Technical Report

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Element-specific and constant parameters used for dose calculations in SR-Site

Sara Nordén, Svensk Kärnbränslehantering AB

Rodolfo Avila, Idalmis de la Cruz,
Kristofer Stenberg, Sara Grolander
Facilia AB

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Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co

Box 250, SE-101 24 Stockholm
Phone +46 8 459 84 00

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors. SKB may draw modified conclusions, based on additional literature sources and/or expert opinions.

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Update notice

The original report, dated December 2010, was found to contain both factual and editorial errors which have been corrected in this updated version. The corrected factual errors are presented below.

Updated 2011-10

Location	Original text	Corrected text
Page 69, Table 7-3, text in table head	...data for microphytes were used.	...data for macrophytes were used.
Page 70, Table 7-4, text in table head	...data for microphytes were used.	...data for macrophytes were used.
Page 108, Figure C-2, figure text	Predictive posterior distribution of the CR for the reference species...	Predictive posterior distribution of the CR (shown on logarithmic scale) for the reference species...
Page 108, Figure C-2, text on x axis	CR	In(CR)
Page 109, Figure C-3, figure text	Predictive posterior distribution of the CR for the reference species...	Predictive posterior distribution of the CR (shown on logarithmic scale) for the reference species…
Page 109, Figure C-3, text on x axis	CR	In(CR)
Page 112, Table D-2, Column Selected values, GM, line Eu	0.0E+00	8.6E+00
Page 112, Table D-2, Column Selected values, GSD, line Eu	0.0	5.4
Page 120, Table D-10, Column Selected values, GM, line Cs	1.8E+00	7.3E+01
Page 120, Table D-10, Column Selected values, GSD, line Cs	8.9	1.3

Updated 2012-03

Location	Original text	Corrected text
Page 66, New paragraph 6.4.5		6.4.5 Average integration time The time interval over which concentration in vegetables from radionuclides accumulated in soil, as a consequence of irrigation with contaminated water, is described by the parameter "AverTime". A value of 50 years was used, which is the same value used by ICRP /2007/ in the derivation of dose coefficients used in calculation of average dose during the life time of adults. This parameter was kept at a constant value in the probabilistic simulations.
Page 73, References		New recerence: CRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. Oxford: Pergamon. (ICRP Publication 103; Annals of the ICRP Volume 37 (2-4)).

Updated 2013-01

The original report, dated December 2010, was found to contain editorial errors which have been corrected in this updated version.

Updated 2013-12

Location	Original text	Corrected text
Page 26, Table 3-1., line "Ra", kolumn "BE"	7.3E+00	2.5E+00 and footnote 2
Page 27, Table 3-2., line "Ra", kolumn "BE"	2.3E+00	2.5E+00 and footnote 4

Abstract

The report presents Best Estimate (BE) values and Probability Distribution Functions (PDFs) of Concentration Ratios (CR) for different types of terrestrial and aquatic biota and distribution coefficients (K_d) for organic and inorganic deposits, as well as for suspended matter in freshwater and marine ecosystems. The BE values have been used in deterministic simulations for derivation of Landscape Dose Factors (LDF) applied for dose assessments in SR-Site. The PDFs have been used in probabilistic simulations for uncertainty and sensitivity analysis of the LDFs. The derivation of LDFs for SR-Site is described in /Avila et al. 2010/. The CR and K_d values have been derived using both site-specific data measured at Laxemar and Forsmark during the site investigation program and literature data. These two data sources have been combined using Bayesian updating methods, which are described in detail in an Appendix, along with the input data used in the statistical analyses and the results obtained. The report also describes a kinetic-allometric model that was applied for deriving values of CR for terrestrial hebivores in cases when site and literature data for an element were missing. In addition, the report presents values for a number of other parameters used in the SR-Site Radionuclide Model for the biosphere: radionuclide decay-ingrowth data, elemental diffusivities, fractions of element content released during decomposition processes, ingestion of food, water and soil by cattle, elements retention fraction on plant surfaces during irrigation. The report also presents parameter values used in calculation of doses to a reference man: dose coefficients for inhalation, ingestion and external exposure, inhalation rates, ingestion rates of food and water.

Contents

1 Introduction

Radioactive waste and spent nuclear fuel from Swedish nuclear power plants are managed by the Swedish Nuclear Fuel and Waste Management Co, SKB. Both waste and spent fuel are planned to be placed in a geological repository. According to KBS-3 method, copper canisters with a cast iron insert containing spent fuel are to be enclosed by bentonite clay and deposited at approximately 500 m depth in granitic bedrock. Approximately 12,000 tonnes of spent nuclear fuel is forecasted to arise from the Swedish nuclear power programme, corresponding to roughly 6,000 canisters in a KBS-3 repository.

Between 2002 and 2007, SKB performed site investigations with the intention on finding a suitable location for a repository. Investigations were focused on two different sites along the eastern coast of southern Sweden; Forsmark in the municipality of Östhammar and Laxemar-Simpevarp in the municipality of Oskarshamn. Data from the site investigations were used to produce comprehensive, multi-disciplinary site descriptions for each of the sites. The resulting site descriptions were reported in /SKB 2008/ (Forsmark) and /SKB 2009/ (Laxemar-Simpevarp). Based on available knowledge from the site descriptions and from preliminary safety assessments of the planned repository, SKB decided in June 2009 to put forward Forsmark as suggested site for the repository. The location of Forsmark is shown in Figure 1-1. An application for the construction of a geological repository for spent nuclear fuel at Forsmark is planned to be filed in 2011.

According to the regulations from the Swedish Radiation Safety Authority, SSM, a safety assessment of the planned repository has to be performed before the construction of the repository starts (SSMFS 2008:21). The assessment should focus on potential developments that may lead to the release of radionuclides. SKB launched the project SR-Site to conduct the safety assessment, which is summarised in the /SKB 2011/.

The safety assessment SR-Site focuses on three major fields of investigation: performance of the repository, the geosphere and the biosphere. This report is a part of the biosphere part of SR-Site, SR-Site Biosphere (see Section 1.3 for references).

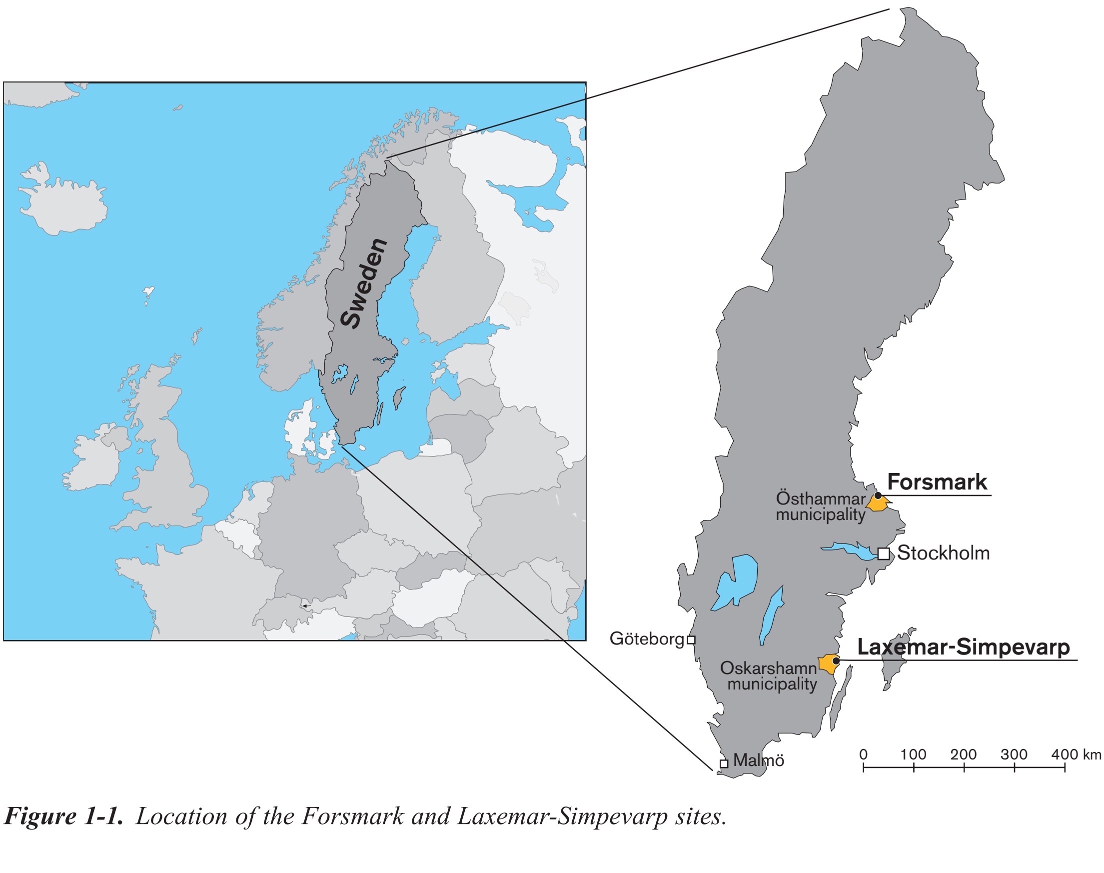

Figure 1-1. *Location of the Forsmark and Laxemar-Simpevarp sites.*

1.1 SR-Site Biosphere

The main objective of the biosphere assessments is to provide estimates for human exposure given a unit release, expressed as *landscape dose conversion factors* (LDFs). Multiplying these factors with modelled release rates from the geosphere results in estimates of the annual doses used to assess compliance with the regulatory risk criterion. The biosphere assessment also includes estimates of exposure to the environment /Torudd 2010/.

To accomplish this, areas that may receive discharged contaminants from deep groundwater from the repository, here called *biosphere object*s, were identified at the site, and the long-term development of these areas was modelled. A biosphere object is defined as an area of the landscape that potentially may receive radionuclides released from a future repository, either through discharge of deep groundwater or by contaminated surface water, at any time during a glacial cycle. In SR-Site, the biosphere at Forsmark is represented by a set of interconnected biosphere objects (see /Lindborg 2010/ for details).

The transport and accumulation of radionuclides in the biosphere objects throughout a full glacial cycle was described with the *Radionuclide Model for the biosphere* /Avila et al. 2010/. The biological uptake by various organisms, some of which are potential food sources for humans, were calculated from activity concentrations in the environment (air, soil, water and food). The activity concentrations for a unit release are then used to calculate the LDFs used to estimate the exposure to humans.

1.2 The Radionuclide Model for the biosphere

The Radionuclide Model for the biosphere is a compartment model, where system components that are considered internally homogeneous by their properties are represented by distinct compartments. A graphical representation of the conceptual model is shown in Figure 1-2, where each box corresponds to a model compartment. Definitions of the model compartments are presented in Table 1-1.

The arrows in Figure 1-2 represent radionuclide fluxes between compartments and fluxes into and out of the system. Radionuclide fluxes are linked to the main fluxes of matter in the biosphere, i.e. water fluxes, particle fluxes and gas fluxes. Fluxes mediated by primary producers have also been considered. The arrow reaching the lower regolith compartment represents radionuclide releases from the geosphere into the biosphere objects. These releases are directed to the deeper parts of the regolith, which at the site normally consists of glacial till deposited on the bedrock (see Section 3.1.1).

Radionuclides released to the lower regolith compartment are distributed to the upper layers of the ecosystems by advection and diffusion. The representation of the waterborne transport of radionuclides between compartments is based on detailed hydrological modelling with MIKE-SHE /Bosson et al. 2010/. The effect of radionuclide sorption on the advective and diffusive transport is taken into account by assuming equilibrium between the pore water and the solid phase of the different compartments. The model also considers the transport of radionuclides absorbed to suspended particles, driven by surface water fluxes, sedimentation and resuspension processes. In this report the parameters describing the retention of radionuclides are presented in Chapter 3.

The radionuclide transport mediated by biota is described in the model through fluxes driven by net primary production in both terrestrial and aquatic ecosystems. It is assumed that equilibrium is established between the activity concentrations of radionuclides in the newly produced biomass and in the corresponding environmental media (upper regolith for terrestrial and water for aquatic ecosystems). The parameters describing the uptake of radionuclides by biota are presented in this report in Chapters 4 and 5.

The calculated activity concentrations in media (soil, water) and potential food sources are used in calculation of doses for derivation of Landscape Dose Factors (LDF) /Avila et al. 2010/. The dose calculations are also based on assumptions on human habits and land use, for example ingestion rate of food and water and irrigation of agriculture land. Parameters describing these assumption are also presented in this report (see Section 6.4).

Two types of simulations were performed in SR-Site; deterministic and probabilistic /Avila et al. 2010/. The derivation of LDF values used in the assessments was based on the deterministic simulations, whereas the probabilistic simulations were used in uncertatinty and sensitivity analyses to estimate the relative importance of different parameters for the derived LDF values /Avila et al. 2010/. This report presents parameter values used in both kinds of simulations. In the deterministic simulations a "Best Estimate" value was used. For probabilistic simulations, whenever possible, probability distribution functions (PDFs) were assigned to the model parameters.

The Kd and CR concepts

The Radionuclide Model uses distribution coefficients (K_d) to describe the partitioning between the dissolved and sorbed phases of an element (for definitions see Section 3.1). The model of radionuclide retention in the regolith assumes that there is an 'apparent sorption', which also includes other processes than reversible sorption to the solid phase; e.g. precipitation, matrix diffusion, biological uptake, chemical reactions and complexation. These processes are not explicitly accounted for in the model, but are assumed implicitly included in K_d values estimated from site measurements. It is also assumed that the dissolved and solid phases are in equilibrium and that the 'apparent sorption' is reversible within the time frame of the assessments. These assumptions contribute to the overall uncertainty associated with K_d estimation, and it is assumed that K_d values obtained from natural elemental distribution are the closest possible approximation for this model parameter.

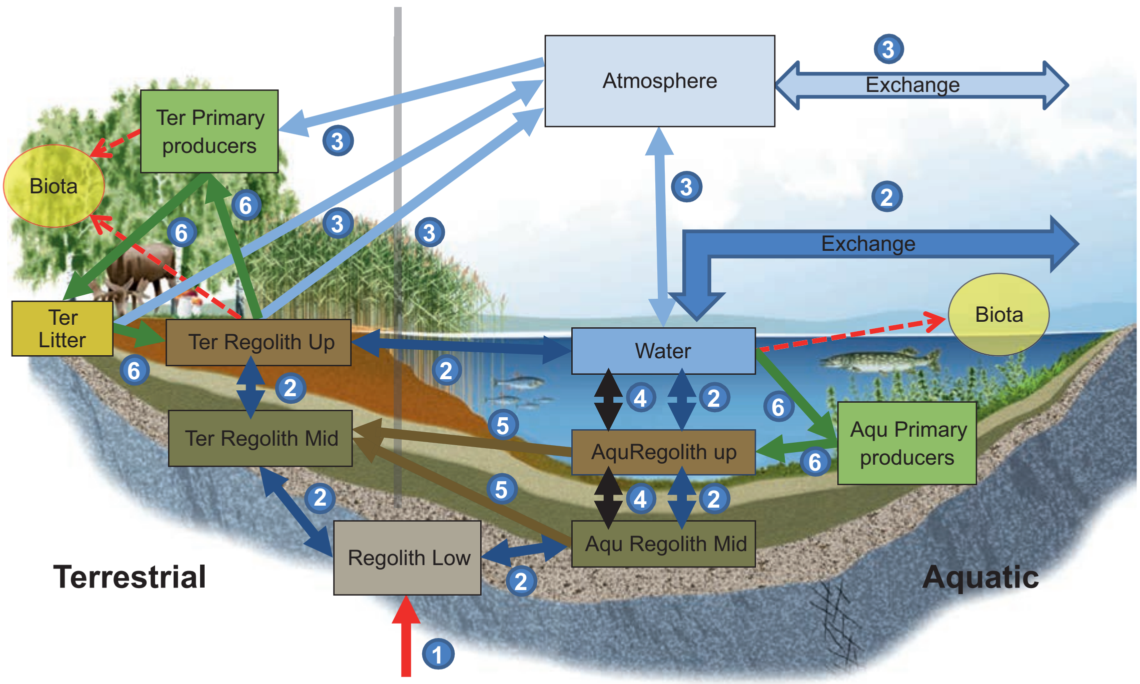

Figure 1-2. Conceptual illustration of the Radionuclide Model for the biosphere. Boxes represent compartments, thick arrows are fluxes, and dotted arrows are concentration computations for biota (these are not included in the mass balance). The model represents one object which contains an aquatic (right) and a terrestrial part (left) with a common lower regolith and atmosphere. The source flux (1 Bq/y) is represented by a red arrow. The radionuclide transport is mediated by different major processes, indicated with dark blue arrows for water, light blue for gas, black for sedimentation/resuspension, dark brown for terrestrialisation, green for biological uptake/decomposition. Import from and export to surrounding objects in the landscape is represented by arrows marked with "exchange". A detailed explanation can be found in /Avila et al. 2010/ and explanation to compartments are given in Table 1-1.

Table 1-1. Compartments in the Radionuclide Model for the biosphere (for further description see /Avila et al. 2010/).

Model name	Description
Regolith Low	The lower part of the regolith overlying the bedrock, primarily composed of till. It is common to the terrestrial and aquatic parts and its origin is from previous glaciation.
Aqu Regolith Mid	The middle part of the regolith in the aquatic part of biosphere objects, usually consisting of glacial and postglacial clays, gyttja and finer sediments which originate mainly from the period after the retreat of the last glacial ice sheet.
Aqu Regolith Up	The part of the aquatic regolith with highest biological activity, comprising approximately 5–10 cm of the upper aquatic sediments where resuspension and bioturbation can maintain an oxidizing environment.
Ter Regolith Mid	The middle part of the terrestrial regolith, containing glacial and postglacial fine material, i.e. former sediments from the seabed/lake bottoms.
Ter Regolith Up	The upper part of the terrestrial regolith which has the highest biological activity, such as the peat in a mire, or the plowing layer in agricultural land.
Litter	Dead plant material overlaying the regolith.
Water	The surface water (stream, lake, or sea water).
Aqu Primary Producers	The biotic community in aquatic habitats, comprising both primary producers and consumers.
Ter Primary Producers	Terrestrial primary producers.
Atmosphere	The lower part of the atmosphere where released radionuclides are fully mixed.

The Radionuclide Model uses concentration ratios (CR) to model uptake of radionuclide by biota (for definitions see Chapter 4 and 5). The use of CR is associated with conceptual uncertainties. This model assumes that there is a linear relationship between concentration in biota and the surrounding media (soil, water or food). However, this assumption is only strictly valid for a few elements which are taken up by passive uptake processes. Many elements are taken up by active procesess or affected by exclusion process by biota and in this case the simple linear relationship is not rigorously valid and the CR approach only provides an approximation of the expected behaviour. These complex processes are modelled by the simplistic CR model and the lack of fit for CR to actual processes will also become a part of the overall model uncertainty.

1.3 This report

The SR-Site Biosphere project was divided into a number of tasks from which several reports have been produced. The hierarchy of the produced reports is shown in Figure 1-3, where the current report is shown in red. As can be seen from the figure, the current report depends on the site-specific data compilation presented in /Tröjbom and Nordén 2010/. The information from the curent report is then used as an input to the Radionuclide Model for the biosphere for derivation of LDF values used in dose assessments /Avila et al. 2010/.

The purpose of this report is to present values for several of the parameter used in the Radionuclide Model for the biosphere /Avila et al. 2010/. The abbreviations of the parameter names used in Radionuclide Model /Avila et al. 2010/ are also used in this report for sake of simpler traceability. The parameter categories for which values are presented here are: element-specific parameters, nuclide-specific parameters, parameters describing human characteristics and parameters used to estimate food consumption by cattle. The parameter values presented in this report, were used in SR-Site simulations for both Forsmark and Laxemar-Simpevarp.

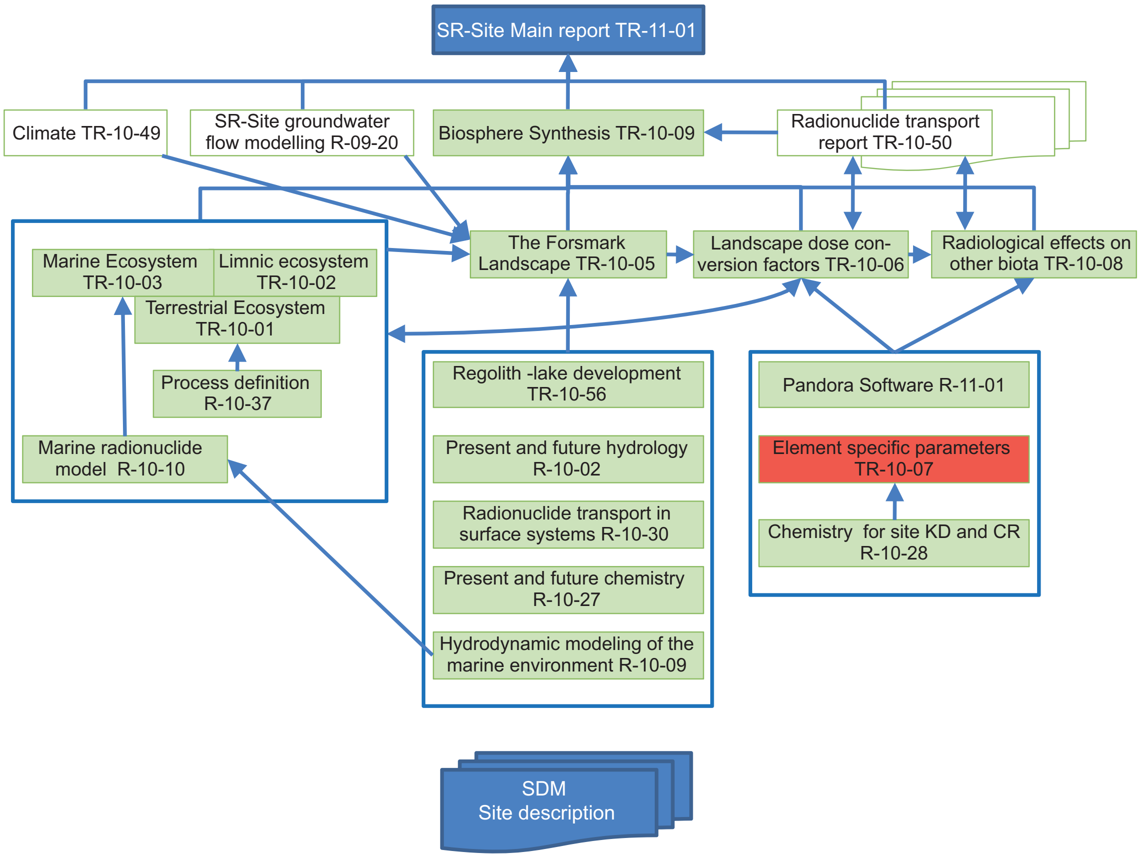

Figure 1-3. *The hierarchy of reports produced in the SR-Site Biosphere project. This report (shown in red) and its dependencies on information from biosphere reports (green) or other reports within SR-Site. Arrows indicates major interactions during the project, but interactions were substantial between most parts of the project throughout the process. The sources of data should be searched for in subordinate reports if not explicitly pointed out. SDM is the site descriptive model /Lindborg 2008/.*

In this Chapter (Chapter 1) an introduction to the SR-Site biosphere project and to the context and purpose of this report is given. Chapter 2 summarises the methods used to assign values to the CR and K_d parameters. In Chapter 3 the data used for deriving K_d values as well as the assigned K_d values are presented. The CR values for terrestrial and aquatic biota and the data used to assign these values are presented in Chapters 4 and 5. In Chapter 6 other parameters used in the SR-Site modelling are presented. In Section 6.1 radionuclide-specific parameters as half-life and dose coefficient for ingestion, inhalation and external exposure are presented. In Section 6.2 other element specific parameters are presented including the diffusivity used to calculate the diffusive fluxes in the Radionuclide model, the decomposition rate describing the behaviour of elements during decomposition and the retention coefficient describing the retention of elements of the surface of vegetation during irrigation. Chapter 6 also includes parameters describing human characteristics (Section 6.4) as ingestion rate of food and water and ihalation rate. Section 6.3 presents the parameters describing the ingestion rate of cattle.

2 Methods for selecting values for concentration ratios and distribution coefficients

In the Radionuclide Model for the biosphere /Avila et al. 2010/, radionuclide concentrations in biota are calculated using several types of equilibrium concentration ratios (CR), which are generally defined as the ratio between the element concentration in the biota to the concentration in different environmental media such as soil, water and animal feeds. A more specific definition of the different types of CRs is given in Chapters 4 and 5. One important difference regarding CRs used in SR-Site, compared with prevalent methods in the literature, is that the concentrations in biotic fractions were "normalised" to carbon content. This means that the concentrations in biotic fractions are expressed in units of kg carbon instead of kg dry or fresh weight. The CR between terrestrial vegetation and soil is thus expressed in units of [Bq/kg C in vegetation] / [Bq/kg dry soil] = kg dw/kg C. Similarly, the CRs between water and aquatic biota are expressed in units of m^3/kg C and the CRs between vegetation and herbivores is expressed in units of kg C/kg C. Concentrations in human food calculated with the CRs are then expressed in units of Bq/kg C. These concentrations are used to calculate radionuclide intake by humans via food ingestion, by multiplying the concentrations in food by the humans' yearly demand of carbon which is expressed in units of kg C/year. Details of how food ingestion doses are calculated in SR-Site can be found in /Avila et al. 2010/.

In the Radionuclide Model for the biosphere equilibrium ratios between concentrations are also used in estimations of the radionuclide retention in the regolith and to calculate their sorption to suspended particles in surface waters. In this case, ratios are taken between the element concentration in solids and the soluble phase of regolith, or between the element concentrations in suspended particles and the soluble phase of surface waters. A more specific definition of different K_d types used in this study can be found in Chapter 3.

