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National Centre for Risk Analysis & Options Appraisal

Guide to Industrial Environmental Risk Screening

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1 Introduction

Context

1.1 In recent years risk assessment has become a tool that both industry and the Environment Agency have turned to when faced with difficult environmental problems. This mirrors the path taken, some years ago, by companies and regulatory authorities confronting health and safety issues. Risk assessment techniques are now well established and proven tools in the health and safety arena. Use of these techniques has resulted in a significant improvement in the understanding, and management of health and safety.

1.2 As with health and safety assessments, environmental risks do not occur in isolation and can normally be attributed to some form of human error. It would seem logical to adopt similar risk assessment techniques to the issue of protecting the environment.

1.3 However, risk assessment techniques are used less widely for environmental issues than would be expected from the health and safety experience. This is, at least in part, because the of complex nature of the environment.

1.4 Risk assessment methods are only of value if they enable companies to identify and concentrate on hazards which need to be controlled in order to reduce risk to the environment. In the health and safety arena the protection of human life is the ultimate goal and thus the basis of any endpoint in the risk assessment. The natural environment consists of all or any of the air, land and water and various sectors of society can place different values on the individual parts. This makes selecting risk criteria and defining environmental endpoints for formal risk assessment difficult.

1.5 This guide is aimed at risk *screening* methods, which although not so specific as formal quantitative risk assessment, will provide a systematic means of assessing and prioritising risks posed by industrial installations to the environment, albeit without addressing specifically the wider issue of risk perception.

1.6 The guide indicates the scope of the Agency's current thinking on the guiding principles that need to be addressed when undertaking an environmental risk screening assessment. It outlines concepts and procedures that form the basis of a practical methodology to undertake environmental risk screening in the industrial context.

Purpose of this Guidance Note

1.7 Risk screening is intended to be simple to implement and interpret, giving insight on accidental loss of containment events and abnormal releases to the environment. Where possible the methodology builds on and develops existing methods and data sources to present the findings in a clear and auditable way.

1.8 This risk screening methodology has been designed to assist operators to examine and understand for **themselves** the environmental hazards posed by the installations they operate. The benefits to companies that arise from understanding the risks posed by activities they undertake will be far greater than if this analysis was done by the Agency.

1.9 Environmental risk screening will also be of particular interest to those involved in the design of new process plant. The most efficient and lowest cost time to reduce any risk is at the design stage. Systematic examination of the potential risks posed by a proposed plant should ensure that any new construction is undertaken in ways that minimise the overall risk to the environment.

1.10 Operators and the Agency will be able to use the results of such studies to inform discussion in relation to cost and benefits for investment options either as a planning tools or as part of the regulatory process.

1.11 Although no substitute for formal quantitative risk assessment, risk screening techniques can enable operators to become proactive without becoming involved in the challenges posed by the more traditional route. Moving away from reacting to individual incidents by understanding the environmental risks posed by a plant and then managing them in a systematic and auditable manner, will enable all concerned to make cost effective decisions with regards to protecting the environment.

Scope and Limitations

1.12 This guidance note is not a specification for work, nor is it prescriptive. Formal site specific procedures will need to be developed, based upon the method outlined, in order to suit individual circumstances. It is expected that as risk screening methods become more widely used that more refined methods will evolve to improve the effectiveness of the technique.

1.13 This guide does not seek to address routine authorised releases as these require separate assessment methods. However, if frequent unauthorised breaches occur or have occurred these can and should be encompassed within a environmental risk screening assessment.

1.14 **This guide carries no legal status and is not intended to be used specifically with any particular environmental regulations.** However, because of the systematic approach it advocates it will be of assistance to those operating or regulating processes controlled by regulation under Water Industry Act 1991, Environmental Protection Act 1990 (LAPC & IPC), CIMAH, COMAH or IPPC.

1.15 For the purposes of this guide the environment is assumed to "consist of all, or any of the following media, namely, the air, water, and land"[1] and harm shall include "harm caused to the health of living organisms or other interference with ecological systems of which they form part and, in the case of man, includes offence caused to any senses or harm to his property;"[2]. Direct harm to humans is normally assessed in health and safety assessments is not specifically within the scope of environmental risk screening assessment, but indirect harm e.g. via the food chain or potable water supply should be included.

2 The Basics Principals of Risk Screening Assessment

2.1 *'Risk'* is a term used to denote the probability of suffering harm from a hazard and embodies both the likelihood and the consequence. The 'hazard' under consideration refers to the potential adverse *effect* posed by the source of the hazard – a toxic substance or hazardous situation and the effect represents the potential to do harm. The actual harm that results from a risk that is realised relates to the observable *damage* that occurs and is often referred to as detriment, impact or response. Hazard, risk and harm are discrete terms and should not be confused or used interchangeably.

2.2 Risk cannot occur without *exposure* of a target or receptor to the source of the hazard. This principle is encapsulated within the phrase 'the *dose* makes the poison'. Risk assessment is a process for assimilating what is known and what can reasonably be inferred about an exposure situation for the purpose of managing risk. Risk assessment can be conducted at various levels of sophistication, ranging from an initial screening of risk using simple "source-pathway-receptor" approach through to detailed analysis of complex risks using quantitative techniques to assess and express consequence and probability in numerical terms.

