Riskbedömning vid användning av sekundära material i anläggningsbyggande

Principles for risk assessment of secondary materials in civil engineering work

Survey

Jan Hartlén, LTH
Ann-Marie Fällman, SGI
Pär-Erik Back, SGI
Celia Jones, Kemakta

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SUMMARY

There is a clear tendency in society to minimise the use of natural resources. In civil engineering, and not the least in infrastructure projects, the last years have made this insight very evident. One way of reducing the consumption is to recycle as much material as possible, such as crushed concrete from demolished buildings and industrial residues.

To be able to re-use residues, the quality both regarding physical and environmental properties has to be proven. The Swedish regulations “Väg 94” issued by Vägverket (Swedish National Road Administration) define that the physical properties shall be as good as the material it replaces, and shall not cause any detrimental environmental effects.

This reports focus on the environmental effect by using residues. To justify re-use, the decision basis shall be based on a profound risk assessment. Primarily, the risk shall be based on a combination of a probability that a damage will occur and a consequence of the damage. The probability is related to factors as volume used, potential for leaching harmful substances transferred to the actual situation/environment and concentrations at target points in soil and water.

Today, no such system exists in Sweden based on relevant risk assessments. In most cases, the assessments are related to concentrations accepted by authorities developed for other applications, as drinking water standard or acceptable change in concentration in surface water. The Swedish Environmental Protection Agency (Naturvårdsverket) has in 1999 issued a report on contaminated soil, where a methodology is presented on how to make the rating. A similar approach could be relevant to utilisation of residues.

In many countries, work is proceeding to develop decision criteria when and how to use secondary materials. This report therefor gives a broad background to such work, especially focusing on the activities in the Netherlands and Denmark. In EU, work is going on giving standards to waste disposal where the waste is divided into different classes based on their hazardous level. CEN is in parallel working with leaching of materials in TC 292.

This project is only a first step on how to develop a robust system, for Swedish conditions, based on a scientific approach. In section 6 of this report, a proposed system is outlined.

The risk assessment of the use of secondary materials in constructions is composed of several parts as follows.

Problem formulation

The aim is to identify the hazardous properties and substances in the material that are relevant in the scenario and to identify the pathways and target points for these substances. This is equivalent to step 1-3 in ENV 12920 “Methodology for the determination of the leaching behaviour of waste under specified conditions”.

Description of the material

The residue needs to be described (Step 3, ENV 12920) and the relevant substances for the risk assessment shall be selected. The description of the waste needs to consist of:
•identification of the physical properties

•identification of the hazardous properties in relation to Council directive on hazardous waste 91/689/EEC
•identification of the composition of the material in relation to inorganic and organic substances.

Description of the scenario

The application/scenario shall be described in detail in relation to the actual construction and to the local environment (Step 2 ENV 12920). The description of the scenario shall include
•geotechnical conditions
•hydrogeological conditions
•biological conditions
•use of the site over time
•exceptional conditions

Selection of target substances and target points

Based on the description of the residue, the target substances are selected.

Several target points will be identified based on the description of the scenario and shall be selected in regard to all relevant exposures to mankind and nature. The pathways addressed in the transport model shall give concentration or exposures of the target substances at the identified target points.

Exposure assessment

The exposure assessment consists of two parts: transport of target substance from source to target point and evaluation of the sensitivity to environmental hazards of the area included in the scenario.

Risk evaluation

The risk evaluation consists of the step, where the calculated exposures and concentrations at the target points are compared to different already set up quality criteria.

Risk management

There is a need for a general statement from the authorities on which level of effect that is acceptable. This is not dealt with in the report.

Future work

A system to evaluate the possibility/risk to use a specific residue has been presented in the report. So far, the presented system is only an outline based on general principles. During the work to outline this system, it became obvious that several important areas need further development before the system can be fully implemented. In this context, different tools need also to be developed. The report present such needs for further research and development in chapter 7.

The outlined system for risk assessment as above, shall be regarded as the basic system, which may not be easy to use on a regular basis. Simplifications are thus needed to obtain a system that is useful in practice. Different applications may also need applied quality assurance systems.

SAMMANFATTNING

Det finns en klar tendens i samhället att minska förbrukningen av naturresurser, såsom sand och grus. Detta gäller inte minst inom infrastruktursektorn som förbrukar stora material-mängder. Ett sätt att reducera förbrukningen är att återanvända material, exvis krossad betong, slagger och andra restprodukter.

För att det skall vara möjligt att återanvända restprodukter, till exempel inom infrastrukturområdet, måste kvaliteten uppfylla ställda krav både vad avser tekniska som miljömässiga egenskaper. I Väg 94 anger Vägverket att vid användning av sekundära material skall de fysikaliska egenskaperna vara minst lika bra som de hos det material som ersätts, och skall inte skadliga miljöeffekter uppstå.

Denna rapport fokuserar på de miljömässiga effekterna av att använda restprodukter. För att användningen av sådana produkter skall kunna motiveras, erfordras att beslutsunderlaget är baserat på en kvalificerad riskbedömning. Risken definieras normalt som en kombination av sannolikheten för att en skada skall uppstå och konsekvensen av denna skada. Sannolikheten bestäms av faktorer som använd volym samt potentialen för spridning av miljöskadliga ämnen **till känsliga punkter i jord och vatten** för den aktuella situationen.

Det finns idag inga relevanta system i Sverige för att göra en sådan riskanalys. I de flesta fall baseras därför riskbedömningarna på jämförelser med andra föroreningsnivåer/halter som myndigheterna godtagit för olika tillämpningar. Hit hör dricksvattenkriteria och tillåtna haltförändringar i ytvatten. Naturvårdsverket har under 1999 (rapport 4918) publicerat hur man skall bedöma förorenad jord. Ett liknande angreppssätt kan vara relevant för användning av restprodukter.

I många länder pågår arbete med att ta fram beslutskriteria för användning av sekundära material. I denna rapport görs en bred presentation av sådana arbeten, med speciell fokusering på aktiviteter i Holland och Danmark. Inom EU pågår arbete att ta fram direktiv för avfallsdeponering där avfallet indelas i olika klasser beroende på risknivån. CEN arbetar parallellt med att ta fram metoder för bestämning av lakegenskaper, CEN (TC292). Dessa arbeten presenteras också, då de har relevans för andra typer av riskbedömningar.

Detta projekt är ett första steg i att utveckla ett robust system för Sverige, baserat på ett vetenskapligt angreppssätt. I kapitel 6 i rapporten ges ramarna för ett sådant system.

Riskbedömningen vid användningen av sekundära material i konstruktioner föreslås bestå av flera delar enligt nedan:

Problemformulering
Syftet är att identifiera miljöstörande egenskaper hos restprodukten som är relevanta för att identifiera spridningsvägar. Detta motsvara steg 1-3 i ENV12920 ”Methodology for determination of a leaching behaviour of waste under specified conditions”.

Beskrivning av materialet
Restprodukten skall beskrivas (steg 3 ENV 12920) och relevanta ämnen för riskbedömning skall väljas. Beskrivningen skall omfatta :
•fysikaliska egenskaper

•miljöfarliga egenskaper i relation till EU direktivet om miljöfarligt avfall 91/689/EEC.
•materialets innehåll av oorganiska och organiska ämnen.

Beskrivning av scenarier
Användningssätt/scenarier skall beskrivas i detalj utifrån användningsområde och lokala miljöförhållanden. (steg 2, ENV 12920). Beskrivning av scenarierna skall innehålla
•geotekniska förhållanden
•hydrogeologiska förhållanden
•biologiska förhållanden
•framtida användning av området
•speciella förutsättningar

Val av kritiska ämnen och kritiska påverkanspunkter
Utifrån materialbeskrivningen väljs kritiska ämnen. Flera påverkanspunkter skall identifieras utifrån uppställda scenarier och med beaktande av möjlig påverkan på människa och natur. Spridningsvägarna skall utifrån transportmodeller ge svar på koncentrationer av kritiska ämnen vid dessa kritiska punkter.

Utvärdering av påverkan
Utvärdering av påverkan består av två delar: Transport av kritiska ämnen från källa till påverkanspunkt och utvärdering av känsligheten för miljöstörning inom aktuellt område.

Riskvärdering
Riskvärdering inbegriper att beräknad påverkan vid kritiska punkter jämförd med redan uppställda kvalitetskriterier. Dos-respons data ingår i denna utvärderingsdel.

Riskhantering
Generell nivå för acceptabel påverkan på natur och människa måste ställas upp av myndigheterna och ingår ej i denna studie. Dessa nivåer utgör grunden för samhällets val av risknivå.

Fortsatt arbete
Ett system för att utvärdera möjlighet/risk vid användning av restprodukter är presenterat i denna rapport. På nuvarande stadium är systemet endast utarbetat på en övergripande nivå baserat på generella principer. Det har under arbetet framkommit att det erfordras fortsatt forskning och utveckling innan ett system likt det föreslagna kan bli färdigutvecklat. Olika ”verktyg” behöver också tas fram till hjälp vid en analys. Förslag till fortsatt forskning och utveckling presenteras i rapporten.

Det föreslagna systemet för riskbedömning presenterat ovan behöver också förenklas och utprovas för att kunna användas i praktiken och för enskilda produkter.

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1 INTRODUCTION

In society, there is a clear tendency to minimize the use of natural resources and thus to save resources for coming generations. In civil engineering and especially in infrastructure projects, the last years have made this insight very evident. One way of reducing the consumption is to recycle as much material as possible. An example of this is to use crushed concrete from demolished bridges as base course material. Another way is to replace natural aggregates by waste material from other areas. An example of this will be using slag from steel industry and waste incineration as sub-base material.

Materials replacing natural aggregates in e.g. roads are normally named secondary materials or residues.

To be able to use a “new material with limited experience in the actual application, the quality both regarding physical and environmental properties has to be proven. The Swedish regulations “Väg 94” issued by Vägverket present such requirements. There it is defined that the physical properties shall be as good as for the material it replaces, and that it shall not cause any detrimental environmental effects.

This reports focus is on the environmental effect. The approach chosen here is to base such a procedure on a risk assessment procedure. Such a procedure is more and more used to facilitate a decision process looked upon as a useful tool to base an objective decision.

Principles for risk assessment have been developed for several applications. Risk assessment is judged also to be well adapted to utilisation of secondary material when evaluating the risk of contaminating soil and groundwater. The problem to use such a model for secondary materials is the complexity of the ground conditions involving factors such as heterogeneity of existing soil layers, the physical properties such as hydraulic conductivity of these layers and the ground water regime.

To achieve a common use of secondary materials, the use must be based on sound principles not causing a negative environmental impact. To justify this use, the decision shall be based on a profound risk assessment. Primarily, the risk is based on a combination of a probability that a damage will occur and a consequence of the damage. The probability is determined by factors as volume used, potential for leaching harmful substances then transferred to the actual situation/environment related to transport models and concentrations at target points in soil and water.

Today, no such system exists in Sweden that is based on relevant risk assessments. In most cases, the assessments are related to concentrations accepted by authorities developed for other applications, such as drinking water standard or change in concentrations in surface water.

In many countries work is proceeding to develop decision criteria when and how to use secondary materials. This report therefor also gives a broad background to such work, especially focusing on the activities in the Netherlands and Denmark.

The Swedish Environmental Protection Agency (Naturvårdsverket) has in 1999 issued a report on contaminated soil where a methodology is presented on how to make the rating etc. A similar approach could be relevant to utilisation of residues.

In EU, work is going on with a directive on waste disposal where the waste is divided into different classes based on their hazardous level. CEN is in parallel working with standardisation of tests for waste materials in TC 292.

This project is a first step how to develop a robust system based on a scientific approach. This first study has its main goal to form the basis for a study, which will result in a total system evaluating residues for recycling, based on practical procedures for product information and quality control.

2 OBJECTIVES OF THE STUDY

The objective of the study was to develop a system for risk assessment of the use of secondary materials in civil engineering work based on general principles of risk assessment and ideas from similar systems in other countries and neighbouring systems in Sweden. Further, the objective was to identify needs of research and development for this system to come into use.

It shall thus be noticed that the purpose not has been to present a system developed for direct use but to find the basis for such a system.

3 PRINCIPLES OF RISK ASSESSMENT

3.1 Principles and concepts

The terminology in the discipline of risk may be confusing, since different writers use the same terms and concepts with different meanings, and a specific phase of the risk area is often given a different name. This calls for definition of the most commonly used terms, concepts and principles. This chapter gives a general view of the terminology, and particularly the principles, of risk assessment in environmental applications.

In the environmental field there are two fundamental phases in *risk analysis*:
- risk assessment, and
- risk management

Some writers present slightly different frameworks, and sometimes an additional step follows after the risk assessment:
- risk evaluation

The relationship between the different phases is presented in Figure 3.1. The first phase, *risk assessment*, is sometimes also named *analysis* or *risk analysis* (note that *risk analysis* is often used as the most general term in risk-based disciplines). The risk assessment process is usually defined as the scientific analysis and characterisation of adverse effects of environmental hazards (Stern & Fineberg, 1996). Risk assessment results in a characterisation of the risk, which can include both qualitative and quantitative descriptors. Risk assessment is often presumed to be scientifically objective and relatively free of value judgements. Below, a more detailed description of risk assessment is given.

In the second phase, the outcome of the risk assessment (i.e. the assessed risk) is compared to certain acceptance criteria. Some writers refer to this phase as *risk evaluation*, while others include this process in the *risk management*. In the risk evaluation process, the significance of the risk is judged and compared (Covello & Merkhofer, 1993). In contrast to risk assessment, risk evaluation and especially risk management deals with value judgements and is partly subjective.

Risk management can be defined as the decision-making phase but other definitions exist (Davies, 1995). In risk management technical, economical, political, social and ethical factors are considered. Risk management can often be divided into several sub-phases, such as priority setting between options, option selection, risk communication, risk reduction and implementation. It is during the risk management process an agency or authority will approve or disapprove of a risk activity.

This report primarily deals with risk assessment and to some extent with risk evaluation. Some other frequently used terms are *risk*, *risk analysis*, *risk assessor, risk manager, harm, hazard and stressor*. Below, these terms are described.

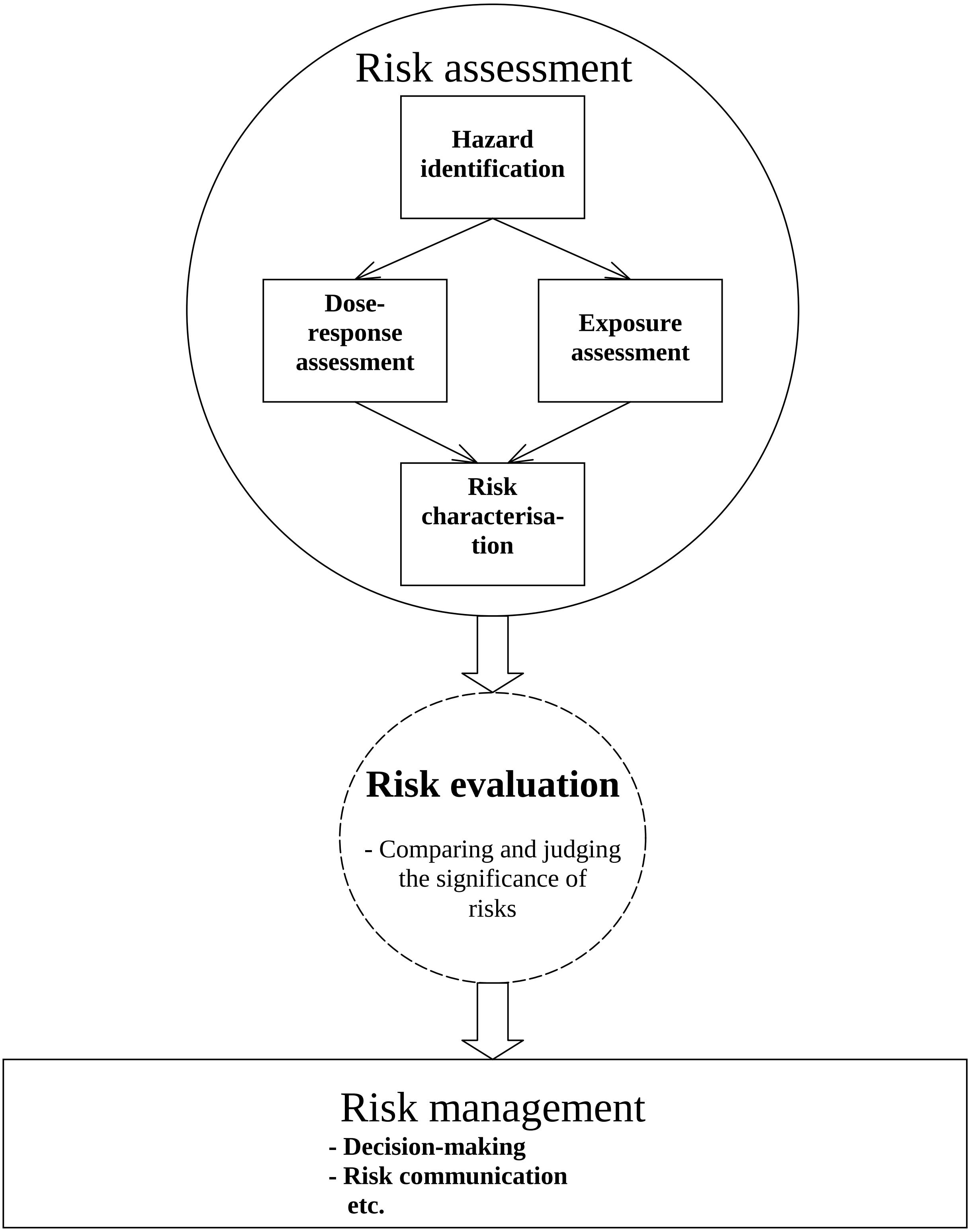

Figure 3.1. Relationship between the different phases in a typical framework for environmental risk assessment and risk management. Modified from Covello & Merkhofer (1993), Neely (1994), Landis & Yu (1995), and NRC (1983).

There are many different definitions of *risk*. In a technical risk-based discipline *risk* is often defined as the combined effect of the likely-hood of a harmful event to occur (caused by a hazard), and the magnitude of the caused harm. Often, the risk is expressed as a number of deaths in a given population during a given period, but many other expressions exist. In certain circumstances risk may be expressed as an economic cost. On the other hand, some writers argue that risk should not be regarded as a quantifiable physical reality at all (Stern & Fineberg, 1996). It is of great importance <u>how</u> risk is defined. There is a clear distinction between probabilistic definitions of *risk* and definitions where probabilities are absent. This will be discussed further in chapter 3.5.2 below.

As mentioned earlier, the term *risk analysis* is often used as a concept including *risk assessment* and *risk evaluation. Risk analysis* can be defined as an activity that applies analytic techniques to the understanding of risks. Sometimes *risk analysis* is also used synonymously with *risk assessment*.

The *risk assessor* is the person or party performing the risk assessment, while the *risk manager* is the one in charge of the problem. The *risk manager* makes the decisions, based on information from the *risk assessor* and other involved parties.

In environmental risk assessments, *harm* may be defined as a negative impact on human health or the environment.

Hazard is an act or phenomenon that possesses a potential to produce harm to humans or what they value (Stern & Fineberg, 1996). Typically, hazard refers to the source of a risk, for example a toxic chemical that is a hazard to human health or the environment. A hazard alone does not constitute a risk, though. A hazard <u>and</u> its exposure to humans or the environment create the risk.

The term *stressor* is often used in ecological risk assessment. A stressor is a substance, circumstance, or energy field that causes impact upon a biological system. Stressors can be biological, physical, or chemical in nature (Landis & Yu, 1995). In this report chemical stressors are considered.

In the following, risk assessment, risk evaluation and risk management will be described in more detail.

3.2 Risk assessment

3.2.1 Framework for risk assessment

A framework formulated by the National Research Council (1983) for use in the U.S. federal agencies is the most frequently referred in environmental or ecological risk assessments. Originally, this framework was written specifically for hazards to humans, but the same principles can be used, and are being used, in environmental and ecological risk assessment. The framework defines four phases in risk assessment:

- Hazard identification (or hazard assessment)
- Dose-response assessment
- Exposure assessment
- Risk characterisation

Sometimes, especially in ecological risk assessment, an initial phase is introduced, see for example U.S. EPA (1992) or Landis & Yu (1995):

- Problem formulation

It must be pointed out that the conceptual framework presented here is maybe the most common one for environmental problems but still one of many, see for example Covello & Merkhofer (1993). Usually however, other frameworks are similar, although the terminology may differ slightly as presented below.