In general, all isotopes of an element are assumed to have the same CR and K_d values, since sorption, uptake by biota and other relevant processes involved are generally very weakly affected by differences in isotopic mass or nuclear emissions, especially for elements with atomic mass greater than about 20 u. There could be situations where different isotopes of the same element may exhibit different bioavailability in soil, sediments and other environmental media. This could be the case when the isotopes found in these media have different origins. However, in situations where constant radionuclide releases occur during very long periods, it is reasonable to expect that radionuclides will be in equilibrium with their stable isotopes and that all isotopes of the same element will behave similarly.

Theoretical analyses have shown that concentrations of elements in the environment will tend to follow lognormal distributions /Ott 1990, 1995/, which is supported by empirical observations of element concentrations in the environment that have been used here for calculation of CR and K_d values. At the same time, lognormal distributions are self-replicating under multiplication and division, i.e. products and quotients of lognormal variables are themselves lognormal distributions /Aitchison and Brown 1957/. Hence, lognormal distributions have been assumed for all CRs and K_ds studied here. The distributions have been parameterised using Geometric Means (GM) and Geometric Standard Deviations (GSD). For the purposes of the assessments these distributions should be representative for the spatial and temporal variations considered. However, the variation observed in the available site-specific data was in most cases too narrow to be representative of the variation that can be expected within the long term period modelled in SR-Site. To address this shortcoming both site specific and representative literature data has been used for derivation of the CR and K_d distributions (see Section 2.1).

The use of the CR and K_d in deterministic and probabilistic assessments is described in /Avila et al. 2010/. The Best Estimate (BE) values of the CRs and K_ds derived here have been used in the deterministic simulations, whereas the derived probability distribution functions (PDFs) have been used in the probabilistic simulations. In the process of generating samples for the probabilistic simulations the PDFs of the CRs and K_ds were truncated at the 1^{st} and 99^{th} percentiles; to avoid using unrealistic combinations of values in the simulations. Correlations between CR and K_d were not taken into considerations in the probabilistic simulations, but nevertheless the issue of correlation between these parameters is relevant and is discussed in Chapter 7.

2.1 Combining site-specific and literature data

The choice of appropriate CR and K_d values is a difficult task, taking into account that values reported in the literature often vary by several orders of magnitude. The most appropriate solution would be to derive the values used in the assessments from representative site-specific data /US EPA 1999, Xu et al. 2008/. As a result of the site investigations conducted by SKB at Forsmark and Laxemar quite a large set of site-specific data has been made available and has been used in the selection of CR and K_d values. In the derivation of BE values and PDFs, data from both Laxemar and Forsmark have been used. This has allowed basing the derivation of CR and K_d values on a larger data set with a better coverage of the expected variation. In this report, data from both Forsmark and Laxemar is therefore referred to as site-specific data. Site-specific data are available for of many of the elements of interest in the safety assessment, but not for all, since some of the elements of interest have not been included in the analysis programme. For some other elements data were collected, but the concentrations were below the detection limits. The amount of site-specific data with values below the detection limit varied between different elements /Tröjbom and Nordén 2010/. For most elements this is not a critical issue, but for some the number of reported values above the detection limit is so low that they should be used with caution. The method applied for handing values below detection limits is presented below.

The method applied for selecting BE values and PDFs for the CRs and K_ds varied between elements depending on the availability of site-specific and literature data. The following situations were encountered and handled:

- Site-specific data were not available, but representative literature data could be found. In this case BE and parameter values of the PDFs (GM and GSD) were derived solely from the literature data (see discussion below in this section).
- Site-specific data were available, but representative literature data could not be found. In this case BE and parameter values of the PDFs (GM and GSD) were derived solely from the site-specific data (Section 2.2).
- Both site-specific and literature data were available. In this case, Bayesian inference methods, which combine site-specific and literature data, were applied to obtain BE and parameters values of the PDFs (Section 2.3).
- Neither site-specific or literature data were available. For several CRs for herbivores BE and parameter values of the PDFs were derived using a kinetic-allometric model (Section 2.4) and in all other such cases data from analogues were used for derivation of concentration ratios. (Section 2.5).

For all parameters of interest literature data were compiled (see Appendix A). The two main references used were a preliminary version of the update of the IAEA database of K_d and CR values that was done within the EMRAS project /IAEA 2010/ and a data base developed within the EC project ERICA /Beresford et al. 2007/. In some cases, these two databases included the same data and therefore a merging of these two databases was not performed. Instead, either or the other database was chosen when selecting literature data. The references were ranked according to the number of observations often resulting in /IAEA 2010/ as the first choice followed by /Beresford et al. 2007/. When data were missing in both of these references, a compilation of parameter values used in earlier SKB safety assessments /Karlsson and Bergström 2002/ was used. Parameters for forest ecosystems are included only to a small extent in these references. Other sources of data were used for these parameters (see Chapter 4). The values presented in /Beresford et al. 2007/were arithmetic means (AM) and arithmetic standard deviations (SD). AMs and SDs were also presented in /IAEA 2010/ when the number of observations were limited. As mentioned above, it was assumed that all CRs and K_ds are lognormally distributed and GM and GSD were used for the parameterisation of the PDFs. Whenever possible, the AM and SD were converted into GM and GSD using either of the two methods described below. In the first (preferred) method AM and SD were converted into GM and GSD using the following equations /Gelman and Hill 2007/:

$$GM = \frac{\mathrm{AM}}{\sqrt{e^{\sigma^2}}}\ ,\quad GSD = e^{\sigma},\quad \sigma = \sqrt{ln\left(\left(\frac{SD}{\mathrm{AM}}\right)^2+1\right)}$$

In the second method, used when the SD was not available, GM and GSD were calculated using the minimum and maximum values, assuming that these cover the range between the 2.5 and 97.5 percentiles of the distribution:

$$GM = \sqrt{min \cdot max}\ , \quad GSD = \left(\frac{max}{min}\right)^{\frac{1}{2*1.96}}$$

2.2 Calculation of CR and K_d values from site-specific data

The calculation of CRs and K_ds from site-specific data requires that values of two different concentrations are combined into a ratio. This can be done in different ways. The only "true sample pairs" in the site-specific data set were "pore water/ solid phase of regolith" and "filtered water/suspended matter" belonging to the same sample. These were used to calculate K_d values, by matching the samples according to an identification code (unique for each locality) and sediment layer, where relevant. For the CRs, samples from different localities at both sites (Forsmark and Laxemar) were combined in order to generate a larger set of CRs. By using unpaired samples, additional variation caused by differences between sample sites may increase the GSD for the parameter value. According to /Sheppard and Eveden 1990/, the GSD for unpaired samples are not much larger than for paired samples which implies that this assumption will not affect the resulting CR in a significant way. When unpaired samples were used, the GM and GSD of the CRs and K_ds were calculated as follows:

1. The GM and GSD of both concentrations used in the calculation of CRs and K_ds were obtained directly from the data values (in cases when some of the values were reported as being below detection limits, the procedure described below was applied to obtain the GM and GSD).
2. It was assumed that both concentrations follow a lognormal distribution and the GMs and GSDs obtained from the first step were used as distribution parameters. The CRs and K_ds were then calculated probabilistically by performing 1,000 simulations using latin- hypercube sampling.
3. The values generated from the probabilistic simulations were used to calculate the GM and GSD of the CRs and K_ds.

Handling of values below detection limits

Several of the studied elements are found in low concentrations in the environment, so that values below detection limits were often reported from the measurements. In cases when some of the reported concentration values were below detection limits and others were above, a procedure was applied that takes into account all available values. The procedure assumes that concentrations are lognormally distributed and it requires that at least three of the reported values are above the detection limit. All reported values are ranked to estimate the cumulative probability (p), i.e. the percentile (p) corresponding to each value. These cumulative probabilities are then used to obtain the inverse of the cumulative distribution function of the standard (or unit) normal distribution, commonly denoted as z(p). For lognormally distributed data, like the element concentrations, there is a linear relationship between the logarithm of the data, ln(X), and the z(p). By performing an ordinary least-squares regression the best fit to the straight line $\ln(X) = a + b*z(p)$ can be obtained and from the coefficients a and b the GM and GSD of the distribution can be derived using the equations given in /Burmaster and Hull 1997/. Only values above the detection limits are used in the fitting procedure. Figure 2-1 shows an example of results obtained from the application of this procedure. It can be seen from this figure that the values below the detection limit have an influence on the z(p) of all values, including values above the detection limits and in this way also affect the estimates of the distribution parameters.

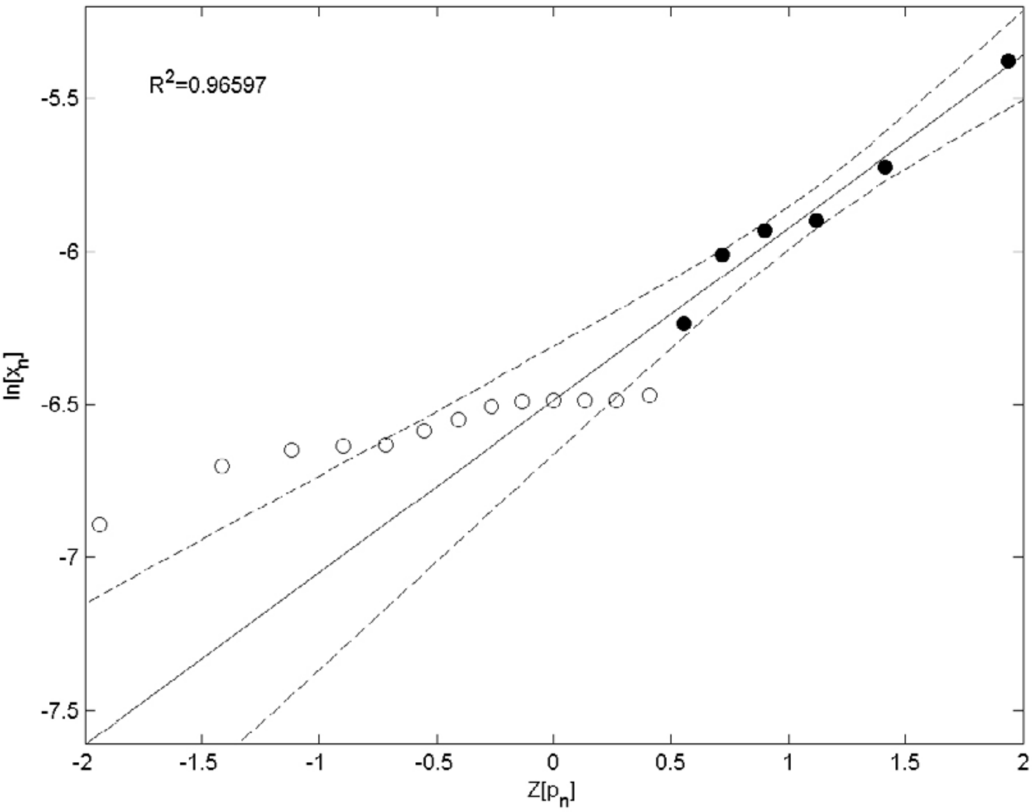

Figure 2-1. *Lognormal probability plot of measured concentrations (X) obtained with the procedure for handling values below detection limits described in the text above. Values below detection limits are shown with unfilled circles and values above detection limits with filled circles. The line corresponds to the best fit to a straight line obtained by least square regression, considering only data above detection limits. A high value, close to 1, of the determination coefficient R^2 indicates a good fit to a straight line, which indicates that the concentrations are lognormally distributed.*

2.3 Combining site and literature data using Bayesian methods

The procedure for assigning a probability distribution to a model parameter, such as a CR or K_d, can be divided in two main steps: i) selection of a probability model or distribution type and ii) estimation of the distribution parameters. As mentioned above, it has been assumed in this study that the CR and K_d are lognormally distributed. The estimation of the distribution parameters, i.e. the GM and GSD, was carried out using Bayesian updating methods /Gelman et al. 2004/. The applied methods are described in detail in Appendix C and are briefly explained below.

If sufficient site data of the CR and K_d are available, then ordinary fitting techniques, like maximum likelihood estimation /Keeping 1995/ can be directly applied to obtain estimates of the distribution parameters. However, these techniques do not give good estimates when only few site data are available. Also, if only available site data is used in the derivation of distribution parameters, then the derived distribution may not be representative for the variety of situations that the distribution should cover. Bayesian updating techniques provide a way of deriving values for distribution parameters taking into account other available relevant information, such as data reported in the literature for other sites and estimates of distributions made by expert judgment.

Bayesian updating is the process of fitting a probability model to various sets of data and estimating probability distributions for the parameters of the probability model. The essential characteristic of Bayesian methods is their explicit use of probability for quantifying uncertainty in model parameters. This is achieved by applying the Bayes' theorem /Bayes 1763/, which in its present-day form, due to /Laplace 1812/, is expressed with the following equation:

$$prob\ (hypothesis|data, I) = \frac{prob\ (data|hypothesis, I) * prob\ (hypothesis|I)}{prob\ (data|I)}$$

The various terms in the Bayes' theorem have formal names /Sivia 1996/. The quantity on the far right, prob(hypothesis|I), is called the **prior distribution.** It represents our stage of knowledge (or ignorance) about the truth of the hypothesis before we have analysed the current data, given all available background information (I). This is modified by the experimental measurements through the **likelihood function**, or prob(data|hypothesis), and yields the **posterior distribution**, prob(hypothesis|data, I). This distribution represents our stage of knowledge about the truth of the hypothesis in the light of the data and all available background information. In parameter estimation problems the term prob(data|I) is simply a normalisation constant (not depending explicitly on the hypothesis) and therefore does not play an important role. However, in some situations, such as model selection, this term plays a crucial role. For that reason, it is sometimes given the special name of **evidence**.

In applications of the Bayes theorem for estimation of distribution parameters, the hypothesis is the value that we would assign to the distribution parameter, for example the GM of a lognormal distribution, given the measured data and other available information. The power of the Bayes' theorem lies in the fact that it relates the quantity of interest (the probability of each specific value of the distribution parameter given the measured data) to a term that we have a better chance of being able to assign (the probability of the measured data given that the distribution parameter has a specific value). Note that this way we are implicitly recognizing that the value of the distribution parameter is an uncertain quantity, meaning that different values are possible with different probabilities.

In this study, statistics of CR and K_d extracted from the IAEA /IAEA 2010/ and ERICA /Beresford et al. 2007/ databases have been used to derive prior distributions for each of the parameters, GM and GSD, of the CR and K_d distributions. These were combined with the site data to obtain posterior distributions of the CR and K_d using the methods described in Appendix C. A difficulty that arises when applying this method is how to treat the prior distributions obtained from the literature data, i.e. whether the prior distribution and the site data are assumed to belong to the same sub-population of interest or the prior distribution represents the whole population to which the sub-population of interest belongs.

In statistics, a population is a set for which statistical inferences are to be drawn. For example, if we are interested in generalisations about a CR from soil to a specific plant type, then we would include in the population all CRs for this specific plant type, independently of soil type. A sub-set of a population is called a sub-population. If there are reasons to believe that different sub-sets in a population have different properties, then these might be easier studied and understood if they are further divided into sub-populations. For example, if we know that the CRs from soil to the specific plant type depend on soil type, then we may want to define different sub-populations of CRs for different soil types. One of these sub-populations might be the sub-population of interest for a given problem. For example if we are dealing with inferences for a given site and we know the soil type in this site, then the CR sub-population of interest would be the one corresponding to this soil type. The combination of distributions of different sub-populations, including the sub-population of interest, defines the distribution of the whole population. The concept of population and sub-population is graphically illustrated in Figure 2-2.

The boundaries of the sub-populations of CRs and K_ds of interest are defined by their expected variation within timeframe of the assessments. This variation will be driven by time variations in site properties, e.g. chemical properties, that influence on CR and K_d values. The boundaries of the sub-population of interest are also influenced by the spatial variability at the site. It is natural to assume that literature data obtained for sites with similar properties belong to the same sub-population as the site of interest. Equally, if the literature data are representative of a much broader range of sites and conditions, then it can be assumed that it represents the whole population to which the sub-population of interest belongs. The decision of how to treat the literature data is not obvious, mainly because of incomplete description of the sites and conditions where they were obtained. Whether the literature data is treated as representative of the sub-population of interest or the whole population will have an effect on how the Bayesian updating is carried out (see Appendix C). In this study, whenever it was possible, the Bayesian updating was carried out for both of these situations. This resulted in that two posterior distributions were obtained for each CR and K_d. The choice of one or the other posterior distribution was done by the rules described below which are biased towards the site data.

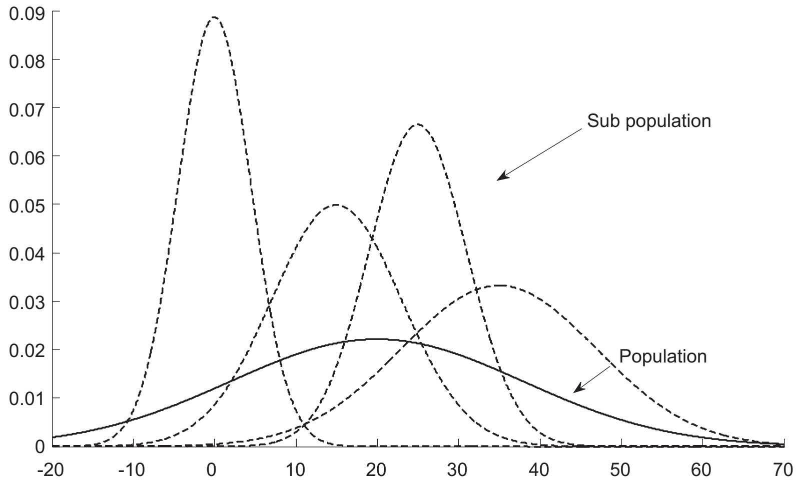

Figure 2-2. *Illustration of the concept of population and sub-population. In this example the population distribution (filled curve) is defined by the combination of four sub-populations (dotted curves).*

The first choice was to select the posterior distribution obtained under the assumption that literature data represent the whole population. The updating method applied in this case is hereafter called the **"Prior from population"** or simply the **"Population"** updating method. In this method the literature data is used to obtain a point estimate of the population distribution. The variation within the sub-population of interest is estimated directly from the data. In this method, the GM of the posterior (updated) distribution will shift more or less to the site-specific data, depending on the number of samples and the variation in both the literature and the site-specific data. This method is the most biased towards the site-specific data and it was therefore the first choice. However, the updating procedure used in this method (see Appendix C) requires that the available site-specific data is sufficient (at least 5 samples) to estimate the variation within the sub-population. Furthermore, for selecting this method we have also required that number of samples in the literature data should be 10 or more, which would give an acceptable characterisation of the central part of the population distribution. Finally, for selecting this method we have required that the GSD of the literature data should be equal or larger than the GSD of the site data. It is recognised that when there are few data the GSD is not well characterized, so site-specific data might show larger GSD than the population. In this case the alternative method (see below) will be chosen, which we consider is an acceptable choice when site data are very scarce.

If it was not possible to select the **"Prior from population"** updating method (see above), then the posterior distribution was selected from the results of Bayesian updating under the assumption that both the literature and the site data belong to the sub-population of interest. The updating method applied in this case is hereafter called the **"Prior from sub-population"** or simply the **"Sub-population"** updating method. This method gives a posterior distribution that is a compromise between the literature and the site data. In this case, the GM of the posterior distribution depends on the number of samples in the literature and site data. The GSD of the posterior distribution depends on how different GMs from the literature and the site data are, and on the variation in the literature and site data.

The selected posterior distributions for the different CRs and K_ds were used in probabilistic simulations presented in /Avila et al. 2010/; as part of the sensitivity and uncertainty analyses performed in the biosphere assessments. The selected posterior distributions were also utilized in the selection of Best Estimate values for the CRs and K_ds, which were used in the deterministic simulations for derivation of Landscape Dose Factors /Avila et al. 2010/. When the selected posterior distribution was the one resulting from application of the **"Prior from population"** updating method, the GM of the posterior distribution was always selected as BE. When the selected posterior distribution was the one resulting from application of the **"Prior from sub-population"** updating and the number of site data samples was 10 or more, the GM of the site data was select as BE; otherwise the GM of the posterior distribution was used as BE. This approach of selecting the BE values intentionally gives a higher weight to the site data.

2.4 Derivation of CRs for herbivores using a kinetic allometric model

The concentrations in meat from terrestrial wild herbivores, such as roe deer and moose, are calculated in SR-Site /Avila et al. 2010/ by multiplying the concentration in the animal diet (in units of Bq/kg C) by a unitless CR defined as the ratio between the concentration in the animal soft tissues (Bq/kg C) and in the animal diet (Bq/kg C). For some elements there were site-specific data of concentrations in the animal diet available and these were available and were used to calculate site-specific CRs. Literature data of these CRs, which could be used for filling gaps in the site-specific data or for applying Bayesian updating methods, are very scarce. Hence, in cases when site-specific data were not available the CRs for herbivores were instead calculated with the kinetic allometric model described in /Avila 2006b/, using the following equation:

$$CR_i = \frac{DMI * fraUptakei * fraSoftTissuesi * Tbioli}{\text{In}(2) * Weight} * (1 - e^{-\text{In}(2) * \frac{Tlife}{Tbiol_i}})$$

where,

CR_i is the Concentration Ratio of the i-th element between the diet and soft tissues of the herbivore [Bq/kg fresh weight per Bq/kg dry weight],

DMI is the daily dry matter intake by the herbivore [kg dry weight/d],

$fraUptake_i$ is the gut uptake fraction of the i-th radionuclide for herbivores [dimensionless],

$fraSoftTissues_i$ is the fraction in soft tissues of total content of the i-th element in the herbivore [dimensionless],

$Tbiol_i$ is the biological half time of the i-th element [d],

Weight is the body weight of the herbivore [kg fresh weight],

T_{life} is the life duration of the herbivore [d].

The above equation differs from the equation in /Avila 2006b/ in two ways. Firstly, the equation in this study is applied to the elements rather that to the radionuclides, as was done in /Avila 2006b/. This means that the radionuclide decay is disregarded, which is considered appropriate for long lived radionuclides. Secondly, the equation in /Avila 2006b/ calculates CR for the whole body of the herbivore, whereas here the CRs refer to soft tissues. To account for this a correction factor, *fracSoft-Tissues*, was introduced.

As in /Avila 2006b/, the biological half time, the DMI and the life duration of the animal were calculated using the following allometric relationships:

$DMI = a1 * Weight^{b1}$ $Tbioli = a2_i * Weight^{b2i}$ $Tlife = a3 * Weight^{b3}$

The values of the coefficients *a* and *b* in the above allometric relationships are given in Table 2-1 and Table 2-2 where the units and references are indicated. The values of other parameters used in the calculation of the CR for herbivores are presented in Table 2-3 and Table 2-4.

Table 2-1. Best Estimate values of the multiplicant (a2) and exponent (b2) in of the allometric relationship for the biological half time (T_{biol}) in herbivores of different elements (Values taken from /Avila 2006b/ and reference therein).

Element	a2 (days)	b2 (relative units)
Am	1.1E+03	7.3E-01
Cl	2.4E+00	2.5E-01
Cs	1.3E+01	2.4E-01
I	1.7E+01	1.3E-01
Pu	1.1E+03	7.3E-01
Ra	2.8E+02	1.8E-01
Sr	6.4E+02	2.6E-01
Tc	4.8E+00	4.0E-01
Th	8.9E+02	8.0E-01
U	5.5E+00	2.8E-01
Zr	5.6E+02	2.5E-01

Table 2-2. Best Estimate (BE) of the multiplicant (a1) and exponent (b1) in of the allometric relationship for the DMI and multiplicand (a3) and exponent (b3) in of the allometric relationship for the life duration of herbivores (Values taken from /Avila 2006b/ and reference therein).

Parameter/ Units	BE
a1. kg/d	6.6E-02
b1. r.u	6.3E-01
a3. d	3.7E+02
b3. r.u	3.5E-01

Table 2-3. Gut uptake fraction ($fraUptake_i$) for the different elements (dimensionless).

Element	BE	Min	Max	Distribution	Reference	Comment
Ac	5.0E-04	–	–	–		
Ag	5.6E-02	1.7E-02	1.5E-01	Uniform	/IAEA 2010/	Adult ruminants
Am	1.4E-04	6.0E-05	5.0E-04	Uniform	/IAEA 2010/	Adult ruminants
Ca	3.0E-01	8.0E-02	4.2E-01	Uniform	/IAEA 2010/	Adult ruminants
Cd	–	–	–	–		
Cl	9.0E-01	7.1E-01	1.0E+00	Uniform	/IAEA 2010/	Adult ruminants
Cm	5.0E-04	3.0E-04	5.0E-04	Uniform	/IAEA 2010/	Value for adult human
Cs	8.0E-01	6.7E-01	9.3E-01	Uniform	/IAEA 2010/	Adult ruminants
Eu	–	–	–	–		
Ho	5.0E-04	1.0E-05	3.0E-03	Uniform	/ICRP 2006b/ /Coughtrey and Thorne 1983/	Value for workers
I	9.8E-01	7.0E-01	1.1E+00	Uniform	/IAEA 2010/	Adult ruminants
Mo	–	–	–	–		
Nb	1.4E-03	5.0E-04	1.0E-02	Uniform	/IAEA 2010/	Adult ruminants
Ni	5.0E-02	1.0E-02	1.0E-01	Uniform	/IAEA 2010/	Value for adult human
Np	1.0E-03	1.0E-03	1.0E-02	Uniform	/Avila 2006b/, /Coughtrey and Thorne 1983/	
Pa	5.0E-04	3.0E-04	5.0E-04	Uniform	/IAEA 2010/	Value for workers
Pb	4.0E-02	1.0E-02	1.1E-01	Uniform	/IAEA 2010/	Adult ruminants
Pd	5.0E-03	–	–	–	/IAEA2001/	
Po	5.0E-01	–	–	–	/IAEA 2010/	Adult humans
Pu	8.5E-05	6.5E-05	1.2E-04	Uniform	/IAEA 2010/	Adult ruminants
Ra	2.0E-01	–	–	–	/Avila 2006b/	
Se	5.2E-01	4.0E-01	6.5E-01	Uniform	/IAEA 2010/	
Sm	5.0E-04	1.0E-05	3.0E-03	Uniform	/ICRP 2006b/	Value for workers
Sn	2.0E-02	1.0E-02	5.0E-02	Uniform	/ICRP 2006b/	Value for workers
Sr	1.1E-01	5.5E-02	2.7E-01	Uniform	/IAEA 2010/	Adult ruminants
Tc	1.0E-01	1.0E-02	1.0E-01	Uniform	/Avila 2006b/ /Thorne 2003/	Range 0.01–0.1
Th	2.0E-04	–	–	–	/Avila 2006b/	
U	1.1E-02	1.0E-02	1.2E-02	Uniform	/IAEA 2010/	Adult ruminants
Zr	6.8E-03	4.0E-04	2.0E-03	Uniform	/IAEA 2010/	Adult ruminants

Table 2-4. Fraction in soft tissues ($fraSoftTissues_i$) of the total content of the different elements in herbivores (dimensionless).