2.3 For a health and safety risk assessment the hazards are all associated with harm to only one primary receptor – 'man'. Environmental risks are significantly more diverse and complex than health and safety risks due to the broad range of pathways and receptors that need to be considered. Additionally, the long term effects including the reversibility of harm need to be taken into account. Data with regards to the effects substances on the environment are in general limited. Research is being undertaken to provide data to fill some of the gaps. However, with the diversity of environmental compartments, pathways and receptors it will be many years if ever before the environmental data set is as complete as the health and safety data set is today. It is, thus, much more difficult to define endpoints and criteria for tolerable environmental risks than for health and safety assessment.

2.4 The first stage of any formal risk assessment is normally to identify scenarios that can result in a potential hazard. These are then screened to select the most significant ones that be progressed to the full numerical assessment. However, for environmental risks the problems that stem from defining precise endpoints and tolerability criteria can make risk screening difficult and full quantitative risk assessment onerous in many cases.

2.5 This guide seeks to use indicators to form the basis of an expanded risk screening assessment which in many cases will provide sufficient information in its own right to be used as the basis for risk management

2.6 Risk is traditionally defined as the product of frequency and consequence. The evaluation system for a risk screening assessment is based upon the same principles. All aspects of plant operation, possible failure modes and resultant environmental outcome may be broken down into broad bands of frequency or consequence of the hazard. In recent years risk assessment convention has tended to move away from frequency of an occurrence to probability and this guide will follow that trend.

2.7 The DoE publication *A Guide to Risk Assessment and Risk Management for Environmental Protection*[3] used a three band matrix, probability being high, medium and low and consequence being severe, moderate and mild, together with a negligible rating.

2.8 More recent experience suggests that three bands of significance does not give sufficient definition and that five bands plus a negligible or insignificant will likely to be more suitable in the environmental context. The negligible or insignificant banding would only be used exceedingly rarely and require rigorous justification.

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Table 1 – An Example Probability/Consequence Matrix

	Consequences (by severity)					
Probability (of harm)	(extreme) *score*=5	(severe) *score*=4	(serious) *score*=3	(significant) *score*=2	(mild) *score*=1	(insignificant) *score*=0
(likely) *score*=5	25	20	15	10	5	0
(probable) *score*=4	20	16	12	8	4	0
(possible) *score*=3	15	12	9	6	3	0
(improbable) *score*=2	10	8	6	4	2	0
(unlikely) *score*=1	5	4	3	2	1	0
(negligible) *score*=0	0	0	0	0	0	0

2.9 Such a matrix is a gross simplification and cannot represent the true complexity of any process or ecosystem, but is useful means to aid initial thinking and prioritisation of processes with regards to environmental risk associated with an operation.

2.10 For an effective risk screening assessment to be undertaken it is necessary to systematically evaluate the probability and consequence elements of the risk posed by the plant. The approach used by this guide is to score individual aspects of the identified scenarios against key indicating factors. This simplifies the situation, avoiding the need to define specific endpoints and tolerability criteria. The indicators need to encompass the most significant environmental risks posed by the operation and installation.

2.11 The following are the suggested indicating factors which are use in this guide:-

- Probability
  - probability of release
  - probability of exposure
  - management factors

- Consequence
  - nature of hazard
  - sensitivity/importance of exposed receptors
  - spatial scale of impact
  - temporal scale of impact

2.12 These factors are still a significant simplification of the real world but cover the most important aspects of risk likely to be posed by a chemical production or processing plant.

3 Scenario Generation and Hazard Identification

3.1 Key to any risk assessment is identifying the scenarios which could result in the plant posing a hazard. The traditional approach is to form a *Hazard Identification Team* which uses "brain storming" techniques to identify possible failures and the associated consequences. In many instances, meetings are already being conducted for health and safety risk assessments, extending or adapting these to consider the environmental risks should not place a significant burden on companies.

3.2 The strategy for environmental risk scenario generation is similar to that for health and safety hazard identification and, much has been written on the subject and the topic is generally well understood in the chemical and process industries. The process is outlined below but for those unfamiliar with the technique there are many purpose written texts[4,5] on the subject, thus, this guide will not seek to explore scenario generation to any depth.

3.3 A hazard identification team should be of a similar constitution to that would be used for health and safety hazard identification typically would consist of:-

- study team leader
- record keeper/scribe
- design/process/control engineer(s) responsible for the plant
- operating manager of the plant
- appropriate maintenance engineer(s)
- representative(s) of the plant crew
- environmental specialist

Prior to the hazard identification meeting, the team should obtain, or be provided with, base information to enable a systematic examination of the hazards. This will include:-

- plant layout including drains, stacks, vents and any other potential release pathways
- plant operating procedures & maintenance records
- all authorisations/consents/licences to operate
- staff training records
- accident history of the plant including near-misses
- inventory of all substances used in the process. (raw materials, intermediates, by-products and products)
- physical, environmental and toxicological information on all substances used in the plant
- environmental context of the plant - proximity and details of important environmental features e.g. centres of population, schools, sites with a protected status, rivers, controlled waters, farms, fish farms, sensitive wildlife and protected species etc.

3.4 The Hazard Identification Team should seek identify and consider scenarios that could result in any unplanned release that would pose a hazard to the environment. This should include all possible materials, the consequence of fire or explosion and the release of heat or cold.

