undertaking a suitable and sufficient MHHHRA, and implementing the findings, this will show the risks from your establishment are as low as reasonably practicable (ALARP), including ensuring appropriate and further measures are in place to manage the risks to the surrounding populations. CDOIF recognises that for organisations not undertaking a suitable and sufficient MHHHRA, there will be some initial costs, but remember this is a legal requirement. CDOIF believes that the guideline will make completing MHHHRA (predictive risk assessment) simpler for industry. It will also support a consistent regulatory approach by the COMAH CA. It should be remembered that in allowing companies to operate, the public expect that they are not putting them at undue risk.

Q *Is there a summary of what is needed to help me convey the key messages to senior leaders?*

A There is a summary of the current good practice principles in the Executive Summary. In addition, the CDOIF guideline has a summary and a process flow diagram at the beginning of each section, these explain how the MHHHRA principles are implemented in order to achieve good practice. **Annex 1** explains MHHHRA in regard to the regulatory context and its legal requirements.

Q *I have been through three COMAH submission cycles, and I haven't received any feedback on predictive issues, am I ok to assume that means I don't need to look at this new guidance?*

A Undertaking a suitable and sufficient MHHHRA is part of producing a safety report. However, a safety report may have been submitted that is not underpinned by a suitable and sufficient MHHHRA. The COMAH CA samples safety reports. Sometimes resources may have resulted in a predictive examination not taking place, and sometimes only certain predictive elements would have been sampled. It is the Operators' responsibility to ensure they have carried out a suitable and sufficient MHHHRA against the current good practice outlined in the CDOIF guideline. If a COMAH Operator benchmarks their MHHHRA approach against the CDOIF guideline, they can identify areas where they may need to update or change their approach to ensure compliance.

Q *This is complicated, am I now going to have to find a consultant?*

A A COMAH Operator should determine if they need access to additional resource to enable them to comply with their legal requirements. The Operator needs to take ownership and ensure they have knowledge of what is required. The CDOIF guidance should enable them to be either an intelligent customer or to undertake the assessments themselves. It is possible that for the MAHS(s) associated with unit operations that are of the highest proportionality, 'suitably qualified risk assessment professionals' will be required to support

the development and implementation of 'suitable and sufficient' approaches to MAHS identification, analysis and assessment. It may be that the Operator decides to have an independent third party only to review their work.

The CDOIF guidance should enable the Operator to determine if the independent third-party provider has the relevant experience. However, remember that a single third-party provider may not always have all the knowledge, competence or capability to undertake all aspects of the MHHRA.

For MAHS(s) of lower severity, the depth, resolution and robustness required for a MHHRA may be less. The knowledge, competence and capability required will depend on the suitable and sufficient approaches adopted.

Only the Operator themselves will have a detailed knowledge and understanding of the operations of their sites. Working with the consultant should be viewed as a partnership, and not a piece of work for them to complete alone unchecked and unsupervised.

Q *I will have hundreds of scenarios, is it ok to simplify and use representatives?*

A Adopting a representative set can significantly reduce the analysis required, and the amount of information needed to make a demonstration of a suitable and sufficient risk assessment. However, it must be absolutely clear which scenarios they are representative of.

For establishments which have multiple identical streams/systems or many near identical unit operations, provided there is parity, it can be reasonable to group these similar major pieces of equipment or unit operations. One piece of equipment or unit operation can be developed to represent the other members. 'Representative' means that it represents the whole of that unit operation or major piece of equipment, its initiating and propagating events, and includes and evaluates all consequences. However, Operators need to recognise that risk assessment is an iterative process. It may be that some unit operation MAHS(s) are found to be no longer representative after further analysis, and that these scenarios will need to be developed further. **See section 4.3 of the CDOIF guideline** for further information.

Q *Is the CDOIF guideline's approach to proportionality in line with HSE's position?*

A HSE are clear that all COMAH sites are deemed high proportionality as they are associated with MAHS(s). HSE welcomes the CDOIF section on proportionality, it is seen as a helpful steer for Operators when considering the proportionality of a unit operation, or establishment. If it had been determined previously that some COMAH establishments were of a low, or medium proportionality, this was likely to have been a misunderstanding as to how HSE interprets proportionality. Operators are reminded that HSE uses proportionality to make judgements across all of the sectors it regulates.