Problem formulation
In the *problem formulation* phase the goals and focus are established through discussions between risk assessor and risk manager. These discussions are an important part of the problem formulation. Major factors to be considered are identified and working hypotheses are developed (Wentsel et al., 1997). In the problem formulation all aspects that have a significance or are of importance for the involved parties should be addressed. Problem formulation can be a crucial part of the risk assessment since it sets the agenda for the following phases (Landis & Yu, 1995).

The problem formulation phase continues with several sub-phases, including stressor characterisation, characterisation of exposure and ecological effects, identification of ecosystems potentially at risk and construction of a conceptual model (Wentsel et al., 1997).

3.2.2 Hazard identification

Hazard identification is the phase where the effects of the stressor are identified. Hazard identification includes collecting information about the toxicity of the stressor, i.e. the harmful substance. It does not deal with concentrations and is not probabilistic in nature (Landis & Yu, 1995). The twofold question that hazard identification should attempt to answer is:

- Is there a hazard, and if so, what is it?

During the hazard identification the physical and chemical properties of the hazard is identified, together with the toxicological effects and possible routes of exposure (Neely, 1994). The effects of the hazard can be separated into effects on human health and effects on the environment. To determine these effects, information needs to be collected about acute toxicity to humans, carcinogenity, acute aquatic toxicity, degradability, ability to bio-accumulate and a number of other properties.

Hazard identification is often included in the problem formulation phase previously described.

3.2.3 Dose-response assessment

In the *dose-response assessment*, a quantitative relationship between the dose of the stressor and the adverse effect is established. This can be done in different ways, for example from experiments on humans, animals or plants, or from epidemiological studies. Safety factors are used to allow for the uncertainties inherent in the data (Elert et al., 1996). In some frameworks this phase of the risk assessment is incorporated in the hazard identification or the exposure assessment. The dose-response relationship is often expressed as “exposure of X parts per million of substance Y for a period of Z hours can produce liver damage” (Davies, 1995).

3.2.4 Exposure assessment

In the *exposure assessment*, modelling or analytical tools are used to assess the magnitude of the exposure of the harmful substance to humans or the environment. The typical question to be answered during the exposure assessment is:

- What exposure can be anticipated under different conditions?

A convenient way of assessing the exposure of a stressor to the environment is by studying the concentration of the stressor in the environment. The concentration is site-specific and is depending on many different parameters. In many cases, the concentration alone cannot be used as a measure of the exposure, since many other factors may be of importance for the uptake of a harmful substance into an organism. A specific concentration may cause different exposures under different conditions, depending on the behaviour of the organism, and of course on the exposure duration. The uptake into the organism may vary due to changes in light, humidity, temperature and a number of other factors.

In ecosystems, hazard and exposure are not easily separated (Stern & Fineberg, 1996). The environment affects the released substance and vice versa.

3.2.5 Risk characterisation

The next phase in the risk assessment process is *risk characterisation* and is often regarded as a synthesis and summary of the previous steps. The purpose of this phase is to combine the information from dose-response assessment and exposure assessment to estimate the amount of adverse effects that will be caused by a substance or other risk source (Davies, 1995). This is usually formalised into a quantitative description of the risk. The risk characterisation provides a good foundation of relevant scientific information for decisions to be made during the following phases (risk evaluation and/or risk management).

Sometimes risk communication is included in the risk characterisation phase, see for example Moore et al. (1997). In this case the purpose is to present the risk in such a way that it can be easily understood. Some writers have an even broader view of risk characterisation, see for example Stern & Fineberg (1996).

3.3 Risk evaluation and risk management

Risk evaluation and *risk management* has briefly been described above. The term risk management is widely used for environmental problems, especially in U.S. risk literature. Usually, risk management has a much broader meaning than risk evaluation. Risk evaluation involves comparing and judging the significance of risk (Covello & Merkhofer, 1993), often by means of acceptance criteria. Risk management on the other hand, may be defined as decision-making, and is a phase where governments, agencies and municipalities, etc. handle and make decisions in risk-related matters. In Sweden, the term risk management (in Swedish: *riskhantering*) is often defined to be all-embracing, comprising all risk-related activities.

During risk evaluation the acceptability of a risk is evaluated but the final decision is usually made during the risk management. The term risk evaluation (in Swedish: *riskvärdering*) is frequently used in Swedish risk literature, for example in publications by Räddningsverket (1989; 1997 & 1998) and by the Swedish Environmental Protection Agency (Naturvårdsverket, 1997). In U.S. risk literature the term is more sparsely used, at least for environmental problems. Often, risk evaluation can be considered as one of many parts of the risk management process, see for example Räddningsverket (1989). In other cases it is separated from the risk management, as by Covello & Merkhofer (1993), but the boundary between the two is rather indistinct.

In contrast to risk assessment, which often is considered to be free from subjectivism, risk management considers scientific, technical, social, economic, ethical and political values. An important part of risk management is *risk communication*. Due to uncertainty in the risk assessment, communication with the public and other involved parties can be crucial for the outcome of the risk management.

Note that the definition of risk management can vary considerably between different authors. Sometimes it is used for the decision-making phase, as mentioned above. Often it includes all risk-related processes other than risk assessment, such as administration, insurance, inventory, evaluation, communication, decisions and implementation.

3.4 The risk assessment - risk management distinction

In practice there is often a diffuse distinction between risk assessment and risk management. Traditionally, risk assessment is believed to be scientifically objective and free of subjectivism, in contrast to risk management. However, the distinction between risk assessment and risk management is widely debated and controversial. Some researchers claim that risk assessment must be kept free from individual (subjective) judgement, others that this is impossible in practice, whereas still others mean that there is, and must be, an overlap between the two phases.

It can be argued that it is impossible for the risk assessment to be absolutely objective. For example, estimating the effects of a hazard can be difficult or impossible to do in a theoretically objective way, and even in the problem formulation of the risk assessment it may be impossible to define the problem without subjectivity. Usually, choices have to be made regarding which effects and consequences should be considered and which to be ignored, in fact an act of judgement. Uncertainty encloses the conclusions that are made. This implies that risk assessment often includes a subjective component, even if it is not desirable. The ambition must be to move the subjective decisions and individual judgement from the risk assessment to the risk management (or to the risk evaluation, if this term is used). The subjective component in a risk assessment can be minimised by using “the best scientific knowledge”.

It is important to note that there may be subjective influences in the direction from risk assessment to risk management but this should not be the case in the opposite direction (Cothern, 1996). Influences from risk management to risk assessment mean that value judgement and subjectivity enters the risk assessment and this should be avoided. As previously mentioned, this is often impossible to avoid in practice. However, measures should be taken to control the subjectivity.

3.5 Conceptual framework for risk assessment of secondary materials

3.5.1 General

Earlier in this chapter, the risk terminology has been discussed. In this chapter a conceptual framework for risk assessment of secondary materials will be presented, based on the conclusions of that discussion. Principally, risk assessment will have to be performed at different occasions:

1. When guideline values or limit values are developed for substances that can be harmful to human health or the environment.
2. In specific projects, where secondary material is planned to be used as construction material. In this type of risk assessment, the risk associated with the use of the materials will be assessed with the help of different criteria, such as limit or guideline values.

Today, the number of limit or guideline values for different substances and different media is incomplete. The first type of risk assessment, listed above, has to be performed when additional guideline or limit values are developed. This is done in a conventional way and is not a part of the conceptual framework presented here.

The second type of risk assessment is the one covered in this report. In Figure 3.2 the conceptual framework is presented graphically and in Figure 3.3 the same framework is presented in Swedish. The framework consists of three basic phases; risk assessment, risk evaluation and risk management. The system for risk assessment of secondary materials, to be developed, will cover the encircled area named "risk assessment" in Figure 3.2, together with certain criteria. The objectivity of the risk assessment will be met by means of using scientific methods in this phase. The "risk management" part will be left with the authorities, organisations, and companies that will use the system.

In this framework, not all principles and concepts presented in chapters 3.1-3.4 are used. Therefore, the concepts in Figure 3.2 will be defined in the following chapters.

3.5.2 The concept of risk

As described in chapter 3.1 the concept of risk can be defined in different ways. A distinction can be made between probabilistic definitions and other definitions of risk. In technical applications the risk is usually made up by the probability of a harmful event and its consequences. However, in the framework proposed in this report there is no possibility to reliably calculate the *probabilities* for harmful effects, without making the system too complicated for its purpose. Therefore, the concentration of a substance at the target points will be used as an indicator of the harmful effects on the environment. When the concentration exceeds the acceptance criteria (guideline values, limit values etc.), the consequences are regarded as unacceptable. There is a certain probability for the concentration to exceed the acceptable level at a target point. In the proposed framework this probability will be calculated based on parameter uncertainty, i.e. uncertainty in the parameters describing the *source* of the harmful substances, the transport *path*, and the *target points*. Thus, the risk is defined as a combination of the *probability* for the concentrations to exceed the acceptance criteria at the target points, and the *consequences*. This implies that the risk concept, as used in this report, is a probabilistic one.

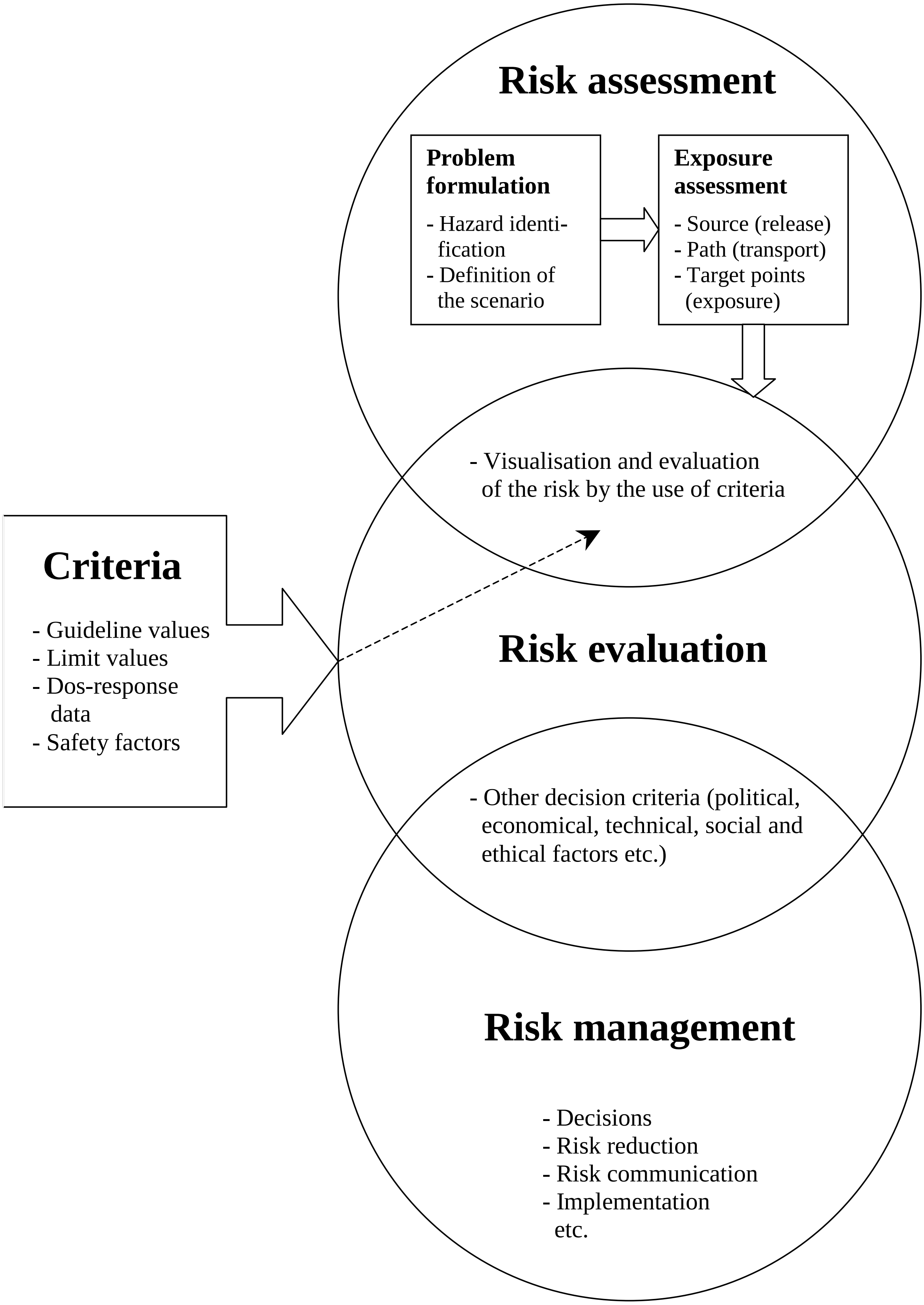

Figure 3.2. Conceptual framework for risk assessment of secondary materials for construction purposes, as described in this report.

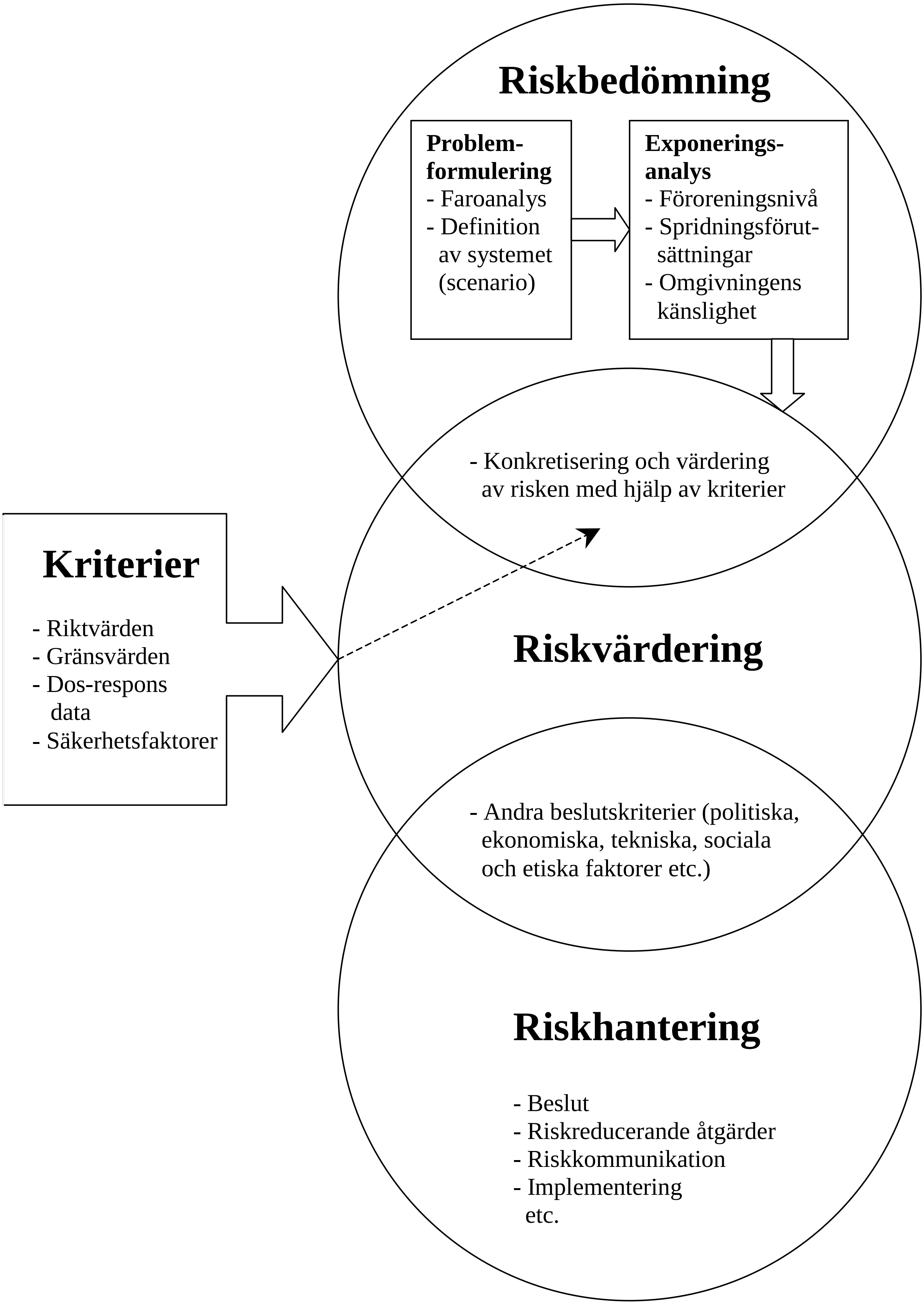

Figure 3.3. Conceptual framework for risk assessment of secondary materials for construction purposes (in Swedish), as described in this report.

The risk concept is valid for each individual substance that is considered in the risk assessment. Different characteristics for different substances will affect the calculated risk. Also, the safety factors, which usually are used for dose-response data, will be taken into consideration when the uncertainty at the target points is calculated and the risk is assessed.

3.5.3 Risk assessment

Problem formulation

Problem formulation is the first step of risk assessment. In the problem formulation the secondary material is studied and possibly harmful substances are identified. One way of doing this is by performing laboratory tests of the total content of a number of different substances in the material. This step is commonly referred to as *hazard identification*. If applicable guideline or limit values do not exist for the identified substances, such values may have to be developed (see chapter 3.5.1).

In the problem formulation phase, the scenario in which the material will be used, has to be defined. All aspects that are of importance or have significance must be considered (Figure 3.4). As an example, this may include characterisation of the source of the harmful substance, characterisation of exposure paths, and identification of different target points (end points).

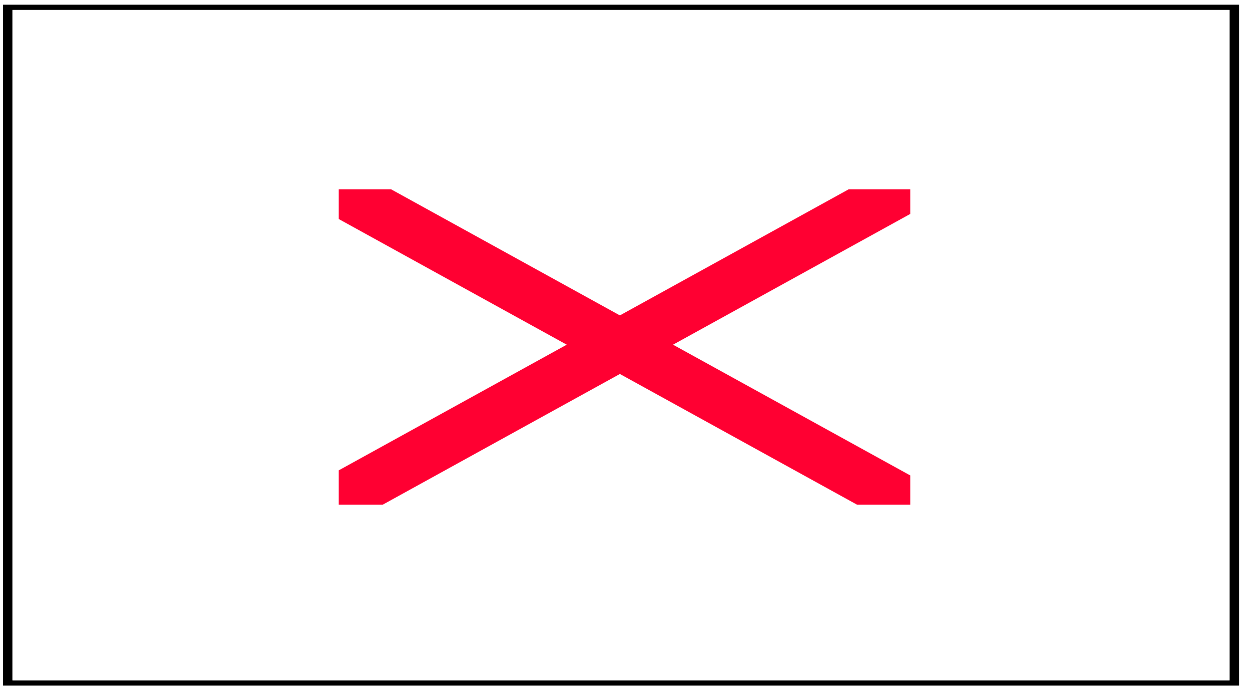

Figure 3.4. In the problem formulation phase, the scenario under which the secondary material will be used, is defined. The scenario both comprises the construction where the secondary material is being used, and the affected surroundings. Modified from Lundgren & Elander (1987).

