Environmental risk tolerability for major accident hazard sites: A method for quantifying and assessing environmental risk

M Nicholas, Environment Agency; I Brocklebank, SEPA; J Coates, CIA; P Davidson, UKPIA; H Bray, TSA

The fields of process safety and environmental protection overlap in the area of prevention and mitigation of Major Accidents to the Environment (MATTEs), from Major Accident Hazard establishments. Both fields rely on identification and evaluation of hazards and the risk they pose, plus adoption of sound management and engineering principles to reduce risk to an acceptable level. But while acceptability or tolerability of risks to people has been extensively debated and defined, tolerability of risk of a MATTE has not received a similar level of attention. The issue has become more important as the UK COMAH Competent Authority aims to seek improvements from operators of establishments where a MATTE could occur. This involves making judgements about significant financial investments at new and existing establishments.

Following Buncefield and other major accidents, many questions have been raised concerning thresholds which can be used to quantify the scale of environmental consequences and the tolerability of those consequences. Within the UK's risk based regulatory regime, these are required to determine that all measures necessary have been used, as part of a demonstration that risks have been controlled to a level that is as low as reasonably practicable.

This paper describes the work undertaken within the UK Chemical and Downstream Oil Industry Forum (CDOIF). A CDOIF working group, consisting of regulators, operators and trade associations was formed in 2011 to produce guidance on environmental risk tolerability for COMAH establishments. A guideline has now been published, which presents an environmental risk screening tool for application at both new and existing establishments. This paper, authored by members of the working group, summarises that guideline. It includes discussion of the thresholds which define MATTE and a matrix approach to quantifying environmental consequence and tolerability thresholds for varying scales of consequence. It also provides guidance on specific elements of the risk assessment process, including incorporation of environmental matters into Cost Benefit Analysis. The method is illustrated with examples.

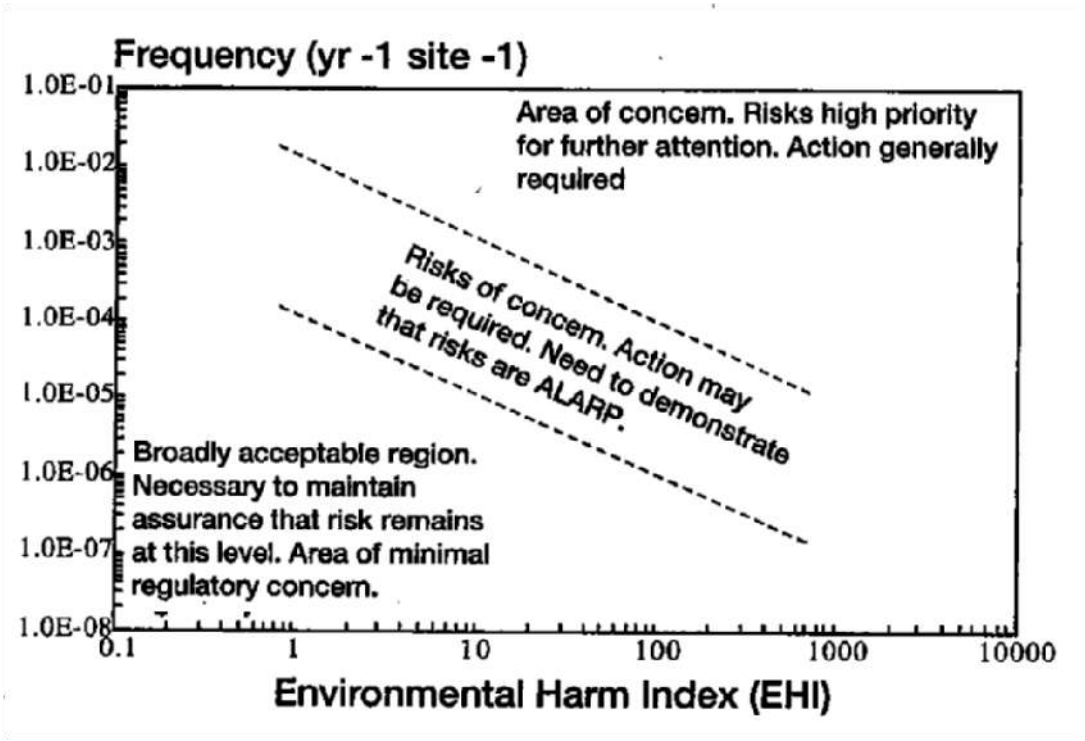
Keywords: Environment, Environmental Tolerability, Major Accident, Risk, MATTE, COMAH

Background

During the late 1990s, European Member States worked to implement the Seveso II Directive into national legislation. In the UK, this resulted in the Control of Major Accident Hazards (COMAH) regulations 1999. One of the key changes this entailed, compared to preceding legislation, was enhanced requirements to protect the environment. The implications of this have been discussed previously by Whitfield (2002) and Vince (2008). In particular, the definition of "Major Accident" includes the concept of "serious danger" to the environment – but what level of danger should be considered serious? And in terms of the measures necessary for control of Major Accidents, what level of risk to the environment is tolerable or acceptable?