Element	BE	Min	Max	Distribution	Reference	Comment
Ac	1.0E+00	–	–	–		Conservative assumption
Ag	1.0E+00	–	–	–		Conservative assumption
Am	6.0E-01	1.0E-01	7.0E-01	Triangular	/Brown et al. 2003/	
Ca	9.0E-02	–	–	–		Same as Sr
Cd		–	–	–		
Cl	1.0E+00	–	–	–	/Brown et al. 2003/	
Cm	6.0E-01	–	–	–	/Brown et al. 2003/	
Cs	1.0E+00	1.0E+00	1.5E+00	Uniform	/Brown et al. 2003/	
Eu		–	–	–		
Ho	1.0E+00	–	–	–		Conservative assumption
I	1.0E+00	–	–	–	/Brown et al. 2003/	
Mo		–	–	–		
Nb	3.0E-01	–	–	–	/Brown et al. 2003/	
Ni	1.0E+00	–	–	–	/Brown et al. 2003/	
Np	5.0E-01	1.0E-01	7.0E-01	Triangular	/Brown et al. 2003/	
Pa	6.0E-01	1.0E-01	7.0E-01	Triangular	same as Am	
Pb	1.0E+00	–	–	–		Conservative assumption
Pd	1.0E+00	–	–	–		Conservative assumption
Po	1.0E+00	–	–	–		Conservative assumption
Pu	6.0E-01	1.0E-01	7.0E-01	Triangular	/Brown et al. 2003/	
Ra	9.0E-02	–	–	–	same as Sr	
Se	1.0E+00	–	–	–		Conservative assumption
Sm	1.0E+00	–	–	–		Conservative assumption
Sn	1.0E+00	–	–	–		Conservative assumption
Sr	9.0E-02	–	–	–	/Brown et al. 2003/	
Tc	1.0E+00	–	–	–	/Brown et al. 2003/	
Th	6.0E-01	1.0E-01	7.0E-01	Triangular	same as Pu	
U	6.0E-01	1.0E-01	7.0E-01	Triangular	same as Am	
Zr	1.0E+00					Conservative assumption

For most parameters required, values could be found in the literature; or it was possible to assign them an appropriate conservative value. An exception was the biological half time, for which values could not be found for several elements of interest (see Table 2-1) and it is difficult to defined a conservative value for this parameter. For elements that have a biological half time that is much longer than the life duration of the herbivore the following simplified equation can be applied for CR calculations, which was used here for cautious estimation of CRs when values of biological half times were missing:

$$CR_i = \frac{DMI * fraUptake_i * fraSoftTissues_i * Tlife}{Weight}$$

To obtain BE values of the CRs, deterministic simulations were carried out with the above model using the BE values given in Table 2-1, Table 2-2, Table 2-3 and Table 2-4 for the different parameters. The deterministic simulations were carried out for roe deer (21.3 kg FW) and moose (279 kg fw), which were the herbivores considered in the dose calculations for derivation of Landscape Dose Factors /Avila et al. 2010/. The average CRs for these two herbivores was selected as BE value for the deterministic simulations in /Avila et al. 2010/. As for other CRs, it was assumed that the values of CRs for herbivores will follow a lognormal distribution. The distribution parameters (GM and GSD) were obtained from probabilistic simulations with the model, using the distributions indicated in Table 2-3 and Table 2-4 for the different parameters. The weight of the herbivores (in kg fw) was assigned a uniform distribution ranging between 5 and 500 kg fw. Parameters that were given conservative values or that had no probability distributions assigned were kept constant in the probabilistic simulations. For each element 1,000 iterations of the model were carried out using Latin Hypercube sampling. In these simulations parameter correlations were not taken into account.

2.5 Use of analogues

The amount of data available for the different CRs treated in this report differs significantly for different elements but also for different environmental media. When data for a specific parameter and element were lacking the principle of analogues was applied. The first analogue was the use of data for stable isotopes for radionuclides as well. This type of analogue was used widely in this report and is not regarded as controversial, since different isotopes are assumed to show the same chemical behaviour in the environment. The exception is light elements (e.g. hydrogen) as well as short-lived isotopes, which may not have reached equilibrium in the environmental media.

The second analogue was the use of data for the same element, but for another biota type. For example, site-specific data for freshwater filter feeders were used also for freshwater crustaceans (see Section 5.1.4), for which no site-specific data were available. The principle of using data for the same element, but for different biota types was also applied in those cases where site-specific data were lacking for freshwater or marine microphytobenthos. Site-specific data for macrophytes from the same ecosystem were used as the first choice (see Section 5.1.2 and 5.2.2). Site-specific data for macrophytes were also used for phytoplankton as a first-choice substitute in both marine and freshwater ecosystems (Section 5.1.1 and 5.2.1). It was concluded that the introduced errors are acceptable and less severe than those introduced when using literature data for the right type of primary producer. For some elements the amount of available data were very restricted (no site-specific and little or no literature data). In such cases, data for the same kind of organism but from a different ecosystem (marine versus freshwater) were used. For example, CR values for marine water plants have also been applied for freshwater primary producers (Sections 5.2.1–5.2.3). This was done for Pd, Pa, Sn and Ac as specified in Chapter 5. In these cases, the relevance of the assigned values is very hard to judge. Fortunately, these elements have not been shown to be of importance for dose to humans in earlier safety assessments.

3 K_d values for regolith and suspended matter

3.1 Definitions

In safety assessment of nuclear facilities solid/liquid distribution coefficients (K_d) have been widely used to describe the sorption and retention of radionuclides. In SR-Site, K_ds were used to describe the relationship between the amount of element associated with the solid phase and the amount of element in solution. K_ds were used both for soil/sediment (related to pore water), or suspended matter (related to filtered water). These K_ds are defined as the ratio between the element concentrations in the solid ($[X]_{solid}$)and liquid ($[X]_{solution}$) phases:

$K_d(X) = [X]_{solid} / [X]_{solution}$

and are expressed as (Bq/kg dw)/(Bq/m^3) = m^3/kg dw

In the process of measurement of K_ds the measured concentrations in the solid phase include traces of elements from the liquid phase that dried onto the solid. The measured K_d values have therefore been corrected to make sure that they are consistent with the above definition. The correction consists of substracting, from the measured K_d values, the moisture content (expressed in the same units as the K_d) of the solid sample just before it was dried for analysis. This correction is relevant only for elements with very low K_d (Cl, Tc), but is quite important for them.

In the safety assessment SR-Site the following types of K_d were used:

- The K_d for the lower layer of the regolith in both terrestrial and aquatic environments consisting of inorganic deposits (kD_regoLow).
- The K_d for organic deposit layers of terrestrial and aquatic environments (Ter_regoUp, Ter_regoMid, Lake_regoUp, Lake_regoMid, Sea_regoUp and Sea_regoMid).
- The K_d for suspended particulate matter in limnic environments, i.e. lakes and running waters (Lake_kD_PM).
- The K_d for suspended particulate matter in marine environments (Sea_kD_PM).

3.1.1 Inorganic and organic deposits

In the Radionuclide Model for the biosphere /Avila et al. 2010/, the regolith of biosphere objects is divided vertically into three layers; regoLow, regoMid and regoUp, as described in Figure 1-2 and Table 1-1. In both terrestrial and aquatic ecosystems, the lower layer (regoLow) is defined as the inorganic layer of glacial till (Figure 1-2 and Figure 3-1). The intermediate layer (regoMid) is divided into one aquatic and one terrestrial part consisting of postglacial deposits such as gyttja, gyttja clay (regomid_PG in Figure 3-1) and glacial clay (regomid_GL in Figure 3-1). The uppermost layer (regoUp) is divided into three parts; one limnic (Lake_regoUp), one marine (Sea_regoUp) and one terrestrial (Ter_regoUp). The layers Lake_regoUp and Sea_regoUp are defined as the uppermost bioturbated part of the organic layer. For lakes this corresponds approximately to the upper most 5 cm of the sediments /Andersson 2010/ and for sea areas this layer is approximately 10 cm deep /Aquilonius 2010/. The Ter_regoUp is defined as the peat layer /Löfgren 2010/.

In the Radionuclide Model for the biosphere /Avila et al. 2010/, it is assumed that radionuclides released from the repository enter the biosphere from the bedrock to the regolith via deep groundwater discharge and first reaches the till layer represented by the compartment regoLow. From there the radionuclides are transported upwards to the regolith layers regoMid and regoUp in aquatic and terrestrial environments respectively (see Figure 1-2). During the simulation, the modelled object will undergo a succession from open sea to a wetland. When this succession take place the deposits defined as regoMid and regoUp in aquatic environments (and its inventory of radionuclides) are transferred to the Ter_regoMid layer see Figure 3-1. When the wetland has emerged to sufficiently high elevation above the sea level, human inhabitants may drain and subsequently use wetlands for crop and livestock production /Lindborg 2010/. The organic layers (peat and gyttja) on drained and cultivated

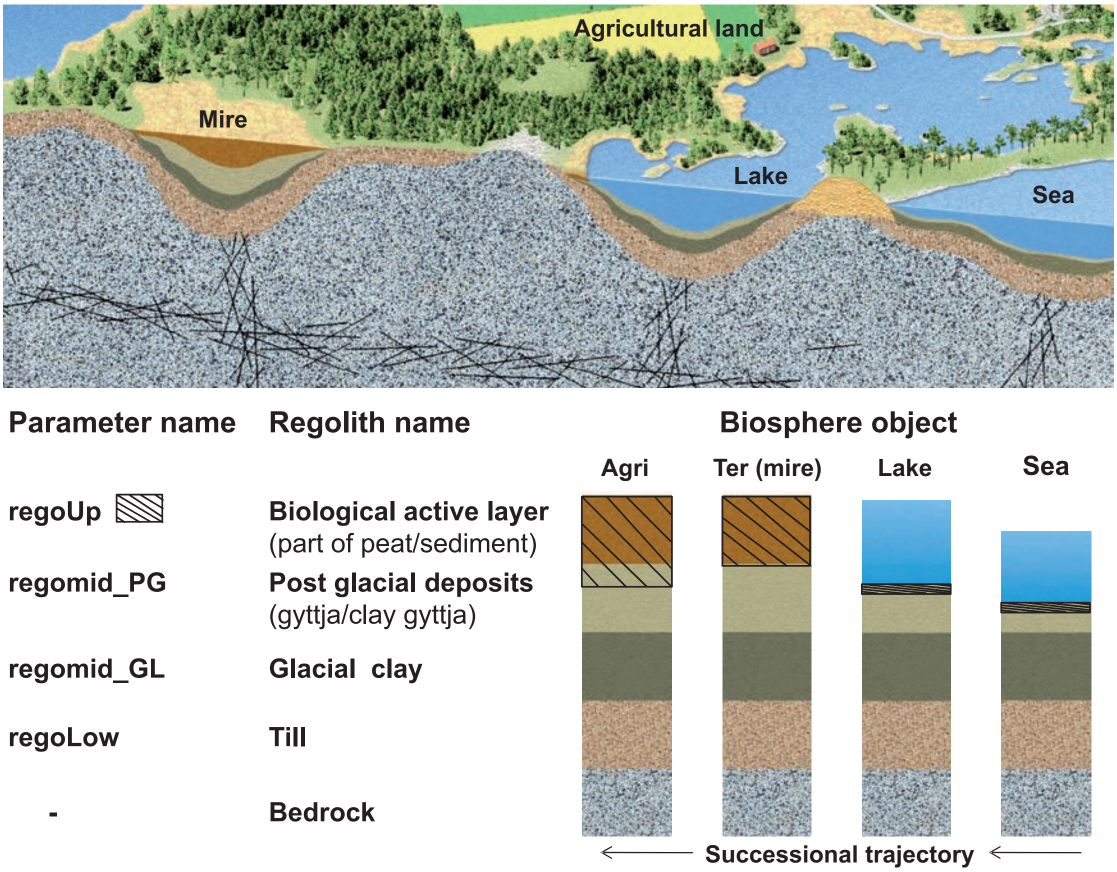

Figure 3-1. The conceptual model of the generalised distribution of the regolith for different types of biosphere objects in SR-Site. The different depths of the various regolith layers in soil profiles are also seen in the landscape pictures, which represents a generalized successional trajectory from sea to mire that is later converted to agricultural land by draining. In the Radionuclide Model for the biosphere, the postglacial (regomid_PG) and the glacial clay (regomid_GL) deposits are joined together and the name of this combined layer (regoMid) was used in this report.

wetlands will rapidly become oxidized and compacted, resulting in an agricultural soil which is a mixture of contaminated organic matter and deeper mineral layers (glacial and postglacial deposits), where radionuclides may have accumulated since the early sea stage /Lindborg 2010/. In the model, this soil layer was given properties of an organogenic soil.

The regoLow layer is assumed to be similar in composition irrespective of which ecosystem it belongs to (sea, lake or mire). The same is also true for the regoMid layer. During the development of a marine bay through lacustrine (lake) and terrestrial phases, the same deposits are assumed to be situated at the same site, although the depth of sediment increases with time as a consequence of sedimentation processes. Characteristics such as porosity, grain size, organic contents and chemical composition of the solid phase change slowly during shore line displacement and transformation process. The chemical composition of the pore water may change at a considerably faster rate, due to e.g. altered hydrological conditions.

In the case of the Radionuclide Model for the biospere, K_d values of deposits are intended to describe the relationship between sediment or soil and associated pore water concentrations, since the inflow of radionuclides are assumed to be via contaminated groundwater reaching the system from below. The K_d values found in the literature usually do describe this relationship for terrestrial areas. For aquatic areas most of the earlier studies estimated the ratio between sediment and lake/sea water (not the sediment pore water). This is used for describing sorption of elements from the surface water phase. Thus many of the literature K_d values of aquatic sediment are of little relevance for our approach since our K_d of deposits are intended to describe the relationship between sediment or soil and associated pore water concentrations.

As mentioned earlier, the goal was to use site-specific data whenever possible. As described in Chapter 2, the number of observations is crucial to how much emphasis is given to the site-specific information. As the site-specific observations were distributed among different deposits distinguished in the model, the number of observation per deposit type was often too low to have any impact on the chosen GM and GSD. We have instead merged all site-specific regolith data into two groups in order to get sufficient numbers of site-specific observation per group. The two groups were: inorganic regolith (till samples) and organic regolith (organic soils, and lake and sea sediments). For the first group, inorganic regolith, the influence of site-data is still very small, but for the organic regolith site-specific characteristics have an influence on the choice of parameter values. This means that for each element two different K_d values are used for regolith in SR-Site: one value for the regoLow layer and one value for the Ter_regoUp, Ter_regoMid, Lake_regoUp, Lake_regoMid, Sea_regoUp, and Sea_regoMid layers. The implication of the simplification in two groups is further discussed in /Tröjbom and Nordén 2010/.

3.2 Values for inorganic deposits

The site-specific chemistry data from Forsmark and Laxemar-Simpevarp were used when calculating site-specific K_d are compiled in /Tröjbom and Nordén 2010/. The amount of site-specific data is small. Data were available for 17 of the 29 elements considered in the simulations. The number of observations varied between 2 and 5 for different elements depending on how many of the data are above the reported detection limits. For the 9 elements that had 5 site observations, the Bayesian method “prior from population” was used, and also for Se and Eu which had 4 site observations each. For the remaining 6 elements the Bayesian method “prior from subpopulation” was used (for further details about the two methods and the reasoning for using either of them, see Chapter 2). For Ni the Bayesian method “prior from population” was used for the probabilistic calculation although the other method was recommended by the rules set. This was because of the large differences observed between the GMs of the site and literature data, which clearly contradicts the hypothesis that they belong to the same sub-population. Generally, the site-specific K_d values were higher than the literature K_d values used in the Bayesian inference methods. The only exceptions were Se, which had lower site-specific values than the values reported in the literature, and Zr, for which the site-specific data and literaturedata were close to each other.

In the case of the 12 elements for which site-specific data were lacking, literature data /IAEA 2010/ were used, where K_d values are presented for different soil types: sand, loam, clay and organic, and for all soil types together. For some elements a best estimate for mineral soils was specified, and in that case these values were used, otherwise the value for all soil types was chosen.

In the case of Ra, 18 site-specific samples of inorganic soil were available from a recent site investigation in Forsmark. This site-specific data have no yet been published and therefore a compilation of the data, together with a description of the sampling and analysis methods is included in Appendix B. The Kd value for Ra are based on the statistics for site-specific data alone since the number of samples was sufficiently large.

The assigned K_d values for inorganic deposits (regoLow) are presented in Table 3-1. All data used for this parameter (kD_regoLow) are valid for surface soil samples, although they should represent subsoil (see definition in Section 3.1.1). The main differences between surface soil and subsoil, concerning retention of elements in deposits, are the amount of organic matter (higher in surface soils) and redox conditions (reducing in subsoils, mainly oxidising in surface soils). Organic matter is generally considered to increase retention of elements in soils, but due to the low organic matter content in surface mineral soils /Sheppard et al. 2009/ the effect of organic matter on sorption is limited. The affect of the redox potential on retention can vary between elements. Low redox potential often results in increasing mobility of trace elements, but no effect or the opposite effect is possible.

Table 3-1. K_d values for the regolith layer "regoLow" (kD_regoLow) used in the Radionuclide Model for the biosphere. Parameter values are given in m^3/kg dw. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.2E+00	1.2E+00	2.0	Literature data /IAEA 2010/
Ag	1.4E-01	1.4E-01	3.0	Literature data /IAEA 2010/
Am	2.6E+00	2.6E+00	6.0	Literature data /IAEA 2010/[1]
Ca	3.4E-02	3.4E-02	1.7	Prior from population
Cd	2.4E-01	2.4E-01	8.4	Prior from population
Cl	4.4E-04	4.4E-04	4.7	Prior from subpopulation
Cm	9.3E+00	9.3E+00	4.0	Literature data /IAEA 2010/[1]
Cs	3.6E+01	3.6E+01	4.1	Prior from population
Eu	1.1E+01	1.1E+01	5.5	Prior from population
Ho	5.2E+00	5.2E+00	9.7	Prior from subpopulation
I	7.1E-03	7.1E-03	5.1	Prior from subpopulation
Mo	1.5E-01	1.5E-01	3.3	Prior from population
Nb	1.9E+00	1.9E+00	5.3	Prior from subpopulation
Ni	3.1E-01	1.8E+00	4.0	Prior from population
Np	2.0E-02	2.0E-02	4.0	Literature data /IAEA 2010/
Pa	1.4E+00	1.4E+00	2.0	Literature data /IAEA 2010/
Pb	7.7E+00	7.7E+00	5.4	Prior from population
Pd	1.4E-01	1.4E-01	2.0	Literature data /IAEA 2010/
Po	2.1E-01	1.9E-01	5.0	Literature data /IAEA 2010/
Pu	7.4E-01	7.4E-01	4.0	Literature data /IAEA 2010/[1]
Ra	2.5E+00[2]	7.3E+00	2.2	Site-specific data
Se	2.2E-02	2.2E-02	2.6	Prior from population
Sm	5.0E+00	5.0E+00	13	Prior from subpopulation
Sn	2.9E-01	2.9E-01	2.0	Literature data /IAEA 2010/
Sr	3.2E-01	3.2E-01	2.9	Prior from population
Tc	6.0E-05	6.0E-05	4.0	Literature data /IAEA 2010/
Th	3.2E+01	3.2E+01	15	Prior from population
U	1.5E+00	1.5E+00	3.3	Prior from population
Zr	4.7E-01	4.7E-01	1.6	Prior from population

[1] Value for all soil types.
[2] /IAEA 2010/.

3.3 Values for organic deposits

As mentioned above the same K_d values were used for the regolith layers Ter_regoUp, Ter_regoMid, Lake_regoUp, Lake_regoMid, Sea_regoUp and Sea_regoMid in SR-Site. In the following text the term Ter_regoUp will be used for all these deposit layers.

The site-specific chemistry data from Forsmark and Laxemar-Simpevarp used when calculating site-specific K_ds are compiled in /Tröjbom and Nordén 2010/. The amount of site-specific data is greater than for inorganic deposits (regoLow, see section above). Data were available for 19 of the 29 elements considered in the simulations. The number of observations varied between 11 and 29 for different elements depending on how many of the data were above the reported detection limits. The Bayesian method "prior from population" was used for five elements, whereas the method "prior from subpopulation" was recommended for the other 10 according to the rules set (see Chapter 2). For these elements, the statistics for site-specific data alone were used as best estimate, whereas the results from "Prior from subpopulation" were used as GMs and GSDs of the PDFs. For four elements (Ag, Cl, Th and U) the results from "Prior from population" were used in the probabilistic calculations since the other method gave unrealistic large GSD values (24, 10, 13 and 5, respectively). Although, the GSD of 5 obtained for U could be condered realistic, the differences in GMs between the site and literature data was too large for considering that they belong to the same sub-population. The reason for using only site-specific data as best estimate was to give priority to site-specific information, since the number of site-specific observations is quite high for this parameter (for all elements except Ag at least 20 observations). For Eu statistics based on site-specific data alone was used as the number of observations for the literature data were not known. The site-specific GMs are somewhat higher for all considered elements than the corresponding values from the Bayesian statistics, but the differences are often marginal.

In the case of Ra, 30 site-specific samples of organic soil were available from a recent site investigation. This site-specific data have no yet been published and therefore a compilation of the data, together with a description of the sampling and analysis methods is included in Appendix B. The K_d value for Ra are based on the statistics for site-specific data alone since the number of samples was sufficiently large.

It should be noted that the literature data only represent organic soils and do not include sediment data, whereas the site-specific data do include sediment data (see Section 3.1.1). In the case of the 10 elements for which site-specific data were lacking, literature data were used. The literature source used was /IAEA 2010/. In this report K_d data are presented for different soil types: sand, loam, clay, organic, and for all soil types together. If the number of observations for organic soils was sufficient (>10), the GM for this soil type was used, otherwise the GM for all soil types was chosen. For two elements (Np and Po), data for organic soils were used despite the low number of observations (4 and 1 respectively). The K_d values provided in /IAEA 2010/ for organic soils were approximatley 40 times higher than those for inorganic soils (0.8 m^3/kg dw compared to 0.02 m^3/kg dw for Np and 7 m^3/kg dw compared to 0.2 m^3/kg dw for Po). The values provided for all soil types are closer to the inorganic values than to organic, so the values for organic soils were used.

The assigned K_d values for organic deposits (Ter_kD_regoUp, Ter_kD_regoMid, Lake_kD_regoUp, Lake_kD_regoMid, Sea_kD_regoUp and Sea_kD_regoMid) are presented in Table 3-2. For most elements, GMs and GSDs were available from the same data source as used for the best estimate. The only exception was for Po. For this element a value was provided for organic soils in /IAEA 2010/ that was based on only one observation. In the absence of information, this value was used as the GM in the probabilistic calculations and used together with the median GSD for all soil types (based on 44 observations).

Table 3-2. K_d values for the regolith layers Ter_regoUp, Ter_regoMid, Lake_regoUp, Lake_regoMid, Sea_regoUp and Sea_regoMid used in the Radionuclide Model for the biosphere. Parameter values are given in m^3/kg dw. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.7E+00	1.7E+00	3.0	Literature data /IAEA 2010/[2]
Ag	6.2E+01	5.2E+01	3.5	Site-specific data. GM and GSD prior from population
Am	2.5E+00	2.5E+00	5.0	Literature data /IAEA 2010/[1]
Ca	6.3E-02	1.5E-02	5.0	Site-specific data. GM and GSD prior from subpopulation
Cd	4.3E+00	2.4E+00	19	Site-specific data. GM and GSD prior from subpopulation
Cl	1.0E-02	1.1E-02	3.5	Site-specific data. GM and GSD prior from population
Cm	9.3E+00	9.3E+00	4.0	Literature data /IAEA 2010/[2]
Cs	2.6E+01	2.6E+01	2.2	Prior from population
Eu	8.6E+00	8.6E+00	5.4	Site-specific data
Ho	1.2E+01	8.2E+00	4.7	Site-specific data. GM and GSD prior from subpopulation
I	7.1E-01	2.4E-01	7.6	Site-specific data. GM and GSD prior from subpopulation
Mo	1.1E+00	4.8E-01	8.8	Site-specific data. GM and GSD prior from subpopulation
Nb	4.0E+01	4.0E+01	3.8	Prior from population
Ni	3.0E+00	1.9E+00	4.3	Site-specific data. GM and GSD prior from subpopulation
Np	8.1E-01	8.1E-01	1.3	Literature data /IAEA 2010/[1]
Pa	2.0E+00	2.0E+00	3.0	Literature data /IAEA 2010/[2]
Pb	4.3E+01	2.8E+01	5.8	Site-specific data. GM and GSD prior from subpopulation
Pd	1.8E-01	1.8E-01	2.0	Literature data /IAEA 2010/[2]
Po	6.6E+00	6.6E+00	5.0	Literature data /IAEA 2010/. Arithmetic mean value[1, 3]
Pu	7.4E-01	7.4E-01	4.0	Literature data /IAEA 2010/[2]
Ra	2.5E+00[4]	2.3E+00	2.1	Site-specific data
Se	5.3E-01	2.3E-01	3.8	Site-specific data. GM and GSD prior from subpopulation
Sm	1.1E+01	7.8E+00	5.3	Site-specific data. GM and GSD prior from subpopulation
Sn	8.0E+00	8.0E+00	3.6	Prior from population
Sr	1.2E-01	1.2E-01	2.7	Prior from population
Tc	3.0E-03	3.0E-03	3.0	Literature data /IAEA 2010/[1]
Th	4.2E+01	4.2E+01	3.7	Site-specific data. GM and GSD prior from population
U	6.5E+00	6.3E+00	3.4	Site-specific data. GM and GSD prior from population
Zr	5.6E+00	5.6E+00	16	Prior from population

[1] Value for organic soils.
[2] Value for all soil types.
[3] GSD for all soil types.
[4] /IAEA 2010/.