3.5 Failures that results in an accidental loss of materials into the environment can occur in one or more of three generic ways:-

- accidental loss of containment from failed plant equipment
- abnormal release from emergency relief vents, flares etc.
- accidental excess release from a *normal* release point

3.6 Work normally already undertaken for health & safety assessments will serve as the basis for much of the base information on the operation of the plant. However, environmental information will probably need to be gathered specifically. **It is important not to rank the environmental risk from a particular scenario low just because it has a low significance from the health and safety stand point.**

3.7 For the purposes of risk screening it is frequently appropriate to consider the plant as a whole, grouping together scenarios with similar cause and likely consequence. From the environmental perspective a release from any one of several places on a plant may well have a similar frequency and consequence and can be thus treated as a *generic* release scenario. A series of scenarios which describe typical events may be especially useful where little or no specific information is available from the health and safety risk assessments. By this means the actual need to consider specific scenarios in detail should be reduced.

3.8 There will be some instances where specific scenarios will be the only way to analyse a particular risk and large or complex plants will need to be considered in parts. It is important that the individual parts being considered are neither too large or small as this may distort the overall analysis. It is thus, recommended that the plant is divided into sections made from similar materials and operating at the same pressure and temperature. Consideration should be given to possible interactions between sections of the plant as for example the sudden transfer of hot liquid into a normally cool part of a plant could be the trigger for an incident to occur.

3.9 The hazard identification team need to pose "*what if*" questions in order to devise appropriate possible failure scenarios for the installation being assessed. It is possible to simplify the problem by defining a generic scenario and assigning this a frequency score. For example - what if the entire contents of the plant were lost to the environment? This would imply catastrophic failure - major rupture of a plant vessel. This would be normally unlikely but could result from a number of different causes. The environmental consequence would be expected to be the similar and thus the consequence analysis would be generic to all the total loss scenarios. Some examples of generic scenarios that need to be considered are set out in Table 2. below. The list is in no way exhaustive. Posing questions will promote discussion around what events could cause plant failure. These would include a review of the chemical pathway being used and what chemical circumstances or mechanical failure could lead to partial or total loss of a plants contents. This approach should simplify the assignment of scores.

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Table 2 - Example Generic Release Scenarios

Scenario 1	Small liquid leak from gland or flange etc. equivalent to 2mm. hole
Scenario 2	Medium liquid leak from gland or flange etc. equivalent to 5mm. hole
Scenario 3	Fracture of a pipe-line, hole equivalent to the diameter of the largest

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Table 2 - Example Generic Release Scenarios

	pipe-line in the section of the plant being considered
Scenario 4	Fracture of a vessel, consider complete loss of plant contents
Scenario 5	Fracture of bursting disk - 10% loss of plant contents
Scenario 6	Failure of effluent treatment works, untreated effluent to river
Scenario 7	Tanker transfer hose fracture 10% of tanker contents lost to drain

3.10 In order to be able to award significance scores the scope of the scenario must cover all the aspects to be assessed but in particular.

- substances & possible quantity released
- duration of release
- by what means and to where will the release impact on the environment
- nature of the environment at the point(s) of likely highest concentration

3.11 Normally, some simple modelling will be required to define each scenario, in order to determine how much material may be released and where it goes in the environment. e.g. If a leak occurs on a plant what will be the magnitude of the release? The release rate will be based upon the pressure and viscosity of the liquid and size of the hole it is leaking from. These rates are calculable from standard engineering models, but the overall magnitude of the release will depend on duration of the release.

3.12 It will be necessary to form a view on the length time it will take before sensors on the plant or someone takes to identify the release is occurring and action is taken to stem it. This will depend on where the leak is physically, can it easily be seen? or will the plant control systems recognise that there is a problem. The hazard identification team may decide that the best approach is to identify several sub-scenarios for leaks that would be not be noticed for different periods of time.

3.13 The hazard identification team must consider the implications of each different sub-scenario and what actions would be necessary or possible to control the release. For example, are trained staff and suitable equipment likely to be available to manage the scenario release? The situation may be different between day and night shifts. With this information the hazard identification team will be able to form a view on which aspects of the sub-scenarios are significant and need to taken account of in the overall assessment.

3.14 It will normally be necessary to model the dispersion of the scenario release through the environment to determine what will be the maximum concentration and where will occur. Proprietary models exist to predict the fate of substances released to all media, although those for air dispersion and water dispersion modelling are more advanced. The concentration of a released substance does not necessarily correspond to environmental harm but for the purposes of risk screening it will serve as an indicator.

3.15 The hazard identification team will also need to consider possible knock-on effects e.g. What would happen if the accident cause a large release to the trade sewer? The environmental harm could result the at sewage works discharge to a controlled water. More significant would be if the release destroyed the biological processes at the sewage works, this could result in all the effluent from the works being discharged essentially untreated.

3.16 All assumptions made to define the scenarios should be fully recorded and attached to the assessment.

4 Environmental Risk Screening Indicators

4.1 Conventional quantitative risk assessment methodology defines risk as the product of probability (or frequency) and consequence. The evaluation system used for this risk screening methodology is based upon the same underlying principles.

4.2 The methodology recommended by this guide evaluates scenarios against probability and consequence indicating factors. The use of indicating factors simplifies the analysis as it is not necessary to determine environmental endpoints. When appropriately chosen indicating factors are used most significant environmental risks will be identified in a semi-quantitative manner. Indicator factors are treated as effectively independent and assigned significance scores with respect to particular aspects of the operation. They are not independent of each other but treating them as such is imperative in order to bring sufficient simplicity to the assessment process to make it viable. The following section outlines the guiding principles and offers practical advice on how determine environmental risk screening scores using indicating factors across a diverse range of plants and circumstances.