Q *Do proportionality judgements include likelihood?*

A It is the HSE view that proportionality judgements within major hazards are based on 'extent and severity', which is the potential number of both deaths and serious injuries, both on and off site. When determining proportionality in order to establish the initial depth and robustness of study, likelihood (frequency), is not taken into consideration; but used to determine risk later on in the assessment process.

Q Does HSE expect an employer to retrospectively apply the 'hierarchy of control' to establishments built and operated before the MHSW Regulation was enacted in 1999? In addition, are employers also required to keep this consideration under review as their establishments, unit operation, science, technology etc. change?

A Yes, COMAH Operators were expected to review and revise their risk assessments when the MHSWR 1999 came into force. Regulation 4 of the MHSWR 1999, requires that where an employer implements any preventive and protective measures, they shall do so on the basis of the principles of prevention outlined within the regulations, known as the 'hierarchy of control'. It is also considered part of good practice for an Operator to confirm the validity of their 'hierarchy of control' as part of any periodic MHHRA review. Such good practice is outlined in an Operator's SMS, and implemented as necessary when operations, technology, and relevant good practice, standards and codes change.

Q Can HSE confirm if RGP, standards or equivalents measures adopted (to deliver the same level of protection) are subject to cost benefit analysis (CBA)?

A HSE's long-standing view is that RGP including standards, or equivalent measures adopted (to deliver the same level of protection), should be in place. Noting that if no relevant RGP is available for the unit operation, the appropriate measures to prevent the initiating and propagating event combinations, should be determined from first principals. Where RGP is available this may form a whole or part of the appropriate measures.

New COMAH establishments are expected to implement current RGP, including standards or equivalent measures, and review and revise the appropriate measures in place when RGP is updated.

If newly introduced or revised RGP cannot be met due to design limitations on an existing COMAH establishment; then the Operator must introduce equivalent measures that give at least the same level of protection. It will then be a judgement as to whether the equivalent measures are sufficient, or if other action is required. If the risk is too high this could require replacement with a process or equipment that meets RGP.

What is not appropriate is where existing establishments have not:

- implemented RGP and standards, or equivalent measures that give the same level of protection; and/or
- have not undertaken steps to review and revise the appropriate measures in place when RGP and standards are updated, implementing these updated appropriate measures within reasonable timescales.

It is important to remember that RGP including standards, or equivalent measures, are not subject to a cost benefit decision informed by producing a CBA, they are considered appropriate measures that should be in place. When justifying equivalent measures to the COMAH CA, the Operator should show they have introduced sufficient equivalent measures to reduce the risk to the same level as they would with current RGP. Where equivalent measures cannot be implemented to reduce the risk, a detailed justification should be made and discussed with the CA.

Decisions involving 'reasonably practicability' using CBA can be used later in the MHHRA process when Operators have shown that the maximum individual risk is below the risk tolerability threshold.

Q *Is Personal Protective Equipment (PPE) a primary layer of protection when considering MAHS(s)?*

A The HSE view is that PPE is not a primary layer of protection for a MAHS. PPE can be used to deal with residual risk after the hierarchy of control has been considered, and all appropriate measures, and further measures, are in place. PPE is at the bottom of the hierarchy of control and is in addition to the appropriate and further measures.

Q *Is a tolerability of risk (ToR) assessment really needed as part of a suitable and sufficient MHHRA for COMAH?*

A It is HSE's view that a tolerability assessment is seen as part of a suitable and sufficient MHHRA for COMAH. This is because of the high proportionality of MAHS(s) under consideration, and because a ToR can:

- support the logical case that all measures necessary have been taken, and that the risks have been reduced so far as is reasonably practicable;
- allow cumulative individual risk to be determined for specified individuals, and different populations both on and off-site;
- indicate if the cumulative individual risk from the establishment to the person is not intolerable;
- show the relative contribution and importance of scenarios to the risk profile of the site; and
- show if the cumulative individual risk from the establishment to the person is below the "intolerable" threshold and then allows consideration of further measures and the demonstration of all measures necessary and ALARP.

Q *If the establishment risk is intolerable and there are no other appropriate measures or further measures that can reduce the risk, what should an Operator do?*

A In such cases, Operators first need to reflect on the resolution of their MHHRA, as it is possible that greater resolution allows less conservatism, which will help to better determine their establishment's risk position. If the establishment risk is still intolerable, they will need to consider replacing or modifying the main contributors to their risk profile (e.g. modifying or changing the unit operation).