Exposure assessment

Since criteria such as guideline values will be used to assess the risk, the step “dose-response assessment” presented in chapter 3.2.4 and Figure 3.1, can be omitted. Usually, the dose-response data have already been considered during the design of the guideline or limit values.

This implies that dose-response data are introduced through guideline values or limit values during the risk evaluation (Figure 3.2).

In the step of *exposure assessment,* exposure at different *target points* is assessed. In this framework this is done by calculating the increase in concentration at the target points, caused by release of a particular substance, i.e. the concentration is used as a measure of the exposure. This simplification is made to avoid that the system becomes too complicated for its purpose. It is also assumed that the biological uptake into different organisms has been considered in the guideline values. To calculate concentrations at the target points, the release of substances from the *source* have to be considered, together with the transport *path*.

The release of substances from the source is a prerequisite for exposure to occur. Therefor, quantification of the release is an important part of the exposure assessment and it is sometimes given a specific name: *release assessment* (Covello & Merkhofer, 1993). The release can be quantified by performing different types of laboratory leaching tests on the secondary material. Data from these tests, together with information about the transport path, is then used in a *transport model* to calculate the increase in concentration at the target points at different duration. This will be the output from the exposure assessment. Transport and exposure in different media have to be considered in the model, primarily in groundwater and surface water.

3.5.4 Risk evaluation

According to Figure 3.1, after exposure assessment would follow “risk characterisation” but this phase has been omitted in this framework. The reason is that the output from the exposure assessment is directly compared with criteria, according to Figure 3.2. In the criteria the dose-response data have already been considered. By means of comparing the calculated concentrations with criteria the risk is roughly “characterised” but *risk evaluation* is a better term for this phase than “risk characterisation”.

In the risk evaluation the calculated concentrations from the exposure assessment is compared with guideline or limit values. As Figure 3.2 shows, there is an overlap between risk assessment and risk evaluation. The risk assessment is relatively objective and free from individual judgement, except for subjectivity that may have entered in the problem formulation. In this framework, the risk is made concrete and is visualised by the use of criteria such as guideline or limit values. This means that criteria affected by value judgement also will influence the assessment of the risk. Therefore, the comparison of data from the exposure assessment with guideline or limit values is considered to be a part of the risk evaluation. This phase is supposed to contain value judgement to a slightly higher degree than the rest of the risk assessment.

When the guideline or limit values are used in the risk evaluation, a qualitative measure of the risk associated with the use of the material is determined. As mentioned earlier, these values are designed and developed outside the framework presented here.

It is important to note that by using criteria such as guideline values, the framework will be affected by uncertainty or systematic errors in these values. This must be taken into consideration when the risk is evaluated.

It is possible to simplify the presented risk assessment process. Instead of model calculations of concentrations at target points (exposure assessment) for each construction project, where the system is used, a limited number of standardised scenarios (Figure 3.4) may be defined. For each scenario there will be a set of guideline or limit values, not for the target points, but instead for the source (the secondary material). Information from laboratory tests on the material are then compared to these criteria (guideline values etc.) to assess and evaluate the risk.

3.5.5 Risk management

In this framework, *risk management* is defined as the process when authorities, municipalities, companies or organisations make decisions (based on the risk assessment) and handle other issues related to the risk problem of secondary materials as construction materials. How this is done in practice is up to the involved parties and is not covered in this report. However, it is important to note that risk communication will be an important part of risk management.

In risk management other types of criteria than guideline or limit values may be regarded, such as political, economical, social and ethical decision criteria. This phase can be considered to be a part of the risk evaluation (Figure 3.2). However, risk management contains value judgement and subjectivity to a higher degree than the previously described phases.

4 INTERNATIONAL AND NATIONAL SYSTEMS FOR ASSESSING RISK ASSOCIATED WITH THE USE OF SECONDARY MATERIALS

4.1 Introduction

Primary and secondary building material contain organic and inorganic compounds, naturally, as well as through contamination or as a result of the production process. Examples of these compounds include heavy metals in municipal solid-waste incineration bottom ash (MSWI-bottom ash), tar compounds in construction and demolition waste and sulphate in mine wastes.
When building materials are exposed to rain or groundwater, these compounds can be released (through leaching) and spread into the soil or into surface water. This chapter contains a review of systems developed in other countries to ensure that secondary materials are used in construction works in such a way that degradation of soil and groundwater quality are minimised.

The review of systems used in other countries covers the Netherlands, France, and Denmark. International systems have been considered briefly. The systems summarised in this chapter include a methodology under development by the European Committee for Standardisation (CEN) and relevant EU directives with associated documents. The following table shows how far the systems in these countries have been developed:

Table 4.1 National and international systems studied.

Country/Organisation	System
The Netherlands	Building materials decree 1996 Phase 1 introduced 1996 Revision, 1999
Denmark	Basis for a general system has been developed, 1998
France	MSWI – regulations Other materials, early 1999
CEN	Methodology for determination of leaching behaviour of waste under specified conditions. Pre-norm, 1998
EU	Council directive on waste, 1991 (amending directive 1975) Council directive on hazardous waste, 1991 Proposal for council directive on landfill of waste, 1996

Each of the systems studied is described in Appendix A.

All the methods studied include leaching-based criteria. The authorities developing the methods regard leaching-based criteria as the most appropriate basis for protection of groundwater. A valid relationship does not exist between other criteria, e.g. the result of total analysis of material carried out after partial digestion of the solid phase and groundwater pollution. Criteria based on solid-phase analysis are more usually associated with evaluation of the health-risks associated with the direct exposure of man or animals to the material, (e.g. dermal contact, oral intake or inhalation).

4.2 What is included in a system for risk assessment

A system for the assessment of the risks to health and the environment associated with the use of secondary materials in construction must be made up of a number of sub-models or sub-systems. Generally, systems for assessment of the risk associated with the use of secondary materials in construction can be said to consist of one or more of the following:

- Characterisation of material with respect to the content of hazardous substances
- Characterisation of material with respect to the leaching behaviour of hazardous substances
- Study of leaching of hazardous substances from the material after placement in a construction
- Transport of hazardous substances to environmental media where exposure of man/other organisms occurs
- Determination of exposure pathways and quantification of exposure of man/other organisms to the contaminant
- Assessment of the health effects or environmental effects associated with the exposure
- Risk evaluation

Risk assessment based guideline or limit values represent values of a parameter at some point in the system which corresponds to an acceptable risk. When the guideline or limit values are applied, a comparison is made between the measured values of a parameter and the calculated acceptable value.

The way in which the studied methods are made up of the various subsystems is presented in table 4.2, below. The thick lines in the table show the point at which limiting or guideline values are set, i.e. the point of comparison between the measured values and the calculated "acceptable" values.

The methods studied cover different parts of the whole system. The methods from the Netherlands and Denmark are the most complete methods, in that they cover the whole system from the characterisation of the secondary material to the estimation of risks associated with exposure to contaminants released from the material. The French directive, which will be replaced, is concerned only with characterisation of material. However, the literature studied in this project does not make clear the basis to the limits set for contaminants concentration in leachate from the material. It is possible that this basis includes consideration of other parts of the assessment system. The EU directives are also mainly concerned with the determination of waste characteristics. The CEN framework for assessment of covers both aspects of characterisation of the material and modelling of the release from material under specific conditions (a well-defined scenario).

The sub-systems making up the method depend to a large extent on the aim of the method. The CEN methodology and the EU directives are not directly concerned with limiting risk from the use of secondary materials. The emphasis of the CEN methodology is the identification of which parameters are important in determining the leaching behaviour of waste materials. The EU directives are concerned more generally with the identification of waste types and hazardous materials and the characterisation of waste with respect to its content of hazardous substances and its environmental behaviour (e.g. leaching behaviour, decomposition etc).

The level of detail contained within each subsystem is also dependent on the aim of the method. The two methods from Denmark and the Netherlands, which have been studied in most detail, have different objectives for environmental protection. The Danish method aims to protect groundwater resources, having made an a-priori decision that this exposure pathway is the most important for substances released from constructions. As a result, the methodology is based on acceptable concentration increases in groundwater, considering only transport to and within a groundwater resource and the drinking-water exposure pathway. The method adopted in the Netherlands aims to protect the soil by setting limits for the immission of substances to the soil. This method protects groundwater and surface waters implicitly, with the reasoning that if soil is protected to the level required, unacceptable contamination of ground- and surface waters will not occur. The method is based on the assessment of risk to man and the environment.

Table 4.2 Overview of systems studied. Thick lines show point where limit values are applied.

	Netherlands		**Denmark**	**France**	**CEN**	**EU directives**
Hazard identification	Substances requiring special attention, black-listed or priority substances		Method for prioritisation of test substances	Important components of MSWI* ashes	Included	Waste (91/156/EEC) Hazardous waste (91/689/EEC)
	Immission -value	**Composition-value**				
Leaching behaviour of material	Standard methods		L/S# depends on scenario	Standard method	Included	Landfill of waste (proposal,1996)
Leaching from the construction	Without with and with extra isolation measures		Seven scenarios defined	-	Included	-
Transport to recipient media	Immission to soil only	Model	Dilution factor	-	-	-
Exposure pathways	All pathways of exposure to soil		Drinking water	-	-	-
Health risks	National criteria		National criteria	-	-	-
Risks to environment	National criteria		National criteria	-	-	-
Risk evaluation	Isolation measures required for non-complying materials			-	-	-

*MSWI – Municipal Solid Waste Incineration
#L/S – Liquid/Solid ratio in leaching tests

4.3 Hazard identification

The prioritisation of substances for analysis during the testing of secondary materials can be based on a number of systems.

In the Netherlands, the building materials decree covers a large number of substances for which national environmental quality objectives have been developed (VROM, 1994). These substances have been selected on the basis of three national lists. The list of chemicals requiring special attention is based on the Chemical Substances Act and is prepared by the Ministry of Housing, Spatial Planning and the Environment. The list of priority substances is based on the fact that in one or more locations in the Netherlands, risks to health and the environment from these substances are greater than negligible. Policy decisions have been issued for the most important priority chemicals. Similar blacklists of chemicals have been developed by the EEC and by international agreements e.g. the Oslo Paris convention.

In Denmark, the assessment methodology itself contains a method for the prioritisation of substances in a test programme. This method is based on the leaching characteristics of the material as measured by simple batch tests, or “availability” tests.

The substances considered in the three national systems studied are shown in table 4.3. The number of substances varies greatly between these countries. The difference can partly be attributed to the extent to which the underlying assessment system has been developed in the different countries, i.e. the number of substances for which toxicological reference values are specified or the number of substances for which environmental quality standards or benchmarks have been set. The differences also represent the extent to which prioritisation has been carried out, either as part of the assessment system, as in Denmark, or by an a priori decision, as in France.

The EU directive on hazardous waste (91/689/EEC) identifies a large number of substances which may render waste hazardous, depending on the properties of the waste (see Appendix A). The directive also identified several waste properties which render waste hazardous. This type of list may also be used to help prioritise the substances for consideration in an assessment.

Table 4.3 Substances considered in three national systems

Netherlands	**Denmark**	**France**
Immission – values Sb, As, Ba, Cd, Cr, Co, Cu, Hg, Pb, Mo, Ni, Se, Sn, V, Zn Br^-,Cl^-,CN (free, complex, thiocyanates), F^-, SO_4^{2-} ***Composition – values*** BTEX, styrene, phenol, cresol, dihydroxybenzenes PAH (10 and total) Vinylchloride, dichloromethane, dichloroethane, trichlormethane, trichloroethylene, tetrachloroethylene, chloronaphthalene Chlorobenzenes (10 and total) Chlorophenols (total) PCP PCB (total of 7) EOX (total) Pesticides Cyclohexanone, phtalates, mineral oils, pyridine, tetrahydrofurane, tetrahydrothiophen	***Coal fly-ash*** 1. SO_4^{2-}, Ca, Na, K, As, Cr, Mo, Se, V (Cd, Cu, Ni, Pb, Zn) 2. B, ammonia 3. Sb ***Coal bottom ash*** 1. SO_4^{2-}, As, Cr, Cu, Mo, Se,V (Cd, Ni, Pb) 2. B, K, Na, Ca 3. Sb ***MSWI slag*** 1. SO_4^{2-}, Cl^-, Ca, Na, K, Al, As, Cd, Cr, Cu, Mo, Ni, Pb, Zn, NVOC 2. Ba, Se, total N 3. Sb	Incompletely combusted material Hg Pb Cd As Cr S TOC

4.4 Characterisation of leaching behaviour

In all the methods studied, the characterisation of the leaching behaviour of secondary materials is carried out by means of leaching tests.

The type or types of leaching tests suggested or specified differ. The EU directive on waste does not specify standardised methods, but does state that a thorough determination of the short and long-term leaching behaviour should be carried out.

In the Danish method, no leaching test is specified, though different types of leaching test are discussed. Batch leaching tests with L/S of 2 and/or 10 are discussed, particularly in respect of characterisation of the “availability” of contaminants at the prioritisation stage. Column tests are suggested for situations where tests with L/S ratios <2 are relevant. In the Danish system, scenario specific considerations determine the L/S ratio to be used in the leaching tests carried out to determine the release of contaminant from the material used in a specific construction scenario.

In the Dutch system, different leaching tests are used for different types of leaching processes, i.e. diffusion and non-diffusion driven leaching. To estimate emission from non-prefabricated materials, a standardised column test is used with a L/S ration of 10. For prefabricated construction materials, a standardised diffusion test is used.

In the French system, again, a standardised leaching test is used. This leaching test (three step batch test at L/S 10) determines the amount of contaminant leached in three subsequent elutions.

4.5 Leaching from the construction

The effect of site-specific factors and of the construction itself on the leaching of contaminants from the material is considered in a simplified model way in both the Danish and Dutch model. The factors which are considered to be important in both models are the local infiltration of rainwater, the modification of infiltration by the surface characteristics of the construction, and the height and the bulk density of the material in the construction. In the Danish system, the values of these parameters are determined by the scenario adopted in the assessment. In the Dutch system, alternative infiltration rates are assumed for scenarios where isolation measures are and are not used; 6 and 300 mm/year respectively. The maximum allowable emissions have then been tabulated for a range of heights within the construction. Leaching from the construction is not considered explicitly in the French system, though the restrictions placed on the use of the secondary material which take into account the same factors as in the Dutch and Danish systems.

Both the Netherlands and the Danish systems consider average values for leaching/emission over time, rather than the time course of emission from the source. Both methods therefore accept that the maximum acceptable values may be exceeded at the beginning of the time period, as long as they are not exceeded by the time-averaged values for the relevant time period. In the Netherlands, the time period considered is 100 years. In Denmark, the time period is set for each contaminant, depending on its chemical and physical properties.

4.6 Transport to the recipient

As with leaching from the construction, transport to the recipient medium to which man or the environment is exposed is modelled in a simplified way. In the Danish system, the process of transport to and dilution within the recipient groundwater magazine is represented by a dilution factor; the ratio between the area of the material in the construction and the catchment area of the recipient groundwater magazine. No retardation of the contaminant within the aquifer is considered.

In the Dutch system, transport is not modelled explicitly, as the system considers only immission to the soil. However, the maximum acceptable immission to soil is calculated from the target value for concentrations of contaminants in soil. Target values are based on a model which includes transport from surface soil to groundwater, surface water and air. The model is based on the fugacity concept, i.e. equilibrium partitioning coefficients between the solid, liquid and gaseous phases in the soil. The pore-water is then assumed to be diluted on reaching the groundwater and surface water.

4.7 Exposure pathways

In the Danish system, only one exposure pathway is considered in the leaching based criteria; the drinking water pathway. (In the composition based criteria for soils, the direct ingestion of soil by children is the only exposure pathway taken into account.) The Dutch model is based on the target values in soil, which are calculated by considering all relevant exposure pathways (see Appendix A). The choice of exposure pathways for inclusion in the system is dependent on whether a priori decisions are made about the relative importance of different exposure pathways.

4.8 Assessment of health risks

The assessment of health risks associated with exposure to a given contaminant is carried out in a similar way in both the Netherlands and Denmark (and in Sweden, see chapter 5). The assessment is based upon information on the dose-effect or dose-response relationship for man. The dose-response data is used to identify a safe dose or a threshold toxic level for a particular adverse effect. The threshold level is established from the results of experiments and epidemiological studies. Safety factors are used to allow for the uncertainties inherent in the data. For most contaminants, this threshold level is expressed as a tolerable daily intake (TDI, expressed in mg/kg body weight/day) for the oral exposure pathways. For the inhalation pathway, a reference air concentration (RfC, expressed in mg/m^3) is used.

For genotoxic carcinogenic contaminants, it is not possible to express a “safe” or threshold dose as even low doses can imply a cancer risk. Increased doses do not affect the severity of the effect, but do increase the risk of the effect occurring. Mathematical extrapolation models which are linear in the low dose region are used to determine the exposure to a chemical which is equivalent to an acceptable risk level. The risk level used in Denmark is a lifetime excess cancer risk of 10^{-6}, which is approximately the same as that on which the Netherlands’ target value is based; 10^{-8} per year.

Toxicological reference values, e.g. TDI values or the intakes or exposures corresponding to a given risk level, are given for a large number of substances by several international or national organisations. Examples are the WHO and the US EPA. Values in these databases have been derived by expert committees after a critical review of the available data. Some countries, e.g. the Netherlands, have their own databases of toxicological reference values. The WHO toxicological reference values are usually adopted in Sweden (e.g. in the Swedish drinking water limits, (Swedish Food Administration, 1993).

4.9 Assessment of risk to the environment

In both the Dutch and the Danish system, the ecotoxicologically based values for soil quality criteria are based on the extrapolation of the results of toxicity tests on a limited number of species. In both systems, the results of toxicological tests reported in the literature are reviewed and assessed for their relevance to chronic exposure of soil organisms. Studies reporting the no-observed effect concentrations (NOECs) from long-term experiments are given priority. In both countries, a statistical technique has been used where possible to extrapolate from the results of ecotoxicological tests on individual species to determine the concentration in soil which is considered to be sufficiently protective of the environment. Where the data are fewer, the lowest NOEC value is often divided by a safety factor to account for the amount and quality of the data.

In Denmark, the reported NOEC values have been assessed to set a level considered to be protective of all soil organisms. This method is similar to that which has been used to derive environmental assessment bases for metals in agricultural and forest soils in Sweden (see chapter 5.2).

In the Netherlands, the criteria represent the level at which there will be no serious disturbance of the soil's capacity to carry out a range of ecological functions. The assumption is made that protection of most of the plant and animal species in the soil will protect the soil function. (If the percentage of species which is disturbed is small, then the chance that the disturbed species is important in terms of ecosystem function is small.) Soil function is assumed to be endangered if the species composition is severely changed. The NOECs for a range of organisms, representative of the range found in soil, are used to construct a distribution curve. This distribution is used to identify the contaminant concentration corresponding to the desired level of protection, expressed as the percentage of species which will not be affected by the contaminant at that concentration. The level of protection chosen for the intervention values is equivalent to protection of 50% of species. The maximum tolerable risk (MTR) is equivalent to protection of 95% of species. The target value is set at a concentration 100 times lower than the MTR.

5 RELATED SYSTEMS IN SWEDEN

5.1 Introduction

In Sweden, assessment methodologies developed for a variety of purposes include some parts of the risk assessment process outlined in Chapter 4.1. However, some parts of the process have not included any existing Swedish methodology. Systems existing in Sweden which have been identified as relevant are shown in Table 5.1:

Table 5.1 Existing systems in Sweden relevant to the assessment of risks associated with the use of secondary materials. Each of these methods is described in Appendix B.

Agency	**System**
Swedish National Chemical Inspectorate	Classification and marking of chemical products
Swedish Environmental Protection Agency	Environmental Assessment Values for • Groundwater • Surface water • Agricultural soils • Forest soils • Contaminated areas
Swedish Environmental Protection Agency	Generic guidelines for contaminated soil
Swedish EPA and Swedish Petroleum Institute	Guidelines for contaminated petrol station sites
Swedish Environmental Protection Agency	Quality criteria for compost and sewage sludge
Swedish Environmental Protection Agency/Länsstyrelsen i Hallandslän	Procedure for selection of grunting compounds with regard to health and environmental safety.

In the remainder of this chapter, the methods developed in Sweden are discussed against the background of other national and international systems. Table 5.2 summarises the available methods being used for each part of the risk assessment system. The available methods are briefly discussed according to their relevance to a system for assessment of risks associated with the use of secondary materials.