4.3 The very wide range of industries and processes that the risk screening approach has the potential to assist means that explicit methods and indicating factors are impossible to define. **Organisations and the industry sectors will need to develop specific methods and factors to take account of their own circumstances, although the figures suggeted in this guide will make a good starting point.** Scores from different industry sectors and sites, therefore, may not be directly comparable.

4.4 However, operators will be able identify the most significant risk on their site and use this information as part of the management procedures of the plant and in discussion with regulators.

4.5 This guide will use two primary indicating factor to estimate the magnitude of the probability and consequence of a risk and then adjust these to refine the assessment:-

- probability of release
    - probability of exposure
    - management factors

- nature of hazard
    - sensitivity/importance of exposed receptors
    - spatial scale of impact
    - temporal scale of impact

4.6 The degree of detailed analysis will be significantly less in a screening assessment than when a full quantitative risk assessment is undertaken. It is inevitable that aspects of the analysis may be reflected in more than one category of the analysis. Any attempt to resolve such interdependency would add significantly complexity and this is unlikely to be warranted for a screening assessment. Nevertheless, the hazard identification team should try to identify and record any significant interdependencies. In the case of anomalies in the results, these might be a good place to start a further iteration of the analysis.

5 Determining Environmental Risk Screening Significance Scores

Probability

5.1 The probability of an incident occurring on a plant which has the potential to harm the environment is made up of several components. The intrinsic reliability of a plant design clearly the major factor and this is assessed in the section probability of release. It is governed by the design of plant and the operations that are undertaken on it. Other factors, including the quality of management and the operating procedures of the plant will clearly influence both the probability of an initial incident and how it develops with respect to releasing harmful quantities substances to the environment.

probability of release

5.2 Methods of assessing a probability of an incident occurring on chemical plants are well developed with respect to health and safety assessments. The starting point is the scenario and the assessment must be carried out in the context of the scenario. There are many sources of data to use. Actual plant data and experience from manufacturers are the most appropriate starting points to obtain failure information.

5.3 Care should be taken to ensure that the records are taken over sufficient time scale as not to be distorted by recent history. e.g. Recent plant improvements may have resulted in a reduction in failure rates from new equipment, but can this be sustained in the longer term supported by standard maintenance procedures? Proprietary hazard indexes, examples include The Dow "*Fire and Explosion Index*"[6] and *The Mond Index*[7] can provide typical failure rates for most types of process plant and equipment. These are based upon world wide experience and can be used as default values in the absence of any more representative data. It is important to choose indexes which are appropriate to the type of operation being assessed for example a piece of equipment may have significantly different failure rates when operated continuously when compared to use in batch operation.

5.4 Index data generally only covers the specific failure of a piece of equipment in a particular set of circumstances. Sequences of events, where one failure causes knock-on consequences in the process operation need to be evaluated by calculation from the individual index data.

5.5 Nor do indexes address the sensitivity of the chemical reactions pathways being used. In some cases this can change radically with minor changes of conditions. Chemical reactions need to be assessed in detail to identify what failure or combination of failures could promote a change in chemical pathways and what the process implications of those might be. Index data can be used to give probabilities on failures which could result in changes to the chemical pathway and result in a release scenario.

5.6 It should be possible to come to some broad view as to the probability of each of the identified events that could result in release scenarios. Use Table 3 to translate the probability of event to the primary risk screening significance factor.

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Table 3 – Probability of Release Significance Score

Probability Label	**Probability** (of an event in a year)	**Score**
Highly probable	> 0.1	5
Probable	0.1 to 10^{-2}	4
Possible	10^{-2} to 10^{-3}	3
Improbable	10^{-3} to 10^{-4}	2
Unlikely	$<10^{-4}$	1
Negligible*	$<10^{-6}$	0

*Note that a negligible ranking is a very rare occurrence see text before using this ranking

5.7 **It must be stressed that the significance scores in Table 3 above are purely illustrative for the benefit of this guide. The scores from these assessments are**

relative, this example will not be appropriate to all industry sectors or installations. It should not be interpreted to mean that The Environment Agency attaches a particular *probability label* or *probability score* to any individual probability.

5.8 Because of the diverse size and nature of plants that this guidance is likely to be relevant to it is not possible give a definitive probability of event verses probability significance score. In general it is expected that this would be a logarithmic relationship and Table 3. above gives an indication of how to consider standard equipment in a plant. It is important that any report using this method states explicitly how the frequency score is derived. Any discussion with an Environment Agency Inspector would be expected to review how appropriate the scenarios and frequency values were for the screening assessment under consideration.

5.9 Screening assessments will be more valuable if the probability ranges and associated scores cover the spectrum of probabilities encountered on the plant/installation being assessed. There is nothing to be gained by arranging for all the Probability of Release Significance Scores to be compressed into a narrow range.

5.10 In this example the probability for the *negligible* band is two orders of magnitude less than the *unlikely* band, in specific cases it may be more appropriate if this is three or more orders of magnitude less. The use of the *negligible* band will be very rare and must be treated with extreme caution. In cases where the consequence of an incident is very significant the use of the *negligible* band is best avoided.

