Contaminants of emerging concern - Reuse of sediment

Ruth Cartuyvels, Karen Van Geert, Jonas Rabaey, Samuel Van Herreweghe, Karen Van Geert, Dirk Dedecker, Griet Van Gestel

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Contents

Sullied Sediments

Sediment Assessment and Clean Up Pilots in Inland Waterways in the North Sea Region

Many of the inland waterways in Europe are under threat due to the introduction of Watch List chemicals that are not currently regulated under the European Water Framework Directive. These chemicals enter our waterways as a result of our day-to-day activities and through industry, and many have been shown to be harmful to wildlife and the wider aquatic environment. Regardless of their source, these pollutants accumulate in the sediments in our rivers and canals over time.

Water regulators and managing authorities do not always know the levels, locations or impacts of these pollutants. Nor do they have the tools to assess sediments confidently and make informed environmental management decisions. To address these issues, the Sullied Sediment project partnership of scientific experts, regulators and water managers is developing and testing new tools that will enable stakeholders to better assess, treat and prevent contamination from these chemicals. This work is being carried out at selected sites in the Elbe, Humber and Scheldt river catchments.

The intention of the Sullied Sediments project is therefore to help regulators and water managers make better decisions with regard to the management, removal and disposal of sediments, thereby reducing economic costs to private and public sector organisations, and the impact of these pollutants on the environment.

The partnership is also working to reduce the extent of chemicals entering the water system by raising awareness about what we, as consumers, are releasing into the environment through the use of common drugs and household products. This includes the involvement of volunteers in a sediment sampling initiative across the North Sea Region, which will inform and empower them as water champions in their local communities.

The Sullied Sediments project has been co-funded by the European Regional Development Fund through the Interreg VB North Sea Region Programme with match funding from the 13 partners involved. The project partnership includes public, private, community and voluntary sector organisations based in the United Kingdom, Germany, Belgium and the Netherlands.

The project has been supported under the Interreg VB North Sea Region Programme's third priority, which is focused on a Sustainable North Sea Region, and is led by the University of Hull (UK).

Website: northsearegion.eu/sullied-sediments

Blog: sulliedsediments.wordpress.com

Twitter:@SulliedSediment

Abstract

Arcadis Belgium NV and Witteveen+Bos Belgium NV developed a decision tool for the management of sediments contaminated with contaminants of emerging concern. The decision system described in this report focuses on the Flemish soil framework, however, the principles on which this system is based are widely applicable in other standardization frameworks. The study provides a method for risk analysis and risk management (both in situ and ex situ) with background information to support a framework of threshold values (soil remediation standards, values for Free use, values for reuse as raw material).

Watercourse managers who have analytical data can evaluate it to make informed decisions. This framework for threshold values makes it possible to place the use of the sediments in the end of waste framework.

The method (approach, strategy) used is elaborated in a code of good practice that describes the approach for substantiating the threshold values for the reuse of sediments contaminated with new substances of emerging concern. The code of good practice enables a soil remediation expert to derive threshold values for the reuse of sediments contaminated with emerging and priority substances. The full report of this methodology is added as appendix.

Introduction

In recent years, there has been a growing awareness of the presence of so-called "emerging contaminants" or "contaminants of emerging concern (CEC's)" in our environment (soil, water, sediment,...) and the possible actual and/or potential problems that these chemical components can cause on humans and the environment. The problem with these emerging substances is that they are usually not included in standard analysis packages, there is no policy available, they have properties that are very different from classic and better known components, the environmental risks of the component is little or not known,... As a result, in addition to raising awareness, there is also a growing need to develop a sustainable policy that can provide an answer to these potential problems.

Arcadis Belgium NV and Witteveen+Bos Belgium NV developed a decision tool for the management of sediments contaminated with emerging contaminants. The decision system focuses on the Flemish soil framework and guidelines, given it was developed by Flemish soil experts. However, the principles on which this system is based are widely applicable in other standardization frameworks. To this end, at the beginning of the report a list of definitions is included that elucidates concepts that are typically used in the Flemish standardization framework.

It is important to note that this report contains a proposal for a decision tool. This proposed decision tool needs further discussion with stakeholders before it can be incorporated into regulation.

The following steps are included in this study:

- Task 1: Collection of basic information from different sources;
- Task 2: Analysis of the data for the Flemish standardization framework;
- Task 3: Decision tree to decide on reuse of Sediment- widely applicable principles
- Task 4: Recommendation for supplementing and updating the code of good practice which describes the methodology used for standardization in Flanders.

It is the intention to provide an answer through a literature study. Insight is obtained into the available threshold values, their analysis methods and cost, their reliability, and the reporting limits. The method (approach, strategy) used for this is elaborated in a code of good practice that describes the approach for substantiating the threshold values for the reuse of sediments contaminated with new substances of concern. The code of good practice must enable a soil remediation expert to derive a substantiated threshold value for the reuse of sediments contaminated with emerging and priority substances. The full report of this methodology is added as appendix

Threshold Values for the reuse of dredged Sediments on the soil are related to the standards for soil and groundwater protection. The threshold values for the assessment of the use of dredged Sediments can be based on soil remediation standards for soil and groundwater, possible background values and determination limits of the prescribed analytical methods.

Research into which emerging substances are relevant for aquatic soils in Flanders was studied by Ecofide. Ecofide's study 'Hotspots of priority and emerging substances in sediment' gives an overview of the priority substances to be investigated in the water system. The study determined which substances of concern are relevant to the sediment and which substances should be tackled as a priority. Based on this document, a selection of 5 substances or groups of substances will be evaluated in detail in this study.

Methods

Task 1. Collection of basic information - Literature review

The purpose of this literature review is to gain a general understanding of the possibilities and bottlenecks in developing a method for evaluating the reuse of sediment contaminated with contaminants of emerging concern. Several studies were selected that, in our opinion, provide interesting challenges and useful elements for developing a methodology:

- List of contaminants of emerging concern -guideline 2013/39/EU.
- NORMAN prioritization methodology and web-based databases
- Strategy for emerging contaminants (Deltares, 2017)
- Hotspots of prioritized and emerging contaminants in sediments (Ecofide, 2020)
- National policies on substances of concern (Bureau KLB, 2017)
- Possible action perspectives for new threats in the soil system (Expertise centrum PFAS, 2018)

The literature review demonstrates the challenges associated with the development of a method for the reuse of sediment with emerging substances. A major challenge, illustrated by the studies of NORMAN, Deltares, and the Expertise centrum PFAS, is the lack of data and the uncertainties associated with the already available data. This lack of information complicates the derivation of standards for the reuse of contaminated sediments. Another considerable issue surfaced in the study of the Expertise centrum, is the importance of clear definitions.

It is essential to consider these bottlenecks when we develop a methodology for the reuse of sediments contaminated with emerging substances. At the same time, this literature study provides us with interesting possibilities to deal with these challenges. First, the studies of NORMAN and Deltares describe the use of different categories. On one hand, categories are based on the availability of information, ranging from category 1 (sufficient evidence for exposure and effects at measured concentrations to establish standards) to category 5 (insufficient data and calculated toxicity for setting standards) and category 6 (sufficient evidence to conclude the substance is not toxic and thus no priority). On the other hand, categories are based on usage type (for example, pesticides, flame retardants, and care products). Next, the study of Bureau KLB shows several similarities between the investigated EU Member States (such as the shared aim of circular economy and the promotion of substitution) indicating it can be useful to take a look at the state of the art in neighbouring countries for methods on how to deal with sediments contaminated with Emerging substances. At last, the Expertise centrum PFAS and the Ecofide study emphasize the importance to determine the endpoint of the source-path-receptor chain. The Expertise centrum study explains it is crucial to understand that the soil is not regarded as a receptor but as a path in this chain and that the soil function is decisive. Thus, the possible threat of an emerging substance should be determined for each soil function (i.e. receptor) separately.

Based on these findings, we chose to work with categories in our decision system as proposed by NORMAN and Deltares. These categories are based on the available information on the substance of emerging concern and the uncertainties/variability of the available data. The categories range from category 1 (all data are available to calculate levels for reuse as soil and/or use as) to category 4 (too little data available to calculate human exposure or too much uncertainty on the available data). Considering the study of the Expertise centrum, we looked at the soil function when we determined the endpoints of the source-path-receptor chain. The following receptors are defined in our decision system: agricultural land use, residential land use, recreational land use, industrial land use, and use as . Depending on the category of the substance, other reuse possibilities apply. At last, we decided to incorporate a comparative screening with international levels into our decision system. This enables consultants/experts to get an idea of the order of magnitude in which the standards are expected. This comparative screening step also allows consultants/experts to verify the Detection limits provided by the analytical laboratories.

Task 1. Collection of basic information - Questionnaire on national policies and standards

A questionnaire was compiled to gain insight into the standardization of emerging contaminants in other countries. The first part of the questionnaire examines the availability of standards for emerging contaminants in the surveyed countries. The second part explores the prioritization of the substances for which the surveyed countries indicated that there are standards available. This part was added because the definition of an emerging contaminant is not clearly defined. Different lists of emerging contaminants exist and the presence of a substance on these lists is dynamic. Meaning, substances that are emerging contaminants now, will no longer be considered emerging contaminants a few years from now.

Several countries were contacted within the Arcadis and Witteveen+Bos consultants, and network of the centre of Expertise on PFAS. Table 1 displays an overview of all contacted countries that did (indicated with '+') or did not (indicated with '0') provide completed questionnaires and/or interviews.

Country	Questionnaire
Netherlands	+
Switzerland	+
Germany	+
France	+
Italy	0
Spain/Portugal	+
Sweden	+
UK	+
US	0
Canada	+
Australia	0

Table 1: Completed ('+') and not completed questionnaires ('0') by country/region.

It is difficult to collect information on standardization and prioritization in the surveyed countries. Standards are still under development ranging from countries without any standards available (UK and Portugal) to countries with indicative and/or approved standards for soil remediation and/or reuse of sediments (Canada, Germany, The Netherlands, and Sweden). The available standards are based on at least human ecotoxicological and/or human toxicological data. In some countries, these data are supplemented with the stand-still principle (Germany), background values, leaching, and duty of care (The Netherlands).

The lack of a general and unambiguous method for reuse of contaminated sediments in other countries complicates the development of a methodology in Flanders as we cannot rely on the development process of other countries. At the same time, it demonstrates that other countries are facing the same challenges and confirms that we are not rediscovering a method that is already established.

Task 2: Evaluation of the information in relation to future framework

Overview of existing international target levels is given in annex 2 of the report added as appendix.

The principles of the decision system for reuse of contaminated Sediment on land are based on Conceptual site models. A Conceptual site model for excavated soils on land differs from a conceptual site model for reuse of sediment on land. Not only the matrix changes from Waterbed to land when the Sediment is applied but also the endpoint receptors and relevant exposure pathways are different. The ecological risks are the driving force to derive a sediment level, however, in case of reuse of sediment, the land use (human risks in different land-use scenarios) and potential leaching towards groundwater are more important.

Figure 1 shows the conceptual site model before dredging (OVAM, studiedag Waterbodem, 2018) . Sediment (indicated in brown) is a part of the Waterbed that can flood onto land (i.e. flooding Sediment) or can be dredged and applied on land (i.e. dredging spoil). Figure 2 shows the Conceptual site model for reuse as soil (Arcadis; The different routes of exposure are indicated in black). The dredged Sediment could also be applied as construction material on land. The conceptual site model for reuse as a construction material is presented in figures 3 and 4. For Flanders, there are two application scenarios described.

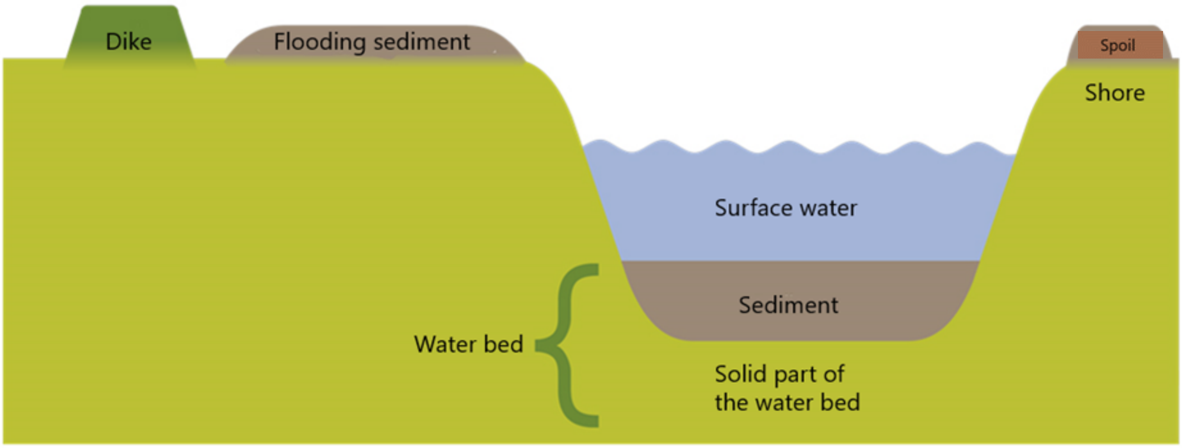

Figure 1 gives the conceptual site model before dredging

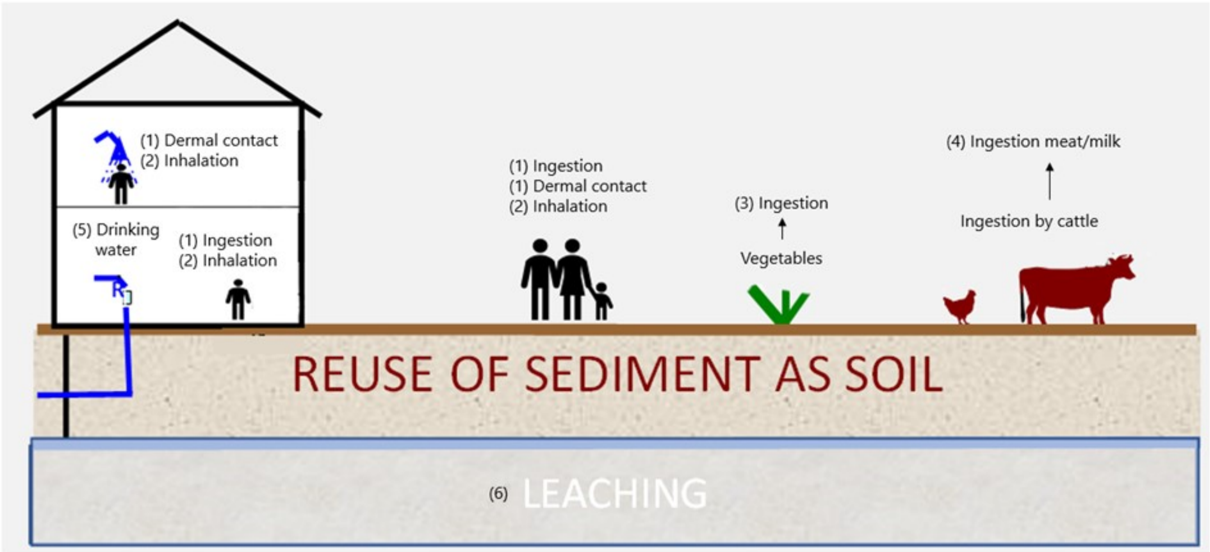

Figure 2 shows the Conceptual site model for reuse as soil (Arcadis).

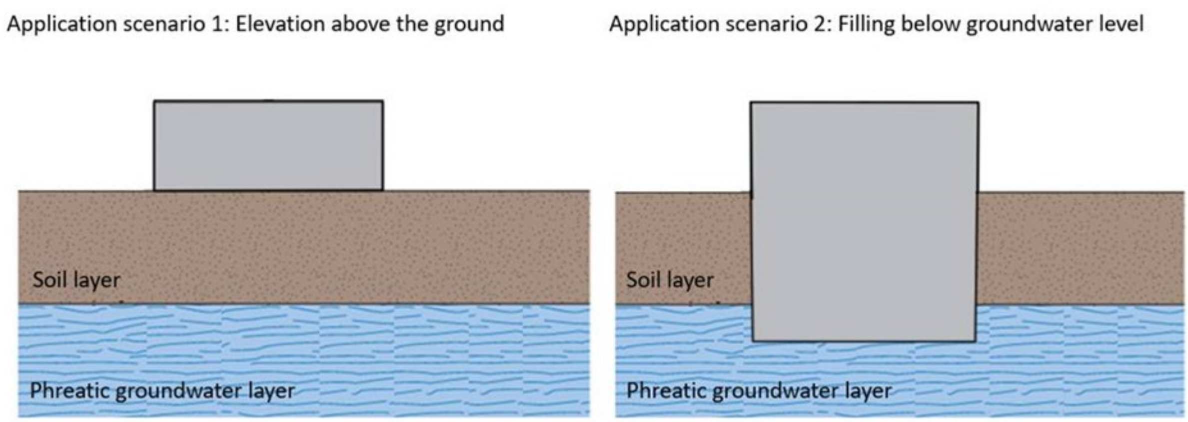

Figure 3 and Figure 4: Conceptual leaching model for reuse of sediment on land.

Depending on the soil usage type, different exposure and spreading pathways should be considered. Table 2 indicates the important exposure and spreading pathways for each soil usage type.

Pathway		Free use	Agricultural use	Residential use	Recreational use	Industrial use	Construction material
1	Soil-human ingestion and dermal contact	X	X	X	X	X	X
2	Soil-vapour-inhalation pathway	X	X	X	X	X	X
3	Soil-plant uptake and consumption	X	X	X			
4	Soil-milk/meat uptake and consumption	X	X				
5	Direct Consumption of drinking water	X	X				
6	Soil-groundwater leaching	X	X	X	X	X	X

Table 2: Exposure and spreading pathways for the different soil usage types. The applicable pathways are indicated with an 'X'

Results : Task 3 - Decision Tree

Basic Principles

This decision system is developed to define reuse possibilities for sediments contaminated with Emerging substances. It is a tiered approach in which the substances are organized into four categories. This classification depends on the availability of physicochemical, ecotoxicological (plant and cattle), and human toxicological data, on one hand, and the uncertainties in these data on the other hand. The more available information on the substance and the lower the uncertainty in this information, the more reuse levels can be calculated for the contaminated Sediment. The following reuse possibilities are specified in this decision system: Free use, agricultural use, residential use, industrial use and use as a construction material.

If no reuse is possible and no cleaning values for treatment can be obtained or no cleaning until Detection limit can be obtained, the deposit or dumping of the Sediment is the final option.

Reuse in the water system is not considered in this study given that under water applications focus on water-toxicity, whereas for the reuse of dredged sediments, human-and land-ecotoxicity are more important endpoint receptors (§2.1.4 “Hotspots of prioritized and emerging contaminants in sediments”).

The possibilities of reuse depend on:

- Availability of data (physicochemical, ecotoxicological (plant/cattle) and human toxicological)
  - All data present → more reuse-levels (Free use, agricultural, residential, industrial, use as construction material) can be calculated → if concentrations lower than specific levels → more reuse possibilities
  - Not all data present/reliable → less reuse levels can be calculated → less reuse possibilities
- The uncertainties/variability of data
  - If uncertainty on crucial data is high → less reuse possibilities are allowed
  - Some uncertainties can be overcome with “uncertainty factors”

The cautionary principle and prevention principle form the basis of the decision system. Given the rapidly evolving knowledge on emerging contaminants, it is important to act conservatively. Therefore, this method attempts to translate uncertainties about Emerging substances into reuse possibilities. Moreover, the greater the uncertainties in data, the more restrictions are posed on the reuse possibilities of the contaminated Sediment in the most sensitive soil types.

At the same time, we must act pragmatically enough to ensure that earthworks can continue. Therefore, this decision system also explores the reuse possibilities of contaminated sediment as a construction material.

As a final step in the decision tree, the so-called "common sense test" should always be done by the expert. For example, it must be checked whether the data found in an old publication is still sufficiently reliable. If only 1 value has been found but the reliability of the source is very high, it must be checked based on expert judgment whether the category obtained for reuse is the correct one,…

Tiered approach

Figure 5 gives the tiered structure of our decision system. In tier 1bis, the contaminated Sediment is considered in one of four reuse categories. Tier 2 to 5 correspond with category 1 to 4. The more uncertain the data on the emerging substance are, the higher the category number and the more restricted the reuse possibilities. Tier 1 forms a screening step that allows consultants/experts and decision-makers to skip the decision system and make rapid conclusions for very clean or highly contaminated sediments. In the following sections, each tier is briefly explained. The details are explained in the report added as appendix.

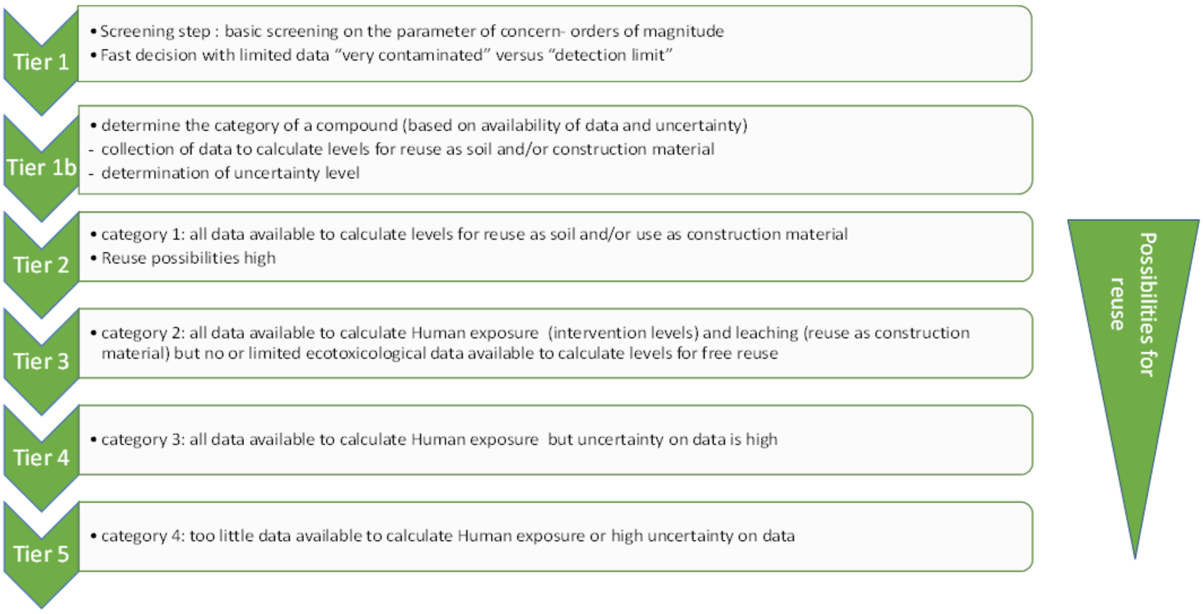

Figure 5: Tiered approach of the decision system

Tier 1- Screening step

A basic screening is built into this system to help consultants/experts and decision makers to gain insight into the magnitude of contamination and to allow them to make straightforward decisions with only limited screening parameters. Hence, the boundary conditions of these steps are based on conservative assumptions. In this screening step, the consultant/expert is assigned three steps.

1. Determine the lowest detection limit that can be measured by the laboratories;
2. The detection limit must be compared to international levels to validate the obtained detection limit and to determine the magnitude of sediment contamination (Ppm level, Ppb level, etc.);
3. Evaluate the potential presence of pure product by an indicative calculation of the expected soil concentration of the pure substance.

An evaluation of those three steps results in two possible shortcuts:

1. The concentration measured in the contaminated sediments exceeds the concentration indicating Pure product (i.e. concentrations exceeding solubility);
2. The measured concentration remains below three times the detection limit. In that case a mandatory leaching test (short term shaking soil-water test) had to be performed and the leaching test should also indicate an eluate with concentrations lower than three times the detection limit.

Note that this tiered decision system is only applicable for sediments used on land. For sediments that will be used under water (i.e. in riverbeds, seaports, deep-sea, etc.), a site-specific risk assessment is required.

Figure 6 demonstrates Tier 1. The aim, background and implementation/interpretation of each decision step is further explained in the report attached as appendix.

Tier 1bis: Determination of the category of a compound

Tier1bis includes the collection of data to calculate levels for reuse as soil and/or as construction material and the determination of uncertainty on these data. The aim of tier 1bis is to assign the contaminated sediment to one of the following categories based on the available information on the emerging substance:

1. Category 1: all data to calculate levels for reuse as soil and/or use as construction material are available;

2. Category 2: all data available to calculate human exposure (intervention levels) and leaching (reuse as construction material) are available, but there are no or limited ecotoxicological data available to calculate levels for free reuse;
3. Category 3: all data to calculate human exposure are available, but the uncertainty on these data is high;
4. Category 4: there is too little data available to calculate human exposure or the uncertainty on these data is high.

To assign the contaminant to its appropriate category, the consultant/expert must obtain the required properties from a reliable database. A list of reliable databases is included in table 3.

Organisation	Weblink of database	Link
World Health Organization	Publications > Environmental Health Criteria > List of EHCs (on chemicals or groups of chemicals) in alphabetical order	Link
Agency for Toxic Substances and Disease Registry	A-Z Index	Link
ECHA European Chemicals Agency	Search for Chemicals	Link
NORMAN	DATABASES > Substance Factsheets	Link
EPA United States Environmental Protection Agency	Environmental Topics > Chemicals and Toxics > > IRIS Assessments > Browse A to Z List of Chemicals	Link
International Agency for Research on Cancer	IARC Monographs	Link
National Library of Medicine PubChem	Explore Chemistry	Link

Table 3: Reliable databases

At last, a final check is incorporated in tier 1bis to ensure the substances are assigned to their appropriate category. This check probes for the presence of the emerging contaminant on the EU list (Appendix 1, annex 5). If so, the substance cannot belong to category 1, given that free use is not permitted for sediments contaminated with substances present on this list. In this case, contaminants that were originally assigned to category 1, now belong to category 2.

The physicochemical and toxicological data should be investigated for each compound separately. When values for certain characteristics are lacking, those of similar compounds belonging to the same group can potentially be used. This is possible for substances for whom guide parameters are presented in one of the reliable databases. In that case, the values presented for this guide parameters can be used, provided that the uncertainty factors are determined, and the most impacted pathways are identified.

Working in usage categories (main groups and subgroups) such as biocides, flame retardants, fluorinated compounds (PFAS), pesticides, personal care products, etc. is also suggested. Every category has “in average” similar characteristics. If group parameters are used, these compounds will automatically end in category 3 or 4 and restrictions for Reuse of Sediment on land will be limited due to the variability of the inherent different compounds within a group.

Figure 7 demonstrates the decision tree to define the compound category. The background and implementation/interpretation of each decision step is further explained in the report attached as appendix.

Tier 2: Compound category 1

For contaminants assigned to category 1, all human toxicological data and ecotoxicological are published in reliable databases (Table 3). This means that all required data to calculate levels for reuse as soil and/or as a construction material are present.

To determine the final reuse application of the contaminated Sediment, a step-by-step approach is lined out for compounds assigned to category 1. In some cases, it is already decided how the Sediment will be preferably reused. Hence, the expert can start at different steps:

1. Calculate free use and/or

2. Calculate levels for reuse as soil (agricultural use, residential use, recreational use, and industrial use) and/or
3. Calculate levels for reuse of sediment as construction material.

After every step, the consultant/expert can decide to clean the contaminated and, thus, stop running through the decision system. Figure 8 gives the decision tree for reuse of sediment of a compound category 1.

Tier 3: Compound category 2

Contaminants are assigned to category 2 when all human toxicological data are presented in a reliable database (Table 3), except for the levels in vegetables and the levels in meat or milk, but the ecotoxicological data are highly uncertain or even lacking. For category 2 substances, all data required to calculate human exposure for recreational or industrial use as well as the data to calculate leaching for reuse as a construction material are available.

The approach for category 2 compounds is highly like that for category 1 substances. The final reuse application of the contaminated sediment can be determined in a step-by-step approach and the consultants/experts can start at different steps. However, due to the uncertainty in ecotoxicological data, the procedure for category 2 compounds differs from the approach for category 1 substances (fewer reuse possibilities, no free use possible).

Figure 9 gives the decision tree for the reuse of sediments contaminated with category 2 compounds.

Tier 4: Compound category 3

Category 3 compounds are characterized by their variability and lack of human and ecotoxicological data. Substances are assigned to category 3 when the uncertainties in the human toxicological data are high, even after an in-depth toxicological desk study is performed.

The approach for category 3 compounds is highly like that for category 1 substances. The final reuse application of the contaminated Sediment can be determined in a step-by-step approach and the consultants/experts can start at different steps. However, due to the great uncertainty in data, the following restrictions are imposed on category 3 substances.

Figure 10 gives the decision tree for reuse of sediment contaminated with category 3 compounds.

Tier 5: Compound category 4

For compounds assigned to category 4, there are no toxicity data available. Consequently, these sediments cannot be used as construction material nor can they be treated for soil reuse as it is impossible to calculate a treatment value with so little data. The only outcome for these sediments is for them to be deposited.

Figure 11 demonstrates the decision tree for reuse of sediment of a compound category 4.