5.2 Characterisation of material

There are two systems in Sweden which are related to the characterisation of material.
The EU directive on hazardous waste (which is enforced in Sweden by SNFS 1996:971, Förordning om farligt avfall) contains a list of substances which render waste hazardous if coupled with certain properties of the waste. This type of list could be used to help determine the types of materials, or substances contained in the materials for which an assessment is necessary. The National Chemicals Inspectorate system for classification and marking of chemical products, KIFS 1996:5 (also based on an EU directive), is a much more detailed hazard assessment of different chemicals. Again, this list could be used in the prioritisation of chemicals for assessment. However, these methods are derived for different purposes and are not completely suited to the assessment of substances for secondary materials.

The Danish system contains a method for the prioritisation of substances for analysis and assessment for different materials, ie to prepare material-specific lists of substances for analysis. No equivalent system exists in Sweden. This type of study (eg, a pre-study of different types of material) could also form the basis for an assessment system. Commonly arising materials need to be considered. New materials will always need to be tested before a risk assessment can be carried out.

Some methods in Sweden and in other countries are based on the analysis of the total composition of material, e.g. the Swedish guidelines for contaminated soil and the Netherlands composition values. These methods do not consider the leaching behaviour of the material explicitly. For secondary materials, methods based on total composition are generally only employed where no suitable tests exist for characterisation of the leaching behaviour, as it is difficult to relate total composition to effects on the groundwater.

Sweden is currently contributing to the development of a European standard for the characterisation of the leaching behaviour of waste within CEN. The different countries studied refer to standardised tests for the characterisation of leaching behaviour. The tests chosen depend to some extent on the methodology adopted. In Denmark, the scenario chosen to represent the mode of employment of secondary material, taking site-specific factors into account, is used to the most appropriate leaching test conditions. In the Netherlands, the most appropriate leaching test is chosen taking into account the physical characteristics of the material and the construction.

5.3 Leaching from the material in-place in the construction.

No method for calculating leaching from in situ material in constructions has been developed in Sweden.

In both the Dutch and Danish systems, the geometry and physical and chemical properties of the in situ material is represented in a simplified way, which facilitates calculation of the maximum acceptable leaching of contaminants from the construction. This value can then be compared with data from leaching tests. Both systems take into account site specific factors, though the Danish system considers a larger number of alternative scenarios.

During the development of a system for risk assessment of secondary materials, some consideration must be given to the extent to which site-specific and scenario or construction specific factors are to be taken into account. This point applies equally to transport of contaminants to the recipient (see 5.4, below).

5.4 Transport to recipient

The Swedish EPAs guideline values for contaminated soil contain a simple model for transport of contaminants from soil to groundwater, surface waters and soil. The model is an equilibrium model, based on equilibrium partitioning coefficients, and does not take into account depletion of the source term. A dilution factor is used in Denmark to account for transport and dilution of contaminated leachate into the groundwater. This approach is thought to be conservative, as retardation of the contaminant along the transport path is not considered. As the Danish system is based on groundwater protection, and does not consider other media or exposure pathways, this simple method is probably adequate. However, if contamination of soils and other media is to be considered, a more complete transport model is needed to account for the important processes. Dilution factors may be used in conjunction with factors to account for the partitioning of the contaminants in the environment. A good example of this approach is the treatment of transport to groundwater in the model used in

Sweden to calculate guideline values for contaminated petrol stations (Swedish EPA/SPI, 1998).

It may be necessary to consider source depletion as a result of leaching, as the source term associated with constructions in which secondary materials are used may be small.

5.5 Exposure pathways

The Swedish model used to develop guidelines for contaminated soil considers several exposure pathways. The choice of exposure pathways and the magnitude of exposure via each pathway is dependent on the land-use (scenario-specific) considered. This type of system could also be adopted for the assessment of secondary materials. The land-uses considered would need to be relevant to different types of construction, e.g. road construction. It may be necessary to develop new land use scenarios in order to cover all the relevant land use types.

5.6 Assessment of risks to human health

The Swedish model for development of soil guideline values adopts similar methods for the assessment of risks to human health as those adopted in the Dutch and Danish models, though the databases used for toxicological reference criteria may differ (see chapter 4.8). Differences arise in the level of risk considered to be acceptable for substances with non-threshold effects. In Sweden, the model for guidelines for contaminated soils is based on a lifetime risk of excess cancer of 10^{-5}, whereas the systems studied from other countries for risk assessment of secondary materials consider a value of 10^{-6}. The difference in values adopted is partly explained by the difference in aim between these two types of system. Systems for risk assessment of secondary materials aim to prevent negative effects arising from use of the materials, whereas systems for assessment of contaminated areas aim to set remediation goals and priorities.

Similar methods will need to be used for a system for risk assessment of secondary materials in Sweden. It should be noted that the list of substances considered in the Swedish guidelines for contaminated soils do not include all the substances which are potentially of importance for assessment of secondary materials. Toxicological reference data for these substances will therefore be needed.

5.7 Assessment of risk to the environment

Several related systems in Sweden contain assessment of risks to the environment. All these values are based on the extrapolation of ecotoxicological test data on a limited number of species to ecosystem level.

One of the methods used attempts to set the “critical” level of contamination, i.e. the concentration above which effects on species begin to be observed at the population level. The critical concentration in soils and water is determined by finding the lowest no observed effect concentration (NOEC) or lowest observed effect concentration (LOEC) and dividing with a safety factor which takes into account the quality of the database. The Swedish environmental assessment values use this method, as does the method used to set limiting concentrations for the use of sewage sludge and compost. However, assessment values have only been developed for a small number of contaminants.

The model for environmental risk-based soil guidelines used in Sweden is based on the Dutch list of ecotoxicological values for soil and the Canadian water quality guidelines (CCME,

1996) for the protection of aquatic life. The Canadian guidelines are also based on the method for setting "critical" levels. The Dutch list is based on a statistical treatment of the data from toxicological tests on a number of species in order to set a level of contamination at which the risks of effects on soil processes, or soil function, are negligible.

There are differences between the "critical levels" adopted in the regulations for application of sewage sludge or compost to soil and those given in the environmental assessment values or soil guideline values for metals. This difference represents a risk evaluation to some extent; the negative effects on the soil ecosystem are weighed against the beneficial effects of sludge/compost application and against the technical difficulty of achieving lower contamination levels in sludge/compost.

5.8 Some conclusions concerning overall methodologies

Two Swedish methodologies; the methodology for risk classification of contaminated areas and the procedure for selection of grouting compounds (see Appendix B), illustrate the overall approaches which may be adopted in risk assessment systems. Both systems are tiered systems, consisting of three stages.

The level of detail included in the assessment varies between the three stages. The number of sub-models, or parts of the assessment system covered by the different tiers often also increases together with the level of detail.

In the Swedish EPAs system for assessment of contaminated areas stage 1 consists of the risk classification described in Appendix B. Stage 2 consists of the generic assessment used in the derivation of soil contamination guidelines. Stage 3 consists of a site specific assessments. The main difference between these three tiers is in the level of detail included in the model.

The procedure for selection of grouting compounds is also a three stage process. The difference between stages in this case is the addition of successive parts of the assessment system at each stage, i.e: hazard identification, followed by risk analysis, followed by site-specific risk assessment.

It is possible that a tiered approach to risk assessment of secondary materials is most appropriate. In this way, materials containing contaminants with only a small potential for causing negative health and environmental effects can be approved at an early stage, avoiding the need for detailed testing. Materials containing large concentrations of hazardous substances can also be screened out at an early stage. More detailed analyses (i.e. stages 2-3) will be needed for substances containing moderate amounts of contaminants with potential for causing negative effects.

Table 5.2 Parts of the risk assessment process from related methods in Sweden and from other national and international systems. (Swedish systems are in italics)

Part of the risk assessment system	**Available methods**
Characterisation of material with respect to the content of hazardous substances	
Prioritisation of materials	EU waste catalogue/EU hazardous waste properties
Prioritisation of contaminants	EU list of substances which render waste hazardous *National chemicals inspectorates classification (including environmental hazard analysis)* Danish prioritation system for each waste type, according to leaching behaviour
Total composition of material	Netherlands composition values. *Swedish EPAs guidleline values for contaminated soil*
Characterisation of leaching behaviour	Standardised methods covering a range of conditions (batch tests and column tests) Leaching test dependent on scenario specification (Danish system)
Leaching from material in place in the construction	Danish system (7 alternative scenarios) Netherlands system (with/without isolation measures) CEN - Site specific.
Transport to recipient where exposure of man and environment occurs	Simple dilution factors (based on ratio of areas) (no retardation considered). *Equilibrium partitioning model, coupled with dilution factors (SwedishEPA/SPI model for contaminated soils).*
Exposure pathways	A priori choice (drinking water) in Denmark *Consideration of several pathways. May be scenario specific. (Swedish EPA model for soil guideline values).*
Assessment of risk to human health	Use of toxicological limiting values (e.g. From WHO, USEPA) in all systems. May need more appropriate treatment of organic materials, e.g. PAHs. *Database developed for Swedish EPA model for soil guideline values may need to be expanded to include more substances, eg, molybdenum, antimony, beryllium.*
Assessment of risk to the environment	*Environmental assessment values* *Swedish EPAs model for contaminated* *Limiting values for sludge/compost application*
Overall methodology	*Tiered approach – simple screening method (Swedish EPA risk classification of contaminated areas.* *Scenario specific (Hallandsås*)

6 USE OF SECONDARY MATERIALS – PROPOSED SYSTEM FOR RISK ASSESSMENT AND RISK EVALUATION

In chapter 6 the proposed system is outlined based on the ideas presented in the previous chapters. The identified needs for further development and for the implementation of the system is presented in chapter 7.

6.1 Outline of the system

Risk assessment of the use of secondary materials in constructions is composed of several parts, cf chapter 3, including

- problem formulation
- exposure assessment
- risk evaluation

Different systems for risk assessment of the use of secondary materials in other countries and of related systems in Sweden have been discussed in previous parts of this report. The purpose of this chapter is to propose a system for risk assessment of the use of secondary materials in Sweden (based on the discussion in chapter 3.5). Identification where approaches to other systems may be used and where new approaches need to be developed are touched.

The system will mainly consist of four parts:

1	Problem formulation	The problem to be solved is stated including a declaration of the material to be used and a description of the scenario in which the construction is placed.
2	Exposure assessment	Concentrations of environmentally crucial substances in different target points are derived. The distribution of these values to occur is estimated.
3	Risk evaluation	The values derived in the exposure assessment are compared to different criteria to estimate the risk. The significance of the risk is estimated.
4	Risk management	Decision criteria formulated by authorities and the risk is communicated to involved parties.

6.2 Problem formulation

The formulation of the problem is essential since the questions to be asked may be different for different scenarios of utilisation. The aim of this chapter is to identify the hazardous properties and substances in the material that are relevant in the scenario and to identify the pathways and target points for these substances. This is equivalent to step 1-3 in ENV 12920 “Methodology for the determination of the leaching behaviour of waste under specified conditions”.

6.2.1 Definition of the problem

The definition of the problem (Step 1, ENV 12920) is partly well understood: can the material be used in civil engineering work with acceptable environmental risk management. However, the material to be used needs to be described as well as the type of scenario in which it will be used.

6.2.2 Description of the material

The material need to be described (Step 3, ENV 12920) and the relevant substances for the risk assessment shall be selected. The description of the waste need to consist of:

- identification of the mechanical properties that are relevant for the release assessment
- identification of hazardous properties in relation to Council directive on hazardous waste 91/689/EEC
- identification of the composition of the material in relation to inorganic and organic substances

The risk assessment of the material does not include an evaluation of the mechanical properties. However, the material has to be proved suitable for the specific engineering purposes, which can be done before or after the environmental risk assessment.

Any identified hazards of the material shall be declared, which includes the hazards identified for workers during the construction. This identification also covers biological properties of the material.

The composition of the material need to be specified which includes both inorganic and organic substances. If the quantity to be used is not a finite known volume that is sampled for the characterisation purpose, also the variation over time and homogeneity of the material need to be verified.

6.2.3 Description of the scenario

The application/scenario shall be described in detail in relation to the construction and to the local environment (Step 2 ENV 12920). The description of the scenario shall include

- mechanical and geotechnical conditions
- hydrogeological conditions
- biological conditions
- use of the site over time
- exceptional conditions (e.g. flooding, earth quakes, landslides etc)

Apart from the conditions identified as in ENV 12920, there is a need to extend the scenario to include the target points for risk evaluation that may be situated also further away from the construction. That is for example ground water sources and surfaces waters that may be exposed to transport of substances from the scenario as well as populated areas which can be exposed to dust.

6.2.4 Selection of target substances and target points

Based on the description of the material target substances are selected according to a specific list (to be derived). These target substances shall be subjected to the following exposure assessment.

Several target points will be identified based on the description of the scenario and shall be selected in regard to all relevant exposures routes to mankind and nature. The pathways addressed in the transport model shall give concentration or exposures of the target substances at the identified target points.

6.3 Exposure assessment

The exposure assessment consists of two parts: transport of target substance from source to target point and an evaluation of the sensitivity to environmental hazards of the area included in the scenario.

6.3.1 Transport of contaminants

The transport of contaminants to the target points is essential for a risk to occur, whether it will be by water or by the hand of a child. The transport of substances through leaching to the environment will be focussed in this chapter. Several transport models exist and are usually very advanced when also geochemical aspects are taken into consideration. There is a need for development of simplified models that still take the variability of the geological parameters into account. However advanced the model is, it is necessary to link the significance/uncertainty of the calculated values to the results.

The source of the contaminants is the actual release under different conditions. The previously mentioned ENV 12920 focuses on the determination of the leaching behaviour and the steps 4 and 5 shall be applied when the source term for the transport modelling is determined. Step 4 in ENV 12920 identifies the key parameters that influence the release from the waste. The appropriate tests are selected based on the properties of the material and the scenario. In step 5 the behavioural model of the release is formed from the influence of the parameters identified in step 4. This step may be incorporated into the actual transport model when the behavioural model is verified. The use of leaching tests and their interpretation into the transport models need to be further developed.

The determination of the source term shall be based on leaching tests as far as possible. The total content of a substance shall only be used for those substances (almost all organic components) where leaching tests are not yet applicable or when the risk assessment call for total content.

The results of the transport modelling will be the concentrations or exposures at the target points and their significance.

6.3.2 Sensitivity of the environment

Special concerns of the environment within the scenario or in the direct vicinity are specified. Other regulations may put restrictions on the area included in the scenario such as water protection area, biologically interesting area etc. In addition, impact on the second generation may be necessary to take into account. These restrictions must be considered in the risk evaluation.

6.4 Risk evaluation

The risk evaluation consists of the step where the calculated exposures and concentrations at the target points are compared to different already set quality criteria. The levels of effect at different exposures and concentrations are defined in these criteria. The significance and level of effect are reported for each target point and target substance.

6.5 Risk management

Risk management generally is the responsibility of the authorities. There is a need for a general statement from the authorities on which level of effect that will be acceptable

The risk evaluation of secondary materials must as much as possible follow the same principles as used for other materials as well as for waste materials and contaminated soil. There is noted a difference in accepted risk to human health in Netherlands for utilisation of secondary materials (lifetime risk of excess cancer of 10^{-6}) and acceptance of risk for contaminated soils in Sweden (lifetime risk of excess cancer of 10^{-5}). The levels of risk that is acceptable may be different for contaminated soil and utilisation of secondary materials, and there is a need for a consistent rationale in the case of such a decision by the authorities.

6.6 Simplified risk assessment

The outlined system for risk assessment above shall be regarded as the complex system which not easily can be used on a regular basis. Simplifications are needed at all levels to obtain a system that is useful in practice.

6.6.1 Problem formulation

There is a need for a list of substances and properties that need to be evaluated in the problem formulation. Some of these substances may be irrelevant for certain materials and a possibility to diverge from the list must also be stated. Several lists exist, both national and from other countries and organisations, of substances and of properties. One of the lists that could be used is the Swedish Chemicals Inspectorate’s “Regulations on Classifying and Labelling of Chemical Products according to their hazardous properties for human health and the environment” which is based on the EU directive “Guide to the classification and labelling of dangerous substances and preparations”, part of Directive 67/548/EEC (version amended by 83/467/EEC).

6.6.2 Exposure assessment

There is a need for different and specified scenarios where the construction and the transport pathways are determined in advance. Simplifications of a pollution transport model can then be made and the amount of parameters to be determined minimised.

6.6.3 Risk evaluation and Risk management

When the acceptable level of exposure at defined target points have been determined, there is a possibility to calculate these values for the scenarios “back” to a point closer to the source. The easiest management would be if such calculations could show the level of leachability that can be allowed at the site where the secondary material is used. This would lead to easier use of the system but by the cost of a less degree of detail in the scenario description.

7 FURTHER WORK

7.1 General

A system to evaluate the possibility or risk to use secondary materials has been presented in this report. So far, the presented system is only an outline based on general principles. Connections to systems in related areas have also been considered. The outline of the principle system revealed that several important areas need further development before the system can be fully implemented. In this respect different tools will need to be developed, which in some cases may need rather thorough studies.

The presented approach is based on several steps, both related to different applications, as well as to e.g. different secondary materials and hydrogeological conditions. However, the same basic principles and risk assessment procedures are used. To make such a system useful, simplifications will be needed mainly through identifying typical scenarios in order to simplify the transport modelling. The goal should be to define levels of parameters that are relevant to the application and can be readily measured with high repeatability and cost efficiency at the laboratory. It is necessary that the risk assessment procedure according to this system is possible to perform without unnecessary delaying an utilisation project.

7.2 Need for basic development

There is thus a need for developing new knowledge and to introduce simplification of the proposed outlined system to turn it into a fully developed and applicable procedure evaluating the relevance of utilising secondary materials. Primarily the following tasks are identified.

Basic research/development:

- Development of (a) transport model(s) based on a source identified by leaching tests. Transport models exist, but there is a need for generalisation and simplification of their use on predefined scenarios. The simplification should relate to typical soil strata with different key parameters related to geohydrology.

- The methodology for long term behaviour of leaching needs to be addressed with a connection to the durability of the product. The break down of a product may be the result of different factors, such as freeze/thaw, traffic and chemical dissolution and pH change. Methods to judge both decomposition over time and its effect on leaching over hundreds of years are needed.

- The variation in different parameters used in the transport modelling need to be identified and quantified, as well as the impact of these variations on the final values in the target points.

- Parameters and components that need to be on a list and for which the material need to be tested or verified for, shall be identified as well as different target points to be used in the transport modelling.

Implication of systems and risk levels:

- Standard scenarios need to be identified and defined as well as parameters linked to them.

- Guideline values for different target points need to be selected and approved by the authorities.

7.3 Implementation of the risk assessment system

It is obvious from chapter 6 that there is a need to simplify a system to be used when approving the use of a residue. Such a work must deal with the following parts:

- An evaluation sheet worked out to be used to make the risk assessment adopted to practical use.
- The simplified system shall be tested on selected residues and calibrated against known field experience.
- Product information shall be rationalised on pre-printed forms. These should be similar to the product information following directives from the Chemical Inspectorate but adjusted for the risk related to use them as civil engineering material.
- A quality assurance system needs to be developed which will give a guarantee that the product have the properties as assumed when doing the risk assessment.

The final system is foreseen to consist of a manual based on the following parts.

- Product information sheet
- Sheet to evaluate the impact (risk assessment).
- Product quality assurance (QA), to show that the product fulfils assumed properties.

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Appendix A

Systems used in different countries to assess risk associated with the use of secondary materials

1. Denmark

A project has been carried out in Denmark [Hjelmar et al, 1998] with the aim of developing the basis for establishment of acceptance criteria for the use of by-products and contaminated soil in construction. The aim of the criteria is to protect groundwater.

The project is a development of a concept based on the establishment of a correlation between the results of a leaching test and the increase in a number of contaminants in groundwater used as drinking-water. A model has been developed to establish the correlation for materials used in a number of well-defined scenarios.

One condition for use of the concept is that there are administrative/politically set limits for increase in the concentration of contaminants in drinking water, and that the background concentration in drinking water is also taken into account.

The project has focussed on three types of secondary material, coal fly-ash, coal bottom ash and MSWI slag. Use of contaminated soils has also been considered.

1.1 Prioritisation of contaminants

The model is intended to cover all substances whose concentration in groundwater or drinking-water is regulated in other contexts. A long list of inorganic and organic components has been given in Miljöstyrelsen [1995a]. The substances listed were selected on the basis of their toxicological and ecotoxicological properties. A system has been developed for the prioritisation of contaminants as the contaminants of importance vary between products and for many secondary materials, a study of the leaching behaviour of a smaller number of contaminants may be sufficient.