The first step in answering these questions led to a UK government research project, involving industry and the regulator, which developed a tool to assist in the management of risks to the aquatic environment (rivers and estuaries) from accidental releases (DETR, 1998). The work developed a method by which consequence to the aquatic environment could be quantified as an Environmental Harm Index (EHI), where EHI is a function of extent, severity and duration of harm. The research also proposed that environmental risk could be managed in the same way as risks to people, so that risk can be qualified to be banded into three zones and decisions on whether risks have been adequately controlled made on that basis (for current ALARP guidance see HSE, 2013a). Environmental risk management criteria, combining consequence (EHI), frequency of harm (per year per site), and banded guidance on required control measures were proposed (see Figure 1). Critically, these criteria are based on the risk posed by a whole COMAH site to the aquatic receptor. A summary of the approach, including more detail on how to calculate EHI, has been provided by Vince (2008).

Figure 1. Environmental risk criteria (fig 8.1, DETR, 1998).



Whilst making a significant contribution to environmental risk management, the research had recognised limitations. It did not cover the full range of environmental receptor types (i.e. it excluded impact to soil, designated conservation sites, groundwater) and the proposed tolerability thresholds were based on an estimation of future numbers of COMAH sites and the frequency of occurrence of incidents. In addition, the quantitative approach to calculation of EHI requires a level of detail and data that is sometimes not available and might be considered disproportionate to carry out for lower hazard/risk sites. The research was not widely publicised so not many COMAH operators became aware of the approach. Whilst it became common to deal with environmental risk in the traditional three zone ALARP matrix form, there was a lack of consistency on the risk criteria adopted by operators. There were differences in the way environmental consequence was qualified, differences in the way frequency was banded and differences in the boundaries of the tolerability criteria – including whether they should be used for the whole risk to an environmental receptor from an establishment or whether they should be applied to individual events or scenarios.

To address the issue of environmental consequence and the thresholds that might be considered a serious danger to various environmental receptors, DETR produced guidance on the interpretation of Major Accident to the Environment – now known generally as the MATTE guidance (DETR, 1999). This addressed the environmental requirements of Seveso II and the COMAH regulations, as well as providing guidance on typical environmental accident scenarios, identifying major accident hazards, assessing and appraising risk and approaches to clean-up and restoration. The guidance also provided thresholds at which environmental consequence should be considered serious (i.e. a MATTE) for 12 categories of receptor (including designated sites, wider habitats, groundwater, built heritage, marine and freshwater habitats). During the first decade of the COMAH regime this guidance has been central to guiding operators and the regulator when determining those accident scenarios that could cause a MATTE and thus fall in scope of COMAH. However, parts of the guidance have now been superseded, due to advances in environmental legislation (for example, the water framework directive introduced a new way of measuring the status of water bodies).

In 2004 the Environment Agency produced internal guidance to officers in England and Wales on “All Measures Necessary”. This guidance confirmed the concept of integrating environmental protection into the existing ALARP framework and presented basic environmental tolerability thresholds. Based on the observation that MATTEs of a scale that required to be reported to Europe (see thresholds in COMAH Schedule 7) had an EHI in the region of 100, such accidents should be considered intolerable if their frequency exceeded $1x10^{-4}$ per year and broadly acceptable at frequencies lower than 1x10-6 per year (see figure 1). The guidance suggested that MATTEs with sub-EC reportable consequence would be tolerable at a higher frequency, but did not state what frequency this would be. The guidance remained internal to EA and was not shared widely with operators.

Thus, up to 2005 it became common amongst COMAH operators to manage MATTE scenarios within the existing ALARP framework (HSE, 2013), but various formats of risk matrix emerged, with no consensus on environmental tolerability criteria. Also, with regard to combining environmental consequence with measures required to reduce frequency of a MATTE, those in the fields of Environmental Protection and Process Safety generally worked along parallel lines, with differing perspectives, and only a few experts and practitioners comfortably bridging the gap. How many Process Safety experts could recall the definition of “Environmental Damage” under the Environmental Liability Directive or know what favourable conservation status implies for a Habitats Directive site? Similarly, how many environmental protection experts understand Functional Safety and Safety Integrity Levels?

