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Guideline for a risk-based approach to the  
management of contaminated former military  
sites in Latvia.

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Forfatter: Grundy, C. & Quint, M. (Dames & Moore, UK).		Oppdragsgiver: Det Norske Utenriksdepartementet Latvian Ministry of the Environment	
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<p><b>Sammendrag:</b></p> <p>This guideline has been produced to assist in the management of contaminated sites in Latvia, in particular disused Russian military sites. A risk-based approach is proposed for adoption in the assessment of such sites in line with the approach adopted in recent years by other countries in the European Union.</p> <p>Some countries have set fixed numerical criteria to assess contaminated land based on generic assumptions on site conditions such as; soil type, depth to groundwater, geology and hydrogeology, and proximity to potential receptors (eg. groundwater supply well, surface water body). Such an approach ignores the fact that contaminated sites vary widely in terms of both complexity and the potential risk they may pose to either human health or the environment. As fixed numerical criteria are nearly always set at very low levels, their use leads to the clean-up of more land than may be necessary. The result is wastage of resources with clean-up costs incurred without an incremental reduction in risk to human health and the environment.</p> <p>In recent years, the principles of risk-based corrective action (RBCA) have been applied. This follows a flexible approach to decision-making whereby corrective action (remedial action) is appropriately tailored to site-specific conditions and hazards. This leads to more cost-effective solutions, and allows the greatest effort to be targeted to where it is most beneficial. In its broadest sense, risk assessment in relation to contaminated land can be defined as "an evaluation of whether there is a potential for adverse effects to occur, based on factual knowledge about a site, and scientific evidence concerning the environmental behaviour and toxicity of the chemicals present".</p> <p>Although this method is applied in the USA (ASTM RBCA)<sup>1</sup>, there are a number of differences between the USA and other countries which must be considered. Dames &amp; Moore have produced a Guideline which sets out an approach for the management of disused Russian military bases in Latvia based on our experience in developing similar guidance for the assessment of contaminated oil industry sites in Europe for Concawe "European oil industry guideline for risk-based assessment of contaminated sites". The approach to the assessment of disused military bases in Latvia has been based on the tiered approach set out in the Concawe document.</p> <p>The underlying concepts of Risk-Based Corrective Action are described in this report.</p> <p><sup>1</sup>ASTM (1995) Standard guide for risk-based corrective action applied at petroleum release sites. ASTM E-1 739. Philadelphia PA: American Society for Testing and Materials.</p>			
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**GUIDELINE FOR A  
RISK-BASED APPROACH  
TO THE MANAGEMENT OF  
CONTAMINATED FORMER  
MILITARY SITES  
IN LATVIA**

Dames & Moore  
5th Floor  
Blackfriars House  
St Mary's Parsonage  
Manchester, UK  
M3 2JA

Tel. No. +44-(0)161 832 0166  
Fax. No. +44-(0)161 832 1493

# CONTENTS

0. EXECUTIVE SUMMARY .....	5
1. INTRODUCTION .....	7
1.1 Use of Risk Assessment in Europe .....	7
1.2 Historical Overview .....	7
1.3 Goals of the Guideline .....	10
2. ENVIRONMENTAL LEGISLATION AND POLICY FOR LATVIA.....	13
2.1 Introduction.....	13
2.2 Legislation.....	13
2.3 Latvian Approach to Assessment of Contaminated Sites .....	14
3. FUNDAMENTALS OF RISK ASSESSMENT.....	16
3.1 Introduction.....	16
3.2 Tiered Approach to Risk Assessment .....	16
4. OVERVIEW OF METHODOLOGY .....	20
4.1 Data Collection .....	20
4.2 Assessment of Need for Immediate Remedial / Corrective Action .....	21
4.3 Development of Conceptual Site Model.....	21
5. DETAILED PROCEDURES FOR TIER ONE ASSESSMENT .....	23
5.1 Introduction.....	23
5.2 Sampling and Analysis.....	23
5.3 Interpretation of Data.....	24
5.3.1 Introduction.....	24
5.3.2 Comparison of Data with RBSLs.....	24
5.3.3 Limitations .....	25
5.3.4 Comparison of Data with Other Relevant Criteria (ORCs) .....	26
5.4 Evaluation of Tier 1 Results.....	26
6. DETAILED PROCEDURES FOR TIER TWO ASSESSMENT .....	28
6.1 Introduction.....	28
6.2 Issues of Concern .....	28
6.3 Data Collection .....	29
6.4 Interpretation of Data.....	29
6.4.1 Introduction.....	29
6.4.2 Site-Specific Risk Assessment .....	30
6.4.3 Comparison of Data with Other Relevant Criteria (ORCs) .....	31
6.4.4 Assessing the Risk from Free Product .....	31
6.4.5 Assessing the Risk to Surface Water .....	31
6.4.6 Ecological Risk Assessment .....	32
6.4.7 Sediment Risk Assessment .....	32
6.4.8 Agricultural Land Use.....	32
6.5 Evaluation of Tier 2 Results.....	32
7. OUTLINE PROCEDURES FOR TIER THREE ASSESSMENT .....	34
7.1 Introduction.....	34
7.2 Tier 3 Site-Specific Risk Assessment .....	34
7.3 Evaluation of Tier 3 Results.....	34
8. RISK-BASED REMEDIAL ACTION .....	35
8.1 Introduction.....	35
8.2 Selection of Most Appropriate Remedial Action Techniques.....	35
8.3 Example Remedial Action Techniques.....	36
8.4 Monitoring and Post-Remedial Action Requirements .....	37
9. BIBLIOGRAPHY .....	38
AFTERWORD.....	39
APPENDIX 1 SITE ASSESSMENT WORKSHEET.....	58
APPENDIX 2 METHODOLOGY FOR QUANTITATIVE RISK ASSESSMENT .....	63

## 0. EXECUTIVE SUMMARY

This guideline has been produced to assist in the management of contaminated sites in Latvia, in particular disused Russian military sites. A risk-based approach is proposed for adoption in the assessment of such sites in line with the approach adopted in recent years by other countries in the European Union.

Some countries have set fixed numerical criteria to assess contaminated land based on generic assumptions on site conditions such as; soil type, depth to groundwater, geology and hydrogeology, and proximity to potential receptors (eg. groundwater supply well, surface water body). Such an approach ignores the fact that contaminated sites vary widely in terms of both complexity and the potential risk they may pose to either human health or the environment. As fixed numerical criteria are nearly always set at very low levels, their use leads to the clean-up of more land than may be necessary. The result is wastage of resources with clean-up costs incurred without an incremental reduction in risk to human health and the environment.

In recent years, the principles of risk-based corrective action (RBCA) have been applied. This follows a flexible approach to decision-making whereby corrective action (remedial action) is appropriately tailored to site-specific conditions and hazards. This leads to more cost-effective solutions, and allows the greatest effort to be targeted to where it is most beneficial. In its broadest sense, risk assessment in relation to contaminated land can be defined as "an evaluation of whether there is a potential for adverse effects to occur, based on factual knowledge about a site, and scientific evidence concerning the environmental behaviour and toxicity of the chemicals present".

Although this method is applied in the USA (ASTM RBCA)<sup>1</sup>[D&M1] , there are a number of differences between the USA and other countries which must be considered. Dames & Moore have produced a Guideline which sets out an approach for the management of disused Russian military bases in Latvia based on our experience in developing similar guidance for the assessment of contaminated oil industry sites in Europe for Concawe "European oil industry guideline for risk-based assessment of contaminated sites". The approach to the assessment of disused military bases in Latvia has been based on the tiered approach set out in the Concawe document.

The underlying concepts of Risk-Based Corrective Action are described in this report.

This Guideline recommends a three tiered approach to the assessment of former military sites in Latvia. It assumes that one starts with relatively little site data, and therefore uses conservative generic assumptions. Where potential risks are demonstrated, by conducting additional investigation and analysis, more site-specific knowledge is used in developing

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<sup>1</sup> ASTM (1995) Standard guide for risk-based corrective action applied at petroleum release sites. ASTM E-1 739. Philadelphia PA: American Society for Testing and Materials.

subsequent clean-up targets. The result is fully protective of human health and the environment throughout Tiers 1, 2 and 3.

The three-tiered approach is based on the principle of source-pathway-target. It starts with an initial assessment of the site which involves gathering general data including potential sources of contaminants, obvious evidence of contamination, land-use, presence of potable groundwater, etc. The pathways by which contaminants could reach identified receptors/ targets or populations at risk are then identified. This enables a Tier 1 assessment to be performed, in which chemical data on the degree of contamination of the site is collected and compared with Risk Based Screening Levels (RBSL) and other relevant criteria. *The RBSLs comprise of a set of trigger concentrations for contaminated soil and groundwater. These figures are not intended to be soil standards or clean-up targets. If exceeded, they are simply an indication that further study is required.* RBSLs are derived using conservative assumptions and, as such, are based on a generalised risk assessment. If the observed values are below these levels, then the risk is identified as being insignificant.

If further assessment is required, Tier 2 and 3 studies are performed. These involve refinements to take into account more site-specific considerations, with the possible collection of additional data. The pathways of exposure may be modelled to prepare quantitative risk estimates, and clean-up criteria may be derived by back-calculation from risk acceptability criteria. Remediation could then be carried out to the clean-up criteria or a monitoring program could be instituted as a viable remedy within the risk framework.

This guideline provides a consistent framework for the assessment of contaminated former military sites. The outcome should be cost-effective in identifying those sites where clean-up is necessary to protect man and the environment.

The guideline has been applied to the assessment of two potentially contaminated sites in Riga, namely Valmieras Prospekts and Viestura Iela. These case studies are included in the reports by Banks et al. (1998a,b) and incorporate a detailed risk assessment approach to the assessment of contamination and the need for further action at the sites.

# **1. INTRODUCTION**

## **1.1 Use of Risk Assessment in Europe**

This document presents a Guideline for a uniform approach to the assessment of contaminated former military sites in Latvia based on risk management principles. The Guideline provides details on how to identify whether or not some form of remedial action is required at such sites, and, if so, the form that this should take. The Guideline links the principles of risk assessment with those of site investigation and remedial action decision-making.

The Guideline draws on the principles of Risk-Based Corrective Action (RBCA) as they have been applied in other parts of the world, primarily in North America and latterly Europe. Since Latvia intends to harmonise its environmental legislation with other countries in the European Union by the year 2005, then a risk-based approach is recommended to the assessment and management of contaminated sites.

The underlying principle is that remedial/corrective action should only be applied to sites which are found to pose unacceptable actual or potential risks to human health and/or the environment. A risk-based approach allows efforts to be focused on sites that pose actual risks, rather than drawing conclusions from the blanket application of non-site-specific criteria at all sites.

Contaminated sites vary widely in terms of their complexity, physical and chemical characteristics, and the potential risk they may pose to human health and the environment. The Guideline recognises this diversity and describes a tiered approach to decision-making in which site assessment, risk assessment and remedial action activities are appropriately tailored to site-specific conditions and hazards. This flexibility allows more focused and cost-effective solutions to be developed than have been used in the past, particularly those designed to achieve uniform standards and procedures.

Under the Guideline, site assessment becomes more detailed at each successive tier, and requires the progressive use of additional information and expertise. It should be noted, however, that not all tiers have to be computed for a conclusion to be reached on the need for and scope of any remedial action. The tiered approach merely allows the level of analysis to be restricted to that needed to make an appropriate risk-based decision. Such an approach is consistent with the evolving contaminated land policies of several European governments, and is therefore considered appropriate for the management of contaminated former military sites in Latvia.

## **1.2 Historical Overview**

The objective of this Guideline is to provide a simple-to-use, rational system for addressing potentially contaminated former military sites in Latvia in a manner which is protective of human health and the environment, in line with government environmental policy in Latvia. It will allow risk-based decisions to be made in an efficient and cost-effective manner and can be used to prioritise remedial actions at numerous sites, where this is necessary.

The Guideline is designed to replace more traditional approaches to contaminated land assessment and remediation, in which investigation and remedial action activities have often taken place in isolation, with no clear linking of the two. Such approaches have tended to lack any detailed scientific evaluation of whether remedial action is necessary and what form this should take to achieve adequate protection of human health and the environment in the most cost-effective manner. The blanket and uniform application of generic standards has compounded the problems of this approach since, when an exceedence of a standard value has been identified, remedial measures have often been implemented with little regard for the actual objective, or how they should be targeted most effectively.

The Guideline has been developed to provide a risk-based framework for consideration by regulators in Latvia and other interested parties across Europe as a scientifically defensible approach for dealing with contaminated land, in particular former military sites. This is especially important at present since a number of countries are developing contaminated land policies which involve the use of risk assessment.

It should be noted that, until recently, risk assessment of contaminated sites often focused on the "worst case" or "reasonable worst case". This was especially so in the USA, where protecting the hypothetical "Maximally Exposed Individual" (MEI) has proved costly to industry, and ultimately society, with minimal positive impacts for the public, and the regulatory and regulated community. This situation can be visualised by considering sites where both soil and groundwater are contaminated, for example with volatile organic compounds. The MEI is assumed to be someone who lives on the site and is exposed to the contamination via all plausible exposure pathways which, in reality, are unlikely to be experienced by one person. These include drinking groundwater from a garden well, eating vegetables grown in the garden, coming into dermal contact with contaminated media and inhaling the organic vapours (both indoors and outdoors) and showering in the same contaminated water. It is only recently that the extensive resources committed to protecting this individual have been reviewed in terms of the overall benefits to society and the environment. Such benefits are often low or even indefinable compared with those that are achieved in other areas of environmental improvement. This resulted in the risk-based corrective action (RBCA) process being adopted in the USA.