The prioritisation system has been developed for evaluation of inorganic contaminants and non-volatile organic compounds (NVOCS) as a collective parameter for organic compounds. Contaminants are classified into three priority classes, based on the maximum concentration in leachate observed in simple leaching tests (availability tests).

The priority classes indicate how the contaminants should be included in a test programme as follows:

- Priority 1: Substances which must be included in a test programme
- Priority 2: Substances which for different reasons also should be included in a test programme but where, because the database is poor, it may be necessary to substitute one type of analysis for another, eg conductivity instead of salt.
- Potential: Substances which may be relevant, eg where a substance has received a lot of attention for some reason, even though data is scarce.

The prioritisation system has been tested on the three secondary materials considered in the project. The prioritisation of substances for these materials is shown in table A1.1 below.

Table A1.1 Classification of substances according to concentration in leachate from availability tests

	Priority 1	**Priority 2**	**Priority 3**
Coal fly-ash	SO_4^{2-}, Ca, Na, K,	B	Sb

	As, Cr, Mo, Se, V (acid ashes, also Cd, Cu, Ni, Pb and Zn)	NH_4-N	
Coal bottom-ash	SO_4^{2-}, As, Cr, Cu, Mo, Se, V (acid ashes, also Cd, Ni and Pb)	B, K, Na, Ca	Sb
Slagg from waste incineration	Cl^-, SO_4^{2-}, Ca, Na, K, Al, As, Cd, Cr, Cu, Mo, Ni, Pb, Zn, NVOC	Ba, Se, total-N	Sb

The intention is that for each type/group of secondary materials, a list of contaminants which ought to be included in a leaching-test quality control will be drawn up. Contaminants will be selected on the basis of

- total content
- maximum leachable amount
- maximum concentration in percoclate evaluated with respect to mobility
- toxicity
- ecotoxicological properties
- limiting concentrations in groundwater/drinkingwater etc.

Other parameters which will be taken into account and which should be determined for the eluate of all by-products include pH, alkalinity, conductivity and redoxpotential (if possible). Some information from total-contents analysis of the material is also relevant to groundwater quality, and should also be taken into account, eg. pH, TOC and loss on ignition.

1.2 Model describing the relationship between leaching and effect on groundwater quality.

A model has been developed to establish, for a definite scenario and a defined by-product or soil type, a relationship between the result of a laboratory leaching test on the material used and the expected effect on groundwater quality. The method also indicates how, on the basis of a leaching test on the material, it can be determined if a maximal value of increase in concentration of a contaminant in groundwater is exceeded or not for the proposed construction.

The model has been used as a basis to set criteria for non-surface use of the three by-products considered and contaminated soil.

The material in place is described by a height H (m) and bulk density d. The general annual infiltration of rainfall in the relevant area is I (mm/year). Maximal acceptable concentration of a contaminant in percolate which escapes from the material is Cv (mg/l) and is defined as:

$$Cv = GK * F * P * NR$$

Where:

GK = maximal acceptable increase in concentration of a contaminant in a drinkingwater intake from an underlying groundwater magazine (mg/l)

F = the relationship between the catchment area of the groundwater resource – and the area covered by the material; ie. the dilution factor leachate/drinkingwater.

P = priority factor, which makes it possible to prioritise some groundwaters higher than others, eg. in relationship to groundwater protection zones. P=1 for high-priority groundwater resources.

NR = infiltration reduction factor, which describes the extent to which infiltration through the material is reduced, e.g. by surface covering. The amount of water which infiltrates through the material is I/NR.

The model does not take into account biogeochemical processes in the underlying groundlayer or groundwater zone which could affect the rate of transport of a contaminant to a bore-hole, eg sorption. These “attenuation” processes therefore are a non-quantified extra safety factor in the calculations.
The parameters adopted in the model are summarised in table A.1.2. Some of the parameters are site-specific. A summary of the assumptions made for the different scenarios considered is given in the next section. In this section, the choice of parameter values is discussed.

Table A.1.2 Parameters used in the Danish model

Parameter	Unit	Meaning
		Environmental protection parameters
GK	mg/l	Acceptable maximal value for the increase in concentration of a contaminant in groundwater at a drinking water borehole resulting from leaching of the material used .
F	-	Dilution factor – relationship between the area of the material as laid out and the catchment area of the groundwater resource considered
Tk	year	Criteria related time period over which the concentration of a contaminant in the percolate can be averaged.
		Regional parameters
P	-	Prioritisation factor, which can be used to adjust the value, depending on the value of the groundwater under the site where the material is used.
I	m/year	Net infiltration
		Scenario and material specific parameters
NR	-	Precipitation reduction factor, which is the factor by which I is multiplied to given the actual infiltration through the material in the construction
d	t/m^3	Bulk density of the material in the construction (on a dry weight basis)
H	m	Average height of the material in the construction

1.2.1 The technical environmental protection parameters

The degree of groundwater protection is very dependent on the chosen parameter values. Values have been chosed with a degree of conservatism to ensure that groundwater contamination to unacceptable levels never occurs:

The dilution factor F – the groundwater volume relative to the leachate volume. should be chosen conservatively – a limited volume will ensure that an eventual pollution up to the limits set will in fact have a only a limited effect on water quality at a bore-hole, as the real dilution will often be significantly greater. A value of 10 is suggested for most point- and linear- uses, but can be greater for larger areas, e.g. car parks or similar. A factor of 10 in many cases ensures sufficient dilution for private wells near roads etc where the by-products or soil are used. Larger groundwater resources have much greater dilution factors – though there is a risk for several contamination sources in the area.

Choice of GK and Tk

The values of GK taken into account

- background concentration
- maximal tolerable concentration (from toxicological point of view)

Where F has been chosen conservatively there is hardly any reason to build in extra safety for other pollution sources. Miljöstyrelsen has suggested GK values and Tk values shown in table A.1.3.

Table A.1.3 ***Values suggested for GK and Tk***

Contaminant	GK (mg/l)	Tk (år)
Cl^-	250	1 or 3
SO_4^{2-}	220	1 or 3
N	150	1 or 3
K	280	1 or 3
As	0.009	10
Cd	0.005	25
Cu	0.1	25
Cr	0.05	10
Hg	0.001	25
Ni	0.015	25
Pb	0.009	25
Se	0.01	10
Zn	0.04	25

1.2.2 Regional parameters

P – prioritisation factor. So far, it has not been possible to prioritise groundwater resources, so all cases have been given highest priority, ie. 1.
I – net infiltration, should be given as a variation-interval. Calculations are recommended with minimum and maximum values of locally derived data for specific cases. Larger values of I give larger values of L/Sk and increased values of Msa. The importance of I to the criteria derived depends on the leaching curve for each contaminant.

1.2.3 Scenario- and material specific parameters

NR – rainfall reduction parameter, can be related to the material's properties, eg hydraulic conductivity, but the permeability and form of the surface normally determines the size of NR. The value of NR can vary greatly depending on whether the surface is asphalted/reinforced (stabilised), covered with bark, covered with topsoil only or vegetated topsoil. Experience has shown that values usually lie between 10 for asphalt covered roads and 1 for grass-vegetated topsoil coverings.
Bulk density, *d*, isprimary material property, which also depends on how the material is used in concrete scenarios, especially on the degree of compaction. In practice, it can vary between 1 and 2 t/m^3 for a wide range of by-products and soil types, with most materials around 1.5 t/m^3. A value of 1.5 has therefore been used in all scenarios.
The height of the material, H is entirely dependent on the scenario and can't be generalised. Small values of H result in relatively leaching and high values of L/S.
H and NR can be adjusted for a given use and material to reduce the environmental effect of use of the material, and to comply with eventual regulatory demands.

1.2.4 Scenarios

The simple scenarios shown in table A.1.4 below represent a framework within which most uses can be represented.

Table A.1.4 ***Scenarios used in calculations with the Danish model***

Parameter	Unit	Use of by-product or contaminated soil							Clean soil
		Road	Path	Larger	Noise-	Ramps	Ditch	Levelling	

				areas			infill		
F	-	10	10	5	10	10	10	1	1
P	-	1	1	1	1	1	1	1	1
NR	-	10	2-5	2-10	2	5	10	1	1
I	m/år	0.2-0.7	0.2-0.7	0.2-0.7	0.2-0.7	0.2-0.7	0.2-0.7	0.2-0.7	0.2-0.7
BD	t/m^3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
H	m	1	0.3	1	5	4	2	1	10

A brief description of the details of each scenario is given below:

Road – material used as a bottom stabilising layer or similar. A dilution factor of 10 is thought to represent a smaller groundwater resource. Maximum height is one meter and the surface is asphalted or similar, therefore NR is 10.

Path – material used as for a road. Again, a hard surface is considered, but because of the narrowness of the paths, NR is only 2-5. Maximum height is only 0.3 m in this case.

Large areas, (eg carparks, squares) – Again, material used as for a road (as bottom stabilising layer). However, the larger area means that a smaller dilution factor is used; F=5. NR depends on the type of surface used – between 2 and 10. Maximum height as for a road, 1m.

Noise-embankment – Can be up to 5m high with a slope of at least 2:1 and a covering of at least 1m clean soil. The crown, with a maximum width 2m can be curved or have a hard surface. NR is set to 2 and F to 10.

Ramps – ie. sliproads to motorways, bridges etc. A hard surface is assumed and a maximum of 4 m height of fill. NR is asumed to be 5 because of the risk for increased infiltration at the sides of the hard surface.

Backfill in ditches for cable and pipeline –a hard surface is assumed. Similar scenario to roads therefore, except maximum height of fill is greater, 2 m.

Levelling, landscaping - Maximum fill height of 1 m is assumed, covered over with clean soil. The large area means that infiltration can contribute a large proportion of the inflow to the groundwater resource, therefore F=1. Infiltration is assumed to be more or less equal to rainfall ie. NR =1.

1.3 Relation to results of leaching tests

1.3.1 Criteria related time-period.

The concentration of many contaminants in leachate is highest (and therefore the flux of contaminants is highest) at the start of the leaching process, and falls with time. For other materials, eg. lead, the variation in concentration level is to a large extent controlled by other factors, eg. pH and redox potential.

As the model is based on contaminant flux, an average value of Cv is assumed over a period Tk – the criteria related timeperiod. This means that it is accepted that the concentration in percolate can exceed Cv at the start of the period as long as the average value over Tk is lower than Cv. Contaminants with steep initial leaching curves and little retention in the groundwater magazine, eg. some salts, (or other factors which will even out the concentration time course) should be assigned relatively short Tk values, whereas contaminants which are adsorbed to a large extent and are less mobile (eg. most heavy metals), can be assigned larger Tk values without risk for exceeding (or coming up to) the acceptable concentration increase. In some cases Tk must be used carefully: Some contaminants, eg. arsenic, are solubility controlled to such an extent that leaching is dependent on the amount of percolating water over a long period of time. A decrease in concentration only occurs after a long time period.

1.3.2 Specific acceptable amount

The specific acceptable amount of a given contaminant, Msa (mg/unit weight of material), which can be leached out over time Tk can be calculated from the equation above using the expression

Msa = GK*F*P*Tk*I(d*H)

Where d is the bulkdensity of material (on a dry weight basis) och H is the height of the material.

Msa, which is calculated from the physical scenario for the form of use of the material, can then be compared to the result of the leaching test for the material which is to be used.

1.3.3 Choice of leaching test

As yet, no standardised leaching test has been specified for used with the method. However, the choice of the most appropriate leaching test is influenced by scenario-specific parameters.

The result of (often accelerated) leaching tests for granular, inorganic material in many cases can be expressed as the leached amount of a given contaminant per unit weight of material as a function of liquid/solid (L/S) ratio, or for a given L/S. L/S (eg expressed in l/kg) can in a number of cases under the assumption of ideal conditions be related to the leaching time for a given scenario with the following expression;

T = (L/S) * d * H/ (I/NR)

This means that where there is the same time-limitation on the physical scenario for use of the material and on the interpretation of a leaching test on the material used, with the help of the above equations, a relationship can be established between the specific acceptable leaching, Msa, and the result of the leaching test.

Msa cannot be exceeded in order to ensure that the effect on groundwater at the point of intake to the drinking water system does not exceed GK. The crtieria-related value of L/S equivalent of Tk is calculated in the following way:

(L/S)k = Tk * I/(NR*d*H)

In the ideal leaching situation, where leaching of a given contaminant can be described as a function of L/S in the form of results of leaching tests, and where this description can be assumed to simulate the leaching process for the actual scenario the following relationship should hold for the material to comply with the groundwater quality criteria for the leached component:

$Umk_i < Msa_i$

Where UMk_i is the accumulated leached amount of component i found at the accumulated L/S values (L/S)k, and where Msa_i is the specific acceptable leached amount of component i calculated for the actual scenario.

The calculated value of L/S can vary very much depending on the scenario, and in many cases will not agree with the leaching data which would allow an exact determination of Umk_i at the required (L/S)k value. In this case, one can instead use the largest value of (L/S)k, for which leaching data are available and use the derived value of accumulated leached amount of the contaminant as an average value. The danger with the use of a too large value of L/Sk is that the evaluation of a material can be too conservative. If the value of UMk_i is unrealistically large, it can act as an inbuilt safety margin. It should always be possible to decide if the exceedence of UMk_i over Msa_i is real or an artifact of UM_i being unrealistically large because it describes the accumulated leaching at a too large L/S value. The alternative is to always "tailor" leaching tests to a specific situation. The Danish authorities have stated that "tailored" tests could be acceptable for the evaluation of the use of larger amounts of a by product, but not for routine testing of a by-products and soil for more general uses – here more simple and standardised test methods are needed.

1.4 Relation of leaching-based criteria to criteria based on total composition.

It is important that regulations for using by-products and contaminated soil are consistent, to avoid situations occurring where different evaluations based on different criteria lead to confusion about the status of a given material. Soil which is regarded as "clean" should be able to satisfy all soil criteria (except for certain very special naturally-occurring soil types). The Danish Ministry of Environment's soil quality criteria are based on total soil analysis. There are two sets of criteria:

– free classification, based on toxicological evaluation, meaning that soils can be used without restrictions if contaminant contents are under the criteria values.
– clean-up values (or "isolation" values – so far only for a few substances), there must be no exposure to soils with contaminant contents exceeding the criteria ie. by clean-up, or removal is necessary.

Soil falling between these two criteria can be regarded as lesser polluted soils and can be used for certain uses.

In the context of leaching-based criteria, the concept of unlimited use for by-products and for soil means that the porewater that is in equilibrium with the soil cannot, at any time, have a contaminant concentration which significantly exceeds background concentration for that contaminant in the underlying groundwater.

In practice, the use of these parameters demands the setting of general background concentrations of contaminants in groundwater, as well as a limit for a significant increase in concentration over background level (or a significant increase in amount of a contaminant which is transported). It is also necessary to develop and standardise a method for testing of leaching from soil, and that a relationship is established between the results of the leaching test and an acceptable increase in the background concentration of contaminants.

The Danish authorities intend to define different classes of soil in order to avoid conflicts between different definitions of "clean" soil. The soil classes aim to ensure that soil which complies with soil quality criteria has the same effect on groundwater quality as soil which can be used in an unrestricted way according to the leaching-test method (or that soil which complies with leaching-based criteria for clean soil also complies with soil quality criteria based on total contents analysis). In relation to this question it is important to note that it is not really possible to establish a direct relationship between the total content (or content measured after digestion with nitric acid) of inorganic contaminants and the amount which can be leached out with a test method.

The Danish authorities aim to define 3 classes of soil:

Group 1 – non contaminated soil which complies with both leaching criteria and free-classification criteria , suitable for use without restriction
Group 2 – contaminated soil which complies with the scenario-definied criteria for leaching for non-surface use of soils
Group 3 - contaminated soil which does not comply with the conditions for Group 2.

Secondary products may also be classified according to these three groups. Most secondary products will fall within groups 2 and 3.

1.5 Toxicological and ecotoxicological basis to soil and groundwater quality criteria

In Denmark, health-risk based soil quality criteria have derived by considering the direct oral intake of soil by children.(Miljöstyrelsen, 1995a). On the basis of an earlier project, it was concluded that this exposure pathway represents the potentially most critical pathway for the majority of substances. Chronic exposure is considered for most substances, though acute exposure is considered for substances with an acute toxic effect, eg. arsenic, cyanides. Both the toxicologically based soil quality criteria and drinking water quality criteria are based on toxicological reference values from WHO/IARC. These values are the tolerable daily intake of a substance (TDI, in mg/kg body weight), or the intake of a substance corresponding to a 10^{-6} lifetime risk of cancer (see section 4.8 in the main report).

Ecotoxicologically based soil quality criteria represent the highest concentration of a contaminant in soil at which there is no risk for ecotoxicological effects, i.e. a predicted no-effect concentration (Miljöstyrelsen 1995b). The values are derived from reviews of toxicity data for soil organisms and processes.

2 THE NETHERLANDS

In the Netherlands the Building Materials Decree (Bouwstoffenbesluit) was issued in 1995 concerning the use of secondary products in construction. The order was issued by VROM (the Ministry of Housing, Spatial Planning and the Environment).

The regulations are planned to come into force in two phases:
Phase 1 – July 1996
Phase 2 – July 1999

The intention of the decision is to protect soils and water and also to stimulate the reuse of secondary products.

The decree covers stony materials that are applied and used outdoors. Stony materials are defined as ”materials that contain at least 10% silicon, calcium or aluminium (in ionic form). In the Building Materials Decree no distinction is drawn between primary and secondary (raw) materials. Examples of stony building materials include; bricks, clinkers, construction and demolition waste, sieve sand, MSWI bottom ash, blast furnace slag, limestone, gravel, porous asphalt (ZOAB), soil (including drained dredging sludge and treated soils, clay and concrete. The decree does not cover wood, synthetic materials, sheet glass and metals.

Concentration limits for the content of several contaminants in secondary products are given. These limits are based on the immission from secondary materials which is considered to be acceptable (from the point of view of the environment). Immission to soil and to surface waters are considered.

Because there are no suitable leaching tests for organic contaminants, it is not possible to derive immission values for organic contaminants in construction materials. Limits for organic substances are therefore based on total concentrations.

The classification of building materials assumes the recovery of the material when the construction is no longer in use. For materials that will be mixed with, or dispersed in, the soil, the criteria for clean soil must be satisfied, (see section A.2.1).

Materials are classified into 2 categories, determined by composition values and immission values. The classification determines which regulations apply for use of the material. The derivation of composition and immission values is considered below, followed by a description of the use of these values in classifying secondary materials

2.1 Composition values

Composition values are given for all substances in the decree. For organic compounds, no suitable leaching tests have been developed. The standards for organic compounds are therefore based on composition values.

For soil, two sets of composition values are given (see next section for how these values are used in classification of materials). The C1 and C2 values are equivalent to target and intervention values. These values are given for a standard soil, i.e. with a clay content of 25% and a humus content of 10%. An expression has been given which can be used to determine the conversion factor to re-express the values for the clay and organic matter content of the actual soil. C2 values are based on the intervention values for soil. However, for a number of substances, the composition values have been adjusted to allow re-use of certain categories of secondary materials. This means that a greater than marginal burdening of the soil is accepted for these compounds in order to ensure re-use of the material.

2.1.1 Target and intervention values for soil

These values are determined from the risks to human health and the environment, which are considered to be acceptable. Target values the concentration in soil at which the risks to human health and the environment are considered to be negligible. Intervention values represent the concentration in soil above which health risks may occur and there is a risk for serious disturbance of the soil ecosystem. The levels of risk, which correspond to the different criteria, are shown in table A.2.1.

Table A.2.1 Levels of risk corresponding to intervention and target values

Value	Risk limit	Human health		Ecosystem
		Threshold	Non-threshold	
Intervention		TDI*	10^{-6} a^{-1}	protection of 50% of species
	Maximum tolerable risk (MTR)	TDI*	10^{-6} a^{-1}	protection of 95% of species
Target	Negligible risk	MTR/100	10^{-8} a^{-1}	MTR/100

* Tolerable daily intake

Health-risk based intervention values are calculated using a model for the distribution of contaminants in the soil, the transport of contaminants from the soil to other environmental media, the exposure of man to contaminants via all relevant exposure pathways and the resulting risks to human health. The model used is shown in Figure A.2.1. The model is very similar to the model used by the Swedish Environmental Protection Agency for the calculation of guideline values for contaminated soil, which is described in Appendix B. Therefore a more detailed description is not given here.

Environmental effects-based intervention values are the concentration in soils at which no ecotoxicological effect is expected to occur in 50% of soil species (at the population level). This value is derived by a statistical extrapolation of ecotoxicological data for a number of different soil species (or functions).