Buncefield and other MATTEs and near misses

Then Buncefield, December 2005. The root causes and lessons learned have been documented extensively (EA, 2008, HSE, 2009, HSE, 2011). However, making the transition from updated knowledge on major accident hazards and control measures, to the process of upgrading existing fuel terminals and refineries, at significant cost to the operators, raised the matter of environmental risk tolerability as a fundamental issue yet to resolve. Whether determining the Safety Integrity Level (SIL) of an overfill protection system or considering adequacy of combined primary, secondary and tertiary containment measures, there is a need to consider risk targets/tolerability in order to determine when enough has been done to control risk (Nicholas, 2013). Thus post Buncefield work brought into focus the urgent need to gain consensus on an environmental tolerability framework.

Other incidents at COMAH / Seveso establishments with serious or potentially serious environmental consequences, including a number of warehouse fires, have recently been reviewed and lessons highlighted (HSL, 2012, European Commission, 2013 and Gyenes, 2014). Many of the environmental protection lessons involve engineering of containment systems for the containment of liquid releases, from spills and firewater runoff, and these lessons have been captured in the UK through update of guidance originally published by CIRIA (1997), with publication of the revised guidance expected in 2014. Whilst these lessons should readily be implemented at new build sites, the approach to making decisions on upgrading existing establishments, the associated costs and practicability, depends on the legislation governing the site (COMAH, Environmental Permitting, Oil Storage Regulations for example). Some requirements are mandatory, others risk based. For COMAH, this again led to a need to agree how to incorporate environmental tolerability within the ALARP framework.

Chemicals and Downstream Oil Industry Forum

As explained by HSE (2013b) "The Chemicals and Downstream Oil Industries Forum (CDOIF) was established in 1997, bringing together regulators and many of the sectors most influential people and organisations. The core aim of the forum is to inform regulatory and industry approaches to issues affecting the safety and health of people, sustainability and the environment.

Through its membership, the forum is able to tackle issues of most importance to manufacturers, primary producers, and service providers. The group aims to adopt pragmatic solutions and develop long-term strategies to ensure that businesses and workers are heard on the issues that matter within the industry."

CDOIF publishes its work on the HSE website (search for "HSE CDOIF resources"). Recent publications at HSE (2013c), from CDOIF working groups include:

- Human Factors review of procedures guidance
- Leak detection guidance
- Preparing for flooding – a guide for regulated site (link to EA publications catalogue)

CDOIF environmental tolerability of risk working group

In 2010 CDOIF agreed to form a working group to examine existing approaches to assessment of environmental risk and develop an environmental risk assessment framework for COMAH. The immediate need was to enable SIL determination for overfill protection systems of gasoline tanks, but application of the CDOIF guideline would be to all COMAH establishments. The COMAH Competent Authority (CA) requires operators to submit site safety reports and / or management system risk assessments that demonstrate that the environmental risk for the whole COMAH establishment has been reduced to a tolerable level.

Members of the CDOIF working group included industry, trade associations, professional bodies and the CA. From the outset it was recognised there was a need to adopt a multidisciplinary approach, both at expert and practitioner levels. Thus the working group included input from professionals including economists and environmental/process safety engineers. The output is a result of discussion and debate, mixed with professional judgement and a degree of legal steer. It is also of note that development of the framework has benefited from parallel discussions taking place during development of other process safety guidance, in particular Energy Institute (EI) guidance on tertiary containment systems (EI, 2013a) and draft EI guidance on SIL determination (EI, 2013b).

The scope of work, limited to assessment of Major Accident Hazards at COMAH sites, was aimed at developing an environmental risk screening tool. Many sites should be able to use this tool without significant (and potentially expensive) external input. It is clear that those sites with greater hazards, risk or complexity may need to provide much more detail, but for those which don't the CDOIF guideline gives an understandable foundation on which to proceed with discussions with regulators. The work included:

- Defining the types of harm to be considered in the assessment, and how harm is to be characterised for risk assessment (this included developing an approach to classify different levels of MATTE consequence based on extent, severity and duration of recovery).
- Providing the risk criteria to be used in assessing the tolerability of the environmental risk from an establishment and, where appropriate, individual scenarios.
- Developing guidance on how risks may be evaluated.

- Developing guidance on how to include the cost of environmental harm in a COMAH cost benefit analysis.

The working group also carried out "road testing" of the framework against several representative establishments so that the impact of the proposed framework could be assessed.