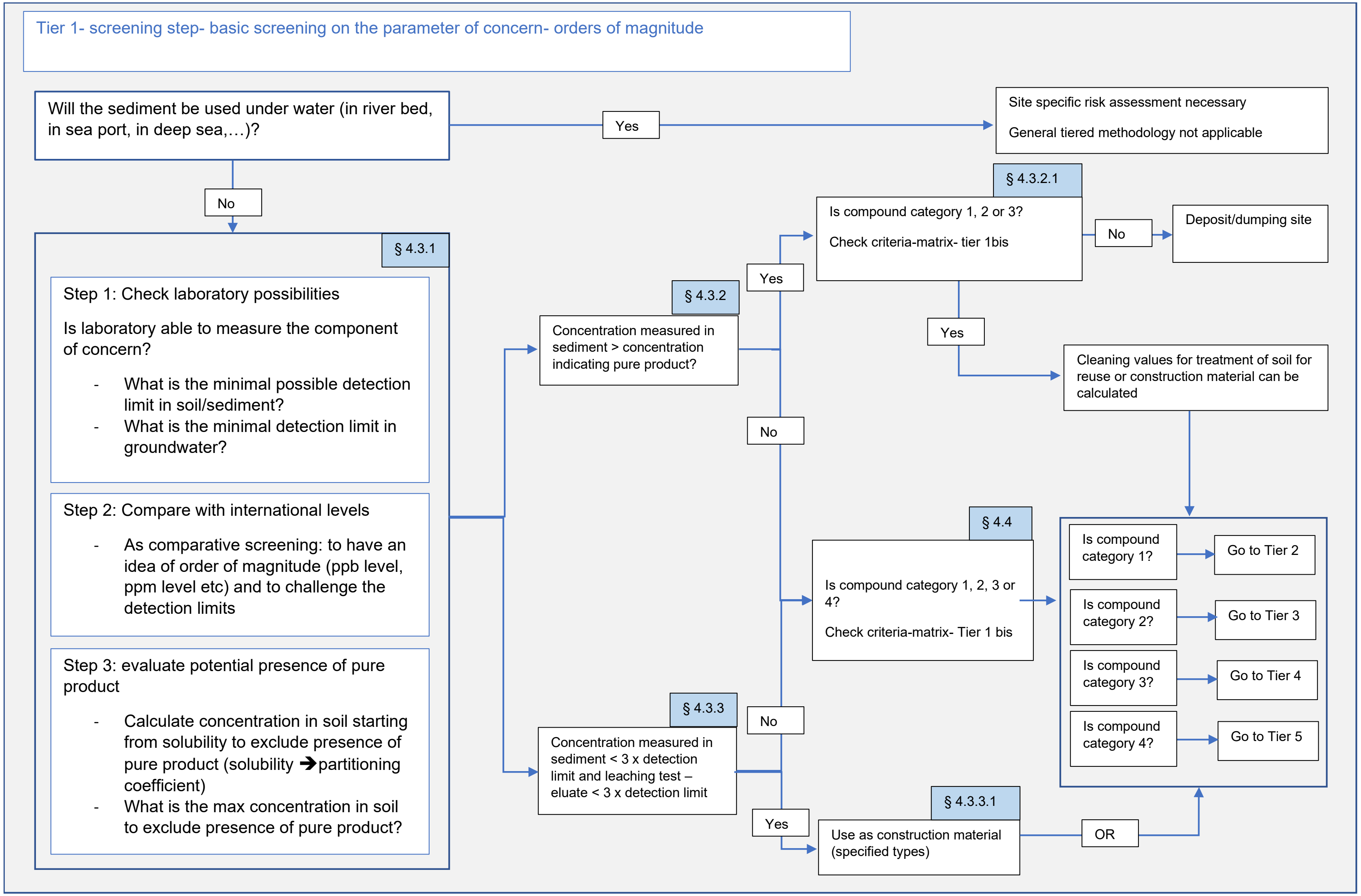

Figure 6: Tier 1.Basic screening.

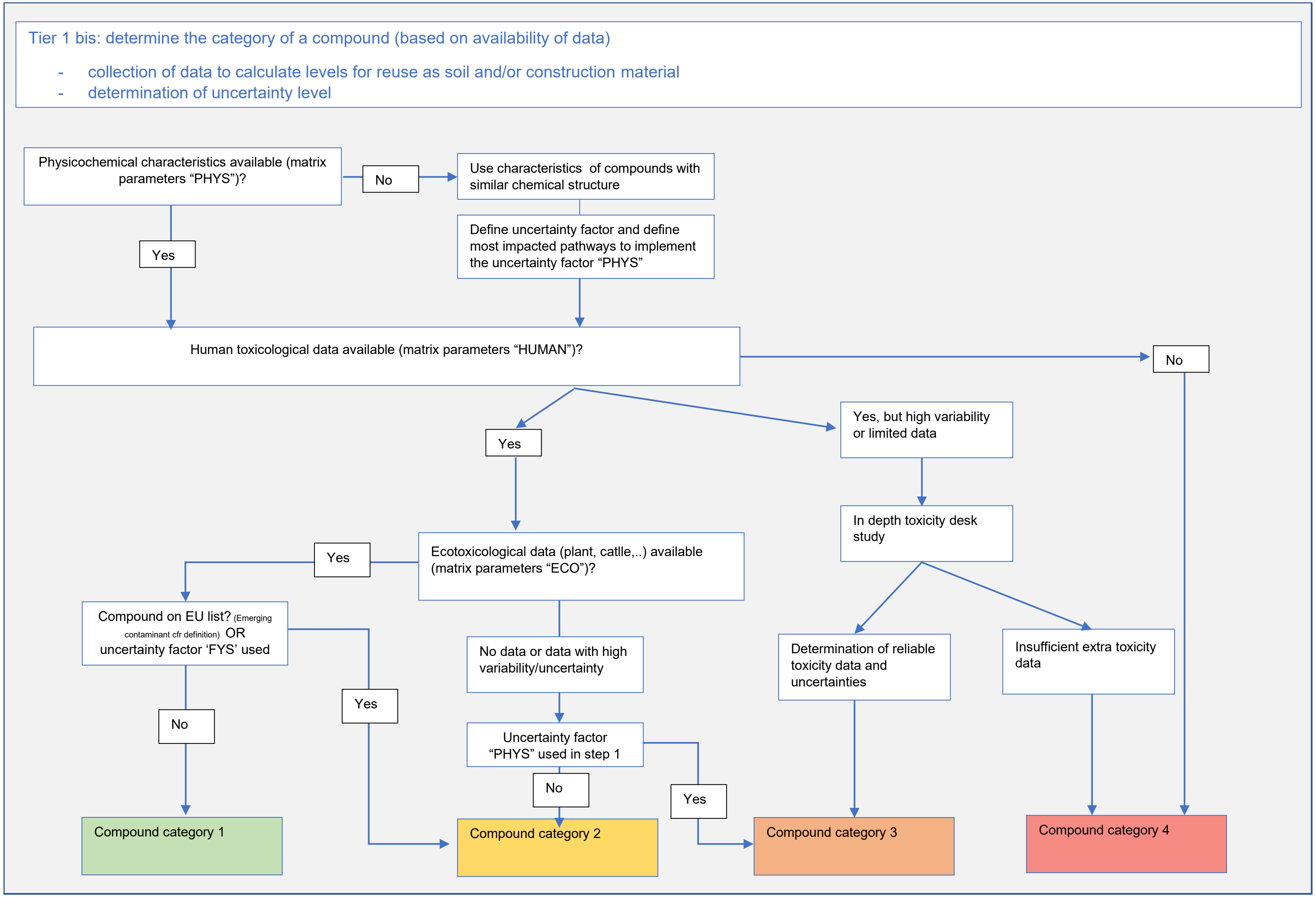

Figure 7: Tier 1bis. Defining the compound category.

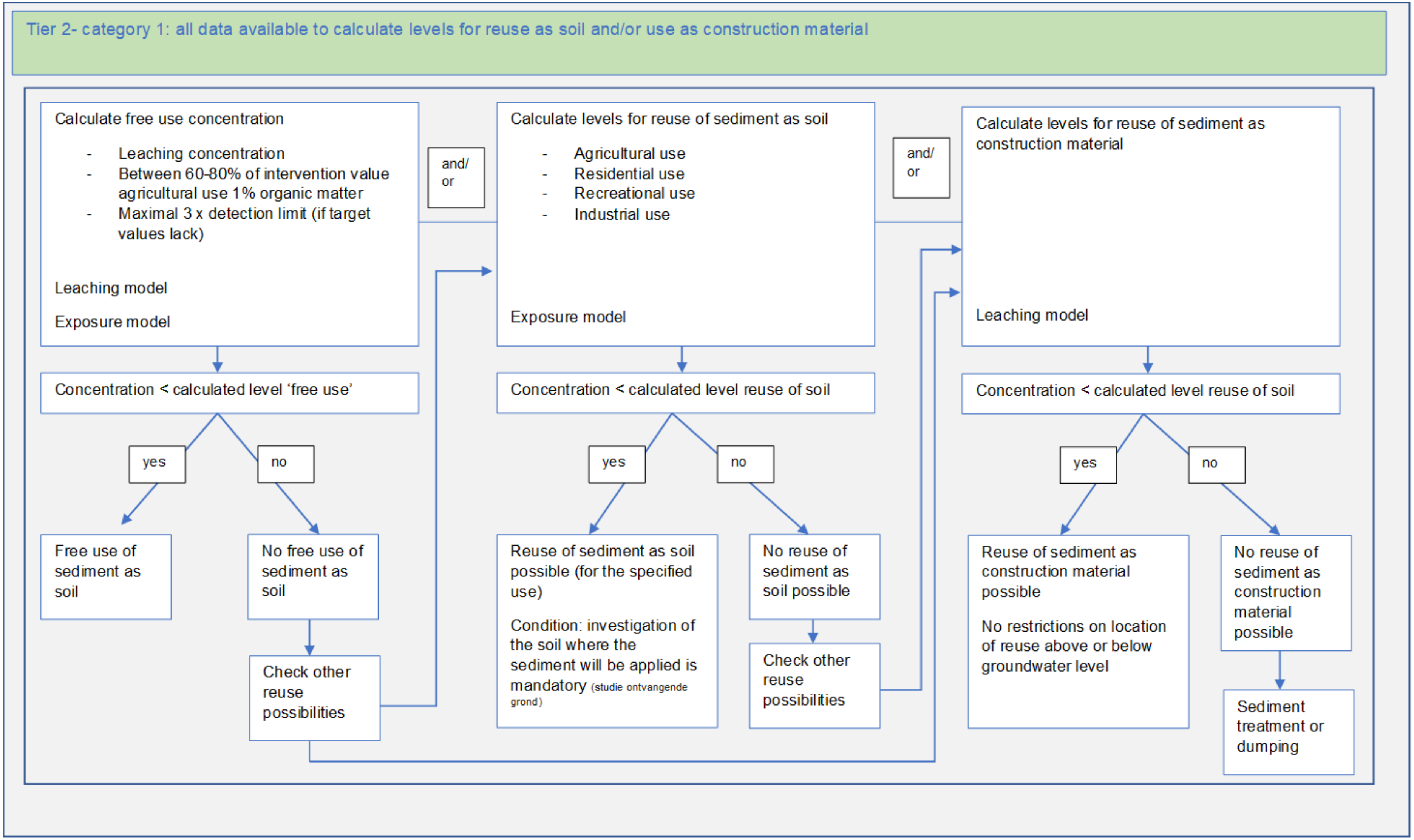

Figure 8: Tier 2. Decision tree for the reuse of sediments contaminated with category 1 compounds

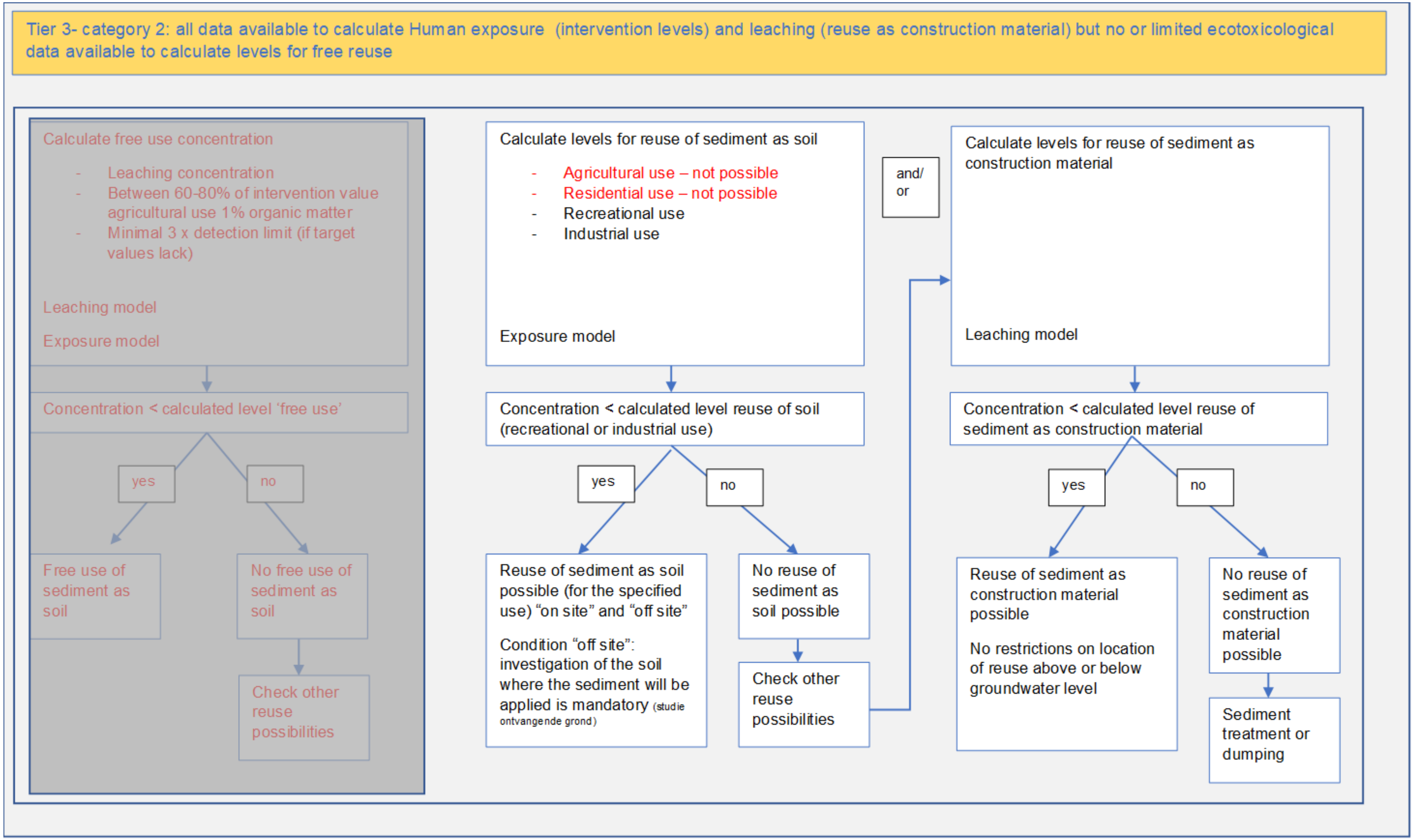

Figure 9: Tier 3. Decision tree for the reuse of sediments contaminated with category 2 compounds. Free use and application within agricultural and residential areas are prohibited

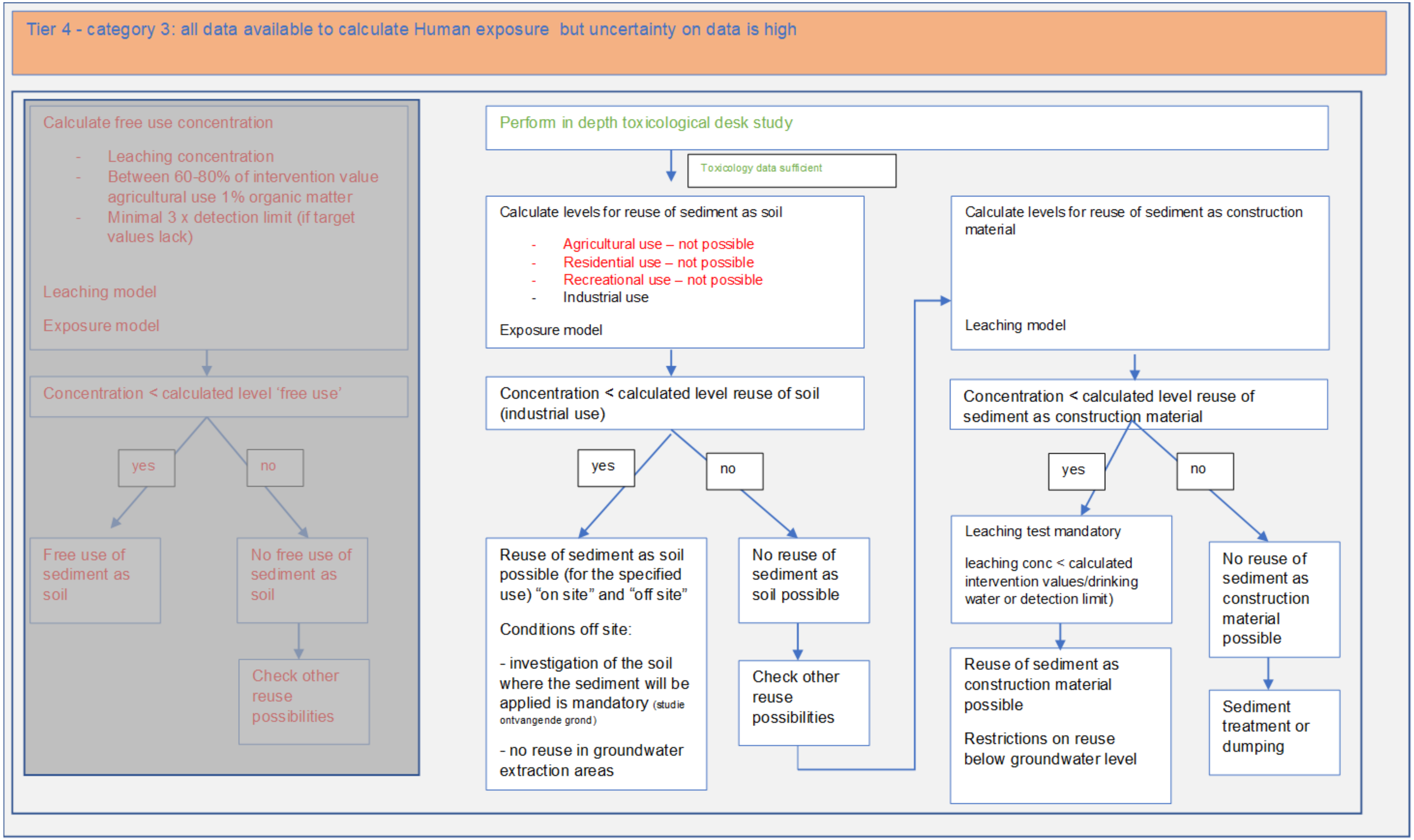

Figure 10: Tier 4. Decision tree for reuse of sediment of a compound category 3. Free use and application within agricultural, residential, and recreational areas are prohibited.

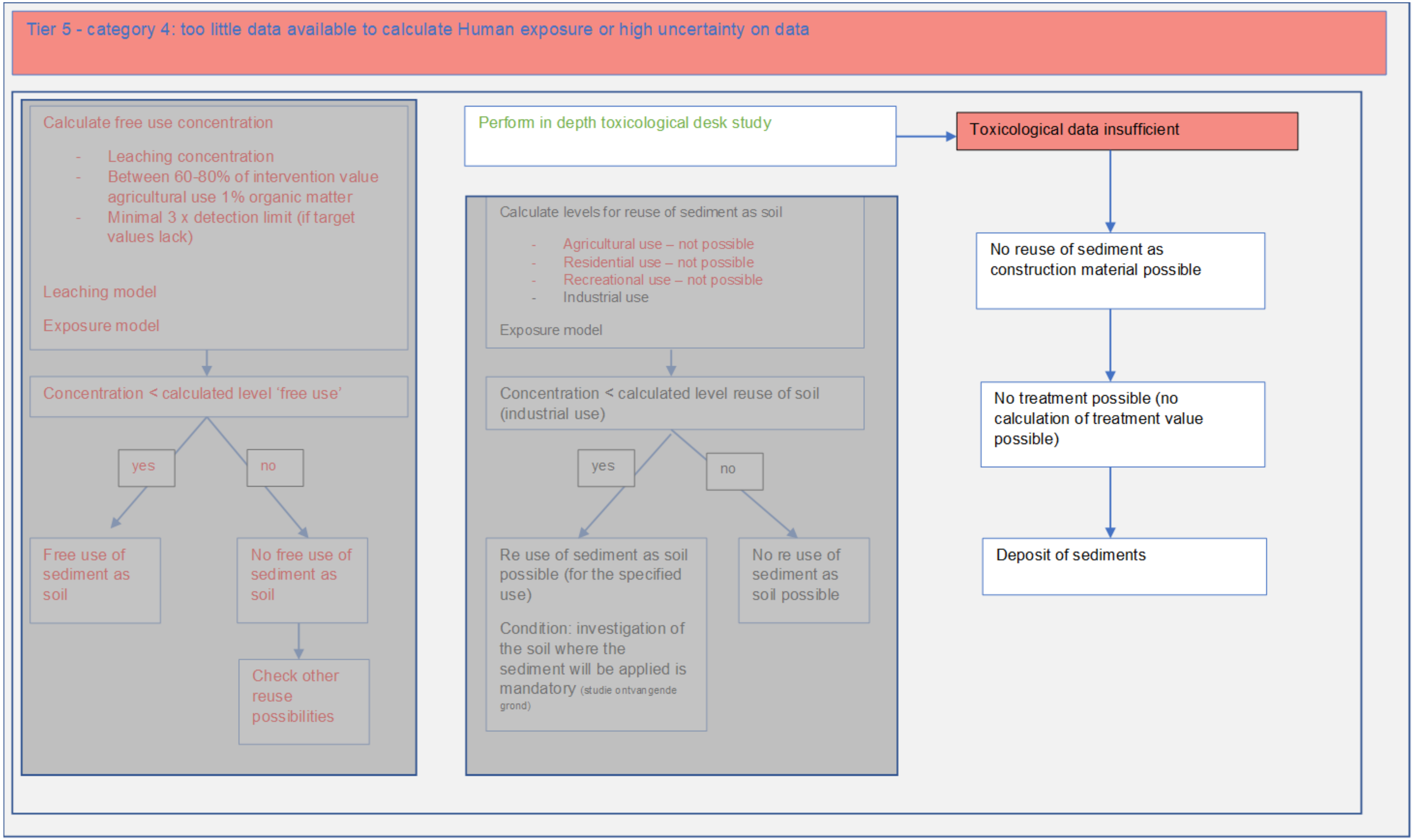

Figure 11: Tier 5. Decision tree for reuse of sediment of a compound category 4. Reuse as soil or as construction material is prohibited

Discussion

To test our decision system, several substances of emerging concern are assigned to a reuse category according to the protocol. These examples are discussed in the report attached as appendix.

The proposed decision framework is developed on how to deal in practice with lack of information and to define reuse possibilities for sediments contaminated with emerging substances. It is a tiered approach in which the substances are organized into four categories. This classification depends on the availability of physicochemical, ecotoxicological (plant and cattle), and human toxicological data, on one hand, and the uncertainties in these data on the other hand. The more available information on the substance and the lower the uncertainty in this information, the more reuse levels can be calculated for the contaminated Sediment.

The driving forces for the development of a methodology for reuse of sediment are land use (human risks in different land-use scenarios) and potential leaching towards groundwater. In other words, the endpoint receptors in this decision system are human- and land-ecotoxicity receptors. The reuse of sediment in the water system is not included in the methodology since other risks can occur for this type of reuse. The reuse of sediment fits perfectly within the principle of the circular economy and can ensure that less primary raw materials are consumed that can have other and more useful applications.

If no reuse is possible and no target values for treatment can be obtained or no cleaning until Detection limit can be obtained, the deposition or dumping of the Sediment is the final option.

It is important to note that this report contains a proposal and needs further discussion with stakeholders before it can be incorporated into regulation.

Conclusion

The decision system described in this report focuses on the Flemish soil framework and guidelines, given it was developed by Flemish soil experts. However, the principles on which this system is based are widely applicable in other standardization frameworks.

One of the most important challenges of “emerging contaminants” is that the knowledge and insights regarding these components can change rapidly. This decision system and categorization of compounds is therefore a dynamic tool that will have to be evaluated based on the evolving scientific insights about these components. Threshold levels and reuse possibilities for sediments should be revised regularly as knowledge on the specific emerging contaminants evolves.

This means the evaluation must be repeated every time an expert has to evaluate the possible reuse of sediments contaminated with substances of emerging concern. Due to an evolution in scientific knowledge, it is very likely that the data used to calculate reuse levels or to decide on possible threshold values for reuse are already outdated. Hence, standards of CEC’s for reuse of sediment calculated by previous evaluations with the decision tree should be actualized with recent data.

Opportunities for reuse of contaminated sediment as soil or as construction material should be considered. Country specific optimization of the decision tree should be made by using specific exposure models or leaching models applicable in the different countries.

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Interreg North Sea Region European Regional Development Fund

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Partners

The Sullied Sediments project partnership comprises 13 project beneficiaries:

Canal and River Trust (UK)

East Riding of Yorkshire Council (UK)

Ecossa (Germany)

Hamburg Port Authority (Germany)

Hamburg University of Applied Sciences (Germany)

Institut Dr Nowak (Germany)

Openbare Vlaamse Afvalstoffenmaatschappij (Belgium)

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Appendix

Decision system on how to deal with sediments contaminated with emerging contaminants – Report

Interreg
North Sea Region
Sullied Sediments
European Regional Development Fund

EUROPEAN UNION

Sustainable North Sea Region
http://northsearegion.eu/sullied-sediments

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CONTAMINANTS OF EMERGING CONCERN REUSE OF SEDIMENT

DECISION SYSTEM ON HOW TO DEAL WITH SEDIMENTS CONTAMINATED WITH EMERGING CONTAMINANTS

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CONTAMINANTS OF EMERGING CONCERN - REUSE OF SEDIMENT

Decision system on how to deal with sediments contaminated with emerging contaminants

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11 *Contact person(s):*
Dirk Dedecker,
Griet Van Gestel

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'Hotspots of priority and Emerging substances in Sediment' (Ecofide, 2020).

INDEX

DEFINITIONS AND ABBREVIATIONS

Words included in the table below, are shown in italics in the text.

LIST OF DEFINITIONS IN THE CONTEXT OF THIS STUDY

Bio-accumulating	Bioaccumulation is the gradual accumulation of substances, such as pesticides or other chemicals, in an organism or environmental compartment. Bioaccumulation occurs when an organism/ environmental compartment absorbs a substance at a rate faster than that at which the substance is lost by catabolism, excretion, or degradation of the component.
Conceptual site model	A Conceptual site model (CSM) is representation of the biological, physical, and chemical processes that determine the ways that contaminants move from sources through the environmental media to environmental receptors.
Construction material	Refers to a term in the Flemish legislation (VLAREMA Appendix 2.2) and defines applications for secondary raw materials, which would otherwise be disposed of as waste, under certain defined conditions. A list of all possible types of Construction materials is included in Annex 4. In Flemish legislation soil materials can be reused as raw material for construction purposes if the construction is included in this list.
Emerging substances	Pollutants that can been detected in water bodies, soil, Sediment, that may cause ecological or human health impacts, and are not regulated under current environmental laws. Sources of these pollutants include agriculture, urban runoff, and ordinary household products (such as soaps and disinfectants) and pharmaceuticals that are disposed to sewage treatment plants and subsequently discharged to surface waters,… "emerging" means that the substance is only now coming to the attention of researchers, policymakers, ... It doesn't have to be new (as in recently developed) chemical components to be labelled as emerging.
Detection limit	The lowest quantity of a substance that can be distinguished from the absence of that substance (a blank value) with a stated confidence level (generally 99%). As a result of technological developments, this value can decrease over time. In addition, this value can be laboratory specific.
Henry-coefficient (H)	The Henry-coefficient indicates the relationship between the Vapor pressure of a substance in the soil air and the corresponding equilibrium concentration in the groundwater. A substance with a low Henry-coefficient will pass from the water phase to the gas phase with difficulty. Easily soluble substances will therefore mainly occur in groundwater and only to a small extent in the soil air.
Land use related to reuse	Agricultural use o Use is based on the Conceptual site model 'agricultural use' and hence specific exposure routes for agricultural use are considered o The level in soil or Sediment that complies with agricultural Conceptual site model can be reused in agriculture areas and natural areas Residential use o o Use is based on the Conceptual site model 'residential use' and hence specific exposure routes for residential use are considered

	○ The level in soil or Sediment that complies with the residential Conceptual site model can be reused in residential, recreational areas or industrial areas Recreational use ○ Use is based on the Conceptual site model 'recreational use' and hence specific exposure routes for recreational use are considered ○ The level in soil or Sediment that complies with the recreational Conceptual site model can be reused in recreational areas or industrial areas Industrial use ○ Use is based on the Conceptual site model 'industrial use' and hence specific exposure routes for industrial use are considered ○ The level in soil or Sediment that complies with the industrial Conceptual site model can be reused in industrial areas.
Use of Sediment Specific definition used in the Flemish guidelines	**Free use** Soil or Sediment can be applied without any restrictions in all types of land use without causing any risks, according to current knowledge. **Use On-site** Reuse of Sediment On-site means that the Sediment is used on the banks of the dredged river. The banks are defined as the 5-meter strip along the river. **Use Off-site** Reuse of Sediment Off-site means that the Sediment is used outside the 5-meter strip along the dredged river.
Reuse of Sediment	Application of Sediment on land after dredging rivers, streams, canals,… Reuse in the water system is not considered in this study given that under water applications focus on water-toxicity, whereas for the reuse of dredged Sediments, human- and land-ecotoxicity are more important endpoint receptors").
Models (exposure and leaching models)	F-leach ○ Software for estimating the risk of leaching and the evolution of soil quality S-Risk ○ S-Risk is a state-of-the-art model for assessing exposure and human health risks at contaminated sites. Fate and distribution of chemical pollutants in soil are calculated according to steady-state conservation of mass principles. It is developed by VITO and is available for users since June 2013. This software is commonly used for risk-evaluation for soil pollution in Belgium.
Persistent	A chemical property of a substance so that it will not break down into a harmless substance or basic elements (e.g. carbon) or will only break down very slowly when emitted in nature.
Pure product	Contamination that potentially occurs in the Sediment as separate phase. In this study, 100% Solubility of the emerging substance is used to calculate potential presence of Pure product in Sediment. This definition is used as a high-level screening step to prevent the reuse of contaminated Sediments with indications of Pure product.
Sediment	Sediment is a part of the Waterbed that can flood onto land (i.e. flooding Sediment) or can be dredged and applied on land (i.e. spoil) (see figure 1).
Solubility (S)	is the property of a chemical substance to dissolve in a liquid (water)
Target value	Corresponds to the level of pollutants or organisms in or on the soil, which allows that the soil can fulfil all its functions without any restrictions being imposed. The Target value is known in the Flemish legislation as "richtwaarde".
Tolerable Daily Intake	Tolerable Daily Intake (TDI) refers to the daily amount of a chemical that has been assessed safe for human being on long-term basis (usually whole lifetime)
Water bed	The water bed is the solid material that is under a water surface. This soil consists of a solid soil and Sediment. Sediment is located on the solid bottom (see figure 1).