3.4 Values for suspended matter in marine ecosystems

The site-specific chemistry data from Forsmark and Laxemar-Simpevarp used when calculating site-specific concentration ratios are compiled in /Tröjbom and Nordén 2010/. The amount of site-specific data concerning suspended matter in marine environments is rather small. Data were available for 18 of the 29 elements considered in the simulations. The number of observations varies between 1 and 8 for different elements depending on how many of the data were above the reported detection limits. No literature data were found for Ca thus statistics for the site-specific data were used (GM and GSD). For Cl, only one site-specific observation was available (0.0005 m^3/kg dw) and the number of observations in literature data were not reported. The value given by /IAEA 2004/ was used as recommended by /Sheppard et al. 2009/. It is close to the site-specific value (a factor of 2 higher).

The Bayesian inference method "prior from population" was used for 14 elements, while the method "prior from subpopulation" was used for the other 2. The reason for using the "prior from subpopulation" method was mainly the low number of literature observations (<10) and for Se the GSD for site-specific data were also larger than the GSD for literature data. For Sn the method "prior from population" was used, although the number of site observations was only 3. There was no information on the number of literature observation so the method "prior from subpopulation" could not be used. Geometric mean values for site-specific data and literature data are very close (48 and 33 m^3/kg respectively). Generally, the site-specific data were higher than the literature data used in the Bayesian inference methods. Exceptions to this were Ni and Th, for which the literature data were higher.

In the case of the 11 elements for which site-specific data were lacking, literature data were used. For six elements (Ag, Am, Cm, Np, Po and Tc) the literature source used was /Beresford et al. 2007/. For Pa and Pu the recommended literature values from /Sheppard et al. 2009/ were used. The value for Pa was based on 4 different studies and includes more than 95 observations whereas the value for Pu was based on 15 studies with more than 541 observations (see /Sheppard et al. 2009/). For Ra the value from /IAEA 2004/ was chosen as recommended by /Sheppard et al. 2009/. The value used in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ was used for Ac and Pd.

The assigned K_d values for suspended particulate matter in marine environments (Sea_kD_PM) are presented in Table 3-3. The assigned K_d values were compared to the literature data presented in Table 6-1 in /Sheppard et al. 2009/ and for most elements the values are of the same order of magnitude. For Cs, I and Se the values based on site-specific data are higher than the literature data (approximately 5–20, 20–100 and 3–10 times higher, respectively), while the value for Sn is approximately 10 times lower.

The values from /Beresford et al. 2007/ are all AMs presented without any statistical information. In the absence of better information, these values were used as GMs in the probabilistic calculations together with the GSD for the same element taken from limnic environments (Lake_kD_PM). The same is true for Pa, for which the best estimate was from /Sheppard et al. 2009/. For Tc, the AM from /Beresford et al. 2007/ and the GSD from /Sheppard et al. 2009/ were taken. In the absence of information the highest GSD of the parameters Lake_kD_PM and Sea_kD_PM for any element (the GSD for Pu for Lake_kD_PM) was used for Cl.

Table 3-3. K_d values for suspended particulate matter in marine environments "Sea_kD_PM" used in the Radionuclide Model for the biosphere. Parameter values are given in m^3/kg dw. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.0E+01	1.0E+01	3.2	Literature data /Karlsson and Bergström 2002/
Ag	1.0E+01	1.0E+01	2.3	Literature data /Beresford et al. 2007/
Am	2.0E+03	2.0E+03	5.7	Literature data /Beresford et al. 2007/
Ca	2.7E-01	2.7E-01	8.6	Site-specific data
Cd	7.7E+01	7.7E+01	11	Prior from population
Cl	1.0E-03	1.0E-03	25	Literature data /IAEA 2004/[1]
Cm	2.0E+03	2.0E+03	9.6	Literature data /Beresford. et al. 2007/
Cs	1.1E+01	1.1E+01	6.7	Prior from population
Eu	2.0E+02	2.0E+02	2.5	Prior from population
Ho	4.6E+01	4.6E+01	5.1	Prior from population
I	3.3E+00	3.3E+00	2.1	Prior from population
Mo	1.6E-01	1.6E-01	17	Prior from population
Nb	2.0E+02	2.0E+02	4.7	Prior from population
Ni	1.4E+01	1.4E+01	1.4	Prior from population
Np	1.0E+00	1.0E+00	4.9	Literature data /Beresford et al. 2007/
Pa	1.1E+03	1.1E+03	3.2	Literature data /Sheppard et al. 2009/
Pb	2.5E+02	2.5E+02	2.7	Prior from population
Pd	1.0E+01	1.0E+01	3.2	Literature data /Karlsson and Bergström 2002/
Po	2.0E+04	2.0E+04	3.2	Literature data /Beresford et al. 2007/
Pu	1.2E+03	1.2E+03	25	Literature data /Sheppard et al. 2009/
Ra	4.0E+00	4.0E+00	3.1	Literature data /IAEA 2004/
Se	3.4E+00	3.4E+00	16	Prior from subpopulation
Sm	4.2E+02	4.2E+02	2.2	Prior from population
Sn	4.7E+01	4.7E+01	2.6	Prior from population
Sr	1.9E-02	1.9E-02	21	Prior from subpopulation
Tc	1.0E-01	1.0E-01	4.6	Literature data /Beresford et al. 2007/
Th	1.0E+03	1.0E+03	4.9	Prior from population
U	1.2E+00	1.2E+00	2.7	Prior from population
Zr	2.6E+02	2.6E+02	4.3	Prior from population

[1] GSD maximum GSD of all "Sea_kD_PM" and "Lake_kD_PM".

3.5 Values for suspended matter in limnic ecosystems

The site-specific chemistry data from Forsmark and Laxemar-Simpevarp used when calculating site-specific concentration ratios are compiled in /Tröjbom and Nordén 2010/. The amount of site-specific data concerning suspended matter in limnic environments is similar tor suspended matter in marine environments. Data were available for 17 of the 29 elements considered in the simulations. The number of observations varies between 2 and 7 for different elements, depending on how much of the data were above the reported detection limits. No literature data were found for Ca so the statistics for the site-specific data alone were used (GM and GSD).

The Bayesian method "prior from population" was used for 12 elements whereas the method "prior from subpopulation" was used for 3 elements. For Se the statistics for site-specific data alone were used since the number of observations in literature data was not known and the GMs and GSDs for site-specific data and literature data were very similar (GM 8.4, GSD 2.1 for site-specific data and GM 3.2 GSD 1.8 for literature data).

The reason for using the "prior from subpopulation" method was, for Ag, the low number of site observations and for Ho and Sr a larger GSD for site-specific data than for literature data. For Cs, I, Nb, Ni, Pb, Th and Zr the site-specific data were higher than the literature data used in the Bayesian inference methods. For the other five elements (Ag, Ho, Sr, Sm and U) the literature data were higher.

In the case of the 12 elements for which site-specific data were lacking, literature information was used. For six elements (Am, Cm, Np, Pu, Ra and Tc) the literature source used was /IAEA 2010/. If possible, field measurements were chosen instead of laboratory studies. The value for Po was taken from /Karlsson and Bergström 2002/. No value was provided in /IAEA 2010/ and the value provided in /Beresford et al. 2007/ was much higher than that used in earlier safety assessments (20,000 m^3/kg compared to 100 m^3/kg). For Cl the recommended literature value from /Veselý et al. 2001/ provided in /Sheppard et al. 2009/ was used. The values used in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used for Ac, Pa, Pd and Sn.

The assigned K_d values for suspended particulate matter in limnic environments (Lake_kD_PM) are presented in Table 3-4. The assigned K_d values were compared to the literature data presented in Table 6-1 in /Sheppard et al. 2009/ and for most elements the values are of the same order of magnitude. For I, Nb, Ni and Se the values based on site-specific data are higher than the provided literature data. For all elements, except Cl, GMs and GSDs were available in the same data sources as used for the best estimate. In the absence of information, the highest GSD of the parameters Lake_kD_PM and Sea_kD_PM for any element (the GSD for Pu for Lake_kD_PM) was used for Cl.

Table 3-4. K_d values for suspended particulate matter in limnic environments "Lake_kD_PM" used in the Radionuclide Model for the biosphere. Parameter values are given in m^3/kg dw. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.0E+01	1.0E+01	3.2	Literature data /Karlsson and Bergström 2002/
Ag	9.3E+01	9.3E+01	2.3	Prior from subpopulation
Am	1.2E+02	1.2E+02	5.7	Literature data /IAEA 2010/
Ca	7.0E-01	7.0E-01	3.2	Site-specific data
Cd	8.6E+01	8.6E+01	4.0	Prior from population
Cl	9.8E-02	9.8E-02	25	Literature data /Veselý et al. 2001/[1]
Cm	5.0E+00	5.0E+00	9.6	Literature data /IAEA 2010/
Cs	9.7E+01	9.7E+01	3.2	Prior from population
Eu	5.8E+01	5.8E+01	2.9	Prior from population
Ho	1.6E+02	1.6E+02	2.2	Prior from subpopulation
I	1.0E+01	1.0E+01	3.7	Prior from population
Mo	6.8E+00	6.8E+00	5.3	Prior from population
Nb	2.3E+02	2.3E+02	3.2	Prior from population
Ni	2.6E+01	2.6E+01	2.3	Prior from population
Np	1.0E-02	1.0E-02	4.9	Literature data /IAEA 2010/
Pa	1.0E+02	1.0E+02	3.2	Literature data /Karlsson and Bergström 2002/
Pb	5.4E+02	5.4E+02	2.9	Prior from population
Pd	2.0E+00	2.0E+00	3.2	Literature data /Karlsson and Bergström 2002/
Po	1.0E+01	1.0E+01	3.2	Literature data /Karlsson and Bergström 2002/
Pu	2.4E+02	2.4E+02	6.6	Literature data /IAEA 2010/
Ra	7.4E+00	7.4E+00	3.1	Literature data /IAEA 2010/
Se	8.4E+00	8.4E+00	2.1	Site-specific data
Sm	1.4E+02	1.4E+02	3.6	Prior from population
Sn	5.0E+01	3.2E+01	1.8	Literature data /Karlsson and Bergström 2002/
Sr	1.1E+00	1.1E+00	3.0	Prior from subpopulation
Tc	5.0E-03	5.0E-03	4.6	Literature data /IAEA 2010/
Th	3.0E+02	3.0E+02	4.6	Prior from population
U	6.3E+00	6.3E+00	9.3	Prior from population
Zr	5.7E+01	5.7E+01	4.4	Prior from population

[1] GSD maximum GSD of all "Sea_kD_PM" and "Lake_kD_PM".

4 Concentration ratios for terrestrial biota

4.1 Terrestrial vegetation, berries, crops and mushrooms

The concentration of elements within a specific crop is estimated using element-specific CRs between the concentrations in the edible part of the crop, $[X]_{crop}$, normalised to the carbon content of the crop, $[C]_{crop}$, and the element concentration in the dry soil, $[X]_{soil}$:

$$CR\_soilToCrop(X) = ([X]_{crop} / [C]_{crop}) / [X]_{soil}$$

and is expressed as ((Bq/kg dw)/(kg C/kg dw))/(Bq/kg dw) = kg dw/ kg C.

In SR-Site CRs for the following crop types were used:

- Pasturage (food for cattle) (cR_soilToPast).
- Cereals (cR_soilToCereal).
- Root crops (cR_soilToTuber).
- Vegetables (cR_soilToVegetab).

CRs were also calculated for vegetation in natural terrestrial ecosystems (mires and forest). The vegetation types of interest in SR-Site are the green parts of vegetation constituting the food source for herbivores, as well as berries:

- Terrestrial primary producers (field and shrub layer together with green parts of trees (shoots)) (Ter_cR_pp).
- Berries (cR_soilToBerr).

The concentration of radionuclides in mushrooms is also used in the dose calculations. The concentration of elements in mushrooms is estimated using element-specific CRs between the concentrations in mushrooms, $[X]_{mush}$, normalised to the carbon content of the mushrooms, $[C]_{mush}$, and the element concentration in the dry soil, $[X]_{soil}$:

$$cR\_soilToMush(X) = ([X]_{mush} / [C]_{mush}) / [X]_{soil}$$

and is expressed as ((Bq/kg dw)/(kg C/kg dw))/(Bq/kg dw) = kg dw/ kg C.

The carbon contents of terrestrial vegetation and mushrooms used in the calculations are presented in Table 4-1. No site-specific chemistry data were available for berries, instead the data (also carbon content) for green vegetation were used (further discussed below). The carbon content of cereals was estimated with Equation 3.3 in /Avila 2006a/ using the content of protein, carbohydrates and lipids in different food products taken from the database of the Swedish Food Administration[1] /Livsmedelsverket 2001/. Data on carbon contents of root crops and vegetables are from /IAEA 2010/. These values are for fresh weight and were converted into dry weight using the values in the fourth column in Table 4-1. Carbon contents of green vegetation and mushrooms are from site-specific data /Tröjbom and Nordén 2010/. The value for green vegetation was also used for pasturage.

For the chemistry content of the green vegetation, site-specific data for species of the field layer (herbs, grasses etc), the shrub layer and the green part of the trees (shoots) were used. This parameter is used both when the flow of elements in a mire or forest is estimated and when the activity concentration in food stuff are being calculated. Chemistry data for mosses were not included when estimating site-specific CRs. According to /Tröjbom and Nordén 2010/ the chemistry of mosses differs from that of other green vegetation from the two sites. In contrast to other terrestrial vegetation mosses do not take up elements from the soil, instead the assimilation of elements is mainly through deposition. A CR between mosses and soil therefore does not describe the normal uptake pathway. Mosses make up a small fraction of the biomass of green vegetation (13%) /Löfgren 2010/ and are not normally consumed by terrestrial herbivores.

[1] The Swedish Food Administration (Livsmedelsverket), 2011. Vikttabell01.2_webb080624. [Online]. Available at: http://www.slv.se/upload/dokument/mat/ldb/vikttabell01.2_webb080624.xls/. [2009-05-11].

Table 4-1. Average values of the carbon content in different terrestrial vegetation types and in mushrooms. See text for further details.

Food type	Carbon content (kgC/kg dw)	Carbon content (kgC/kg fw)	Dry weight (% total weight)	Reference
Cereals	0.45	0.39	87	/Avila 2006a/. Dry weight value estimated from /IAEA 2010/
Root crops	0.48	0.10	21	Estimated from /IAEA 2010/ (tubers)
Vegetables	0.39	0.03	8.85	Estimated from /IAEA 2010/
Green vegetation (mosses excluded)	0.51			/Tröjbom and Nordén 2010/
Mushrooms	0.46			/Tröjbom and Nordén 2010/
Pasture (same as green vegetation)	0.51			/Tröjbom and Nordén 2010/

No site-specific data for berries were available and the amount of literature data were also limited. For example /IAEA 2010/ aggregated transfer factors for seven species of berries (T_{ag}, in m^2/kg dw) were presented for Cs only. According to /Sheppard et al. 2010a/ the CRs for different plant types correlated for most elements, in general the CRs for leafy vegetation is higher than the CRs for berries. /Sheppard et al. 2010a/ also state that CRs for fruit crops are similar to CRs for cereals which indicate that the best choice of surrogate for berries would probably be cereals, but no site-data for cereals are available thus CRs for green vegetation is used as a proxy for berries. This assumption may lead to overestimation of uptake of radionuclides by berries.

The crops considered in SR-Site are cereals, root crops and vegetables. No site-specific chemical data are available for these crops. Instead literature data were used when estimating values for the different calculations. Another kind of vegetation treated is pasturage which is regarded as food for cattle producing milk and meat consumed by humans. Site-specific data on grass from pasturage areas were not available, so data for the green parts of vegetation from forest and mire were used (see first part of this section). If cattle are put out to pasture in semi-natural areas, this is the fraction of the vegetation they will consume. It could be argued that the fodder consumed by high producing cattle today is more in the form of cereals than as grass, especially if the cattle are always kept indoors. The situation we have modelled is when cattle are put out to pasture in the summer and the fodder consumed in the winter is harvested by haymaking on high producing grass areas. For this scenario green vegetation is a better analogue to fodder than cereals. A comparison between the CRs used for green vegetation and cereals in this study reveals that the former are in the same order of magnitude or higher for most elements (23 of 29). Higher CRs for cereals were used for Cd, Cl, Mo, Nb, Sn and U (ratio of CRs in green vegetation and cereals are 0.4, 0.4, 0.1, 0.1, 0.05 and 0.1 respectively). /Sheppard et al. 1999/ also states that the range of CRs for Cl in natural vegetation is much greater and includes that of crops.

The site-specific soil data used for terrestrial vegetation CRs all come from samples from the rooting zone of forest or wetlands. We have not specified a predefined rooting zone depth, instead the soil samples used were within the zone where roots were found at each specific location. For samples of mushrooms the soil and mushroom were sampled from the same localities at the same time, whereas soil and vegetation samples were sampled at different times but at the same locations. In an ideal situation, soil samples from the whole soil profile within the rooting zone would be collected and analysed. Then an average concentration within the whole rooting zone could be calculated or the concentrations of different soil layers could be related to the abundance of roots in each specific layer. This was unfortunately not the case here and since data from several fractions of the soil profiles were lacking a proper relationship to root abundance at different soil depths could not be established. Instead the few soil samples available were regarded as random samples of the whole rooting zone.

In the mushroom study conducted by /Johansson et al. 2004/, three different fractions of the soil were sampled and analysed, bulk soil, rhizosphere fraction and soil-root interface fraction, for definitions see /Johansson et al. 2004/. For the parameter cR_soilToMush samples from the bulk soil fraction (representing a fraction in less intimate contact with roots) were used since it best represents the conditions simulated by the Radionuclide Model for the biosphere.

4.1.1 Values used in SR-Site

The site-specific chemistry data from Forsmark and Laxemar-Simpevarp used when calculating element-specific CRs are compiled in /Tröjbom and Nordén 2010/. Of all site-specific data used for CR estimations the data concerning terrestrial vegetation are the most abundant. Data were available for 17 of the 29 elements considered in the simulations. For all elements the number of observations was 19 except for Ra which had 5 site-specific observations. No literature data were provided for Sn so statistics for the site-specific data alone were used (GM and GSD). Site-specific data statistics were used for Nb and Sm as well. Information on the number of literature observations was lacking making it unsuitable to use the Bayesian method "prior from subpopulation". As the GSD for site-specific data were greater than that for literature data statistics for site-specific data alone were used.

The Bayesian method "prior from population" was used for 10 elements, while the method "prior from subpopulation" was recommended for 4 elements. In the case of the elements for which the Bayesian method "Prior from subpopulation" was recommended by the rules set in Chapter 2, the statistics for site-specific data only were used as a best estimate, while the results from "Prior from subpopulation" were used as GMs and GSDs. The reason for this choice was to give priority to site-specific information since the number of site-specific observations is quite high for this parameter (19 observations). The site-specific GMs are somewhat lower than the corresponding values from the Bayesian statistics for all elements except Zr. The differences were often marginal, however.

In the case of the 12 elements for which site-specific data were lacking, literature data were used. For seven elements (Am, Cm, Np, Po, Pu, Tc and Th) data for stems and shoots of pasturage from the literature /IAEA 2010/ were used. Data are provided for different soil types; sand, loam, clay as well as all soil types. The latter was chosen to represent a larger variation. In the absence of better information the values used for pasturage in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used for Ac, Ag, Pa, Pd and Se.

As mentioned above, no site-specific data are available for crops. Instead, data from the literature were used. The data source used is /IAEA 2010/ which presents "recommended values". For some elements a distinction is made between different soil types (sand, loam, organic or "all soil types"). The values for "all soil types" were chosen to represent a greater variation. Data for "tubers" were used for root crops and data for "leaves" from "leafy vegetables" was chosen for vegetables. For cereals the data in /IAEA 2010/ were divided into the two categories "grain" and "stems and shoots". Data for grains were used since this is the part consumed by humans. For elements not included in /IAEA 2010/, the values used for root crops, vegetables and cereals in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used. Data concerning Ca were not available in these two sources. Instead data for the analogue Sr from /IAEA 2010/ were used.

The assigned CRs for different kinds of terrestrial vegetation are presented in Table 4-2 to Table 4-5. For most elements GSD was available from the same data source as the best estimate was taken. For cR_soilToCereal no GSD was provided for Zr in /IAEA 2010/ since the value was based on one single value. The same was also true for I, Nb and Zr for cR_soilToTuber and for Zr for cR_soilToVegetab. The highest GSD value for all crops was used in these cases (value for Tc and U in cR_soilToVegetab).

For mushrooms the site-specific chemistry data from Forsmark used when calculating element-specific CRs are compiled in /Tröjbom and Nordén 2010/. Data are from one study in Forsmark /Johansson et al. 2004/ and contains samples of both mushrooms and soil at the same locations. Several mushroom species were analysed and the variation within this group was greater than within terrestrial animals and terrestrial vegetation (green parts) /Tröjbom and Nordén 2010/. A wide variation in transfer factor to mushroom has also been reported by other authors, e.g. /Calmon et al. 2009/. All species were pooled together for SR-Site. The reason for this is to include natural variation in element composition between different species and also to fully utilize the limited set of site-specific data (see further discussion in /Tröjbom and Nordén 2010/).

The site-specific data on CRs for mushrooms have a high number of observations (8 or 9 per element) but somewhat fewer elements than other data; 8 of the 26 elements of interest were analysed. No literature data were found for Ca, I or Pb so statistics for the site-specific data alone was used (GM and GSD). Also for Ni, Sr, Th and U site-specific data statistics were used since information on the number of observations in the literature data was lacking, making it impossible to use the Bayesian method "prior from subpopulation". As the GSD for site-specific data were greater than those for literature data, statistics for site-specific data alone were used. The only element for which Bayesian inference methods was done was Cs for which the method "prior from population" was used.

The literature data concerning CR to mushroom was limited. Best estimate values for Am, Np, Pu, Ra and Tc were taken from /Avila 2006a/. When no CR data for mushrooms were available, data for green vegetation were used. For the elements Cd, Cl, Eu, Ho, Mo, Nb, Sm, Sn and Zr site-specific data for green vegetation were chosen (for references see Table 4-2). Literature data for pasturage were used for Ac, Ag, Cm, Pa, Pd, Po and Se. Data for Cm and Po were from /IAEA 2010/, while values used for pasturage in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used for the other elements.

The CRs for mushrooms are presented in Table 4-6. In /Avila 2006a/ no statistical information was given, thus for the elements based on this reference the GSD for the CR for natural vegetation (Ter_cR_pp) was used.