5.11 Before assigning the final frequency of release score(s) it is necessary to consider a variety of other factors which could impinge on the frequency of release score. These include age of plant, maintenance, management, staffing etc. Examples of these are shown in some of the following adjustment tables but it may be necessary to develop further (or alternative) adjustment indicating factors for specific plants if the examples outlined in this guide are not sufficient or appropriate.

probability of exposure

5.12 When an incident has occurred it will not necessarily result in a release to the environment that causes harm. For example a small leak that is rapidly identified and stemmed is unlikely to cause any real environmental harm. Similarly if an appropriate boom and skimming equipment were immediately available to clean up a minor oil spill the probability of real environmental harm for that scenario would be reduced. Thus, where procedures and equipment appropriate to the scenario incident are in place to prevent an incident developing to the full environmental scenario the probability significance score can be modified to take account of the reduced probability of environmental harm. Table 4 gives examples of adjustments to the raw Probability of Release Significance Scores to take account of the probability of exposure.

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Table 4 – Probability of Exposure Adjustment

Probability of Exposure Criteria	**Score**
Unmanned/remotely operated plant	+1
Safeguards/control procedures in place to limit exposure to environment	-1
real time monitoring to identify loss of containment with feed back to control room	-1

management factors

5.13 The quality of management of a plant or installation will have a significant influence upon the probability of an incident occurring. For an initial evaluation subjective evaluation of the quality of management is not advised. In the case of poor management this could appear as criticism of senior management which may bias the results as staff could be reluctant to openly make such criticism. This guide suggests the use of criteria which are widely recognised as being indicators representative of the quality of management but without actually assessing management specifically.

5.14 Table 5. is made up of six sections (A - F) each of which examines key aspects of the management of a plant. The most appropriate category from each of these sections should be chosen and added to the Probability of Release score from Table 3 above.

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Table 5 – Management Factors Adjustment

Section	Management Factor Criteria	Step-up/ Step-down
A	Poor history of safety/environmental accidents	+2
A	Poor history of safety/environmental accident "near misses"	+1
A	Average safety/environmental accident record	0
A	Significantly better than average safety/environmental accident record	-1
B	Plant manager has been responsible for plant less than 6 months and this is their first post at this level of seniority	+2
B	plant manager been responsible for plant less than 6 months	+1
B	plant manager responsible for the plant between 6 months and 5 years	0
B	plant manager been responsible for plant more than 5 years	-1
C	no formal operating procedures exist	+2
C	formal operating procedures exist but have not been audited within the last 12 months	0
C	operating procedure exist and have been audited within the last 12 months	-1
D	preventative: reactive maintenance ratio worse the 30:70	+1
D	preventative: reactive maintenance ratio between 30:70 & 80:20	0
D	preventative: reactive maintenance ratio better than 80:20	-1
E	no formal training for operational staff	+1
E	ad hoc training only for operational staff	0
E	all operational staff have been (re)trained within the last 12 months	-1
F	no formal environmental management system	0
F	plant operates under a fully accredited environmental management system	-1

5.15 The management factors table will need to be interpreted in the light of the specific circumstances being assessed. It may be necessary to add further sections to the table. In which case the principle to be used is that as the probability factors reflect divergence from normal industry best practice and adjustment should be proportionate to the deviations from that normal practice.

Consequence

5.16 The harm that results from the accidental release of a material into the environment is highly dependent on the nature of the material, the sensitivity of the receptors, the persistence of the released material in the environment and what natural mechanisms exit to repair any harm. Detailed analysis of these aspects is extremely complex. Generating data and undertaking detailed analysis is time consuming and expensive and many organisations avoid environmental risk assessment studies altogether because of this difficulty. The risk screening approach uses indicators to act as surrogates for the detailed information. The risk screening concept attempts to simplify some of the more difficult aspects that are necessary for a QRA and thus enable risk assessment to be more widely used. Even this approach is complex and the validity of the indicators chosen as examples in this guide open to debate. It is anticipated that feed back that will result from the use of this methodology will serve improve the selection of indicators and give greater understanding on the relative importance of each of them.

5.17 In the absence of detailed environmental analysis and the risk criteria derived from it the approach adopted by this guide is to examine the hazard posed to the environment independently to the sensitivity of the environment. The combination of these factors will provide a score which will be a surrogate for the risk posed to the environment by a potential release scenario. This will cause operators to consider the environment in a structured way and make appropriate decisions about how to protect it from harm.

5.18 The assessment needs to be made in the context of the amount of substance released and/or the maximum environmental concentration that could result from the scenario being considered. In most cases it will only be necessary to consider the short term exposure that would result from an accidental release but in rare cases long term exposure from e.g. a leaking uninspected drainage system, may also need to be included. This can be adjusted to take account of other consequence factors.

Nature of Hazard

5.19 It is proposed that environmental harm be judged by considering the maximum environmental concentration of a released substance from the scenario in comparison to a reference level for that substance. Statutory reference standards already exist for some substances in the form of environmental quality standards (EQSs). The Environment Agency has published environmental action level (EALs) standards (for consultation) for many substances which do not have EQSs in the Technical Guidance Note "Best Practicable Environmental Option Assessments for Integrated Pollution Control"[8] It is recognised that many of these levels are not based upon environmentally significant data, having been derived from work place exposure limits etc. however in the absence of better information this approach will take account some aspects of the *toxicity* (although not necessarily environmental toxicity) of the material that may be released.