Vapor pressure (D)	The Vapor pressure of a substance indicates the pressure that a vapor exerts when it enters equilibrium with the pure liquid or pure solid phase. Vapor pressure is a measure of the tendency to evaporation. The higher the Vapor pressure, the more the component will evaporate to the gas phase.

LIST OF ABBREVIATIONS

CEC's	Chemicals of Emerging Concern
EFSA	European Food Safety Authority
NORMAN	The NORMAN network enhances the exchange of information on emerging environmental substances and encourages the validation and harmonization of common measurement methods and monitoring tools so that the requirements of risk assessors and risk managers can be better met. It specifically seeks both to promote and to benefit from the synergies between research teams from different countries in the field of Emerging substances.
OVAM	Public Waste Agency of Flanders
PFAS	Per- and polyfluoroalkyl substances
PNEC	Predicted No Effect Concentration
Ppm	Parts Per Million
Ppb	Parts Per Billion
REACH	Is a European Union regulation dating from 18 December 2006. REACH addresses the production and use of chemical substances, and their potential impacts on both human health and the environment. The name 'REACH' means Registration, Evaluation, Authorization, and restriction of Chemicals.
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (Dutch governmental organization)
VITO	Flemish Institute for Technological Research

1 INTRODUCTION

In recent years, there has been a growing awareness of the presence of so-called "emerging contaminants" or "contaminants of emerging concern (*CEC’s*)" in our environment (soil, water, *Sediment*,...) and the possible actual and/or potential problems that these chemical components can cause on humans and the environment. The problem with these *Emerging substances* is that they are usually not included in standard analysis packages, there is no policy available, the substance has properties that are very different from classic and better known components, the environmental risks of the component is little or not at all known....

As a result, in addition to raising awareness, there is also a growing need to develop good and sustainable policy that can provide an answer to these potential problems.

To support policy makers in their decisions, the Interreg project sullied *Sediment*s was started. The aim of this project is to enable regulators and water managers to make better decisions regarding *Sediment* management, removal, and disposal, thereby reducing economic costs and the impact of these pollutants on the environment.

The *OVAM* (“Public Waste Agency of Flanders”) participated in the Interreg project Sullied *Sediment*s. The main objective of this European project is to develop knowledge and tools to support water managers in their decision-making on the management of contaminated *Sediment*s. One of the key elements in this project is the investigation of possible effects of *Emerging substances* (*CEC’s* or Chemicals of Emerging Concern). Therefore, Arcadis Belgium NV and Witteveen+Bos Belgium NV developed a decision tool for the management of *Sediment*s contaminated with emerging contaminants. Both experts already have a large expertise on the problem of "emerging contaminants" and are part of the Centre of Expertise on *PFAS* that already exists in the Netherlands since 2013.

The decision system focuses on the Flemish soil framework and guidelines, given it was developed by Flemish soil experts. However, the principles on which this system is based are widely applicable in other standardization frameworks. To this end, at the beginning of the report a list of definitions is included that elucidates concepts that are typically used in the Flemish standardization framework. ***It is important to note that this report contains a proposal for a decision tool. This proposed decision tool needs further discussion with stakeholders before it can be incorporated into regulation***.

The following steps are included in this study:
Task 1: Collection of basic information from different sources;
Task 2: Analysis of the data for the Flemish standardization framework;
Task 3: Decision tree to decide on reuse of *Sediment*- widely applicable principles
Task 4: Recommendation for supplementing and updating the code of good practice which describes the methodology used for standardization in Flanders.

This study contributes to work package WP4 of the Interreg project Sullied *Sediment*s. Instruments are developed to assess the risks associated with polluted *Sediment*s. Consequently end-of-waste criteria can be developed for dredged *Sediment*s to encourage reuse. We provide a method for risk analysis and risk management (both in situ and ex situ) with background information to support a framework of standards, so that watercourse managers who have analytical data can evaluate it to make informed decisions. The methodology for deriving standards (soil remediation standards, values for *Free use*, values for reuse) is used to assess possible standards for contaminants of emerging concern. This framework for standards makes it possible to place the use of the *Sediment*s in the end of waste framework.

With this study, *OVAM* wants to gain insight into the risks that sullied *Sediment*s can cause in the environment because of the reuse of spoils from dredging and clearance works. The focus is on contaminants that are listed on the list of priority substances established within the EU (daughter directive priority substances directive 2013/39 / EU) as well as on the wide variety of *Emerging substances*. The question is whether assessment values for *Sediment*s contaminated with these *Emerging substances* are already available in other countries. The intention is not to look at the legislation, but to focus on the assessment values that are used in countries that are "frontrunners" in the field of Emerging Contaminants and priority substances. These values are evaluated, and it is determined whether the format of this value is in accordance with local legislation.

It is the intention to provide an answer to the above question through a literature study. Insight is obtained into the available threshold values, their analysis methods and cost, their reliability, and the reporting limits. The method (approach, strategy) used for this is elaborated in a code of good practice that describes the approach for substantiating the threshold values for the reuse of *Sediment*s contaminated with new substances of concern. The code of good practice must enable a soil remediation expert to derive a substantiated threshold value for the reuse of *Sediment*s contaminated with emerging and priority substances.

Threshold Values for the reuse of dredged *Sediment*s on the soil are related to the standards for soil and groundwater protection. The threshold values for the assessment of the use of dredged *Sediment*s can be based on soil remediation standards for soil and groundwater, possible background values and determination limits of the prescribed analytical methods.

Research into which *Emerging substances* are relevant for aquatic soils in Flanders was studied by Ecofide. Ecofide's study 'Hotspots of priority and *Emerging substances* in *Sediment*' gives an overview of the priority substances to be investigated in the water system. The study determined which substances of concern are relevant to the *Sediment* and which substances should be tackled as a priority. Based on previous documents, a selection of 5 substances or groups of substances will be evaluated in detail in this study.

2 TASK 1: LITERATURE REVIEW AND INTERNATIONAL QUESTIONNAIRE

Task 1 includes the collection of basic information from different sources. By means of a literature study and questionnaires combined with interviews within Arcadis and Witteveen+Bos, an overview will be made of the standards/assessment values that are available and the main criteria used to determine those values i.e. human toxicology, ecotoxicology, leaching, zero tolerance, other policy or scientific criteria. For this purpose, a questionnaire is drawn up. Where necessary interviews were set up to clarify the answer or to collect more specific information.

Additionally, information on laboratory methodologies of emerging contaminants, costs and *Detection limit*s will be collected.

2.1 LITERATURE

The purpose of this literature review is to gain general understanding of the possibilities and bottlenecks in developing a method for the *Reuse of Sediment* for *Emerging substances*. Several studies were selected that, in our opinion, provide interesting challenges and useful elements for developing a methodology. For each of the selected studies, we provided a summary and a separate section in which these elements of interest are listed. By no means is it our intention to present an all-comprehensive in-depth literature study. This would be a task as it is too extensive and not covered by the scope of this study.

2.1.1 List of contaminants of emerging concern

There are different lists of contaminants of emerging concern present in literature. The most important list that is internationally best known within soil legacy is the list of priority substances – guideline 2013/39/EU. This list will, therefore, form the main basis of this study. This list was also used in the prioritization study for *Sediment* contamination of Ecofide (cf. paragraph 2.1.4).

This list of priority substances will be used to make an inventory of existing international data and to evaluate a methodology for *Reuse of Sediment* on land.

2.1.2 *NORMAN* prioritization methodology and web-based databases

2.1.2.1 Summary of the study

Prioritization methodology

The *NORMAN* prioritization method is a strategy of the *NORMAN* network[1] to prioritize the substances from the *NORMAN* database. This methodology consists of two steps:

1. Subdividing the *NORMAN* substances in six action categories and potential subcategories.
2. Ranking these substances within these action categories.

The *NORMAN* action categories range from category 1 (sufficient evidence for exposure and effects at measured concentrations for the establishment of standards) to category 5 (insufficient data and

[1] Network of reference laboratories, research centers and related organizations for monitoring of emerging environmental substances

calculated toxicity for setting standards) and category 6 (sufficient evidence that the substances are not toxic at the measured concentrations and therefore are no priority for further action).
This classification is based on 13 questions about:

- The presence of the substance in the *NORMAN* database
- The availability of monitoring data
- Analytical detection levels (LoQ)
- The availability of ecotoxicity data
- The extent to which the *PNEC* is exceeded

For the ranking within the action categories following three elements are used:

- Exposure
- Hazard
- Risk

Every substance can gain a maximum of one point for each of these three elements (resulting in a maximum score of 3). Based on this score, the substances are prioritized within the *NORMAN* action categories. This ranking can differ between action categories depending on the information available. Therefore, only comparisons of substances within the same action category are recommended.

Web-based databases
NORMAN organizes the development and maintenance of various web-based databases (https://www.*NORMAN*-network.com/nds/) for the collection & evaluation of data/information on *Emerging substances* in the environment. These databases are being developed and integrated with the primary aims of:

- Bringing together existing knowledge on *Emerging substances* and,
- Setting up a framework for the systematic collection, elaboration, and scientifically sound evaluation of future data.

NORMAN has the ambition to become the primary data source and global one-stop-shop for all issues regarding *Emerging substances*, contributing to the creation of the early-warning system for emerging pollutants and subsequent policy actions. It is uncertain whether all *NORMAN* databases are regularly updated with new information and hence whether this ambition is realistic.

2.1.2.2 Challenges and interesting elements for a methodology for reuse of *Sediment*s

Following challenges and interesting elements for the development of a new methodology for the reuse of *Sediment*s are identified from this study itself as from considerations when going through this study:

- The classification into action categories according to the *NORMAN* method is partly based on **ecotoxicological data**. The human-toxicological classification only plays a role in the hazard score and thus in the ranking within the categories. Therefore, the current *NORMAN* method is particularly suitable for estimating the risks to the ecosystem. The risks of **exposure routes** that are of specific importance **to humans**, such as the intake of soil particles or food, have been underexposed in this approach and should be considered separately within the framework for reuse of *Sediment*s.
- *NORMAN* includes seven substance properties in the ranking: carcinogenicity, mutagenicity, reprotoxicity, the combination "*Persistent*, *Bio-accumulating* and toxic" and endocrine disruption. These properties are hence available in their web-based databases for the different substances. The combination of **"*Persistent* and mobile (PMOC)" is not included**. This may be justified for prioritization from an ecotoxicological perspective, but not from the perspective of protecting groundwater and reuse of contaminated *Sediment* on land.

- *NORMAN* has various web-based databases. These databases include a lot of chemical, physicochemical and toxicological properties of emerging contaminants. The references (source) of these data are not always mentioned in the database, hence difficult to establish whether the **actual data** are present. However, these databases can be used within a first indicative step towards the calculation of target levels.

2.1.3 Strategy for emerging contaminants (Deltares, 2017)

2.1.3.1 Summary of the study

This study provides a strategy for emerging contaminants in surface water and groundwater based on four steps:

1. Gathering **basic information** on emerging contaminants:
    - Lists of contaminants of emerging concern
    - Concentrations of these emerging contaminants in surface-and groundwater
    - Load by product use
    - Hazard properties of these contaminants and data on their ecotoxicity
    - Technical and social feasibility of possible measures for these substances
2. Selection of **relevant information** and combining this information in an overview table. This overview table contains following parameters:
    - *NORMAN* action categories
    - Usage type
    - Risk score
    - Presence of these substances on the lists of 'contaminants of emerging concern'
    - The mobility and persistence of these substances (PMOC)
    - Policy related parameters
3. **Synthesis** of this overview table with an indication of **priority substances** based on relevant cross-sections in an overview table.
4. Follow-up steps for these priority substances, substance groups and sources (additional information, formulation of measures, …)

This strategy designates priority substances and provides insight into the information available for these substances. In this way, it is depicted for which substances additional information is required and for which substances measures can be formulated.

2.1.3.2 Challenges and interesting elements for a methodology for reuse of *Sediment*s

Following challenges and interesting elements for the development of a new methodology for the reuse of *Sediment*s are identified from this study itself as from considerations when going through this study:

- To keep a good overview of the number of new substances, working in **usage categories** (main groups and subgroups) such as biocides, flame retardants, fluorinated compounds (*PFAS*), pesticides, personal care products, etc. is suggested.
- Every category has "in average" **similar characteristics**. The characteristics of these groups can be used as a tier 1 indicative screening to set targets and/or use restrictions for *Reuse of Sediment* on land.
- Different categories are based on the **level of (qualitative) accessible knowledge** e.g. toxicity, mobility, etc. If too little data are available for a specific compound, the methodology to derive the target level will be different compared to compounds with extensive data available.

2.1.4 Hotspots of prioritized and emerging contaminants in *Sediment*s (Ecofide, 2020)

2.1.4.1 Summary of the study

This report describes an approach to assess which priority and *Emerging substances* may be relevant for *Sediment*. In this draft method the following is investigated for both the priority and *Emerging substances*:

1. The $logK_{oc}$ or $logK_{ow}$ of the substance
2. Data on the occurrence in the Flemish *Sediment*
3. Data on the occurrence in biota from Flanders
4. Data on the occurrence in Flemish surface water
5. Data on occurrence in specific locations such as hotspots

The $logK_{oc}$ or $logK_{ow}$ of the substance is an indication for the adsorption of these substances to *Sediment*. If $logK_{oc}$ or $logK_{ow}$ is higher than or equal to 3, the substances adsorb well to the *Sediment*. In this case, a standard must be derived. The monitoring data in the Flemish *Sediment*, biota and surface water indicate a potential risk of these substances. For example, bioaccumulation in the food chain (biomagnification) can result in a negative impact on top predators even when there is no direct effect on the aquatic ecology. The official standards or more indicative limit values provide insight into the effects of these priority and *Emerging substances*.

Combining the information on the $logK_{oc}$ or $logK_{ow}$, the monitoring data in Flemish *Sediment*, biota, and surface water together with the official standards or indicative limit values provides insight into the question to what extent the substance is relevant for *Sediment*.

2.1.4.2 Interesting elements for a methodology for reuse of *Sediment*s

Following interesting elements for the development of a new methodology for the reuse of *Sediment*s are identified from this study itself as from considerations when going through this study:

- Use of **physicochemical characteristics**
- The EU directive on the standardization of substances (EU, 2011) describes when the derivation of a standard for *Sediment* is recommended. The trigger values to be used are the same as those used under the *REACH* regulations. In general, it is stated that substances with an organic carbon adsorption coefficient (K_{oc} value) below 500 to 1000 l/kg will hardly or not bind to *Sediment*. Therefore, a **$logK_{oc}$ or $logK_{ow} \geq 3$** is used as the trigger value to derive a standard for *Sediment*. This prioritization criterium can also be interesting to use in case of reuse of *Sediment*s. Substances that bind to *Sediment* will also be important to assess in case of reuse of *Sediment*.
- **Endpoint receptors**: Whereas the Ecofide study and this study both focus on priority and emerging contaminants in *Sediment*, the Ecofide study aims to determine which priority and *Emerging substances* are relevant for *Sediment*s, whilst this study formulates guidelines for the reuse on the land of *Sediment*s contaminated with these relevant priority-and *Emerging substances*. As a consequence, the Ecofide study focuses on ecological risks as driving force to derive *Sediment* intervention levels, whilst for the development of a methodology for reuse of *Sediment*, land use (human risks in different land-use scenarios) and potential leaching towards groundwater are more important. In other words, the endpoint receptors in the Ecofide study are water-ecotoxicity receptors, whereas the endpoint receptors in this decision system must be human-and land-ecotoxicity receptors.

2.1.5 National policies on substances of concern (Bureau KLB, 2017)

2.1.5.1 Summary of the study

The purpose of this study was to gain insight into the national policies on substances of concern in six EU Member States: Belgium, Denmark, Germany, France, The Netherlands, and Sweden. This study was commissioned by the Ministry and the *RIVM* of the Netherlands to acquire inspiration for further development of Dutch policies to keep contaminants of high concern out of the environment. The study resulted in ideas and inspiration regarding prioritization of substances, emission control, substitution, and circular economy.

Several countries developed further national prioritization methods for substances of concern. All six countries control emissions by permitting systems and most countries have stricter standards for more hazardous chemicals. Also, all countries promote substitution. However, 'soft' or voluntary measures to affect substitution seem not the most effective. Rather, pressure encourages the search for alternatives. All the investigated EU Member States share the aim of a circular economy, but due to the hinder of substances of concern on the re-use/recycling of products, there is no or solely an implicit or case-by-case connection between this aim and the avoidance/substitution of substances.

2.1.5.2 Interesting elements for a methodology for reuse of *Sediment*s

Following interesting elements for the development of a new methodology for the reuse of *Sediment*s are identified from this study itself as from considerations when going through this study. This study also shows other points of interest such as registration, societal concerns, and targeted information. Product registrations help to gain insight into the substances that are on the national markets, the quantities in which they are supplied, and the companies that supply these products. This, in turn, enables policymakers to assess the relevance of certain substances and to prioritize these substances. In some countries there exist measures to proactively assemble and translate societal concerns into policy priorities. Lastly, targeted information may help consumers in their purchasing decisions and companies to gain the right knowledge about the substances of concern present in their products and the risk properties of these substances.

2.1.6 Possible action perspectives for new threats in the soil system (Expertise centrum *PFAS*, 2018)

2.1.6.1 Summary of the study

This report explores possible action frameworks for new threats in the soil system by targeting the following questions:

1. What is known about new threats in the national and international soil work field and which substances are regarded as a threat?
2. Which European rules and guidelines exist for new and *Emerging substances*?
3. Which methods can be used to determine the (negative) effects of these substances on the soil system?
4. Which examples can be used to determine how to deal with new threats?

It is important to note that these new threats are not only related to new, currently unknown substances with unknown threats. They are also related to known substances with previously unknown (new) threats and known substances with new applications.

To be able to act adequately on the various threats that new and *Emerging substances* can pose on the soil system, this report proposes a methodology of ranking (in advance) and signalling (afterward, reactively) on these substances.

The risks of new or *Emerging substances* for the soil system are assessed using the Source-Path-Receptor approach. The substances that pose a potential risk to the soil usage are selected and ranked by the following formula:

Risk (concern) = usage (tonnage) * risk (toxicity) * risk of exposure

Periodical confrontation with unknown or unexpected, potentially harmful substances in the soil is inevitable. Therefore, these substances must be signalled, and an action framework needs to be developed to identify potential damage at an early stage, to assess this damage as quickly as possible, and to respond to it as effectively as possible. There are three ways in which these potentially harmful substances can be signalled. They can be featured in the news; they can surface during chemical analyses or they can be substitutes for known harmful substances. For all these substances, an action framework should be composed to determine whether their risk is real (yes/no) and to determine the extent of the problem (local/regional/national).

Eventually, (the risks of) new threats must be demonstrated in practice and once the harmful substances are identified, the required measures must be assessed.

2.1.6.2 Challenges and interesting elements for a methodology for reuse of *Sediment*s

Following challenges and interesting elements for the development of a new methodology for the reuse of *Sediment*s are identified from this study itself as from considerations when going through this study:

- Interesting **definition**: when looking at the 'new threats' to the soil system, it is important to realize that this is not just about 'new', currently unknown substances, but that this may also relate to existing substances that become available through new forms of applications (circular economy) or new insights into existing substances (e.g. lead). New threats to the soil system can, therefore, be related to:

  1. New, yet unknown substances with yet unknown threats
  2. Known substances with a previously recognized (new) threat
  3. Known substances with new applications

- Challenges about a **lack of substance information**: when a substance is found in the environment, it is necessary to determine the properties of this substance and the substance behaviour that is associated with these properties. It is not possible to describe substance-specific information in a generic action framework. However, a generic overview of substance properties (volatility, mobility, polarity, etc.) and associated behaviour (toxicity, degradability, degree of bioaccumulation, etc.) can be included. Based on the properties of the 'substance in question', it is possible to estimate the associated behaviour. An action framework is needed on how to deal in practice with lack of information.
- Ranking based on **exposure route and risk assessment**: when determining exposure, one must know the "endpoints" in the source-path receptor chain. It is important that the soil is not regarded as a receptor but as a path. The function of the soil is decisive. Depending on the function of the soil, it can be assessed whether a substance damages the microbiology of the soil, damages the quality of crops or animal products, or can lead directly to human exposure. It is important to determine per soil function (per receptor) whether a substance can potentially be soil threatening. The driving force to derive *Sediment* intervention levels are ecological risks, whilst for the development of a methodology for reuse of *Sediment*, land use (human risks in different land-use scenarios) and potential leaching towards groundwater are more important. In other words, the endpoint receptors in this decision system must be human-and land-ecotoxicity receptors.

2.1.7 Conclusion literature study

The literature review demonstrates the challenges associated with the development of a method for the *Reuse of Sediment* with *Emerging substances*. A major challenge, illustrated by the studies of *NORMAN*, Deltares, and the Expertise centrum *PFAS*, is the lack of data and the uncertainties associated with the already available data. This lack of information complicates the derivation of standards for the reuse of contaminated *Sediment*s. Another considerable issue surfaced in the study of the Expertise centrum, is the importance of a clear definition.

It is essential to consider these bottlenecks when we develop a methodology for the reuse of *Sediment*s contaminated with *Emerging substances*. At the same time, this literature study provides us with interesting possibilities to deal with these challenges. First, the studies of *NORMAN* and Deltares describe the use of different categories. On one hand, categories are based on the availability of information, ranging from category 1 (sufficient evidence for exposure and effects at measured concentrations to establish standards) to category 5 (insufficient data and calculated toxicity for setting standards) and category 6 (sufficient evidence to conclude the substance is not toxic and thus no priority). On the other hand, categories are based on usage type (for example, pesticides, flame retardants, and care products). Next, the study of Bureau KLB shows several similarities between the investigated EU Member States (such as the shared aim of circular economy and the promotion of substitution) indicating it can be useful to take a look at the state of the art in neighbouring countries for methods on how to deal with sediments contaminated with *Emerging substances*. At last, the Expertise centrum *PFAS* and the Ecofide study emphasize the importance to determine the endpoint of the source-path-receptor chain. The Expertise centrum study explains it is crucial to understand that the soil is not regarded as a receptor but as a path in this chain and that the soil function is decisive. Thus, the possible threat of an emerging substance should be determined for each soil function (i.e. receptor) separately.

Based on these findings, we chose to work with categories in our decision system as proposed by *NORMAN* and Deltares. These categories are based on the available information on the substance of emerging concern and the uncertainties/variability of the available data. The categories range from category 1 (all data are available to calculate levels for reuse as soil and/or use as) to category 4 (too little data available to calculate human exposure or too much uncertainty on the available data). Considering the study of the Expertise centrum, we looked at the soil function when we determined the endpoints of the source-path-receptor chain. The following receptors are defined in our decision system: agricultural land use, residential land use, recreational land use, industrial land use, and use as . Depending on the category of the substance, other reuse possibilities apply. At last, we decided to incorporate a comparative screening with international levels into our decision system. This enables consultants/experts to get an idea of the order of magnitude in which the standards are expected. This comparative screening step also allows consultants/experts to verify the *Detection limit*s provided by the analytical laboratories (Tier 1, §4.3)

2.2 QUESTIONNAIRE ON NATIONAL POLICIES AND STANDARDS

A questionnaire was compiled to gain insight into the standardization of emerging contaminants in other countries. The first part of the questionnaire examines the availability of standards for emerging contaminants in the surveyed countries. The second part explores the prioritization of the substances for which the surveyed countries indicated that there are standards available. This part was added because the definition of an emerging contaminant is not clearly defined. Different lists of emerging contaminants exist and the presence of a substance on these lists is dynamic. Meaning, substances that are emerging contaminants now, will no longer be considered emerging contaminants a few years from now.

Several countries were contacted within the Arcadis and Witteveen+Bos consultants, and network of the centre of Expertise on *PFAS*. Table 1 displays an overview of all contacted countries that did (indicated with '+') or did not (indicated with '0') provide completed questionnaires and/or interviews.

Country	Questionnaire
Netherlands	+
Switzerland	+
Germany	+
France	+
Italy	0
Spain/Portugal	+
Sweden	+
UK	+
US	0
Canada	+
Australia	0

Table 1: Completed ('+') and not completed questionnaires ('0') by country/region.

The completed questionnaire is presented in annex 1.

<u>*Limitations*</u>
Given its leading questions, the study has a broad scope. The extent of the data collection has however been limited by its timeframe and budget. The topic of emerging contaminants is a dynamic topic with lots of changes in short time intervals. For that reason, the project team cannot claim completeness of the overviews and information. Moreover, to a certain extent the amount and types of information that were available depended on the level of openness and self-presentation of policies on government websites, on the expert that was interviewed, as well as on how the relevant authorities are organized (e.g. one central agency or an amalgam of federal and regional bodies).

2.2.1 Question 1: Are there specific standards available for soil remediation or the reuse of *Sediment*s on land, *Waterbed* or in surface water for *PFAS*, dioxins, brominated flame retardants, heptachlor, or other emerging contaminants?

In the first question of the questionnaire, all countries indicated they have standards available for at least one emerging contaminant, except for the UK and Portugal. More in detail, The Netherlands rely on a standard framework for the distribution of dredged material on adjacent plots and the application of dredged material on land (formalized in the Soil Quality Decree). In this standard framework, both the soil function and the soil quality are categorized into three soil function classes: agriculture/nature, residential, and industry. For example, the soil function 'location where children play' is categorized in the residential soil function class. Thus, the maximum application values on land depend both on the soil function and the quality of the receiving land plot. For most of the municipalities in the Netherlands, the quality of the receiving soil is determined in a "soil function class map and soil quality map". Canada (Ontario), Germany, and Sweden did not specify the framework they apply for the distribution and application of dredged materials.

In the UK and Portugal, there are not yet specific standards available for soil remediation or reuse of *Sediment*s for *PFAS*, dioxins, brominated flame retardants, heptachlor, or other *Emerging substances*.

However, their legislation does describe how to deal with emerging contaminants if they are detected. For the United Kingdom (UK), the Environmental Protection Agency (EPA_UK) Guidelines state that risk-based values for reuse or remediation need to be developed by a site-specific approach. More specifically, a strategy is developed for the reuse of dredging and other soil-like materials (for example bankside materials from engineering work). Canal & River Trust (CRT) determines whether the material is hazardous or not (based on screening data derived by consultants). If the substance is classified as hazardous, bankside disposal is deemed inappropriate. When the component is considered non-hazardous or inert, bankside disposal is possible if it does not form a risk to CRT staff, the public, or grazing animals. Also, it can only be disposed on land when allowed by the National Dredging Team or the Environment Team. First, a conservative screening approach is assumed by providing screening values applicable to residential land use without plant uptake and to the grazing animal. Thus, based on human toxicological and ecotoxicological data. As these criteria are intended to be a screening tool, an exceedance of these criteria does not necessarily mean that the material cannot be deposited or is unsuitable. Rather, it indicates that the conceptual model for risk-assessment should be further considered (including the probable receptor). For Portugal, the general act Lei n.º 58/2005, de 29 de Dezembro (Lei da Água) Water Act of 2005 applies. In this act, five classes of materials are distinguished according to the degree of contamination ranging from clean dredged material (class 1) to very contaminated material (class 5):

Class 1: Clean dredged material - can be deposited in the aquatic environment or replaced in places subject to erosion or used to feed beaches without standards restrictive.
Class 2: Dredged material with trace contamination - can be immersed in the aquatic environment taking attention to the characteristics of the receiving environment and the legitimate use of the same.
Class 3: **Slightly contaminated dredged material** - can be used for earthworks or in the case immersion it requires a detailed study of the deposition and subsequent monitoring
Class 4: **Contaminated dredged material** - preposition on land, in a waterproofed place, with the recommendation of subsequent coverage of impermeable soils.
Class 5: Very contaminated material - ideally it should not be dredged and in imperative cases, the dredged materials should be sent for previous treatment and or deposition in a duly authorized waste landfill, being prohibited its immersion.

Even though there are no specific classification data for *PFAS*, dioxins, brominated flame retardants, or heptachlor, this act describes that “In cases where chemical analysis is necessary, it is mandatory to analyse the substances that may be present due to specific and/or diffuse pollution sources”. Hence, when there is a known source of water contamination by these contaminants, they should be analysed. Contrary to the UK, Portugal did not inform us about the strategy they apply after analysing the contaminants.

From the four countries indicating to have standards available, Canada (Ontario) reported that the type of standard (soil remediation standard/standard for reuse of *Sediment*s) varied between provinces, but in general Ontario has a well-developed process for assessing and managing contaminated *Sediment*s given its location on the great lakes. The answers of Germany disclosed they only have standards for soil remediation as there is no definition of “*Sediment*” in their soil protection regulations. The *Reuse of Sediment* on land is considered "soil" and thus included within the Soil Protection Act. The other three countries (Portugal, The Netherlands, and Sweden) did not inform on the type of standard. The Netherlands indicated they have both soil remediation standards and standards for the reuse of *Sediment*s.

When asked about the substance groups for which standards are available, Canada (Ontario) indicated there are standards available for dioxins, heptachlor, and brominated flame retardants.

Germany and The Netherlands, in turn, revealed they had standards available for *PFAS*, dioxins, heptachlor, and brominated flame retardants. Our contact person in Sweden stated they have standards for *PFAS* available. Note that this person is an expert on *PFAS*, therefore, it is possible that Swedish standards also exist for other emerging contaminants but that this information did not *REACH* us. The individual substances for these four countries are included in Annex 2.

For the question on the legal status of these standards, Canada (Ontario) indicated these standards are included in regulation as they are defined in the Environmental Protection Act. In Germany, The Netherlands, and Sweden, there are both preliminary/indicative values and standards included in regulation (approved values). In Germany, the trigger and action values of dioxins/furans are included in regulation (presented in the Federal Soil Protection Act). Also, they have preliminary/indicative values available for brominated flame retardants, *PFAS*, dioxin/furan, and heptachlor resulting from an orientating survey (2019) with average results for these emerging contaminants in some environmental compartments. In the Netherlands approved values for heptachlor and heptachlor epoxide as well as for *PFAS* exist. These for heptachlor and heptachlor epoxide are included in Soil Quality Regulation, Appendix B "Background values and maximal values for soil and dredged material"). These for *PFAS* are presented in the temporary framework of action ("Tijdelijk handelingskader"). In addition, indicative levels for serious soil contamination of *PFAS* exist. As these indicative values have more uncertainty as compared to intervention values, authorities need to take other considerations into account when deciding about serious *PFAS* contamination. These considerations are presented in the Circular Soil Remediation (2013).

