SLOVENSKI STANDARD
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Karakterizacija blata - Vodilo za oceno tveganja s poudarkom na uporabi in odlaganju blata

Characterisation of sludges - Guide to risk assessment especially in relation to use and disposal of sludges

Charakterisierung von Schlämmen - Anleitung zur Risikobwertung im Besonderen im Bezug auf Nutzung und Lagerung von Schlämmen

Caractérisation des boues - Guide pour l'évaluation du risque en relation avec l'usage et le mise en décharge des boues

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Characterisation of sludges - Guide to risk assessment especially in relation to use and disposal of sludges

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Contents

Foreword

This document (CEN/TR 15584:2007) has been prepared by Technical Committee CEN/TC 308 “Characterisation of sludges”, the secretariat of which is held by AFNOR.

1 Summary

This report has been prepared within the framework of CEN/TC 308 on Characterization of Sludges. The Scope includes sludges from treating municipal, industrial and food processing wastewaters, sludge from treating raw water to make it potable, and other residues having similar potential environmental impacts.

The objectives of the report are to review the methodology of risk assessment, risk management and risk communication especially as they have been applied to sludges. It includes references to, and reviews of, some major risk assessments and abstracts of others that have been published.

Sludge is the inevitable residue of treating raw potable water and municipal and industrial wastewaters. Treatment of these waters is designed to remove unwanted constituents from the water and concentrate them into a small side-stream - “sludge”. The sludge may also contain surplus biomass cultured during biological treatment processes. The objective of treatment is to avoid adverse impacts on the environment and human health when the effluent is discharged into the environment or water is supplied for human consumption. The concentration of beneficial constituents and of pollutants in (and health risks associated with) a sludge depends on the initial quality of the wastewater or raw water, and the extent of treatment required to meet quality standards for effluent discharge, and potable water.

Where effluent quality standards are raised, in order to reduce pollutant loads on the environment, the quantity of sludge produced inevitably increases. To be consistent, the use or disposal of the sludge must also be environmentally acceptable, sustainable and cost-effective. Sludge management typically represents about half of the overall costs of wastewater treatment. Its management will become increasingly complex as environmental standards become more stringent, and if outlets for sludge become more constrained by legislation and public attitudes.

EU policy on waste is to promote waste avoidance, minimisation and recycling above disposal. Disposal of sludge to sea ceased at the end of 1998. Disposal of sludges to landfill, which is currently the major outlet for some sludges in Europe, is widely regarded as unsustainable. Sludge production cannot be avoided (although the quantity can be reduced by treatment). The only remaining significant options are recycling or destruction by combustion. Recycling options include use on land as an organic fertiliser or soil improver for farming, land restoration, etc. Destruction options include combustion with or without energy recovery, gasification, and using the sludge as a process fuel, with the ash being used or landfilled.

Many sludges and residues contain beneficial constituents and properties with positive environmental advantages. For example, recycling phosphate and thus reducing the need to extract primary raw material and extending the life of the planet’s reserves.

The EU has decided (CEC, 2000) that environmental policies should be proportionate to risk and non-discriminatory. When there is sufficient information, there should be risk assessment and, when there is insufficient information, measures should be put in place to fill the information gap and an interim precautionary approach applied.

In popular understanding, “safe” can be interpreted as “something we don’t have to worry about”. There is a social factor as well as the numerical factor. Some people talk of the “One-hit” model, especially for carcinogens, which assumes that interaction of a single molecule with DNA could trigger mutation that could replicate as cancer but if this were applied universally it would stop all activity. Doing risk assessment lets us understand the aspects that drive the risk and therefore enables us to target the regulation – it improves the way we regulate.

Risk assessment should inform a decision rather than support a decision that has already been taken, i.e. the science should come first and then the politics (informed by the science). Equally the performance of risk assessment needs to be adequately resourced (time, money, people, etc.), it needs to be transparent (i.e. the models and assumptions should be published) and stakeholders need to be involved at the earliest stages. The fundamental question is “risk of what to whom”. Risk communication has emerged as an essential activity.

In order to increase public and stakeholder confidence the views of non-expert audiences may be brought into the risk assessment process and supporting [background] documents should be published so that the assumptions and models are clearly visible.

There is abundant information about the fate and transport of the constituents of sewage sludges, but less information about the other sludges. However, relatively few risk assessments have been published.