Q *What is expected of an Operator if their establishments cumulative individual risk falls within the broadly acceptable region of the proposed COMAH tolerability framework?*

A The legal requirement of SFAIRP is applied to all risks, even if within the broadly acceptable region of the COMAH tolerability framework. HSE has confirmed that as most MAHS risks are not insignificant, and their consequences may impact on multiple people (extent and severity) onsite and/or offsite, Operators will still need to consider further measures and implement them if the cost is proportionate to the benefits.

Q *If a further measure identified was clearly not practical to implement, is a CBA still required?*

A If a further measure cannot practically be applied, then the selection criteria adopted by the Operator should ensure that it would not be on the shortlist, as it could not be delivered. If a further measure can be delivered, then it can only be discounted by CBA, there is no other way for an Operator to demonstrate that the cost is, or if it is not, proportionate to the benefit.

Q *As well as periodically reviewing and revising a MHHHRA when the information on which it is based changes, or periodically in line with the SMS, should an Operator also review their internal emergency plan?*

A Regulation 12(6) of COMAH states:

An operator must at suitable intervals not exceeding three years –

a) review and, where necessary, revise the internal emergency plan.

Regulation 12(8) of COMAH states:

In carrying out a review of an internal emergency plan, the operator must take into account –

a) any changes at the establishment or within the emergency services concerned;

b) any relevant new technical knowledge; and

c) any relevant new knowledge concerning the response to major accidents.

COMAH guidance (L111, para 231) states: 'A review of the adequacy and accuracy of the emergency planning arrangements should follow any modifications or other significant changes to the establishment. Under these circumstances, Operators should not wait until the three-year review of their emergency plans is due.'

CDOIF suggests that as significant changes to the establishment will likely require a review and revision of the MHHHRA, the technical information to be considered when reviewing the internal emergency plan will include the most current MHHHRA.

Q *Why does this document not consider major accidents to the environment (MATTEs)?*

A There is currently a CDOIF guide on MATTEs. The MHHHRA guideline links to the MATTE guideline as necessary, including when undertaking cost-benefit analysis (CBA) and the need to consider costs to the environment. While preparing this guideline on MHHHRA, CDOIF noted that the language used in relevant safety legislation (for example, Health and Safety at Work etc. Act 1974, and the Management of Health and Safety at Work Regulations 1999), associated reference documents and guidance was different to that used when considering risk assessments related to major accidents to the environment (MATTE). It was not within the scope of this CDOIF guideline to develop a holistic regime, with a common language, when undertaking the assessment of major hazards associated with human harm and the environment. CDOIF recognises the value of undertaking such work in the future.

Q *Will CDOIF review and revise the CDOIF MHHHRA guideline, if necessary, in the future?*

A CDOIF expects that it will review and revise this guideline, if necessary, after three to five years. This may include additional examples from Operators who have applied the guideline.

Q *As this is the first version of the MHHHRA guideline, lessons will clearly be learnt when Operators apply these good practice principles. How can these be addressed?*

A CDOIF will set a mechanism to identify areas where further clarification or additional guidance is needed. This can be addressed when CDOIF reviews and revises the guideline.

TECHNICAL NOTES:

1. The meaning of 'Unit Operation' in the context of other process engineering terms

Historically, chemical processing developed separately in different industries such as textiles, soap boiling, or shale oil; or focussed on producing specific products such as soda ash, sulphuric acid, and arsenic. Commonality of elements/techniques was considered within the context of that industry, but at that time not methodically across all. In 1916 Arthur D Little developed the concept of the '**unit operation**' to identify and explain the process principles of the common building blocks that different processes used, for example filtration and distillation. The term 'unit operation' has been in common use in chemical engineering since that time.

A **unit operation** is a defined physical change, and/or defined **chemical transformation**, performed within a fixed defined **system**.

A [process] **system** is a fixed arrangement of **process equipment** whose boundaries are defined. It may be used to perform a particular process, or a number of defined processes. It is normally designed to be operated either continuously, or just to produce single batches. 'System' may also be used to describe any fixed defined arrangement of components and equipment, such as the 'control system'.