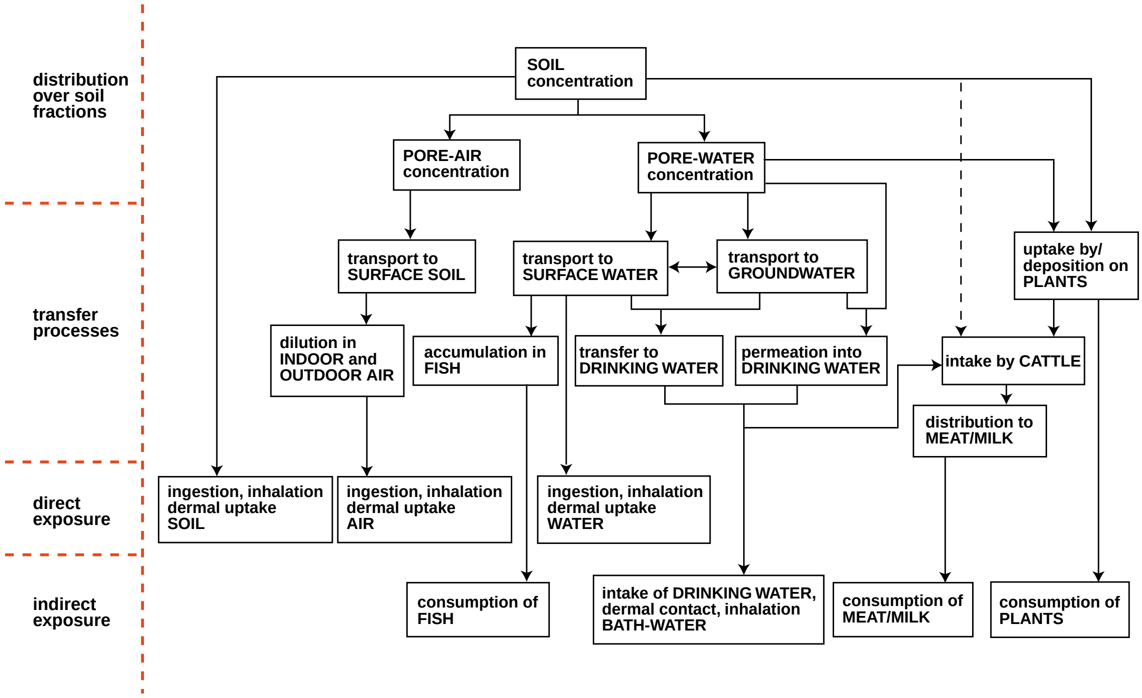


Figure A.2.1. The C-soil model used to derive intervention values for soil (Swartjes and van den Berg, 1993).

2.2 Immission values, I.

The basis for these standards is the maximum quantity of inorganic compounds which may disperse into soil and surface water without causing unacceptable burdening.

The policy of marginal soil burdening is defined as;
"A burdening as the result of leaching from a construction material which leas to a 1% increase of a compound in the solid phase of the soil compared to the target value for soil quality in 100 years averaged over the first metre of a soil considered to be homogenous." (RIVM, 1996). Protection of the soil at the level of marginal soil burdening is assumed to protect the groundwater at the level of the target value, and that the surface water will be protected at an acceptable level. Thus, there is no numerical basis regarding protection of the groundwater.

The maximum allowable immission Imax (mg/m^2) of a compound in the soil over a period of 100 years for a 1 metre thick soil is calculated at 1% of the target value for soil quality. For constructions above the groundwater level, the rainwater functions as the transport medium for contaminants. This results in the following formula;

Imax (Jyr) = /100 * T_s * $_s$ * h

Where

Imax (Jyr) = the maximum allowable immission into the soil of compound M in J years (mg/m^2. Jyr)
= 1 the factor for marginal burdening of the soil (%/J years)
T_s = target value soil quality of compound M (mg/kg)
$_s$ = average dry density of soils = 1500 kg/m^3
h = thickness of layer of soil (m) = 1
J = 100 years, number of years in which immission may be achieved.

The setting of standards for chloride and sulphate is not base on the definition of marginal soil burdening, but does have the same sort of relationship to the target value for groundwater quality. The acceptable emission is considered to be an average increase of chloride and sulphate in the leaching medium which is or becomes groundwater of 100% of the target value for groundwater quality in the first year. The formula used is:

Imax (Jyr) = /100 * T_{gw} * Q_2 * J

= 100 the factor for marginal burdening of the groundwater (%/J years)
T_{gw} = target value groundwater of compound M (mg/l)
Q_w = flux, 300 mm rainwater /m^2 per year
J = 1 year, number of years in which immission may be achieved.

It should be noted that the setting of standards is based on the average concentrations /emissions and not on the course of the concentration and/or the course of the emission from the source over time. When developing the standards the course of the concentration however can be kept in mind, for example when, peak burdening occurs.

For the sake of the calculations, the emission of compounds from a construction material is regarded as being a burden to one compartment only, that is to say that in the calculation it is assumed that there is no spreading of the compounds over more than one compartment.

The maximum allowable immissions are shown in Table A2.2.

Table A2.2 Maximum allowable immissions to soil (groundwater for chloride and sulphate)

Compound	**soil**	**groundwater**
	mg/m^3 per 100 years	mg/m^2 per 1 year*
As	435	
Ba	3000	
Cd	12	
Co	300	
Cr – total	1500	
Cu	540	
Hg	4.5	
Mo	150	
Ni	525	
Pb	1275	
Sb	39	
Se	15	
Sn	300	
V	1020	
Zn	2100	
Br	300	
Cl		30 000
F	7500	
SO_4		45 000
CN – total	75	
CN – free	15	

*with infiltration of 300 mm/year

2.3 Classification of materials

Generally, materials are classified into the following three categories:

- Category 1; building material which exceeds none of the composition and immission values. These materials may be used without additional environmental protection.
- Category 2; a building material which does not exceed any of the composition values, The calculated immission value exceeds the permitted value. However, when isolation measures are taken, the calculated immission remains under I. There is a maximum value of the calculated I before isolation measures are taken.
- Materials whose use in construction is forbidden. Materials, which exceed the maximum immission value, even when isolation measures are taken. All materials, which exceed the composition, value. Materials in this category can be used after treatment so that they comply with the categories above. Materials which fall within this category must be disposed of as solid waste.

These three categories are shown in Figure A.2.3a.

There are exceptions to the classification, use of these materials is allowed to encourage re-use and minimise waste. These materials are;

- MSWI bottom ash, allowed to exceed the I and C values. In this case a special third category (special category MSWI bottom ash) is created. This ash can be used if *special* isolation measures are taken (i.e., measures over the normal isolation measures for category 2). See Figure A.2.3.b.
- Tar asphalt aggregates (TAA). These materials always exceed the C value for PAHs. They are allowed to be used if they exceed the C_{PAH} but do not exceed the C-values of other compounds. TAA materials may only be applied if *special* isolation measures are taken. The normal rules relating to immission values apply (i.e. emission calculated after isolation measures are taken). See figure A.2.3.d.
- Soil. A distinction has to be drawn between clean soil and polluted soil. In order to distinguish between the tree categories, there are two C values. Soil is considered to be clean if its composition values are lower than C_e1. In this case, there are no limits according to immission levels. If the C value is between C_e1 and C_e2, the immission level has to be determined and the soil assigned to category 1, 2, or forbidden for use. Soil with a C value higher than C_e2 may not be used as building material. The C_e1 and C_e2 values correspond to the target and intervention values for soil. (See Figure A.2.3.c)

Category 2 building materials, MSWI bottom ash and TAA are usually used in road bases, stabilisation layers, elevations and embankments. The directive describes standard constructions together with relevant isolation measures. The isolation requirements are:

- The work must be situated at least 0.5 metres above the mean highest groundwater level (MHG). (There are regulations as to how MHG should be determined.)
- Measures should be taken against contact with rainwater. (The directive describes how this should be done).

Deviation from the standard constructions is allowed but a specialist must then determine whether the isolation of equivalent standard.Isolation measures must be checked periodically to see if they are still working.

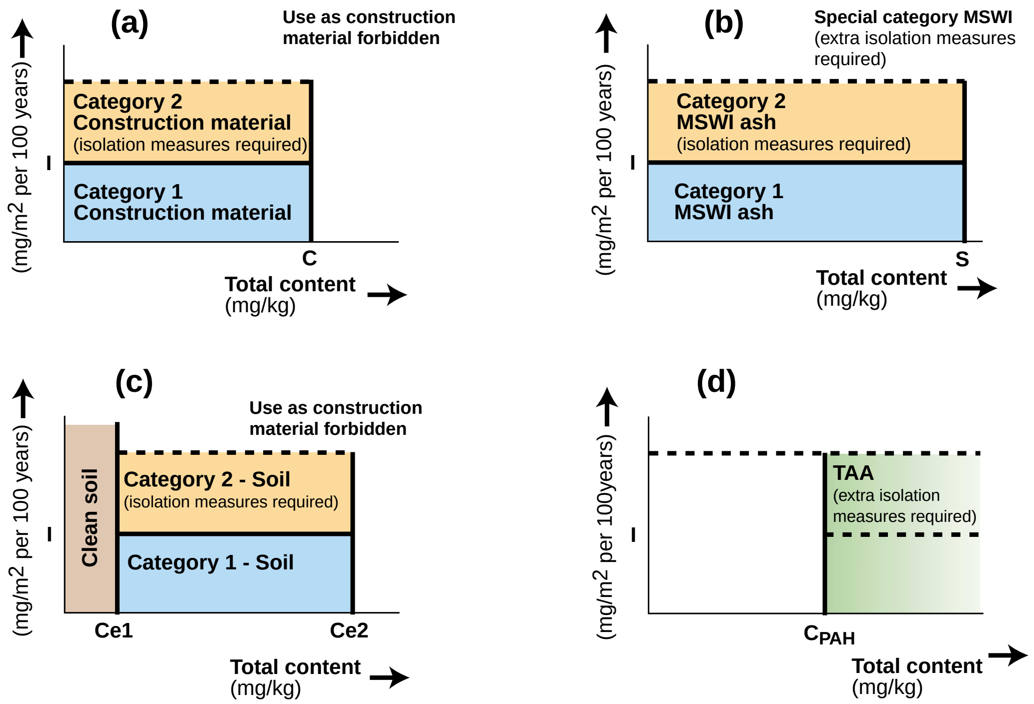


Figure A.2.3. Categories of secondary material for use in construction work (Building materials decree, Netherlands, 1996).

2.4 Method for determination of emission from the material

The immission value of a compound depends on the leaching from the building material, type of construction and the dimensions of the building material in the construction.

The immission from a construction material is calculated from the results of laboratory leaching tests, taking into account the way in which the material is used in the construction.

Two methods of emission are of importance:

- Emission which is chiefly the result of the dissolving of compounds, This usually occurs directly after the application of a construction material, and results in a short, relatively high, peak burdening. This type of emission is usually most important for non-prefabricated construction materials.
- Emission which is the result of the diffusion of compounds. The burdening is more evenly distributed over a longer time period. This type of emission is usually most important for monolithic materials

The method for calculation of the maximum allowable immission from the results of test of the leaching behaviour of the material is summarised below for both types of emission.

2.4.1 Non-prefabricated (granular) materials.

The relationship between emission from a non-prefabricated construction material and the immission in the soil is described by the following equation:

$$Emax(Jyr) = \frac{Imax(Jyr)}{dc * h}$$

Where;

Emax (J yr) =	maximum allowable emission per J years (mg/kg)
Imax(J yr) =	maximum allowable immission per J years (mg/m^3)
d_c =	dry density of the construction material (kg/m^3)
h =	total thickness of the construction layers which consists of roughly the same construction materials (m)

To estimate emission from non-prefabricated materials, a standardised column test is used (NEN 7343), with a L/S ratio of 10. The leaching with an L/S ratio of 10 must therefore be extrapolated and/or interpolated to an L/S ratio, which is equal to J years.

Emax(Jyr) = Emax (L/S=10) * $f_{ext,n}$ (h,Ni,)
where;

$f_{ext,n}$ (h,Ni,) =	the extrapolation/interpolation factor from L/S 10 to J years in which the thickness of the layer (h), infiltration (Ni) and the constant have been quantified.

Thus Emax can be expressed as:

$$\text{Emax}(L/S=10)=\frac{\text{Imax(Jyr)}}{dc*h*f_{ext,n}}$$

Research has shown that the leaching of compounds from natural soils to groundwater under natural conditions is small compared to leaching in the lab (<10%). Therefore, a choice has been made to correct the maximum allowable emissions, which are related to the marginal soil burdening, with the leaching value for soil in the lab, thus:

$$\text{Emax}(L/S=10)=\frac{\text{Imax(Jyr)}}{dc*h*f_{ext,n}(h,Ni,\kappa)}$$

The constant is a measure for the rate of leaching and therefore determines the form of the leaching curve, which is assumed to be described by a model in which the concentration reduces exponentially with an increasing L/S ratio. Values of have been tabulated for inorganic contaminants.

Ni is assumed to be 300 mm/year for constructions where no particular protective measures to prevent leaching are taken (i.e. where category 1 materials are used, see below) and 6 mm/year for constructions where protective measures are taken (i.e. where category 2 materials are used).

The maximum allowable emissions for category 1 and category 2 construction materials can therefore be tabulated for inorganic compounds for a range of application heights.

2.4.2 Prefabricated materials

For estimation of the emission from prefabricated construction materials during a period of Years (Max (J years)) a standardised diffusion test is used (EN 7345). In this test, emission from a construction material during a 64 day period is determined. The emission must be extrapolated to a period of 100 years (and 1 year for chloride and sulphate).

Correction factors are applied to account for exhaustion (source depletion), effective diffusion coefficient change, the period of wetting and the temperature difference.

The maximum allowable emission measured after 64 days (expressed per unit surface area of the material) is related to maximum allowable immission over J years as;

$$Emax(64d) = \frac{Imax(Jyr)}{f_{ext,v}(h, x\%, De) * f_{tem}}$$

where;

Emax (64 days) = maximum allowable emission in 64 days (mg/m^2)
Imax (J years) = maximum allowable immission over J years (mg/m^2)
$f_{ext,v}$ (h, x%, $D_{e)}$ = extrapolation factor for the extrapolation from 64 days to J years in which depletion depth (h), wetting period (x%) and change in effective diffusion coefficient have been quantified.
f_{tem} = correction factor for the difference between the temperature in laboratory and in practice.

These extrapolation factors have been tabulated [RIVM, 1996] for different conditions related to different types of applications.

2.5 Other regulations

Minimum quantities of building materials are specified for category 2 materials, TAA or MSWI bottom ash – in order to prevent the dispersion of small quantities of category 2 building materials.
The use of category 2 materials and category 1 soil must be reported to the authorities in advance of use.
Building materials must be removed after a work loses its function (except in the case of material classified as clean soil).

3 FRANCE

A circular issued by the Minister of Environment in 1994 covers the use of MSWI bottom ash in road construction. A new directive, which will replace the current one, is in preparation. The new directive will cover other secondary materials, and will be more generally applicable to use in different types of construction. The new directive will be based on the methodology developed by CEN (see below).

The directive divides MSWI bottom ashes into three categories, based on the result of standardised leaching tests. The suitability of the three categories of ashes for use in road construction is shown in Table A.3.1.

Table A.3.1 ***Categories of MSWI***

Class	**Leaching characteristics**	**Use**
V Valorisation	Weakly leachable	May be used in road construction according to conditions stipulated in circular

M Maturation	Intermediate	May not be used immediately. Must be stored under controlled conditions for a maximum of 12 months, after which further testing reclassifies the material under class V or class M, depending on whether or not the criteria for class V are satisfied. This class may also be used after stabilising.
S Stockage	Strongly leachable	Must be disposed of in a waste disposal facility

The pollution potential of the ashes is measured using standardised leaching tests (standard NF X 31-210). The accumulated amount of six inorganic pollutants and total organic carbon leached from the material in three successive elutions is expressed per unit dry weight of the material. The ashes are then classified as shown in table A.3.2.

Table A.3.2 Classification of MSWI ashes based on their leaching characteristics.

Class	**V**	**M**	**S**
Incompletely combusted material	<5%	<5%	>5%
Soluble fraction	<5%	<10%	>10%
Inorganic constituents (mg/kg)			
Hg	<0.2	<0.4	>0.4
Pb	<10	<50	>50
Cd	<1	<2	>2
As	<2	<4	>4
Cr(VI)	<1.5	<3	>3
SO_4^{2-}	<10 000	<15 000	<15 000
COT	<1500	<2000	>2000

The conditions stipulated for the use of class V ashes are as follows;

The material may be used in:

- The construction of roads and car parks, as a stabilising underlayer, with the exception of road embankments, which are to be in contact with water.
- Compacted embankments, with a maximum height of 3 m, without control of infiltration on condition that the surface is;
  - Covered by a road or car park
  - Covered by a building or construction
  - Covered by at least 0.5m vegetated, clean soil.

The material may not be used:

- In areas prone to flooding
- Near water resources, which is interpreted as at least 30 m from any groundwater or surface water body
- As backfill in trenches with metal pipes (e.g. gas mains)
- In drainage systems

Placement of the material should be done in such a way as to limit contact with rainwater, surface water and groundwater. One example, which is given, is that the material must be at a sufficient distance above the groundwater table. It is recognised that protective measures taken before or during construction are of importance in minimising the total impact associated with use of the material.

4 CEN (EUROPEAN COMMITTEE FOR STANDARDISATION)

CEN has published a pre-norm on the methodology for determination of leaching behaviour of waste under specified conditions (ENV 12920, 1997). Because this methodology considered leaching behaviour in a disposal or utilisation scenario within a specified time frame, the methodology is relevant to the use of secondary materials in construction. The methodology is very general in nature and identifies factors, which may be relevant for inclusion in an assessment, rather than specifying an exact assessment method. The external conditions, which have a direct influence on the release of constituents from a waste, are considered. However, the methodology does not take into account the migration of constituents leached from the site into the surrounding environment and the resulting impact on human health and environment.

The methodology is an eight-stage method, consisting of the following steps:

1. Definition of the problem and the solution sought.
   This requires description of:
   - The type of scenario
   - The type of waste
   - The nature of the assessment question (e.g. release after a specified time, comparison of different options, comparison with regulations)
1. Description of the scenario, under both normal and extreme conditions. The following information may be relevant:
   - Mechanical and geotechnical conditions, e.g.
     - waste characteristics and proposed preparation, e.g. compaction, sorting
     - dimensions of disposal/utilisation site
     - nature and thickness of layers above, below and around the waste
     - bulk density
     - expected lifetime of the containment system
   - Hydrogeological and climatic conditions, e.g.
     - Sources and nature of leachant
     - Infiltration rate
     - Details of leachant circulation
     - Permeability of surrounding materials
   - Biological conditions
   - Use of the site at different times
   - Extreme conditions, e.g. maximum height of groundwater table, flooding.
2. Description of the waste. Relevant properties may be
   - Nature and origin of waste
   - Total chemical composition
   - Physical properties (e.g. density, porosity, particle size distribution, water content)
   - Geotechnical properties (e.g. strength, permeability, thermodynamic stability) relevant to determining the water transport regime
   - Mineralogy, chemical speciation

- Chemical properties (e.g. buffer-capacity, reducing capacity, organic matter content, thermodynamic stability)

3. Determination of the influence of parameters on leaching behaviour. This step consists of identifying and determining the influence of the key chemical, physical, geotechnical, mechanical and biological parameters on the release from the waste in the specified scenario during the specified time frame. Relevant parameters may be:
   - Chemical parameters (e.g. nature of the leachant, effect of the chemical context of the disposal/utilisation scenario in terms of pH, redox potential, CO_2, salinity, dissolved organic matter
   - Physical parameters (e.g. sensitivity to temperature, moisture absorption capacity, particle size, consistency or rheology, water transport dynamics
   - Mechanical and geotechnical parameters (e.g. permeability, effect of the mechanical treatments applied in the scenario, such as compaction, which may influence water transport and therefore leaching)
   - Biological parameters (e.g. biodegradation, biotransformation)
4. Modelling of leaching behaviour. The model should be developed taking into account the relevant physical, geotechnical, biological and chemical parameters identified in step 4. The degree of detail in the model will depend on the problem.
5. Model validation. This step can consist of
   - Verification of the consistency between parameter specific tests and simulation tests
   - Field verification of predicted behaviour
   - Comparison with analogue materials (natural or archaeological)
6. Conclusions
7. Reporting

5 EU DIRECTIVES

Two council directives and a proposed council directive can be considered relevant to the assessment of effects of use of secondary materials in construction. The relevant points in these directives are discussed below;

5.1 Council directive on waste 91/156/ECC

This directive is concerned with measures to achieve a number of overall objectives;

- The prevention or reduction or waste production
- The development of appropriate techniques for the final disposal of wastes to ensure that human health and the environment are not adversely affected
- Stimulation of recycling, re-use or reclamation of wastes
- The use of wastes as a source of energy

Waste is defined as any substance, which is contained in the European Waste Catalogue (annex 1 of the Commission Decision 94/3/EC, establishing a list of wastes pursuant to Article 1 of council directive on waste).