It is now considered that corrective/remedial action at contaminated sites should be based on the practical application of risk-based methods. Clearly, it is impracticable and unrealistic to attempt to protect this hypothetical individual at all costs.

Risk assessment in regard to contaminated land has as its basis a principle published by the US National Academy of Sciences (NAS) in 1983. This principle identifies four elements of the risk assessment process as follows:

- hazard identification, in which the main potential adverse health effects are identified. In practice, hazard identification has been replaced by the term "site characterisation" and involves examination of the site and collation of relevant data and information;



- exposure assessment, in which the potential intake levels/exposures for target populations are calculated;
- dose-response assessment, in which the relationship between dose level and adverse health effects of chemicals are defined; and
- risk characterisation, which combines the exposure and dose-response information to predict the likelihood of adverse health effects arising in the target population.

Fundamental to an understanding of risk assessment is the basic principle of toxicology, that "the dose makes the poison". This refers to the fact that every substance may be toxic, no matter how benign it seems in everyday experience. The critical factors are the amounts which can be taken into the body before adverse effects occur and the probability of those effects occurring.

The purpose of a risk assessment is to carry out an evaluation of the possibility that toxic effects will occur in respect of human health, by quantitatively predicting exposure levels and then combining them with toxicity information. Well-established methods are available to predict the potential human exposure to substances present at contaminated sites, and suitable toxicity information (in the form of dose-response criteria) is available from authoritative sources, such as the World Health Organisation. The combination of predicted exposure levels with toxicity information provides an assessment of risk. In situations where it appears that there is a significant risk (ie. the predicted exposure is in excess of the "tolerable" exposure), acceptable soil contaminant concentrations can be derived or the exposure setting changed to bring the potential exposure levels down to within the tolerability limits. It should be noted that such limits are themselves subject to considerable uncertainty and so usually err considerably on the side of safety.

Risk assessment is now seen by regulators and industry in many countries as the best way forward in managing potential contaminated land issues. It has been incorporated into government environmental regulations in the USA, Canada, Australia, New Zealand, the Netherlands and the UK and is being considered in many others. In its broadest sense, risk assessment in relation to contaminated land can be defined as:

*"an evaluation of whether there is a Potential for adverse effects to occur, based on factual knowledge about a site and scientific evidence concerning the environmental behaviour and toxicity of the chemicals present"*.

Risk assessment has developed rapidly since its initial use in addressing environmental issues in the USA in the mid-1980s. Historically, it was regarded as distinct from risk management, the latter being concerned with the implementation of measures designed to mitigate any issues identified by the former. This separation developed so that objective, scientific appraisals of risk could take place in isolation from economic or political factors.

More recently it has been recognised that, while the separation of risk assessment and risk management makes sense philosophically, it can lead to problems in risk-based decision-making. This is because some sites present insignificant risk, whereas others may have the potential to present significant risk, and so merit a more detailed examination. Clearly, with

perhaps hundreds of thousands of potentially contaminated sites world wide, risk assessment has to be streamlined to allow low risk sites to be screened out at an early stage, and allow a more detailed investigation into sites which have the potential to pose higher risk.

It is now accepted in various European countries that risk assessment is most cost-effectively applied within a tiered framework that is acceptable to both the regulators and regulated community. The amount of time and effort that is invested in assessing risk is therefore defined on a site by site basis, taking into account site conditions and the potential exposure pathways to the human and environmental receptors of concern. A tiered approach also allows the use of increasing amounts of site-specific data to replace the conservative generic assumptions that are initially made with less detailed site-specific knowledge.

The risk-based approach to dealing with contaminated land has considerable advantages over the use of generic standards. It allows the assessment of site-specific conditions to determine whether or not there is a potentially unacceptable risk at a contaminated site and the need for, and scope of, any corrective/remedial action can subsequently be determined. Site-specific risk-based corrective action levels are typically less conservative than generic standards as they are calculated using site-specific data (the latter are designed to be applicable to the most sensitive of situations). As a result, corrective/remedial action is only carried out in situations where a need has been identified through a comprehensive evaluation of the associated risks, taking into account all local circumstances.

This Guideline outlines a tiered risk assessment framework that provides a logical and technically defensible means of evaluating potential risks at potentially contaminated former military sites in Latvia. The Guideline provides a framework into which new scientific information can be integrated as it becomes available, and allows country-specific requirements and assumptions to be incorporated.

The final, and perhaps most important benefit of the risk-based process is that it identifies the most important issues surrounding a site. This allows the exposure pathways of concern to be identified and any potential for exposure to be eliminated through institutional controls, natural attenuation and/or remedial techniques. The key is that the approach is flexible enough to facilitate the reduction or mitigation of potential site risks, as needed.

Many countries in the European Union have either adopted risk-based approaches to contaminated land corrective action decision-making or are in the process of doing so. It is important that, within developing legislation, the opportunity for using innovative techniques is left open. This will ensure that advances in knowledge and scientific developments can be incorporated into existing frameworks.

### **1.3 Goals of the Guideline**

This guideline has been prepared in response to a request by NGU (Geological Survey of Norway) to develop a guidance document for the management and assessment of contaminated former military sites in Latvia using a risk-based approach. Two case studies have been used to test the guideline; these are the Viestura and Valmieras sites in Riga which are contaminated with oils and heavy metals respectively. Banks et al. (1998a,b) detail the risk assessment of the two case study sites and any requirements for future action.

The guideline is intended to form a decision-making tool for the management of contaminated sites using a risk-based approach. It considers the risks posed by soil and groundwater contaminants to human health and other sensitive environmental receptors such as groundwater and surface water, and ecological receptors and is specific to the current or proposed use of the site. The guideline does not consider political, social or economic factors with respect to their potential influence on the management of contaminated sites.

Policy and legislation governing environmental protection in Latvia is still being formulated and it is intended that harmonisation occurs with legislation set by other countries within the European Union (see Chapter 2.0 for further details on legislation). The use of a risk-based approach for contaminated sites is in line with the approach adopted by other EU countries, and is therefore considered appropriate for use in Latvia.

The guideline provides a tiered approach to the assessment and management of contaminated former military sites which includes the following stages:

- (1) Identification of potential site contaminants associated with current and former use(s).
- (2) Study of site environmental setting to identify environmentally-sensitive receptors (eg. groundwater, surface water) and the identification of pathways by which contamination might impact on the receptors. This study will always be specific to the current and/or proposed uses of the site.
- (3) Consideration of the need for site investigation; if after a consideration of the source (contaminant) - pathway - target (receptor) relationship there is the potential for environmental risks then a site investigation should be carried out to quantify the nature and extent of the contamination.
- (4) Design of objectives of the site investigation - definition of the foci of the investigation, for example contaminants which are especially mobile or investigation of only shallow contamination.
- (5) Development of Conceptual Site Model - the environmentally-sensitive receptors and pathways will be identified for the proposed use(s) of the site to form the Conceptual Site Model.
- (6) Data Assessment - data will be compared with generic screening criteria to identify potential contaminants of concern. The guidelines will be used with due consideration of the proposed end-use.
- (7) Quantitative Modelling - a computer model is used to estimate quantitatively exposure along various pathways where contaminant concentrations are found to exceed screening criteria. The output is a series of hazard index values. Where the hazard index is  $>1$  or for carcinogenic risk greater than 1 in 10,000, then further action is required. This can include either further, more detailed modelling to form a more refined risk assessment or the development of risk-based clean-up levels or control of pathways/sources, etc.

Each of these stages will be outlined later in this document. A worksheet has been included at Appendix 1 which is intended to act as a basic site assessment to determine whether any source (contaminant) - pathway - target (receptor) relationships exist, and the requirement for risk assessment, or further investigation.

The use of  $1 \times 10^{-4}$  as an Acceptable Risk Level (ARL) for carcinogenic risk is based on the fact that the WHO uses  $1 \times 10^{-5}$  in setting drinking water standards, which apply to a large population across Europe under a highly certain exposure scenario, whereas typically at contaminated sites only a few individuals would be exposed under extremely hypothetical conditions. As a result, the probability of an actual case of cancer occurring would be substantially less due to contamination at such sites than via the quality of European drinking water, even with the higher ARL. Such a level is also consistent with draft UK and French risk assessment guidelines and is the adopted value in the Netherlands, upon which the Dutch Intervention Values are based (see below).

Further details on specific aspects of the risk assessment methodology, including modelling procedures, can be obtained from the sources listed in the Bibliography (Section 9).

## **2. ENVIRONMENTAL LEGISLATION AND POLICY FOR LATVIA**

### **2.1 Introduction**

The National Environmental Policy Plan for Latvia (1995)<sup>2</sup> has been used as a basis to summarise the status of environmental legislation and policy in Latvia. This was the first strategic document on environmental protection ever to be produced in Latvia and was developed under the guidance of the Environmental Protection Department at the Ministry of Environmental Protection and Regional Development. The plan was developed in conjunction with specialists from various institutions in Latvia, and in consultation with the Ministry of Housing, Physical Planning and Environment of the Netherlands, and the Swedish Environmental Protection Agency.

Priority environmental problems were identified in the policy plan and measures for their resolution set out. The major environmental problems were identified to be concentrated in so-called 'hot-spots'; the large industrial centres, transportation crossroads and in territories abandoned by the Russian army. Only a few environmental problems were found to be manifest throughout the country as a whole including transboundary pollution.

Latvian environmental policy has been set on the basis of well-established principles which are widely accepted throughout Europe such as 'polluter pays', 'precautionary principle' and 'best available technology'. It is intended that future legislation set in Latvia will be in line with that set by other countries in Europe (refer to 2.2. below).

### **2.2 Legislation**

Environmental law for Latvia may be divided into two parts:

- laws that govern general policy goals; and
- subordinate legislation that specifies standards and codes, and the functions of government agencies.

In the constitutional law of Latvia for 'human and civil rights and duties' (1991), there is a provision that 'laws shall provide the general framework for environmental protection in Latvia, which shall then be further specified in other enactments'. Specific laws relating to environmental protection include: Environmental Protection (1991); Environmental Protection Committee (enacted in 1990 but revoked in 1993 due to the establishment of the Ministry of Environmental Protection and Regional Development); and Regulations on the Republic of Latvia's State Environmental Protection Inspection (1990).

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<sup>2</sup> National Environmental Policy Plan for Latvia, Ministry of Environmental Protection and Regional Development, Riga 1995.

However, a number of environmental issues are not regulated at all by the legislation and some laws are outdated and require to be re-drafted. Some specific environmental problems are being tackled by enactments adopted in the past by the Council of Ministers or presently by the Cabinet of Ministers. They include environmental protection, pollution and hazardous sites ('risk objects').

The policy plan sets out the intention to co-ordinate enactments with European Union (EU) directives such that by 2005 the EU system of standards should be completely introduced in the Republic of Latvia.

Latvian environmental legislation is also influenced by the signing of international agreements. Latvia has become party to several conventions and several others are signed and prepared for ratification.

### **2.3 Latvian Approach to Assessment of Contaminated Sites**

The National Environmental Policy Plan detailed the criteria used in the analysis of the priority environmental problems, namely:

- the problem poses a serious threat to human health;
- the problem may create irreversible changes in ecosystems, thus reducing biodiversity or degrading the landscape; or
- Latvia's international obligations foresees the taking of active measures to solve the problem.

The use of criteria which focus on the risk to human health associated with environmental pollution is in common with the approach adopted by other European countries, and is therefore in keeping with the guidance developed herein for a risk-based approach to the management of contaminated former military sites. Forty-five problems were identified on the basis of the above criteria and included the following of priority importance which are relevant to the management of contaminated sites:

- transboundary pollution;
- eutrophication of watercourses and the degradation of aquatic ecosystems;
- low quality of drinking water;
- impact of waste on the environment;
- impact of transport on the environment;
- impact of agriculture on the environment.

The policy plan particularly considers the risk of accumulated pollution with the potential risks to human health, as well as degradation of ecosystems. This is noted to be a new issue and the Latvian policy plan mentions the following specific measures to be used:

- assessment of 'harmfulness' and 'hazardousness' of substances;

- gathering information and assessment of risk sources recording and evaluation of hazardous objects are necessary as well as gathering information on content of hazardous substances accumulated in the human body, plants, soil, water, as well as its impact assessment.”

Other measures include:

- determination of environmental factors harmful for human health;
- evaluation of cause-effect links between the data on environmental pollution and diagnosis of registered diseases.

This approach described in the policy plan is in common with that adopted by other European countries, ie. the incorporation of a risk-based approach to assess the risks to human health and other environmental receptors associated with environmental pollutants.

## **3. FUNDAMENTALS OF RISK ASSESSMENT**

### **3.1 Introduction**

The approach developed for the Ministry of Environment of Latvia is of a tiered nature. It is summarised by individual elements below, in advance of the remainder of this guideline, which describes it in detail.

The tiered approach to risk-based corrective action described in this Guideline facilitates the best use of time and resources at potentially contaminated former military sites in Latvia. It is justified on the grounds that many sites do not need a detailed risk assessment to be performed in order that they can be declared safe, provided that conservative assumptions are made and any increase in the level of accuracy would result in a decrease in the estimated level of risk.

Progression through the tiers results in greater investments of resources (time and money) in order to reach the increasing data and analytical requirements. At the same time, conservative "generic" assumptions are replaced by site-specific values, producing less stringent targets for increasingly cost-effective remedial action. Throughout the process the level of protection of human health and the environment remains constant.