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Table 6 – Nature of Hazard Significance Score

Hazard Label	Environmental Concentration from Scenario	Score
Extreme	>(EQS or EALS) x 10^2	5
Severe	(EQS or EAL) x 10 to (EQS or EAL) x 10^2	4
Serious	(EQS or EAL) to (EQS or EAL) x 10	3
Significant	(EQS or EAL) x 10^{-1} to (EQS or EAL)	2
Mild	<(EQS or EAL) x 10^{-1}	1
Insignificant*	<(EQS or EAL) x 10^{-3}	0

*Note that an insignificant ranking is a very rare occurrence, see text before using this ranking

5.20 Similar to the probability of release evaluation the primary consequence table, nature of hazard, is logarithmic, with the exception of the final insignificant band, with respect to environmental concentration of the released material. Any release which does not cause a recognised standard to be exceeded is deemed not of great significance. The release may still however cause a breach of an authorisation or consent limit[1]. In such circumstances it may be more appropriate to replace the EQS or EAL limit with one based upon environmental concentrations derived from authorisation or discharge consent. The *insignificant* rating must also similarly be used with extreme caution and in cases where the probability analysis shows an event is likely to occur frequently the use of the *insignificant* band should be avoided

5.21 In the absence of specific standards for a substance or where more information has become available since the technical guidance note was published it will be necessary to derive an appropriate "standard" from primary data. Volume II of the Technical Guidance Note "Best Practicable Environmental Option Assessments for Integrated Pollution Control" describes how the interim EALs published in the note have been derived. In the absence of specific standards a similar methodology should be adopted, ensuring that as is far as possible the main hazards to the environment are considered.

- toxicity to aquatic organisms
- toxicity to flora
- toxicity to fauna

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[1] The Environmental Protection Act 1990 requires operators to use the Best Available Technique Not Entailing Excessive Cost (BATNEEC) to prevent or minimise releases to the environment. This implies that a zero release is optimum. IPC authorisations may contain release limits that are lower than is necessary to not breach an EQS or EAL because they are BATNEEC. It is thus possible to have an accidental release exceed an authorisation limit but not breach an EQS.

- ozone creation potential
- potential to harm the ozone layer
- global warming potential
- potential to harm the built environment

There are many sources of environmental hazard information e.g. The Dictionary of Substances and their Effects[9], which will assist the risk screening assessors to determine appropriate standards.

importance of exposed receptors

5.22 It is important to safeguard the whole environment but some parts of it are regarded as particularly important. These important environmental features need to be taken account of in the consequence score so as to afford greater protection to the most important features.

5.23 As part of the generation of scenarios environmental receptors that could possibly be harmed by the operation will have been identified. This should include the proximity of and the possibility of affecting sites requiring particular protection e.g.

- sites designated for statutory conservation (e.g. SSSIs)
- rivers/controlled waters
- groundwater protection zones
- farms
- fish farms
- sensitive wildlife
- underground aquifers
- listed buildings

5.24 A spill of material that is toxic to aquatic organisms into a river will be likely to cause harm down the complete course of that river until it discharges into the sea and dilution is sufficient to mitigate the action of the material. It is thus necessary to consider all environmental features down river from a plant that might be affected.

5.25 The release of either ozone depleting substance or materials with global warming potential need to be treated with care. The number of environmental receptors that could be affected are vast and the impact will be global. However, in most cases the quantity of material released on an incremental basis compared with the total release of ozone depleting substances or materials with global warming potential will be so small as to render the scenario insignificant from that perspective.

5.26 The importance of a site or receptor can be represented by an estimate of its ecological or conservation value. The most significant of these areas are already identified by having some legal form of protected status e.g. Site of Special Scientific Interest(SSSI), National Nature Reserve, Special Area of Conservation(SAC), Special Protection Area(SPA), Ramsar Site etc. These are managed by a variety bodies, many having statutory responsibility like English Nature or in Wales the Countryside Council for Wales. The Environment Agency Publication *Conservation Designations in England and Wales*[10] gives a detailed review of the statutory conservation designations that will assist in the identification of sites that require protection. Other sites of conservation value include County Naturalist's Trust Nature Reserve, Local Authority Nature Reserve, National Parks and Areas of Outstanding Natural Beauty and sites managed by the Royal Society for the Protection of Birds and the National Trust.

5.27 Unfortunately there is not a central register of sites that have a statutory conservation status, however, local authorities in discharging their duties under the town & country planning legislation will normally hold most of this information.

5.28 The scenario will have identified the pathway(s) any released material take through the environment. If any release will impact on a site which has some protection designation this needs to be taken into account in the consequence analysis according to the level of designation. As sites have significance at different area, regional and national levels this can be used as the basis for assessing the significance indicator.

5.29 World Heritage sites and certain European level sites designated as of global significance are the most important. They protect a unique habitat or ecological community (e.g. the saltmarshes of East Anglia), or because they support a significant proportion of the World or European population of a particular species. (Usually the breeding or migration site for a species of bird).

5.30 Ramsar sites, SPAs and SACs are sites designated by Europe under the Ramsar convention and Habitats Directive (they may also be SSSIs, National Nature Reserves etc.) are at the next level of importance. Other SSSIs, National Nature Reserves, are of UK national significance and County Naturalist Trust Sites, local authority nature reserves, etc, are of local importance.