Table 4-2. CRs used for terrestrial primary producers (Ter_cR_pp). The same values are used for pasturage (cR_soilToPast) and berries (cR_soilToBerr) in the Radionuclide Model for the biosphere. Parameter values are given in kg dw/kg C. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.0E-03	1.0E-03	4.0	Literature data /Karlsson and Bergström 2002/
Ag	1.1E+00	9.8E-01	3.1	Literature data /Karlsson and Bergström 2002/
Am	2.9E-03	2.9E-03	4.1	Literature data /IAEA 2010/
Ca	2.0E+00	2.0E+00	3.0	Prior from population
Cd	7.9E-01	7.9E-01	3.4	Prior from population
Cl	3.4E+01	4.7E+01	3.8	Site-specific data. GM Prior from subpopulation
Cm	2.0E-03	2.0E-03	2.4	Literature data /IAEA 2010/
Cs	1.9E-01	1.9E-01	4.2	Prior from population
Eu	3.7E-03	3.7E-03	2.7	Prior from population
Ho	2.9E-03	2.9E-03	2.5	Prior from population
I	5.6E-01	8.6E-01	4.8	Site-specific data. GM Prior from subpopulation
Mo	1.9E-01	1.9E-01	3.4	Prior from population
Nb	4.0E-03	4.0E-03	3.5	Site-specific data
Ni	1.8E-01	1.8E-01	2.7	Prior from population
Np	1.2E-01	1.2E-01	2.7	Literature data /IAEA 2010/
Pa	6.6E-03	6.6E-03	3.2	Literature data /Karlsson and Bergström 2002/
Pb	2.1E-02	2.1E-02	2.4	Prior from population
Pd	4.4E-01	4.4E-01	3.2	Literature data /Karlsson and Bergström 2002/
Po	2.4E-01	2.4E-01	4.2	Literature data /IAEA 2010/
Pu	1.1E-03	1.1E-03	3.0	Literature data /IAEA 2010/
Ra	1.4E-01	1.4E-01	4.6	Prior from population
Se	4.4E+01	1.2E+01	2.4	Literature data /Karlsson and Bergström 2002/
Sm	2.6E-03	2.6E-03	4.5	Site-specific data
Sn	5.0E-02	5.0E-02	2.1	Site-specific data
Sr	5.5E-01	2.1E+00	2.6	Site-specific data. GM Prior from subpopulation
Tc	1.5E+02	1.5E+02	3.0	Literature data /IAEA 2010/
Th	1.9E-01	1.9E-01	5.5	Literature data /IAEA 2010/
U	1.7E-03	1.7E-03	4.1	Prior from population
Zr	3.0E-03	5.8E-04	3.3	Site-specific data. GM Prior from subpopulation

Table 4-3. CR values used for cereals (cR_soilToCereal). Parameter values are given in kgdw/kgC. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	1.0E-03	2.6E-04	3.2	Literature data /Karlsson and Bergström 2002/
Ag	1.0E+00	8.9E-01	3.0	Literature data /Karlsson and Bergström 2002/
Am	4.9E-05	4.9E-05	11	Literature data /IAEA 2010/
Ca	2.5E-01	2.5E-01	2.7	Literature data /IAEA 2010/[1]
Cd	2.0E+00	2.0E+00	2.7	Literature data /IAEA 2010/
Cl	8.0E+01	8.0E+01	1.6	Literature data /IAEA 2010/
Cm	5.1E-05	5.1E-05	3.3	Literature data /IAEA 2010/
Cs	7.0E-02	7.0E-02	4.1	Literature data /IAEA 2010/
Eu	5.1E-04	5.1E-04	3.2	Literature data /Karlsson and Bergström 2002/
Ho	2.6E-04	2.6E-04	3.2	Literature data /Karlsson and Bergström 2002/
I	2.6E-01	2.6E-01	3.2	Literature data /Robens et al. 1988/
Mo	1.8E+00	1.8E+00	14	Literature data /IAEA 2010/[2]
Nb	3.1E-02	1.6E-02	1.9	Literature data /IAEA 2010/
Ni	6.0E-02	6.0E-02	2.7	Literature data /IAEA 2010/
Np	6.5E-03	6.5E-03	5.0	Literature data /IAEA 2010/
Pa	7.7E-03	7.7E-03	3.2	Literature data /Karlsson and Bergström 2002/
Pb	2.5E-02	2.5E-02	3.6	Literature data /IAEA 2010/
Pd	7.7E-02	7.7E-02	3.2	Literature data /Karlsson and Bergström 2002/
Po	5.3E-04	5.3E-04	1.0	Literature data /IAEA 2010/
Pu	2.1E-05	2.1E-05	6.7	Literature data /IAEA 2010/
Ra	3.8E-02	3.8E-02	12	Literature data /IAEA 2010/
Se	5.1E+01	1.3E+01	2.4	Literature data /Karlsson and Bergström 2002/
Sm	2.6E-04	2.6E-04	3.2	Literature data /Karlsson and Bergström 2002/
Sn	1.0E+00	2.6E-01	3.2	Literature data /Karlsson and Bergström 2002/
Sr	2.5E-01	2.5E-01	2.7	Literature data /IAEA 2010/
Tc	2.9E+00	2.9E+00	3.6	Literature data /IAEA 2010/
Th	4.7E-03	4.7E-03	3.4	Literature data /IAEA 2010/
U	1.4E-02	1.4E-02	7.7	Literature data /IAEA 2010/
Zr	2.2E-03	2.2E-03	14	Literature data /IAEA 2010/[2]

[1] Value for Sr.
[2] GSD maximum GSD of all crops (cR_soilToCereal, cR_soilToTuber and cR_soilToVegetab).

Table 4-4. CR values used for root crops (cR_soilToTuber). Parameter values are given in kgdw/kgC. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	4.9E-04	4.3E-03	4.9	Literature data /Karlsson and Bergström 2002/
Ag	1.9E+00	1.4E+00	2.7	Literature data /Karlsson and Bergström 2002/
Am	4.3E-04	4.3E-04	6.0	Literature data /IAEA 2010/
Ca	3.3E-01	3.3E-01	3.0	Literature data /IAEA 2010/[1]
Cd	3.1E+00	3.1E+00	14	Literature data /IAEA 2010/[2]
Cl	5.8E+01	6.1E+01	1.8	Literature data /Karlsson and Bergström 2002/
Cm	3.1E-04	3.1E-04	3.7	Literature data /IAEA 2010/
Cs	1.1E-01	1.1E-01	3.0	Literature data /IAEA 2010/
Eu	5.8E-04	5.8E-04	3.2	Literature data /Karlsson and Bergström 2002/
Ho	8.7E-04	8.7E-04	3.2	Literature data /Karlsson and Bergström 2002/
I	2.0E-01	2.0E-01	14	Literature data /IAEA 2010/[2]
Mo	1.9E+00	1.9E+00	3.2	Literature data /Karlsson and Bergström 2002/
Nb	8.2E-03	8.2E-03	14	Literature data /IAEA 2010/[2]
Ni	3.9E-01	3.9E-01	3.2	Literature data /Karlsson and Bergström 2002/
Np	1.2E-02	1.2E-02	2.5	Literature data /IAEA 2010/
Pa	5.8E-03	5.8E-03	3.2	Literature data /Karlsson and Bergström 2002/
Pb	3.1E-03	3.1E-03	7.4	Literature data /IAEA 2010/
Pd	3.9E-01	3.9E-01	3.2	Literature data /Karlsson and Bergström 2002/
Po	5.5E-03	5.5E-03	5.8	Literature data /IAEA 2010/
Pu	2.2E-04	2.2E-04	5.5	Literature data /IAEA 2010/
Ra	2.0E-02	2.0E-02	6.8	Literature data /IAEA 2010/
Se	3.9E+01	1.1E+01	2.4	Literature data /Karlsson and Bergström 2002/
Sm	3.9E-04	3.9E-04	3.2	Literature data /Karlsson and Bergström 2002/
Sn	5.8E-01	9.7E-01	3.2	Literature data /Karlsson and Bergström 2002/
Sr	3.3E-01	3.3E-01	3.0	Literature data /IAEA 2010/
Tc	4.7E-01	4.7E-01	3.7	Literature data /IAEA 2010/
Th	4.1E-04	4.1E-04	9.9	Literature data /IAEA 2010/
U	1.0E-02	1.0E-02	6.4	Literature data /IAEA 2010/
Zr	4.1E-03	4.1E-03	14	Literature data /IAEA 2010/[2]

[1] Value for Sr.
[2] GSD maximum GSD of all crops (cR_soilToCereal, cR_soilToTuber and cR_soilToVegetab).

Table 4-5. CR values used for vegetables (cR_soilToVegetab). Parameter values are given in kgdw/kgC. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	1.3E-01	1.3E-01	4.6	Literature data /Karlsson and Bergström 2002/
Ag	5.3E-04	5.3E-04	3.3	Literature data /IAEA 2010/
Am	8.0E-04	8.0E-04	3.3	Literature data /IAEA 2010/
Ca	2.2E+00	2.2E+00	6.0	Literature data /IAEA 2010/[1]
Cd	1.7E+01	1.7E+01	3.2	Literature data /Karlsson and Bergström 2002/
Cl	7.7E+01	7.7E+01	1.7	Literature data /IAEA 2010/
Cm	4.1E-03	4.1E-03	4.5	Literature data /IAEA 2010/
Cs	1.8E-01	1.8E-01	6.0	Literature data /IAEA 2010/
Eu	1.0E-01	1.0E-01	3.2	Literature data /Karlsson and Bergström 2002/
Ho	1.0E-01	1.0E-01	3.2	Literature data /Karlsson and Bergström 2002/
I	6.1E-01	6.1E-01	3.7	Literature data /Robens et al. 1988/. GSD from /IAEA 2010/ (all soil types)
Mo	1.4E+00	1.4E+00	1.2	Literature data /IAEA 2010/
Nb	4.2E-02	4.2E-02	1.3	Literature data /IAEA 2010/
Ni	6.7E-01	6.7E-01	3.2	Literature data /Karlsson and Bergström 2002/
Np	8.0E-02	8.0E-02	3.0	Literature data /IAEA 2010/
Pa	1.0E-02	1.0E-02	3.2	Literature data /Karlsson and Bergström 2002/
Pb	2.4E-01	2.4E-01	13	Literature data /IAEA 2010/
Pd	6.7E-01	6.7E-01	3.2	Literature data /Karlsson and Bergström 2002/
Po	2.2E-02	2.2E-02	6.9	Literature data /IAEA 2010/
Pu	2.4E-04	2.4E-04	2.7	Literature data /IAEA 2010/
Ra	2.7E-01	2.7E-01	6.7	Literature data /IAEA 2010/
Se	6.7E+01	1.8E+01	2.4	Literature data /Karlsson and Bergström 2002/
Sm	1.0E-01	1.0E-01	3.2	Literature data /Karlsson and Bergström 2002/
Sn	1.7E+00	3.3E+00	3.2	Literature data /Karlsson and Bergström 2002/
Sr	2.2E+00	2.2E+00	6.0	Literature data /IAEA 2010/
Tc	5.3E+02	5.3E+02	14	Literature data /IAEA 2010/[2]
Th	3.5E-03	3.5E-03	6.0	Literature data /IAEA 2010/
U	5.9E-02	5.9E-02	14	Literature data /IAEA 2010/[2]
Zr	1.2E-02	1.2E-02	14	Literature data /IAEA 2010/[2]

[1] Value for Sr.
[2] GSD maximum GSD of all crops (cR_soilToCereal, cR_soilToTuber and cR_soilToVegetab).

Table 4-6. CR values used for mushrooms in SR-Site (cR_soilToMush). Parameter values are given in kgdw/kgC The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.0E-03	1.0E-03	4.0	Literature data for pasturage /Karlsson and Bergström 2002/
Ag	1.1E+00	9.8E-01	3.1	Literature data for pasturage /Karlsson and Bergström 2002/
Am	2.9E-03	2.9E-03	4.1	Literature data /Avila 2006a/. GSD for Ter_cR_pp (Am)
Ca	6.0E-02	6.0E-02	3.2	Site-specific data
Cd	7.9E-01	7.9E-01	3.4	Site-specific data for green vegetation
Cl	3.9E+01	4.7E+01	3.8	Site-specific data for green vegetation
Cm	2.0E-03	2.0E-03	2.4	Literature data for pasturage /IAEA 2010/
Cs	3.0E+01	3.0E+01	6.5	Prior from population
Eu	3.7E-03	3.7E-03	2.7	Site-specific data for green vegetation
Ho	2.9E-03	2.9E-03	2.5	Site-specific data for green vegetation
I	6.7E-02	6.7E-02	2.3	Site-specific data
Mo	1.9E-01	1.9E-01	3.4	Site-specific data for green vegetation
Nb	4.0E-03	4.0E-03	3.5	Site-specific data for green vegetation
Ni	3.2E-01	3.2E-01	2.4	Site-specific data
Np	1.5E-01	1.5E-01	2.7	Literature data /Avila 2006a/. GSD for Ter_cR_pp (Np)
Pa	6.6E-03	6.6E-03	3.2	Literature data for pasturage /Karlsson and Bergström 2002/
Pb	2.6E-02	2.6E-02	2.4	Site-specific data
Pd	4.4E-01	4.4E-01	3.2	Literature data for pasturage /Karlsson and Bergström 2002/
Po	2.4E-01	2.4E-01	4.2	Literature data for pasturage /IAEA 2010/
Pu	4.4E-03	4.4E-03	3.0	Literature data /Avila 2006a/. GSD for Ter_cR_pp (Pu)
Ra	5.9E+00	5.9E+00	4.6	Literature data /Avila 2006a/. GSD for Ter_cR_pp (Ra)
Se	4.4E+01	1.2E+01	2.4	Literature data for pasturage /Karlsson and Bergström 2002/
Sm	2.6E-03	2.6E-03	4.5	Site-specific data for green vegetation
Sn	5.0E-02	5.0E-02	2.1	Site-specific data for green vegetation
Sr	9.1E-02	9.1E-02	3.4	Site-specific data
Tc	2.2E+00	2.2E+00	3.0	Literature data /Avila 2006a/. GSD for Ter_cR_pp (Tc)
Th	8.1E-03	8.1E-03	3.1	Site-specific data
U	1.3E-02	1.3E-02	9.1	Site-specific data
Zr	2.5E-03	5.8E-04	3.3	Site-specific data for green vegetation

4.2 Transfer coefficients to milk and meat

The radionuclides in water and fodder consumed by cattle are assumed to be partly transferred to their muscles and, in the case of lactating animals to their milk as well. The concentration of radionuclides in the fodder were estimated using element-specific CRs (cR_soilToPast), see Section 4.1, while the concentration in water is calculated directly in the Radionuclide Model /Avila et al. 2010/. The transfer coefficient for meat (tC_cowMeat) is defined as the ratio between the concentration in the muscle, $[X]_{muscle}$, and the total daily intake of the radionuclides via fodder and water, $X_{fodder+water}$:

$$tC\_cowMeat\ (X) = [X]_{muscle} / X_{fodder+water}$$

and is expressed as (Bq/kg fw))/(Bq intake/day) = day/kg fw.

The transfer coefficient for milk (tC_cowMilk) is defined as the ratio between the concentration in the milk, $[X]_{milk}$, and the total daily intake via fodder and water, $X_{fodder+water}$:

$$tC\_cowMilk\ (X) = [X]_{milk} / X_{fodder+water}$$

and is expressed as (Bq/l))/(Bq intake/day) = day/l.

No site-specific data are available for the transfer of different elements from fodder and water to milk and meat from cattle. Instead literature data were used for all elements.

4.2.1 Values used in SR-Site

Since no site-specific data are available for the transfer of radionuclides to meat and milk from domestic animals literature data were used. Data are available on several types of milk (cow, sheep and goat) and several types of meat (cow, sheep, goat, pig and poultry) but only data for cows were used. Animal production in the Forsmark area today is reported in /Löfgren 2010 (Table 4-12)/. Cow milk is the only milk produced in the area and beef represents 84% of the total meat production (sheep meat 4% and chicken 12%). Moreover, it can be expected that beef transfer factors used with beef feed intake values will estimate meat concentrations similar to what one would obtain for other animals. This is explained by the fact that transfer coefficients for meat vary by species, whereas concentration ratios from feed to meat show very little variation between species. The data sources used are /IAEA 2010/ which gives GMs for elements with more than two observations and AMs when values are based on one or two observations. For elements not included in /IAEA 2010/ the values used in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used.

The assigned transfer coefficients for milk and meat are presented in Table 4-7 and Table 4-8. Where other information is lacking the AMs from /IAEA 2010/ (Am, Nb, and Pu for tC_cowMilk and Am, Cl, Nb, Ra and Zr for tC_cowMeat) were used as GMs in the probabilistic calculations. For most elements, GSDs were available from the data source used. In a few cases this information was lacking and the highest GSD value for any element (Th value for tC_cowMilk and the value for Pu for tC_cowMeat) was then used. The only use of the GSDs in the biosphere assessments is to serve as parameter of the PDFs used in probabilistic simulations. Hence, overestimation of GSDs will not affect the calculation of LDFs /Avila et al. 2010/, which are derived from deterministic simulations.

Table 4-7. Transfer coefficients for milk used in SR-Site (tC_cowMilk). Parameter values are given in day/l. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	2.0E-06	2.0E-06	3.2	Literature data /Karlsson and Bergström 2002/
Ag	5.0E-05	5.0E-05	3.2	Literature data /Karlsson and Bergström 2002/
Am	4.2E-07	4.2E-07	5.8	Literature data /IAEA 2010/[1]
Ca	1.0E-02	1.0E-02	1.6	Literature data /IAEA 2010/
Cd	1.0E-04	1.0E-04	3.2	Literature data /Karlsson and Bergström 2002/
Cl	1.7E-02	1.1E-02	1.1	Literature data /Karlsson and Bergström 2002/
Cm	2.0E-05	2.0E-05	3.2	Literature data /Karlsson and Bergström 2002/
Cs	4.6E-03	4.6E-03	3.3	Literature data /IAEA 2010/
Eu	2.0E-05	2.0E-05	3.2	Literature data /Karlsson and Bergström 2002/
Ho	2.5E-06	3.0E-06	3.2	Literature data /Karlsson and Bergström 2002/
I	5.4E-03	5.4E-03	2.9	Literature data /IAEA 2010/
Mo	2.0E-03	2.0E-03	3.2	Literature data /Karlsson and Bergström 2002/
Nb	4.1E-07	4.1E-07	5.8	Literature data /IAEA 2010/[1]
Ni	9.5E-04	9.5E-04	5.8	Literature data /IAEA 2010/[1]
Np	5.0E-06	5.0E-06	3.2	Literature data /Karlsson and Bergström 2002/
Pa	5.0E-05	1.0E-05	3.2	Literature data /Karlsson and Bergström 2002/
Pb	1.9E-04	1.9E-04	3.7	Literature data /IAEA 2010/
Pd	1.0E-03	1.0E-03	3.2	Literature data /Karlsson and Bergström 2002/
Po	2.1E-04	2.1E-04	1.4	Literature data /IAEA 2010/
Pu	1.0E-05	1.0E-05	5.8	Literature data /IAEA 2010/[1]
Ra	3.8E-04	3.8E-04	2.0	Literature data /IAEA 2010/
Se	4.0E-03	4.0E-03	1.8	Literature data /IAEA 2010/
Sm	2.0E-05	2.0E-05	3.2	Literature data /Karlsson and Bergström 2002/
Sn	1.0E-03	1.0E-03	3.2	Literature data /Karlsson and Bergström 2002/
Sr	1.3E-03	1.3E-03	1.9	Literature data /IAEA 2010/
Tc	2.0E-05	1.0E-04	3.2	Literature data /Karlsson and Bergström 2002/
Th	5.0E-06	3.1E-06	5.8	Literature data /Karlsson and Bergström 2002/
U	1.8E-03	1.8E-03	1.9	Literature data /IAEA 2010/
Zr	3.6E-06	3.6E-06	2.4	Literature data /IAEA 2010/

[1] Information about variation is not available. The highest GSD of all elements were used.

Table 4-8. Transfer coefficients for meat used in SR-Site (tC_cowMeat). Parameter values are given in day/kg fw. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	2.00E-05	2.00E-05	3.2	Literature data /Karlsson and Bergström 2002/
Ag	3.00E-03	3.50E-03	1.3	Literature data /Karlsson and Bergström 2002/
Am	5.00E-04	5.00E-04	7.9	Literature data /IAEA 2010/[1]
Ca	1.30E-02	1.30E-02	5.1	Literature data /IAEA 2010/
Cd	4.00E-04	4.00E-04	3.2	Literature data /Karlsson and Bergström 2002/
Cl	1.70E-02	1.70E-02	7.9	Literature data /IAEA 2010/[1]
Cm	2.00E-05	2.00E-05	3.2	Literature data /Karlsson and Bergström 2002/
Cs	2.20E-02	2.20E-02	2.2	Literature data /IAEA 2010/
Eu	6.00E-03	6.00E-03	3.2	Literature data /Karlsson and Bergström 2002/
Ho	5.00E-03	5.00E-03	3.2	Literature data /Karlsson and Bergström 2002/
I	6.70E-03	6.70E-03	2.1	Literature data /IAEA 2010/
Mo	1.00E-03	1.00E-03	3.2	Literature data /Karlsson and Bergström 2002/
Nb	2.60E-07	2.60E-07	7.9	Literature data /IAEA 2010/[1]
Ni	5.00E-03	5.00E-03	3.2	Literature data /Karlsson and Bergström 2002/
Np	1.00E-03	1.00E-03	3.2	Literature data /Karlsson and Bergström 2002/
Pa	1.00E-05	1.00E-05	3.2	Literature data /Karlsson and Bergström 2002/
Pb	7.00E-04	7.00E-04	1.7	Literature data /IAEA 2010/
Pd	1.00E-03	1.00E-03	3.2	Literature data /Karlsson and Bergström 2002/
Po	5.00E-03	1.70E-03	1.7	Literature data /Karlsson and Bergström 2002/
Pu	1.10E-06	1.10E-06	7.9	Literature data /IAEA 2010/
Ra	1.70E-03	1.70E-03	7.9	Literature data /IAEA 2010/[1]
Se	1.50E-02	1.40E-03	3.9	Literature data /Karlsson and Bergström 2002/
Sm	5.00E-03	5.00E-03	3.2	Literature data /Karlsson and Bergström 2002/
Sn	1.00E-02	1.00E-02	3.2	Literature data /Karlsson and Bergström 2002/
Sr	1.30E-03	1.30E-03	2.7	Literature data /IAEA 2010/
Tc	1.00E-04	1.00E-04	3.2	Literature data /Karlsson and Bergström 2002/
Th	2.30E-04	2.30E-04	2.2	Literature data /IAEA 2010/
U	3.90E-04	3.90E-04	1.3	Literature data /IAEA 2010/
Zr	1.20E-06	1.20E-06	7.9	Literature data /IAEA 2010/[1]

[1] Information about variation is not available. The highest GSD of all elements were used.

4.3 Wild terrestrial herbivores

For the terrestrial part of the Radionuclide Model, doses from the intake of meat from wild terrestrial herbivores are also calculated. The concentration of elements in herbivore muscle is a function of element concentration in their food. It was assumed that the food items consumed by wild terrestrial herbivores are green parts of vegetation (field and shrub layer as well as green parts of trees (shoots)) and mushrooms, see below. Concentrations in both muscle, $[X]_{herbivore\ muscle}$, and food, $[X]_{herbivore\ food}$, are normalised to carbon content ($[C]_{herbivore\ muscle}$ and $[C]_{herbivore\ food}$ respectively). The concentration ratio to terrestrial herbivores from their food is expressed as:

$$cR\_foodToHerbiv(X) = ([X]_{herbivore\ muscle} / [C]_{game\ muscle}) / (\gamma_{veg} * [X]_{herbivore\_veg\_food} / [C]_{herbivore\_veg\_food} + \gamma_{mush} * [X]_{mushrooms} / [C]_{mushrooms})$$

where

γ_{veg} = proportion of herbivore food consisting of vegetation (unitless).

γ_{mush} = proportion of herbivore food consisting of mushrooms (unitless).

The concentration ratio is expressed as ((Bq/kg dw)/(kg C/kg dw))/((Bq/kg dw)/(kg C/kg dw)) = – (unitless).

The carbon contents of muscle from herbivores as well as of their food used in the calculations are presented in Table 4-9.

The diet for herbivores was the sum of the diets of dominating herbivores in proportion to their biomass. According to /Löfgren 2010/ the proportions between densities of these two species in Forsmark are 63% moose and 37% roe deer. The diet of moose consists of approximately 1% mushrooms and the rest primary producers. For roe deer the corresponding figure is 14% /Avila 1998, Avila et al. 1999/. The weighted diet used for terrestrial herbivores is therefore 6% mushrooms and 94% vegetation. Vegetation includes herbs, deciduous trees and conifers (e.g. Table 4-8 in /Truvé and Cederlund 2005/). Part of the deciduous trees includes wood. Generally, the measured concentrations representing the wood are lower for most elements compared to the green tissue in trees (e.g. Figure 9-4 in /Löfgren 2010/). However, the deciduous trees consumed by roe deer and moose is mainly restricted to younger trees where the bark and phloem tissue is eaten. It is here assumed that the radionuclide transfer by deciduous browse is similar to that due to eating green vegetation tissue.

The larger terrestrial herbivore species present at Forsmark and Laxemar are moose, roe deer, hare, wild boar and deer /Löfgren 2010/. Site-specific chemistry data from Forsmark are available for moose and different species of small rodents. Chemistry data from Laxemar also include roe deer. Small rodents are not assumed to be part of the human diet but as the analyses of site-specific data in /Tröjbom and Nordén 2010/ showed that the chemistry of terrestrial animals were very similar, data for small rodents has also been included in the calculations in order to increase the number of observations. This is also in accordance to /Sheppard et al. 2010b/ and /Howard et al. 2009/ which found that the same CR data apply to all kinds of species (domestic vs. wild, furry vs, feathered). Chemistry data for green vegetation are available for the field and shrub layer as well as tree shoots from both sites. Mushroom data are only available from Forsmark.

The chemical analyses of mushrooms included fewer elements than the analyses of vegetation and herbivores. When chemistry data for mushrooms were lacking and data for vegetation and herbivores were available, the concentration ratio between herbivore and vegetation was used instead of the combined concentration ratio. The mushroom portion of the diet is low (6%, see above). According to a comparison performed in /Tröjbom and Nordén 2010/ some metals occur in higher concentration in mushrooms compared to green vegetation and for those elements the contribution may be somewhat underestimated if vegetation data are used as an analogue.

Table 4-9. Average carbon content in muscle from terrestrial herbivores (arithmetic mean value for moose, roe deer and small rodents) as well as carbon content in their food. Site-specific data /Tröjbom and Nordén 2010/.

Biota type	Carbon content (kg C/kg dw)
Herbivore muscle	0.44
Green vegetation consumed by herbivores	0.51
Mushrooms	0.46

4.3.1 Values used in SR-Site

The site-specific data for terrestrial herbivores, mushrooms and green vegetation are provided in /Tröjbom and Nordén 2010/. The chemistry data for vegetation are the same as those used for uptake in terrestrial vegetation described in Section 4.1, i.e. field and shrub layers as well as green parts of trees from Forsmark and Laxemar-Simpevarp. For mushrooms the site-specific data used were from Forsmark /Johansson et al. 2004/ as described in Section 4.1. The GM was used when assigning the BE parameter values. For those elements where site-specific data were lacking, parameter values were calculated using a model described in Section 2.4.

The assigned CRs for terrestrial herbivores are presented in Table 4-10. The model used to estimate this parameter for a number of elements (Section 2.4) was also used to generate GSD values. The model was run 1,000 times and the GMs and GSDs were calculated from the results. As can be seen in the table these GSD values are all lower than the values based on site-specific data, which can be explained as follows. The variation in CR values derived from site data is influenced by variation in concentrations in the animal feeds, variations in assimilation and retention of elements and other processes related to the turnover of incorporated elements by herbivores. At the same time, the variation in CRs calculated with the model is only influenced by animal-related variables. Moreover, for many of the studied elements conservative values were assigned to several model parameters.