CDOIF Guideline - Environmental Risk Tolerability for COMAH Establishments

CDOIF finalised and published its guideline in 2013 (HSE, 2013d). The guideline sets out a screening methodology for assessment of environmental risk within the ALARP framework (HSE, 2013a). It establishes a tolerability of risk matrix defining the frequency range of the Intolerable, Tolerable if ALARP (TifALARP) and Broadly Acceptable zones for different levels of environmental consequence and provides further guidance on some elements of the risk assessment process. There is an expectation from CDOIF (i.e. shared by the CA) that the guideline (or equivalent) should now be used to carry out environmental risk assessment for COMAH. The document remains open for comment and revision until the end of 2014 to allow industry to use the process and provide feedback on any significant issues that might arise from its application.

What follows is an illustrated overview of the work and examples based on releases to surface water. The examples include extracts from the guidance (Figures 2, 3 and 4 below) but it is essential that the CDOIF publication is accessed and considered in full to understand the agreed framework and thresholds for all environmental receptors. The guideline is structured under the following headings:

- Executive summary & Scope
- Definition of types of environmental harm
- Risk criteria and evaluating risks
- Cost Benefit Analysis
- Completing the risk assessment

Information is provided on certain aspects of environmental risk assessment, but not the whole methodology. So, for example, the section on Cost Benefit Analysis (CBA), provides advice on how to include the cost of environmental harm in COMAH CBA, including appropriate disproportion factor and discounting rate. But, to carry out an assessment it would be necessary to source relevant cost of incidents data and to understand the existing guidance published by the CA (as referenced by CDOIF) on ALARP and when/how to carry out a CBA (if necessary).

Fundamental to the CDOIF approach is the concept of establishment risk. It was agreed by CDOIF that for COMAH, environmental risk tolerability should be based on the risk posed to a specific receptor from all MATTE scenarios at a single establishment that could impact that receptor. In section 4.3 of the guidance (HSE, 2013d) it is explained that a risk assessment can either sum all risk to a receptor, for direct comparison with tolerability criteria, or presume that the risk under assessment is only a fraction of total risk, and the risk thresholds/targets need to be reduced appropriately, depending on the scale of other areas of risk compared to that under assessment.

In order to assess the establishment risk to the environment it is necessary to carry out a structured approach and this will usually be based around the source>pathway>receptor model. It is highlighted that detailed guidance on the approach can be found elsewhere, e.g section13 of the Safety Report Assessment Manual (HSE, 2010). Once potential MATTE scenarios have been identified, there are a range of approaches that can be used to carry out evaluation of environmental consequence, to confirm MATTE scenarios, and these are not explored in depth. However, what is covered is how consequence should be qualified / quantified in order to determine risk thresholds.

Chapter 3 of the CDOIF guideline revisits the environmental receptors discussed by DETR (1999) and in many cases proposes revision to the harm thresholds which should be considered as serious (i.e. the MATTE thresholds). These receptors can broadly be considered as subsets of the following receptor types: terrestrial habitats, freshwater habitats, marine habitats and groundwater bodies. The proposed MATTE thresholds reflect a great deal of work, taking into consideration developments in legislation, experience from application of COMAH and discussion of serious environmental incidents of the past. It can be considered that the thresholds also reflect changes in public perception of tolerability of environmental risk, to the extent that this is reflected in the framework of European environmental law. Some MATTE thresholds have been updated due to changes in environmental law. For example, MATTE thresholds for freshwater habitats, previously defined in terms of Environment Agency General Quality Assessment (GQA) scheme, have been redefined by reference to water body status under the Water Framework Directive (WFD). Also, since the MATTE guidance was published, the Environmental Liability Directive with its' definitions of environmental harm has come into force and MATTE thresholds have been redefined to reflect the thresholds for environmental harm. Other thresholds have been changed due to experience (for example, some of the thresholds contain extent of severity as either a specified area/distance or as percentage of receptor affected - the lesser applies. For very small receptors this can lead to thresholds which are too small to be considered MATTE, so in some cases only an area/distance has been determined and for others it is clarified that the percentage criteria will not reduce the thresholds to lower than half the area/distance criteria).