5.31 It should also be noted that a number of species are protected under the Wildlife and Countryside Act irrespective of their location. Whether the protection offered by the Act applies specifically to accidental releases from industrial processes is unclear. The spirit of the Act suggests that these species are deserving of best endeavours in their protection and thus where such species are identified as being likely to be impacted in the scenario appropriate adjustment should be applied.

5.32 Where the scenario incident could lead to an indirect effect on human populations this needs to be reflected in the consequence score. Examples of this would be incidents that could contaminate the human food chain or where large numbers of people or vulnerable people could be exposed to the incident.

5.33 Table 7 shows how these factors can be incorporated into the consequence significance score. The most significant aspects identified in the table should have their significance adjustment score added to that of the nature of hazard table.

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Table 7 – Importance of Exposed Sites/Receptors Adjustment

Criteria	**Step-up**
site/receptor of global significance in the likely pathway	+4
site/receptor designated for protection at European level in the likely pathway	+3
site/receptor designated for protection at national level in the likely pathway	+2
site/receptor designated for protection at local level in the likely pathway	+1
area lacking any formal conservation status (most of the UK)	0
Incident has potential to contaminate human food chain	+1
area of high human density e.g. housing estate, in likely pathway	+1
Vulnerable human population e.g. hospital or school, in the likely pathway	+2

5.34 Sensitivity of a site or receptor is often viewed as the magnitude of the damage (or change) that might result in the ecology of the site in relation to the magnitude of the stress placed upon it.

5.35 Examples of ecological change which might indicate degrees of sensitivity might include:-

- behavioural and physiological adaptation, typified by species migration to elsewhere and new biological mechanisms to adapt to or detoxify the pollutant.
- reductions in growth rate
- mortality amongst one or more species
- changes to breeding behaviour
- a fundamental change in the ecological community types

5.36 The living environment is a dynamic system and understanding how all parts of it interact is too complex to form the basis of meaningful generic indicators for a risk screening assessment. However, consideration should be given, whilst developing the scenario, as whether or not any part of the environment at the point likely to receive the greatest concentration of released material is especially sensitive to it.

5.37 Where the environment has already been recently damaged a further release may cause proportionately more harm than normal. It should be noted that it is particularly hard to define when the environment has recovered from previous harm (see section on environmental recovery time). In some cases the previous challenge may even have given the ecosystem some degree of immunity but in the absence of any better information a recently harmed part of the environment should be considered as more sensitive than normal and the consequence score increased to take account of the likely extra harm that would result if a further release was made before full recovery has occurred.

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Table 8 – Sensitivity of Exposed Receptors/Sites Adjustment

Criteria	**Step-up/ Step-down**
Sensitive species or habitat or ecosystem likely to be impacted by incident	+1
Environment still stressed (or not fully recovered) from a previous incident	+1

Temporal scale of impact

5.38 There are three temporal aspect which need to be considered:- persistence, recovery time and time for environmental damage to become apparent.

5.39 Some substances are persistent in the environment and do not degrade. The environmental harm caused by a release will continue for many years. Mechanisms for degradation include hydrolysis, photolysis, oxidation, reduction and biodegradation and overall degradation rate will in part depend upon the environmental compartment the substance is in. An example of how this can be done is set out in Table 9 based upon the half-life $t_{½}$ of the material in the environmental compartment defined by the release scenario.

5.40 Recovery can be meant in different senses, depending on whether considering individuals, populations, or communities. Generation time is considered the time taken for an organism to develop from birth to the birth of its own offspring. Generally longer for large mammals (humans, c. 25 years) than small mammals (rabbits, a few weeks). However, the time taken for a particular population to recover will depend on the magnitude of the reduction in the population, the generation time, and rates of fertility and mortality. If the population is locally extinct, it will also depend on how rapidly they can migrate from elsewhere. An oak woodland could take up to 2000 years to recover full diversity if it was totally destroyed. Where a key structural component of the habitat is affected e.g. the physical/chemical nature of the habitat, or a '*keystone species*' (trees, or a top predator), the community may change fundamentally, and also take much longer to recover. If the change is physical or chemical, full recovery will depend (partly) on the half-life of the change and where the change is ecological, it will depend on the ecology of the species concerned.

5.41 It must also be recognised that no environment is static, in the absence of any incident it will evolve, albeit only slowly. It is very difficult to define and evaluate what the recovery time will be following an incident. This guide suggests that an appropriate indicator factor could be the generation time of the keystone species. Scenario will identify where the maximum concentration of released material will occur. The hazard identification team should look to see what species are present in these areas and try identify the keystone species (animal and/or plants).The will often be the physically largest. As a recovery time indicating factor, the generation time of the keystone species is appropriate in the absence of any better information. If the ecosystem is such that the species can rapidly migrate to re-colonise from near by e.g. from further up stream when pollution harms a river, the recovery time can be halved.

5.42 In most accidental release incidents from industrial installations the resulting environmental damage becomes almost immediately apparent. Clean up or mitigation can be started immediately and will obviously be the responsibility of the organisation responsible for the incident. Some releases may not be immediately apparent and mitigation not possible for some time. An example of this would be where a material spill contaminates soil and subsequently seeps into an underground aquifer. This could take several tens of years to happen leaving a future generation the problem and expense of cleaning up the aquifer. Where evidence of environmental damage and any necessary mitigation measures will be delayed the consequence score must be increased.