In the last question of the first part, the countries were asked how their standards were established. The Canadian *Sediment* levels are based on a NOEL (ecotoxicological risks), whereas the soil values vary, but range from background to risk-based (human toxicological risks) with a risk tolerance of 1 in a million for cancer and 0.2 or 0.5 HI for non-carcinogens. In Germany and The Netherlands, the standards are also based on these ecotoxicological and human toxicological data. In addition, the German standards are also based on the stand-still principle. In the Netherlands, they also look at the national background levels, leaching, and the principle of duty of care ("zorgplicht") next to the human and ecotoxicological data. In Sweden, the *PFAS* standards are risk-based, and sometimes certain *PFAS* are grouped based on "road across assumptions" (example: some PFAA's are considered equally toxic as PFOS).

2.2.2 Question 2: How did you obtain these priority substances?

In the UK, Canada-Ontario, Germany, and Portugal, they did not prioritize any *Emerging substances*. In Sweden, prioritizing and grouping *PFAS* is a huge topic. So far, certain PFAAs, related substances (i.e. precursors), and one perfluoroalkyl ether acid (GenX) are prioritized starting from the OECD list (containing 4730 *PFAS*) using intrinsic properties (P, B, T, M, etc.) and/or risk assessment.

2.2.3 Conclusion output questionnaires

In conclusion, it was difficult to collect information on standardization and prioritization in the surveyed countries. Standards are still under development ranging from countries without any standards available (UK and Portugal) to countries with indicative and/or approved standards for soil remediation and/or reuse of *Sediment*s (Canada, Germany, The Netherlands, and Sweden). The available standards are based on at least human ecotoxicological and/or human toxicological data. In some countries, these data are supplemented with the stand-still principle (Germany), background values, leaching, and duty of care ("zorgplicht") (The Netherlands).

The lack of a general and unambiguous method for reuse of contaminated *Sediment*s in other countries complicates the development of a methodology in Flanders as we cannot rely on the development process of other countries. At the same time, it demonstrates that other countries are facing the same challenges and confirms that we are not rediscovering a method that is already established.

3 TASK 2: EVALUATION OF THE INFORMATION IN RELATION TO FUTURE FRAMEWORK

3.1 OVERVIEW OF EXISTING INTERNATIONAL TARGET LEVELS

In Annex 2 an overview table is presented with:

- EU list 2013/39/EU
- Log K_{ow}: this parameter is important to judge whether a contaminant has a higher chance to adsorb on the *Sediment* and hence can be spread via *Reuse of Sediment* as "soil"
- Most important end point receptor: some compounds are listed on the EU list because of the ecotoxicological risk and not human risk. Therefore, the endpoint receptor is important in the evaluation of the possibilities of *Reuse of Sediment* on land. In most countries *Reuse of Sediment* is seen as "soil" and hence human exposure pathways are the dominant pathways to determine a risk-based level.
- Existing levels in the different countries as well as the criteria that are used (human exposure, drinking water, plant uptake, etc.).

3.2 *CONCEPTUAL SITE MODELS*

The principles of the decision system for reuse of contaminated *Sediment* on land are based on *Conceptual site models*. A *Conceptual site model* for excavated soils on land differs from a *Conceptual site model* for *Reuse of Sediment* on land. Not only the matrix changes from *Waterbed* to land when the *Sediment* is applied but also the endpoint receptors and relevant exposure pathways are different. The ecological risks are the driving force to derive a *Sediment* level, however, in case of reuse of *Sediment*, the land use (human risks in different land-use scenarios) and potential leaching towards groundwater are more important.

The differences in *Conceptual site model*s are further clarified in the following sections together with the relevant exposure and spreading pathways.

3.2.1 *Conceptual site model* before dredging (= *Sediment*)

The *Conceptual site model* of the *Sediment* before dredging is shown in figure 1.The dominant exposure and spreading pathways are:

- Exposure towards ecological organisms in the water body
- Spreading of the top layer *Sediment* due to the waterflow in the river
- Indirect human exposure via exposure of contaminated food-biota

The tolerable concentrations of *Emerging substances* in *Sediment* are mainly based on the ecotoxicity levels in *Sediment*. The ecotoxicity endpoints are different in *Sediment* (e.g. water organisms) than the ecotoxicity endpoints on land (e.g. plants).

Figure 1 shows the conceptual site model before dredging (OVAM, studiedag Waterbodem, 2018) . Sediment (indicated in brown) is a part of the Waterbed that can flood onto land (i.e. flooding Sediment) or can be dredged and applied on land (i.e. spoil).

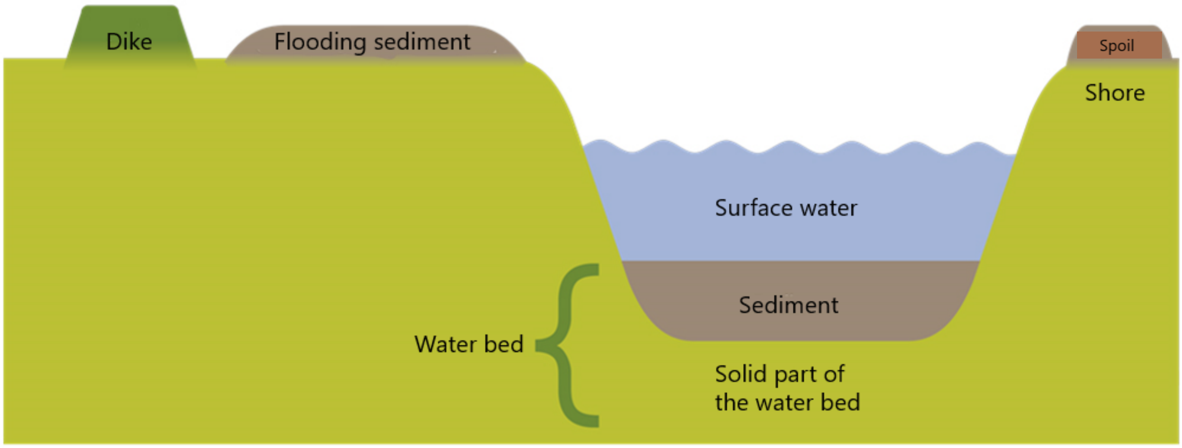

Figure 1 gives the conceptual site model before dredging

3.2.2 *Conceptual site model* for *Reuse of Sediment* on land (as soil)

The *Conceptual site model* for reuse as soil is shown in figure 2. After application of the dredged *Sediment* on land, the dominant exposure and spreading pathways are:

- Human toxicity-exposure routes dependent on the land usage type (e.g. dermal contact, drinking water, inhalation, ingestion);
- Plant toxicity;
- Uptake by human/cattle;
- Leaching

Therefore, the tolerable concentrations of the contaminated *Sediment* that will be reused on land should be mainly based on human toxicity-exposure routes dependent on the land usage type and leaching.

Figure 2 shows the *Conceptual site model* for reuse as soil (Arcadis). The different routes of exposure are indicated in black.

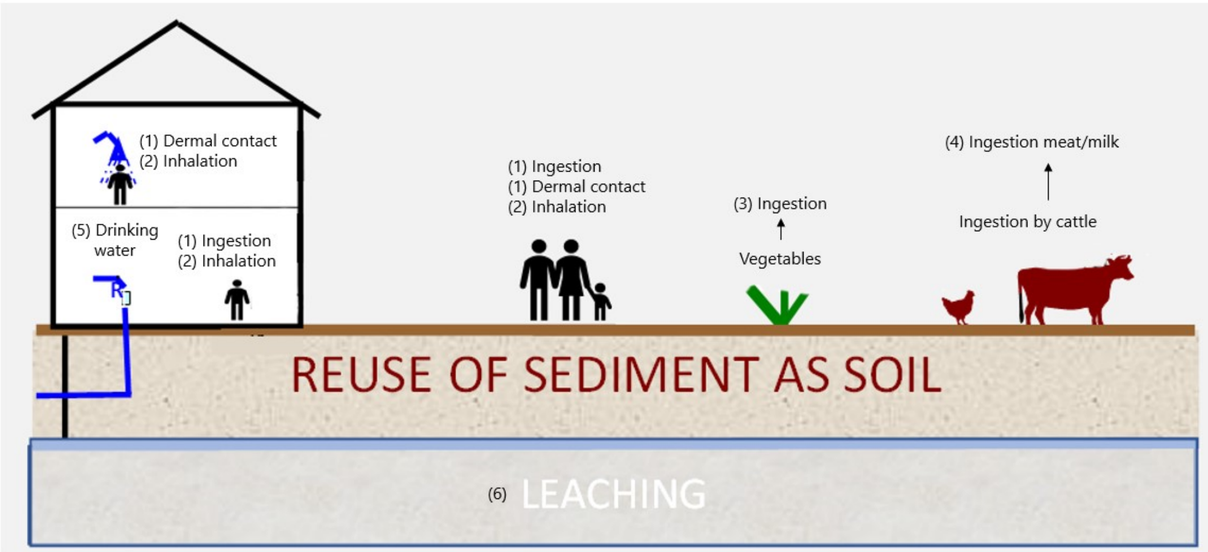

Figure 2: Conceptual site model for reuse as soil (Arcadis).

3.2.3 *Conceptual leaching model* for *Reuse of Sediment* on land (as *construction material*)

The dredged Sediment could also be applied as construction material on land. The conceptual site *model* for reuse as a c*onstruction material* is presented in figures 3 and 4. For Flanders, there are two application scenarios described by the Flemish Institute For Technological Research (*VITO*) (publication 'Principes bij het afleiden van de waarde vrij gebruik en de waarde voor bouwkundig bodemgebruik').

In both cases, the tolerable concentrations are based on:

- Human toxicity-exposure routes dependent on industrial use;
- Leaching (for constructions above and below groundwater level)

Two application scenarios are described by the Flemish Institute for Technological Research (*VITO* N.V.): elevation (top left) and filling (bottom right).

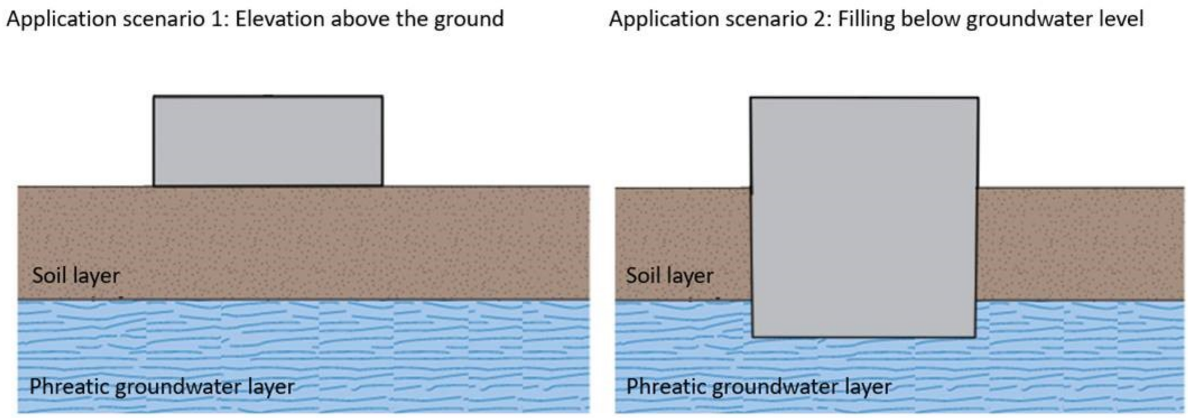

Figure 3 and Figure 4: Conceptual leaching model for reuse of sediment on land.

3.2.4 Exposure and spreading pathways

Depending on the soil usage type, different exposure and spreading pathways should be considered. Table 2 indicates the important exposure and spreading pathways for each soil usage type.

	Pathway	*Free use*	Agricultural use	Residential use	Recreational use	Industrial use	*Construction material*
1	Soil-human ingestion and dermal contact	X	X	X	X	X	X
2	Soil-vapour-inhalation pathway	X	X	X	X	X	X
3	Soil-plant uptake and consumption	X	X	X			
4	Soil-milk/meat uptake and consumption	X	X				
5	Direct Consumption of drinking water	X	X				
6	Soil-groundwater leaching	X	X	X	X	X	X

Table 2: Exposure and spreading pathways for the different soil usage types. The applicable pathways are indicated with an 'X'

Note: leaching is not always accounted for in current intervention levels of standard parameters. However, within the cautionary principle and the known uncertainties of emerging contaminants, it must be considered for all soil usage types within this decision system.

4 TASK 3: DECISION TREE TO DECIDE ON REUSE OF *SEDIMENT*

4.1 BASIC PRINCIPLES

This decision system is developed to define reuse possibilities for *Sediment*s contaminated with *Emerging substances*. It is a tiered approach in which the substances are organized into four categories. This classification depends on the availability of physicochemical, ecotoxicological (plant and cattle), and human toxicological data, on one hand, and the uncertainties in these data on the other hand. The more available information on the substance and the lower the uncertainty in this information, the more reuse levels can be calculated for the contaminated *Sediment*. The following reuse possibilities are specified in this decision system: *Free use*, agricultural use, residential use, industrial use and use as a c*onstruction material*.
If no reuse is possible and no cleaning values for treatment can be obtained or no cleaning until *Detection limit* can be obtained, the deposit or dumping of the *Sediment* is the final option.

Reuse in the water system is not considered in this study given that under water applications focus on water-toxicity, whereas for the reuse of dredged *Sediment*s, human-and land-ecotoxicity are more important endpoint receptors (§2.1.4 "Hotspots of prioritized and emerging contaminants in *Sediments*").

One of the most important properties of "emerging contaminants" is that the knowledge and insights regarding these components can change rapidly. This decision tree can therefore be a dynamic tool that will have to be evaluated based on the scientific insights about these components. On the other hand, it is also important that the evaluation is repeated every time an expert encounters emerging contaminant in *Sediment*. Due to an evolution in scientific knowledge, it is very likely that the data used previously is already outdated. The reuse of standards by previous evaluations with the decision tree will possibly lead to an incorrect evaluation

The possibilities of reuse depend on

- **Availability of data**
  (physicochemical, ecotoxicological (plant/cattle) and human toxicological)
  - All data present → more reuse-levels (*Free use*, agricultural, residential, industrial, use as c*onstruction material*) can be calculated → if concentrations lower than specific levels → more reuse possibilities
  - Not all data present/reliable → less reuse levels can be calculated → less reuse possibilities
- The **uncertainties/variability of data**
  - If uncertainty on crucial data is high → less reuse possibilities are allowed
  - Some uncertainties can be overcome with "uncertainty factors"

The cautionary principle and prevention principle form the basis of the decision system. Given the rapidly evolving knowledge on emerging contaminants, it is important to act conservatively. Therefore, this method attempts to translate uncertainties about *Emerging substances* into reuse possibilities. Moreover, the greater the uncertainties in data, the more restrictions are posed on the reuse possibilities of the contaminated *Sediment* in the most sensitive soil types.

At the same time, we must act pragmatically enough to ensure that earthworks can continue. Therefore, this decision system also explores the reuse possibilities of contaminated s*ediment* as a c*onstruction material*.

As a final step in the decision tree, the so-called "common sense test" should always be done by the expert. For example, it must be checked whether the data found in an old publication is still sufficiently reliable. If only 1 value has been found but the reliability of the source is very high, it must be checked based on expert judgment whether the category obtained for reuse is the correct one,…

4.2 TIERED APPROACH

Figure 5 gives the tiered structure of our decision system. In tier 1bis, the contaminated *Sediment* is considered in one of four reuse categories. Tier 2 to 5 correspond with category 1 to 4. The more uncertain the data on the emerging substance are, the higher the category number and the more restricted the reuse possibilities. Tier 1 forms a screening step that allows consultants/experts and decision-makers to skip the decision system and make rapid conclusions for very clean or highly contaminated *Sediment*s. In the following sections, each tier is explained in more detail.

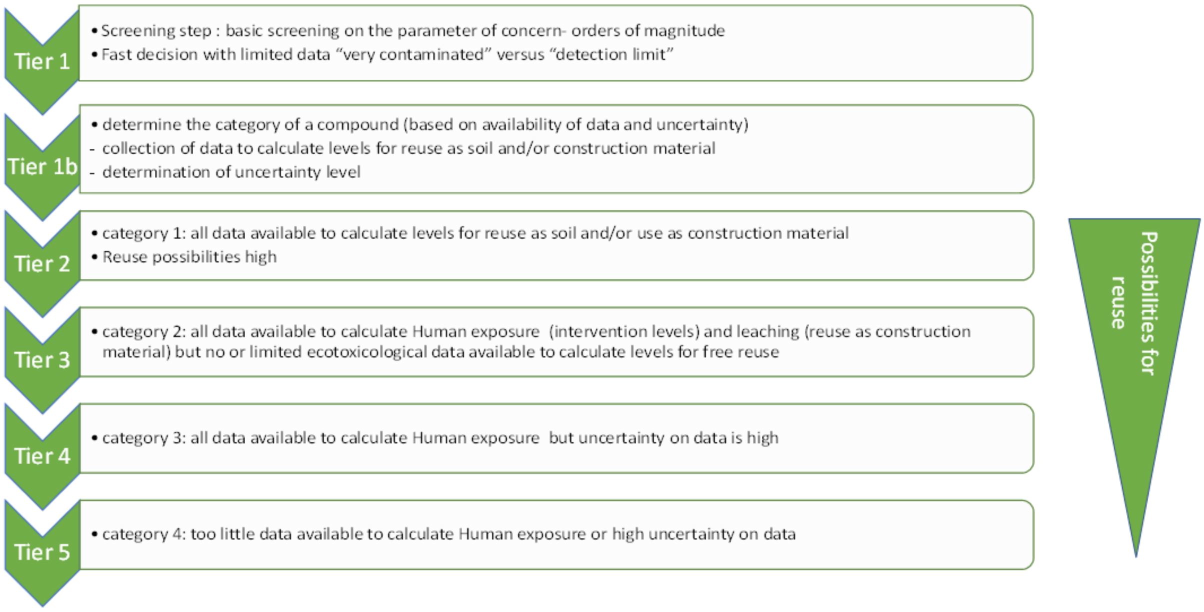

Figure 5: Tiered approach of the decision system

4.3 TIER 1- SCREENING STEP

A basic screening (§4.3.1) is built into this system to help consultants/experts and decision makers to gain insight into the magnitude of contamination and to allow them to make straightforward decisions with only limited screening parameters. Hence, the boundary conditions of these steps are based on conservative assumptions. In this screening step, the consultant/expert is assigned three steps.

1. He must determine the lowest *Detection limit* that can be measured by the laboratories.
2. The *Detection limit* must be compared to international levels to validate the obtained *Detection limit* and to determine the magnitude of *Sediment* contamination (*Ppm* level, *Ppb* level, etc.);

3. The consultant/expert must evaluate the potential presence of *Pure product* by an indicative calculation of the expected soil concentration of the pure substance.

An evaluation of those three steps results in two possible shortcuts:

1. The concentration measured in the contaminated *Sediment*s exceeds the concentration indicating *Pure product* (i.e. concentrations exceeding *Solubility*) (§4.3.1.3 and §4.3.2.1);
2. The measured concentration remains below three times the *Detection limit*. In that case a mandatory leaching test (short term shaking soil-water test) had to be performed and the leaching test should also indicate an eluate with concentrations lower than three times the *Detection limit* (§4.3.3.1).

Note that this tiered decision system is only applicable for *Sediment*s used on land. For *Sediment*s that will be used under water (i.e. in riverbeds, seaports, deep-sea, etc.), a site-specific risk assessment is required.

Figure 6 demonstrates Tier 1. In paragraph §4.3.1 until 4.3.3 the aim, background and implementation/interpretation of each decision step is further explained.

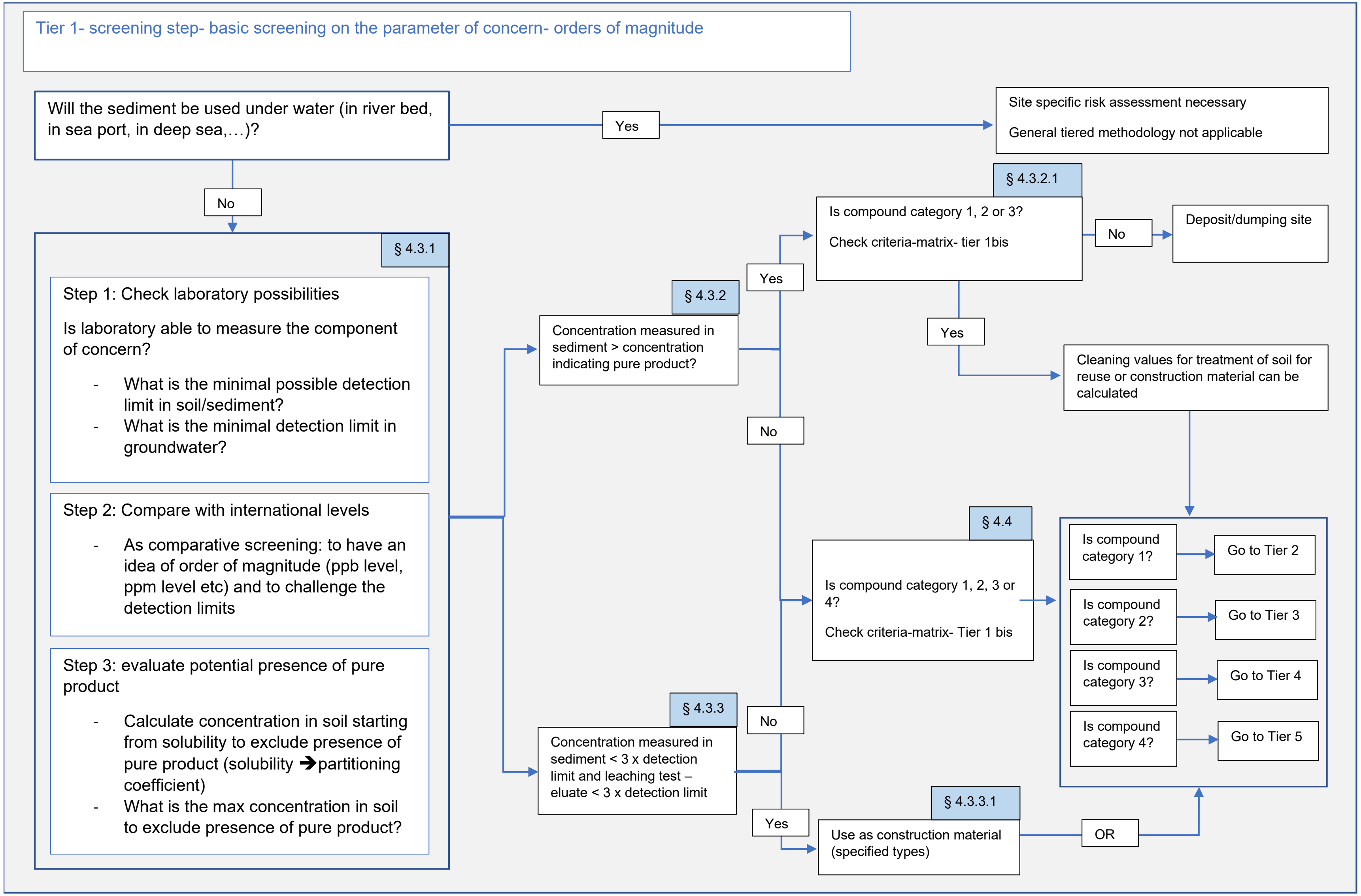

Figure 6: Overview of tier 1. The paragraph numbers indicate the paragraphs that can be consulted for a more detailed explanation of each step.

4.3.1 Collection of limited screening parameters and information on order of magnitude

4.3.1.1 Step 1: Check laboratory possibilities

Aim

This step aims to find answers on the following questions:

- What is the lowest *Detection limit* possible in soil/*Sediment*?
- What is the lowest *Detection limit* possible in groundwater?

Background/challenges

Emerging contaminants are often not standard parameters. Consequently, those components are not typically measured by the laboratories and estimating a feasible *Detection limit* is difficult. The knowledge and expertise of the laboratories on these *Emerging substances* are also evolving fast. On top of this, the lowest *Detection limit* presented by the laboratories should be small enough or, at least, align with the available levels (e.g. international standards, etc.).

Implementation and interpretation

Consultants/experts should consult at least two independent laboratories, specialized in the analysis of a wide range of substances. The price of the analysis should also be requested because lower *Detection limit*s are often associated with higher costs. By consulting two independent laboratories, the *Detection limit*s can be compared, and insight is gained into the feasibility of the laboratories.). If the difference is more than a factor 10, he must ask scientific institutions for the lowest *Detection limit* that can be measured.
If an order of magnitude can be derived from the international evaluation (§4.3.1.2), the consultants/experts can determine a representative *Detection limit* compatible with the international order of magnitude. Subsequently, they can use this information, for example, to opt for analysis with higher *Detection limit*s and often lower cost prices. In case no order of magnitude can be obtained from the international evaluation, the lowest *Detection limit* is retained in this screening step.

4.3.1.2 Step 2: Compare with international levels

Aim

International levels are used as a first indicative and comparative screening to get an idea of the order of magnitude (*Ppb* level, *Ppm* level, etc.) and to challenge the *Detection limit*s reported by the laboratories.

Background/challenges

Only for a few *Emerging substances*, international standards are known and integrated in legislation. The boundary conditions of these international standards differ between countries. Thus, these international standards cannot simply be adopted as such. Therefore, the international levels are only included in the screening step of the decision system.

Implementation and interpretation

The following standards should be verified and, when available, compared in magnitude:

- International standards for emerging contaminants in **soil** and **groundwater**. Standards from the Netherlands can be consulted here. The risk reduction program of US made comprehensive tables available of characteristics and protective levels of a multitude of compounds. This indicative protective concentration levels (of the Texas Risk Reduction Program) can also be consulted in the tables here to get a first insight in the orders of magnitude.

- International levels for emerging contaminants in environmental compartment **drinking water** or **surface water**. These levels give an indication of human toxicology and ecotoxicology, respectively. Therefore, these values also provide insight into the order of magnitude.

4.3.1.3 Step 3: Evaluate potential presence of *Pure product*

Aim
An indication of pure emerging substance (i.e. concentrations exceeding *Solubility*) is not desirable for the reuse of contaminated *Sediment*. Therefore, the potential presence of *Pure product* can be used as a straightforward criterion to determine whether reuse is excluded or not.

Background/challenges
When the concentration of *Emerging substances* in the *Sediment* is too high, reuse of the *Sediment* is excluded and, thus, collecting more information on toxicity is of limited relevance.

Implementation and interpretation
1. The consultants/experts should verify the *Solubility* of the emerging contaminant in at least two reliable databases and select the most conservative (i.e. lowest) *Solubility* among these values. A list of reliable databases is included in Annex 3. In this step, 100% *Solubility* of the emerging substance is used to calculate potential presence of *Pure product* instead of 1-10% (which is the case for other contaminants such as Volatile organic chlorine compounds (VOC) in the Flemish soil legislation) because this is a high level screening step to prevent the reuse of too contaminated *Sediment*s. For *Sediment*s contaminated with substances with concentrations equal to 1% and 10% of the *Solubility*, further evaluation is possible by completing the next tiers, as the reuse of these concentrations in *Sediment*s is not directly excluded (§4.4-4.8).
2. The consultants/experts must calculate the concentration of the contaminant in soil using the *Solubility* and the partitioning coefficient according to the following formula to exclude the presence of the pure substance.

$$C_s = K_d . C_m$$

With:

K_d = partitioning coefficient
C_m = the concentration of the solute in the mobile phase
C_s = concentration of the solute in stationary phase

In this calculation, 2% organic matter should be used as a reference. *Sediment*s typically have higher percentages of organic matter, however, since this is an elimination step and a high-level decision step, we advise to be conservative.
If different solubilities are reported in different sources, it is advised to use the most conservative *Solubility* in this tier 1 screening, i.e. lowest *Solubility* at temperature 10-20°C.

4.3.2 Concentration measured in *Sediment* versus concentration indicating *Pure product*.

The potential presence of *Pure product* can be used as a straightforward criterion to determine whether reuse is excluded. In general, there are two options:

1. Concentration measured in *Sediment* > concentration indicating *Pure product* (§4.3.2.1)
→ treatment necessary before reuse or dumping of *Sediment*

2. Concentration measured in *Sediment* < concentration indication *Pure product* (§4.3.2.2)
   → reuse probably possible
   → the reuse type depends on the level of toxicity and the level of uncertainty.

4.3.2.1 <u>Concentration measured in *Sediment* > concentration indicating *Pure product*</u>

In case the concentration present in the *Sediment*s corresponds with the potential presence of the pure emerging substance, reuse (without treatment) is excluded, and the following two options remain:

1. The contaminated *Sediment* is dumped in a deposit site
2. The contaminated *Sediment* is assigned to one of the reuse categories (cf. tier 1 bis, §4.4) to determine whether cleaning values for treatment can be derived. This option is preferable as *Sediment* can be reused after treatment.

4.3.2.2 <u>Concentration measured in *Sediment* < concentration indicating *Pure product*</u>

In case the concentration present in the *Sediment* is lower than the concentration indicating the presence of pure substance, the contaminated *Sediment* is assigned to one of the four categories in tier 1bis (cf. §4.4) to evaluate the reuse possibilities (without treatment).

4.3.3 Concentration measured in *Sediment* < 3 x *Detection limit* and leaching test – eluate < 3 x *Detection limit*?

<u>Aim/background</u>
This criterion can be applied to quickly select all *Sediment*s with very low or even non-measurable concentrations. Reuse is highly probable for these *Sediment*s. This high-level criterion is a pragmatic approach to prevent costs to perform in-depth desktop study.

4.3.3.1 <u>Concentration measured in *Sediment* < 3 x *Detection limit* and leaching test – eluate < 3 x *Detection limit*</u>

In case both the concentration in the *Sediment* and the eluate of the leaching test stay below three times the *Detection limit*, this straightforward screening tier 1 shortcut can be applied, and the consultant/expert can directly decide to use the *Sediment* as a *Construction material*. In this case, little/no desk study is performed on toxicity level, and taking into account the uncertainties for analysis (expertise of the laboratories on these *Emerging substances* are also evolving), not all types of *Construction material*s are allowed (from precautionary principle) in this tier 1 step.

A list of all possible types of *Construction material*s is included in Annex 4. In Flemish legislation soil materials can be reused as raw material for construction purposes if the construction is included in this list.