2 Scope

The Scope of this document includes sludges from treating municipal, industrial and food processing wastewaters, sludge from treating raw water to make it potable, and other residues having similar potential environmental impacts.

The purpose of this document is to discuss risk assessment in general and especially as it has been applied to sludges for an audience of specialists and non-specialists. The objective is to set risk assessment in the context of policy making and operating sludge use and disposal.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Not applicable

4 Terms and definitions

For the purposes of this report, the following terms and definitions apply:

4.1
harm
physical injury or damage to the health of people or damage to property or the environment

[ISO/IEC Guide 51]

4.2
hazard
potential source of harm

[ISO/IEC Guide 51]

4.3
risk
combination of the probability of occurrence of harm and the severity of that harm

[ISO/IEC Guide 51]

4.4
perceived risk
sum of risk and “outrage” – outrage is what makes people upset

4.5
contaminant
substance, material or agent that is unwanted in a sludge

[CR 13455 : 1999]

4.6
pollutant
contaminant present in a sludge that due to its properties, amount or concentration causes harm

[CR 13455 : 1999]

4.7
potentially toxic element
chemical elements that have a potential to cause toxicity to humans, flora and fauna. Typically, this term refers to “heavy metals” and others such as arsenic, selenium, boron, fluorine that exhibits a typical, dose related, sharp toxicity curve

[CR 13455 : 1999]

4.8
user
anybody exposed to the product, including professional and non-professional (amateur) users, and general public exposed not from a user standpoint

[CR 13455 : 1999]

4.9
intended use
use of a product, process or service in accordance with information provided by the supplier

[ISO/IEC Guide 51]

4.10
reasonably foreseeable misuse
use of a product, process or service in a way not intended by the supplier, but which may result from readily predictable human behaviour

[ISO/IEC Guide 51]

4.11
safety
freedom from unacceptable risk

[ISO/IEC Guide 51]

4.12
protective measure
means used to reduce risk

[ISO/IEC Guide 51]

4.13
residual risk
risk remaining after protective measures have been taken

[ISO/IEC Guide 51]

4.14
tolerable risk
risk that is accepted in a given context based on current values of society

[ISO/IEC Guide 51]

4.15
risk analysis
systematic use of available information to identify hazards to estimate the risk

[ISO/IEC Guide 51]

4.16
risk evaluation
procedure based on the risk analysis to determine whether the tolerable risk has been achieved

[ISO/IEC Guide 51]

4.17
risk assessment
overall process comprising a risk analysis and a risk evaluation

[ISO/IEC Guide 51]

4.18
Monte Carlo Analysis (MCA) or Simulation
process of repeatedly sampling from probability distributions to derive a distribution of outcomes (i.e. risks or hazards)

5 Introduction

About 500 years ago, Paracelsus (1493-1541) wrote: "Dosis facit venenum." ("The dose makes the poison."). The relationship between dose and response (effect) is still one of the most fundamental concepts of toxicology (the science of poisons), but when we discuss environmental alarms and chemical health risks it is sometimes forgotten. A logical consequence of the dose concept is that all environmental risk analysis is more or less quantitative in nature.

Risk management is at the heart of European policy on the environment as well as other aspects of life. It is also at the heart of many businesses. For example, risk assessment is the foundation of the insurance and pensions industries.

In order for there to be a risk [4.3] to a receptor there must be a source of the hazard [4.2] and a pathway by which a sufficient (harmful) dose is delivered to the receptor. In the case of the use or disposal of sludges, the sludge could be a source of chemical or biological hazards, the receptors could be organisms living in soil or water or on the surface of the land, and the pathway could be direct ingestion of the sludge or via air, plants or water.

Risk assessment [4.17] is often portrayed incorrectly as being different from the precautionary principle, indeed they are sometimes portrayed as being incompatible. The precautionary principle was first recognised at international level in the World Charter for Nature, adopted by the UN General Assembly in 1982. It was enshrined at the United Nations' Conference on Environment and Development, meeting at Rio de Janeiro in June 1992 (Annex C principle 15) this and European Commission policy (CEC, 2000) show that they are both part of managing environmental risk.