The waste catalogue is not exhaustive, further waste types may be added in future. The catalogue contains a listing of a large number of waste types in the categories shown in table A.5.1:

Table A.5.1 Categories of waste according to 91/156/EEC

1	Wastes from exploration, mining, dressing and further treatment of minerals and quarrying
2	Wastes from agricultural, horticultural, hunting, fishing and aquaculture primary production, food preparation and processing
3	Wastes from wood processing and the production of paper, cardboard, pulp, panels and furniture
4	Wastes from the leather and textile industries
5	Wastes from petroleum refining, natural gas purification and pyrolythic treatment of coal
6	Wastes from inorganic chemical processes
7	Wastes from organic chemical processes
8	Wastes from the manufacture, formulation, supply and use of coatings, paints, varnishes and vitreous enamels, adhesive, sealants and printing inks
9	Wastes from the photographic industry
10	Inorganic waste from thermal processes
11	Inorganic waste with metals from metal treatment and the coating of metals; non-ferrous hydro-metallurgy
12	Wastes from shaping and surface treatment of metals and plastics
13	Oil wastes
14	Wastes from organic substances employed as solvents
15	Packaging, absorbents, wiping cloths, filter materials and protective clothing not otherwise specified

Table A.5.1 Continued.

16	Waste not otherwise specified in the catalogue
17	Construction and demolition waste
18	Wastes from human or animal health care and/or related research
19	Wastes from waste treatment facilities; off-site waste water treatment plants and the water industry
17	Municipal wastes and similar commercial, industrial and institutional wastes including separately collected fractions

5.2 Council directive on hazardous waste 91/689/EEC

Hazardous waste is defined in this directive on the basis of Annexes. Annex 1 is a list of generic waste types. Annex 1A contains 18 generic waste types, which are considered hazardous is they have one or more of the properties listed in Annex III of the directive. Annex 1B contains 21 generic waste types, which are considered hazardous if they contain any of the constituents in Annex II and have one or more of the properties in Annex III.

Annex II contains a list of 51 substances or groups of substances which render wastes hazardous when they have properties described in Annex III. These substances are listed in Table A.5.2. Many substances, which commonly occur in secondary materials, are included in this list.

The properties of wastes which render them hazardous (Annex III), are summarised below and given in full in Table A.5.3:

- Explosive
- Oxidising/flammable
- Irritant
- Harmful to health
- Toxic
- Carcinogenic
- Corrosive
- Infectious
- Teratogenic
- Mutagenic
- Release toxic gases in contact with air, water or oxygen
- Give rise to other substances possessing the properties in this list, e.g. leachate
- Ecotoxic

The definitions of the hazard properties toxic, harmful, corrosive, irritant, carcinogenic, teratogenic and mutagenic are given in the “Guide to the classification and labelling of dangerous substances and preparations”, part of Directive 67/548/EEC (version amended by 83/467/EEC). The Swedish Chemicals Inspectorate’s Regulations on Classifying and Labelling of Chemical Products are based on these directives, and are discussed in Appendix B.

Substances, which are classified as harmful according to one of the above categories, must exceed a defined concentration in the waste for the waste to be classified as harmful. The concentration defined depends on the definition of harmful, e.g. substances classified as very toxic must be present in concentrations exceed in 0.1%, substances classified as toxic must exceed concentrations of 3% and substances classified as harmful must exceed concentrations of 25% (Council decision, 1994).

A list of hazardous wastes has been drawn up, based on the same waste categories as the waste catalogue.

5.3 Proposed council directive on the landfill of waste (18th September 1996)

This proposal for a council directive is not yet complete, but proposes a framework for the classification landfill sites and determination of appropriate wastes for each class of landfill.

Landfill sites shall be classified into the following classes:
- Landfill for hazardous waste
- Landfill for non-hazardous waste
- Landfill for inert waste.

General requirements for all classes of landfills are stipulated, together with the barrier properties required for the three different classes of landfill. Barrier properties may be natural (i.e. geological) or may be artificially reinforced. In addition, the leachate collection and sealing system required by the three different classes of landfill that are stipulated. These requirements are summarised in table A.5.4.

Table A.5.4 General conditions required for different classes of landfill

	Barrier conditions		**Leachate collection and bottom sealing**	**Surface sealing**
	K (m/s)	**Thickness (m)**		
Hazardous	$\leq 1.0 \cdot 10^{-9}$	≥5	Artificial liner and drainage layer ≥0.5m	Artificial liner, impermeable mineral layer, drainage layer ≥0.5m and top soil cover ≥1m
Non-hazardous	$\leq 1.0 \cdot 10^{-9}$	≥1	Artificial liner and drainage layer ≥0.5m	Gas drainage layer, impermeable mineral layer, drainage layer ≥0.5m and top soil cover ≥1m
Inert	$\leq 1.0 \cdot 10^{-7}$	≥1	-	-

The acceptance criteria for wastes that can be accepted in the different classes of landfill are then defined in annex II. The general principles for acceptance of waste are that the composition, leachability, long-term behaviour and general properties of a waste must be known as precisely as possible. At present, waste acceptance at a landfill can be based on the origin and nature of the waste, or on waste analysis methods and limiting values for waste properties. However, standardised waste acceptance procedures and relevant sampling procedures are to be developed based on standardised waste analysis methods and limit values for waste properties.

Criteria for acceptance at a specific class of landfill must be derived by considering protection of the surrounding environment (particularly groundwater and surface water), of the environmental protection systems (liners and leachate treatment systems), of the intended waste stabilisation processes in the landfill and of human-health.

Examples of waste property based criteria are given as;
- Requirements on knowledge of total composition
- Limitations on the amount of organic matter in the waste
- Requirements or limitations on the biodegradability of the organic waste components
- Limitations on the amount of specified, potentially harmful/hazardous components
- Limitations on the potential and expected leachability of specified, potentially harmful/hazardous components
- Ecotoxicological properties of the waste and the resulting leachate.

The property based criteria for waste acceptance must be generally most closely defined for inert waste landfills, where the barrier properties are not so effective, and least closely defined for hazardous waste landfills, where barrier properties are designed for a high degree of environmental protection.

The general characterisation and testing of waste is to be based on three-levels:
1. Basic characterisation; a thorough determination of the short and long-term leaching behaviour and/or characteristic properties of the waste. Compliance with criteria allows the waste to be accepted on a reference list (i.e. assigned to a landfill class).
2. Compliance testing; periodical (e.g. annual) testing by simpler standardised analysis and behaviour-testing methods to determine whether a waste complies with permit conditions

and/or reference criteria. The tests focus on key variables and behaviour identified by basic characterisation. Compliance with criteria allows the waste to remain on a site-specific list.

3. On-site verification; rapid checking of each waste load at the landfill to confirm that the waste is the same as that which is described in the documentation and that which has previously been tested (may take the form of visual examination).

Table A.5.2 Constituents of wastes which render them hazardous when they have the properties described in Table A.5.3 (Annex II from 91/689/EEC)

C1	Beryllium; beryllium compounds
C2	Vanadium compounds
C3	Chromium(VI) compounds
C4	Cobalt compounds
C5	Nickel compounds
C6	Copper compounds
C7	Zinc compounds
C8	Arsenic; arsenic compounds
C9	Selenium; selenium compounds
C10	Silver compounds
C11	Cadmium; cadmium compounds
C12	Tin compounds
C13	Antimony; antimony compounds
C14	Tellurium; tellurium compounds
C15	Barium compounds; excluding barium sulphate
C16	Mercury; mercury compounds
C17	Thallium; thallium compounds
C18	Lead; lead compounds
C19	Inorganic sulphides
C20	Inorganic flourine compounds, excluding calcium flouride
C21	Inorganic cyanides
C22	The following alkaline or alkaline earth metals: lithium, sodium, potassium, calcium, magnesium in uncombined form;
C23	Acidic solutions or acids in solid form
C24	Basic solutions or bases in solid form
C25	Asbestos (dust and fibres)
C26	Phosphorus: phosphorus compounds, excluding mineral phosphates
C27	Metal carbonyls
C28	Peroxides
C29	Chlorates
C30	Perchlorates
C31	Azides
C32	PCBs and/or PCTs
C33	Pharmaceutical or veterinary compounds
C34	Biocides and phyto-pharmaceutical substances (e.g. pesticides, etc)
C35	Infectious substances
C36	Creosotes
C37	Isocyanates; thiocyanates
C38	Organic cyanides (e.g. nitriles, etc)
C39	Phenols, phenol compounds
C40	Halogenated solvents
C41	Organic solvents, excluding halogenated solvents
C42	Organic solvents, excluding halogenated solvents
C43	Aromatic compounds; polycyclic and heterocyclic organic compounds
C44	Aliphatic amines
C45	Aromatic amines
C46	Ethers
C47	Substances of an explosive character, excluding those listed elsewhere in this Annex
C48	Sulphur organic compounds
C49	Any congener of polychlorinate dibenzo-furan
C50	Any congener of polychlorinated dibenzo-p-dioxin
C51	Hydrocarbons and their oxygen; nitrogen and/or sulphur compounds not otherwise taken into account in this Annex.

Table A.5.3 Properties of wastes which render them hazardous (Annex III from 91/689/EEC)

H1	'Explosive': substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene
H2	'Oxidising': substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances
H3-A	'Highly flammable': liquid substances and preparations having a flash point below 21°C (including extremely flammable liquids),or substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or -solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition or gaseous substances and preparations which are flammable in air at normal pressure, or substances and preparations which, in contact with water or damp air, evolve highly flammable gases in dangerous quantities
H3-B	'Flammable': liquid substances and preparations having a flash point equalt to or greater than 21°C and less than or equal to 55°C.
H4	'Irritant': non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation.
H5	'Harmful': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks.
H6	'Toxic': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks.
H7	'Carcinogenic': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence.
H8	'Corrosive': substances and preparations which may destroy living tissue of contact.
H9	'Infections': substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organism.
H10	'Teratogenic': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce non-hereditary congenital malformations or increase their incidence.
H11	'Mutagenic': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence
H12	Substances and preparations which release toxic or very toxic gases in contact with water, air or an acid.
H13	Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above.
H14	'Ecotoxic': substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment.
Note: Attribution of the hazard properties 'toxic' (and 'very toxic'), 'harmful', 'corrosive' and 'irritant' is made on the basis of the criteria laid down by Annex VI, part IA and part II B, of Council Directive 67/548/EEC of 27 June 1967 of the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, in the version as amended by Council Directive 79/831/EEC.	

Appendix B

Existing systems in Sweden relevant to the assessment of risk associated with the use of secondary materials

1. SWEDISH NATIONAL CHEMICALS INSPECTORATE –CLASSIFICATION AND MARKING OF CHEMICAL PRODUCTS (KIFS 1996:5)

Chemical products are classified and marked according to their hazardous properties for human health and the environment.

1.1 Classification according to hazard to human health

Chemical preparations are classified according to human-health hazard based on their content of hazardous substances. The criteria for classification of chemical preparations are based on the concentrations of a hazardous substance at which the toxicological end-points used in the classification system occur.

The hazardous properties of substances are classified according to the results of test-data for a number of properties. The classification systems for each set of properties are outlined below.

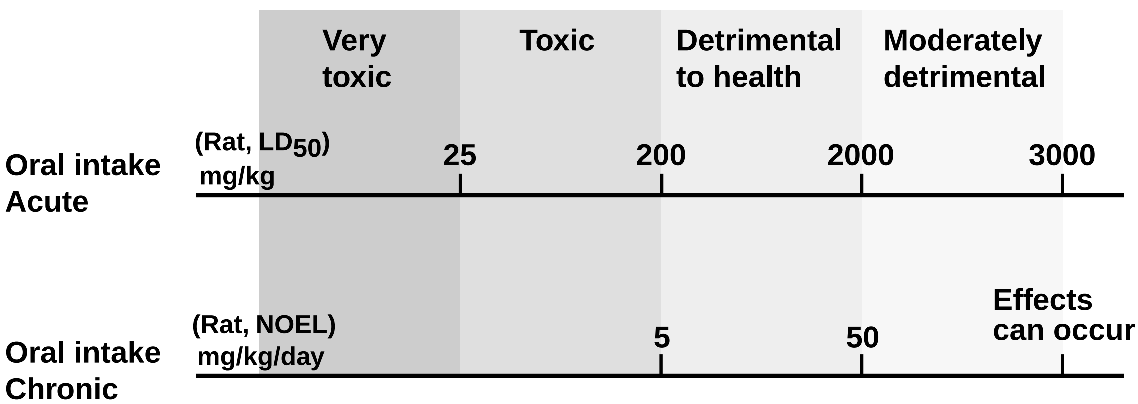
1.1.1 Toxicity

The acute toxicity of substances may be classified as very toxic, toxic, damaging to health and moderately damaging to health for each of the exposure pathways ingestion,inhalation and skin contact. The classification is based on LD_{50} data for mammals.

The chronic toxicity of substances may be classified as toxic, damaging to health or moderately damaging to health for each of the three exposure pathways. The classification is based on the chronic dose (mg/kg body weight and day).

As an example, the classification system for oral intake is shown in figure B.1.1.

Figure B.1.1. Classification of toxicity following oral intake



1.1.2 Corrosive, irritating and drying to the skin

Corrosivity is classified into very corrosive or corrosive according to whether deep tissue damage occurs after exposure of undamaged skin to the substance over a period of three minutes or four hours respectively

Substances are classified as irritating to skin, airways, eyes or seriously damaging to eyes based on data for relevant toxicological end-points and and exposure times from animal tests and/or data on human exposure.

Substances are classified as drying to the skin if they have solvents for fats.

1.1.3 Cause of allergies

For the inhalation pathway, substances are classified as causing allergies if allergic reactions are caused in people at a higher frequency than can be expected in a normal population. Following skin contact, substances are classified as causing allergies if the substance induces allergic reactions in a significant proportion of people and/or the substance is sensitising in animal tests.

1.1.4 Carcinogenic properties

Substances may be classified into two groups according to the degree of carcinogenicity (low and medium-high carcinogenicity) based on epidemiological studies, suitable animal studies and other relevant information.

1.1.5 Mutagenic properties

Substances may be assigned to categories 1, 2 and 3 (substances which are mutagenic in humans, which are probably mutagenic in humans and which are possibly mutagenic in humans), according to the weight of evidence for their mutagenic properties.

1.1.6 Reproductive toxicity

As for mutagenic properties, substances may be assigned to three groups, according to the weight of evidence for reproductive toxicity in humans.

1.1.7 Other hazardous properties

Substances as which are inflammable, explosive, give rise to toxic gases in contact with water or oxygen, which accumulate in the body to levels where damage occurs or which cause damage to nursing infants are also classified as hazardous to human health.

1.2 Classification according to environmental hazard

Substances are classified according to their hazard to aquatic and terrestrial environments. For the aquatic environment, the classification is based on the toxicity, persistence and bioaccumulation of substances. Table B.1.1 summarises the system used.

Substances may be classified according to their effects in other environments into the following classes:

- Toxic to plants
- Toxic to animals
- Toxic to soil-dwelling organisms
- Toxic to bees
- Can cause damaging long-term effects on the environment. Again, the assessment should be based on the toxicity, persistence and bioaccumulation of the substances together with the expected or observed environmental behaviour and fate.
- Damaging to the ozone layer, based on EU council directive 594/91/EEG.

Table B.1.1 **Classification of substances in KIFS 1996:5; hazard to the aquatic environment .**

	Very toxic and can cause long-term effects in aquatic environments	Very toxic	Toxic and can cause long-term effects in aquatic environments	Damaging to aquatic organisms and can cause long-term effects in aquatic environments	Can cause long-term effects in aquatic environments
Toxicity	Fish, 96hr LD_{50}≤1mg/l or Daphnia,48hr EC_{50}≤1mg/l or Algae, 72hr IC_{50}≤1mg/l	Fish, 96hr LD_{50}≤1mg/l or Daphnia,48hr EC_{50}≤1mg/l or Algae, 72hr IC_{50}≤1mg/l	Fish, 96hr LD_{50}≤10mg/l Or Daphnia,48hr EC_{50}≤10mg/l Or Algae, 72hr IC_{50}≤10mg/l	Fish, 96hr LD_{50}≤100mg/l or Daphnia,48hr EC_{50}≤100mg/l or Algae, 72hr IC_{50}≤100mg/l	-
Persistence	Not easily degradable	-	Not easily degradable	Not easily degradable	Low solubility, <1mg/l and/or Not easily degradable
Bio-accumulation	Log Pow≥3.0 or BCF*≤100	-	Log Pow≥3.0 Or BCF*≤100	-	Log Pow≥3.0 or BCF*≤100

* BCF = experimentally determined bioaccumulation factor.

#A substance is considered easily degradable if:

1. Biodegradation studies over 28 days show degradation of
   - 70% based on dissolved organic carbon
   - 60% based on oxygen consumption or carbon dioxide production
2. BOD_5/COD ≥ 0.5
3. Other data show that the substance is degraded by > 70% within 28 days.

2. SWEDISH EPA'S ENVIRONMENTAL ASSESSMENT VALUES.

The Swedish Environmental Protection Agency has developed values which are intended to be used as a basis for assessment of the condition of the environment (Swedish EPA, 1999a-e). Values have been developed for six different environments; coastal and marine, freshwater, groundwater, agricultural, forest, contaminated areas. Values are given for assessments of a number of aspects of environmental quality, eg biodiversity, water quality, however, this report concentrates on assessment basis values for metals in the freshwater, groundwater and soils. Where values are given for other contaminants, these are also discussed.

2.1 Groundwater

Environmental assessment values for groundwater are based on risks to both human health and the environment (Swedish EPA, 1999a). The boundary between classes 1 and 2 is the concentration in water where effects beginning to be seen in sensitive surface waters (this boundary is equivalent to the boundary between classes 2 and 3 in the environmental quality standards for surface waters). The boundaries between classes 2,3, 4 and 5 are based on the Swedish National Food Administration drinking water standards (1993), ie are based on the risk to human health associated with the use of groundwater as drinking water. The values are given for four metals are shown in table B.2.1.

Table B.2.1 Environmental assessment values for groundwater

Class	Metal concentration	Metal concentration (µg/l)				Effect
		Cd	Zn	Pb	As	
1	Very low	<0.05	<5	<0.2	<1	ca. background concentration
2	Low	0.05 -0.1	5.0 – 20	0.2 - 1.0	1.0 - 5.0	< Concentration where effects are observed in sensitive surface waters
3	Medium	0.1 - 1	20 – 300	1.0 - 3.0	5.0 - 10	< may be used for drinking water – some reservations
4	High	1.0 - 5.0	300 – 1000	3.0 - 10	10 - 50	< below the drinking water limit
5	Very high	>5	>1000	>10	>50	> above the drinking water limit

2.2 Surface water

The environmental assessment values for metals in surface water are based on the biological effects on aquatic organisms (Swedish EPA, 1999b). Surface waters are divided into five effect-related classes on the basis of the metal concentrations, as shown in table B.2.2. The values given for seven metals are shown in table B.2.3.

Table B.2.2 Water quality classes; metal contents

Class	Metal content	Effect
1	Very low	ca. background concentration, ie.water without anthropogenic influence
2	Low	Small risk for biological effects
3	Medium	Effects observed in sensitive surface waters
4	High	Increased risk for biological effects
5	Very high	Short exposures affects the survival of aquatic organisms

Table B.2.3 Environmental assessment values for surface water (µg/l)

Class	Metal concentration	Cu	Zn	Cd	Pb	Cr	Ni	As
1	Very low	<0.5	<5	<0.01	<0.2	<0.3	<0.7	<0.4
2	Low	0.5 - 3.0	5.0 - 20	0.01 - 0.1	0.2 - 1.0	0.3 - 5.0	0.7 - 15	0.4 - 5
3	Medium	3.0 - 9.0	20 - 60	0.1 – 0.3	1.0 - 3.0	5.0 - 15.0	15 - 45	5.0 - 15
5	High	9.0 - 45	60 - 300	0.3 – 1.5	3.0 - 15.0	15.0 - 75.0	45 – 225	15 - 75
5	Very high	>45	>300	>1.5	>15	>75	>225	>75

2.3 Agricultural soils

Environmental assessment values for agricultural soils with respect to their metal content are based on the concentrations in soil which have been shown to affect microbial activity or plant growth (Swedish EPA 1999c). For relatively insoluble metals, critical concentrations for microbial activity have not been established. This is because it is not the total concentration is soil which determines the extent of toxic effect on microorganisms but the bioavailable fraction.