Site-specific data based on one observation were used for Eu and Ho. As no information on variation is available, the highest GSD for this parameter (value for Pb) was used.

Table 4-10. Concentration ratios for terrestrial herbivores (cR_foodToHerbiv) used in the Radionuclide Model for the biosphere. Parameter values are given in kgC/kgC. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	4.7E-02			Estimated with model (Section 2.4)
Ag	5.3E+00			Estimated with model (Section 2.4)
Am	7.8E-03	6.7E-03	1.4	Estimated with model (Section 2.4)
Ca	1.7E-01	1.7E-01	3.0	Site-specific data
Cd	1.9E-01	1.9E-01	3.3	Site-specific data
Cl	1.3E+00	1.3E+00	3.5	Site-specific data, vegetation only
Cm	2.9E-02	2.1E-02	1.4	Estimated with model (Section 2.4)
Cs	2.3E+00	2.3E+00	4.1	Site-specific data
Eu	3.7E-01	3.7E-01	5.5	Site-specific data, vegetation only[1]
Ho	6.8E-01	6.8E-01	5.5	Site-specific data, vegetation only[1]
I	2.5E+00	1.7E+00	1.3	Estimated with model (Section 2.4)
Mo	3.8E-01	3.8E-01	3.1	Site-specific data, vegetation only
Nb	5.3E-01	5.3E-01	3.4	Site-specific data, vegetation only
Ni	1.3E-01	1.3E-01	3.6	Site-specific data
Np	4.8E-02	3.8E-02	1.4	Estimated with model (Section 2.4)
Pa	2.9E-02	2.1E-02	1.4	Estimated with model (Section 2.4)
Pb	9.4E-02	9.4E-02	5.5	Site-specific data
Pd	4.8E-01			Estimated with model (Section 2.4)
Po	4.8E+01			Estimated with model (Section 2.4)
Pu	4.7E-03	3.7E-03	1.5	Estimated with model (Section 2.4)
Ra	9.9E-01	9.3E-01	1.1	Estimated with model (Section 2.4)
Se	5.0E+01	4.8E+01	1.2	Estimated with model (Section 2.4)
Sm	1.1E-01	1.1E-01	4.9	Site-specific data, vegetation only
Sn	2.4E+00	2.4E+00	3.9	Site-specific data, vegetation only
Sr	2.5E-02	2.5E-02	3.0	Site-specific data
Tc	2.2E-01	1.1E-01	1.8	Estimated with model (Section 2.4)
Th	7.2E-01	7.2E-01	2.7	Site-specific data
U	3.3E-01	3.3E-01	3.5	Site-specific data
Zr	1.6E+00	1.6E+00	3.9	Site-specific data, vegetation only

[1] The highest GSD for this parameter (for Pb) was used in lack of other information.

5 Concentration ratios for aquatic biota

The concentration of elements in aquatic biota is estimated using element-specific CRs for each biota type. The ratio is calculated between the element concentrations in of the biota, $[X]_{biota}$, normalised to the carbon content of the biota fraction, $[C]_{biota}$, and the element concentration in filtered water, $[X]_{water.}$ For fish, crustacean and filter feeders the concentrations of their edible fractions are used:

CR_"aquatic biota"(X) = $([X]_{biota} / [C]_{biota}) / [X]_{water}$

and is expressed as $((Bq/kg\ fw)/(kg\ C/kg\ fw))/(Bq/m^3) = m^3/kg\ C$. In SR-Site concentration ratios for the following biota types were used (for definitions see /Andersson 2010/ (fresh water ecosystems) and /Aquilonius 2010/ (marine ecosystems):

- Freshwater primary producers divided into phytoplankton, microphytobenthos and macrophytes (Lake_cR_pp_plank, Lake_cR_pp_ubent, Lake_cR_pp_macro).
- Freshwater fish (cR_watToFish_Lake).
- Freshwater crustaceans (cR_watToCray_Lake).
- Marine primary producers divided into phytoplankton, microphytobenthos and macrophytes (Sea_cR_pp_plank, Sea_cR_pp_ubent, Sea_cR_pp_macro).
- Marine fish (cR_watToFish_Sea).

The CR for primary producers are used in the Radionuclide Model for the biosphere /Avila et al. 2010/ to model dynamically the uptake of radionuclides. It is considered that the accumulation of radionuclides in primary producers might have an effect on the distribution of radionuclides in the ecosystems. Other types of biota are assumed to hold only a small fraction of the total content of elements in the ecosystems and marginal impact in the elements distribution. The radionuclide concentrations in these biota types are therefore calculated by multiplying the concentrations of radionuclides dissolved in water by the corresponding CR.

Values of the carbon content in aquatic biota used in the CR calculations are presented in Table 5-1. Due to difficulties in separating phytoplankton and microphytobenthos from particulate detritus, carbon content of these organisms are often related to cell volume or chlorophyll instead of dry weight in literature. The carbon content in freshwater and marine microphtyobenthos in Forsmark differs from each other for no obvious reason. Since conversion factors in literature are sparse, we have chosen to keep the site-specific values from Forsmark despite the difference between environments.

Based on the results of the explorative analyses performed on the site-specific data set in /Tröjbom and Nordén 2010/ fish are treated as one single group and not further divided into functional groups. The study showed that the chemistry of fish was similar and no differences could be seen based on food preferences.

Table 5-1. Average values of the carbon content in different aquatic biota /Tröjbom and Nordén 2010/.

Biota type	Carbon content (kgC/kg dw)
Freshwater phytoplankton	0.17[1]
Freshwater microphytobenthos	0.38
Freshwater macrophytes/macroalgae	0.34
Freshwater crustaceans	0.36[2]
Freshwater fish	0.44
Marine phytoplankton	0.17
Marine microphytobenthos	0.14
Marine macrophytes/macroalgae	0.33
Marine fish	0.45

[1] Value for marine phytoplankton.

[2] Value for marine crustacean.

5.1 Freshwater ecosystems

The site-specific chemistry data from Forsmark and Laxemar-Simpevarp used when calculating element-specific CRs are compiled in /Tröjbom and Nordén 2010/. Data were available for macrophytes, microphytobenthos and fish. Data for filter feeders were also available and were used for crustaceans (see below).

The amount of site-specific data were somewhat greater for filter feeders and macrophytes compared to fish (data for 16 elements for filter feeders and macrophytes compared to 10 elements for fish). The number of observations per element varies depending on the amount of data above the reported detection limit. The number of site-specific observations varied for fish between 4 and 9, for filter feeders between 2 and 6 and for macrophytes between 4 and 9. For microphytobenthos the number of site-specific observations was only one.

5.1.1 Values used in SR-Site for phytoplankton

No site-specific data were available for freshwater phytoplankton. The first choice was to use site-specific data for macrophytes as recommended by /Tröjbom and Nordén 2010/. Principle Components Analyses (PCA) of the site-specific data for limnic and marine primary producers /Tröjbom and Nordén 2010/ showed the expected distinction between microphytobenthos, macrophytes and phytoplankton. Microphytobenthos seem to accumulate a number of elements to a greater degree than the other primary producers. Marine phytoplankton also have higher concentrations of some elements (fewer than for the former). Using data for macrophytes as a substitute may therefore lead to underestimation of the CR value.

The second choice was to use literature data for freshwater phytoplankton from /Beresford et al. 2007/. Site-specific data for macrophytes are similar or lower than literature data for freshwater phytoplankton /Beresford et al. 2007/. The greatest differences are seen for Pb (approximately 400 times lower), Ag (approximately 200 times lower) and Zr (approximately 100 times lower). The CRs for the other elements are about ten times lower than the AMs reported in /Beresford et al. 2007/ (min or max values are missing for most of these elements). The consequences of using CRs based on site-specific data for macrophytes instead of literature phytoplankton data may therefore be a slight underestimation of the uptake of those elements.

For those elements not represented in these two sources (Ac, Pa, Pd and Sn) the values used for marine water plants in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used.

The assigned CRs for freshwater phytoplankton are presented in Table 5-2. For most elements GSD were available from the data source used for the best estimate. In those few cases when the AMs from /Beresford et al. 2007/ could not be converted into GMs (for Am, Np and Tc), the GMs and GSDs from /IAEA 2010/ were used in the probabilistic calculations. For Np the GSD is based on only two observations which may give a too small range.

5.1.2 Values used in SR-Site for microphytobenthos

There was only one observation of site-specific data for microphytobenthos. No literature information for this group of primary producer was found and thus Bayesian inference methods could not be used. Instead, the site-specific values were used as best estimates when available. Site-specific data for macrophytes were available for more elements than for microphytobenthos and in such cases site-specific data for the former were also used for the later. As no literature data for microphytobenthos was found, a comparison to investigate the influence of using site-specific data for macrophytes is hard to perform. Phytoplankton in /Beresford et al. 2007/ are the most closely resembling the microphytobentos. The CR values used here are of the same order of magnitude (for Ra) or lower than data from /Bereford et al. 2007/ (approximately 10 times lower for Se and approximately 200 times lower for Ag).

For those elements where site-specific data were lacking, parameter values were assigned using literature data. The reference used was /Beresford et al. 2007/ which does not contain data for microphytobenthos, so instead values for phytoplankton were used. For elements not included in /Beresford et al. 2007/ (Ac, Pa, Pd and Sn) the values used for marine water plants in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used.

The assigned CRs for freshwater microphytobenthos are presented in Table 5-3. Only for a few elements GSD were available from the data source used for the best estimate. As mentioned before, the site-specific data for Lake_cR_pp_ubent are all based on one observation. Because of lack of other information, the GSD for the same element for Lake_cR_pp_macro was used. These GSD are all based on site-specific data. In one case (for Ni) both the GM and the GSD for Lake_cR_pp_macro were also used for Lake_cR_pp_ubent. In those cases when the presented AMs from /Beresford et al. 2007/ could not be converted into GMs (for Am, Np and Tc) GM and GSD from /IAEA 2010/ were used in the probabilistic calculations. For Np the GSD is based on only two observations and may give too small a range.

5.1.3 Values used in SR-Site for macrophytes

In the case of macrophytes the Bayesian method "prior from population" was used for two elements while the method "prior from subpopulation" was used for 9 elements. For Ag, Ca, Eu, Ho, Mo, Nb, Sm and Zr no literature data were found. Instead, statistics for site-specific data alone were used. The reason for using "prior from subpopulation" was in most cases the low number of literature observations. For Sr the GSD for site-specific data was larger than for literature data. This was also the case for some of the elements with few literature observations. In general, the site-specific values used in the Bayesian inference methods were lower than the literature data. The exceptions to this were I and Cs which had higher site-specific values, and Ni, U and Pb for which site-specific and literature values were close.

For the elements which lacked site-specific data, literature data were used. For macrophytes values from the literature sources /IAEA 2010/ and /Beresford et al. 2007/ were used. The former provides values for "Edible primary producers" while the later provides values for "Vascular plants". Neither of these two categories contain exactly the same vegetation included in our group, but species from our group may be part of both. If values for a specific element were given in both references, the one with highest number of observations was selected. The only exception to this is Tc for which the values provided differ widely; 0.08 m^3/kg C in /IAEA 2010/ and 18 m^3/kg C in /Beresford et al. 2007./ The number of observations was not given in /Beresford et al. 2007/. The value used for CR in marine macrophytes is 480 m^3/kg C (value from /Beresford et al. 2007/) and there may be a difference between these two ecosystem types, but a difference of almost 10,000 times seems unreasonable. The higher value for freshwater vegetation was therefore used. Limnic primary producers have not been included in SKB´s earlier safety assessments so data for this parameter are lacking in /Karlsson and Bergström 2002/. For elements not included in /IAEA 2010/ or /Beresford et al. 2007/ (Ac, Pa, Pd and Sn) CRs for marine water plants in /Karlsson and Bergström 2002/ were used, in the absence of better information.

The assigned CRs for freshwater macrophytes are presented in Table 5-4. For most elements GSD were available from the data source used for the best estimate. The AM value used for Tc (from /Beresford et al. 2007/) could not be converted into a GM. This value was instead used as a GM in the probabilistic calculations together with a GSD from /IAEA 2010/. The GSD may be too small for Np as this value is based on two observations only. For Ni and Pb the Bayesian method "prior from population" was used for the probabilistic calculations although the other method was recommended by the rules set up. This was because the recommended method gave unrealistic large GSD (29 for Ni and 23 for Pb).

5.1.4 Values used in SR-Site for crustaceans

No site-specific data were available for freshwater crustaceans. Instead, the first choice was to use site-specific data for freshwater filter feeders as recommended by /Tröjbom and Nordén 2010/. In this study the site-specific data for fish, crustaceans and filter filters in the marine environment as well as the site-specific data for freshwater fish and filter feeders were analysed by PCA. The analysis revealed a pattern that was interpreted to indicate that filter feeders were a better analogue than fish. For freshwater filter feeders the Bayesian method "prior from population" was used for eight elements whereas the method "prior from subpopulation" was used for 10 elements. The number of literature observations was not presented for Ho, thus disallowing Bayesian methods. Instead site-specific data alone were used for this element. For Sn site-specific data for marine filter feeders were used (site-specific data only) as data for freshwater filter feeders were missing.

The site-specific data used were compared to literature data for freshwater crustacean (from /IAEA 2010/ and /Beresford et al. 2007/) and for most elements the values were of the same order of magnitude. The largest deviation was for Cd (site-specific data 1,100 m^3/kg C and 1.2 /IAEA 2010/ or 62 /ERICA 2007/ m^3/kg C for literature data) and Mo (site-specific data 3 m^3/kg C and 0.006 m^3/kg C for literature data /IAEA 2010/). For Ca and Pb the values based on site-specific data were somewhat higher than those based on literature data (GM for Ca approximately 3 and 0.3 m^3/kg C for site and literature data /IAEA 2010/ respectively, GM for Pb approximately 50, 0.3 and 10 m^3/kg C for site-specific data, literature data /IAEA 2010/ and /Beresford et al. 2007/ respectively). For one element (Ra) the value based on site-specific data were lower than those based on literature data in freshwater crustaceans (GM approximately 0.2, 1 and 20 for site-specific data, literature data /IAEA 2010/ and /Beresford et al. 2007/ respectively). The value used is within the wide range reported in /IAEA 2010/ however (0.02–22 m^3/kg C).

The second choice was to use literature data for “freshwater invertebrates” from /IAEA 2010/ or for “freshwater crustaceans” from /Beresford et al. 2007/. Generally, data from the reference with the highest number of observations were chosen. The exceptions to this were for Np and Pu for which values from /Beresford et al. 2007/ were used. In both cases the values in /Beresford et al. 2007/ are approximately 10 times lower than the values given in /IAEA 2010/, but also 3–10 times higher than values used in earlier safety assessments /Karlsson and Bergström 2002/. For those elements not represented in /IAEA 2010/ or /Beresford et al. 2007/ the values used for freshwater crustaceans in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used.

The assigned CR values for freshwater crustacean are presented in Table 5-5. For most elements GSD were available from the data source used. The AM value used for Np (from /Beresford et al. 2007/) could not be converted into a GM. This value was instead used as a GM in the probabilistic calculations together with a GSD from /IAEA 2010/. The GSD for Np as well as for Po and Pu may be too small since they are based on few observations . For Ra and U the Bayesian method “prior from population” were used for the probabilistic calculations although the other method was recommended by the rules set up. This was because the recommended method gave unrealistic large GSDs (65 for Ra and 14 for U).

5.1.5 Values used in SR-Site for fish

For fish the Bayesian method “prior from population” was used only for one element (Sr), while the method “prior from subpopulation” was used for 10 elements. The reason for using “prior from subpopulation” was in seven cases that the GSD was higher for site-specific data than for literature data. For Nb and U the number of literature observations was low and for Ra the number of site observations was low. The site-specific data used in the Bayesian inference methods were generally lower than the literature data. Exceptions to this were Ca and Ra, which had higher site values, and Sr and Mo, for which the site-specific and literature data were close.

For the elements that lacked site-specific data, literature data were used. Values from /IAEA 2010/ were used as the first choice. If data were lacking, values from /Beresford et al. 2007/ were used. Also for Po, Pu and Th data from /Beresford et al. 2007/ were used, since the number of observations was greater in /Beresford et al. 2007/ than in /IAEA 2010/. In the absence of better information the values used for freshwater fish in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used for Ac, Ho, Pa, Pd, Sm and Sn.

The assigned CRs for freshwater fish are presented in Table 5-6. For all elements, GMs and GSDs were available in the same data sources as used for the best estimate. The GSDs of Ag, Am, Cd, Cm, Np and Tc are based on less than 5 observations and are probably too small. In order not to underestimate the variation of this rather important parameter (concerning dose to humans), these GSD values were replaced by the highest GSD value for this parameter (the value for Nb). For Ra and U the Bayesian method “prior from population” was used for the probabilistic calculations although the other method was recommended by the rules set up. This was because the recommended method gave unrealistic large GSD (8 for Ra and 11 for U).

Table 5-2. Concentration ratios used for freshwater phytoplankton in SR-Site (Lake_cR_pp_plank). Parameter values are given in m^3/kg C. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	7.9E+01	1.6E+01	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Ag	7.6E+00	7.6E+00	1.1	Site-specific data for macrophytes
Am	1.2E+03	1.1E+02	8.3	Literature data /Beresford et al. 2007/. Arithmetic mean. GM and GSD from /IAEA 2010/
Ca	8.5E+00	8.5E+00	3.7	Site-specific data for macrophytes
Cd	6.1E+01	6.1E+01	6.6	Site-specific data for macrophytes
Cl	1.3E+00	1.3E+00	7.2	Site-specific data for macrophytes
Cm	5.6E+02			Literature data /Beresford et al. 2007/
Cs	1.2E+01	1.2E+01	5.3	Site-specific data for macrophytes
Eu	1.9E+01	1.9E+01	5.6	Site-specific data for macrophytes
Ho	8.6E+00	8.6E+00	5.3	Site-specific data for macrophytes
I	3.0E+00	3.0E+00	3.4	Site-specific data for macrophytes
Mo	4.4E+00	4.4E+00	3.4	Site-specific data for macrophytes
Nb	2.7E+01	2.7E+01	3.4	Site-specific data for macrophytes
Ni	7.0E+00	5.5E+00	3.0	Site-specific data for macrophytes
Np	1.2E+03	2.1E+02	1.1	Literature data /Beresford et al. 2007/. Arithmetic mean. GM and GSD from /IAEA 2010/. Based on only two samples so GSD is probably too small
Pa	1.0E-01	1.0E-01	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Pb	3.3E+01	3.8E+01	5.3	Site-specific data for macrophytes
Pd	3.2E+01	2.2E+01	2.7	Literature data for marine water plants /Karlsson and Bergström 2002/
Po	7.6E+02	7.6E+02	1.2	Literature data /Beresford et al. 2007/
Pu	1.3E+02	1.3E+02	2.0	Literature data /Beresford et al. 2007/
Ra	2.6E+01	2.6E+01	4.9	Site-specific data for macrophytes
Se	6.8E+00	6.8E+00	1.5	Site-specific data for macrophytes
Sm	2.0E+01	2.0E+01	6.6	Site-specific data for macrophytes
Sn	1.6E+00	1.6E+00	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Sr	4.1E+00	4.1E+00	3.8	Site-specific data for macrophytes
Tc	2.3E-01	1.6E-01	4.9	Literature data /Beresford et al. 2007/. Arithmetic mean. GM and GSD from /IAEA 2010/
Th	1.1E+01	1.1E+01	4.9	Site-specific data for macrophytes
U	2.7E+00	2.7E+00	3.0	Site-specific data for macrophytes
Zr	7.5E+00	7.5E+00	3.8	Site-specific data for macrophytes

Table 5-3. Concentration ratios used for freshwater microphytobenthos in SR-Site (Lake_cR_pp_ubent). Parameter values are given in m³/kg C. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	7.9E+01	1.6E+01	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Ag	7.6E+00	7.6E+00	1.1	Site-specific data for macrophytes
Am	1.2E+03	1.1E+02	8.3	Literature data for phytoplankton /Beresford et al. 2007/. Arithmetic mean. GM and GSD for phytoplankton in /IAEA 2010/
Ca	2.6E+00	2.6E+00	3.7	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Ca)
Cd	1.3E+02	1.3E+02	6.6	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Cd)
Cl	3.0E-02	3.0E-02	7.2	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Cl)
Cm	5.6E+02	5.6E+02		Literature data for phytoplankton /Beresford et al. 2007/
Cs	3.5E+01	3.5E+01	5.3	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Cs)
Eu	5.4E+02	5.4E+02	5.6	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Eu)
Ho	6.0E+02	6.0E+02	5.3	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Ho)
I	3.1E+00	3.1E+00	3.4	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (I)
Mo	7.6E+01	7.6E+01	3.4	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Mo)
Nb	1.1E+03	1.1E+03	3.4	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Nb)
Ni	3.7E+01	5.5E+00	3.0	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Ni)
Np	1.2E+03	2.1E+02	1.1	Literature data for phytoplankton /Beresford et al. 2007/. Arithmetic mean. GM and GSD from /IAEA 2010/. Based on only two samples so GSD is probably too small
Pa	9.5E-02	9.5E-02	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Pb	6.5E+02	3.8E+01	5.3	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Pb)
Pd	3.2E+01	2.2E+01	2.7	Literature data for marine water plants /Karlsson and Bergström 2002/
Po	7.6E+02	7.6E+02	1.2	Literature data for phytoplankton /Beresford et al. 2007/
Pu	1.3E+02	1.3E+02	2.0	Literature data for phytoplankton /Beresford et al. 2007/
Ra	2.6E+01	2.6E+01	4.9	Site-specific data for macrophytes
Se	6.8E+00	6.8E+00	1.5	Site-specific data for macrophytes
Sm	8.3E+02	8.3E+02	6.6	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Sm)
Sn	1.6E+00	1.6E+00	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Sr	7.4E-01	7.4E-01	3.8	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Sr)
Tc	2.3E-01	1.6E-01	4.9	Literature data for phytoplankton /Beresford et al. 2007/. Arithmetic mean. GM and GSD from /IAEA 2010/
Th	6.8E+02	6.8E+02	4.9	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Th)
U	1.0E+02	1.0E+02	3.0	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (U)
Zr	1.5E+02	1.5E+02	3.8	Site-specific data (only one observation). GSD for Lake_cR_pp_macro (Zr)

Table 5-4. Concentration ratios used for freshwater macrophytes in SR-Site (Lake_cR_pp_macro). Parameter values are given in m^3/kg C. The Best Estimate (BE) is used in the deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	7.9E+01	1.6E+01	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Ag	7.6E+00	7.6E+00	1.1	Site-specific data
Am	5.1E+01	5.1E+01	8.3	Literature data /IAEA 2010/
Ca	8.5E+00	8.5E+00	3.7	Site-specific data
Cd	6.1E+01	6.1E+01	6.6	Prior from subpopulation
Cl	1.3E+00	1.3E+00	7.2	Prior from subpopulation
Cm	1.6E+00	1.6E+00	2.6	Literature data /Beresford et al. 2007/
Cs	1.2E+01	1.2E+01	5.3	Prior from population
Eu	1.9E+01	1.9E+01	5.6	Site-specific data
Ho	8.6E+00	8.6E+00	5.3	Site-specific data
I	3.0E+00	3.0E+00	3.4	Prior from subpopulation
Mo	4.4E+00	4.4E+00	3.4	Site-specific data
Nb	2.7E+01	2.7E+01	3.4	Site-specific data
Ni	7.0E+00	5.5E+00	3.0	Prior from subpopulation. Prior from population used for probabilistic calculations.
Np	9.9E+01	9.9E+01	1.1	Literature data /IAEA 2010/. Based on two observations which may give a too small GSD
Pa	1.0E-01	1.0E-01	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Pb	3.3E+01	3.8E+01	5.3	Prior from subpopulation. Prior from population used for probabilistic calculations.
Pd	3.2E+01	2.2E+01	2.7	Literature data for marine water plants /Karlsson and Bergström 2002/
Po	3.3E+01	3.3E+01	2.7	Literature data /Beresford et al. 2007/
Pu	3.6E+02	3.6E+02	14	Literature data /IAEA 2010/
Ra	2.6E+01	2.6E+01	4.9	Prior from subpopulation
Se	6.8E+00	6.8E+00	1.5	Prior from population
Sm	2.0E+01	2.0E+01	6.6	Site-specific data
Sn	1.6E+00	1.6E+00	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Sr	4.1E+00	4.1E+00	3.8	Prior from subpopulation
Tc	1.8E+01	1.8E+01	4.9	Literature data /Beresford et al. 2007/. GSD from /IAEA 2010/
Th	1.1E+01	1.1E+01	4.9	Prior from subpopulation
U	2.7E+00	2.7E+00	3.0	Prior from subpopulation
Zr	7.5E+00	7.5E+00	3.8	Site-specific data