Table 3 gives an overview of applications in which soil materials can be reused (based on the high-level screening in tier 1) in accordance with the Flemish legislation.

Construction material	Definition
Paved roads and paths	The use of excavated soil in the foundation as long as the layer of excavated soil has a maximum thickness of 60 centimetres, unless a different thickness is specified in the general specifications, the special specifications or in the design of the paved road or the path for technical construction purposes. The use of excavated soil underneath paved roads and paths in a shoulder, abutment or raised slope structure

Shoulders, abutments and raised slopes	The use of excavated soil from the top of the foundation of the embankment to the surface covering, on condition that the excavated soil that is used in the shoulder, the abutment or the slope structure is covered by one or more of the following elements: • a durable hardened layer or covering layer; • a stable construction; an erosion-resistant protection layer of at least 50 cm thick in which the soil meets the conditions for using excavated soil as the base;
Noise barriers	The use of excavated soil from a depth of 30 cm below the ground level to the covering, on condition that the excavated soil that is used in the noise barrier is covered by one or more of the following elements: • a durable hardened layer or covering layer; • a stable construction; • an erosion-resistant protection layer of at least 50 cm thick in which the soil meets the conditions for using excavated soil as the base
Driveways, car parks or floor plates	The use of excavated soil in the foundation as long as the layer of excavated soil has a maximum thickness of 60 centimetres, unless a different thickness is specified in the general specifications, the special specifications or in the design for technical construction purposes;
Abutments and retaining walls	The use of excavated soil in the anchoring structure of the construction.
Applications of excavated soil in dimensionally stable products	1° concrete products; 2° cement products; 3° ceramic products

Table 3: List of acceptable Construction materials (and their definition) for substances that occur in very low concentrations and do not leach according to the high-level screening step in tier 1.

When reuse as soil is considered or other types of *Construction material* are demanded, the consultant/expert has to perform an in-depth desktop study to determine the category of the contaminated *Sediment* in tier 1bis to examine all reuse possibilities of the contaminated *Sediment*.

4.3.3.2 Concentration measured in *Sediment* > 3 x *Detection limit* and/or leaching test – eluate > 3 x *Detection limit*

In case the concentration in the *Sediment* and /or in the eluate of the leaching test exceed three times the *Detection limit*, no straightforward selection for reuse is possible. The consultant/expert must continue to tier 1bis of the decision-system to assign the emerging substance to the right category (§4.4).

4.4 TIER 1BIS: DETERMINATION OF THE CATEGORY OF A COMPOUND

Tier1bis includes the **collection of data** to calculate levels for reuse as soil and/or as *Construction material* and the determination of **uncertainty** on these data. The aim of tier 1bis is to assign the contaminated *Sediment* to one of the following categories based on the available information on the emerging substance:

Category 1: all data to calculate levels for reuse as soil and/or use as *Construction material* are available.
Category 2: all data available to calculate human exposure (intervention levels) and leaching (reuse as *Construction material*) are available, but there are no or limited ecotoxicological data available to calculate levels for free reuse.
Category 3: all data to calculate human exposure are available, but the uncertainty on these data is high.
Category 4: there is too little data available to calculate human exposure or the uncertainty on these data is high.

Table 4 presents an overview of the level of (un)certainty in data per category and the different characteristics per aspect (physicochemical data, human toxicological data and ecotoxicological data). The relevance of each of the characteristics is related to the models used to calculate the reuse levels (for Flanders *S-Risk* and *F-leach*; cf. 'Basisinformatie voor risico-evaluatie: werkwijze voor het opstellen van bodemsaneringsnormen en toetsingswaarden, richtwaarden en streefwaarden' and '*F-LEACH* 3.0: handleiding bij de software –update 2015'). The level of (un)certainty is presented by means of a specific coding. It is important to note that the meaning of each code can differ slightly depending on the aspect it is used for (physicochemical data, human toxicological data and ecotoxicological data). To avoid misinterpretation, the meaning of each code is presented below.

For **physicochemical** characteristics: X = value published in at least two reliable databases and the variability between the databases is:
low (< factor 10);
(X) = value published in at least two reliable databases and the variability between the databases is high (> factor 10) or
= value is published in only one reliable database;
0 = no data available.

For **human toxicological** data:
X = value published in at least two reliable databases;
(X) = value is published in only one reliable database;
0 = no data available.

For the human toxicological data, the variability between the databases is not considered because the most conservative value is preserved in case of deviating values.

For **ecotoxicological** data:
X = value published in at least two reliable databases and the variability within and between the databases are low (< factor 10);
(X) = value published in at least two reliable databases and the variability within and between the databases are high (> factor 10) or
= value is published in only one reliable database;
0 = no data available.

For ecotoxicological data the variability within a database is also considered in addition to the variability between databases because the reliable databases often provide ranges for ecotoxicological data.

More detailed information is given in paragraphs §4.4.1 to 4.4.3.
Table 4 gives the required physicochemical and toxicological characteristics.

X indicates data with high certainty;
(X) indicates data with high uncertainty;
0 indicates missing data.

The exact meaning of the code depends on the aspect it is used for (physicochemical data, human toxicological data and ecotoxicological data) cf. paragraph 4.4.

Characteristic	**Type**	**Category 1**	**Category 2**	**Category 3**	**Category 4**
Human exposure					
Physicochemical data					
Solubility (S)	PHYS	X	X	X or (X)	X or (X)
Vapor pressure (D)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)
Human toxicity data					
Carcinogenicity	HUMAN	X	X	(X) or in-depth study	0
Tolerable Daily Intake or reference Dose (for carcinogenic or non-carcinogenic compounds)	HUMAN	X	X	(X) or in-depth study	0
Tolerable Level in air	HUMAN	X or not relevant (*)	X or not relevant (*)	(X) or not relevant (*)	0
Drinking water level	HUMAN	X	(X) or 0	(X) or 0	0
Level in vegetables	HUMAN	X	(X) or 0	(X) or 0	0
Level in meat/milk	HUMAN	X	(X) or 0	(X) or 0	0
Ecotoxicological levels					
Toxicity data					
Levels for cattle and plants	ECO	X	(X) or 0	(X) or 0	0
Bioconcentration factor	ECO	X	(X) or 0	(X) or 0	0
Leaching					
Physicochemical data					
Solubility (S)	PHYS	X	X	X or (X)	X or (X)
Octanol/water partition	PHYS	X	X	X or (X)	X or (X)

coefficient (Kow)					
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)
Toxicity data					
Tolerable Daily Intake	HUMAN	X	X	(X) or in-depth study	0

Table 4 Required physicochemical and toxicological characteristics.

(*) The *Vapor pressure* (D), *Henry-coefficient* (H) and Tolerable Level in air are only relevant for volatile compounds. A chemical generally is considered volatile if its molecular weight is less than 200 grams per mole (g/mol), *Vapor pressure* is greater than 1 millimetre of mercury (mm Hg), or Henry's law constant (ratio of a chemical's *Vapor pressure* in air to *Solubility* in water) is greater than 10-5 atmosphere-meter cubed per mole (atm m^3 mol^{-1}), though some chemicals that exhibit properties outside of these general guidelines may also be classified as volatile (EPA, Vapour intrusion, 2012). If the molecular weight is greater than 200 grams/mole (g/mol), the *Vapor pressure* is less than 1 millimetre of mercury (mm Hg) and/or Henry's law constant is less than 10-5 atmosphere-meter cubed per mole (atm m^3 mol^{-1}), the chemical is considered not volatile and these characteristics (indicated with an asterisk) do not play a role in the categorization of the substance. This also applies when the *Vapor pressure* and/or *Henry-coefficient* are only present in one of the reliable databases. In this case, the characteristic is labelled "not relevant".

Figure 7 demonstrates the decision tree to define the compound category.

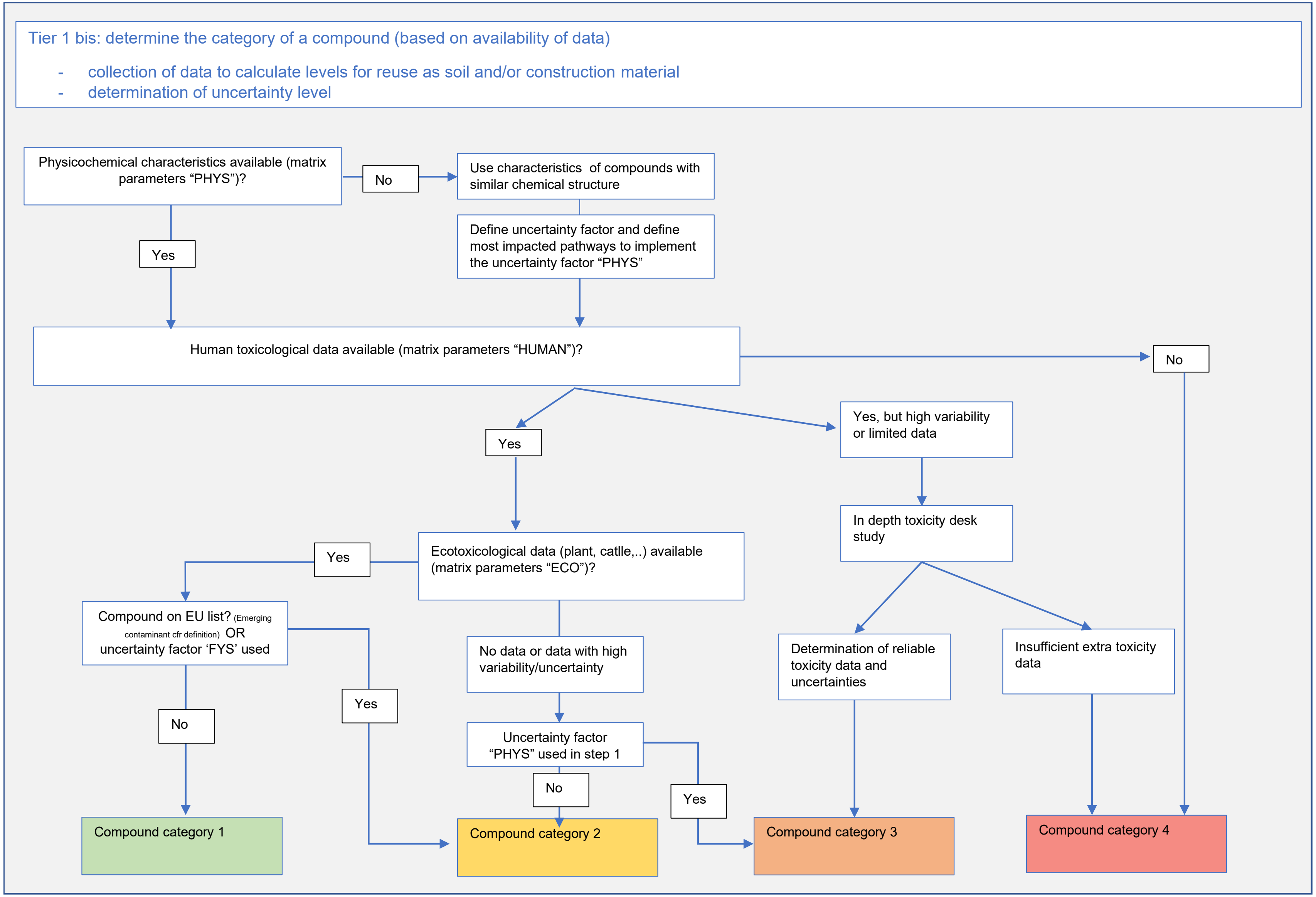

Figure 7: Tier 1bis of the decision tree. The purpose of this tier is to define the compound category .

4.4.1 Physicochemical characteristics

To assign the contaminant to its appropriate category, the consultant/expert must obtain the required physicochemical properties (cf. table 4 and table 5) from a reliable database. A list of reliable databases is included in Annex 3. From the collected physicochemical data, the consultant/expert must preserve the most conservative value.

Most physicochemical properties of a compound are expected to be readily available. In case some characteristics are missing/the variability in these characteristics is too high (more than factor 10), uncertainty factors must be determined. Also, the most impacted pathway should be identified to implement this uncertainty factor. This pathway is linked to the reuse possibilities. An initial uncertainty factor of 10 is proposed in combination with limited use of the contaminated *Sediment* (i.e. reuse as soil industrial areas and use as a *Construction material*). Subsequently, consultants/experts and decision-makers can choose to perform an in-depth study to determine a components specific uncertainty factor which will probably result in more reuse possibilities. When uncertainty factors are used for physicochemical properties, the substance cannot be classified into category 1 and 2. Hence, *Free use* and application within agricultural, residential, or recreational areas are prohibited.

	Physicochemical characteristics	Interpretation and implementation	Most Impacted pathways – mitigation of uncertainty
	CAS number	Important for general identification	-
	Other names	Important for general identification	-
	Formula	Important for general identification	-
	Molar mass	Important for general identification Used for calculation of diffusion coefficient	-
PHYS	*Solubility* (S)	Parameter used to define partitioning between soil media in *S-Risk* and *F-leach*.	Soil-groundwater leaching If *Solubility* is uncertain, one should be careful of leaching effects of reused *Sediment*. Therefore, an extra uncertainty factor of 10 (*) should be used and a leaching test is mandatory to exclude any leaching risks.
PHYS	Vapour pressure (D)	Parameter important to calculate vapour intrusion and, therefore, essential to calculate reuse levels in residential, recreational, or industrial areas. If *Vapor pressure* is below 1 mmHg (**) the compound is considered limited volatile. Exposure via volatilization will, therefore, be limited. The highest value presented in the databases should be selected to act conservatively.	Soil-vapour-inhalation pathway If the vapour pressure is uncertain, an extra uncertainty factor of 10 (*) should be used and the compound cannot be classified into categories 1 and 2, and can, therefore, only used in industrial areas or as *Construction material* from a precautionary point of view. If the chemical is considered non-volatile (**), the *Vapor pressure* (D) does not play a role in the categorization.
PHYS	Octanol-water coefficient (Kow)	Parameter used to define partitioning between soil media in *S-Risk* and *F-leach* If log K_{ow} is higher than 3, the compound will adsorb well to the soil matrix. Thus, leaching will be limited. This value is also important to evaluate and calculate potential plant uptake. The lowest log K_{ow} value should be selected to act conservatively.	Soil-groundwater leaching If the log K_{ow} is uncertain, one should be careful of leaching effects of reused *Sediment*. Therefore, an extra uncertainty factor of 10 (*) should be used and a leaching test is mandatory to exclude any leaching risks. Soil-plant uptake If the variability is too high, the impacted pathway “plant uptake” had a high uncertainty and therefore reuse in residential or agricultural use should be excluded.

	Physicochemical characteristics	Interpretation and implementation	Most Impacted pathways – mitigation of uncertainty
PHYS	*Henry-coefficient* (H)	Parameter important to calculate vapour intrusion and, therefore, crucial to calculate reuse levels in residential, recreational, or industrial areas. If the *Henry-coefficient* is not available, it can be deducted from the vapour pressure value via the *Solubility* and the vapour pressure. The highest value should be selected to act conservatively.	Soil-vapour-inhalation pathway. If the *Henry-coefficient* is uncertain, an extra uncertainty factor of 10 (*) should be used and the compound cannot be classified into categories 1 and 2, and can, therefore, only used in industrial areas or as *Construction material* from a precautionary point of view. If the chemical is considered non-volatile (**), *Henry-coefficient* (H) does not play a role in the categorization.
PHYS (***)	Diffusion coefficient in air and water (***)	Parameter important to calculate vapour intrusion and, therefore, important to calculate reuse levels in residential, recreational, or industrial areas. This value is often not present, the diffusion coefficients in air and water can be calculated from the molar mass, the diffusion coefficient in water is a factor 10000 lower than the diffusion coefficient in air (cf. Basisinformatie risico-evaluaties, deel 3). $D_a = 0.036 * \sqrt{76/M}$ $D_w = 3.6 * \sqrt{76/M}$	Soil-vapour-inhalation pathway. Diffusion coefficient can be calculated from molar Mass. This value is always indicative and based on theoretical calculations. If the chemical is considered non-volatile (**), diffusion coefficient does not play a role in the categorization.

Table 5: overview of relevant physicochemical characteristics, implementation, and impacted pathways.

(*) An indicative uncertainty factor of 10 is proposed. However, it is recommended to do more in depth study to define a component specific uncertainty factor This in dept study will probably result in more reuse possibilities.

(**) A chemical generally is considered volatile if its molecular weight is less than 200 grams per mole (g/mol), *Vapor pressure* is greater than 1 millimetre of mercury (mm Hg), or Henry's law constant (ratio of a chemical's *Vapor pressure* in air to *Solubility* in water) is greater than 10-5 atmosphere-meter cubed per mole (atm m^3 mol^{-1}), though some chemicals that exhibit properties outside of these general guidelines may also be classified as volatile (EPA, Vapour intrusion, 2012).

(***) This parameter is not included in table 4 as it is advised to use a theoretical calculation based on Molar Mass. Molar Mass is available for all compounds.

In case a physicochemical characteristic cannot be found in the listed databases, characteristics of compounds with similar chemical structures can be used. E.g. same group of compounds (chloropesticides, specific dioxins, …), linear or non-linear structure, etc.

Working in usage categories (main groups and subgroups) such as biocides, flame retardants, fluorinated compounds (PFAS), pesticides, personal care products, etc. is suggested. Every category has "in average" similar characteristics. If group parameters are used, these compounds will automatically end in category 3 or 4 and restrictions for Reuse of Sediment on land will be limited due to the variability of the inherent different compounds within a group.

4.4.2 Human toxicity data

To assign the contaminant to its appropriate category, the consultant/expert must, in a second step, obtain the required human toxicological properties (cf. table 4 and table 6) from a reliable database. A list of reliable databases is included in Annex 3.

If the data are lacking or variability of several orders of magnitude is registered, it is mandatory to perform an in-depth toxicity study. Subsequently, the consultant/expert can determine reliable toxicity data and uncertainty factors, or he can decide there are insufficient toxicity data available. In this case, the substance can only be classified into categories 3 and 4. Due to the uncertainty of the data, it is impossible to assign these compounds into categories 1 or 2. This means that contaminated *Sediment* contaminated can only be applied in recreational, industrial areas or as a *Construction material*. The *Sediment* cannot be used in agricultural or residential areas.

	Human Toxicological data	Interpretation and implementation	Most Impacted pathways – mitigation of uncertainty
HUMAN	Carcinogenicity	Whether a compound is Carcinogenic or not is important to derive acceptable levels. In Flanders 1 additional cancer per 100 000 individuals for life exposure to soil pollution is used.	Consumption of drinking water Soil-plant uptake and consumption Soil-milk/meat uptake and consumption If there is an uncertainty as to whether a component is carcinogenic, worst case should always be considered
HUMAN	*Tolerable Daily Intake* or Reference Dose (TDI)	This value is used to assess the calculated exposure (via *S-Risk*) and to calculate the soil remediation standard for groundwater (cf. Basic information for risk evaluation). This groundwater standard is essential to determine the leaching of the *Emerging substances*.	Consumption of drinking water Soil-plant uptake and consumption Soil-milk/meat uptake and consumption In case of deviating values, the lowest TDI value should always be considered
HUMAN	Tolerable Level in air (TCL)	This value is used to indicate what the maximum concentration of a certain component in the air may be without causing damage to an individual.	Soil-vapour-inhalation pathway In case of deviating values, the lowest TCL value always be considered.

		This value is only relevant for volatile compounds (**)	If the chemical is considered non-volatile (**), the Tolerable Level in air does not play a role in the categorization.
HUMAN	Drinking water level	This value is used to indicate what the maximum concentration of a certain component in drinking water may be without causing damage to an individual	Consumption of drinking water In case of deviating values, the lowest drinking water level value should always be considered
HUMAN	Level in vegetables	This value is used to indicate what the maximum concentration of a certain component in vegetables may be without causing damage to an individual	Soil-plant uptake and consumption In case of deviating values, the lowest value should always be considered
HUMAN	Level in meat/milk	This value is used to indicate what the maximum concentration of a certain component in meat/milk may be without causing damage to an individual	Soil-milk/meat uptake and consumption In case of deviating values, the lowest value should always be considered

Table 6: overview of relevant human toxicological characteristics, implementation, and impacted pathways

(**) A chemical generally is considered volatile if its molecular weight is less than 200 grams per mole (g/mol), *Vapor pressure* is greater than 1 millimetre of mercury (mm Hg), or Henry's law constant (ratio of a chemical's *Vapor pressure* in air to *Solubility* in water) is greater than 10-5 atmosphere-meter cubed per mole (atm m^3 mol^{-1}), though some chemicals that exhibit properties outside of these general guidelines may also be classified as volatile (EPA, Vapour intrusion, 2012).

4.4.3 Ecotoxicological data

To assign the contaminant to its appropriate category, the consultant/expert must, in a second step, also obtain the required ecotoxicological properties (cf. table 4 and table 7) from a reliable database. A list of reliable databases is included in Annex3.

	Ecotoxicological levels	Interpretation and implementation	Most Impacted pathways – mitigation of uncertainty
ECO	Toxicity levels for cattle and plants	This value represents the toxicity of a component for animals and plants	Soil-plant uptake and consumption Soil-milk/meat uptake and consumption In case of deviating values, the lowest value should always be considered. If not available, ecotoxicity studies can be performed.
ECO	Bioconcentration factor	The bioconcentration factor (BCF) of a chemical is a measure of the ability of this	Soil-plant uptake and consumption

		substance to accumulate in the body of organisms from the environment (bioaccumulation of bioconcentration).	Soil-milk/meat uptake and consumption In case of deviating values, the compound is automatically excluded from category 1.

Table 7: overview of relevant ecotoxicological characteristics, implementation, and impacted pathways.

4.4.4 Compound on EU list

At last, a final check is incorporated in tier 1bis to ensure the substances are assigned to their appropriate category. This check probes for the presence of the emerging contaminant on the EU list (Annex 5). If so, the substance cannot belong to category 1, given that *Free use* is not permitted for *Sediment*s contaminated with substances present on this list. In this case, contaminants that were originally assigned to category 1, now belong to category 2.

4.4.5 Groups of compounds

The physicochemical and toxicological data should be investigated for each compound separately (as described in §4.4.1 to 4.4.3.). When values for certain characteristics are lacking, those of similar compounds belonging to the same group can potentially be used. This is possible for substances for whom guide parameters are presented in one of the reliable databases included in Annex 3 (e.g. octabromodiphenyl ether is presented as a guide parameter for decabromodiphenyl ether in the European Chemicals Agency (ECHA) database). In that case, the values presented for this guide parameters can be used, provided that the uncertainty factors are determined, and the most impacted pathways are identified.

Working in usage categories (main groups and subgroups) such as biocides, flame retardants, fluorinated compounds (*PFAS*), pesticides, personal care products, etc. is also suggested. Every category has "in average" similar characteristics. If group parameters are used, these compounds will automatically end in category 3 or 4 and restrictions for *Reuse of Sediment* on land will be limited due to the variability of the inherent different compounds within a group.

4.5 TIER 2: COMPOUND CATEGORY 1

Category 1: all data are available to calculate levels for reuse as soil and/or use as construction material.

For contaminants assigned to category 1, all human toxicological data (indicated with 'HUMAN in table 4 and table 6) and ecotoxicological data (indicated with 'ECO in table 4 and table 7) are published in reliable databases (Annex 3). This means that all required data to calculate levels for reuse as soil and/or as a *Construction material* are present.

Figure 8 shows the decision tree for *Reuse of Sediment* of a compound category 1.

To determine the final reuse application of the contaminated *Sediment*, a step-by-step approach is lined out for compounds assigned to category 1. In some cases, it is already decided how the *Sediment* will be preferably reused. Hence, the expert can start at different steps:

1. Calculate ***Free use*** and/or
2. Calculate levels for reuse as **soil** (agricultural use, residential use, recreational use, and industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as *Construction material*

After every step, the consultant/expert can decide to clean the contaminated and, thus, stop running through the decision system.

Step 1- calculate *Free use*

In the first step, consultants/experts must calculate the concentration for *Free use* applying models designed to this purpose (for Flanders *F-leach* and *S-Risk*). This is only possible when an acceptable groundwater threshold is determined based on the TDI (*Tolerable Daily Intake*). This calculated value must compile with three conditions. First, care must be taken that no leaching occurs at this concentration. Second, the concentration should lie between 60% and 80% of the intervention value for agricultural use containing 1% organic matter. Third, the concentration cannot exceed the *Target value*. In case this *Target value* is lacking, the maximum concentration is defined as three times the *Detection limit*. For *Free use* of the contaminated *Sediment*, the measured concentration needs to be lower than the calculated value for *Free use*. In case the measured concentration exceeds the calculated value for *Free use*, the *Sediment* is too contaminated for *Free use* and the expert must go to step 2.

Step 2 – calculate levels for *Reuse of Sediment* as soil

In the second step, consultants/experts can calculate the levels for agricultural, residential, recreational, and industrial use to examine whether the contaminated *Sediment* can be applied within these soil usage types. These levels can be calculated using an exposure model (for Flanders *S-Risk*). For *Sediment*s with concentrations below the calculated value, reuse is possible within the specific soil usage type (e.g. residential soil use) provided the receiving soil is equally or less contaminated and there are no additional risks linked to the application of the contaminated *Sediment*. In case the measured concentration exceeds the calculated values for all four soil usage types, the *Sediment* is too contaminated, and the expert must go to step 3.

Step 3 – calculate levels for use as a *Construction material*

In the third and last step of tier 2, consultants/experts can calculate the concentration for *Reuse of Sediment* as a *Construction material* using specific software (for Flanders *F-leach*). When the measured concentration in the *Sediment* is lower than this calculated value, the *Sediment* can be used as a *Construction material* without any restrictions on the application site, meaning it can be applied both above and below the groundwater level. For *Sediment*s with concentrations exceeding the calculated value, reuse as a *Construction material* is prohibited. These *Sediment*s must be treated or deposited.

A list of possible types of *Construction material*s is included in Annex 4.

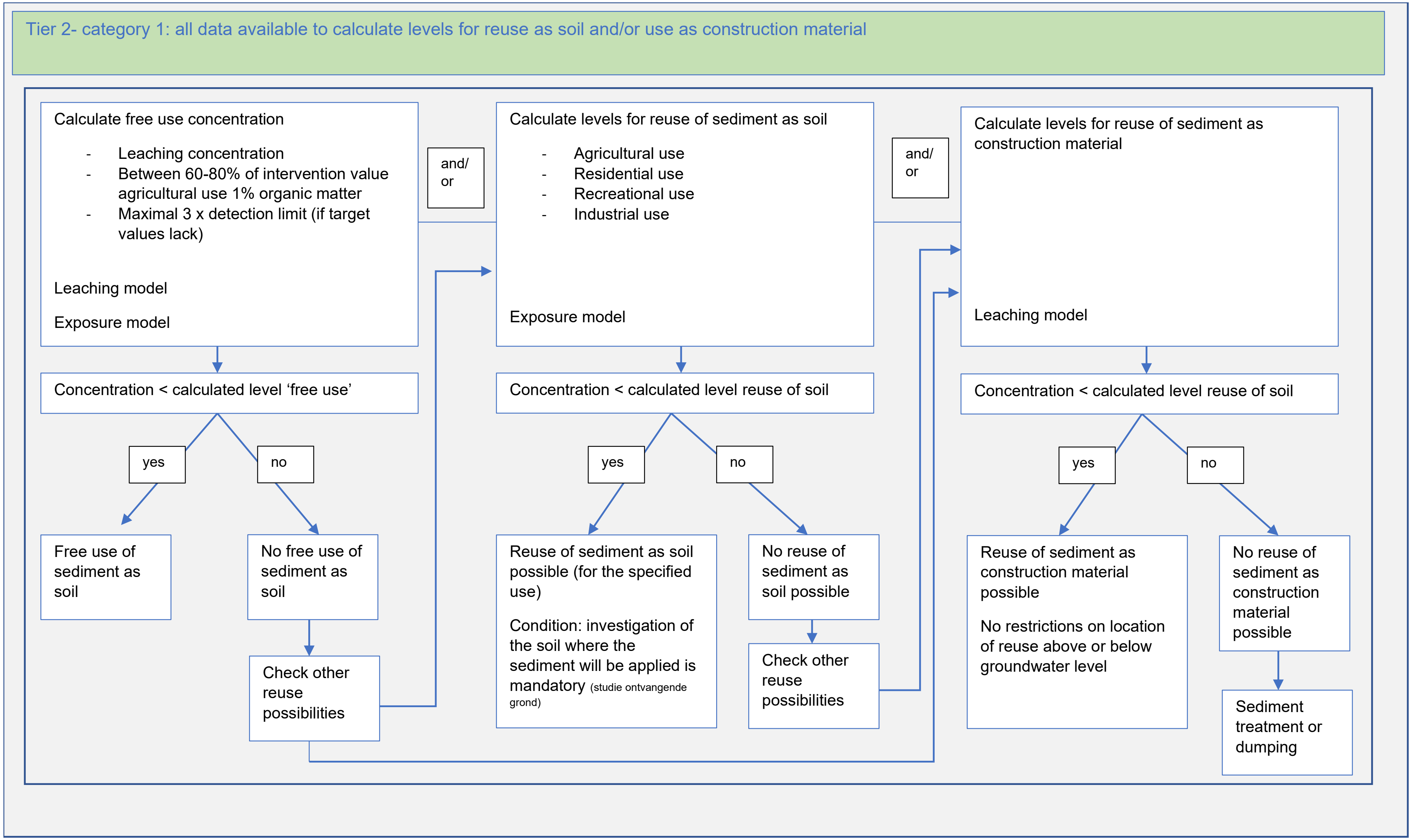

Figure 8: Decision tree for the reuse of Sediments contaminated with category 1 compounds

4.6 TIER 3: COMPOUND CATEGORY 2

Category 2: all data are available to calculate levels for recreational and industrial soil use and/or use as construction material.

Contaminants are assigned to category 2 when all human toxicological data are presented in a reliable database (Annex 3), except for the levels in vegetables and the levels in meat or milk (indicated with 'HUMAN' in table 4 and table 6), but the ecotoxicological data are highly uncertain or even lacking (indicated with 'ECO in table 4 and table 7). For category 2 substances, all data required to calculate human exposure for recreational or industrial use as well as the data to calculate leaching for reuse as a *construction material* are available.