In broad terms the approach can progressively incorporate the following key steps, as required:

- Initial Assessment;
- Emergency Response Decision/Action;
- Tier 1 - Assessment and Remedial Action Decision;
- Tier 2 - Assessment and Remedial Action Decision;
- Tier 3 - Assessment and Remedial Action Decision.

The outcome of each step can include tier upgrade, remedial action, compliance monitoring or a conclusion that no further action is required.

### **3.2 Tiered Approach to Risk Assessment**

The first step, the "initial site assessment", involves the gathering of general data about the site. The assessor is required to identify the following:

- potential contaminant sources (eg. oil spillages/leakages associated with former military bases);
- potential exposure pathways;
- obvious environmental impacts, if any;
- the presence of potentially impacted humans and environmental resources (eg. workers, residents, surface water bodies, etc.);



- the current and proposed site land-use;
- the presence/absence of potable groundwater beneath the site; and
- conceptual site model(s).

This is followed by the collection of chemical data, via intrusive investigations, and a comparison of the data with Risk-Based Screening Levels (RBSLs) and other relevant criteria (ORCs). It is also appropriate at this early stage to assess whether an emergency response action is required.

RBSLs represent chemical concentrations in soil and groundwater that, in the vast majority of cases, do not pose a significant risk to human health. ORCs relate to existing exposure media that have also been sampled (eg. indoor air) and they are legal standards, guidelines or aesthetic criteria. RBSLs are typically derived using conservative assumptions and contaminant migration models. They are of an "evergreen nature" and subject to change as new modelling approaches and input parameters are developed. RBSLs are therefore conservative values against which measured contaminant concentrations can be compared. Where measured concentrations are below these screening criteria it may be assumed that the identified contamination does not pose a significant risk.

In the absence of specific Latvian guidelines, it is suggested that Dutch Intervention Values (DIVs)(VROM 1994) are used as RBSLs for soil and WHO drinking water standards for groundwater. These values can be found in Tables 1 and 2 respectively, although it should be noted that they change from time to time and should be checked each time before use. The rationale for using these values is that the DIVs are risk-based and consider numerous exposure pathways and a 1 in 10,000 ARL while the latter form the basis of much drinking water legislation in Europe and worldwide.

If the Tier 1 criteria (RBSLs and ORCs) are satisfied, then normally no further action is required. However, a change in site use or in conditions at the site would require this assessment to be re-visited. If the criteria are not satisfied, then the possibility of remedial action should be reviewed for its cost-effectiveness. If it is clear that remedial action to achieve these levels would not be cost-effective, then the need for interim measures should be considered, before a Tier 2 assessment is carried out, involving the collection of additional data, if required. The decision regarding whether or not to carry out a Tier 2 assessment should include a comparison of the cost of achieving Tier 1 remedial action goals with the cost associated with completing a Tier 2 assessment, bearing in mind that the achievement of the Tier 2 site-specific goals should be significant less costly to achieve than Tier 1 goals.

The Tier 2 assessment involves a refinement of the study to take into account more site-specific considerations with the collection of additional site investigation data if required. In regard to data interpretation, of particular importance may be the replacement of "worst-case" assumptions with more site-specific information. Different modelling techniques (which take into account chemical attenuation in the environment between source and receptor) may be employed or, alternatively, the models that were used to generate the RBSLs may be used, with appropriate refinement of the input values where site-specific data is available. It is recommended that the assessment takes place in a "forward manner" where quantitative risk

estimates are generated for the site. The "forward calculation" of risk gives an overall perspective on the significance of potential risks to public health and the environment from measured chemical concentrations and is consistent with the "risk assessment" requirements of many regulators in the European Union.

Risk estimates are compared with appropriate acceptability criteria in order to determine the outcome of the Tier 2 assessment. This is in contrast to the Tier 1 analysis where measured contaminant concentrations were compared with RBSLs derived by taking an insignificant risk level and back-calculating a "safe" concentration. If corrective action target levels are needed, they may be developed using either the estimated risk levels or the same techniques as used in the original development of RBSLs, except that site-specific parameters are used in the equations. The new target levels, which incorporate site-specific assumptions and parameters, are termed Site-Specific Target Levels (SSTLs).

If the acceptability criteria at Tier 2 are met, then no further action is required, except, perhaps, periodic monitoring for a finite period of time, if justified. If the criteria are exceeded by the site-specific risk estimates, the cost-effectiveness of achieving Tier 2 remedial action goals, which may include changes in land-use, exposure pathway control measures or Site-Specific Target Levels (SSTLs), should be reviewed in relation to undertaking a Tier 3 assessment, bearing in mind that the achievement of Tier 3 site-specific goals will likely be less costly to achieve than Tier 2 goals. If remedial action is still not considered to be practical or cost effective, a Tier 3 assessment should be carried out, although interim remedial action may still be needed. Such action could include obvious hot-spot removal or temporary containment measures and focuses on reducing risks which, while as yet not quantified accurately, are judged by the assessor as likely to need addressing following Tier 3. By carrying out such interim measures, any potential risk posed by the site while the Tier 3 assessment takes place, is avoided, or at least reduced. Alternatively, interim measures may not be driven by real risk but by aesthetic considerations and the adverse publicity that could accrue if action is not taken where contamination has been identified.

The Tier 3 assessment evaluates further the risks posed by the site and provides the information required to more effectively focus any remedial action required. It will often require more site-specific data, more sophisticated modelling (such as numerical fate/transport models and pharmaco-kinetic modelling) or a combination of the two. The Tier 3 assessment provides forward calculations of risk which are then compared with acceptability criteria to assess the need for remedial action, as at Tier 2. If the risks are found to be unacceptable, the options for remedial action should be reviewed and appropriate control measures put in place and/or a remedial scheme designed and implemented. If the risks are not significant, then the situation may need to be monitored for a finite period of time, to make sure that it does not deteriorate due to unforeseen circumstances.

It should be noted that throughout the assessment approach, a number of options are available under the heading of "remedial action" and can be summarised as follows:

- institutional controls (procedures or facilities that eliminate the possibility of exposure eg. protective work practices or a restriction on use of the land);
- natural attenuation;

- bioremediation;
- technology-based remedial methods (eg. pump and treat); and
- chemical treatment, etc.

## **4. OVERVIEW OF METHODOLOGY**

The initial assessment of a contaminated site involves the collection of data concerning site conditions in order to aid in the Tier 1 assessment. It is also an early opportunity to assess the need for carrying out any emergency measures. The individual components are described below.

### **4.1 Data Collection**

The initial site assessment provides the building blocks upon which all other works at the site are based. A basic site assessment worksheet is included at Appendix 1. A robust desk study, incorporating a good understanding of the site's history/operations and its environmental setting, will allow a focused data collection exercise to be planned and implemented. The desk study (which can include a questionnaire sent to site personnel, if available) should be combined with a site reconnaissance visit to confirm or support its findings.

Key operational history information to collect and assess includes the following:

- site size and age;
- previous and current use(s) and associated activities;
- chemicals and fuels used and stored;
- old tank details, volumes, age and testing records;
- drainage system information;
- hardstanding distribution and condition;
- location of below ground utility service lines and other preferential contaminant migration pathways (eg. culverts);
- spillage and leakage history;
- solid/hazardous waste management practices; and
- areas formerly used for waste disposal.

For larger/older sites in particular it will be appropriate to collect local historic topographic maps and aerial photographs of the facility to cross-check historical detail provided by site records.

An environmental setting assessment places the site within its local context. Key information to obtain here includes:

- land-use (on-site and adjacent areas, past, present and proposed future use);

- regional and, if available, local geology and hydrogeology;
- proximity to surface water bodies which may receive site-derived contamination and their use;
- local resource potential of groundwater and surface water bodies (eg. potable supply, other supply purposes) including location of down-gradient wells;
- the location of sensitive ecological habitats (defined according to EC Directive 79/409/EEC or EC Directive 92/43); and
- data on local foundations and cellars.

Sources of information include local and regional geological, hydrogeological, aquifer vulnerability and topographic maps of an appropriate scale, along with site records (eg. geotechnical and general site investigation). These can be supplemented by site-specific information prompted by a questionnaire and detailed inspection during the site reconnaissance visit (see Appendix 1).

The purpose of the environmental setting assessment is to identify: 1) the location of humans and environmental resources ("receptors") that could be impacted by the site; and 2) potentially significant exposure pathways. The latter should include a consideration of the possibility of preferential contaminant migration pathways, such as utility conduits.

#### **4.2 Assessment of Need for Immediate Remedial / Corrective Action**

At a very small proportion of sites, it may become obvious during initial site reconnaissance and/or Tier 1 intrusive investigations, that there is an immediate potential threat of harm to human health or the environment. Examples include issues such as the obvious pollution of a watercourse associated with contamination at a site. If such threats exist, an action plan will need to be developed immediately to address such issues without waiting for the completion of the tiered sequence of tasks. Professional judgement will be needed on the urgency of response.

#### **4.3 Development of Conceptual Site Model**

The data collected during the initial site assessment should be used to develop a "conceptual site model" (CSM) that will be refined as the analysis proceeds. The CSM is a description of how potential chemical sources at the site could contribute to increased levels of risk in potentially exposed receptors. It is a qualitative evaluation of the sources, exposure pathways and receptors identified during the desk study and site reconnaissance visit and can be used to test assumptions and field data to produce a complete view of the site-specific situation. The most important potential human exposure pathways that can exist at contaminated sites are as follows (depending on land-use):

- accidental soil/dust ingestion (indoors and outdoors);

- skin contact with soil/dust (indoors and outdoors);
- inhalation of vapours from soil sources (indoors and outdoors);
- inhalation of vapours from groundwater sources (indoors and outdoors);
- inhalation of vapours from free product;
- leaching of chemicals from soil or free product to groundwater or surface waters;
- domestic use of groundwater or surface waters (potentially leading to ingestion and inhalation of contaminants);
- consumption of home-grown fruits and vegetables.

Where appropriate, a site can be divided into discrete areas, each with its own CSM, in addition to an overall CSM for the site as a whole.

Early development of the CSM and constant reassessment in the light of investigative results can have a profound influence on the investigation and sampling activities. This can enhance the latter's cost-effectiveness by making sure that samples are taken from the areas that are most likely to be contaminated and from the media that are most relevant to those contaminant migration/exposure pathways likely to pose a significant risk (this is especially important for Tiers 2 and 3). It can also guide the sampling of off-site receptor locations that may have already been impacted by the migration of contaminants.

The CSM's focus is on which pathways for a given site are complete. A complete pathway exists only if there is a source of sufficient strength, a pathway for migration of Contaminants of Concern (COC) from source to receptor, *and* an exposure point for the receptor, ie. a source-pathway-target relationship exists. The process of progressing from Tier 1 to Tier 2 or Tier 2 to Tier 3 involves a more complete analysis of whether these pathways are complete and should be retained in the CSM.

For simplicity, Tier 1 RBSLs are based largely on land-use, with a given land-use calling up a set of default pathways. The CSM should challenge whether these pathways exist at the site; if not, the contribution of that pathway may be removed from the RBSL. This, in effect, is a simple Tier 2 analysis.

## **5. DETAILED PROCEDURES FOR TIER ONE ASSESSMENT**

### **5.1 Introduction**

The Tier 1 assessment involves the collection of data concerning site conditions, the interpretation of chemical data by reference to suitable Risk Based Screening Levels (RBSLs) and other relevant criteria (ORCs) and an evaluation of the overall results. For Latvia, the Dutch Intervention Values are considered to be suitable RBCLs (Risk Based Clean-up Level) for human health risk assessment, and the Norwegian drinking water guidelines have been used in the groundwater contamination assessment. The individual components of the assessment are described below.

The Tier 1 data collection exercise relies on the conceptual site model to ascertain the distribution and character of existing chemical contamination. A balance must be struck between the provision of sufficient information to allow an appropriate Tier 1 evaluation and the minimising of detail which can, if required, be collected during subsequent tiers. In general, the amount of information necessary for the Tier 1 assessment is generally less than that collected for Tier 2 and certainly Tier 3 assessments. At some sites, however, the benefits of collecting sufficient information during the initial site assessment to allow subsequent Tier 2 assessment without a need for further site works may be considerable (eg. due to site access issues).

### **5.2 Sampling and Analysis**

Most Tier 1 assessments should include the sampling of on-site soils and shallow groundwater, if present. Soil vapour surveying may be used to screen a site to help pinpoint potential "hot-spot" areas of volatile organic contamination which may have already been highlighted by the desk study and site reconnaissance. The preferred option at most sites is to bias the sampling program towards identifying the maximum levels of on-site contamination by focusing on most likely source areas (eg. locations of old spills). In rare cases where site information is absent (eg. an old derelict site or site area long since demolished) systematic sampling may have to be applied. In such cases a statistically appropriate number of samples must be collected, ascertained according to the methods described in the documentation listed in the Bibliography (Section 9).

The Tier 1 intrusive site investigation may be limited to within the site boundary because the assessment is based on assumed on-site receptor scenarios. Occasionally, however, it may be necessary to sample nearby off-site wells/watercourses. This is especially important with regard to the identification of immediate hazards requiring an emergency response (see below) and it should be guided by the initial site reconnaissance. To some degree the extent of migration can also be assessed by including down hydraulic gradient boundary locations in the sampling plan.

The laboratory analysis of samples should initially focus on chemicals known to have been used or stored on-site which are relevant to the particular medium being evaluated. It is good practice to include a wide range of suspected contaminants at the Tier 1 stage, with progressively fewer being needed at subsequent levels of analysis. To this end, data

pertaining to site history, especially any information regarding chemical usage, leaks and waste disposal activities, should be used. It is important that all key hazardous chemicals which have been stored or used on-site are included for analysis at this stage because a site which passes the Tier 1 assessment (ie. none of the contaminants exceed the Tier 1 screening criteria) should not require any additional evaluation.