Table 5-5. Concentration ratios used for freshwater crustacean in SR-Site (cR_watToCray_Lake). Parameter values are given in m³/kg C. The Best Estimate (BE) is used in the deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	1.2E+01	1.2E+01	3.2	Literature data /Karlsson and Bergström 2002/
Ag	2.4E+01	2.4E+01	23	Site-specific data for filter feeder (prior from subpopulation)
Am	3.0E+01	3.0E+01	7.0	Literature data /IAEA 2010/
Ca	2.6E+00	2.6E+00	6.8	Site-specific data for filter feeder (prior from subpopulation)
Cd	1.1E+03	1.1E+03	2.6	Site-specific data for filter feeder (prior from population)
Cl	8.2E-01	8.2E-01	6.1	Site-specific data for filter feeder (prior from subpopulation)
Cm	1.2E+02	1.2E+02	1.1	Literature data /IAEA 2010/
Cs	6.0E+00	6.0E+00	4.7	Site-specific data for filter feeder (prior from population)
Eu	2.1E+01	2.1E+01	9.5	Site-specific data for filter feeder (prior from subpopulation)
Ho	7.3E+00	7.3E+00	5.8	Site-specific data for filter feeder (site-specific data)
I	1.8E+00	1.8E+00	3.5	Site-specific data for filter feeder (prior from population)
Mo	2.8E+00	2.8E+00	3.8	Site-specific data for filter feeder (prior from population)
Nb	7.8E+00	7.8E+00	2.3	Site-specific data for filter feeder (prior from subpopulation)
Ni	3.4E+00	3.4E+00	2.4	Site-specific data for filter feeder (prior from population)
Np	1.4E+01	1.4E+01	1.0	Literature data /Beresford et al. 2007/. GSD from /IAEA 2010/. Based on two observations which may give a too small GSD
Pa	1.2E+00	1.2E+00	3.2	Literature data /Karlsson and Bergström 2002/
Pb	4.6E+01	4.6E+01	4.6	Site-specific data for filter feeder (prior from population)
Pd	3.7E+00	3.7E+00	3.2	Literature data /Karlsson and Bergström 2002/
Po	1.2E+02	1.2E+02	1.2	Literature data /Beresford et al. 2007/. Based on two observations which may give a too small GSD
Pu	1.3E+01	1.3E+01	1.5	Literature data /Beresford et al. 2007/. Based on three observations which may give a too small GSD
Ra	2.4E-01	1.2E+01	1.5	Site-specific value for filter feeder (BE prior from subpopulation, GM and GSD prior from population)
Se	4.6E+01	4.6E+01	1.2	Site-specific data for filter feeder (prior from population)
Sm	1.9E+01	1.9E+01	11	Site-specific data for filter feeder (prior from subpopulation)
Sn	6.8E+00	6.8E+00	1.2	Site-specific data for marine filter feeder (site-specific data)
Sr	3.9E+00	3.9E+00	3.3	Site-specific data for filter feeder (prior from subpopulation)
Tc	3.2E-01	3.2E-01	9.8	Literature data /IAEA 2010/
Th	1.2E+01	1.2E+01	5.2	Site-specific data for filter feeder (prior from subpopulation)
U	1.9E+00	1.6E+00	4.6	Site-specific data for filter feeder (BE prior from subpopulation, GM and GSD prior from population)
Zr	1.7E+00	1.7E+00	4.1	Site-specific data for filter feeder (prior from population)

Table 5-6. Concentration ratios used for freshwater fish in SR-Site (cR_watToFish_Lake). Parameter values are given in m³/kg C. The Best Estimate (BE) is used in the deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.1E+00	4.9E-01	2.1	Literature data /Karlsson and Bergström 2002/
Ag	1.2E+00	1.2E+00	7.3	Literature data /IAEA 2010/.[1]
Am	1.9E+00	1.9E+00	7.3	Literature data /IAEA 2010/.[1]
Ca	1.4E-01	1.4E-01	2.6	Prior from subpopulation
Cd	1.1E+00	1.1E+00	7.3	Literature data /Beresford et al. 2007/.[1]
Cl	3.2E-01	3.2E-01	4.1	Prior from subpopulation
Cm	1.2E+00	1.2E+00	7.3	Literature data /Beresford et al. 2007/.[1]
Cs	2.6E+01	2.6E+01	2.6	Prior from subpopulation
Eu	1.4E+00	1.4E+00	4.9	Literature data /IAEA 2010/.
Ho	3.3E-01	3.3E-01	3.2	Literature data /Karlsson and Bergström 2002/
I	3.0E-01	3.0E-01	2.8	Prior from subpopulation
Mo	2.4E-02	2.4E-02	2.4	Prior from subpopulation
Nb	2.2E-01	2.2E-01	7.3	Prior from subpopulation
Ni	2.3E-01	2.3E-01	1.9	Literature data /IAEA 2010/
Np	1.2E+00	1.2E+00	7.3	Literature data /Beresford et al. 2007/.[1]
Pa	1.1E-01	1.1E-01	3.2	Literature data /Karlsson and Bergström 2002/
Pb	2.7E-01	2.7E-01	2.9	Literature data /IAEA 2010/
Pd	1.1E+00	1.1E+00	3.2	Literature data /Karlsson and Bergström 2002/
Po	2.0E+00	2.0E+00	2.1	Literature data /Beresford et al. 2007/
Pu	2.8E-01	2.8E-01	3.7	Literature data /Beresford et al. 2007/
Ra	5.8E-02	1.9E-01	5.5	Prior from subpopulation. Prior from population used for probabilistic calculations
Se	3.4E+01	3.4E+01	2.9	Prior from subpopulation
Sm	3.3E-01	3.3E-01	3.2	Literature data /Karlsson and Bergström 2002/
Sn	3.3E+01	3.3E+01	3.2	Literature data /Karlsson and Bergström 2002/
Sr	3.3E-02	3.3E-02	4.3	Prior from population
Tc	3.3E-01	3.3E-01	7.3	Literature data /Beresford et al. 2007/[1]
Th	8.5E-01	8.5E-01	2.3	Literature data /Beresford et al. 2007/
U	4.6E-03	2.1E-03	6.3	Prior from subpopulation. Prior from population used for probabilistic calculations
Zr	1.4E-01	1.4E-01	3.6	Prior from subpopulation

[1] The values are based on less than 5 observations which may give a too small GSD. Instead the highest GSD for this parameter (the value for Nb) was used.

5.2 Marine ecosystems

The site-specific chemistry data from Forsmark and Laxemar-Simpevarp used when calculating element-specific CRs are compiled in /Tröjbom and Nordén 2010/. Data were available for phytoplankton, microphytobenthos, macrophytes and fish. The amount of site-specific data were somewhat greater for fish and macrophytes (data for 15 of the 26 elements considered in the simulations for macrophytes, and for 14 elements for fish) compared to phytoplankton (data for 11 elements). The number of observations per element varies depending on the amount of data above the reported detection limit. The number of site-specific observations varied for fish between 5 and 10, for macrophytes between 5 and 10 and for phytoplankton between 2 and 3. For microphytobenthos the number of site-specific observations was only two.

5.2.1 Values used in SR-Site for phytoplankton

For marine phytoplankton the Bayesian method "prior from subpopulation" was used for 6 elements. For Ca, Cl, I, Mo and Ni no literature data were found, thus statistics for site-specific data alone were used. The reasons for using "prior from subpopulation" instead of "prior from population" were the small number of site-specific observations (3). The GSDs for site-specific data were in most cases smaller than for literature data but for Pb the opposite was true (GSD for site-specific data 7.3 and for literature data 3.4). The site-specific data used in the Bayesian inference methods were higher than the literature data for Cd, Cs, Se and Zr and lower for Pb and Th.

For the elements which lacked site-specific data the first choice was to use site-specific data for macrophytes as recommended by /Tröjbom and Nordén 2010/ (7 elements). Data are lacking in /Beresford et al. 2007/ for three of these elements (Ho, Sm and Sn), thus a comparison with literature data could not be made. For Nb and U the CR values based on site-specific data for macrophytes were of the same order of magnitude as the literature data for phytoplankton provided in /Beresford et al. 2007/. The value used for Sr was approximately 10 times lower than literature data.

The second choice was to use literature data for marine phytoplankton from /Beresford et al. 2007/. For those elements not represented in these sources (Ac, Pa and Pd) the values used for marine water plants in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used.

The assigned CRs for marine phytoplankton are presented in Table 5-7. For all elements, GMs and GSDs were available in the same data sources as used for the best estimate. For Cs GM and GSD for site-specific data were used.

5.2.2 Values used in SR-Site for microphytobenthos

For microphytobenthos the amount of site-specific data was very small (2 observations). No literature information for this group of primary producers was found thus Bayesian inference methods could not be used. Instead, the site-specific data values were used as a best estimate when available (for 14 elements).

Site-specific data for macrophytes were available for more elements than for microphytobenthos and in such cases site-specific data for the former were also used for the latter (for 4 elements, see Table 5-9 for references). As no literature data concerning microphytobenthos were found, the values were compared to literature data for marine phytoplankton. The CRs for Nb and U were of the same magnitude as literature data, while that for Sr was approxmatley 10 times lower. No literature data for Sn were available.

For those elements where site-specific data were lacking, parameter values were assigned using literature data from the literature. The data source used was /Beresford et al. 2007/ which does not include data for microphytobenthos, instead values for phytoplankton were used. For elements not included in /Beresford et al. 2007/, the values used for marine water plants in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used (for Ac, Pa and Pd).

The assigned CR values for marine microphytobenthos are presented in Table 5-8 For all elements, GMs and GSDs were available in the same data sources as used for the best estimate.

5.2.3 Values used in SR-Site for macrophytes

For macrophytes the Bayesian method "prior from population" was used for 8 elements while the method "prior from subpopulation" was used for 7 elements. For Ca, no literature data were found. Instead statistics for site-specific data alone were used. For Ho and Sm, the GSD for site-specific data were larger than that for literature data. As information about the number of literature observations was lacking, statistics for site-specific data alone were also used for these two elements. The reason for using "prior from subpopulation" was in all cases that the GSD for site-specific data was larger than the GSD for literature data (same size for Sr). For Th the few literature observations (N=6) was another reason. The site-specific data used in the Bayesian inference methods were generally higher than the literature data. The only exceptions to this were Eu and I for which literature data were higher.

For the elements that lacked site-specific data, literature data were used. The literature source used was /Beresford et al. 2007/ which reports CRs for both "Vascular plants" and "Macroalgae". The values are the same for both plant types for those elements drawn from this reference. In the absence of better information, the values used for marine water plants in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used for Ac, Pa and Pd.

The assigned CRs for marine macrophytes are presented in Table 5-9. For all elements, GMs and GSDs were available in the same data sources as used for the best estimate. For Cm, Np, Po, Pu, Ra and Tc the AMs presented in /Beresford et al. 2007/ were used as best estimate whereas these AMs converted GMs were used in the probabilistic calculations. The differences between these mean values were marginal (compare the second and third columns in Table 5-9).

5.2.4 Values used in SR-Site for fish

For fish, the Bayesian method "prior from population" was used for nine elements while the method "prior from subpopulation" was used for 3 elements. Statistics for site-specific data alone were used for Ca, I and Pb and also for the best estimate used for Cd. Literature data for Ca were not found and for I and Pb information on the number of literature observations is lacking. The GSDs for site-specific data are also larger than for literature data for these two elements. For Cd the reason for using site-specific data was the larger GSD from site-specific data compared to literature data. Statistics from the method "prior from subpopulation" were used in the probabilistic calculations for Cd. The reason for using "prior from subpopulation" was in all cases the small number of literature observations. For Zr, the GSD was also larger for site-specific data than for literature data. Generally, the site-specific data used in the Bayesian inference methods were lower than the literature data. The exceptions were Cs and Th for which the site-specific data were higher.

For the elements which lacked site-specific data, literature information were used. The literature source /Beresford et al. 2007/ was used as the first choice. In the absence of better information, the values used for brackish water fish in SKB´s earlier safety assessments /Karlsson and Bergström 2002/ were used for Ac, Eu, Ho, Pa and Pd.

The assigned CR values for marine fish are presented in Table 5-10. For most elements, GSDs could be estimated from the used data sources. For Cm and Np /Beresford et al. 2007/ provides only an AM without any information that could be used to estimate a GSD. In these cases the AMs were used as GMs together with the highest GSD value for that parameter (the value for Pb) in the probabilistic calculations.

Table 5-7. Concentration ratios used for marine phytoplankton in SR-Site (Sea_cR_pp_plank). Parameter values are given in m^3/kg C. The Best Estimate (BE) is used in the deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	7.9E+01	1.6E+01	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Ag	1.1E+03	1.1E+03	2.4	Literature data /Beresford et al. 2007/
Am	4.3E+03	4.3E+03	2.3	Literature data /Beresford et al. 2007/
Ca	2.5E-01	2.5E-01	1.1	Site-specific data
Cd	1.6E+01	1.6E+01	2.7	Prior from subpopulation
Cl	1.3E-01	1.3E-01	1.0	Site-specific data
Cm	6.0E+03	6.0E+03	2.0	Literature data /Beresford et al. 2007/
Cs	1.8E+00	7.3E+01	1.3	Prior from subpopulation. Site-specific data were used in the probabilistic calculations.
Eu	8.4E+00	1.0E+01	10	Site-specific data for macrophytes
Ho	5.7E+00	5.7E+00	9.8	Site-specific data for macrophytes
I	6.2E+00	6.2E+00	1.6	Site-specific data
Mo	1.2E+00	1.2E+00	1.1	Site-specific data
Nb	1.1E+01	1.1E+01	3.3	Site-specific data for macrophytes
Ni	3.5E+01	3.5E+01	1.3	Site-specific data
Np	3.7E+00	3.7E+00	1.5	Literature data /Beresford et al. 2007/
Pa	9.5E-02	9.5E-02	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Pb	5.0E+03	5.0E+03	5.3	Prior from subpopulation
Pd	3.2E+01	2.2E+01	2.7	Literature data for marine water plants /Karlsson and Bergström 2002/
Po	4.5E+02	4.5E+02	2.8	Literature data /Beresford et al. 2007/
Pu	2.2E+03	2.2E+03	2.5	Literature data /Beresford et al. 2007/
Ra	2.2E+01	2.2E+01	2.1	Literature data /Beresford et al. 2007/
Se	2.8E+01	2.8E+01	5.1	Prior from subpopulation
Sm	7.7E+01	7.7E+01	4.6	Site-specific data for macrophytes
Sn	1.3E+01	1.3E+01	3.7	Site-specific data for macrophytes
Sr	4.7E-01	4.7E-01	2.6	Site-specific data for macrophytes
Tc	5.8E-02	5.8E-02	2.9	Literature data /Beresford et al. 2007/
Th	1.2E+04	1.2E+04	2.8	Prior from subpopulation
U	2.4E+00	2.4E+00	2.1	Site-specific data for macrophytes
Zr	9.9E+02	9.9E+02	2.2	Prior from subpopulation

Table 5-8. Concentration ratios used for marine microphytobenthos in SR-Site (Sea_cR_pp_ubent). Parameter values are given in m^3/kg C. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source
Ac	7.9E+01	1.6E+01	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Ag	1.1E+03	1.1E+03	2.4	Literature data for phytoplankton /Beresford et al. 2007/
Am	4.3E+03	4.3E+03	2.3	Literature data for phytoplankton /Beresford et al. 2007/
Ca	2.6E+00	2.6E+00	1.1	Site-specific data
Cd	8.2E+02	8.2E+02	1.4	Site-specific data
Cl	1.0E-01	1.0E-01		Site-specific data
Cm	6.0E+03	6.0E+03	2.0	Literature data for phytoplankton /Beresford et al. 2007/
Cs	4.4E+02	4.4E+02	1.1	Site-specific data
Eu	2.2E+01	2.2E+01	1.7	Site-specific data
Ho	1.6E+01	1.6E+01	1.2	Site-specific data
I	1.4E+02	1.4E+02	1.6	Site-specific data
Mo	2.5E+01	2.5E+01	1.6	Site-specific data
Nb	1.1E+01	1.1E+01	3.3	Site-specific data for macrophytes
Ni	8.5E+02	8.5E+02	1.5	Site-specific data
Np	3.7E+00	3.7E+00	1.5	Literature data for phytoplankton /Beresford et al. 2007/
Pa	9.5E-02	9.5E-02	3.2	Literature data for marine water plants /Karlsson and Bergström 2002/
Pb	1.5E+03	1.5E+03	6.4	Site-specific data
Pd	3.2E+01	2.2E+01	2.7	Literature data for marine water plants /Karlsson and Bergström 2002/
Po	4.5E+02	4.5E+02	2.8	Literature data for phytoplankton /Beresford et al. 2007/
Pu	2.2E+03	2.2E+03	2.5	Literature data for phytoplankton /Beresford et al. 2007/
Ra	2.2E+01	2.2E+01	2.1	Literature data for phytoplankton /Beresford et al. 2007/
Se	5.2E+01	5.2E+01	1.4	Site-specific data
Sm	6.1E+01	6.1E+01	1.2	Site-specific data
Sn	1.3E+01	1.3E+01	3.7	Site-specific data for macrophytes
Sr	4.7E-01	4.7E-01	2.6	Site-specific data for macrophytes
Tc	5.8E-02	5.8E-02	2.9	Literature data for phytoplankton /Beresford et al. 2007/
Th	3.7E+04	3.7E+04	1.5	Site-specific data
U	2.4E+00	2.4E+00	2.1	Site-specific data for macrophytes
Zr	1.5E+04	1.5E+04	1.1	Site-specific data

Table 5-9. Concentration ratios used for marine macrophytes in SR-Site (Sea_cR_pp_macro). Parameter values are given in m^3/kg C. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	7.9E+01	1.6E+01	3.2	Literature data /Karlsson and Bergström 2002/
Ag	1.5E+01	1.5E+01	2.3	Literature data /Beresford et al. 2007/
Am	7.9E+00	7.9E+00	2.7	Literature data /Beresford et al. 2007/
Ca	8.3E-01	8.3E-01	3.3	Site-specific data
Cd	1.0E+02	1.3E+01	3.4	Prior from subpopulation
Cl	3.0E-02	3.0E-02	1.8	Prior from population
Cm	1.3E+02	1.3E+02	2.3	Literature data /Beresford et al. 2007/
Cs	4.9E+00	4.9E+00	4.3	Prior from population
Eu	8.4E+00	1.0E+01	10	Prior from subpopulation
Ho	5.7E+00	5.7E+00	9.8	Site-specific data
I	1.2E+01	1.2E+01	2.1	Prior from population
Mo	6.5E-01	6.5E-01	2.4	Prior from population
Nb	1.1E+01	1.1E+01	3.3	Prior from subpopulation
Ni	1.7E+01	1.7E+01	2.1	Prior from population
Np	7.2E-01	7.2E-01	1.8	Literature data /Beresford et al. 2007/
Pa	9.5E-02	9.5E-02	3.2	Literature data /Karlsson and Bergström 2002/
Pb	1.9E+01	9.9E+00	3.8	Prior from subpopulation
Pd	3.2E+01	2.2E+01	2.7	Literature data /Karlsson and Bergström 2002/
Po	1.3E+01	1.3E+01	2.0	Literature data /Beresford et al. 2007/
Pu	2.9E+01	2.9E+01	3.5	Literature data /Beresford et al. 2007/
Ra	1.2E+00	1.2E+00	1.7	Literature data /Beresford et al. 2007/
Se	1.2E+01	1.2E+01	2.1	Prior from population
Sm	7.7E+01	7.7E+01	4.6	Site-specific data
Sn	1.3E+01	1.3E+01	3.7	Prior from population
Sr	4.7E-01	4.7E-01	2.6	Prior from subpopulation
Tc	3.9E+02	3.9E+02	1.9	Literature data /Beresford et al. 2007/
Th	1.2E+02	5.8E+01	6.9	Prior from subpopulation
U	2.4E+00	2.4E+00	2.1	Prior from population
Zr	9.1E+01	2.3E+01	3.5	Prior from subpopulation

Table 5-10. Concentration ratios used for marine fish in SR-Site (cR_watToFish_Sea). Parameter values are given in m^3/kg C. The Best Estimate (BE) is used in deterministic calculations and the geometric mean (GM) and geometric standard deviation (GSD) in probabilistic calculations.

Element	BE	GM	GSD	Data source or Bayesian method
Ac	1.0E+00	4.5E-01	2.1	Literature data for brackish water fish /Karlsson and Bergström 2002/
Ag	1.7E+01	1.7E+01	2.9	Literature data /Beresford et al. 2007/
Am	3.7E-01	3.7E-01	2.6	Literature data /Beresford et al. 2007/
Ca	2.3E-01	2.3E-01	3.0	Site-specific data
Cd	6.7E-01	1.7E+00	6.5	Site-specific data. GM and GSD from prior from subpopulation
Cl	1.4E-03	1.4E-03	1.9	Prior from population
Cm	1.0E+00	1.0E+00	6.1	Literature data /Beresford et al. 2007/. Arithmetic mean[2]
Cs	2.1E+00	2.1E+00	2.0	Prior from population
Eu	1.0E+00	1.0E+00	3.2	Literature data for brackish water fish /Karlsson and Bergström 2002/
Ho	3.0E-01	3.0E-01	3.2	Literature data for brackish water fish /Karlsson and Bergström 2002/
I	1.1E-01	1.1E-01	2.1	Site-specific data
Mo	2.3E-02	2.3E-02	2.0	Prior from population
Nb	1.7E-01	1.7E-01	2.1	Prior from population
Ni	9.8E-02	2.6E-01	4.9	Prior from subpopulation
Np	1.0E-02	1.0E-02	6.1	Literature data /Beresford et al. 2007/. Arithmetic mean[2]
Pa	1.0E-01	1.0E-01	3.2	Literature data for brackish water fish /Karlsson and Bergström 2002/
Pb	4.7E-01	4.7E-01	6.1	Site-specific data
Pd	1.0E-01	1.0E-01	3.2	Literature data for brackish water fish /Karlsson and Bergström 2002/
Po	1.9E+01	1.9E+01	2.0	Literature data /Beresford et al. 2007/[1]
Pu	5.0E-01	5.0E-01	3.7	Literature data /Beresford et al. 2007/[1]
Ra	7.3E-01	7.3E-01	3.1	Literature data /Beresford et al. 2007/[1]
Se	4.8E+01	4.8E+01	1.9	Prior from subpopulation
Sm	2.0E-01	2.0E-01	3.5	Prior from population
Sn	3.9E+00	3.9E+00	2.5	Prior from population
Sr	7.1E-03	7.1E-03	3.3	Prior from population
Tc	1.5E-01	1.5E-01	3.3	Literature data /Beresford et al. 2007/
Th	1.1E+00	1.1E+00	3.3	Prior from population
U	1.9E-03	1.9E-03	2.1	Prior from population
Zr	4.1E-01	5.1E-01	4.8	Prior from subpopulation

[1] Values for the whole animal were converted to value for muscles using correction factors (7, 30 and 2 for Po, Pu and Ra respectively) from /Hosseini et al. 2008/.
[2] Information on variation is not available. The highest GSD for this parameter was used (the value for Pb).

6 Other parameters

In this chapter other biosphere objects and time independent parameters used in the Radionuclide Model are presented. Section 6.1 covers the radionuclide-specific parameters, Section 6.2 presents the element-specific parameters, Section 6.3 presents the parameters describing human characteristics and habits.

For some of the parameters presented in this Chapter there were no grounds for assigning a lognormal distribution. In such cases, uniform distribution were used, implying an equal probability to all values in the given interval between the min and max values presented. Some parameters have not been assigned PDFs. The reasoning for this is often lack of information making it impossible to estimate relevant variation. For parameters describing human characteristics and habits no PDFs were assigned since LDFs for Reference man with fixed characteristics were calculated.

6.1 Radionuclide-specific parameters

6.1.1 Half-life and decay chains

The half-lives of the radionuclides considered in SR-Site are shown in Table 6-1. The decay chains considered in the simulations are also presented. The data were taken from /LBNL 1999/.

6.1.2 Dose coefficients for ingestion, inhalation and external exposure from the ground

Definitions

In the dose calculations, radionuclide-specific dose coefficients are used for converting the activity levels (in Bq) to dose to humans (Sv). The doses obtained with these coefficients are the effective committed doses to an adult. Three different kinds of coefficients are used in SR-Site:

- Dose coefficients for ingestion, expressed as (Sv/Bq) (dosCoef_ing_water and dosCoef_ing_food).
- Dose coefficients for inhalation, expressed as (Sv/Bq) (dosCoef_inhal).
- External dose coefficients for external exposure from radionuclides in or on the ground, expressed as (Sv/h)/(Bq/m^3) (dosCoef_ext).

The dose coefficient for internal exposure via ingestion is defined as the committed effective dose to an individual from a unit intake of the radionuclide orally with food or water. The dose is integrated over 50 years, hence the dose coefficients correspond to life-time doses for an adult. For radionuclides with decay chains, the values include the contribution from short-lived daughter radionuclides, assuming secular equilibrium. A list of short-lived daughter radionuclides included in the dose coefficients of different radionuclides can be found in /EU 1996/. The dose coefficients for ingestion used here are based on /EU 1996/, where the values given are independent of the ingestion pathway, i.e. via food or water. The only exception was C-14, for which different dose coefficients wer used here for ingestion via food and via water, because carbon is present in different chemical forms in water and food, and C-14 in food is more bioavailable /Leggett 2004/. The value for food is about 10 times higher than the coefficient for water.

The dose coefficient for internal exposure via inhalation is defined as the committed effective dose to an individual from a unit intake of the radionuclide with inhaled air. The dose is integrated over 50 years. Hence, the dose coefficients correspond to life-time doses for an adult. For radionuclides with decay chains, the values include the contribution from short-lived daughter radionuclides, assuming secular equilibrium. A list of short-lived daughter radionuclides included in the dose coefficients of different radionuclides can be found in /EU 1996/.

Table 6-1. Half-life (y) and the decay chains considered in the Radionuclide Model of SR-Site /LBNL 1999/.