Risk assessment has established itself as an essential tool for the management of environmental risk and has been widely adopted by businesses, regulators and the financial sector. However, the perception of risks by members of the general public can differ from the quantitative assessments of risks. For example, it was difficult to persuade people to wear seat belts in cars, not to smoke, etc. because members of the general public's perceptions of the risks differed from those calculated by actuaries. The realisation of this dichotomy led to awareness that "risk communication" is also important. Table 1 gives examples of actuarial risks associated with normal everyday activities to give some context and to put the subject into perspective.

Table 1 – Examples of risks involved in normal activities (from FWR, 2002)

Activity	Risk Of	Cases per million
Travel 1000 miles by air	Fatal accident	3
Travel 1000 miles by car	Fatal accident	20
Travel 1000 miles by motorcycle	Fatal accident	400
Working 10 years in a factory	Fatal accident	300
1 glass of wine per day for 10 years	Cirrhosis	1000
1 cigarette per day for 10 years	Heart attack or lung cancer	2500
Living 1 year at age 30	Death from all causes	1000
Living 1 year at age 55	Death from all causes	10000

Figure 1 gives a representation of the major components of the process of hazard identification, risk assessment, risk management and risk communication. It shows examples of the types of data that are required; if there are insufficient data the precautionary principle should be invoked, in a way that is proportionate to the likely risk and on a time-limited basis, until the data necessary to estimate risk have been obtained (CEC, 2000). Cultural and political values are also shown as components because, for example, levels of risk or practices that are acceptable in one community might be unacceptable in another. It would seem illogical to have measures for different regulated activities within the same population that give markedly different levels of protection so there needs to be some consistency and proportionality.

A number of assumptions have to be made when assessing risk (as indicated in Figure 1). For example, when assessing the risk of transmitting toxic chemicals from sludge, via soil to crops and then to humans it is necessary to make assumptions about the proportion of the diet that comes from sludge treated land. It is important to document these assumptions in order that the basis is transparent. If somebody finds the result difficult to accept, they can then check the assumptions and models to see whether they are reasonable.

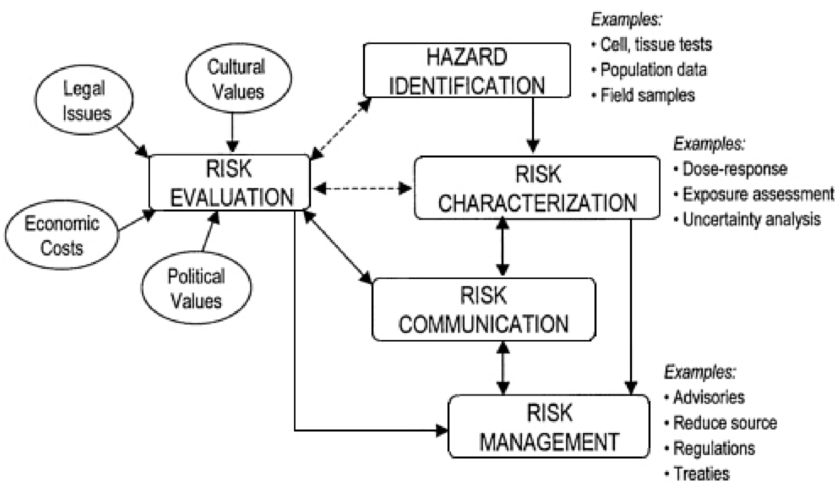

Figure 1 – The major components of the risk assessment and risk management process (from NAS, 2002)

5.1 Hazard, Risk and Communication

Crompton (2005) discussed the distinction of hazard and risk by the example of cyanide in a kitchen; the hazard is always very high but the risk depends on the exposure. If the bottle is clearly labelled and locked away in a safe the risk is small; if the bottle is unlabelled and in an unlocked kitchen cupboard the risk is much greater; if the cyanide is in a cup of tea the risk is very high indeed.

A newspaper headline “Cyanide found in kitchen” would be accurate and scary but it does not describe the risk. The same headline would be true if there were apples in the kitchen because apple pips contain small (non-harmful) amounts of amygdalin that breaks down to cyanide. The dose of cyanide from apple pips is so small that it is metabolised and is harmless, even if the coating is broken open by mastication.