### **5.3 Interpretation of Data**

#### **5.3.1 Introduction**

The data collected during Tier 1 are interpreted by reference to Risk-Based Screening Levels (RBSLs) and other relevant criteria (ORCs). RBSLs are used to screen chemical concentrations in on-site soil and groundwater while ORCs are used to interpret data for additional media that have been sampled, for example, off-site well water.

#### **5.3.2 Comparison of Data with RBSLs**

The comparison of data with RBSLs is a relatively straightforward exercise in which measured on-site soil and groundwater concentrations are evaluated, based on the specific land-use designation, and whether or not there is potable groundwater underlying the site. RBSLs are typically calculated using conservative assumptions applicable to the country in which the site is situated and using the sum of the exposure pathways that could co-occur under a specific land-use scenario. The Dutch Intervention Values should be used for the Tier 1 assessment in the absence of specific criteria for Latvia (See Table 1). Comparison should also be made with the WHO criteria for drinking water as part of the Tier 1 evaluation (see Table 2).

For added complexity, soil RBSLs can be land-use specific (ie. different RBSLs are set for different land-uses). Groundwater RBSLs can be based on the conservative (worst-case) assumption, ie. the site is located on an existing or potential drinking water supply utilised by a residence with a domestic well. Exposure could therefore occur both via the ingestion of contaminated groundwater and via the inhalation of vapours from the water. It should be noted at this stage that the RBSLs only take into account human health risk and do not address aesthetic, ecological and other criteria.

If analysis of the conceptual site model shows that any of the default pathways are not complete, then the contribution of that pathway to the RBSL may be removed. The main focus of RBSLs is the prevention of long-term (chronic) dose levels from repeated exposure to chemicals in soil and groundwater. This is of primary importance at contaminated sites since the risks of chronic effects are generally more common than those of short-term (acute) effects. Any site at which chemical concentrations are less than the appropriate RBSLs can be assumed to pose no significant risk of either acute or chronic effects.

Soil RBSLs specific to Latvia should ideally be provided for surficial soils (taken to be <0.5m depth) and related to the following land-uses:

- current (industrial);
- residential (with and without gardens);



- commercial (office); and
- abandonment, with open access to the public.

Such RBSLs should be highly conservative and err considerably on the side of caution, as a result of the methodology and assumptions used in their derivation.

In order to use the RBSLs the assessor must establish:

1. the current and proposed site land-use;
2. inventory of completed pathways for the site;
3. whether potable groundwater is present beneath the site; and
4. whether the assumptions made in deriving the RBSLs are potentially under conservative in relation to site-specific conditions (this is most unlikely, but not impossible).

The RBSLs relate to various land-uses and incorporate exposure assumptions specific to these land-uses. As a result, it is essential that the correct values are used in the comparison exercise.

If a targeted intrusive investigation has been carried out (as would normally be the case), the maximum detected chemical concentrations should be compared with the RBSLs, on the grounds that if there is an insignificant risk from these, then there is an insignificant risk from the entire site. Maximum concentrations have been used for the two case study sites and are included in Banks et al. (1998a,b). It should be noted that the use of maximum values from targeted investigations places considerable importance on the quality of the data collection activities.

At sites where there is more than one chemical present the possibility of additive toxic effects can be considered, although this is generally part of a more refined Tier 2 or 3 analysis. It may also be important to consider background concentrations of chemicals in soil and air, along with potential up-gradient sources for groundwater, to enable the assessment to focus on site-related contamination only.

### 5.3.3 Limitations

Although the comparison of measured concentrations with RBSLs represents a suitable Tier 1 screening tool, there are several limitations which must be considered in order to decide whether they are to be relied on to make site-specific risk-based corrective action decision at a particular site. These are as follows:

- RBSLs do not explicitly cover risk issues related to multiple compounds, surface water, free product or agricultural land-use. As a result, these must be confirmed as being absent or evaluated as part of a follow-on Tier 2 assessment;

- RBSLs do not consider risks to ecological receptors. As a result, sensitive ecological habitats must be confirmed as being absent or an ecological risk assessment developed as part of a Tier 2 assessment;
- The assumptions used in generating the example RBSLs are conservative in almost all cases. However, as mentioned above, there may be rare occasions where such assumptions are under-conservative and a check is therefore necessary as to their applicability to the site in question;
- RBSLs do not address the risk of damage to materials through corrosion geotechnical issues such as ground stability, environmental impacts from ongoing industrial processes, flooding risk, construction worker safety or aesthetic issues (eg. soil staining). These must be dealt with separately where appropriate.

Neither the RBSLs nor the information in this guideline should be viewed as a definitive list of standards. They are based on current knowledge and assumptions concerning exposure parameters and toxicology and, consequently, should be viewed as an "evergreen" set of values that is to be continually updated whenever new methodologies and parameters are developed. Where required, fate and transport estimations are based on conservative models.

#### 5.3.4 Comparison of Data with Other Relevant Criteria (ORCs)

At certain sites, data may have been collected from off-site wells and local watercourses. These data can be compared with suitable criteria for the particular contaminant of concern. For example, the comparison of off-site well concentrations with legal standards or drinking water guidelines may indicate whether a potential risk already exists via the off-site groundwater migration pathway.

#### **5.4 Evaluation of Tier 1 Results**

If the measured on-site chemical concentrations exceed the RBSLs and the RBSLs are appropriate to the site in question the possibility of remedial action should be reviewed in relation to its cost-effectiveness. The review should focus on the following alternatives:

1. Reducing the concentrations to below RBSLs;
2. Controlling certain exposure pathways (by referring to Tier 1 pathway contribution tables); or
3. Changes in land-use, backed up by deed restrictions or other institutional controls.

If any of these measures would be more cost-effective than a Tier 2 assessment, bearing in mind that the latter may point to substantially less costly remedial action being needed then they may be carried out. If, however, they are judged to be inappropriate, then the process should proceed to Tier 2. If any measured receptor point concentrations exceed ORCs, it is possible that this would trigger remedial action.

If the on-site chemical concentrations do not exceed the RBSLs, the assessment finishes, and the site can be considered to represent no significant risk and normally no further action is required. Compliance monitoring may be implemented, subject to the views of the regulatory authority, to confirm that current conditions persist or improve with time. If however, the land-use changes or there is a change in site conditions, then this assessment may need to be repeated.

## **6. DETAILED PROCEDURES FOR TIER TWO ASSESSMENT**

### **6.1 Introduction**

The Tier 2 assessment involves a more detailed evaluation of the site focusing on exposure pathways that have caused exceedence of RBSLs and addressing other issues identified at Tier 1, such as land use. This may require the collection of more data and/or the completion of more sophisticated risk assessment.

Tier 2 provides the opportunity for the assessor to consider contaminant fate and transport in more detail than is the case at Tier 1. This is achieved by the replacement of conservative or default assumptions with site-specific information and the use of more sophisticated chemical fate and transport models. In these ways, the Tier 2 assessment provides a less conservative and more realistic examination of the issues surrounding a site and therefore a more cost-effective set of corrective action goals, if needed.

It is important to note that both Tier 1 and Tier 2 remedial action goals are based on achieving similar levels of human health and environmental resource protection; however, in moving to Tier 2 the assessor is able to develop more cost-effective action plans because the conservative assumptions made in Tier 1 are replaced with more realistic site-specific assumptions.

### **6.2 Issues of Concern**

The first step in a Tier 2 assessment is to identify the issues of concern requiring further analysis. This is accomplished by revisiting the CSM and reviewing which pathways are complete and contribute to receptor exposure. Incomplete pathways or Contaminants of Concern which do not contribute to risk can be eliminated from further analysis. Tier 2 assessment will include the sources, chemicals and exposure pathways which caused the exceedence of the RBSLs in Tier 1, along with any other exposure scenarios not covered at Tier 1 (eg. agricultural land-use).

The chemical sources could include known or assumed areas of high concentration (hot-spots) or contaminated groundwater which contains the chemicals that exceeded the RBSLs. The human exposure pathways include all those which made a significant contribution to the RBSLs which were exceeded in Tier 1, identified by means of pathway contribution tables.

An important aspect of Tier 2 is the consideration of potential exposure at "compliance points", as opposed to anywhere in an environmental medium. Such points include property boundaries or locations between source areas and reasonable potential receptors, or they could be receptor locations themselves. Remedial action goals for source areas are then based on the demonstrated and predicted attenuation (reduction in concentration with distance) of compounds that migrate away from the source area.

## **6.3 Data Collection**

Tier 2 data collection activities are designed to build upon the information collected as part of Tier 1 in order that the site assessment can focus on the most important issues. The Tier 1 data set should be re-appraised and summary tables produced which highlight the chemical and physical characteristics of the various environmental media, within all relevant site areas and depth zones. In cases where it is believed the data set is suitably robust to facilitate an adequate Tier 2 assessment then this should proceed. If this is not the case then an appropriate Tier 2 site investigation program should be planned to fulfil the additional data needs.

Tier 2 investigations could be directed towards better characterising the magnitude and distribution of contamination along the migration pathway(s) identified to be of concern. This may involve the collection of geological, hydrogeological and chemical data to replace conservative assumptions made in the previous tier. The amount of Tier 2 data required could also depend on factors such as the degree of site contamination (the extent to which Tier 1 investigation data failed the RBSLs), the suitability of the generic assumptions used at Tier 1, site environmental sensitivity, and the proposed land-use.

During the Tier 2 data collection activities, every effort should be made to collect samples from exposure or compliance points as such locations represent points at which potential receptors could actually become exposed. Amongst other things, such data may assist in the calibration of chemical fate and transport models, if required. In many cases it can be used to eliminate the need for, or to check the validity of, sophisticated pathway-specific modelling by providing actual exposure data. However, it must be remembered that such measurements are only “snapshots” in time and that, although the detection of high concentrations may indicate a potential problem, the interpretation of low contaminant concentrations is much more difficult. An assessment needs to take into account at least the phys-chem properties of the particular contaminants and appropriate toxicity data so that the significance of such low concentrations can be determined.

## **6.4 Interpretation of Data**

### **6.4.1 Introduction**

The interpretation of data at Tier 2 takes the form of:

1. Site-specific risk assessment;
2. The development of Site-Specific Target Levels (SSTLs) and/or;
3. Comparison of measured or predicted concentrations with ORCs or RBSLs;
4. Comparison of measured or predicted compliance point concentrations with ORCs or RBSLs.

Where estimated risks exceed acceptable levels, or where the measured concentrations exceed ORCs or RBSLs, Site-Specific Target Levels can be developed to aid in the setting of Tier 2

remedial action goals. Tier 2 focuses on all chemicals detected at the site at concentrations which exceed the Tier 1 RBSLs, as discussed previously.

#### 6.4.2 Site-Specific Risk Assessment

The Tier 2 site-specific risk assessment should take place in a "forward manner", in which quantitative risk estimates are generated for the site and compared with appropriate acceptability criteria. This allows the statistical treatment of data, if required, and it should enable a clear view of the presence or absence of a significant risk at the site.

The Tier 2 risk assessment techniques involve the use of either: 1) the algorithms used to generate RBSLs or 2) other models and approaches. In either case, site-specific data should be used in the place of conservative assumptions, wherever possible. Within the Tier 2 assessment it is also possible to evaluate whether a potential risk exists by predicting contaminant concentrations at the off-site receptor or compliance point, and comparing these to the RBSLs.

The models are used to predict attenuation of contaminants away from the source area. They are based on interpolating and extrapolating site-specific data through the use of conservative "screening" mathematical models. In general the better the site investigation data the more accurate the modelling results. These models are characterised by the following:

- the models are relatively simplistic, and are often algebraic or semi-analytical expressions;
- model input is limited to practically attainable site-specific data, or easily estimated quantities (eg. soil porosity, soil bulk density);
- site-specific validation/calibration studies are not necessary provided worst case assumptions are used in setting the input parameters;
- source depletion due to physical removal mechanisms (eg. leaching) can be considered;
- biodegradation can be considered provided either: 1) site-specific data is available to demonstrate its occurrence; or 2) documented evidence is available from other, similar sites;
- the models are based on descriptions of relevant physical/chemical phenomena. Any mechanisms that are neglected result in predictions that are conservative relative to those likely to occur.

For above-ground exposure pathways, the chemical data which form the input to a Tier 2 risk assessment should be health-conservative estimates of the concentrations present across the relevant exposure area (eg. garden). These are typically either maximum detected values or 95% upper confidence limits of arithmetic mean values, calculated using algebraic or geostatistical techniques. Alternatively, certain risk assessment software can accept whole data sets or probability distributions of contaminant concentrations. For groundwater

modelling, the maximum detected on-site concentration (soil or groundwater) should normally be used as the source concentration in the model, in order to be conservative.

Examples of the models available for performing Tier 2 risk assessment are provided in the Bibliography (Section 9). These can typically be used with relatively little experience, although their input parameters and limitations must be clearly understood by the assessor as they can be fundamentally important to the results. In many cases there will be significant uncertainty surrounding many of the input factors to the risk model. The risk output from the model often depends on the product of several "uncertain" parameters, and thus the uncertainties in the output will depend, in a multiplicative manner, on the uncertainties in the input. Conservative input should provide a conservative model output, but it is considered good practice to carry out a model sensitivity analysis. This implies systematically varying the input parameters, one by one, over a probable range, to examine the impact on the risk output. Not only does such a practice identify the most important sources of uncertainty in the model, it also helps to identify the parameters which should be focused on most cost-effectively in a future Tier 3 assessment.