The approach for category 2 compounds is highly like that for category 1 substances (§4.5). The final reuse application of the contaminated *Sediment* can be determined in a step-by-step approach and the consultants/experts can start at different steps. However, due to the uncertainty in ecotoxicological data, the procedure for category 2 compounds differs from the approach for category 1 substances in the following aspects:

- Fewer reuse possibilities in step 2: the contaminants assigned to category 2 lack ecotoxicological data, or the uncertainties in these data are high. Therefore, *Sediment*s contaminated with these compounds cannot be used within the agricultural or residential soil usage types.
- No *Free use* possible: as category 2 compounds cannot be applied in agricultural and residential areas, *Free use* of the contaminated *Sediment* is excluded as well. For the step-by-step approach described in the previous section, this means that consultants/experts must pass the first step (i.e. calculation of *Free use* concentration) and start with 2 or 3.

2. Calculate levels for reuse as soil (recreational use and industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as *Construction material*

After every step, the consultant/expert can decide to clean the contaminated *Sediment* and, thus, stop running through the decision system.

Step 2 – calculate levels for *Reuse of Sediment* as soil within recreational and industrial areas
In the second step, consultants/experts can calculate the levels for recreational, and industrial use to examine whether the contaminated *Sediment* can be applied within these soil usage types. These levels can be calculated using an exposure model (for Flanders *S-Risk*). For *Sediment*s with concentrations below the calculated value, reuse is possible within the specific soil usage type (e.g. recreational soil use) provided the receiving soil is equally or less contaminated and there are no additional risks linked to the application of the contaminated *Sediment*. In case the measured concentration exceeds the calculated values for both soil usage types, the *Sediment* is too contaminated, and the expert must go to step 3.

Step 3 – calculate levels for use as a *Construction material*
In this step, consultants/experts can calculate the concentration for *Reuse of Sediment* as a *Construction material* using specific software (for Flanders *F-leach*). When the measured concentration in the *Sediment* is lower than this calculated value, the *Sediment* can be used as a *Construction material* without any restrictions on the application site, meaning it can be applied both above and below the groundwater level. For *Sediment*s

with concentrations exceeding the calculated value, reuse as a *Construction material* is prohibited. These *Sediment*s must be treated or deposited.

A list of possible types of *Construction material*s is included in Annex 4.

Figure 9 shows the decision tree for the reuse of *Sediment*s contaminated with category 2 compounds.

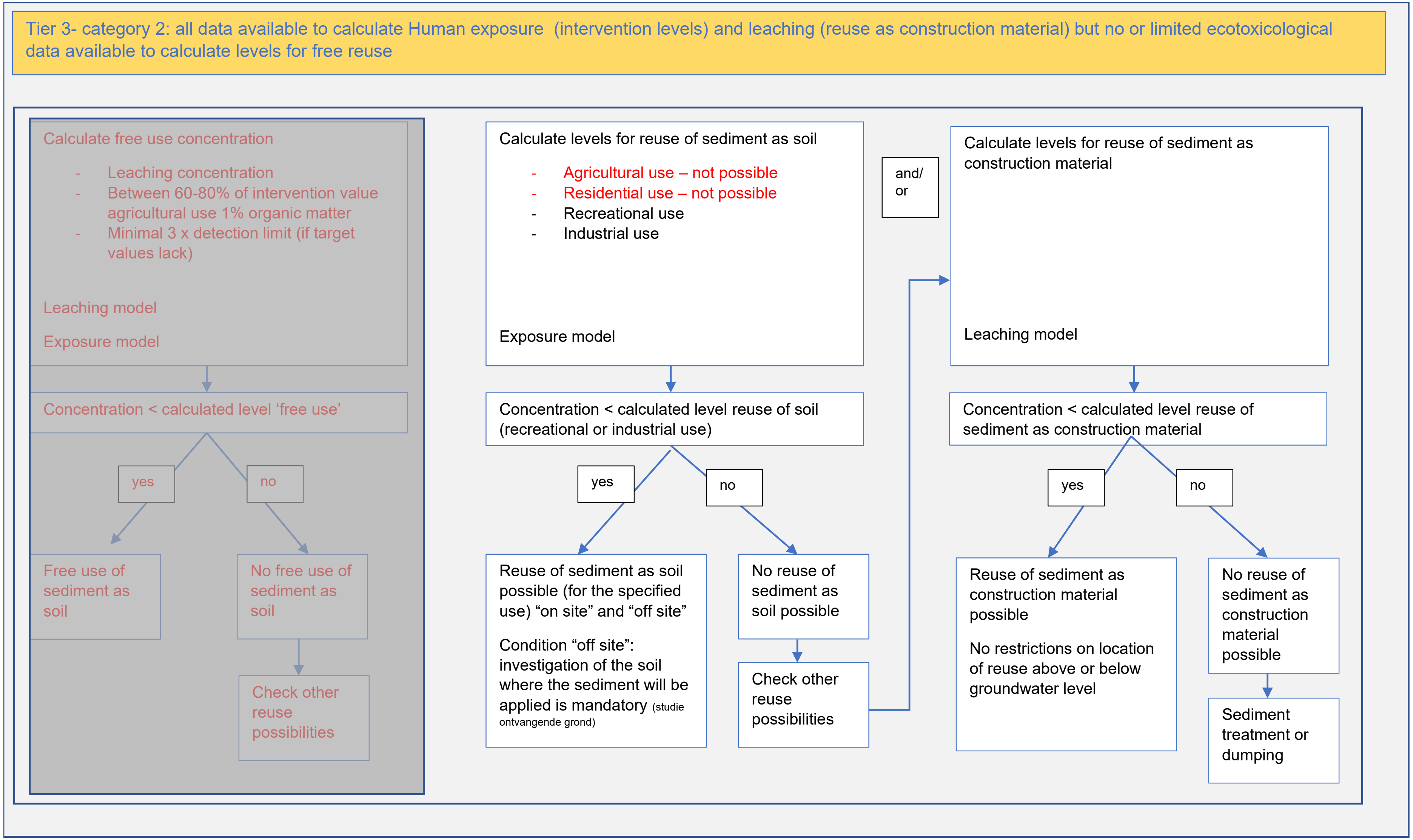

Figure 9: Decision tree for the reuse of Sediments contaminated with category 2 compounds. Free use and application within agricultural and residential areas are prohibited

4.7 TIER 4: COMPOUND CATEGORY 3

Category 3: all data are available to calculate levels for industrial soil use and/or use as construction material.

Category 3 compounds are characterized by their variability and lack of human and ecotoxicological data. Substances are assigned to category 3 when the uncertainties in the human toxicological data are high, even after an in-depth toxicological desk study is performed.

The approach for category 3 compounds is highly like that for category 1 substances (§4.5). The final reuse application of the contaminated *Sediment* can be determined in a step-by-step approach and the consultants/experts can start at different steps. However, due to the great uncertainty in data, the following restrictions are imposed:

For reuse as soil:
- The contaminated *Sediment* can only be applied in industrial areas;
- The reuse of contaminated *Sediment*s within groundwater extraction areas is prohibited.

For use as a *Construction material*:
- Leaching tests are mandatory
- The application possibilities below groundwater level are limited.

For the step-by-step approach, this means that consultants/experts must pass the first step (i.e. calculation of *Free use* concentration) and start with 2 or 3. In addition, the reuse possibilities within step 2 and 3 are more restricted:

2. Calculate levels for reuse as **soil** (industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as ***Construction material***

After every step, the consultant/expert can decide to clean the contaminated and, thus, stop running through the decision system.

Step 2 – calculate levels for *Reuse of Sediment* as soil
In the second step, consultants/experts can calculate the level for industrial use to examine whether the contaminated *Sediment* can be applied within this soil usage type. This level can be calculated using an exposure model (for Flanders *S-Risk*). For *Sediment*s with concentrations below the calculated value, reuse within industrial areas is possible, provided the receiving soil is equally or less contaminated and there are no additional risks linked to the application of the contaminated *Sediment*. In case the measured concentration exceeds the calculated value for industrial use, the *Sediment* is too contaminated, and the expert must go to step 3.

Step 3 – calculate levels for use as a *Construction material*
In this step, consultants/experts can calculate the concentration for *Reuse of Sediment* as a *Construction material* using specific software (for Flanders *F-leach*). When the measured concentration in the *Sediment* is lower than this calculated value, the *Sediment* can be used as a *Construction material*. However, due to the great uncertainty in data, the application possibilities below groundwater level are not allowed. Table 8 presents all types of *Construction material*s permitted for category 3 compounds. For *Sediment*s with concentrations exceeding the calculated value, reuse as a *Construction material* is prohibited. These *Sediment*s must be treated or deposited.

Construction material	Definition
Paved roads and paths	The use of soil and sediment in the foundation as long as the layer of soil has a maximum thickness of 60 centimetres, unless a different thickness is specified in the general specifications, the special specifications or in the design of the paved road or the path for technical construction purposes. The use of soil and sediment underneath paved roads and paths in a shoulder, abutment or raised slope structure
Shoulders, abutments and raised slopes	The use of soil and sediment from the top of the foundation of the embankment to the surface covering, on condition that the excavated soil that is used in the shoulder, the abutment or the slope structure is covered by one or more of the following elements: • a durable hardened layer or covering layer; • a stable construction; • an erosion-resistant protection layer at least 50 cm thick in which the soil meets the conditions for using excavated soil as the base;
Noise barriers	The use of soil and sediment from a depth of 30 cm below the ground level to the covering, on condition that the soil that is used in the noise barrier is covered by one or more of the following elements: • a durable hardened layer or covering layer; • a stable construction; • an erosion-resistant protection layer at least 50 cm thick in which the soil meets the conditions for using soil and sediment as the base
Driveways, car parks or floor plates	The use of soil and sediment in the foundation as long as the layer of excavated soil has a maximum thickness of 60 centimetres, unless a different thickness is specified in the general specifications, the special specifications or in the design for technical construction purposes;

Table 8: List of applications for the use of soil and sediment in constructions

Figure 10 shows the decision tree for *Reuse of Sediment* contaminated with category 3 compounds.

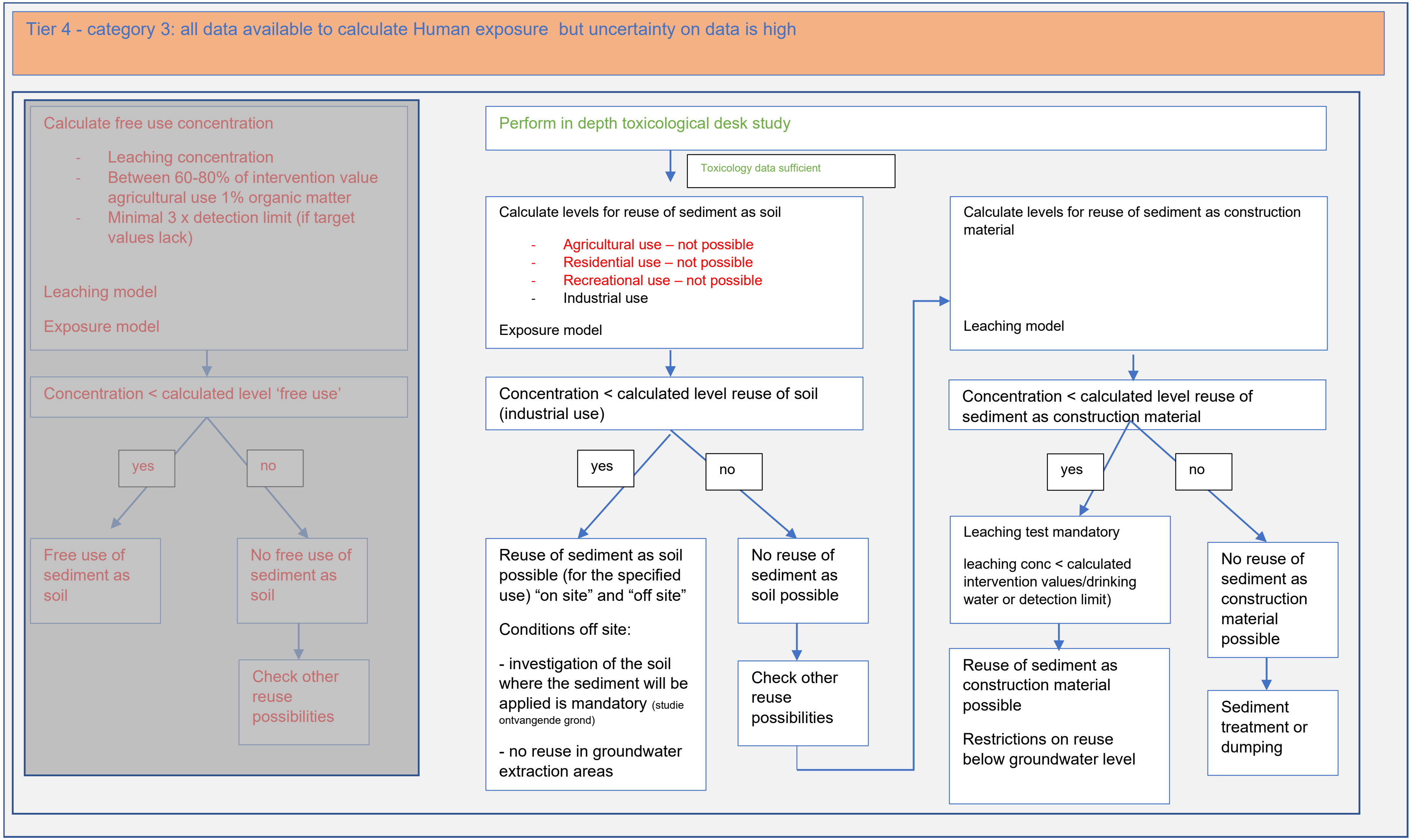

Figure 10: decision tree for Reuse of Sediment of a compound category 3.Free use and application within agricultural, residential, and recreational areas are prohibited.

4.8 TIER 5: COMPOUND CATEGORY 4

Category 4: no toxicity data available to calculate levels for soil use and/or use as construction material.

For compounds assigned to category 4, there are no toxicity data available. Consequently, these *Sediment*s cannot be used as *Construction material* nor can they be treated for soil reuse as it is impossible to calculate a treatment value with so little data. The only outcome for these *Sediment*s is for them to be deposited.

Figure 11 shows the decision tree for *Reuse of Sediment* of a compound category 4.

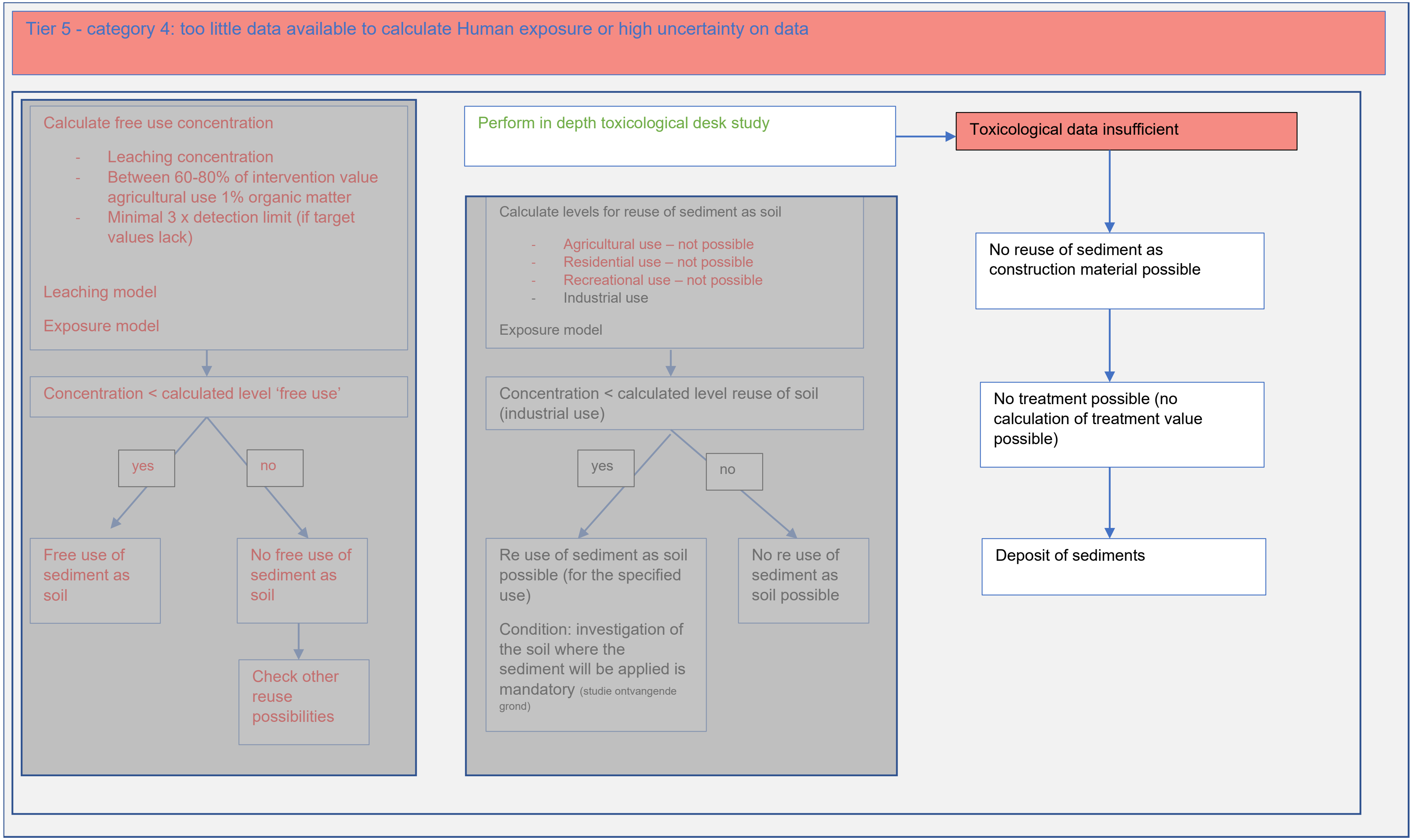

Figure 11: decision tree for Reuse of Sediment of a compound category 4.Reuse as soil or as Construction material is prohibited.

4.9 EXAMPLES

To test our decision system, several *Emerging substances* are assigned to a reuse category according to the protocol described in §4.4. These examples are discussed in the following sections.

Tier1bis includes the **collection of data** to calculate levels for reuse as soil and/or *Construction material* and the determination of **uncertainty** on these data.
The aim of tier 1bis is to assign the contaminated *Sediment* to one of the following categories based on the available information on the emerging substance:

Category 1: all data to calculate levels for reuse as soil and/or use as *Construction material* are available.
Category 2: all data available to calculate human exposure (intervention levels) for recreational and industrial use and leaching (reuse as *Construction material*) are available, but there are no or limited ecotoxicological data available to calculate levels for free reuse.
Category 3: all data to calculate human exposure for industrial use and leaching (reuse as *Construction material*) are available, but the uncertainty on these data is high.
Category 4: there is too little data available to calculate human exposure or the uncertainty on these data is high.

The level of (un)certainty in the collected data is presented by means of a specific coding. It is important to note that the meaning of each code can differ slightly depending on the aspect it is used for (physicochemical data, human toxicological data and ecotoxicological data). To avoid misinterpretation, the meaning of each code is presented below.

For **physicochemical** characteristics:
- X = value published in at least two reliable databases and the variability between the databases is low (< factor 10);
- (X) = value published in at least two reliable databases and the variability between the databases is high (> factor 10) or
  = value is published in only one reliable database;
- 0 = no data available.

For **human toxicological** data:
- X = value published in at least two reliable databases;
- (X) = value is published in only one reliable database;
- 0 = no data available.

For the human toxicological data, the variability between the databases is not considered because the most conservative value is preserved in case of deviating values.
For **ecotoxicological** data:
- X = value published in at least two reliable databases and the variability within and between the databases is low (< factor 10);
- (X) = value published in at least two reliable databases and the variability within and between the databases is high (> factor 10) or
  = value is published in only one reliable database;
- 0 = no data available.

For ecotoxicological data the variability within a database is also considered in addition to the variability between databases because the reliable databases often provide ranges for ecotoxicological data.

4.9.1 Heptachlor

4.9.1.1 Categorization of Heptachlor

All databases listed in Annex 3 were consulted. Most of these databases showed results for the physicochemical characteristics and human toxicity data listed below. Tables 9, 10, and 11 show an overview of the availability and variability in the physicochemical characteristics, human toxicological data, and ecotoxicological data for Heptachlor.

	Physicochemical characteristics	Heptachlor	Code
General	CAS number	76-44-8	-
General	Other names (most used)	Heptachlorane Heptamul 3-Chlorochlordene	-
General	Molecular Formula	$C_{10}H_5Cl_7$	-
General	Molar mass (g/mol)	373.3	-
PHYS	*Solubility* (S)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	Vapour pressure (D)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10) The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Heptachlor is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
PHYS	Octanol-water coefficient (Kow)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	*Henry-coefficient* (H)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10) The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Heptachlor is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant

Table 9: Overview of the availability and variability of general and physicochemical data for Heptachlor

	Human Toxicological data	Heptachlor	Code
HUMAN	Carcinogenicity	Value published in at least two reliable databases	X
HUMAN	*Tolerable Daily Intake* or Reference Dose (for non-carcinogenic or carcinogenic compounds)	Value published in at least two reliable databases	X

HUMAN	Tolerable Level in air	The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Heptachlor is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
HUMAN	Drinking water level	Value published in at least two reliable databases and the variability between the databases is high (> factor 10)	(X)
HUMAN	Level in vegetables	Value is published in only one reliable database	(X)
HUMAN	Level in meat/milk	Value is published in only one reliable database	(X)

Table 10: Overview of the availability and variability of human toxicological data for Heptachlor.

Ecotoxicological data		Heptachlor	
ECO	Toxicity levels for cattle and plants	Not data available	0
ECO	Bioconcentration factor	Value published in at least two reliable databases and the variability within and/or between the databases is high (> factor 10)	(X)

Table 11: Overview of the availability and variability of ecotoxicological data for Heptachlor.

To assign Heptachlor to one of the reuse categories, the results from tables 9, 10 and 11 are compared to the information required for each category (table 4).

Characteristic	Type	Category 1	Category 2	Category 3	Category 4	Heptachlor
Human exposure						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	X
Vapor pressure (D)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Human toxicity data						
Carcinogenicity	HUMAN	X	X	(X) or in-depth study	0	X

Tolerable Daily Intake or reference Dose (for carcinogenic or non-carcinogenic compounds)	HUMAN	X	X	(X) or in-depth study	0	X
Tolerable Level in air	HUMAN	X or not relevant (*)	X or not relevant (*)	(X) or not relevant (*)	0	Not relevant
Drinking water level	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in vegetables	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in meat/milk	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Ecotoxicological levels						
Toxicity data						
Levels for cattle and plants	ECO	X	(X) or 0	(X) or 0	0	0
Bioconcentration factor	ECO	X	(X) or 0	(X) or 0	0	(X)
Leaching						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	X
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Toxicity data						
Tolerable Daily Intake	HUMAN	X	X	(X) or in-depth study	0	X

Table 12: Overview of the availability and variability of data for Heptachlor compared to the required data from table 4.

4.9.1.2 <u>Heptachlor: category 2 compound</u>

Table 12 shows that the availability and variability in data for heptachlor categorizes heptachlor in:

Category 2: all human toxicological data are presented in a reliable database, except level in vegetable and meat/milk

To determine the final reuse application of the contaminated *Sediment* following steps 2 and/or 3 of the step-by-step approach.

2. Calculate levels for reuse as **soil** (recreational and industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as *Construction material*

4.9.2 PFOS

4.9.2.1 Categorization of PFOS

All databases listed in Annex 3 were consulted. Tables 13, 14, and 15 show an overview of the availability and variability in the physicochemical characteristics, human toxicological data, and ecotoxicological data.

Physicochemical characteristics		PFOS	Code
General	CAS number	1763-23-1	-
General	Other names (most used)	Perfluorooctanesulfonic acid Perfluorooctane sulfonate	-
General	Molecular Formula	$C_8HF_{17}O_3S$	-
General	Molar mass (g/mol)	500.13	-
PHYS	*Solubility* (S)	Value published in at least two reliable databases and the variability between the databases is high (> factor 10)	(X)
PHYS	Vapour pressure (D)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10) The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence PFOS is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
PHYS	Octanol-water coefficient (Kow)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	*Henry-coefficient* (H)	Value is published in only one reliable database The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence PFOS is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant

Table 13: Overview of the availability and variability of physicochemical data for PFOS.

Human Toxicological data		PFOS	Code
HUMAN	Carcinogenicity	Value published in at least two reliable databases	X
HUMAN	*Tolerable Daily Intake* or Reference Dose (for non-carcinogenic or carcinogenic compounds)	Not data available	0
HUMAN	Tolerable Level in air	The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence PFOS is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
HUMAN	Drinking water level	Value is published in only one reliable database;	(X)
HUMAN	Level in vegetables	Value is published in only one reliable database;	(X)
HUMAN	Level in meat/milk	Value is published in only one reliable database;	(X)

Table 14: Overview of the availability and variability of human toxicological data for PFOS.

Ecotoxicological data		PFOS	
ECO	Toxicity levels for cattle and plants	No data available	0
ECO	Bioconcentration factor	Value published in at least two reliable databases and the variability within and/or between the databases is high (> factor 10)	(X)

Table 15: Overview of the availability and variability of ecotoxicological data for PFOS.

To assign PFOS to one of the reuse categories, the results from tables 13, 14 and 15 are compared to the information required for each category (table 4).

Characteristic	Type	Category 1	Category 2	Category 3	Category 4	PFOS
Human exposure						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	(X)
Vapor pressure (D)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant

Human toxicity data						
Carcinogenicity	HUMAN	X	X	(X) or in-depth study	0	X
Tolerable Daily Intake or reference Dose (for carcinogenic or non-carcinogenic compounds)	HUMAN	X	X	(X) or in-depth study	0	in depth study
Tolerable Level in air	HUMAN	X or not relevant (*)	X or not relevant (*)	(X) or not relevant (*)	0	Not relevant
Drinking water level	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in vegetables	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in meat/milk	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Ecotoxicological levels						
Toxicity data						
Levels for cattle and plants	ECO	X	(X) or 0	(X) or 0	0	0
Bioconcentration factor	ECO	X	(X) or 0	(X) or 0	0	(X)
Leaching						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	(X)
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Tolerable Daily Intake	HUMAN	X	X	(X) or in-depth study	0	0

Table 16: Overview of the availability and variability of data for PFOS compared to the required data from table 4.

4.9.2.2 PFOS: category 3 compound

Table 16 shows that the availability and variability in data for PFOS is limited. However, after an in-depth toxicity desk study a reliable toxicity data can be determined. This in-depth toxicity desk study shows values for the Reference Dose in other research (*EFSA*, *RIVM*, etc.). In addition, *VITO* performed an in-depth literature review on the selection of Reference Dose. Therefore, PFOS can be classified in:

Category 3: uncertainties in the human toxicological data are high, but an in-depth toxicological desk study is performed.

To determine the final reuse application of the contaminated *Sediment* following steps 2 and/or 3 of the step-by-step approach.

2. Calculate levels for reuse as **soil** (industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as *Construction material*

4.9.3 Dioxins

4.9.3.1 Tetrachlorodibenzodioxin

Categorization of tetrachlorodibenzodioxin

All databases listed in Annex 3 were consulted. Tables 17, 18, and 19 show an overview of the availability and variability in the physicochemical characteristics, human toxicological data, and ecotoxicological data.

	Physicochemical characteristics	Tetrachlorodibenzodioxin	Code
General	CAS number	1746-01-6	-
General	Other names (most used)	2,3,7,8-Tetrachlorodibenzo-P-dioxin TCDD Tetradioxin	-
General	Molecular Formula	$C_{12}H_4Cl_4O_2$	-
General	Molar mass (g/mol)	322	-
PHYS	*Solubility* (S)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	Vapour pressure (D)	Value published in only one reliable database The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Tetrachlorodibenzodioxin is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
PHYS	Octanol-water coefficient (Kow)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	*Henry-coefficient* (H)	Value published in only one reliable database The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Tetrachlorodibenzodioxin is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant

Table 17: Overview of the availability and variability of physicochemical data for Tetrachlorodibenzodioxin.

	Human Toxicological data	Tetrachlorodibenzodioxin	Code
HUMAN	Carcinogenicity	Value published in at least two reliable databases	X
HUMAN	*Tolerable Daily Intake* or Reference Dose (for non-carcinogenic or carcinogenic compounds)	Value published in at least two reliable databases	X
HUMAN	Tolerable Level in air	The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Tetrachlorodibenzodioxin is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
HUMAN	Drinking water level	Value published in only one reliable database	(X)
HUMAN	Level in vegetables	No data available	0
HUMAN	Level in meat/milk	Value published in only one reliable database	(X)

Table 18: Overview of the availability and variability of human toxicological data for Tetrachlorodibenzodioxin

	Ecotoxicological data	Tetrachlorodibenzodioxin	
ECO	Toxicity levels for cattle and plants	No data available	0
ECO	Bioconcentration factor	Value published in at least two reliable databases and the variability within and/or between the databases is high (> factor 10)	(X)

Table 19: Overview of the availability and variability of ecotoxicological data for Tetrachlorodibenzodioxin.

To assign Tetrachlorodibenzodioxin to one of the reuse categories, the results from tables 17, 18 and 19 are compared to the information required for each category (table 4).

Characteristic	Type	Category 1	Category 2	Category 3	Category 4	Tetrachlorodibenzodioxin
Human exposure						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	X
Vapor pressure (D)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant

Human toxicity data						
Carcinogenicity	HUMAN	X	X	(X) or in-depth study	0	X
Tolerable Daily Intake or reference Dose (for carcinogenic or non-carcinogenic compounds)	HUMAN	X	X	(X) or in-depth study	0	X
Tolerable Level in air	HUMAN	X or not relevant (*)	X or not relevant (*)	(X) or not relevant (*)	0	Not relevant
Drinking water level	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in vegetables	HUMAN	X	(X) or 0	(X) or 0	0	0
Level in meat/milk	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Ecotoxicological levels						
Toxicity data						
Levels for cattle and plants	ECO	X	(X) or 0	(X) or 0	0	0
Bioconcentration factor	ECO	X	(X) or 0	(X) or 0	0	(X)
Leaching						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	X
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X	X	X or (X)	X or (X)	Not relevant
Tolerable Daily Intake	HUMAN	X	X	(X) or in-depth study	0	X

Table 20: Overview of the availability and variability of data for Tetrachlorodibenzodioxin compared to the required data from table 4.