5.2 Risk Assessment and the Precautionary Principle

Life is a continual process of managing and assessing risks. Take as an example crossing a road. By experience and example we learn to estimate the density and speed of the traffic and to assess when the risk [of being hit by a vehicle] is acceptably low to attempt to cross the road. If the traffic is so continuous and fast that there are no breaks for the risk to be acceptable we can walk to the nearest controlled crossing, i.e. employ risk reduction technology. However a person who is deaf and blind would not have the data required for assessing the risk; a deaf and blind person would be wise to employ the Precautionary Principle and not cross the road until their data gap was filled, e.g. by the assistance of a sighted person.

The authority responsible for the safety of pedestrians might decide that the risk of injury from crossing roads was unacceptable and all roads should be fenced. Traffic control lights would still entail the risk that vehicles might not stop; also, they disrupt traffic flow and cause delays. To eliminate the risk of pedestrian-vehicle collision, crossing would be permitted only at monitored subways (underpasses) or bridges. Monitoring would be in order to manage the risk of muggings. This approach is taken for motorways, autobahns, freeways and other very high-risk roads but it would be disproportionate to apply the policy to all roads. The cost of creating and maintaining the infrastructure and the inconvenience would be disproportionate to the risk. In practice, the authorities responsible for road safety assess the risks from data they have collected about accidents.

The Precautionary Principle is an integral part of risk assessment. If there are sufficient data to assess the risk with a reasonable degree of confidence, action/policy is based on the data. As with all scientific and engineering exercises, a margin of safety will be applied. The size of this margin is related to the confidence in the data and also to political choice. The tolerable level of risk for which the action/policy provides protection is also a political decision; the EU has decided this should be consistent and proportionate. If having examined the available data, they are considered to be insufficient or inconsistent, an interim and proportionate action/policy is established and at the same time the necessary measures are put in hand to fill that data gap so that a risk assessment is possible.

6 Source – Pathway – Receptor

It is fundamental that in order for there to be a risk there must be a receptor and that there must be a pathway by which the hazard is transmitted from the source to the receptor. If one of these elements in the chain is missing there can be no risk.

When considering sludge as a source of hazards, there are several possible receptors and several possible pathways; they are outlined in Table 2.

Table 2 – Generalised examples of possible source-pathway-receptor chains for use and disposal of sludges

Source →	Pathway →	Receptor	Consideration
Sludge →		human	Direct ingestion or via skin puncture etc.
Sludge →	soil →	human	Direct ingestion or via skin puncture etc.
Sludge →	soil → plant →	human	Dietary intake of plant material from sludge treated land diluted through food retail chain
Sludge →	soil → plant → animal →	human	Dietary intake of products from animals grazing or fed on crops from sludge treated land
Sludge →	soil → animal →	human	Direct ingestion of sludge treated soil by animals and transmission to humans
Sludge →	soil → airborne dust →	human	Respiration of dust from sludge treated land
Sludge →	(soil) → air →	human	Respiration of dust, odour, bioaerosols and airborne chemicals – includes incineration etc.
Sludge →	soil → ground/surface water →	human	Contamination of drinking water sources – includes landfill of sludges and ashes
Sludge →	soil → surface water → fish →	human	Dietary intake of contaminated fishes
Sludge →	soil → surface water →	fish	Toxicity to fishes from contaminated water, flora and fauna
Sludge →	soil → plant →	animal	Toxicity to animals eating plants growing in sludge treated soil
Sludge →	soil →	animal	Toxicity to direct ingestion of sludge treated soil
Sludge →	soil →	plant	Toxicity to plants growing in sludge treated soil
Sludge →	soil →	soil biota	Toxicity to soil organisms and impairment of soil functions
Sludge →	soil → soil biota →	predator	Toxicity to predators of soil organisms

When assessing risk it is essential to estimate the change [modulation] of “availability” or effective dose at each step in a pathway crucial. In the case of sewage sludge, the amount of research has been substantial (e.g. summarised in ICON, 2001 and Smith, 1996 and 2000). There has been less research on the other sludges but effects could be deduced judiciously from the sewage sludge data.

Table 2 lists examples of pathways and receptors that might be considered in a risk assessment for use and/or disposal of sludges. It is mainly concerned with chemical and biological risks. From a business or operational point of view, one could add the risk of legal action for not complying with regulations, for damage to the company's/organisation's reputation, for creating an actionable nuisance or for accidents to employees and others through a lack of regard to health and safety.