Whilst DETR (1999) and the CDOIF guideline present (minimum) impact thresholds for MATTE, the working group also agreed at an early stage that not all MATTEs are of equal concern. The group agreed to band MATTEs into 4 differing scales of impact and assign different tolerability criteria to each. Chapter 4 and 6 of the guideline explain how the scale of impact (i.e. consequence) of those identified MATTE scenarios can be assessed to determine the appropriate tolerability criteria and make judgements on tolerability of establishment risk. To determine appropriate risk tolerability criteria it is necessary to understand the potential unmitigated consequence (i.e. the potential consequence from the credible scenarios before any mitigation measures

are employed). As presented in Appendix 4 of the guidance, consequence is evaluated within a 4 band range (levels A – D) by considering

1. Severity of potential harm for the given scenarios (unmitigated, escalation considered) : Severity (which is strictly extent and severity) has been classified into 4 bands, one bellow MATTE thresholds and three increasing severity of MATTE.
2. Duration of potential harm (unmitigated – natural recovery periods) : Duration has been classified into 4 bands, again one below MATTE thresholds and three above. Different ranges of duration are considered for differing receptor types, because of differences in natural recovery times (Note: groundwater recovery is very long term and here "duration" is used as a proxy to differentiate between public drinking water sources and other groundwater to ensure appropriate differentiation of tolerability between these receptor types. Duration is included in the drinking water person-hours calculation uses for severity)

The potential severity and duration of the unmitigated consequence are combined using a matrix to establish the consequence level (A – D). Each level of consequence has assigned tolerability criteria, such that with increasing consequence, tolerable frequency decreases (these are discussed in the example which follows).

In order to consider whether risks have been reduced so far as is reasonably practicable (SFAIRP), it is necessary to consider mitigated risk (frequency and consequence after all existing protection layers have been adopted) compared to the appropriate tolerability criteria. Here, mitigated risk also includes any additional conditional modifiers, such as probability of ignition or for migratory species, time at risk. Comparison of mitigated risk to tolerability criteria can be done by one of two methods:

1. Aggregate all risk to the receptor and compare it to the tolerability criteria appropriate to the consequence level. Mitigated risk is calculated by summing the frequencies of all independent scenarios at the establishment which can impact the receptor at or above the consequence level (after credit is claimed for protection layers). This is repeated for each consequence level.
2. For assessment of a specific scenario, reduce the tolerability criteria appropriate to the consequence level for that scenario by an appropriate factor when considering other MATTE scenarios at the establishment that also impact the receptor. For example, if the scenario in question is one of ten other MATTE scenarios that could equally impact the receptor, then the tolerability criteria would be reduced by a factor of 10 if applied to a single scenario.

By comparison of mitigated risk with the appropriate tolerability criteria, risk can be managed in the context of the ALARP framework (HSE, 2013a). The guideline provides greater clarification on expectations for existing sites (as well as new) within the ALARP/COMAH framework, which has greatly assisted discussions with regulators. Thus, adequacy of risk reduction measures can be viewed in terms of established guidance and if necessary, further risk reduction measures adopted SFAIRP. Chapter 5 provides guidance on integration of environment into any CBA. The approach is best illustrated by example.

Chemicals warehousing example

Consider an establishment, a chemicals warehouse, with potential to cause impact to surface water – in this case a freshwater habitat with no drinking water abstractions. The major accident hazards from the establishment that might impact the freshwater habitat would need identification and would typically include spills, more serious loss of containment (e.g. from a fire) and firewater runoff. In addition, the freshwaters that could be impacted would need to be identified. It is then necessary to combine the hazards of the chemicals at the establishment, the credible scenarios and potential pathways to determine potential impact on the receptor (source>receptor>pathway model). Reference to historic incidents can help in this respect, though these usually represent consequence after some form of mitigation and the assessment to determine tolerability criteria needs to consider unmitigated consequence. Once potential consequence is predicted then the CDOIF consequence level can be determined through reference to the severity and duration tables (Note: these tables provide a summary of the more detailed harm thresholds and they need to be read in conjunction with information presented in section 3.2 of the guideline - HSE, 2013d). Figure 2 and 3 are extracts of the parts of those tables relevant to freshwater (surface water).

Figure 2. Extract from CDOIF guideline, Appendix 4 : Table 1 – Severity (HSE 2013d).

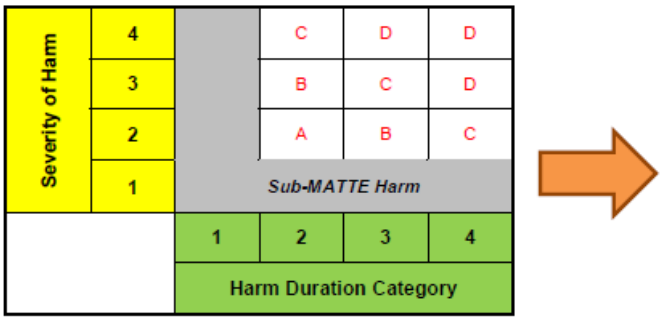
Row	DETR Table Ref	Receptor Type	Severity of Harm			
			Significant *While this level of harm might be significant pollution, it is not considered a MATTE.*	Severe *DETR Criteria - the lowest level of harm that might be considered MATTE.*	Major	Catastrophic
		Severity Level →	1	2	3	4
15	12	Fresh and estuarine water habitats	Impact below that of Severity level 2	WFD Chemical or ecological status lowered by one class for 2-10km of watercourse or 2-20ha or 10-50% area of estuaries or ponds. Plus interruption of drinking water supplies, as per DETR Table 6	WFD Chemical or ecological status lowered by one class for 10-200km of watercourse or 20-200ha or 50-90% area of estuaries and ponds. Plus interruption of drinking water supplies, as per DETR Table 6	WFD Chemical or ecological status lowered by one class for >200km of watercourse or >200ha or >90% area of estuaries and ponds. Plus interruption of drinking water supplies, as per DETR Table 6