#### 6.4.3 Comparison of Data with Other Relevant Criteria (ORCs)

If additional data have been collected from off-site wells and local watercourses as part of a Tier 2 assessment, they can be compared with ORCs, as at Tier 1. For example, the comparison of off-site measured groundwater concentrations with RBSLs will indicate whether a potential health hazard exists via this migration pathway at the time of measurement.

#### 6.4.4 Assessing the Risk from Free Product

The risk from free product, if present, should be addressed. Such an assessment should allow the modelling of indoor air and groundwater (if present) impacts, based on known product characteristics. Groundwater quality data obtained from the site could also be used to assess the effects, if any, on groundwater. Again, "real" data are preferred over modelled contaminant concentrations, where they are available. It is often standard practice in risk assessment to consider a free LNAPL (e.g. hydrocarbon) lens, floating on the groundwater table, as a source of dissolved contamination to groundwater. In such cases, it is considered appropriate to estimate the dissolved contaminant concentration at source as the maximum solubility of the LNAPL phase. This has been assumed in the case of the specific examples of the Valmieras iela and Viestura prospekts sites. Most risk assessment models do not take account of the possible migration of the LNAPL lens downgradient along the water table. This must be considered unsatisfactory, and future developments of risk assessment techniques should focus on developing models of such migration.

#### 6.4.5 Assessing the Risk to Surface Water

The risk to surface water can be assessed by measuring contaminant concentrations in lakes, rivers, etc., or modelling them using computer software available for this purpose.

#### 6.4.6 Ecological Risk Assessment

An ecological risk assessment is the process of evaluating the likelihood that adverse ecological effects will occur. If an ecological risk assessment is deemed necessary, a tiered approach is recommended to ensure the cost-effective protection of ecological resources, mirroring the approach taken to protecting human health.

#### 6.4.7 Sediment Risk Assessment

In cases where contamination is present in sediment, chemical bioaccumulation relevant to certain organic chemicals such as PAHs and heavy metals may need to be assessed by reference to appropriate fugacity-based partitioning models. These can be obtained from various published sources, such as the US EPA's Computerized Risk and Bioaccumulation System (CRABS). CRABS can simulate chemical accumulation from sediment into the food chain, and ultimately humans, using measured sediment concentrations, tissue residue information, thermodynamic partitioning, first-order kinetic modelling or toxicokinetics.

#### 6.4.8 Agricultural Land Use

At some sites, it may be appropriate to consider agricultural land-use rather than industrial or residential development. Risks to farm workers, soil vitality and water resources from the contamination could therefore be considered to be of paramount importance, depending on the crops planned.

Risks to farm workers can be assessed using similar approaches to normal human receptors, except perhaps with different exposure assumptions (eg, soil loading on the skin and dust inhalation may be greater). In order to assess risk to soil vitality, a review of the available literature may identify toxicity thresholds for soil organisms. Such thresholds are available from the Netherlands and the USA (Oak Ridge National Laboratory).

### **6.5 Evaluation of Tier 2 Results**

If the site-specific risk assessment acceptability criteria are met and there are no exceedences of ORCs then no further action is required, except, perhaps, periodic monitoring for a finite period of time. If the criteria are exceeded, SSTLs can be derived from the results of the risk assessment. Following this, the cost effectiveness of achieving Tier 2 remedial action goals, which may include SSTLs, should be reviewed, bearing in mind that Tier 3 site-specific goals are likely to be less costly to achieve than Tier 2 goals. If remedial action is still not considered to be cost-effective, a Tier 3 assessment should be carried out, although interim remedial action may be needed (this could include hot-spot removal, localised containment or institutional controls).

Remedial action goals could include source removal or the blocking of individual exposure pathways based on the results of the risk assessment. In the case of the former, SSTLs should be developed from the predicted attenuation of contaminants away from the source area. For example, if the risk assessment model predicts exposure/compliance point groundwater concentrations which are 100 times lower than the measured on-site concentrations (and the relationship between on-site and off-site concentrations is linear), then the SSTL for on-site



groundwater should be 100 times greater than the relevant RBSL or ORC (eg. drinking water standard). Measured exposure/compliance point concentrations can be used to corroborate the model's predictions.

## **7. OUTLINE PROCEDURES FOR TIER THREE ASSESSMENT**

### **7.1 Introduction**

The Tier 3 assessment involves the collection of more site-specific data, if necessary, and a further evaluation of the potential risks from site-related contamination using advanced techniques including, for example, numerical fate/transport models and pharmaco-kinetic considerations. In some cases this can result in a conclusion being reached that no remedial action is required with the likely exception of a finite period of monitoring. In others, the on-site concentrations may still be found to pose a significant risk and remedial action goals need to be developed. These could include the calculation of, and remediation to, Tier 3 clean-up levels, which are normally higher (less conservative) than their Tier 2 counterparts.

It is important to note that both Tier 2 and Tier 3 remedial action goals are based on achieving similar levels of human health and environmental resource protection. However, in moving to Tier 3 the assessor is able to develop more cost-effective action plans because certain conservative assumptions and modelling techniques used in Tier 2 are replaced with site-specific data and more realistic approaches.

### **7.2 Tier 3 Site-Specific Risk Assessment**

The Tier 3 risk assessment approaches may involve the use of Tier 2 techniques, with added refinements made, or the utilisation of additional techniques, as follows:

- revised treatment of non-detect values;
- calibration of models with measured data;
- numerical modelling of groundwater pathways;
- revision to toxicity criteria; and
- site-specific bioavailability/leachability data.

### **7.3 Evaluation of Tier 3 Results**

If the site-specific risk assessment acceptability criteria are met and there are no exceedences of ORCs or RBSLs then no further action is required, except a possible need for periodic monitoring for a finite period of time. If the criteria are exceeded, the cost-effectiveness of achieving Tier 3 remedial action goals, which could include site-specific clean-up levels should be reviewed. A review of the options available for remedial action is provided in Section 8; the concept of Best Practical Environmental Option (BPEO) is a useful guiding principle, and is in line with the environmental policy principles in Latvia.

## **8. RISK-BASED REMEDIAL ACTION**

### **8.1 Introduction**

This section provides a summary of the range of remedial action measures that are available for contaminated sites representing the Risk Management options. These include the following:

- traditional remediation processes that reduce contaminant concentrations;
- exposure pathway elimination methods, such as capping and hydraulic containment;
- land-use restrictions (administrative and institutional controls - these are especially important at larger sites); and
- monitoring of natural attenuation between sources and receptors (for the purpose of validating the conclusion to take no further action).

All of these options are equally valid within the risk-based remedial action framework, provided they are implemented correctly, as they are all capable of reducing risks to acceptable levels.

It should be noted that the measures described in this section should only be utilised in connection with the tiered assessment approach described above. It should also be noted that other measures may become available and be developed as "best practice" in the remediation of contaminated sites as risk-based remedial action evolves.

### **8.2 Selection of Most Appropriate Remedial Action Techniques**

Following the identification of an unacceptable risk associated with site-related contamination, a number of risk management strategies may be considered. The works may vary from simple risk mitigation measures to large-scale site remediation. The management tool used in the selection of the most appropriate remedial action approach for a site is a technical (engineering) feasibility study, incorporating design and costing.

It is also necessary when comparing remedial action options to consider short-term risks to health and the environment during their implementation, such as exposure of construction workers to vapours and dust and the potential for effects on nearby residents, and accident hazards to site personnel. Clearly, a remedial action programme must not, in addressing one set of risks, create others that negate the gains to health and the environment that remediation was intended to bring about.

It is inherent within the tiered approach that potential remedial action options and approaches are evaluated, and their merit revisited as analysis proceeds (ie. as part of assessing the need for tier-specific remedial action, whether interim or final). A technical (engineering)

feasibility study should be carried out to assess the site-specific practicalities associated with undertaking one or more potential remedial action measure(s), which also forms part of the cost benefit analysis.

Once the selection of one or more appropriate options has been made a detailed design can be drawn up and budget cost estimates made. In cases where highly technical solutions may be required, simple bench scale or field pilot studies (ie. pilot plant scale testing) may be required to better assess the feasibility of a particular scheme prior to full scale design and costing (eg. for dual phase extraction or bioremediation).

### **8.3 Example Remedial Action Techniques**

The following techniques represent the principal methods by which remedial action at contaminated sites can be achieved, whether as an interim measure or a long-term solution:

- ongoing monitoring of the natural attenuation of contaminated media (in particular in cases where source removal has been achieved and/or where natural processes (eg. biodegradation) are expected to reduce the contaminant levels over time);
- contractual instruments or physical barriers limiting the use of property or land to avoid a potentially unacceptable exposure to current or future site users
- fencing-off contaminated areas, restricting access to subsoils and restricting site land-use;
- vapour exclusion membranes, removal of ducting, passive venting techniques;
- installation of specialist physical isolation barriers to restrict exposure/ migration pathways at existing or redeveloped sites;
- capping of contaminated areas where direct exposure pathways drive the risk assessment or where the leaching of soil contaminants to groundwater via rainfall infiltration is a concern;
- construction of physical barriers or collection systems to restrict contaminant migration to surface and or groundwater including cut-off walls or collection drains, vitrification, stabilisation;
- in-situ treatment of contaminated materials to reduce the source term, for example, vacuum extraction for volatiles;
- receptor point remedial action includes the treatment of contaminated water as it is abstracted from a groundwater supply well;
- removal and disposal/treatment of contaminated soils includes ex-situ bioremediation, landfilling, incineration, soil washing, thermal desorption, etc.

#### **8.4 Monitoring and Post-Remedial Action Requirements**

Following the implementation of remedial action measures, a site monitoring system should be considered. For example, at those sites where estimated risks are acceptable, but where significant residual contamination is known to exist, a requirement to monitor may be set by the regulatory authority. If site conditions change in the future then further remedial action measures may be necessary.

Monitoring can take one of two principal forms. Firstly, validation monitoring is designed to ensure that contaminated material has been removed or treated to an acceptable degree leaving residual concentrations at acceptable levels. This is usually performed at the time of (or immediately after) the remedial works. Secondly, longer term monitoring is often implemented to prove that the site condition, post-corrective action, does not represent an ongoing risk to the wider environment. It is important to pre-define the period of time for which monitoring is required.

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## **AFTERWORD**

Dames & Moore are pleased to have had the opportunity of participating in this project and trust that it meets your requirements. Should you wish to discuss any issues outlined herein, please do not hesitate to contact the undersigned.

Yours faithfully  
for **DAMES & MOORE**

Dr Colette Grundy  
**Report Manager**

Mr Mike Quint  
**Project Director**

**TABEL 1 and 2**



# Table 1

**Table 1.**

**Target and intervention values for microcontaminations for a standard soil (10% organic substance and 25% lutum). Soil/sediment in mg/kg, groundwater in  $\mu\text{g/l}$ ; unless otherwise indicated.**

substance	soil/sediment (mg/kg dry soil)		groundwater ( $\mu\text{g/l}$ )	
	target value	intervention value	target value	intervention value
<b>I metals</b>				
arsenic	29	55	10	60
barium	200	625	50	625
cadmium	0.8	12	0.4	6
chromium	100	380	1	30
cobalt	20	240	20	100
copper	36	190	15	75
mercury	0.3	10	0.05	0.3
lead	85	530	15	75
molybdenum	10	200	5	300
nickel	35	210	15	75
zinc	140	720	65	800
<b>II inorganic compounds</b>				
cyanides free	1	20	5	1500
cyanides complex (pH < 5) <sup>1</sup>	5	650	10	1500
cyanides complex (pH $\geq$ 5)	5	50	10	1500
thiocyanates (sum)		20		1500
<b>III Aromatic compounds</b>				
benzene	0.05 (d)	1	0.2	30
ethylbenzene	0.05 (d)	50	0.2	150
phenol	0.05 (d)	40	0.2	2000
cresols (sum)		5	(d)	200
toluene	0.05 (d)	130	0.2	1000
xylene	0.05 (d)	25	0.2	70
catechol		20	(d)	1250
resorcinol		10		600
hydroquinol		10		800

Table 1 (ctnd.)

Table 1 (cont.)

Target and intervention values for microcontaminations for a standard soil (10% organic substance and 25% lutum). Soil/sediment in mg/kg, groundwater in µg/l; unless otherwise indicated.

substance	soil/sediment (mg/kg dry soil)		groundwater (µg/l)	
	target value	intervention value	target value	intervention value
<b>IV Polycyclic aromatic hydrocarbons (PAHs)</b>				
PAH (sum 10) <sup>2,11</sup>	1	40	-	-
naphthalene			0.1	70
anthracene			0.02	5
phenanthrene			0.02	5
fluoranthene			0.005	1
benzo(a)anthracene			0.002	
chrysene			0.002	
benzo(a)pyrene			0.001	
benzo(ghi)perylene			0.0002	
benzo(k)fluoranthene			0.001	
indene(1,2,3cd)pyrene			0.0004	
<b>V Chlorinated hydrocarbons</b>				
1,2-dichloroethane		4	0.01(d)	400
dichloromethane	(d)	20	0.01(d)	100
tetrachloromethane	0.001	1	0.01(d)	10
tetrachloroethene	0.01	4	0.01(d)	40
trichloromethane	0.001	10	0.01(d)	400
trichloroethene	0.001	60	0.01(d)	500
vinyl chloride		0.1		
chlorobenzenes (sum) <sup>3,11</sup>		30		-
monochlorobenzene	(d)	-	0.01(d)	180
dichlorobenzenes (sum)	0.01	-	0.01(d)	50
trichlorobenzenes (sum)	0.01	-	0.01(d)	10
tetrachlorobenzenes (sum)	0.01	-	0.01(d)	
pentachlorobenzene	0.0025			
hexachlorobenzene	0.0025	-	0.01(d)	

Table 1 (ctnd.)