Individuals might be exposed to hazards via several pathways. Classically risk assessments have assessed each pathway in turn for receptors based on a number of assumptions. Assumptions would include exposure time, body weight, and other factors depending whether the assessment is being modelled for the average individual in the general population, individuals that are exposed more than the average. Risk management strategies are developed according to the pathway with the greatest risk to protect the average individual, the highly exposed individual (HEI) or the most exposed (MEI). This is called deterministic assessment, more recently there has been a trend to assess the probabilities of exposure to the different pathways etc. in combination (see clause B.8.6 for a discussion of deterministic and probabilistic risk assessment).

In some cases the product(s) of transformation and breakdown on the pathway from the source to the receptor are themselves hazards, for example the metabolites of DDT, DDE and DDD, also have toxic effects.

DDT is a pesticide once widely used to control insects in agriculture but now banned in many countries because of damage to wildlife, it breaks down to DDE, and DDD. They are all broken down rapidly in air by sunlight ($t_{½}$ = 2 days). They are strongly sorbed by soil; most DDT in soil is broken down slowly to DDE and DDD by microorganisms; the half-life of DDT in soil is 2-15 years, depending on the type of soil. DDT and DDE build up in plants and in fatty tissues of fish, birds, and other animals.

DDT is still used in some countries because it is inexpensive and very effective for controlling malaria mosquitoes and locusts.

This is an example of balancing risks and cultural and political values. When there is risk of millions of deaths per year because of malaria (mosquitoes) and starvation (locusts), the environmental risk from DDT might be considered acceptable until a preferable control is available.

7 A framework for environmental risk assessment and management

At the outset it is essential to decide and understand the purpose and context, i.e. the “risk of what to whom”. The analysis should be systematic and logical. It should consider how the output will be used, and the cost, social acceptability and effects of the risk management measures that will emerge.

Figure 2 shows a framework for environmental risk assessment and risk management (Anon, 2000 and Pollard and Guy, 2001).