Figure 3. Extract from CDOIF guideline, Appendix 4 : Table 2 – Duration (HSE 2013d).

Description	Short term	Medium term	Long term	Very long term
	Harm with such short recovery is not considered a MATTE.			
Harm Duration Category →	1	2	3	4
LAND	≤ 3 years	> 3 years or > 2 growing seasons for agricultural land	> 20 years	> 50 years
SURFACE WATER (ALL EXCEPT PUBLIC OR PRIVATE DRINKING WATER SOURCE)	≤ 1 year	> 1 year	>10 years	>20 years
GROUNDWATER BODY				

From these tables (figure 2 & 3) both the severity of harm and duration of harm can be categorised (1-4). If either severity or duration fall in category 1, then the impact is considered to be below MATTE thresholds. If this is the case for all receptors then the scenario can be screened out of a COMAH assessment (except for consideration of benefits in CBA). Severity and duration are combined to give the consequence level (A-D), along with the associated frequencies of the Intolerable and Broadly Acceptable boundaries (figure 4).

Figure 4. Extract from CDOIF guideline, Appendix 4 : Table 3, Matrix for deriving receptor tolerability for MATTE (HSE, 2013d).



Frequency at which the CDOIF consequence level is reached or exceeded	Frequency per receptor per establishment per year	
	Intolerable (greater than)	Broadly Acceptable (less than)
A	1.0 E-02	1.0 E-04
B	1.0 E-03	1.0 E-05
C	1.0 E-04	1.0 E-06
D	1.0 E-05	1.0 E-07

Thus, for different scales of consequence (A-D), the TifALARP zone has been established. It decreases by an order of magnitude for each incremental increase in consequence level (see CDOIF guideline section 6.2.1.4 for this same information presented in risk matrix format).

Considering the chemicals warehouse example, if a major fire could cause runoff that could lower the WFD classification of a river over a distance ~4-6km, with a recovery period of 3-4years, then

- from figure 2, severity of harm = 2
- from figure 3, duration of harm = 2
- from figure 4, CDOIF consequence level = A

Considering the same warehouse example (but perhaps with a larger inventory of more hazardous substances), if a major fire could cause runoff that could lower the WFD classification of a river over a distance ~130km, with a recovery period of ~15years, then

- from figure 2, severity of harm =3
- from figure 3, duration of harm =3
- from figure 4, CDOIF consequence level = C

In terms of the incidents described by European Commission (2013) –

- Accident 1 (This is the Biolab incident, as discussed by HSL, 2012) - It was reported, more than 2500 fish were killed over a 6 km stretch of river and estimated that the river would take 4 to 7 years to return to pre-incident condition. These mitigated impacts fall in scope of MATTE (CDOIF severity 2, duration 2, consequence level A). In this case the emergency responder mitigation was partially effective, reducing consequence but not avoiding a MATTE and it is considered credible that the potential unmitigated consequence for the Biolab fire scenario should be considered to have potential CDOIF consequence level B.
- Accident 3 (Sandoz warehouse fire) – Serious impact over 250km of river was reported (CDOIF severity 4). Thus, depending on recovery time, the unmitigated consequence would be either CDOIF consequence level C or D (the Rhine recovery took several years, aided by fish/eel restocking, and a precautionary approach would assume natural recovery time would have exceeded 10 years, thus resulting in CDOIF consequence level D). The incident was also reported to have caused water supplies along the Rhine, up to the Netherlands, to stop pumping water for drinking water generation for up to 18 days. However, due to a lack of information in the literature as to scale of abstractions effected we have not attempted here to estimate CDOIF consequence based on the thresholds for interruption of drinking water.