Table 1 (cont.)

Target and intervention values for microcontaminations for a standard soil (10% organic substance and 25% lutum). Soil/sediment in mg/kg, groundwater in µg/l; unless otherwise indicated.

substance	soil/sediment (mg/kg dry soil)		groundwater (µg/l)	
	target value	intervention value	target value	Intervention value
<b>V Chlor. hydr.carb.(ctnd.)</b>				
chlorophenols (sum) <sup>11</sup>		10		-
monochlorophenols (sum)	0.0025	-	0.25	100
dichlorophenols (sum)	0.003	-	0.08	30
trichlorophenols (sum)	0.001	-	0.025	10
tetrachlorophenols (sum)	0.001	-	0.01	10
pentachlorophenol	0.002	5	0.02	3
chloronaphthalene		10		6
polychlorobiphenyles (sum) <sup>2</sup>	0.02	1	0.01(d)	0.01
<b>VI Pesticides</b>				
DDT/DDE/DDD <sup>6</sup>	0.0025	4	(d)	0.01
driins <sup>7</sup>		4		0.1
aldrin	0.0025		(d)	
dieldrin	0.0005		0.02ng/l	
endrin	0.001		(d)	
HCH-compounds <sup>8</sup>		2		1
α-HCH	0.0025		(d)	
β-HCH	0.001		(d)	
γ-HCH	0.05 µ/kg		0.2 ng/l	
carbaryl		5	0.01(d)	0.1
carbofuran		2	0.01(d)	0.1
maneb		35	(d)	0.1
atrazine	0.05 µ/kg	6	0.0075	150
<b>VII other contaminations</b>				
cyclohexanone	0.1	270	0.5	15000
phthalates (sum) <sup>1</sup>	0.1	60	0.5	5
mineral oil	50	5000	50	600
pyridine	0.1	1	0.5	3
styrene	0.1	100	0.5	300

Table 1 (cont.)

tetrahydrofuran	0.1	0.4	0.5	1
tetrahydrothiophene	0.1	90	0.5	30

(d) = detection limit

## Table 1 (cont.)

### Footnotes to Table 1:

1. Acidity: pH (0.01 M CaCl<sub>2</sub>). For the determination pH  $\geq 5$  and pH  $< 5$  the 90-percentile of the measured values is true.
2. PAH (sum of 10) means: the sum of anthracene, benzo(a)anthracene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, phenanthrene, fluoranthene, indene(1,2,3-cd)pyrene, naphthalene, benzo(ghi)perylene.
3. Chlorobenzenes (sum) means: the sum of all chlorobenzenes (mono-, di-, tri-, tetra-, penta- and hexachlorobenzene).
4. Chlorophenols (sum) means: the sum of all chlorophenols (mono-, di-, tri-, tetra-, and pentachlorophenol).
5. Intervention value polychlorobiphenyles (sum) means: the sum of PCB 28, 52, 101, 118, 138, 153, 180. The target value is true for the sum minus PCB 118.
6. DDT/DDD/DDE means: the sum of DDT, DDD, and DDE.
7. Drins means: the sum of aldrin, dieldrin and endrin.
8. HCH-compounds means: the sum of  $\alpha$ -HCH,  $\beta$ -HCH,  $\gamma$ -HCH and  $\delta$ -HCH.
9. Phtalates (sum) means: the sum of all phtalates.
10. Mineral oil refers to the sum of the alkanes, subdivided or not. If there is a contamination involving mixtures (for instance petrol or domestic fuel oil) the aromatic and/or polycyclic aromatic hydrocarbon rate must be determined in addition to the alkane rate. For practical reasons this sum parameter was considered sufficient. Further toxicological and chemical differentiation is being studied.
11. The sum value for polycyclic aromatic hydrocarbons, chlorophenols and chlorobenzenes in soil/sediment is true for the total concentration of the compounds from the relevant group. If only one compound from a group is involved in a contamination, the value equals the intervention value for the relevant compound.  
In case of two or more compounds, the value for the sum of these compounds is valid. For soil/sediment the effects can be added up directly (e.g. 1 mg substance A has the same effect as 1 mg substance B) and can be tested against a sum value by adding up of the concentrations for the relevant compounds (see for further information on addivity the Technical Commission Soil Protection Advisory Report 1989<sup>3</sup>). For groundwater the effects can be added up indirectly, as fraction of the individual intervention value (e.g. 0.5 x intervention value substance B). This means that a sum formula has to be used in order to assess if the intervention value is exceeded. The intervention value for the sum of a substance group in groundwater is exceeded if:

<sup>3</sup> Technical Commission Soil Protection Advisory Report on soil contamination from polycyclic aromatics. TCB A89/03

## Table 1 (cont.)

$$\sum \frac{\text{conc.}_i}{I_i} \geq 1$$

$I_i$

where:

$\text{conc.}_i$  = measured concentration of a substance from the relevant group

$I_i$  = intervention value for the relevant substance

### Additional observations to Table 1:

#### Intervention values for substances not mentioned

For the broadest substance groups (e.g. (non)organochloro-pesticides) the individual (toxicological) substance properties deviate from the average substance properties in the group. The same holds for sets of substances, like volatile chlorinated hydrocarbons or extractable organochloro-compounds which are difficult to characterize and for sets of inorganic compounds with different speciations (for instance sulphides).

For the assessment of substances which have not been mentioned, it is advisable to compare them with chemically and toxicologically related substances given in Table 1.

For individual aliphatic hydrocarbon chlorides not included in the Table, an upper limit of 50 mg/kg dry substance constitutes the intervention value for soil/sediment; for individual organochloro-pesticides, respectively non-chlorinated pesticides the upper limit soil/sediment is 5, respectively 10 mg/kg dry substance.

The upper limit for the intervention values groundwater for individual aliphatic hydrocarbon chlorides, individual organochloro-pesticides and non-chlorinated pesticides can be derived using the equilibrium calculations referred to in RIVM report No. 725201007.

For individual inorganic compounds intervention values will be included in due course. Both toxicological and eutrophication aspects will be taken into consideration.

It is moreover possible to follow a faster procedure in formulating intervention values for substances for which no intervention values are yet available. Through the province a request may be directed to the regional environmental health inspectorate to bring in the RIVM for the deduction of ad-hoc intervention values. In the context of the technical-scientific aspects of this test value RIVM advises the Minister of Housing, Spatial Planning and the Environment, who subsequently stipulates the ad-hoc test value for the case of contamination concerned.

#### Harmonization intervention values and limit values

The intervention values soil/sediment for arsenic, chromium and lead have been equated to the limit values for newly formed sediment. The policy aspect that the intervention value at least equals the limit value has prevailed over a strict toxicological approach in view of the relatively large degree of uncertainty concerning the description of the eco-chemical properties of these heavy metals. Improvement of this description (among others the distribution over the solid and fluid phases of the soil) may lead to modification of the standards. In connection with the toxicological properties of the species of chromium, the distinction between chromium (III) and chromium (VI) is relevant. In the Dutch soil chromium (VI) is not a generally occurring speciation. In case of a contamination from chromium (VI) this speciation should be given special attention.

## Table 1 (cont.)

### Soil research

For the general principles of physical and chemical soil research (for instance location choice of observation points, drilling systems to be used, the method of soil and groundwater sampling, sample preservation, pre-treatment, refinement and analysis of samples) the reader is referred to the protocols to the preliminary and further research or the Soil Protection Guideline.

### Scale of the contamination

The intervention values represent average values for a soil volume of 25 m<sup>3</sup> (soil/sediment) and 100 m<sup>3</sup> (groundwater). For the sampling strategy see the protocols to the preliminary and further research. If it is likely that soil contamination of the scale referred to will occur from point sources of contamination (for instance on the basis of calculation) if no measures were taken in the short term (a few months at most), this constitutes a case of serious contamination as well.

### Serious contamination given rates below the intervention values

In the policy paper Intervention Values Soil Clean-up it is stated that a soil contamination case is also considered serious if the contamination moves autonomously into other environmental compartments or objects to such an extent that detrimental effects to the public health or the environment may occur while the intervention values are not exceeded (for instance exceeding of the maximum tolerable risk for man from consuming crops from allotments or inhalation of contaminated indoor air through the creeping-spaces).

Man can be exposed to soil contamination via a large number of exposure routes. In determining the human exposure for the purpose of deriving intervention values it has been assumed that all potential exposure routes operate. In order to be able to determine the exposure a "standard exposure scenario" was taken as starting-point. This contains data like the amount of time spent outdoors, the body weight of a child and an adult and the amount of time spent showering. The intervention values have been calculated in such a way that if man is exposed in correspondence with the standard exposure scenario, the maximum tolerable risk level for man is exceeded.

Most factors only play a minor role in the exposure. Some factors, however, like soil ingestion and consumption of crops grown on contaminated soil, affect the exposure to a large extent. If the standard for such factors is exceeded this may lead to exposure over the human MTR, without the intervention value being exceeded. If the standard for such factors is exceeded, this may lead to exposure exceeding the human MTR, without the intervention value being exceeded. In actual practice this problem is limited to situations involving lead and cadmium contaminations and situations in which the consumption of contaminated crops is significantly higher than the percentage of 10 which is used in the standard calculation. In situations involving inhalation of volatile compounds in creeping-spaces and indoor air it is also possible that the human MTR is exceeded at rates below the intervention values.

If it is likely that this is indeed the case, it is to be recommended to carry out additional research into the actual exposure occurring. Additional research is required in order to establish how much the actual exposure deviates from the standard exposure calculation and the results this is likely to have. The C-soil model, developed for the derivation of intervention values by RIVM, must be used for this purpose. In the formula for exposure as a consequence of crop consumption, the actually occurring exposure must be filled in. As the next step is best to determine the rates of contaminants in food crops. The actually occurring exposure must be compared to the toxicologically based maximum tolerable risk (MTR) level for man. If this is exceeded, it is a case of serious contamination.

If it is likely that the exposure as a result of inhalation of volatile compounds is higher than

## Table 1 (cont.)

determined on the basis of calculations, it is to be recommended to carry out measurements of the concentrations for such compounds in creeping-spaces or indoor air.

### "Trigger-function" EOX

No intervention value has been stipulated for EOCI or EOX. The reason for this is that using such a parameter has no value in toxicological respect. The determination of the EOX rate therefore has no function in relation to the assessment whether a case of (soil) contamination is serious or not. The EOX determination can, however, fulfil a so-called trigger function. It can be used to get an indication if intervention values for individual halogen compounds are being exceeded or not.

### Criterion for further research

The protocols for the preliminary and further research use the criterion  $1/2(\text{intervention value} + \text{target value})$  in order to indicate that further research is required. For substances for which no target value was determined,  $1/2(\text{intervention value})$  must be used in stead of  $1/2(\text{intervention value} + \text{target value})$ .

### Substances for which no target value has been given

The target values from Table 1 correspond with the target values as given in the Policy Statement on the Memorandum "Environmental quality objectives Soil and Water (MILBOWA)" (Parliamentary papers II 1991/92, 21 990 and 21 250, No. 3). The policy statement also contains target values which have not been included in the Table. This concerns values which are particularly useful in preventive policy. These will be included in the Soil Protection Guideline.

Table 1 also contains substances or substance groups for which an intervention value was quantitatively determined, but for which no target value was determined in this way. In most cases the reason is that the required scientific information is not yet available. As these substances may cause environmental problems when they are found in soil and/or groundwater, target values will be included for these substances or substance groups in the Soil Protection Guideline in as far as possible.

### *Differentiation of soil types*

#### Inorganic compounds

The target and intervention values for heavy metals (including arsenic) in soil/sediment, like the target values depend on the lutum content and/or organic substance content. In assessing the quality of a soil the values for a standard soil are converted into values for the relevant soil on the basis of measured contents of organic substance (the weight percentage loss on ignition related to the total dry weight of the soil) and contents of lutum (the weight percentage mineral constituents with a diameter smaller than  $2 \mu\text{m}$  related to the total dry weight of the soil). To this purpose relevant average values of the lutum and organic substance content are determined. The converted values can then be compared to the measured metal contents in the soil.



## Table 1 (cont.)

For the conversion the following soil type correction formula can be used:

$$I_b = I_{st} \times \frac{A + Bx\% \text{ lutum} + Cx\% \text{ org.subst.}}{A + Bx25 + Cx10} \quad (1)$$

where:

- $I_b$  = intervention values valid for the soil to be assessed (mg/kg)
- $I_{st}$  = intervention value for the standard soil (mg/kg)
- %lutum = measured percentage of lutum in the soil to be assessed
- %org.subst. = measured percentage of organic substance in the soil to be assessed
- A, B and C = substance-dependent constant (Table 2)

For application of the soil type correction for target values the intervention value ( $I_b$  and  $I_{st}$ ) in formula (1) is replaced by the target value.

## Table 1 (cont.)

**Table 2 Substance-related metal constants**

substance	A	B	C
arsenic	15	0.4	0.4
barium <sup>1</sup>	30	5	0
cadmium	0.4	0.007	0.021
chromium	50	2	0
cobalt <sup>1</sup>	2	0.28	0
copper	15	0.6	0.6
mercury	0.2	0.0034	0.0017
lead	50	1	1
molybdenum <sup>2</sup>	1	0	0
nickel	10	1	0
zinc	50	3	1.5

The constants for barium and cobalt have been taken from the report \* Background rates for nine trace metals in surface water, groundwater and soil in the Netherlands\*; J.H.M. de Bruijn and C.A.J. Denneman (1992). Publication series soil protection 1992/1.