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Table 9 - Temporal Scale Adjustment

Reversibility of harm criteria	**Step-up/ Step-down**
$t_{1/2}$ for degradation greater than 3 years	+3
$t_{1/2}$ for degradation between 100 days and 3 years	+2
$t_{1/2}$ for degradation between 10 days and 100 days	+1
$t_{1/2}$ for degradation between 1 days and 10 days	0
$t_{1/2}$ for degradation less than 1 day	-1
Never recover	+3
Recovery possible but will take over 10 years	+2
Substantial recovery could take up to 10 years	+1
Substantial recovery expected within a year	0
Substantial recovery expected in less than 1 month	-1

Guide to Industrial Environmental Risk Screening **Table 9 - Temporal Scale Adjustment**	
Environmental damage not immediately apparent	+1
Environmental damage immediately apparent	0

spatial scale

5.43 The size of area that a release may affect is also an important aspect of consequence. An event with the potential to cause wide spread harm is of greater significance than one in which harm is localised. In general the more wide spread the pollution from an event the lower the concentration and the more likely the environment will be able to tolerate the effects.

5.44 There are some notable exceptions to this the most obvious being when a river becomes polluted. The river acts as a conduit to carry the pollution essentially undiluted along its entire length. The Sandoz chemical warehouse fire is a well documented example[11]. The aerially dispersed products of combustion and smoke affected the local area but the contaminated fire water caused contamination to spread the entire down stream length of the River Rhine.

5.45 The table below suggests a scoring system to use to judge to significance of an event with respect to the spatial impact of the event.

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Table 9 – Spatial Scale Adjustment

Spatial Scale Label	Criteria	Step-up/ Step-down
International/ National	event has an impact throughout more than one region of U.K. and possibly on other countries	+4
Regional	event has an impact throughout an entire region of the country e.g. 2 - 3 counties	+3
Area	event has an impact over wide area e.g. throughout a county	+2
Neighbourhood	event has impact in the immediate neighbourhood e.g. 5 miles	+1
Local	the impact is localised and limited to with in a few hundred metres of the event	0
Immediate vicinity	the impact is restricted to a very immediate vicinity e.g. within the authorised/consented mixing zone in a river	-1

6 Calculation is Risk Screening Score

6.1 The risk screening significance score for each scenario is calculated by adding the relative adjustment scores to the respective primary probability and primary consequence scores and then multiplying them. In the unlikely situation that either the probability or consequence scores is zero the other factor should be examined before the scenario is dismissed. If the corresponding score was very large there could still be a significant residual risk due to the uncertainty associated with determining scores.

7 Environmental Risk Management

7.1 The final result of a risk screening assessment will be a series of scenarios each with a screening assessment score. Provided all the scores were derived on the same basis this will result in a rank ordered list of scenarios that present the greatest risk to the environment. The list can be used directly as the basis of risk management by addressing the risk from scenarios that have the highest scores. In other instances it may be more appropriate to undertake a full QRA on the scenarios with the highest score in order understand the significance of the risk in greater detail. The methodology cannot define what is BATNEEC/ALARP or BPEO in any particular situation but will serve to inform what and where environmental risks arise. In many instances undertaking the assessment will be valuable in its own right as it will cause a structured examination of the process in the context of the environment.The results should serve to inform operators where it is necessary to consider improving environmental performance and form the starting point for constructive discussions with regulators.

Glossary of Terms

CIMAH	Control of Industrial Major Accident Hazards – Regulations implimented in 1984
COMAH	Control of Major Accidents – European Directive 96/82/EC implimented in UK law by [YYYYYY]
EA95	Environemt Act 1995
EAL	Environment Assessment Level – see reference[8]
Ecosystem	All the animals and plants in an area, considered from the point of view of their relationship to each other
EPA90	Environment Protection Act 1990
EQS	Environmental Quality Standard – statutory level set by the Secretary of State –see reference[8]
Exposure	The hazard reaching the receptor
Frequency	The number of times an event occurs in a given time
Global Warming Potential	Contribution to atmospheric absorption of radiation leading to increase in global temperature
Harm	Extent of the detriment resulting from the realisation of a potential hazard
Hazard	Adverse effect posed by a substance or situation
IPC	Integrated Pollution Control – system that is used to regulate the potentially most polluting industries sectors as defined in schedules under EPA90. Considers the release to all media
IPPC	Integrated Pollution Prevention and Control – EC Directive 96/61, due to implimented in UK law.
LAPC	Local Authority Pollution Control – system of pollution control used to regulated less potentially polluting industries as defined in schedules under EPA90. Considers releases to air only and is operated by local authorities.
Ozone creation potential	
Pathway	Route by which a released substance travels to the receptor
Probability	Likelyhood of an event occuring
Receptor	A vulnerable organism or part of the environment that is being considered in a scenario
Risk	Probability of suffering harm from a hazard – embodies both likelyhood and consequence
Scenario	A set of circumstances that could result in a hazardous situation
Source	The substance or situation that could pose an adverse effect
SSSI	Site of Special Scientific Interest – an area of land notified under the Wildlife and Countryside Act 1981 as being of special nature conservation interest.
WIA91	Water Industry Act 1991

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