Tetrachlorodibenzodioxin: category 2 compound

Table 20 shows that the availability and variability in data for Tetrachlorodibenzodioxin categorizes Tetrachlorodibenzodioxin in:

Category 2: all human toxicological data are presented in a reliable database, except levels in vegetable and meat/milk

To determine the final reuse application of the contaminated *Sediment* following steps 2 and/or 3 of the step-by-step approach.

2. Calculate levels for reuse as **soil** (recreational and industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as *Construction material*

4.9.3.2 Tetrachlorodibenzofuran

Categorization of tetrachlorodibenzofuran

All databases listed in Annex 3 were consulted. Tables 21, 22, and 23 show an overview of the availability and variability in the physicochemical characteristics, human toxicological data, and ecotoxicological data.

	Physicochemical characteristics	Tetrachlorodibenzofuran	Code
General	CAS number	51207-31-9	-
General	Other names (most used)	2,3,7,8-Tetrachlorodibenzofuran 2,3,7,8-TCDF TCDF	-
General	Molecular Formula	$C_{12}H_4Cl_4O$	-
General	Molar mass (g/mol)	306	-
PHYS	*Solubility* (S)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	Vapour pressure (D)	The molar weight is greater than 200 g/mol and the *Vapor pressure* is estimated below 1 mmHg, hence tetrachlorodibenzofuran is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
PHYS	Octanol-water coefficient (Kow)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	*Henry-coefficient* (H)	Value published in only one reliable database The molar weight is greater than 200 g/mol and the *Vapor pressure* is estimated below 1 mmHg, hence tetrachlorodibenzofuran is considered limited volatile. Exposure via volatilization will, therefore, be limited	Not relevant

Table 21: Overview of the availability and variability of physicochemical data for Tetrachlorodibenzofuran.

	Human Toxicological data	Tetrachlorodibenzofuran	Code
HUMAN	Carcinogenicity	Value published in only one reliable database	(X)
HUMAN	*Tolerable Daily Intake* or Reference Dose	Value published in only one reliable database	(X)
HUMAN	Tolerable Level in air	Value published in only one reliable database The molar weight is greater than 200 g/mol and the *Vapor pressure* is estimated below 1 mmHg, hence tetrachlorodibenzofuran is considered limited volatile. Exposure via volatilization will, therefore, be limited	Not relevant
HUMAN	Drinking water level	No data available	0
HUMAN	Level in vegetables	No data available	0
HUMAN	Level in meat/milk	Value published in only one reliable database	(X)

Table 22: Overview of the availability and variability of human toxicological data for tetrachlorodibenzofuran.

	Ecotoxicological data	Tetrachlorodibenzodioxin	Code
ECO	Toxicity levels for cattle and plants	No data available	0
ECO	Bioconcentration factor	Value published in at least two reliable databases and the variability within and/or between the databases is high (> factor 10)	(X)

Table 23: Overview of the availability and variability of ecotoxicological data for Tetrachlorodibenzofuran.

To assign Tetrachlorodibenzofuran to one of the reuse categories, the results from tables 21, 22 and 23 are compared to the information required for each category (table 4).

Characteristic	Type	Category 1	Category 2	Category 3	Category 4	Tetrachlorodibenzofuran
Human exposure						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	X

Vapor pressure (D)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Human toxicity data						
Carcinogenicity	HUMAN	X	X	(X) or in-depth study	0	(X)
Tolerable Daily Intake or reference Dose (for carcinogenic or non-carcinogenic compounds)	HUMAN	X	X	(X) or in-depth study	0	(X)
Tolerable Level in air	HUMAN	X or not relevant (*)	X or not relevant (*)	(X) or not relevant (*)	0	Not relevant
Drinking water level	HUMAN	X	(X) or 0	(X) or 0	0	0
Level in vegetables	HUMAN	X	(X) or 0	(X) or 0	0	0
Level in meat/milk	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Ecotoxicological levels						
Toxicity data						
Levels for cattle and plants	ECO	X	(X) or 0	(X) or 0	0	0
Bioconcentration factor	ECO	X	(X) or 0	(X) or 0	0	(X)
Leaching						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	X
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X	X	X or (X)	X or (X)	Not relevant
Tolerable Daily Intake	HUMAN	X	X	(X) or in-depth study	0	(X)

Table 24: Overview of the availability and variability of data for Tetrachlorodibenzofuran compared to the required data from table 4.

<u>Tetrachlorodibenzofuran: category 3 compound</u>

Table 24 shows that the availability and variability in data for Tetrachlorodibenzofuran categorizes Tetrachlorodibenzofuran in:

Category 3: uncertainties in the human toxicological data are high

To determine the final reuse application of the contaminated *Sediment* following steps 2 and/or 3 of the step-by-step approach.

2. Calculate levels for reuse as **soil** (industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as *Construction material*

4.9.4 Polybrominated diphenyl ethers (PDB's)

4.9.4.1 Octabromodiphenyl ether

Categorization of Octabromodiphenyl ether

All databases listed in Annex 3 were consulted. Tables 25, 26, and 27 show an overview of the availability and variability in the physicochemical characteristics, human toxicological data, and ecotoxicological data.

	Physicochemical characteristics	Octabromodiphenyl ether	Code
General	CAS number	32536-52-0	-
General	Other names (most used)	1,1'-Oxybis(2,3,4,5-tetrabromobenzene)	-
General	Molecular Formula	$C_{12}H_2Br_8O$ or C_6HBr_4-O-C_6HBr_4	-
General	Molar mass (g/mol)	801.4	-
PHYS	*Solubility* (S)	Value published in only one reliable database	(X)
PHYS	Vapour pressure (D)	The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Octabromodiphenyl ether is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
PHYS	Octanol-water coefficient (Kow)	Value published in only one reliable database	(X)
PHYS	*Henry-coefficient* (H)	Value published in only one reliable database The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Octabromodiphenyl ether is considered limited volatile. Exposure via	Not relevant

		volatilization will, therefore, be limited.	

Table 25: Overview of the availability and variability of physicochemical data for Octabromodiphenyl ether

	Human Toxicological data	Octabromodiphenyl ether	Code
HUMAN	Carcinogenicity	Value published in at least two reliable databases	X
HUMAN	*Tolerable Daily Intake* or Reference Dose	Value published in only one reliable database	(X)
HUMAN	Tolerable Level in air	The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Octabromodiphenyl ether is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
HUMAN	Drinking water level	Value published in only one reliable database	(X)
HUMAN	Level in vegetables	Value published in only one reliable database	(X)
HUMAN	Level in meat/milk	Value published in only one reliable database	(X)

Table 26: Overview of the availability and variability of human toxicological data for Octabromodiphenyl ether.

	Ecotoxicological data	Octabromodiphenyl ether	
ECO	Toxicity levels for cattle and plants	No data available	0
ECO	Bioconcentration factor	Value published in only one reliable database	(X)

Table 27: Overview of the availability and variability of ecotoxicological data for Octabromodiphenyl ether.

To assign Octabromodiphenyl ether to one of the reuse categories, the results from tables 25, 26 and 27 are compared to the information required for each category (table 4).

Characteristic	Type	Category 1	Category 2	Category 3	Category 4	Octabromodi phenyl ether
			Human exposure			
			Physicochemical data			
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	(X)
Vapor pressure (D)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	(X)
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
			Human toxicity data			
Carcinogenicity	HUMAN	X	X	(X) or in-depth study	0	X
Tolerable Daily Intake or reference Dose (for carcinogenic or non-carcinogenic compounds)	HUMAN	X	X	(X) or in-depth study	0	(X)
Tolerable Level in air	HUMAN	X or not relevant (*)	X or not relevant (*)	(X) or not relevant (*)	0	Not relevant
Drinking water level	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in vegetables	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in meat/milk	HUMAN	X	(X) or 0	(X) or 0	0	(X)
			Ecotoxicological levels			
			Toxicity data			
Levels for cattle and plants	ECO	X	(X) or 0	(X) or 0	0	0
Bioconcentration factor	ECO	X	(X) or 0	(X) or 0	0	(X)
			Leaching			
			Physicochemical data			
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	(X)
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	(X)
Henry-coefficient (H)	PHYS	X	X	X or (X)	X or (X)	Not relevant
Tolerable Daily Intake	HUMAN	X	X	(X) + in depth study	(X) or 0	(X)

Table 28: Overview of the availability and variability of data for Octabromodiphenyl ether compared to the required data from table 4.

Octabromodiphenyl ether: category 3 compound

Table 28 shows that the availability and variability in data for Octabromodiphenyl ether categorizes Octabromodiphenyl ether in:
Category 3: uncertainties in the human toxicological data are high

To determine the final reuse application of the contaminated *Sediment* following steps 2 and/or 3 of the step-by-step approach.

4. Calculate levels for reuse as **soil** (industrial use) and/or
5. Calculate levels for *Reuse of Sediment* as *Construction material*

4.9.4.2 Decabromodiphenyl ether

Categorization of Decabromodiphenyl ether

All databases listed in Annex 3 were consulted. Tables 29, 30, and 31 show an overview of the availability and variability in the physicochemical characteristics, human toxicological data, and ecotoxicological data.

	Physicochemical characteristics	Decabromodiphenyl ether	Code
General	CAS number	1163-19-5	-
General	Other names (most used)	Decabromodiphenyl oxide Pentabromophenyl ether Bis(pentabromophenyl) ether	-
General	Molecular Formula	$C_{12}Br_{10}O$	-
General	Molar mass (g/mol)	959.2	-
PHYS	*Solubility* (S)	Value published in at least two reliable databases and the variability between the databases is high (> factor 10)	(X)
PHYS	Vapour pressure (D)	Value published in at least two reliable databases and the variability between the databases is high (> factor 10) The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Decabromodiphenyl ether is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
PHYS	Octanol-water coefficient (Kow)	Value published in at least two reliable databases and the variability between the databases is low (< factor 10)	X
PHYS	*Henry-coefficient* (H)	Value published in at least two reliable databases and the variability between the databases is high (> factor 10)	Not relevant

		The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Decabromodiphenyl ether is considered limited volatile. Exposure via volatilization will, therefore, be limited.	

Table 29: Overview of the availability and variability of physicochemical data for decabromodiphenyl ether

	Human Toxicological data	Decabromodiphenyl ether	Code
HUMAN	Carcinogenicity	Value published in at least two reliable databases	X
HUMAN	*Tolerable Daily Intake* or Reference Dose	Value published in only one reliable database	(X)
HUMAN	Tolerable Level in air	Value published in only one reliable database The molar weight is greater than 200 g/mol and the *Vapor pressure* is less than 1 mmHg, hence Decabromodiphenyl ether is considered limited volatile. Exposure via volatilization will, therefore, be limited.	Not relevant
HUMAN	Drinking water level	No data available	0
HUMAN	Level in vegetables	Value published in only one reliable database	(X)
HUMAN	Level in meat/milk	Value published in only one reliable database	(X)

Table 30: Overview of the availability and variability of human toxicological data for Decabromodiphenyl ether.

	Ecotoxicological data	Decabromodiphenyl ether	Code
ECO	Toxicity levels for cattle and plants	Value published in only one reliable database	(X)
ECO	Bioconcentration factor	Value published in only one reliable database	(X)

Table 31: Overview of the availability and variability of ecotoxicological data for Decabromodiphenyl ether.

To assign Decabromodiphenyl ether to one of the reuse categories, the results from tables 29, 30 and 31 are compared to the information required for each category (table 4).

Characteristic	Type	Category 1	Category 2	Category 3	Category 4	Decabromodiphenyl ether
Human exposure						

Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	(X)
Vapor pressure (D)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X or not relevant (*)	X or not relevant (*)	X or (X) or not relevant (*)	X or (X) or not relevant (*)	Not relevant
Human toxicity data						
Carcinogenicity	HUMAN	X	X	(X) or in-depth study	0	X
Tolerable Daily Intake or reference Dose (for carcinogenic or non-carcinogenic compounds)	HUMAN	X	X	(X) or in-depth study	0	(X)
Tolerable Level in air	HUMAN	X or not relevant (*)	X or not relevant (*)	(X) or not relevant (*)	0	Not relevant
Drinking water level	HUMAN	X	(X) or 0	(X) or 0	0	0
Level in vegetables	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Level in meat/milk	HUMAN	X	(X) or 0	(X) or 0	0	(X)
Ecotoxicological levels						
Toxicity data						
Levels for cattle and plants	ECO	X	(X) or 0	(X) or 0	0	(X)
Bioconcentration factor	ECO	X	(X) or 0	(X) or 0	0	(X)
Leaching						
Physicochemical data						
Solubility (S)	PHYS	X	X	X or (X)	X or (X)	(X)
Octanol/water partition coefficient (Kow)	PHYS	X	X	X or (X)	X or (X)	X
Henry-coefficient (H)	PHYS	X	X	X or (X)	X or (X)	Not relevant
Tolerable Daily Intake	HUMAN	X	X	(X) or in-depth study	0	(X)

Table 32: Overview of the availability and variability of data for Decabromodiphenyl ether compared to the required data from table 4.

Decabromodiphenyl ether: category 3 compound

Table 32 shows that the availability and variability in data for Decabromodiphenyl ether categorizes Decabromodiphenyl ether in:
Category 3: uncertainties in the human toxicological data are high

To determine the final reuse application of the contaminated *Sediment* following steps 2 and/or 3 of a step-by-step approach.

2. Calculate levels for reuse as **soil** (industrial use) and/or
3. Calculate levels for *Reuse of Sediment* as *Construction material*

5 CONCLUSION AND RECOMMENDATIONS

This proposed decision framework is developed on how to deal in practice with lack of information and to define reuse possibilities for *Sediment*s contaminated with *Emerging substances*. It is a tiered approach in which the substances are organized into four categories. This classification depends on the availability of physicochemical, ecotoxicological (plant and cattle), and human toxicological data, on one hand, and the uncertainties in these data on the other hand. The more available information on the substance and the lower the uncertainty in this information, the more reuse levels can be calculated for the contaminated *Sediment*.

The driving forces for the development of a methodology for Reuse of Sediment are land use (human risks in different land-use scenarios) and potential leaching towards groundwater. In other words, the endpoint receptors in this decision system are human- and land-ecotoxicity receptors. The Reuse of Sediment in the water system is not included in the methodology since other risks can occur for this type of reuse. The Reuse of Sediment fits perfectly within the principle of the circular economy and can ensure that less primary raw materials are consumed that can have other and more useful applications.

If no reuse is possible and no target values for treatment can be obtained or no treatment until *Detection limit* can be obtained, the deposition or dumping of the *Sediment* is the final option.

It is important to note that this report contains a proposal for a decision tool. This proposed decision tool needs further discussion with stakeholders before it can be incorporated into regulation.

5.1 GENERAL RECOMMENDATIONS

The decision system described in this report focuses on the Flemish soil framework and guidelines, given it was developed by Flemish soil experts. However, the principles on which this system is based are widely applicable in other standardization frameworks. Country specific exposure models or leaching models applicable in the different countries can be used within this general decision system.

One of the most important challenges of “emerging contaminants” is that the knowledge and insights regarding these components can change rapidly. This decision system and categorization of compounds can therefore be a dynamic tool that will have to be evaluated based on the scientific insights about these components. Therefore, levels or reuse possibilities should be revised regularly as knowledge on the specific emerging contaminants evolves.

This means that the evaluation should be repeated every time an expert has to evaluate the possible reuse of emerging contaminants in *Sediment*. Due to an evolution in scientific knowledge, it is very likely that the data used to calculate reuse levels or to decide on possible ruse is already outdated. Hence, standards of *CEC’s* for *Reuse of Sediment* calculated by previous evaluations with the decision tree should be actualized with recent data.

For certain terms originating from Flemish soil legislation, reference is made to the definitions and glossary. Opportunities for reuse of contaminated *Sediment* as soil or as *Construction material* should be considered. Further definition or listing of possible application should be considered to optimize reuse possibilities. Country specific optimization should be made.

A specific check is incorporated in tier 1bis to ensure the substances are assigned to their appropriate category. This check probes for the presence of the emerging contaminant on the EU list (Appendix 1, annex 5). If so, extra constraints (less possibilities for reuse) are given. Policy makers can define specific lists in this step, and hence make country specific optimizations.

5.2 ADDITIONAL RECOMMENDATIONS FOR FLANDERS

This action framework is specifically developed for emerging contaminants and is not completely in line with existing legislation/guidelines in Flanders for dealing with non-standard parameters such as "study of receiving land"(studie ontvangende grond (SOG)). This decision system should therefore be a separate methodology and guideline and hence not an exception on the existing Flemish guidelines.

This methodology is a concept proposed methodology and the soil remediation sector in Flanders should be consulted before finalization.

6 REFERENCES

Bureau KLB, 2017. *National policies on substances of concern*.
Deltares, 2017. *Strategy for emerging contaminants*.
Ecofide, 2020. *Hotspots of prioritized and emerging contaminants in Sediments*.
Expertise centrum PFAS, 2018. *Possible action perspectives for new threats in the soil system*.
OVAM, 2015. *Basisinformatie voor risico-evaluatie: werkwijze voor het opstellen van bodemsaneringsnormen en toetsingswaarden, richtwaarden en streefwaarden' and 'F-LEACH 3.0: handleiding bij de software –update.*
OVAM, 2016. *Basisinformatie voor risico-evaluaties: Werkwijze voor het opstellen van bodemsaneringsnormen, toetsingswaarden, richtwaarden en streefwaarden- Deel 1*.
OVAM, 2016. *Basisinformatie voor risico-evaluaties: Uitvoeren van een humaan-toxicologische locatiespecifieke risico-evaluatie - Deel 2*.
VITO, 2018. *Principes bij het afleiden van de waarde vrij gebruik en de waarde voor bouwkundig bodemgebruik.*

7 ANNEXES

7.1 ANNEX 1: QUESTIONNAIRES

UK
Canada-Ontario
Germany
Portugal
Netherlands
Sweden
Switzerland

	Questions	Answers UK
1	**Are there specific standards available for soil remediation or the reuse of sediments on land, waterbed or in surface water for the following substances:** - PFAS - dioxines - Brominated flame retardants - Heptachlor	No, there are no specific standards available. However, in the EPA_UK Guidelines is described how to deal with emerging contaminants when they are detected (i.e. develop risk-based values for reuse or remediation by a site-specific approach). This strategy is further explained in the Sullied Sediments report in paragraph 2.2. Note that, in the UK, sediments are only really considered in relation to off-shore disposal and CEFAS levels. (CEFAS = Centre for Environment Fisheries and Aquaculture science)
1.1	**Indicate which standards:** - Soil remediation - Standards for the reuse of sediments	/
1.2	**Indicate for which of the following substances:** - PFAS - Dioxines - Brominated flame retardants - Heptachlor - Other: ………………………	Brominated flame retardants
1.3	**For which individual substances?** Please provide us with these standards (or a link to these standards). (Example: background values, standards for the application of sediments on land, …)	Cfr. Annex 2
1.4	**What is the legal status of these standards?** - Preliminary/ indicative values - Standards are included in regulation (approved values) - Both preliminary and approved values	/

1.5	**How were these standards established?** **In other words, these standards are based on:** - The 'stand-still'-principle - Leaching - Human toxicological risks - Ecotoxicological risks - Policy-based: ………………………………. (Example: 'Null tolerance'-policy) - Detection limit of the laboratory - Other: ……………………………………….. Comment: if the substantiation of these standards is based on certain studies, please provide us with these studies (or a link to these studies).	/ Note: the strategy to develop standards in case they are detected is further described in question 1 (above) and in paragraph 2.2. of the Sullied Sediments report.
2	**How did you obtain these priority substances?**	
2.1	 **Which lists form the base of your prioritization of emerging contaminants?** - The European list (Directive 2013/39/EU; see attachment) - The Norman list of emerging substances (see attachment) - Other: ……………………………………….. Comment: In case other lists were used for the prioritization of emerging contaminants, please provide us with these lists (or a link to these lists).	No
2.2	**Did you prioritize emerging contaminants within these lists? In other words, did you select specific priority substances from these lists?** - No - Yes, continue with question 2.2.1.	No

2.2.1	**How were these emerging contaminants prioritized given the uncertainties due to lack of information about emerging substances? In other words, how were these uncertainties dealt with?** (Example: in the NORMAN method, substances are subdivided into 6 different action categories based on the information available about these substances)	/

Table 33: Completed questionnaire by UK

	Questions	Answers Canada (Ontario)
1	**Are there specific standards available for soil remediation or the reuse of sediments on land, waterbed or in surface water for the following substances:** - PFAS - dioxines - Brominated flame retardants - Heptachlor	Yes, there are background site condition standards available.
1.1	**Indicate which standards:** - Soil remediation - Standards for the reuse of sediments	The type of standard (soil remediation standard/ standard for reuse of sediments) varies between provinces, but in general, Ontario has a well-developed process for assessing and managing contaminated sediments given its location on the great lakes.
1.2	**Indicate for which of the following substances:** - PFAS - Dioxines - Brominated flame retardants - Heptachlor - Other: ……………………….	Brominated flame retardants Dioxins Heptachlor
1.3	**For which individual substances?** Please provide us with these standards (or a link to these standards). (Example: background values, standards for the application of sediments on land, …)	Cfr. Annex 2
1.4	**What is the legal status of these standards?** - Preliminary/ indicative values - Standards are included in regulation (approved values) - Both preliminary and approved values	These standards are included in regulation (approved values). The background values and groundwater values are defined in the Environmental Protection Act.

1.5	**How were these standards established?** **In other words, these standards are based on:** - The 'stand-still'-principle - Leaching - Human toxicological risks - Ecotoxicological risks - Policy-based: …………………………………. (Example: 'Null tolerance'-policy) - Detection limit of the laboratory - Other: ……………………………………….. Comment: if the substantiation of these standards is based on certain studies, please provide us with these studies (or a link to these studies).	Human and ecotoxicological risks. The Canadian sediment levels are based on a NOEL, whereas the soil values vary, but range from back ground to risk based (with a risk tolerance of 1 in a million for cancer and 0.2 or 0.5 HI for non-carcinogens).
2	**How did you obtain these priority substances?**	
2.1	 **Which lists form the base of your prioritization of emerging contaminants?** - The European list (Directive 2013/39/EU; see attachment) - The Norman list of emerging substances (see attachment) - Other: ……………………………………….. Comment: In case other lists were used for the prioritization of emerging contaminants, please provide us with these lists (or a link to these lists).	No
2.2	**Did you prioritize emerging contaminants within these lists? In other words, did you select specific priority substances from these lists?** - No - Yes, continue with question 2.2.1.	No

2.2.1	**How were these emerging contaminants prioritized given the uncertainties due to lack of information about emerging substances? In other words, how were these uncertainties dealt with?** (Example: in the NORMAN method, substances are subdivided into 6 different action categories based on the information available about these substances)	/

Table 34: Completed questionnaire by Canada-Ontario

	Questions	Answers Germany
1	**Are there specific standards available for soil remediation or the reuse of sediments on land, waterbed or in surface water for the following substances:** - PFAS - dioxines - Brominated flame retardants - Heptachlor	Yes, there are trigger values available for pollutants which might cause hazardous soil changes.
1.1	**Indicate which standards:** - Soil remediation - Standards for the reuse of sediments	Soil remediation standards as there is no definition of "sediment" in their soil protection regulations. The reuse of sediment on land is considered "soil" and thus included within the Soil Protection Act.
1.2	**Indicate for which of the following substances:** - PFAS - Dioxines - Brominated flame retardants - Heptachlor - Other: ……………………….	Brominated flame retardants PFAS Dioxins Heptachlor
1.3	**For which individual substances?** Please provide us with these standards (or a link to these standards). (Example: background values, standards for the application of sediments on land, …)	Cfr. Annex 2
1.4	**What is the legal status of these standards?** - Preliminary/ indicative values - Standards are included in regulation (approved values) - Both preliminary and approved values	Both preliminary/indicative values and standards included in regulation (approved values). *Approved values*: The trigger and action values for Dioxins/Furans are included in the Federal Soil Protection Act. *Indicative/preliminary values:* There is an indicative survey (2019) available with average results of Brominated flame retardants, PFAS, Dioxin/Furan and Heptachlor in some environmental compartments. These are preliminary/indicative values.

t	**How were these standards established?** **In other words, these standards are based on:** - The 'stand-still'-principle - Leaching - Human toxicological risks - Ecotoxicological risks - Policy-based: …………………………………. (Example: 'Null tolerance'-policy) - Detection limit of the laboratory - Other: ……………………………………….. Comment: if the substantiation of these standards is based on certain studies, please provide us with these studies (or a link to these studies).	Human toxicological risks, ecotoxicological risks, and stand-still principle. *Human and ecotoxicological risks*: The purpose is to obtain trigger values for soil - human health and soil - groundwater and soil-plant pathways Actions to achieve this goal include determining values for pollutants for the soil - human health and soil-plant pathways Indicative values *Stand-still principle:* The purpose of the Act is to protect and restore the functions of the soil on a permanent sustainable basis. Actions to achieve this goal include the prevention of harmful soil changes as well as rehabilitating soil, contaminated sites, and waters contaminated by such sites in such a way that any contamination remains permanently below the hazard threshold. Whilst prevention aims to protect and preserve soil functions on a long-term basis, the object of remediation is mainly to avert concrete hazards in a spatial, temporal, and manageable causative context.
2	**How did you obtain these priority substances?**	
2.1	**Which lists form the base of your prioritization of emerging contaminants?** - The European list (Directive 2013/39/EU; see attachment) - The Norman list of emerging substances (see attachment) - Other: ……………………………………….. Comment: In case other lists were used for the prioritization of emerging contaminants, please provide us with these lists (or a link to these lists).	No

2.2	**Did you prioritize emerging contaminants within these lists? In other words, did you select specific priority substances from these lists?** - No - Yes, continue with question 2.2.1.	No
2.2.1	**How were these emerging contaminants prioritized given the uncertainties due to lack of information about emerging substances? In other words, how were these uncertainties dealt with?** (Example: in the NORMAN method, substances are subdivided into 6 different action categories based on the information available about these substances)	/

Table 35: Completed questionnaire by Germany

	Questions	Answers Portugal
1	**Are there specific standards available for soil remediation or the reuse of sediments on land, waterbed or in surface water for the following substances:** - PFAS - dioxines - Brominated flame retardants - Heptachlor	No, there are no specific standards available. However, the general act "Lei n.º 58/2005, de 29 de Dezembro (Lei da Água) Water Act of 2005" describes that that "In cases where chemical analysis is necessary, it is mandatory to analyse the substances that may be present due to specific and/or diffuse pollution sources". Hence, when there is a known source of water contamination by emerging contaminants, they should be analysed.
1.1	**Indicate which standards:** - Soil remediation - Standards for the reuse of sediments	/
1.2	**Indicate for which of the following substances:** - PFAS - Dioxines - Brominated flame retardants - Heptachlor - Other: ………………………..	Brominated flame retardants
1.3	**For which individual substances?** Please provide us with these standards (or a link to these standards). (Example: background values, standards for the application of sediments on land, …)	Cfr. Annex 2
1.4	**What is the legal status of these standards?** - Preliminary/ indicative values - Standards are included in regulation (approved values) - Both preliminary and approved values	/

1.5	**How were these standards established?** **In other words, these standards are based on:** - The 'stand-still'-principle - Leaching - Human toxicological risks - Ecotoxicological risks - Policy-based: ………………………………… (Example: 'Null tolerance'-policy) - Detection limit of the laboratory - Other: ……………………………………….. Comment: if the substantiation of these standards is based on certain studies, please provide us with these studies (or a link to these studies).	/
2	**How did you obtain these priority substances?**	
2.1	**Which lists form the base of your prioritization of emerging contaminants?** - The European list (Directive 2013/39/EU; see attachment) - The Norman list of emerging substances (see attachment) - Other: ……………………………………….. Comment: In case other lists were used for the prioritization of emerging contaminants, please provide us with these lists (or a link to these lists).	No
2.2	**Did you prioritize emerging contaminants within these lists? In other words, did you select specific priority substances from these lists?** - No - Yes, continue with question 2.2.1.	No

2.2.1	**How were these emerging contaminants prioritized given the uncertainties due to lack of information about emerging substances? In other words, how were these uncertainties dealt with?** (Example: in the NORMAN method, substances are subdivided into 6 different action categories based on the information available about these substances)	/

Table 36: Completed questionnaire by Portugal

	Questions	Answers the Netherlands
1	**Are there specific standards available for soil remediation or the reuse of sediments on land, waterbed or in surface water for the following substances:** - PFAS - dioxines - Brominated flame retardants - Heptachlor	Yes, there are standards available.
1.1	**Indicate which standards:** - Soil remediation - Standards for the reuse of sediments	Soil remediation standards and standards for the reuse of sediments, given they have indicative levels for serious soil contamination and levels for the reuse of dredged material.
1.2	**Indicate for which of the following substances:** - PFAS - Dioxines - Brominated flame retardants - Heptachlor - Other: ………………………..	PFAS Dioxins Heptachlor Brominated flame retardants
1.3	**For which individual substances?** Please provide us with these standards (or a link to these standards). (Example: background values, standards for the application of sediments on land, …)	Cfr. Annex 2

1.4	**What is the legal status of these standards?** - Preliminary/ indicative values - Standards are included in regulation (approved values) - Both preliminary and approved values	Both preliminary/indicative values and standards included in regulation (approved values). *Approved values*: The maximum values for Heptachlor and Heptachlor epoxide included in Soil Quality Regulation, Appendix B "Background values and maximal values for soil and dredged material". PFAS values for reuse of sediments and soil are included in the temporary action framework ("tijdelijk handelingskader"). *Indicative/preliminary values*: There exist indicative levels for serious soil contamination of PFAS. As these indicative values have more uncertainty than intervention values, authorities need to take other considerations into account in their decision making about serious PFAS contamination. These considerations are presented in the Circular Soil Remediation (2013).
1.5	**How were these standards established?** **In other words, these standards are based on:** - The 'stand-still'-principle - Leaching - Human toxicological risks - Ecotoxicological risks - Policy-based: …………………………………. (Example: 'Null tolerance'-policy) - Detection limit of the laboratory - Other: ……………………………………….. Comment: if the substantiation of these standards is based on certain studies, please provide us with these studies (or a link to these studies).	Human toxicological risks, ecotoxicological risks, national background levels, leaching and duty of care ("zorgplicht") *Human toxicological risks, ecotoxicological risks, and background levels:* The maximum values depend on the function and are therefore based on ecological, humane quality objectives and on the national background level. In the maximum values, ecology is the driving force for standardization. *Leaching:* Leaching has been taken into account in the past and is integrated into the standard values, but is no further specified with the transition from the former "Building Materials Decree" to the "Soil Quality Decree". In relation to leaching, the standard values were based on the basic principle of "marginal soil load" (1% deterioration of the receiving soil in a period of 100 years). However, with the transition to the Soil Quality Decree, this is now less strictly implemented in the standard values. *The duty of care:* The duty of care ("zorgplicht") is implemented in such a way that soil and dredging sludge containing a (potentially) harmful substance for which no application standards have been included in the context of the Soil Quality Decree may not be applied if concentrations of the substance are set above the determination limit. This interpretation of the statutory duties of care elaborates on the precautionary principle underlying the general environmental policy. If the consequences of a

		(potentially) harmful substance for people and the environment are not yet known, irresponsible risks for people and the environment should not be taken. Therefore, the existing environmental quality should not deteriorate further, and the substance must be prevented from spreading further into the environment.
2	**How did you obtain these priority substances?**	
2.1	**Which lists form the base of your prioritization of emerging contaminants?** - The European list (Directive 2013/39/EU; see attachment) - The Norman list of emerging substances (see attachment) - Other: ……………………………………….. Comment: In case other lists were used for the prioritization of emerging contaminants, please provide us with these lists (or a link to these lists).	/

2.2	**Did you prioritize emerging contaminants within these lists? In other words, did you select specific priority substances from these lists?** - No - Yes, continue with question 2.2.1.	/
2.2.1	**How were these emerging contaminants prioritized given the uncertainties due to lack of information about emerging substances? In other words, how were these uncertainties dealt with?** (Example: in the NORMAN method, substances are subdivided into 6 different action categories based on the information available about these substances)	/

Table 37: Completed questionnaire by the Netherlands

	Questions	Answers Sweden
1	**Are there specific standards available for soil remediation or the reuse of sediments on land, waterbed or in surface water for the following substances:** - PFAS - dioxines - Brominated flame retardants - Heptachlor	Yes, there are specific standards available.
1.1	**Indicate which standards:** - Soil remediation - Standards for the reuse of sediments	/
1.2	**Indicate for which of the following substances:** - PFAS - Dioxines - Brominated flame retardants - Heptachlor - Other: ……………………….	PFAS
1.3	**For which individual substances?** Please provide us with these standards (or a link to these standards). (Example: background values, standards for the application of sediments on land, …)	Cfr. X.
1.4	**What is the legal status of these standards?** - Preliminary/ indicative values - Standards are included in regulation (approved values) - Both preliminary and approved values	Both preliminary/indicative values and standards included in regulation (approved values) depending on the jurisdiction. New standards are also under development.