For molybdenum no soil type correction is used.

In case of measurement problems arising from low organic substance or lutum rates, percentages of 2% organic substance and lutum can be assumed. As soon as measurement methods improve this will no longer be necessary.

For the other inorganic compounds (Table 1, sub II) the intervention values have not been related to soil characteristics. This means that for all soils the same intervention and target value is valid.

### Organic compounds

The intervention and target values for organic compounds have been related to the organic substance rate in the soil. In the assessment of the quality of the soil the values for a standard soil are divided by ten and multiplied by the measured organic substance rate. The values thus converted can be compared to the measured organic compound rates.

## Table 1 (cont.)

The conversion formula:

$$I_b = I_{st} \times \frac{\% \text{ org. subst.}}{10} \quad (2)$$

where:

- $I_b$  = intervention value valid for the soil to be assessed (mg/kg)  
 $I_{st}$  = intervention value standard soil (mg/kg)  
%org.subst. = measured percentage organic substance in the soil. For soils with measured organic substance contents of more than 30% respectively less than 2%, contents of respectively 30% and 2% are used.

For application of the soil type correction for target values the intervention values ( $I_b$  and  $I_{st}$ ) in formula (1) are replaced by the target value.

### Groundwater

For groundwater the intervention and target values for both inorganic and organic compounds have been made independent of the soil type.

### Soil analyses

In urban areas the soil structure and composition has been strongly influenced by man. The variation of the soil structure and composition, moreover, is considerable and within relatively short distance.

Therefore it is not possible to carry out an adequate soil type correction without a thorough soil analysis.

For the way in which soil type correction is used under these circumstances, see the forthcoming ministerial regulations for the preliminary and further research under Article 1, second paragraph, Soil Protection Act.

### Illustrations application of soil type correction

#### **Example 1: chromium**

Data:

intervention value (standard soil)	= 380 mg/kg
measured content	= 350 mg/kg
measured % lutum	= 10
measured % organic substance	= 10

Question: Does the measured content in this soil exceed the intervention value?

With the help of formula 1 the intervention value for chromium for the relevant soil is calculated:

$$\text{Intervention value} = 380 \times \frac{(50 + 2 \times 10)}{(50 + 2 \times 25)} = 266$$

This means that the measured content in the relevant soil, 350 mg/kg, exceeds the intervention value.

## Table 1 (cont.)

### Example 2: atrazine

Data:

intervention value (standard soil)	= 6 mg/kg
measured content	= 10 mg/kg
measured % lutum	= 10
measured % organic substance	= 20

Question: does the measured content in this soil exceed the intervention value?

By means of formula 2 the intervention value atrazine for the relevant soil is calculated:

$$\text{Intervention value} = 6 \times \frac{20}{10} = 12$$

This means that the measured content in the relevant soil, 10 mg/kg does not exceed the intervention value.

### Soil type correction use

An intervention or target value has been differentiated for soil type by taking into account the organic and/or lutum content of the soil to be assessed. By means of the given soil type correction formulas the corresponding intervention or target value can be calculated for any soil type.

In daily practice we observe that many soil samples with many different contaminants must be assessed. It will be more simple to convert the measured contents into the intervention and target values for a standard soil (instead of calculating the values for the relevant soil to be assessed). To this purpose the correction formulas may be simply adapted. The result of the assessment remains the same.

## Annex 2

## Tables of guideline values

The following tables present a summary of guideline values for microorganisms and chemicals in drinking-water. Individual values should not be used directly from the tables. The guideline values must be used and interpreted in conjunction with the information contained in the text and in Volume 2, *Health criteria and other supporting information*.

**Table A2.1. Bacteriological quality of drinking-water<sup>a</sup>**

Organisms	Guideline value
<b>All water intended for drinking</b>	
<i>E. coli</i> or thermotolerant coliform bacteria <sup>b,c</sup>	Must not be detectable in any 100-ml sample
<b>Treated water entering the distribution system</b>	
<i>E. coli</i> or thermotolerant coliform bacteria <sup>b</sup>	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample
<b>Treated water in the distribution system</b>	
<i>E. coli</i> or thermotolerant coliform bacteria <sup>b</sup>	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample. In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period

<sup>a</sup> Immediate investigative action must be taken if either *E. coli* or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause must be determined by immediate further investigation.

<sup>b</sup> Although *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

<sup>c</sup> It is recognized that, in the great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, the national surveillance agency should set medium-term targets for the progressive improvement of water supplies, as recommended in Volume 3 of *Guidelines for drinking water quality*.

**Table A2.2. Chemicals of health significance in drinking-water****A. Inorganic constituents**

	Guideline value (mg/litre)	Remarks
antimony	0.005 (P) <sup>a</sup>	
arsenic	0.01 <sup>b</sup> (P)	For excess skin cancer risk of $6 \times 10^{-4}$
barium	0.7	
beryllium		
boron	0.3	NAD <sup>c</sup>
cadmium	0.003	
chromium	0.05 (P)	
copper	2 (P)	ATO <sup>d</sup>
cyanide	0.07	
fluoride	1.5	Climatic conditions, volume of water consumed, and intake from other sources should be considered when setting national standards
lead	0.01	It is recognized that not all water will meet the guideline value immediately; meanwhile, all other recommended measures to reduce the total exposure to lead should be implemented
manganese	0.5 (P)	ATO
mercury (total)	0.001	
molybdenum	0.07	
nickel	0.02	
nitrate (as NO <sub>3</sub> <sup>-</sup> )	50	The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1
nitrite (as NO <sub>2</sub> <sup>-</sup> )	3 (P)	
selenium	0.01	
uranium		NAD

**B. Organic constituents**

	Guideline value (µg/litre)	Remarks
<i>Chlorinated alkanes</i>		
carbon tetrachloride	2	
dichloromethane	20	
1,1-dichloroethane		NAD
1,2-dichloroethane	30 <sup>b</sup>	for excess risk of $10^{-5}$
1,1,1-trichloroethane	2000 (P)	
<i>Chlorinated ethenes</i>		
vinyl chloride	5 <sup>b</sup>	for excess risk of $10^{-5}$
1,1-dichloroethene	30	
1,2-dichloroethene	50	
trichloroethene	70 (P)	
tetrachloroethene	40	
<i>Aromatic hydrocarbons</i>		
benzene	10 <sup>b</sup>	for excess risk of $10^{-5}$
toluene	700	ATO
xylenes	500	ATO
ethylbenzene	300	ATO
styrene	20	ATO
benzo[a]pyrene	0.7 <sup>b</sup>	for excess risk of $10^{-5}$
<i>Chlorinated benzenes</i>		
monochlorobenzene	300	ATO
1,2-dichlorobenzene	1000	ATO
1,3-dichlorobenzene		NAD
1,4-dichlorobenzene	300	ATO
trichlorobenzenes (total)	20	ATO
<i>Miscellaneous</i>		
di(2-ethylhexyl)adipate	80	
di(2-ethylhexyl)phthalate	8	
acrylamide	0.5 <sup>b</sup>	for excess risk of $10^{-5}$
epichlorohydrin	0.4 (P)	
hexachlorobutadiene	0.6	
edetic acid (EDTA)	200 (P)	
nitrilotriacetic acid	200	
dialkyltins		NAD
tributyltin oxide	2	

Table 2 (cont.)

**C. Pesticides**

	Guideline value ( $\mu\text{g/litre}$ )	Remarks
alachlor	20 <sup>b</sup>	for excess risk of $10^{-5}$
aldicarb	10	
aldrin/dieldrin	0.03	
atrazine	2	
bentazone	30	
carbofuran	5	
chlordane	0.2	
chlorotoluron	30	
DDT	2	
1,2-dibromo- 3-chloropropane	1 <sup>b</sup>	for excess risk of $10^{-5}$
2,4-D	30	
1,2-dichloropropane	20 (P)	
1,3-dichloropropane		NAD
1,3-dichloropropene	20 <sup>b</sup>	for excess risk of $10^{-5}$
ethylene dibromide		NAD
heptachlor and heptachlor epoxide	0.03	
hexachlorobenzene	1 <sup>b</sup>	for excess risk of $10^{-5}$
isoproturon	9	
lindane	2	
MCPA	2	
methoxychlor	20	
metolachlor	10	
molinate	6	
pendimethalin	20	
pentachlorophenol	9 (P)	
permethrin	20	
propanil	20	
pyridate	100	
simazine	2	
trifluralin	20	
chlorophenoxy herbicides other than 2,4-D and MCPA		
2,4-DB	90	
dichlorprop	100	
fenoprop	9	
MCPB		NAD
mecoprop	10	
2,4,5-T	9	

**D. Disinfectants and disinfectant by-products**

Disinfectants	Guideline value (mg/litre)	Remarks
monochloramine	3	
di- and trichloramine chlorine	5	NAD ATO. For effective disinfection there should be a residual concentration of free chlorine of $\geq 0.5$ mg/litre after at least 30 minutes contact time at pH < 8.0
chlorine dioxide		A guideline value has not been established because of the rapid breakdown of chlorine dioxide and because the chlorite guideline value is adequately protective for potential toxicity from chlorine dioxide
iodine		NAD
Disinfectant by-products	Guideline value ( $\mu\text{g/litre}$ )	Remarks
bromate	25 <sup>b</sup> (P)	for $7 \times 10^{-5}$ excess risk
chlorate		NAD
chlorite	200 (P)	
chlorophenols		
2-chlorophenol		NAD
2,4-dichlorophenol		NAD
2,4,6-trichlorophenol	200 <sup>b</sup>	for excess risk of $10^{-5}$ , ATO
formaldehyde	900	
MX		NAD
trihalomethanes		The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1
bromoform	100	
dibromochloromethane	100	
bromodichloromethane	60 <sup>b</sup>	for excess risk of $10^{-5}$
chloroform	200 <sup>b</sup>	for excess risk of $10^{-5}$
chlorinated acetic acids		
monochloroacetic acid		NAD
dichloroacetic acid	50 (P)	
trichloroacetic acid	100 (P)	
chloral hydrate (trichloroacetaldehyde)	10 (P)	
chloroacetone		NAD

Table 2 (cont.)

Disinfectant by-products	Guideline value (µg/litre)	Remarks
halogenated acetonitriles		
dichloroacetonitrile	90 (P)	
dibromoacetonitrile	100 (P)	
bromochloroacetonitrile		NAD
trichloroacetonitrile	1 (P)	
cyanogen chloride (as CN)	70	
chloropicrin		NAD

<sup>a</sup> (P) – Provisional guideline value. This term is used for constituents for which there is some evidence of a potential hazard but where the available information on health effects is limited; or where an uncertainty factor greater than 1000 has been used in the derivation of the tolerable daily intake (TDI). Provisional guideline values are also recommended: (1) for substances for which the calculated guideline value would be below the practical quantification level, or below the level that can be achieved through practical treatment methods; or (2) where disinfection is likely to result in the guideline value being exceeded.

<sup>b</sup> For substances that are considered to be carcinogenic, the guideline value is the concentration in drinking-water associated with an excess lifetime cancer risk of  $10^{-5}$  (one additional cancer per 100 000 of the population ingesting drinking-water containing the substance at the guideline value for 70 years). Concentrations associated with estimated excess lifetime cancer risks of  $10^{-4}$  and  $10^{-6}$  can be calculated by multiplying and dividing, respectively, the guideline value by 10.

In cases in which the concentration associated with an excess lifetime cancer risk of  $10^{-5}$  is not feasible as a result of inadequate analytical or treatment technology, a provisional guideline value is recommended at a practicable level and the estimated associated excess lifetime cancer risk presented.

It should be emphasized that the guideline values for carcinogenic substances have been computed from hypothetical mathematical models that cannot be verified experimentally and that the values should be interpreted differently than TDI-based values because of the lack of precision of the models. At best, these values must be regarded as rough estimates of cancer risk. However, the models used are conservative and probably err on the side of caution. Moderate short term exposure to levels exceeding the guideline value for carcinogens does not significantly affect the risk.

<sup>c</sup> NAD – No adequate data to permit recommendation of a health-based guideline value.

<sup>d</sup> ATO – Concentrations of the substance at or below the health-based guideline value may affect the appearance, taste, or odour of the water.

**Table A2.3. Chemicals not of health significance at concentrations normally found in drinking-water**

Chemical	Remarks
asbestos	U
silver	U
tin	U

U – It is unnecessary to recommend a health-based guideline value for these compounds because they are not hazardous to human health at concentrations normally found in drinking-water.

**Table A2.4. Radioactive constituents of drinking-water**

	Screening value (Bq/litre)	Remarks
gross alpha activity	0.1	If a screening value is exceeded, more detailed radionuclide analysis is necessary. Higher values do not necessarily imply that the water is unsuitable for human consumption
gross beta activity	1	

Table 2 (cont.)