Standards for cadmium have been based on the recommended maximum cadmium concentration in food.
The values given are shown in table B.2.4.

Table B.2.4 Environmental assessment values for agricultural soils.

		Metal concentration (mg/kg)					
Metal l		Quality class					
		Ver y Low	Low	Medium	High	Very high	
	Description Class1	1	2	3	4	5	Description Class 5
Pb		<7	8-15	16-30	31-50	>50	Toxic to plants and microorganisms
Cd		<0.1	0.1-0.2	0.21-0.3	0.31-0.4	>0.4	High concentrations in crops may occur
Cu	Deficiency in crops may occur	<7	7-20	21-35	36-50	>50	Toxic effects on plants
Ni		<5	5-10	11-20	21-30	>30	Toxic effects on plants
Zn	Deficiency in crops may occur	<7	7-50	51-100	101-150	>150	Toxic effects on plants

2.4 Forest soils

Environmental assessment values for forest soils have been given for three quality classes and five metals (Swedish EPA, 1999d). Again, these classes are based on the effects on soil biota. The lower boundary (ie between low and medium metal concentration) is equivalent to the concentration where there begins to be a risk for biological effects. The boundary between medium and high metal concentration has been set at concentratios where biological effects in the soil are well documented. The values are shown in Table B.2.5.

Table B.2.5 Environmental assessment values for forest soils.

Class	Metal concentration	Metal concentration (mg/kg)				
		Cd	Cu	Hg	Pb	Zn
1	Low	<1	<15	<0.2	<25	<100
3	Medium	1-10	15 – 500	0.2 – 2	25 – 1000	100 – 500
5	High	>10	>500	>2	>1000	>500

3. RISK CLASSIFICATION OF CONTAMINATED AREAS

Contaminated areas are classified into four risk categories (Swedish EPA, 1999e) based on information concerning :

- The hazard associated with the contaminants present
- The concentrations and amounts of contaminants
- The potential transport and spreading of contaminants from the site

- The exposure potential for man and the value of the environment from a nature-protection point of view.

Information concerning each of these four aspects is collected for the contaminated site. For each aspect, the site is classified into one of four groups; low, medium, high and very high.

3.1 Hazard assessment

The classification of hazard associated with the contaminants is based on KIFS 1994:12, (described in 1 of this appendix) and as shown below:

Hazard class	**KIFS1994:12 classification.**
Low	Moderately damaging to health
Medium	Damaging to health, irritating, damaging to the environment
High	Toxic, corrosive, damaging to the environment
Very high	Very toxic

3.2 Amount and concentration of contaminants

Classification of the concentration of contaminants in soils, waters and surface waters is based on other guideline values. The the upper concentration limit for the lowest class (less serious contamination) are taken from other guideline values or environmental quality standards. Other classes are determined by the degree by which the measured concentration exceeds the upper boundary for “less serious” contamination. The classification system is shown in table B.3.1:

Table B.3.1 Classification of degree of contamination of soils, groundwaters and surface water.

Severity of contamination	**Medium**	**Concentration**
Less serious	Soil:	<Guideline value for contaminaned soils – sensitive land use (Swedish EPA, 1996)
	Groundwater:	<Drinking water quality standards (Swedish National Food Administration, 1993)
	Surface water	<Concentration at which there is an increased probability of biological effects (Swedish EPA, 1999b)
Fairly serious	Soil, surfacewater and groundwater	1-3 times the guideline value adopted as the upper boundary for less serious contamination.
Serious	Soil, surfacewater and groundwater	3-10 times the guideline value adopted as the upper boundary for less serious contamination.
Very serious	Soil, surfacewater and groundwater	>10 times the guideline value adopted as the upper boundary for less serious contamination.

Values are given for a larger number of contaminants than for other the environmental quality standards. In order to derive these values, it has been necessary to base some of the values on environmental quality standards from other countries e.g. Canadian Water Quality Criteria (CCME, 1993).

The amount of contaminant is classified taking into account the hazard associated with the contaminants present, as shown in the table B.3.2. Classification according to the volume of contaminated material is also shown.

Table B.3.2 Classification of the amount of contaminant at the source and of the volume of contaminated material.

	Amount of contaminant/ volume of contaminated material			
Hazard	**Small**	**Medium**	**Large**	**Very large**
Very high	-	-	Some kg	Tens kg
High		Some kg	Tens kg	Hundreds kg
Medium	Some kg	Tens kg	Hundreds kg	Ton
Volume of contaminated material	<1000 m^3	1000-10 000 m^3	10 000-100 000 m^3	>100 000 m^3

3.3 Potential transport

Classification of the potential for transport and spreading of the contaminant from the site is based on the estimated rate of transport within one media, or the time for transport from one medium to another (eg from soil to groundwater). The classification scheme is shown in table B.3.3:

Table B.3.3 Classification of contaminated sites according to the potential contaminant transport

	Potential transport class			
	Small	**Medium**	**Large**	**Very large**
From buildings and construction	No spreading	<5% per year	5-50% per year	>50% per year
In soil and groundwater	No spreading	<0.1 m per year	0.1–10m per year	>10m per year
From soil and ground-water to surface water	>1000 years	1000-100 years	100-10 years	>10 years
In surface water	No spreading	<0.1km per year	0.1-10km per year	>10km per year
In sediment	No spreading	<0.1m per year	0.1–10m per year	>10m per year

3.4 Sensitivity/Protection value

Contaminated sites are similarly classified into four classes based on the number extent to which man is exposed to the contaminated site. This exposure is assessed at the level of the individual and is independent of the number of people exposed.The classification system is shown below:

Sensitivity	Exposure
Low	No exposure, (eg. a small enclosed area with no land use)
Medium	Occupational exposure to a lesser extent. No groundwater use(eg industrial area)
Large	Occupational exposure under whole working day Exposure of children to a lesser extent Use of groundwater/surface water as drinking water Agricultural activities Use as “green area” (eg. shops, offices, other business use)
Very large	Permanent occupation Exposure of children to a larger extent Use of groundwater or surface water as drinking water (eg. nursery, school)

A similar classification is based on protection value of the species and ecosystems exposed to contaminants, as shown below:

Protection value	Exposure
Low	Very polluted area. Ecosytem destroyed by human activitiy(eg. waste disposal site, asphalted area)
Medium	Somewhat disturbed ecosystem

	Very common ecosystem type in that region (eg. normal forestry and agricultural areas)
Large	Area with a less common ecosytem (for that region). Area where species or ecosystems that are of value to nature protection are exposed to contaminants(eg. water-line areas, sensitive water bodies, recreational areas, urban parks).
Very large	Areas with species or ecosystems which, locally or regionally, are of great value with respect to nature-protection (eg. national parks, nature reserves, marine reserves, areas with biotope protection, areas with rare or threatened species).

3.5 Risk classification

For contaminated areas, potential transport is regarded as the probability of contact with the contaminant occurring, and the other three aspects correspond to the consequences. The final risk classification is therefore carried out by weighing the potential transport against the three other aspects (contaminant hazard, contaminant amount/concentration and the exposure/protection value of the site). Generally, the hazard associated with the contaminant and contaminant concentration/amount is given higher priority than the sensitivity/protection value of the site. The site is assigned to risk classes 1 – 4, depending on the severity of the risk.

4. GENERIC GUIDELINES FOR CONTAMINATED SOIL

The Swedish Environmental Protection Agency published guidelines for contaminated soil in 1996. In 1998, guideline values for petrol-station sites were developed jointly by the Swedish EPA and the Swedish Petroleum Institute (SPI). These generic guideline values are given in table B.4.1.

The guideline values for contaminated soils are intended to be used in assesments of contaminated sites to indicate contaminant levels which do not pose unacceptable risks to humans or the environment. Generic values have been developed for a range of inorganic and organic substances of importance at contaminated sites, including heavy metals, cyanides, phenols, aromatics and PAHs. The guideline values were developed for typical Swedish conditions with respect to geology, hydrology and human exposure.

The model contains the following parts:

- Distribution of the contaminant between the solid, liquid and gaseous phase in the soil
- Transport of the contaminant to the recipient medium (i.e. the medium to which man or other organisms are exposed)
- Exposure of man to the contaminant
- The health risks associated with the calculated exposure
- Environmental risks associated with the resulting concentrations in environmental media.

The model determines the concentration in soil which is equivalent to a risk which is determined to be acceptable.

4.1 Assessment of risks to human health and the environment

The assessment of health risk associated with exposure to a given contaminant is based upon information on the dose-effect or dose-response relationship for man. The dose-response data is used to identify a safe dose or a threshold toxic level for a particular adverse effect. The threshold level is established from the results of expseriments and epidemiological studies. Safety factors are used to allow for the uncertainties inherent in the data. For most contaminants, this threshold level is expressed as a tolerable daily intake (TDI, in mg/kg body weight per day) for the oral exposure pathway. For the inhalation pathway a reference air concentration (RfC, expressed in mg/m^3 is used.

For genotoxic carcinogenic contaminants, it is not possible to express a “safe” or “threshold” dose as even low doses can imply a cancer risk. Increased doses do not affect the severity of the effect, but do increase the risk of the effect occurring. Therefore, mathematical extrapolation models which are linear in the low dose region are used to determine the exposure to a chemical which is equivalent to an acceptable risk level. The risk level used in the model is a lifetime excess cancer risk of 1 in 10^{-5}.

The values chosen for the toxicological parameters (ie, TDI, RfC and intake equivalent to a lifetime cancer risk of 1 in 10^{-5}) were from WHO [1993], USEPA [IRIS] and other databases.

Risks to the environment are considered both on the contaminated site itself and in recipient water bodies which receive contaminants as a result of leaching from the soil and transport in groundwater or surface waters. The acceptable concentration of contaminants in soil on site represents the concentration at which there is no serious disturbance of the soil’s capacity to carry out the range of ecological functions required by the land use. The ecotoxicologically based values are based on the ecotoxicological intervention values derived in the Netherlands [Crommentuijin et al, 1995], which are derived from the most comprehensive available ecotoxicological database. The acceptable concentration of contaminants in surface water are based on the Canadian Water Quality Guidelines [CCME, 1996] which are set at concentrations which are protective of all forms of freshwater aquatic life at all stages of the life cycle.

4.2 Exposure pathways

For each substance, different types of land use were considered:

- Land with sensitive use (KM), eg land used for residential areas, kindergarten, agriculture, groundwater extraction, etc.
- Land with less sensitive use and groundwater extraction (MKM GV), eg land used for offices, industry, roads etc
- Land with less sensitive use as above but with no groundwater extraction (MKM).

The land-use determines which exposure pathways are considered for the human health, as shown in the table B.4.2. The land use also determines the intensity or duration of exposure.

Table B.4.2 ***Exposure pathways considered for different land use***

Exposure pathway	**KM**	**MKM GV**	**MKM**
Soil ingestion	X	X	X

Dermal contact	X	X	X
Inhalation of dust	X	X	X
Inhalation of vapour	X	X	X
Drinking water	X	X	
Ingestion of vegetables grown in contaminated soil	X		
Ingestion of fish	X		

The guideline values for contaminated petrol stations consider two additional types of land use, parkland and soil with a low level of use.

The choice of land use also affects the concentration considered to be acceptable in soil from an ecotoxicological viewpoint, as the land use determines which functions are required of the soil.

4.3 Distribution and transport of contaminants.

The distribution of contaminants between the solid phase os the soil, porewater and the soil atmosphere has been assumed to be in equilibrium. The equilibrium concentration in each of the three phases has been calculated according to the fugacity model, using contaminant specific equilibrium distribution coefficients.

Transport of substances in the different phases to media where exposure of man and other organisms occurs is represented by a dilution factor, which can be derived from more detailed transport models. An example which is relevant to the use of secondary materials in construction is the transport of contaminants in the soil pore water with infiltrating groundwater. This water is diluted on reaching the groundwater. When the groundwater then reaches a surface water body, eg a lake, further dilution occurs. The dilution assumed depends on the relative water volumes and turnover times. In the Swedish EPA/SPI guideline values for contaminated petrol station sites, the dilution factors for groundwater (drinking water)/pore water were assumed to depend on the yield of the well and the distance of the well from the site. The values used are shown in table B.4.3.

Table B.4.3Dilution factors used for well yields and distances from the contaminated site.

Yield of well*	**Distance**	**Dilution factor#**
Small (20 m^3/d)	0	5
	35	12
	100	30
	500	80
Medium (80 m^3/d)	0	12
	35	30
	100	80
	500	200
Large (400 m^3/d)	0	50

	35	30
	100	80
	500	200
Very large (2000 m^3/d)	0	200
	35	600
	100	1600
	500	4000

* SGUs classification of yield for surface wells [SGU]
# For a contaminated area of 1000m^2, infiltration 200 m^3/year

The dilution factor surface water /groundwater was assumed to be 4000, which represents outflow to a small lake.

Table B.4.1 Swedish EPA's guideline values (mg/kg TS) for contaminated soil (with Swedish EPA/SPI's guideline values for contaminated petrol station sites) .

Land use	**Sensitive**	**Less sensitive, groundwater use**	**Less sensitive, groundwater not used**	**Park/Low degree of use**
Generic guidelines for contaminated soils (SEPA, 1996)				
Metals				
Arsenic	15	15	40	
Lead	80	300	300	
Cadmium	0.4	1	12	
Cobalt	30	60	250	
Coppar	100	200	200	
Chromium(total)	120	250	250	
Chromium(VI)	5	15	20	
Mercury	1	5	7	
Nickel	35	150	200	
Vanadium	120	200	200	
Zinc	350	700	700	
Other inorganic substances				
Total cyanide (only where there are no available cyanides)	30	80	1000	
Available cyanide	1	2	20	
Phenols and chlorophenols				
Phenol and cresol	4	10	40	
Sum of chlorophenols except pentachlorophenol	2	10	10	
Pentachlorophenol	0.1	3	5	
Chlorobenzenes				
Sum of mono- and dichlorobenzenes	15	30	30	
Sum of tri-,tetra and pentachlorobenzenes	1	20	30	
Hexachlorobenzenes	0.05	20	30	
Other chlorinated substances				
Total PCB (with specified method)	0.02	4	7	
Dioxines, furans and planar PCBs(as TCDD equivalents)	10ng/kg TS	250ng/kg TS	250ng/kg TS	
Dibromochloromethane	2	4	100	
Bromodichloromethane	0.5	2	8	
Carbon tetrachloride	0.1	0.2	3	
Trichloromethane	2	8	50	
Trichloroethylene	5	30	60	
Tetrachloroethylene	3	20	60	
1,1,1-trichloroethane	40	90	90	
Dichloromethane	0.1	0.3	60	
Nitrogen compounds				
2,4-dinitrotoluene	0.5	2	20	
BTEX				
Benzene	0.06	0.2	0.4	
Toluene	10	35	35	
Ethylbenzene	12	50	60	
Xylene	15	60	70	
PAH				
Sum of carcinogenic PAH	0.3	7	7	
Sum of other PAH	20	40	40	
Branch specific guidelines for contaminated petrol stations (values for soils with normal permeability and contaminant depth of 0.7 – 2 m (*) (SEPA/SPI 1998)				
Aliphatics				
>C5-C8	50	200	200	50-200

>C8-C10	100	350	350	100-500
>C10-C12	100	500	500	100-500
>C12-C16	100	500	500	100-500
Sum of >C5-C16	100	500	500	100-500
>C16-C35	100	1000	1000	100-1000
Aromatics				
Benzene	0.08	0.4	0.4-3	0.6
Sum of toluene, ethylbenzene and xylene	10	40	60	30-40
>C8-C10	40	200	200	100-200
>C10-C35	20	40	40	20-40
Sum of carcinogenic PAH	0.3	8-40	8-40	8-40
Sum of other PAH	20	40	40	20-40
Other				
MTBE	6	35	120	35
1,2-dichloroethylene	0.05	0.15	0.2	0.7
1,2-dibromomethane	0.00002	0.0002	0.02	0.0002
Lead (inorganic)	100	300	300	150-300
Tetraethyl lead	0.00004	0.004	0.04	0.0003

- Values are given in SEPA/SPI (1998) for soils with low, normal and high permeability, and contaminant depths of 0-0.7, 0.7–2.0 m and >2m.

5. QUALITY CRITERIA FOR COMPOST AND SEWAGE SLUDGE

The Swedish EPA has set limits for metal concentration in soils to which sewage sludge can be applied and for the annual application of metals to soil in sewage sludge in order to avoid harmful a long-terma build up of metals in agricultural soil to levels where there is a risk for harmful effects in the soil, vegetation, animals and man (SNFS 1998:4).

Sewage sludge may not be applied to land soil with metal concentrations exceeding the limits shown in table B.5.1:

Table B.5.1 Concentration limits for metals in agricultural soils for the application of sewage sludge

Metal	mg/kg dry weight
Lead	40
Cadmium	0.4
Coppar	40
Chromium	60
Mercury	0.3
Nickel	30
Zinc	100

The limiting concentration for zinc may be exceeded in Jämtlands, Stockholms, Södermanlands, Uppsala, Västernorrlands and Västmanlands län, where the zinc concentraion may be up to 150 mg/kg ts.

The annual addition of metals to soil with sewage sludge or with compost may not exceed the amounts shown in table B.5.2:

Table B.5.2 Application of sewage sludge to agricultural soils, application limits for metals.

Metal	Annual addition of metals (g/ha and year)	
	From 1995	From 2000
Lead	100	25
Cadmium	1.75	0.75
Coppar	600	300
Chromium	100	40
Mercury	2.5	1.5
Nickel	50	25
Zinc	800	600

These values are annual average values calculated over a seven year period. The limits are based on studies of the annual addition of metals to soil (eg. in fertiliser, manure, pollution, sewage sludge) and the annual loss from soil (eg by leaching, removal in crops) (Andersson,1992). The values are intended to achieve a balance between metal addition and loss in the soil and to avoid long-term accumulation.

Limits for the metal content in sewage sludge and compost have also been derived. The values for compost are based a EU Commission decision nr 1488/97. The values for sewage sludge are derived from the limit on annual addition and the assumption of an application rate of 1 tonne/ha and year.

In Denmark a system with two sets of limiting values for metals in sewage sludge and compost has been introduced. One set of limits is based on the metal content per unit dry weight, as in the table above, and one set of limits is based on the metal content per unit phosphorus content. The owner of the product can decide which limit to use. In this way, the positive effects of the product (P fertilisation) are offset against the negative effects, ie. Addition of metals to the soil. This system is only appropriate however for P-rich products. It is not yet clear whether a similar system will be introduced in Sweden.

6. PROCEDURE FOR SELECTION OF GROUTING COMPOUNDS WITH REGARD TO HEALTH AND ENVIRONMENTAL SAFETY

This document (MGG,1998) has been approved by the Swedish EPA and by the county authorities for use in the case of Hallandsås. The objective of the procedure is to act as a framework for the assessment of chemical products for a specific use in order to avoid negative consequences to health and the environment.
The procedure is a three stage process.

1. Hazard analysis: In this stage the inherent properties of the material are assessed. The analysis should include a materials safety data sheet (MSDS) according to KIFS 1994:12 (see section 5.1). All the properties of the product discussed in section 5.1 should be assessed. Some further information relevant to the particular use as

grouting compounds is required as a complement to the MSDS. Information should be given on the function and chemical hardening process of the product, particularly in respect to site-specific aspects, including the hardening time at the relevant temperature, need for other chemicals, substances which are given off during hardening, effect of running water on the process and the hardened product. Information should also be given about any existing occupational exposure limits for the product and about requirements for protective equipment. Information about measures to be taken in the case of spills or leakage is also to be given.

2. Risk analysis: Risks to health and the environment resulting from the use of the grouting compound should be assessed at this stage, taking into account the following information;
   - Hazard analysis
   - Amount of the compound used
   - Method of use
   - Need for water treatment (drainage water from the tunnel and water subject to spill)
   - Treatment of waste rock from the tunnel
   - Need for protective equipment
   - Need for health-checks
3. Safety assessment: The uses or the conditions for use which do not imply unacceptable damage or effects on personnel, groundwater, crops, animals and drinking water supplies are specified for the compound assessed.