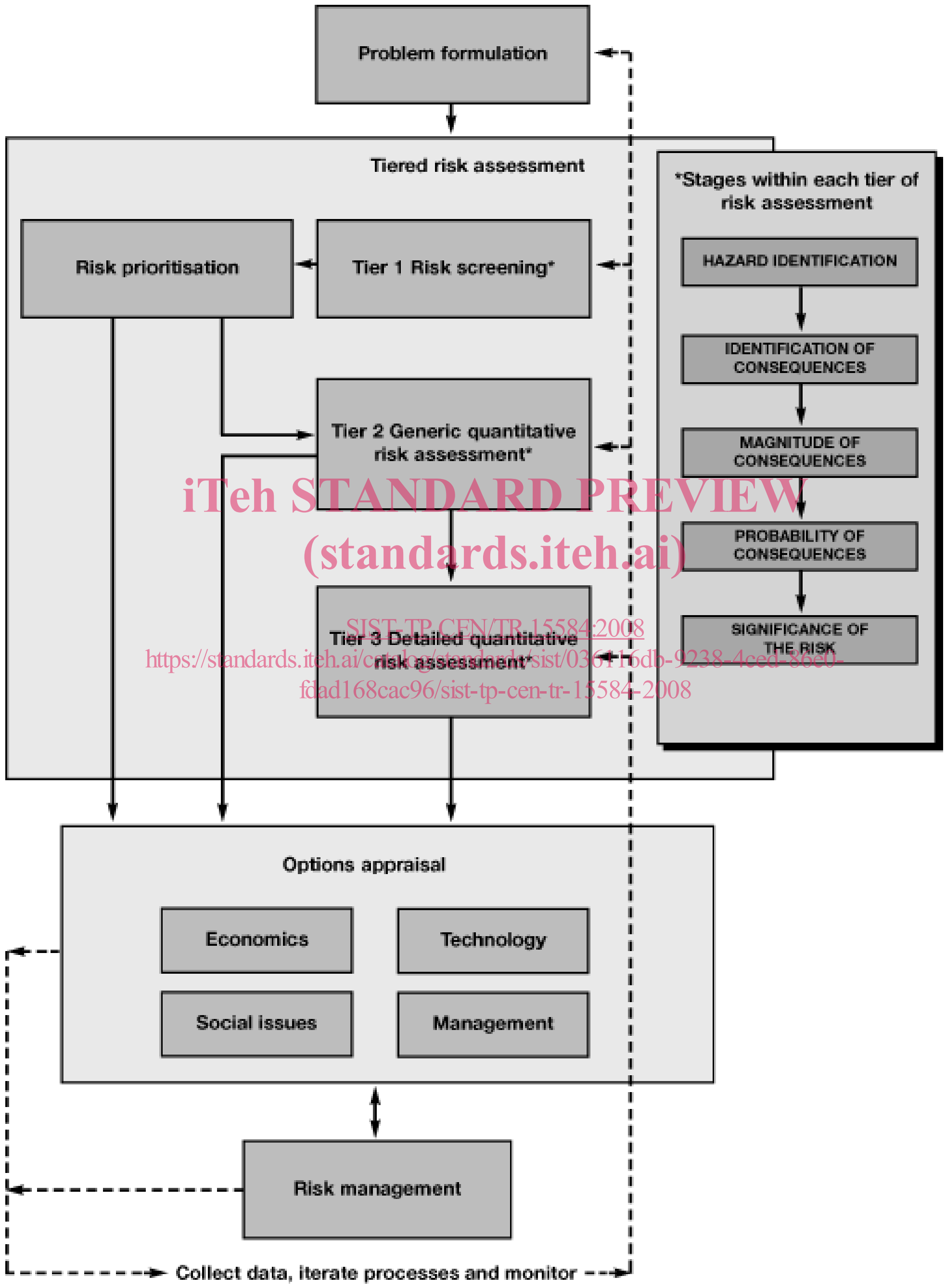

Figure 2 – An example of a framework for environmental risk assessment and risk management (from Anon, 2000)

A risk assessment framework is useful to show how the component stages relate to each other and inform the overall decision being made. Agreeing the framework early on can avoid misunderstandings between experts, stakeholders and the public later on. It is now agreed that it is good practice to involve stakeholders at the earliest stage so that they agree the model rather than presenting them with completed assessment only to find they argue about the fundamental basis.

A pragmatic approach to environmental risk assessment can transform what may sometimes appear to be an extremely detailed, complex and resource-intensive process into a practical aid to decision-making. Figure 2 provides a framework for a tiered approach to environmental risk assessment and management where the level of effort put into assessing each risk is proportionate to its priority (in relation to other risks) and its complexity (in relation to an understanding of the likely impacts); it also illustrates:

— the importance of correctly defining the actual problem at hand;

— the need to screen and prioritise all risks before quantification;

— the need to consider all risks in the options appraisal stage; and

— the iterative nature of the process.

The subject is discussed in more detail in Annex B the following is a summary.

7.1 Problem formulation

Defining the problem and the boundaries clearly and unambiguously is a critical step and it should be documented so that if the eventual decision is challenged or audited. If possible, stakeholders should be involved at this early stage to get agreement on this foundation of the assessment.

Defining the intention (e.g. to apply sludge to farmland without impairing the health of soil, wildlife or consumers of crops and livestock products, etc.) is also important and consists of four facets. What was the baseline (health of soil, wildlife, etc. and the pre-existing hazards before the intention) what are the components and the process, and what is the forecast for the situation after the intention?

Having defined the intention it should be justified: given the risks, benefits and costs does society want sludge applied to land or does it want it to be incinerated at location X? Not in my back-yard is clearly not appropriate in the context of not justifying an intention, the exercise presupposes that an issue exists and that a solution must be found.

When formulating the problem it is essential to consider the options that are available to control the risk(s), i.e. how the source, the pathway and the receptor can be influenced/changed to manage the risk. For example, can the content of chemical hazard be reduced by controlling the sources of discharge or by banning their inclusion in products? Can the biological risk be controlled by sludge treatment, preferably based on Hazard Analysis and Critical Control Point, and can restrictions on the cropping and grazing of treated land be implemented as a second barrier?

In the rich farming area of the Nile Delta in Egypt additional organic matter and plant nutrients are highly valued by farmers but the farming is intensive and on a very small scale with much hand-working. If sewage sludge is to be supplied into such a situation it is obvious that there can be no second barrier to control the risk and the sludge must be treated so that its biological risk is no greater than field soil. It would make little sense to reduce the risk below the ambient (baseline) level.

The problem is formulated as a conceptual model of the source-pathway-receptor such as Figure 3, which requires data about dietary composition, drinking water intake, bioconcentration factors and many more that are discussed in B.1.6.