These examples demonstrate that, when considering prediction of consequence, there will be a degree of uncertainty and a conservative approach (in accordance with the precautionary principle) needs to be adopted. The assessment of consequence might need to be repeated with a greater degree of rigour. In the case of surface waters, the EHI method could be used as a reference to guide selection of appropriate tolerability criteria, so for the Sandoz example, DETR (1998) stated that the incident resulted in an EHI of at least 1000, which from figure 1 gives a TifALARP zone of 10^{-5} to 10^{-7} per site per year (i.e. the same as the tolerability criteria for CDOIF consequence level D).

Once CDOIF consequence levels of all MATTE scenarios are understood, then tolerability of risk can be considered (this is done separately for each receptor). Simplifying the warehouse example, for illustrative purposes, it shall be considered that small incidents (e.g. loss of containment from single containers) have been assessed to be sub-MATTE and are thus screened out. The risk of a MATTE comes from one scenario – full warehouse fire. It is then necessary to apply an appropriate risk assessment technique (LOPA or event tree) or assume generic event data is applicable. In this case (for example only) we'll say the mitigated frequency of a full warehouse fire causing a MATTE is found to be $1x10^{-3}$ per year (Note: this value is illustrative, but none-the-less typical of a warehouse, with direct pathways to an adjacent watercourse, without sprinklers and little

secondary/tertiary containment capacity). Failure rate and event data should be determined on a site specific basis and the frequency of MATTE could be lower given consideration of other potential protection layers, such as available containment systems to reduce frequency or quantity of liquid runoff.

If the establishment comprises the single warehouse, then:

- If potential consequence is established to be at CDOIF consequence level A, then the TifALARP zone is 10^{-2} to 10^{-4} per receptor per establishment per year. Warehouse fire MATTE frequency at $1x10^{-3}$ per year falls in the middle of this range, thus further measures need to be considered and adopted SFAIRP. Such measures might be preventive (improved segregation, reduced inventories) or mitigatory (install sprinkler system, upgrade secondary/tertiary containment).
- If potential consequence is established to be at CDOIF consequence level C, then the TifALARP zone is 10^{-4} to 10^{-6} per receptor per establishment per year and warehouse fire MATTE frequency at $1x10^{-3}$ per year falls in the intolerable zone where risk needs to be reduced further, almost irrespective of cost.

If the establishment comprises the warehouse, plus other installations with surface water MATTE potential, then either:

- the risk of other MATTEs which impact surface water needs to be aggregated with the warehouse MATTE and compared to establishment risk tolerability criteria.

or

- the contribution to the establishment risk from the warehouse vs other scenarios needs to be estimated and tolerability criteria apportioned accordingly. For example, it might be known (or estimated) that the warehouse fire scenario is one fifth of the overall MATTE risk from the establishment to the river. In this case the tolerability criteria for the application to the warehouse fire scenario only could be assumed to be one fifth of the establishment tolerability criteria. That is the scenario specific TifALARP range for a consequence level A becomes $2x10^{-3}$ to $2x10^{-5}$ per receptor per year. The warehouse fire MATTE frequency at $1x10^{-3}$ per year falls at the top end of the TifALARP zone and the ALARP demonstration would be adjusted accordingly.

In order to complete an ALARP demonstration for this example it would be necessary for the operator to demonstrate to the CA that, if mitigated risk does not fall in the Broadly Acceptable region, they have considered what more can be done to reduce risk, implement (or plan to implement) those measures that are reasonably practicable and only dismissed options where cost is grossly disproportionate. These further risk reduction measures could be preventive (e.g. improved material segregation or control of ignition sources) or mitigatory (e.g. installation of sprinkler system or improved firewater containment). The risk after these measures are implemented should be demonstrated to be ALARP.

This example is deliberately simplified and reference should be made to the CDOIF guideline (HSE, 2013d) for further discussion on the methodology, including aggregation where scenarios with different consequence levels exist at the establishment (section 6) and how to integrate environment into CBA (section 5). Also, it needs to be restated that environmental ALARP decisions should be made within the context of existing ALARP suite of guidance (HSE, 2013a).

Summary and future of application of the CDOIF guideline

This paper has introduced the CDOIF Guideline – Environmental Risk Tolerability for COMAH sites, and the background behind it. The most significant aspect of the work is believed to be the level of consensus reached on environmental tolerability criteria, differing for different consequence levels. The process has also delivered guidance on many other aspects including

- Production of a screening methodology which can be used by operators without significant and potentially expensive external input (though higher hazards or risks or more complex sites might then require more detailed assessment).
- Definition of MATTE thresholds and a range of MATTE consequences (levels A-D) based on extent/severity and duration of harm.
- Details of risk assessment and CBA methodology with greater clarity on assessment of risk at new and existing establishments.