**Table A2.5. Substances and parameters in drinking-water that may give rise to complaints from consumers**

	Levels likely to give rise to consumer complaints <sup>a</sup>	Reasons for consumer complaints
<i>Physical parameters</i>		
colour	15 TCU <sup>b</sup>	appearance
taste and odour	–	should be acceptable
temperature	--	should be acceptable
turbidity	5 NTU <sup>c</sup>	appearance; for effective terminal disinfection, median turbidity ≤1NTU, single sample ≤5NTU
<i>Inorganic constituents</i>		
aluminium	0.2 mg/l	depositions, discoloration
ammonia	1.5 mg/l	odour and taste
chloride	250 mg/l	taste, corrosion
copper	1 mg/l	staining of laundry and sanitary ware (health-based provisional guideline value 2 mg/litre)
hardness		high hardness: scale deposition, scum formation low hardness: possible corrosion
hydrogen sulfide	0.05 mg/l	odour and taste
iron	0.3 mg/l	staining of laundry and sanitary ware
manganese	0.1 mg/l	staining of laundry and sanitary ware (health-based provisional guideline value 0.5 mg/litre)
dissolved oxygen	–	indirect effects
pH	–	low pH: corrosion high pH: taste, soapy feel preferably <8.0 for effective disinfection with chlorine
sodium	200 mg/l	taste
sulfate	250 mg/l	taste, corrosion
total dissolved solids	1000 mg/l	taste
zinc	3 mg/l	appearance, taste
<i>Organic constituents</i>		
toluene	24–170 µg/l	odour, taste (health-based guideline value 700 µg/l)
xylene	20–1800 µg/l	odour, taste (health-based guideline value 500 µg/l)
ethylbenzene	2–200 µg/l	odour, taste (health-based guideline value 300 µg/l)

	Levels likely to give rise to consumer complaints <sup>a</sup>	Reasons for consumer complaints
monochlorobenzene	10–120 µg/l	odour, taste (health-based guideline value 300 µg/l)
1,2-dichlorobenzene	1–10 µg/l	odour, taste (health-based guideline value 1000 µg/l)
1,4-dichlorobenzene	0.3–30 µg/l	odour, taste (health-based guideline value 300 µg/l)
trichlorobenzenes (total)	5–50 µg/l	odour, taste (health-based guideline value 20 µg/l)
synthetic detergents	–	foaming, taste, odour
<i>Disinfectants and disinfectant by-products</i>		
chlorine	600–1000 µg/l	taste and odour (health-based guideline value 5 mg/l)
chlorophenols		
2-chlorophenol	0.1–10 µg/l	taste, odour
2,4-dichlorophenol	0.3–40 µg/l	taste, odour
2,4,6-trichlorophenol	2–300 µg/l	taste, odour (health-based guideline value 200 µg/l)

<sup>a</sup> The levels indicated are not precise numbers. Problems may occur at lower or higher values according to local circumstances. A range of taste and odour threshold concentrations is given for organic constituents.

<sup>b</sup> TCU, time colour unit.

<sup>c</sup> NTU, nephelometric turbidity unit.

**APPENDIX 1**  
**SITE ASSESSMENT WORKSHEET**

**APPENDIX 1. SITE ASSESSMENT WORKSHEET**

**(1) General site information**

(i) Full address and National Grid Reference and site size (Hectares)

.....  
.....  
.....  
.....  
.....

(ii) Plan of site with scale (please attach. Also attach site photos if available).

**(2) Current and previous site uses**

(i) Current land-use:

- Light industrial  Commercial
- Mixed commercial/ residential use
- Heavy industrial  Agricultural
- Derelict  Other  - please give details

(ii) General description of current site-use and nature of works/activities, including length of time site has been used for this purpose.

.....  
.....  
.....  
.....  
.....

(ii) Previous site uses including nature of works/activities, including length of time site has been used for this purpose.

.....  
.....  
.....  
.....  
.....

**(3) Potential Contamination (Sources)**

(i) Visual and olfactory evidence

- Visual/olfactory indications (unusual colours, oil contamination, strong odours)
- Waste disposal areas
- Evidence of leakages, spillages
- Derelict plant, drums, tanks, etc.

(ii) Other evidence of potential contamination. Please give details if yes to any of the following:

- Discussions with site owner/occupier
- Previous investigations
- Previous pollution incidents
- Regulatory authority interest/action

.....  
.....  
.....  
.....  
.....

**(4) Site Setting and Environmental Receptors (Targets)**

Surrounding land-use:

- |                  |                          |                 |                          |       |
|------------------|--------------------------|-----------------|--------------------------|-------|
| Light industrial | <input type="checkbox"/> | Mixed (specify) | <input type="checkbox"/> | ..... |
| Heavy industrial | <input type="checkbox"/> | Commercial      | <input type="checkbox"/> |       |
| Agricultural     | <input type="checkbox"/> | Residential     | <input type="checkbox"/> |       |

Site Topography: Flat  Steep  Variable (specify)  .....

Ground conditions: Made ground  Typical thickness .....m  
Evidence of contamination   
Specify .....

Natural ground type - specify, eg. clay, alluvium, etc.  
.....  
Typical thickness .....m

Groundwater Depth (m)  
Aquifer status .....  
.....  
.....  
Abstraction(s) .....  
Quality data .....

Surface Water Type .....  
(stream, lake, river) Distance to site (m) .....  
Abstraction(s) .....  
Quality data .....

Ecological Receptors (Site of Special Scientific Interest, protected habitat, etc.)

.....  
.....  
.....

**(5) Pathways**

- Ingestion
- Inhalation
- Dermal Contact
- Free product Migration and Vapour Inhalation  
Migration of Contaminated Groundwater

**(6) Summary**

- (i) Is there any potential for contamination to have occurred or be occurring?
- (ii) Are there any sensitive receptors which might be affected by the contamination?
  - human health, eg. site workers, nearby residents
  - groundwater beneath the site
  - nearby surface water course
  - nearby ecological habitat

**(7) Requirements for Action**

If you have answered yes to both questions in Section (6), ie. a source-pathway-target relationship exists, then it is recommended that further assessment of the site is carried out in the form of site investigation or preliminary risk assessment.

If you have answered no to both questions, then it is considered that no further action is necessary. However, should there be a change in site conditions in the future, or a change in land-use, then this site assessment should be repeated.

**APPENDIX 2**  
**METHODOLOGY FOR QUANTITATIVE RISK ASSESSMENT**

## APPENDIX 2

### METHODOLOGY FOR QUANTITATIVE RISK ASSESSMENT FOR SOIL AND GROUNDWATER CONTAMINATION

#### 1. Risks to Groundwaters and Surface Waters - Conceptual Model

The risk to groundwater and surface waters (hereafter referred to as ‘controlled waters’) is calculated from observed soil and groundwater contamination. From the observed concentration, a set of equations are used to predict what the concentration would be in groundwater down hydraulic gradient of the source area(s). These simulated concentrations are then compared with target concentrations in the groundwater, to see if the observed contamination could pose a significant risk to the receiving groundwaters.

The simulated concentrations are determined for a specified distance from the site. This is taken as the distance to the nearest receptor (such as well or stream which receives groundwater). If no receptor is identified, then a “compliance point” may be selected.

To calculate what the predicted groundwater concentrations would be arising from a soil concentration, three main steps are used:

- leaching of contamination from soil to pore water;
- mixing of pore water into the aquifer;
- transport and attenuation of contamination in the aquifer.

Partitioning of contaminants in the unsaturated zone between solid, aqueous and gaseous phases is performed as Step 1 in the methodology to produce groundwater contamination (leachate) concentrations directly below the site. These partitioning values are calculated using site specific parameters including soil porosity and soil organic carbon content. Chemical specific parameters such as Henry’s law constants and partition coefficients are also used.

The second step is the simulation of dilution of the porewaters below the site as mixing into the aquifer occurs. This step uses more site specific parameters such as source dimensions, effective rainfall, hydraulic conductivity and gradient.

For the third step, the Domenico analytical solution to the advection-dispersion equation is used to simulate the concentrations of a contaminant at a point away from the source. The parameters used in this equation are listed in the section on Relevant Equations below. All three steps of the model are linked to calculate a concentration at the receptor. This is then compared to the target concentrations of the potential chemicals of concern, to determine which calculated concentrations exceed the target concentrations. A Controlled Waters Hazard Index (CWHI) is then produced which gives the ratio of calculated to target concentrations. Compounds where the CWHI exceeds one are identified as potentially posing a significant risk to controlled waters. A Risk Based Clean-up Level (RBCL) for soil



is also calculated based on the maximum permissible soil concentration that would allow compliance with the target water standards.

The risks that existing groundwater contamination potentially pose to controlled waters receptors are calculated using the attenuation factor from the Domenico analytical solution to calculate dissolved phase concentrations at the chosen compliance point.

## 2. Relevant Equations

The following are the equations used for the model simulations (Steps 1 - 3):

### 2.1 Step 1 - Calculation of Soil Leaching Concentrations

A partitioning equation is used to calculate the concentration of contaminant in pore waters that is in equilibrium with the measured soil concentration.

#### 2.1.1 Soil partitioning equation:

$$C_s = C_T (K_d + (q_w + q_a H') / r_b)$$

where:  $K_d$  = soil-water partition coefficient (l/kg)

$q_w$  = water-filled soil porosity ( $l_{\text{water}}/l_{\text{soil}}$ )

$q_a$  = air-filled soil porosity ( $l_{\text{air}}/l_{\text{soil}}$ )

$H'$  = Henry's law constant (unitless)

$r_b$  = dry soil bulk density (kg/l)

$C_s$  = concentration in soil (mg/kg)

$C_T$  = concentration in porewater (mg/l)

Reference USEPA, (1994)

#### 2.1.2 Calculation of $K_d$ for non-polar organic chemicals:

$$K_d = K_{oc} f_{oc}$$

where:  $K_{oc}$  = organic carbon partition coefficient (l/kg)

The organic carbon partition coefficient ( $K_{oc}$ ) is chemical-specific with values being readily available from published sources.

Reference USEPA, (1994)

#### 2.1.3 Fraction of organic carbon:

$$f_{oc} = f_{om} / 1.724$$

where:  $f_{oc}$  = fraction of organic carbon

$f_{om}$  = fraction of organic matter

Reference Dragun, (1988)

## 2.2 Step 2 - Calculation of Mixing of Porewaters into Aquifer

The pore water is mixed into the aquifer, based on a mass balance approach. This gives a dilution factor by which the leaching porewater is diluted.

Calculation of mixing of porewater into aquifer via a dilution factor:

$$DF = 1 + \frac{(K i d)}{(I L)}$$

where	DF	=	dilution factor
	K	=	hydraulic conductivity (m/d)
	d	=	mixing zone depth (m)
	i	=	hydraulic gradient (m/m i.e. unitless)
	I	=	infiltration rate (m/d)
	L	=	length of source parallel to groundwater flow (m)

### 2.2.1 Mixing Zone Depth

$$d = (0.0112 L^2)^{0.5} + d_a \{1 - \exp[(-LI)/(Kid_a)]\}$$

where:	d	=	mixing zone depth (m)
	L	=	source length parallel to groundwater flow (m)
	I	=	infiltration rate (m/yr)
	K	=	aquifer hydraulic conductivity (m/yr)
	i	=	hydraulic gradient (m/m)
	d <sub>a</sub>	=	aquifer thickness (m)

Reference DoE, (1994)

## 2.3 Step 3 - Calculation of Attenuation in Saturated Zone.

### 2.3.1 Derivation of an attenuation factor (AF) :

AF values may be obtained by the use of the Domenico equation. The Domenico equation is an analytical solution of the advection-dispersion equation for solute transport which allows for retardation and decay of the contaminant. The equation is that of Domenico (1987) and gives a concentration ( $g/cm^3$ ) along the centerline ( $x, y = 0, z = 0$ ) of a dissolved plume:

eqn. 1

$$C(x) = C_{source} \exp \left\{ \frac{x}{2\alpha_x} \left[ 1 + \left( 1 + \frac{4\lambda\alpha_x}{u} \right)^{1/2} \right] \right\} \cdot \left( \operatorname{erf} \left[ \frac{S_w}{4\sqrt{\alpha_y x}} \right] \right) \cdot \left( \operatorname{erf} \left[ \frac{S_d}{4\sqrt{\alpha_z x}} \right] \right)$$

where:  $u = K_s i / \theta_s$   
 $K_s$  = saturated hydraulic conductivity (cm/day)  
 $i$  = hydraulic gradient  
 $\theta_s$  = volumetric water content of saturated zone  
 $x$  = distance along centerline from down-gradient edge of dissolved plume source [cm]  
 $y$  = depth below water table (cm)  
 $z$  = distance (lateral) away from dissolved plume centreline (cm)  
 $\alpha_x$  = longitudinal dispersivity (approximately  $0.1 x$ )  
 $\alpha_y$  = transverse dispersivity (approximately  $\alpha_x/3$ )  
 $\alpha_z$  = vertical dispersivity (approximately  $\alpha_x/10$ )  
 $\lambda$  = first order degradation constant ( $d^{-1}$ )  
 $S_w$  = source width (perpendicular to flow in the horizontal plane (cm))  
 $S_d$  = source depth (perpendicular to flow in the vertical plane (cm))  
 $\operatorname{erf}$  = error function

To take account of retardation of the contamination due to sorption the following  $U_d$  may be substituted for  $u$  velocity:

eqn. 2

$$U_d = \frac{K_s i}{\theta_s R_c}$$

where:  $R_c$  = retardation factor defined by:

eqn. 3

$$R_c = \left[ 1 + \frac{K_d \rho_g}{\theta_s} \right]$$

where:  $\rho_g$  = soil bulk density ( $\text{g}/\text{cm}^3$ )  
 $K_d$  = soil water partition coefficient ( $\text{mg}/\text{g}$ )

The Domenico equation is solved for an assumed unit contaminant concentration immediately beneath the site (eg. 1 mg/l) and the simulated maximum concentration at the compliance point is observed. The output of the equation is used to calculate the AF as follows

$$AF = 1/C$$

where: C = simulated compliance point concentration. The AF is used to estimate the concentration at a given distance down the centreline of a plume, at the time when the plume has reached steady state. AF values do not allow for the possibility that contaminant concentrations could decrease with time.

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