1.5	**How were these standards established?** **In other words, these standards are based on:** - The ‘stand-still’-principle - Leaching - Human toxicological risks - Ecotoxicological risks - Policy-based: ………………………………… (Example: ‘Null tolerance’-policy) - Detection limit of the laboratory - Other: ……………………………………….. Comment: if the substantiation of these standards is based on certain studies, please provide us with these studies (or a link to these studies).	They are usually risk based. Sometimes PFAS are grouped based on “read across” assumptions e.g. all PFAAs are equally toxic as PFOS.
2	**How did you obtain these priority substances?**	
2.1	**Which lists form the base of your prioritization of emerging contaminants?** - The European list (Directive 2013/39/EU; see attachment) - The Norman list of emerging substances (see attachment) - Other: ……………………………………….. Comment: In case other lists were used for the prioritization of emerging contaminants, please provide us with these lists (or a link to these lists).	The OECD list of the universe of PFAS (contains 4270 PFAS).
2.2	**Did you prioritize emerging contaminants within these lists? In other words, did you select specific priority substances from these lists?** - No - Yes, continue with question 2.2.1.	So far, only certain PFAAs (and related substances = precursors) and one perfluoroalkyl ether acid (GenX) are prioritized.

2.2.1	**How were these emerging contaminants prioritized given the uncertainties due to lack of information about emerging substances? In other words, how were these uncertainties dealt with?** (Example: in the NORMAN method, substances are subdivided into 6 different action categories based on the information available about these substances)	Based on intrinsic properties (P, B, T, M etc.) and/or risk assessment (paper Ian Cousins)

Table 38: Completed questionnaire by Sweden

	Questions	Answers Switzerland
1	Are there specific standards available for soil remediation or the reuse of sediments on land, waterbed or in surface water for the following substances: - PFAS - dioxines - Brominated flame retardants - Heptachlor	Yes, for dioxanes and heptachlor.
1.1	 Indicate which standards: - Soil remediation - Standards for the reuse of sediments	guiding values and remediation values depending on use (pplaygrounds, private gardens, agricultural use, industrial use)
1.2	Indicate for which of the following substances: - PFAS - Dioxines - Brominated flame retardants - Heptachlor - Other: ………………………..	 Dioxins Heptachlor
1.3	For which individual substances? Please provide us with these standards (or a link to these standards). (Example: background values, standards for the application of sediments on land, …)	Cfr. Annex 2
1.4	What is the legal status of these standards? - Preliminary/ indicative values - Standards are included in regulation (approved values) - Both preliminary and approved values	These standards are included in regulation (Soil Ordinance) (https://www.admin.ch/opc/de/classified-compilation/19981783/index.html)
1.5	How were these standards established? In other words, these standards are based on: - The ‘stand-still’-principle - Leaching - Human toxicological risks - Ecotoxicological risks - Policy-based: …………………………………. (Example: ‘Null tolerance’-policy)	Human and ecotoxicological risks. Leaching

	- Detection limit of the laboratory - Other: ……………………………………….. Comment: if the substantiation of these standards is based on certain studies, please provide us with these studies (or a link to these studies).	
2	How did you obtain these priority substances?	
2.1	Which lists form the base of your prioritization of emerging contaminants? - The European list (Directive 2013/39/EU; see attachment) - The Norman list of emerging substances (see attachment) - Other: ……………………………………….. Comment: In case other lists were used for the prioritization of emerging contaminants, please provide us with these lists (or a link to these lists).	No
2.2	Did you prioritize emerging contaminants within these lists? In other words, did you select specific priority substances from these lists? - No - Yes, continue with question 2.2.1.	No
2.2.1	How were these emerging contaminants prioritized given the uncertainties due to lack of information about emerging substances? In other words, how were these uncertainties dealt with? (Example: in the NORMAN method, substances are subdivided into 6 different action categories based on the information available about these substances)	/

Table 39: Completed questionnaire by Switzerland

7.2 ANNEX 2: OVERVIEW OF EXISTING *TARGET VALUES*

UK
Germany
The Netherlands
Portugal
Canada-Ontario

(1) existing levels of standard parameters are not included in the table
not yet completed

General substance information						standard or emerging contaminant (in most EU countries) (1)	Levels UK	
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	reuse (banksite)-project specific (project CRT), 6% Soil Organic matter Grazing animals (mg/kg)	reuse (banksite)-project specific (project CRT) 6% Soil Organic matter human health (without plant uptake) (mgkg)
15972-60-8	240-110-8	Alachlor		2,9				
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter	133 grazing animals - risk model	37000 human health without plant uptake
1912-24-9	217-617-8	Atrazine		2,6				
71-43-2	200-753-7	Benzene		2,1		standard parameter		
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)			
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter		
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator			
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology			
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology			
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter		
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter		
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator			
330-54-1	206-354-4	Diuron		2,8				
115-29-7	204-079-4	Endosulfan	x	3,8	ecology			
206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter	26,7 grazing animals - risk model	1600 human health without plant uptake
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)			
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9				

608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology			
34123-59-6	251-835-4	Isoproturon		2,5				
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter	250 grazing animals - risk model	310 human health without plant uptake
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter	20 grazing animals - risk model	56 human health without plant uptake
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter	133 grazing animals - risk model	13 human health without plant uptake
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter	100 grazing animals - risk model	180 human health without plant uptake
not applicable	not applicable	Nonylphenols	x	4,5	ecology			
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology			
608-93-5	210-172-0	Pentachlorobenzene	x	5,2				
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology			
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter		
122-34-9	204-535-2	Simazine		2,2				
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology			
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology			
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter		
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology			
115-32-2	204-082-0	Dicofol	x	4,1	predator			
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)			
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology			
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)			
74070-46-5	277-704-1	Aclonifen		4,4	ecology			
42576-02-3	255-894-7	Bifenox		3,6	ecology			

28159-98-0	248-872-3	Cybutryne		4	ecology			
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology			
62-73-7	200-547-7	Dichlorvos		1,9				
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator			
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)			
886-50-0	212-950-5	Terbutryn		3,5	ecology			

Table 40: Overview of existing target values in the UK

General substance information							Levels Germany				
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	Orientative value agricultural, vegetable garden mg/kg.dm	orientative value (soil) playground mg/kg.dm	orientative value (soil) residential mg/kg.dm	orientative value (soil) park and recreation mg/kg.dm	orientative value (soil) industrial and commercial mg/kg.dm
15972-60-8	240-110-8	Alachlor		2,9							
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter					
1912-24-9	217-617-8	Atrazine		2,6							
71-43-2	200-753-7	Benzene		2,1		standard parameter					
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)						
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter					
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator						
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology						
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology						
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter					
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter					
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator			4 soil -human pathway (direct contact)	8 soil -human pathway (direct contact)	20 soil -human pathway (direct contact)	40 soil -human pathway (direct contact)
330-54-1	206-354-4	Diuron		2,8							
115-29-7	204-079-4	Endosulfan	x	3,8	ecology						

206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter					
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)						
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9							
608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology			0,5 soil -human pathway (direct contact)	1 soil -human pathway (direct contact)	2,5 soil -human pathway (direct contact)	80 soil -human pathway (direct contact)
34123-59-6	251-835-4	Isoproturon		2,5							
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter					
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter					
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter					
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter					
not applicable	not applicable	Nonylphenols	x	4,5	ecology						
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology						
608-93-5	210-172-0	Pentachlorobenzene	x	5,2							
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology						
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter					
122-34-9	204-535-2	Simazine		2,2							
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology						
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology						
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter					
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology						
115-32-2	204-082-0	Dicofol	x	4,1	predator						

1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)						
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology						
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)		5 - 40 ng Teq/kg.dm	30 ng Teq/kg.dm soil -human pathway (direct contact)	60 ng Teq/kg.dm soil -human pathway (direct contact)	150 ng Teq/kg.dm soil -human pathway (direct contact)	300 ng Teq/kg.dm soil -human pathway (direct contact)
74070-46-5	277-704-1	Aclonifen		4,4	ecology						
42576-02-3	255-894-7	Bifenox		3,6	ecology						
28159-98-0	248-872-3	Cybutryne		4	ecology						
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology						
62-73-7	200-547-7	Dichlorvos		1,9							
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator						
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)						
886-50-0	212-950-5	Terbutryn		3,5	ecology						

Table 41: Overview of existing target values in Germany, part 1

General substance information							Levels Germany				
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	Trigger value agricultural, vegetable garden mg/kg.dm	Trigger value (soil) playground mg/kg.dm	Trigger value (soil) residential mg/kg.dm	Trigger value (soil) park and recreation mg/kg.dm	Trigger value (soil) industrial and commercial mg/kg.dm
15972-60-8	240-110-8	Alachlor		2,9							
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter					
1912-24-9	217-617-8	Atrazine		2,6							
71-43-2	200-753-7	Benzene		2,1		standard parameter					
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)						
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter					
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator						
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology						
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology						
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter					
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter					
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator			20	40	100	200
330-54-1	206-354-4	Diuron		2,8							
115-29-7	204-079-4	Endosulfan	x	3,8	ecology						
206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter					
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)			4 soil -human pathway	8 soil -human pathway	20 soil -human pathway	200 soil -human pathway

								(direct contact)	(direct contact)	(direct contact)	(direct contact)
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9							
608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology			5 soil -human pathway (direct contact)	10 soil -human pathway (direct contact)	25 soil -human pathway (direct contact)	400 soil -human pathway (direct contact)
34123-59-6	251-835-4	Isoproturon		2,5							
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter					
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter					
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter					
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter					
not applicable	not applicable	Nonylphenols	x	4,5	ecology						
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology						
608-93-5	210-172-0	Pentachlorobenzene	x	5,2							
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology			50 soil -human pathway (direct contact)	100 soil -human pathway (direct contact)	250 soil -human pathway (direct contact)	250 soil -human pathway (direct contact)
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter					
122-34-9	204-535-2	Simazine		2,2							
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology						
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology						

67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter					
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology						
115-32-2	204-082-0	Dicofol	x	4,1	predator						
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)						
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology						
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)						
74070-46-5	277-704-1	Aclonifen		4,4	ecology						
42576-02-3	255-894-7	Bifenox		3,6	ecology						
28159-98-0	248-872-3	Cybutryne		4	ecology						
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology						
62-73-7	200-547-7	Dichlorvos		1,9							
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator						
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)						
886-50-0	212-950-5	Terbutryn		3,5	ecology						

Table 42: Overview of existing target values in Germany, part 2

General substance information							Levels Germany				
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	Action value (soil) playground mg/kg.dm	Action value (soil) residential mg/kg.dm	Action value (soil) park and recreation mg/kg.dm	Action value (soil) industrial and commercial mg/kg.dm	Orientative value - soil-groundwater µg/l
15972-60-8	240-110-8	Alachlor		2,9							
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter					
1912-24-9	217-617-8	Atrazine		2,6							
71-43-2	200-753-7	Benzene		2,1		standard parameter					
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)						
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter					
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator						
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology						
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology						
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter					
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter					
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator						2,5-13
330-54-1	206-354-4	Diuron		2,8							
115-29-7	204-079-4	Endosulfan	x	3,8	ecology						
206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter					

118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)							
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9								
608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology							0,01- 0 03
34123-59-6	251-835-4	Isoproturon		2,5								
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter						
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter						
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter						
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter						
not applicable	not applicable	Nonylphenols	x	4,5	ecology							
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology							
608-93-5	210-172-0	Pentachlorobenzene	x	5,2								
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology							0,1 (ecotoxicology) 0,1 (human)
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter						
122-34-9	204-535-2	Simazine		2,2								
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology							
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology							
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter						
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology							
115-32-2	204-082-0	Dicofol	x	4,1	predator							
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)							

124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology						
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)		100 ngTEq/kg.dm soil - human pathway (direct contact)	1000 ngTEq/kg.dm soil - human pathway (direct contact)	1000 ngTEq/kg.dm soil - human pathway (direct contact)	10000 ngTEq/kg.dm soil - human pathway (direct contact)	
74070-46-5	277-704-1	Aclonifen		4,4	ecology						
42576-02-3	255-894-7	Bifenox		3,6	ecology						
28159-98-0	248-872-3	Cybutryne		4	ecology						
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology						
62-73-7	200-547-7	Dichlorvos		1,9							0,00006 (ecotoxicology) 0,1 (human)
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator						
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)						0,03 (ecotoxicology) 0,03 (human)
886-50-0	212-950-5	Terbutryn		3,5	ecology						

Table 43: Overview of existing target values in Germany, part 3

General substance information							Levels the Netherlands		
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	max levels for spreading sediment on adjacent parcel mg/kg.dm	Max levels -reuse in residential area mg/kg.dm	Max levels -reuse in industrial area mg/kg.dm
15972-60-8	240-110-8	Alachlor		2,9					
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter			
1912-24-9	217-617-8	Atrazine		2,6			0,035		0,035
71-43-2	200-753-7	Benzene		2,1		standard parameter			
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)				
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter			
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator				
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology				
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology				
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter			
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter			
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator		0,045		8,3
330-54-1	206-354-4	Diuron		2,8					
115-29-7	204-079-4	Endosulfan	x	3,8	ecology		0,0009		0,0009
206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter			
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)		0,0085		0,027
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9					

608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology		0,001 (alfa HCH) 0,002 (beta HCH) 0,003 (gamma HCH)		0,001 (alfa HCH) 0,002 (beta HCH) 0,04 (gamma HCH)
34123-59-6	251-835-4	Isoproturon		2,5					
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter			
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter			
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter			
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter			
not applicable	not applicable	Nonylphenols	x	4,5	ecology				
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology				
608-93-5	210-172-0	Pentachlorobenzene	x	5,2			0,0025		0,0025
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology		0,003		1,4
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter			
122-34-9	204-535-2	Simazine		2,2					
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology		0,065		0,065
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology				
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter			
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology				
115-32-2	204-082-0	Dicofol	x	4,1	predator				
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)				
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology				
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)		0,000055 (dioxine)		0,000055 (dioxine)
74070-46-5	277-704-1	Aclonifen		4,4	ecology				

42576-02-3	255-894-7	Bifenox		3,6	ecology				
28159-98-0	248-872-3	Cybutryne		4	ecology				
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology				
62-73-7	200-547-7	Dichlorvos		1,9					
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator				
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)		0,0007 (heptachlor) 0,002 (heptachlo epoxide)		0,0007 (heptachlor) 0,002 (heptachlo epoxide)
886-50-0	212-950-5	Terbutryn		3,5	ecology				

Table 44: Overview of existing target values in The Netherlands, part 1

General substance information							Levels the Netherlands		
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	Max emission levels - large scale reuse in industrial area mg/kg.dm	Max emission target levels - a mg/kg L/S 10	Max emission target levels - a mg/kg dm
15972-60-8	240-110-8	Alachlor		2,9					
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter			
1912-24-9	217-617-8	Atrazine		2,6			0,5	not applicable	not applicable
71-43-2	200-753-7	Benzene		2,1		standard parameter			
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)				
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter			
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator				
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology				
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology				
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter			
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter			
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator		60	not applicable	not applicable
330-54-1	206-354-4	Diuron		2,8					
115-29-7	204-079-4	Endosulfan	x	3,8	ecology		0,1	not applicable	not applicable
206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter			
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)		1,4	not applicable	not applicable
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9					
608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology		0,5	not applicable	not applicable
34123-59-6	251-835-4	Isoproturon		2,5					

7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter			
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter			
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter			
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter			
not applicable	not applicable	Nonylphenols	x	4,5	ecology				
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology				
608-93-5	210-172-0	Pentachlorobenzene	x	5,2			5	not applicable	not applicable
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology		5	not applicable	not applicable
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter			
122-34-9	204-535-2	Simazine		2,2					
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology		0,065	not applicable	not applicable
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology				
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter			
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology				
115-32-2	204-082-0	Dicofol	x	4,1	predator				
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)				
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology				
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)		0,000055 (dioxine)	not applicable	not applicable
74070-46-5	277-704-1	Aclonifen		4,4	ecology				
42576-02-3	255-894-7	Bifenox		3,6	ecology				
28159-98-0	248-872-3	Cybutryne		4	ecology				
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology				
62-73-7	200-547-7	Dichlorvos		1,9					

not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator				
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)		0,0007 (heptachlor) 0,1 (heptachlo epoxide)	not applicable	not applicable
886-50-0	212-950-5	Terbutryn		3,5	ecology				

Table 45: Overview of existing target values in The Netherlands, part 2

General substance information							Levels Portugal		
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	Class 1: Clean dredged material - can be deposited in the aquatic environment or replaced in places subject to erosion or used to feed beaches without standards restrictive.	Class 2: Dredged material with trace contamination - can be immersed in the aquatic environment taking attention to the characteristics of the receiving environment and the legitimate use of the same.	class 3: Slightly contaminated dredged material - can be used for earthworks or in the case immersion it requires a detailed study of the deposition and subsequent monitoring
15972-60-8	240-110-8	Alachlor		2,9					
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter			
1912-24-9	217-617-8	Atrazine		2,6					
71-43-2	200-753-7	Benzene		2,1		standard parameter			
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)				
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter	<1 mg/kg.dm	1-3 mg/kg.dm	3-5 mg/kg.dm
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator				
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology				
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology				
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter			
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter			
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator				
330-54-1	206-354-4	Diuron		2,8					
115-29-7	204-079-4	Endosulfan	x	3,8	ecology				

206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter			
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)		< 5 µg/kg.dm	5-25 µg/kg.dm	25-100 µg/kg.dm
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9					
608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology				
34123-59-6	251-835-4	Isoproturon		2,5					
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter			
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter			
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter			
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter			
not applicable	not applicable	Nonylphenols	x	4,5	ecology				
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology				
608-93-5	210-172-0	Pentachlorobenzene	x	5,2					
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology				
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter			
122-34-9	204-535-2	Simazine		2,2					
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology				
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology				
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter			
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology				
115-32-2	204-082-0	Dicofol	x	4,1	predator				
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)				
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology				

not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)				
74070-46-5	277-704-1	Aclonifen		4,4	ecology				
42576-02-3	255-894-7	Bifenox		3,6	ecology				
28159-98-0	248-872-3	Cybutryne		4	ecology				
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology				
62-73-7	200-547-7	Dichlorvos		1,9					
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator				
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)				
886-50-0	212-950-5	Terbutryn		3,5	ecology				

Table 46: Overview of existing target values in Portugal, part 1

General substance information							Levels Portugal	
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	class 4: Contaminated dredged material - preposition on land, in a waterproofed place, with the recommendation of subsequent coverage of impermeable soils.	class 5: Very contaminated material - ideally it should not be dredged and in imperative cases, the dredged should be sent for previous treatment and or deposition in a duly authorized waste landfill, being prohibited its immersion.
15972-60-8	240-110-8	Alachlor		2,9				
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter		
1912-24-9	217-617-8	Atrazine		2,6				
71-43-2	200-753-7	Benzene		2,1		standard parameter		
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)			
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter	5-10 mg/kg.dm	> 10 mg/kg.dm
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator			
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology			
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology			
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter		
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter		
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator			
330-54-1	206-354-4	Diuron		2,8				
115-29-7	204-079-4	Endosulfan	x	3,8	ecology			
206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter		
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)		100-300 µg/kg.dm	< 300 µg/kg.dm
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9				

608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology			
34123-59-6	251-835-4	Isoproturon		2,5				
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter		
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter		
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter		
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter		
not applicable	not applicable	Nonylphenols	x	4,5	ecology			
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology			
608-93-5	210-172-0	Pentachlorobenzene	x	5,2				
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology			
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter		
122-34-9	204-535-2	Simazine		2,2				
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology			
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology			
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter		
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology			
115-32-2	204-082-0	Dicofol	x	4,1	predator			
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)			
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology			
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)			
74070-46-5	277-704-1	Aclonifen		4,4	ecology			
42576-02-3	255-894-7	Bifenox		3,6	ecology			
28159-98-0	248-872-3	Cybutryne		4	ecology			

52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology			
62-73-7	200-547-7	Dichlorvos		1,9				
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator			
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)			
886-50-0	212-950-5	Terbutryn		3,5	ecology			

Table 47: Overview of existing target values in Portugal, part 2

General substance information							Levels Canada-Ontario		
CAS number	**EU Number**	**Name of priority substance (EU 2013/39/EU**	**Identified as priority hazardous substance**	**Log Kow (Ecofide, 20018)**	**Most important end point receptor (Ecofide 2018)**	**standard or emerging contaminant (in most EU countries) (1)**	**Full depth background standards agricultural use µg/kg dm**	**Full depth background standards residential/parkland/industrial use µg/kg dm**	**Full depth background standards residential/parkland/industrial use sediment µg/kg**
15972-60-8	240-110-8	Alachlor		2,9					
120-12-7	204-371-1	Anthracene	x	4,7	ecology	standard parameter			
1912-24-9	217-617-8	Atrazine		2,6					
71-43-2	200-753-7	Benzene		2,1		standard parameter			
not applicable	not applicable	**Brominated diphenylethers**	x	5,9-9,4	human (biota)				
7440-43-9	231-152-8	Cadmium and its compounds	x	na	ecology	standard parameter			
85535-84-8	287-476-5	Chloroalkanes, C 10-13	x	6	predator				
470-90-6	207-432-0	Chlorfenvinphos		3,9	ecology				
2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)		5	ecology				
107-06-2	203-458-1	1,2-dichloroethane		1,5		standard parameter			
75-09-2	200-838-9	Dichloromethane		1,3		standard parameter			
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	x	7,5	predator				
330-54-1	206-354-4	Diuron		2,8					
115-29-7	204-079-4	Endosulfan	x	3,8	ecology		0,04	0,04	not applicable
206-44-0	205-912-4	Fluoranthene		5,2	human (biota)	standard parameter			
118-74-1	204-273-9	Hexachlorobenzene	x	5,7	human (biota)		0,01	0,01	0,02
87-68-3	201-765-5	Hexachlorobutadiene	x	4,9					

608-73-1	210-168-9	Hexachlorocyclohexane (HCH)	x	3,5	ecology		0,01	0,01	not applicable
34123-59-6	251-835-4	Isoproturon		2,5					
7439-92-1	231-100-4	Lead and its compounds		na	ecology	standard parameter			
7439-97-6	231-106-7	Mercury and its compounds	x	na	predator	standard parameter			
91-20-3	202-049-5	Naphthalene		3,3	ecology	standard parameter			
7440-02-0	231-111-4	Nickel and its compounds		na	ecology	standard parameter			
not applicable	not applicable	Nonylphenols	x	4,5	ecology				
not applicable	not applicable	Octylphenols (6)		3-5,3	ecology				
608-93-5	210-172-0	Pentachlorobenzene	x	5,2					
87-86-5	201-778-6	Pentachlorophenol		3,3-5,1	ecology		0,1	0,1	not applicable
not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	x	5,8-6,6	human (biota)	standard parameter			
122-34-9	204-535-2	Simazine		2,2					
not applicable	not applicable	Tributyltin compounds	x	3,1-3,8	ecology				
12002-48-1	234-413-4	Trichlorobenzenes		4,2	ecology				
67-66-3	200-663-8	Trichloromethane (chloroform)		2		standard parameter			
1582-09-8	216-428-8	Trifluralin	x	5,3	ecology				
115-32-2	204-082-0	Dicofol	x	4,1	predator				
1763-23-1	217-179-8	**Perfluorooctane sulfonic acid and its derivatives (PFOS)**	x	uncertain	human (biota)				
124495-18-7	not applicable	Quinoxyfen	x	4,7	ecology				
not applicable		**Dioxins and dioxin-like compounds**	x	6,0-8,2	human (biota)		0,000007 (TEQ)	0,000007 (TEQ)	not applicable
74070-46-5	277-704-1	Aclonifen		4,4	ecology				
42576-02-3	255-894-7	Bifenox		3,6	ecology				

28159-98-0	248-872-3	Cybutryne		4	ecology				
52315-07-8	257-842-9	Cypermethrin (10)		6,6	ecology				
62-73-7	200-547-7	Dichlorvos		1,9					
not applicable		Hexabromocyclododecanes (HBCDD)	x	5,6	predator				
76-44-8/ 1024-57-3	200-962-3/ 213-831-0	**Heptachlor and heptachlor epoxide**	x	5,4	human (biota)		0,05 (hetachlor) 0,05 (heptachlor epoxide)	0,05 (hetachlor) 0,05 (heptachlor epoxide)	not applicable
886-50-0	212-950-5	Terbutryn		3,5	ecology				

Table 48: Overview of existing target values in Canada-Ontario

7.3 ANNEX 3: RELIABLE DATABASES

Organisation	Weblink of database	Link
World Health Organization	Publications > Environmental Health Criteria > List of EHCs (on chemicals or groups of chemicals) in alphabetical order	Link
Agency for Toxic Substances and Disease Registry	A-Z Index	Link
ECHA European Chemicals Agency	Search for Chemicals	Link
NORMAN	DATABASES > Substance Factsheets	Link
EPA United States Environmental Protection Agency	Environmental Topics > Chemicals and Toxics > > IRIS Assessments > Browse A to Z List of Chemicals	Link
International Agency for Research on Cancer	IARC Monographs	Link
National Library of Medicine PubChem	Explore Chemistry	Link

Table 49: Reliable databases

7.4 ANNEX 4: LIST OF APPLICATIONS FOR CONSTRUCTION PURPOSES

MB_Lijst_bouwkundig_bodemgebruik_Lijst_vormvast_product (ovam.be)

Construction material	Definition
Paved roads and paths	The use of soil and sediment in the foundation as long as the layer of soil and sediment has a maximum thickness of 60 centimetres, unless a different thickness is specified in the general specifications, the special specifications or in the design of the paved road or the path for technical construction purposes. The use of soil and sediment underneath paved roads and paths in a shoulder, abutment or raised slope structure
Shoulders, abutments and raised slopes	The use of soil and sediment from the top of the foundation of the embankment to the surface covering, on condition that the excavated soil that is used in the shoulder, the abutment or the slope structure is covered by one or more of the following elements: • a durable hardened layer or covering layer; • a stable construction; an erosion-resistant protection layer of at least 50 cm thick in which the soil meets the conditions for using excavated soil as the base;
Noise barriers	The use of soil and sediment from a depth of 30 cm below the ground level to the covering, on condition that the excavated soil that is used in the noise barrier is covered by one or more of the following elements: • a durable hardened layer or covering layer; • a stable construction; • an erosion-resistant protection layer of at least 50 cm thick in which the soil meets the conditions for using excavated soil as the base
Driveways, car parks or floor plates	The use of soil and sediment in the foundation as long as the layer of soil and sediment has a maximum thickness of 60 centimetres, unless a different thickness is specified in the general specifications, the special specifications or in the design for technical construction purposes;
Abutments and retaining walls	The use of soil and sediment in the anchoring structure of the construction.
Applications in dimensionally stable products	1° concrete products; 2° cement products; 3° ceramic products

Table 50: List of acceptable applications for the use of soil and sediment in constructions for substances that occur in very low concentrations and do not leach according to the high-level screening step in tier 1.

7.5 ANNEX 5 DIRECTIVE 2013/39/EU OF THE EUROPEAN PARLIAMENT AND THE COUNCIL OF 12 AUGUST 2013

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