Process equipment are discrete items which are connected together in a fixed configuration to form the **system**, these items include: vessel, column, agitator, valve, piping spool, pump, heat exchanger, instrument, filter. Equipment used to provide services, such as steam boilers, and cooling water towers, are often referred to as ancillary equipment.

A **chemical process** is a series of one or more **unit operations**, usually performed in a set order; to perform a **chemical, and/or physical change(s)**, to produce a desired product. The chemical process may also produce by-products which may or may not add value. There may be a number of nested processes performed, first to manufacture the raw materials, then the intermediates, then a further process to turn the intermediates into the final product. Dependent on the substance, the whole process could be performed in one vessel, or across several vessels; it is common that intermediates are purchased from different companies rather than the whole process performed by a single company. In the case of refineries there are a number of processes which are combined to transform crude oil to the most economic range of products.

A **physical change** can be one of: state, solid/liquid/gas, for example evaporation; particle size or distribution, such as achieved by crystallisation, or milling; physical separation from a mixture, such as filtration; change of containment, such as packaging, or storage; change in enthalpy without either change of state or chemical change, such as heating, or cooling; mixing of a number of liquids and solids; dissolution of solids/gases into liquids; increase in pressure, such as compression. Physical changes may be accompanied by a change in enthalpy and/or entropy and are often reversible.

A **chemical transformation** is where one or more substances (**reactants**), are brought together to have their atomic or molecular structures rearranged to form new substances (**products**), with different properties; this can be brought about by **chemical reaction**, or **thermal molecular dissociation** (less commonly for industrial processes, the transformation can be brought about by specific frequencies of light or electrical potential difference).

A **chemical reaction** is the bringing together of two or more chemical reactants, in process conditions that cause/promote chemical bonds to be broken and rearranged to form different

substances as products; this is often accompanied by an energy change. If energy is released then lost from the system, as occurs in exothermic reactions, the reaction is usually irreversible; this is because the products have a lower enthalpy so are more stable than the reactants. Endothermic reactions require energy to form the products and may be reversible. Both exothermic and endothermic reactions may require heating for the reaction to be initiated (though less common industrially, some reactions may be initiated by light or electrical potential difference).

Thermal dissociation is the breaking apart of molecules due to the application of heat causing thermal breakdown. This can occur in both ionic and organic chemical transformation. The materials may stay in their dissociated (broken-down state), or dependent upon the particular substance, or mixture composition, they may reassociate on cooling.

In most cases a unit operation will encompass all of the sub-systems required to support that chemical transformation. For example, a continuous distillation unit is used to separate mixtures of materials having different boiling point ranges. To perform the unit operation the system normally comprises of a distillation column, reboiler, reflux condenser, reflux drum, buffer feed and product tanks. It could be argued that as heat exchangers the reflux condenser and re-boiler are also unit operations in their own right but are more usefully considered as sub-systems. Quite often there may be localised safety trips for the sub-systems and often a global trip for the unit operation as a whole.

A batch reactor system (glass lined reactor vessel, agitator, charge flask, overhead condenser, jacket heat exchanger, reflux condenser, vent condenser, distillate receiver and pump) may perform **consecutive unit operations**. For example, this could be a reaction, then a distillation to remove a by-product, followed by the addition of another raw material and a further different reaction; these are effectively different unit operations taking place within the same reactor and its sub systems; and could give rise to different MAHS(s) for each stage.

Conversely there are major operations which are colloquially referred to as unit operations but are actually a process comprising of a number of closely coupled, but distinct and separate, unit operations. For example, a fluidised bed catalytic cracker consists of four distinct unit operations: hydrocarbon reactor, catalyst regenerator, stripper/separator and primary fractionator, together with their respective sub-systems.

2. HSE Research Report 151 - Good practice and pitfalls in risk assessment

One of the pitfalls when undertaking risk assessment is dividing the time spent on the hazardous activity between several individuals - the 'salami slicing' approach to risk estimation (**see section 3.2 of the report and case study 8, 17 and 20. Note: railway industry examples are also included**).

3. Trans IChemE, Part B, Process Safety and Environmental Protection, 2006, 84(B2): p101–10.

This outlines that calculating the individual risk partly involves estimating the individual risk to people who are present at each of the locations of interest for all of the time (that is, 24 hours a day, every day of the year).

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