It is believed that this work is a significant step to gaining wider consensus on tolerability of environmental risk for COMAH. It is expected that COMAH operators will use the CDOIF guideline (or equivalent) when writing safety reports or carrying out other risk assessment necessary for COMAH. It is anticipated the guideline provides an understandable foundation on which to proceed with discussions with regulators. It is recognised that such application will inevitably raise further questions and thus the CDOIF working group will remain active through 2014 to resolve any issues that arise.

The work has been shared with other European regulators at a Seveso experts meeting. In addition, CDOIF has planned a workshop for practitioners to discuss any issues arising during implementation. Through these events (including HAZARDS 24) wider feedback on the framework will be gathered. The authors and CDOIF would thus welcome any comments on the approach from environment and safety experts worldwide (all-be-it that the approach has been designed to work within the UK regulatory environment) and will consider them during 2014 as part of the ongoing work of CDOIF.

Acknowledgements

The Authors would like to recognise the work of CDOIF, in particular Peter Davidson, as lead author of the CDOIF guideline and Nick Cook for bringing the seeds of the matrix approach to the working group. Also, all those who have reviewed and fed back on the various drafts during its development.

References

CIRIA (1997), CIRIA Report 164: Design of Containment Systems for the Prevention of Water Pollution from Industrial Accidents, ISBN 086017476X

DETR (Department of Environment, Transport and the Regions), 1998, Management of Harm to the Environment: Criteria for the Management of Unplanned Releases, ISBN 0117534560

DETR (Department of Environment, Transport and the Regions), 1999, Guidance on the Interpretation of Major Accident to the Environment for the Purposes of the COMAH Regulations, ISBN 011753501X

EA (Environment Agency), 2008, COMAH Competent Authority Policy on Containment of Bulk Hazardous Liquids at COMAH Establishments, EA on behalf of the Competent Authority for the Control of Major Accident Hazards

EI (Energy Institute), 2013a, Guidance on risk assessment and conceptual design of tertiary containment systems for bulk storage of petroleum, petroleum products, or other fuels, ISBN 9780852936528

EI (Energy Institute), 2013b, DRAFT Guidance on Safety Integrity Level (SIL) Determination – under development

Gyenes, Z., Heraty Wood, M, 2014, Lessons Learned from Major Accidents having Significant Impact to the Environment, (For presentation at Hazards 24)

HSE (Health and Safety Executive), 2009, Safety and environmental standards for fuel storage sites Process Safety Leadership Group Final report, HSE Books, ISBN 9780717663866

HSE (Health and Safety Executive), 2010, SRAM Section 13 Guidance For Environmental Assessment Of COMAH Safety Reports Under Remodelled COMAH Assessment and Inspection procedures, webpage accessed 12/12/13, http://www.hse.gov.uk/comah/guidance/sram.pdf

HSE (Health and Safety Executive), 2011, Buncefield: Why did it happen? HSE on behalf of the Competent Authority for the Control of Major Accident Hazards

HSE (Health and Safety Executive), 2013a, ALARP suite of guidance, webpage accessed 12/12/13, http://www.hse.gov.uk/risk/theory/alarp.htm

HSE (Health and Safety Executive), 2013b, CDOIF, webpage accessed 12/12/13, http://www.hse.gov.uk/aboutus/meetings/committees/cif/index.htm

HSE (Health and Safety Executive), 2013c, CDOIF resources, webpage accessed 12/12/13, http://www.hse.gov.uk/aboutus/meetings/committees/cif/resources.htm

HSE (Health and Safety Executive), 2013d, CDOIF Guideline - Environmental Risk Tolerability for COMAH Establishments, webpage accessed 12/12/13, http://www.hse.gov.uk/aboutus/meetings/committees/cif/environmental-risk-assessment.pdf

HSL (Health and Safety Laboratory), 2012, Major Accident to the Environment (MATTE): UK case studies of incidents and near misses 1999-2010, F8/12/33, pending publication (available from lead author of this paper; Mike Nicholas – EA)

European Commission, 2013, Major accidents having significant impact to the environment, Lessons Learned Bulletin No 3, webpage accessed 12/12/13, http://ipsc.jrc.ec.europa.eu/index.php/Information-material/503/0/

Nicholas, M., Whitfield, A., 2013, The Buncefield Accident and the Environmental Consequences for Fuel Storage Sites and other Sites in the UK, Regulated under the Seveso Directive, Chemical Engineering Transactions, 31, 457-462 DOI: 10.3303/CET1331077

Vince, I., 2008, Major Accidents to the Environment, 1st Edition, ISBN 9780750683890

Whitfield, A., 2002, COMAH and the environment - Lessons Learned from Major Accidents 1999–2000, *Trans IChemE*, Vol 80, Part B, January 2002, 40-46.