Nuclide	Half-life (y)	Considered decay chains
Po-210	0.4	Pb-210->Po-210
H-3	12.33	
Eu-152	13.54	
Cd-113m	14.1	
Nb-93m	16.13	
Cm-244	18.1	
Ac-227	21.8	
Pb-210	22.3	
Sr-90	28.8	
Cs-137	30.1	
Sn-121m	55.01	
Pu-238	87.7	
Sm-151	90	
Ni-63	100.1	
Am-242m	141	
Ag-108m	418	
Am-241	432.2	
Mo-93	781.4	
Ho-166m	1.200	
Ra-226	1.600	Ra-226->Pb-210->Po-210
Cm-246	4.730	
C-14	5.730	
Pu-240	6.563	
Th-229	7.340	
Am-243	7.370	Am-243->Pu-239->U-235->Pa-231
Cm-245	8.500	
Nb-94	20.300	
Pu-239	24.110	
Pa-231	32.760	
Th-230	75.380	Th-230->Ra-226->Pb-210->Po-210
Ni-59	76.000	
Sn-126	1.00E+05	
Ca-41	1.03E+05	
U-233	1.59E+05	U-233->Th-229
Tc-99	2.11E+05	
U-234	2.46E+05	U-234->Th-230->Ra-226->Pb-210->Po-210
Cl-36	3.01E+05	
Pu-242	3.73E+05	
Se-79	1.13E+06	
Zr-93	1.53E+06	
Np-237	2.14E+06	
Cs-135	2.30E+06	
Pd-107	6.50E+06	
I-129	1.57E+07	
U-236	2.34E+07	
U-235	7.04E+08	U-235->Pa-231
U-238	4.47E+09	U-238->U-234->Th-230->Ra-226->Pb-210->Po-210
Th-232	1.41E+10	

The external exposure comes from radiation emitted by the radionuclides in surrounding environmental media such as air, water and soils. Previous safety assessments of planned geologic repositories in Sweden and Finland /Bergström et al. 1999, Karlsson and Bergström 2002, Avila and Bergström 2006/ have shown that for most radionuclides of concern the external exposure gives a minor contribution to the total dose. The external exposure from air and water is negligible for all radionuclides of concern, while for radionuclides with high gamma-energy and low bioavailability, such as Nb-94, the external exposure to radionuclides accumulated in the ground (soil) could give an important contribution to the total dose. Hence, exposure from radionuclides accumulated in the ground is the only external exposure pathway included in SR-Site. The dose coefficient for external exposure is defined as the dose rate to which an individual is exposed from a unit volumetric concentration in soil of the radionuclide. For radionuclides with decay chains, the values include the contribution from short-lived daughter radionuclides, assuming secular equilibrium.

Values used in SR-Site

The dose coefficients used in SR-Site are presented in Table 6-2. Only values for adults are given since doses to other age groups were not calculated in SR-Site /Avila et al. 2010/. The dose coefficients used for ingestion and inhalation are based on /EU 1996/. The inhalation coefficients are specified for different kinds of absorption in the lungs: fast, moderate and slow. Slow retention causes the highest exposure for most radionuclides, but there are exceptions; for example for isotopes of the actinides Np, Pu, Am and Cm the highest exposure is observed for fast absorption. The highest value for each isotope across different classes of absorption was used. The values used for external exposure are based on the case of homogeneous distribution of the radionuclide in a soil layer of infinite depth /Eckerman and Leggett 1996/. The values were derived from calculations for a typical silt soil with a density of 1,600 kg/m^3, 20% air and 30% water content reported in /Eckerman and Ryman 1993/ taking into account the latest values of tissue weighting factors recommended by /ICRP 1996/.

Table 6-2. Dose coefficients for ingestion (Sv/Bq) /EU 1996/, inhalation (Sv/Bq) /EU 1996/ and external exposure from the ground (Sv/h per Bq/m^3) /Eckerman and Leggett 1996/.

Nuclide	Ingestion	Inhalation	External exposure
Ac-227	1.1E-06	5.5E-04	0
Ag-108m	2.3E-09	3.7E-08	1.7E-13
Am-241	2.0E-07	9.6E-05	7.2E-16
Am-242m	1.9E-07	9.2E-05	1.2E-15
Am-243	2.0E-07	9.6E-05	2.4E-15
C-14	5.8E-10[1]	5.8E-09	2.1E-19
Ca-41	1.9E-10	1.8E-10	0
Cd-113m	2.3E-08	5.2E-08	1.2E-17
Cl-36	9.3E-10	7.3E-09	4.8E-17
Cm-244	1.2E-07	5.7E-05	1.7E-18
Cm-245	2.1E-07	9.9E-05	5.9E-15
Cm-246	2.1E-07	9.8E-05	1.6E-18
Cs-135	2.0E-09	8.6E-09	6.2E-19
Cs-137	1.3E-08	3.9E-08	6.5E-14
Eu-152	1.4E-09	4.2E-08	1.3E-13
H-3	1.8E-11	2.6E-10	0
Ho-166m	2.0E-09	1.2E-07	1.9E-13
I-129	1.1E-07	9.8E-09[2]	1.8E-16
Mo-93	3.1E-09	2.3E-09	8.9E-18
Nb-93m	1.1E-10	1.8E-09	1.3E-18
Nb-94	1.7E-09	4.9E-08	1.8E-13
Ni-59	6.3E-11	4.4E-10	0
Ni-63	1.5E-10	1.3E-09	0
Np-237	1.1E-07	5.0E-05	1.3E-15
Pa-231	7.1E-07	1.4E-04	3.4E-15
Pb-210	6.9E-07	5.6E-06	3.8E-17
Pd-107	3.7E-11	5.9E-10	0
Po-210	1.2E-06	4.3E-06	9.5E-19
Pu-238	2.3E-07	1.1E-04	2.2E-18
Pu-239	2.5E-07	1.2E-04	5.1E-18
Pu-240	2.5E-07	1.2E-04	2.2E-18
Pu-242	2.4E-07	1.1E-04	1.9E-18
Ra-226	2.8E-07	9.5E-06	5.6E-16
Se-79	2.9E-09	6.8E-09	3.0E-19
Sm-151	9.8E-11	4.0E-09	1.3E-20
Sn-121m	3.8E-10	4.5E-09	2.9E-17
Sn-126	4.7E-09	2.8E-08	2.3E-13
Sr-90	2.8E-08	1.6E-07	1.2E-17
Tc-99	6.4E-10	1.3E-08	2.1E-18
Th-229	4.9E-07	2.4E-04	5.6E-15
Th-230	2.1E-07	1.0E-04	2.1E-17
Th-232	2.3E-07	1.1E-04	8.8E-18
U-233	5.1E-08	9.6E-06	2.4E-17
U-234	4.9E-08	9.4E-06	6.6E-18
U-235	4.7E-08	8.5E-06	1.3E-14
U-236	4.7E-08	8.7E-06	3.4E-18
U-238	4.5E-08	8.0E-06	1.5E-18
Zr-93	1.1E-09	2.5E-08	0

[1] For C-14 a distinction is made between intake via food and water. The tabulated value is used for ingestion via food whereas the dose coefficient used for intake via water is 2.9E-11 /Leggett 2004/.
[2] Refers to the soluble gas form.

6.2 Other element-specific parameters

6.2.1 Diffusivity

Diffusivity (diffcoef) is a proportionality constant between the mass flux due to molecular diffusion and the gradient in the concentration of the element. This coefficient has an SI unit of m^2/s, but in SR-Site the unit $m^2/year$ is used. The diffusivity is used in the Radionuclide Model /Avila et al. 2010/ for calculation of the diffusion fluxes between different regolith compartments. The values used are the recommended values for diffusivities in free solution in Table 5-11 in /Liu et al. 2006/. This parameter was treated as a constant in probabilistic simulations. The values used are shown in Table 6-3.

Table 6-3. Values used for the parameter Diffusivity (diffcoef) in SR-Site. Values in $m^2/year$ recalculated from Table 5-11 in /Liu et al. 2006/.

Element	Diffusivity ($m^2/year$)
Ac	3.2E-02
Ag	5.4E-02
Am	3.2E-02
C	3.8E-02
Ca	3.2E-02
Cl	6.3E-02
Cm	3.2E-02
Cs	6.6E-02
Ho	3.2E-02
I	2.6E-02
Nb	3.2E-02
Ni	2.1E-02
Np	3.2E-02
Pa	3.2E-02
Pb	3.2E-02
Pd	3.2E-02
Po	3.2E-02
Pu	3.2E-02
Ra	2.8E-02
Se	3.2E-02
Sm	3.2E-02
Sn	3.2E-02
Sr	2.5E-02
Tc	3.2E-02
Th	4.7E-03
U	3.2E-02
Zr	3.2E-02

6.2.2 Element behaviour during decomposition

To describe the turnover of elements in terrestrial ecosystems one parameter describing the behaviour of different elements during decomposition was used (Ter_df_decomp). The parameter gives the fraction of the element retained in the organic part of the litter compared to the dry mass. The parameter is dimensionless.

Studies have described how the element composition changes over time for decomposing litter e.g. /Brun et al. 2008, Tyler 2005, Sheppard and Evenden 1990/, see also /Berg and McClaugherty 2003/. Basically, some elements increase in concentration (mass-normalized) and some decrease over time. This means that some elements are retained and thereby show increasing concentrations, while others are more easily released from the litter. Such patterns are influenced by both physical and chemical properties that may be species-specific and are probably not site-specific /Staaf 1982, Johansson 1995/. Generally, there is a problem in describing element concentrations in decaying litter due to the enrichment via phenomena such as regional/global atmospheric deposition and local deposition from leaching vegetation, humus and minerogenic dust. In order to obtain retention factors of different elements during decomposition, data from the site investigations were used to make rough estimates.

/Brun et al. 2008/ grouped a large number of elements according to their behaviour in decomposing litter of Scots pine, Norway spruce, Oak and Alder from six localities at the Forsmark and Laxemar-Simpevarp sites. Those elements that show a more or less continuous decrease over time and those classified as nutrients were grouped together (here called carbon-like elements, see Table 6-4). The other elements were classified as a group of elements that to some degree is retained in the litter. Those elements that were difficult to classify according to /Brun et al. 2008/ were included in the group for elements retained in litter. The study did not take into account the possibility of atmospheric deposition of elements during the study period, which made the calculated estimates conservative for some elements. The methods and the experiment setup was also described in /Mjöfors et al. 2007/. The data were based on the green parts of trees, where coniferous trees dominated the samples. It is assumed that the calculated retention also represents other green tissues, such as herbs, grasses and mosses. This has to be considered as a cautious assumption because the turnover of more nitrogen rich litter, such as litter from herbs, are considered to be faster and thereby is the retention in litter probably somewhat overestimated. The change in the amount of the element (A_i) in the litter over time *dt* is described by,

$$\frac{dA_i}{dt} = -\text{mass\_loss} \times \text{Ter\_df\_decomp}_i \times A_l \qquad (6\text{-}1)$$

where *mass_loss* describes the mass loss (as fraction of initial mass) and $Ter\_df\_decomp_i$ denotes how the concentration of the element *i* is related to the mass loss. By integrating this differential equation the relationship between A_i at two different points in time, t_1 and t_2 was obtained:

$$A_{i(t_2)} = A_{i(t_1)} \times e^{-mass\_loss \times Ter\_df\_decomp \times (t_2 - t_1)} \qquad (6\text{-}2)$$

Equation 6-2 was then rearranged to give *Ter_df_decomp*.

$$Ter\_df\_decomp = \frac{-1}{mass\_loss \times (t_2 - t_1)} \times \text{In}\left(\frac{Ai(t_2)}{Ai(t_1)}\right) \qquad (6\text{-}3)$$

This experiment was followed over a period of two years (t_2–t_1), where the concentration of the element at the start and at the end was known ($conc_{t1}$ and $conc_{t2}$). The concentration of element *i* at time t_2 is a function of the initial mass, the concentration at t_2 and the mass loss at t_2 (from /Mjöfors et al. 2007/ Appendix A2), which gives,

$$Ter\_df\_decomp = \frac{-1}{mass\_loss \times (t_2 - t_1)} \times \text{In}\left(\frac{conc(t_2) \times mass(t_1) \times (1 - mass\_loss)}{conc(t_1) \times mass(t_1)}\right) \qquad (6\text{-}4)$$

Variables describing the mass can be abbreviated giving the following expression,

$$Ter\_df\_decomp = \frac{-1}{mass\_loss \times (t_2 - t_1)} \times \text{In}\left(\frac{conc(t_2)}{conc(t_1)} \times (1 - mass\_loss\right) \qquad (6\text{-}5)$$

Ter_df_decomp was calculated for each locality and tree species (N=6, see above) and a GM was estimated for each element (Table 6-4). The GM seemed to be the best description of the central value and a GM was then calculated for the two groups, carbon-like elements and other elements, which were normalised to carbon-like elements by dividing the two GMs by the GM of carbon-like elements (Table 6-5). The rational for using two groups for describing element behaviour during decomposition was to make robust estimates based on fairly small sample sizes. The minimum and maximum values for the two groups represent the span of normalised GMs for the different elements within each group. This calculation reflects a simplistic model assuming a first order relationship between mass loss and element loss, which is an approximation for a more complex pattern. This is regarded to be sufficiently accurate for the application.

Table 6-4. Elements grouped according to patterns from a Principal Component Analysis in /Brun et al. 2008/ (Carbon-like or Other elements). These elements where studied in a litter decomposition study in Forsmark and Laxemar-Simpevarp /Mjöfors et al. 2007/. /. Values in the third column correspond to the calculated Ter_df_decomp variable before normalising to carbon-like elements (see text).

Element	Group	Geometric mean
B	Carbon-like	0.66
K	Carbon-like	1.10
Mg	Carbon-like	0.58
Mn	Carbon-like	0.44
Na	Carbon-like	0.85
Rb	Carbon-like	0.55
Ba	Carbon-like	0.24
Ca	Carbon-like	0.35
P	Carbon-like	0.42
S	Carbon-like	0.98
Sc	Carbon-like	0.32
Sr	Carbon-like	0.44
Au	Carbon-like	1.36
Tl	Carbon-like	no estimate, N<3
Cr	Carbon-like	0.59
Zn	Carbon-like	0.04
Ag	Other	0.07
Ce	Other	0.03
Co	Other	0.15
Cs	Other	0.05
Cu	Other	0.20
Fe	Other	0.04
La	Other	0.04
Mo	Other	0.07
Ni	Other	0.08
Pb	Other	0.02
Sb	Other	0.04
Ti	Other	0.03
Y	Other	0.04
Cd	Other	0.04
Hg	Other	0.10
Sn	Other	0.03
Zr	Other	0.04
Li	Other	0.24
Se	Other	no estimate, N<3
Ge	Other	no estimate, N<3
Nb	Other	no estimate, N<3
Th	Other	no estimate, N<3
U	Other	no estimate, N<3
Hf	Other	no estimate, N<3
As	Other	no estimate, N<3
Bi	Other	no estimate, N<3
Ga	Other	no estimate, N<3
V	Other	no estimate, N<3
Geometric mean	*Carbon-like elements*	*0.47*
Geometric mean	*Other elements*	*0.06*

Table 6-5. Values used for the parameter “Ter_df_decomp” in SR-Site.

Element group	Ter_df_decomp Geometric mean	Min	Max
Carbon-like elements	1	0.09	2.87
Other elements	0.12	0.05	0.51

6.2.3 Retention coefficient

When modelling irrigation with contaminated water in SR-Site an element-dependent retention coefficient (coefRetent) is used to estimate the fraction of radionuclides intercepted by the above-ground parts of the vegetation during irrigation that is retentained in the vegetation surface /Bergström and Barkefors 2004/. The parameter is dimensionless and has earlier been described in /Bergström and Barkefors 2004/. The values recommended in that study are presented in Table 6-6. The value for monovalent cations was used for Cs whereas the value for anions was used for Cl and I. For the rest of the elements the value for cations (the highest value) was used in order to be conservative. The minimum and maximum values given in /Bergström and Barkefors 2004/ were used, assuming a uniform distribution.

Table 6-6. Values used for the parameter “coefRetent” (dimensionless) bin SR-Site (from Table 8-1 in /Bergström and Barkefors 2004/).

Chemical form	Best estimate	Min value	Max value
Anions	0.5	0.3	0.7
Monovalent cations	1.0	0.7	1.3
Cations	2.0	1.5	2.5

6.3 Consumption of food, water and soil by cattle

Transfer of radionuclides to milk and meat is based on cattle’s intake of contaminated fodder, water and soil (some inadvertent consumption of soil when grazing is assumed). Fodder was treated as one kind of item, instead of dividing it into different kinds (e.g. pasturage and concentrated fodder) as used in earlier assessments. Fodder was assumed to be produced in the area, and contamination via uptake from soil was considered. The concentrations of radionuclides in water and soil are obtained in the Radionuclide Model /Avila et al. 2010/, while concentration in food is obtained using element-specific CRs between soil and pasturage (cR_soilToPast), see Section 4.1.

As consumption of fodder and water is considerably larger for dairy cattle than for beef cattle, different parameter values were used for these two cattle types (Table 6-7). According to /Karlsson et al. 2001/, the water consumption of dairy cows (ingRate_water_milk) is approximately 70 L/day, while it is approximately 20–60 L/day for beef cows (ingRate_water_meat).

In Table 185 in /SLU 1996/, food consumption of dairy cattle (ingRate_food_milk) is given for five different alternatives for fodder composition (*sw. foderstatsalternativ*) and yield levels (*sw. avkastningsnivåer*). The total amount of food needed was calculated assuming a water content of 15% for cereals, concentrate and hay and a C content of 46% of dry weight (site-specific C content of green vegetation /Löfgren 2010/). The lowest, highest and AMs of the five different alternatives were used as minimum, maximum and best estimate values (see Table 6-7).

In Table 229 in /SLU 1996/, the food consumption of beef cattle (ingRate_food_meat) is presented for eight different alternatives concerning weight at slaughter. The energy amounts needed expressed as MJ per kg produced meat are used together with the mean value of the nutrient content in hay, cereals and concentrate specified in the same table. The amount was converted to C assuming a C content of 46% per dry weight (site-specific C content of green vegetation /Löfgren 2010/). The lowest age at slaughter of each category was used to convert the figures into annual consumption rates.

This is a conservative approach that gives a higher annual consumption rate (the same amount of food is consumed over a shorter time period). The lowest, highest and arithmetic mean values of the eight different alternatives were used as minimum, maximum and best estimate values (see Table 6-7).

The consumption of soil (ingRate_soil_Cow) adhering to vegetation consumed by cattle was calculated by /Davis et al. 1993/ and the value was extracted from that study in /Karlsson et al. 2001/. A relatively wide parameter range was set because of the difficulties in verifying such data.

Table 6-7. Parameter values used for cattle's consumption.

Parameter name	Value	Unit	Min	Max	Distribution type	Reference
Water consumption, dairy cow (ingRate_water_milk)	0.07	m^3/d	0.065	0.075	Uniform	/Karlsson et al. 2001/
Water consumption, beef cow (ingRate_water_meat)	0.04	m^3/d	0.02	0.06	Uniform	/Karlsson et al. 2001/
Food consumption, dairy cow (IngRate_food_milk)	7.1	kgC/d	6.2	7.9	Uniform	/SLU 1996/
Food consumption, beef cow (IngRate_food_meat)	4.0	kgC/d	3.0	5.0	Uniform	/SLU 1996/
Soil consumption, dairy and beef cow (IngRate_soil_Cow)	0.3	kgDW/d	0.15	0.5	Uniform	/Karlsson et al. 2001/

6.3.1 Density and carbon contents of meat and milk

The density and carbon content of meat and milk (Table 6-9) were used when calculating the concentration of radionuclides in meat and milk from domestic cattle. The density is expressed in kg/l and the carbon content in kg C/kg fresh weight. Only mean values for these parameters were used in the Radionuclide Model for the biosphere, since none of these parameters was varied probabilistically.

The value of density of milk (densMilk) was obtained from the Swedish National Food Administration /Livsmedelsverket 2001/. The milk density varies somewhat between milk with different fat contents, but the difference is very small (1.03–1.04 kg/l). A 5% variation is assumed to cover the min and max interval and a normal distribution is assumed.

In the absence of site-specific data on the carbon content of milk (conc_C_milk), the value for this parameter was taken from /Avila 2006a/. The parameter was calculated from the following equation, relating the protein, carbohydrate and fat contents with the C content in food /Altman and Ditmer 1964, Dyson 1978, Rouwenhorst et al. 1991/:

$$CC_k = 0.53 \cdot \mathrm{Pr}oteins_k + 0.44 \cdot Carbohydrates_k + 0.66 \cdot Lipids_k$$

where,

CC_k is the C content in the food product "*k*" [kg C/kg FW],

$Proteins_k$ is the protein content in the food product "*k*" [kg /kg FW],

$Carbohydrates_k$ is the carbohydrate content in the food product "*k*" [kg /kg FW],

$Lipids_k$ is the lipid content in the food product "*k*" [kg /kg FW].

The values of the carbon content of proteins, carbohydrates and lipids in milk, used in the calculations were taken from the database of the Swedish Food Administration (Livsmedelverket) available online at www.slv.se. A 5% variation is assumed to cover the min and max interval and a normal distribution is assumed, this data were used to estimate a mean value carbon content of milk for the deterministic calculations.

Data on the carbon content of meat (conc_C_meat) was estimated from site-specific data for mammals /Tröjbom and Nordén 2010/. The carbon content in meat of larger mammals and small rodents from Forsmark and Laxemar varies between 0.34 and 0.51 kg C/kg dw. The mean value for mammals is 0.45 kg C/kg dw. The mean dry weight of mammals is 0.26 kg dw/kg fw, giving a carbon content of 0.12 kg C/kg fw.

Table 6-8. Parameter values used for density and carbon content of meat and milk.

Parameter name	Value	Unit	Std	Min	Max	Distribution type	Reference
Milk density (densMilk)	1.03	kg fw/l		0.9785	1.0815	Normal	/Livsmedelsverket 2001/
C content of milk (conc_C_milk)	0.064	kg C/kg fw		0.0608	0.0672	Normal	/Avila 2006a/
C content of meat (conc_C_meat)	0.12	kg C/kg fw	0.02	–	–	Normal	Site-specific data/ Tröjbom and Nordén 2010/

6.3.2 Parameter values for carbon and hydrogen

Carbon was modelled somewhat differently in SR-Site compared to the other elements. As is a common practice /IAEA 2001/, a so-called specific activity model was used for C-14 /Avila et al. 2010/. This is motivated by the strong influence that the carbon cycle has on the environmental behaviour of this radionuclide. One of the differences is that element-specific CRs have not been used and carbon is therefore not dealt with in this report describing these parameters. The radionuclide-specific dose coefficients were used also for C-14 and H-3 (see Section 6.1).

6.4 Human characteristics

Parameters that describe habits and properties of the exposed individual were primarily collected from the literature. In line with international recommendations /ICRP 2006a/, fixed, slightly conservative values were chosen for these parameters. Thus these parameters were excluded from the probabilistic simulations, leaving the uncertainty distribution in LDFs to primarily reflect the environmental uncertainties.

6.4.1 Ingestion rate of water

The water consumption value used for humans (ingRate_wat) in dose calculations should not include the water that is contained in food, since its contribution to water balance in humans is indirectly included in the calculations of the internal dose from food ingestion. The reference values in /ICRP 2002/ are given for total water intake with food and fluids (see Table A-1 in /Avila and Bergström 2006/). Daily consumption of water in fluids and food varies markedly from one person to another, depending on individual habits, such as dietary habits and exercise, and environmental factors such as air temperature and humidity, as well as age and gender. A study on an adult population in France /Antoine et al. 1986/ quoted in /ICRP 2002/ estimated "visible" water intakes such as tap water (650 ml/day) and other drinks (678 ml/day), i.e. a total of 0.5 m^3/y of water consumption with fluids (drinking). A study in the US /Ershow and Cantor 1989/ quoted in /ICRP 2002/ showed total values of water consumption with fluids by adults of 0.4–0.6 m^3/y, including intake of drinking water, water added to beverages and water added to food during preparation, but not water intrinsic in unprocessed food. The values reported in the above studies, as well as in /ICRP 1975/, are close to the value of 0.6 m^3/y that was used in previous assessments and this value was used in SR-Site (see Table 6-9).

6.4.2 Ingestion rate of food

The human food ingestion rate (ingRate_C) used in SR-Site is expressed in kg C per year. The total intake of C by an individual is related to the food energy intake, 10 kcal is approximately equivalent to 1 g organic (food) C. Total energy expenditure is age and gender dependent (see Table A-1 in /Avila and Bergström 2006/) and varies widely due to individual differences in activity, body size and body composition. The reference value of energy expenditure by an adult male given in /ICRP 2002/ is 2,800 kcal/day (Table A-1 in /Avila and Bergström 2006/) and since usage of metabolic fuel is normally balanced by variations in food intake /ICRP 2002/, we can estimate that the yearly C intake is around 102 kg. The same calculation for adult females gives a value of 66 kg C/year. Carbon intake by male adults can also be estimated from the values of protein intake (0.095 kg/day), carbohydrate intake (0.39 kg/day) and fat intake (0.12 kg/day) given in /ICRP 1975/ and the C content in proteins, carbohydrates and fats: 0.53, 0.44 and 0.66 kg C/kg, respectively /Altman and Ditmer 1964, Dyson 1978, Rouwenhorst et al. 1991/. This gives a value of around 110 kg C/year for adult males, which is the value used in SR-Site (Table 6-9). The same calculation for adult females gives a value of around 76 kg C/year.

6.4.3 Inhalation rate

To calculate exposure through inhalation, the inhalation rate (inhalRate, expressed in m^3/h) is used. The inhalation rate of an individual varies during the day depending on the activities and time spent outdoors and indoors. In /ICRP 2002/, reference values of total inhalation during a day are provided for members of the public at various ages (see Table A-1 in /Avila and Bergström 2006/). The highest value, 22 m^3/day, is for adult males, which is close to the value used in previous assessments, i.e. 1 m^3/h or 24 m^3/day and this value is used also in SR-Site (Table 6-9).

6.4.4 Exposure time

The exposure time to the contaminated air (inhalation) and the contaminated ground (external exposure) depends on the exposure context and in particular the type of human activity leading to the exposure. For pessimistic assessments a value of 8,760 h/year can be used, implying 100% percent exposure time. This was used in SR-Site (Table 6-9).

Table 6-9. Parameter values used concerning human behaviour.

Parameter name	Value	Unit	Reference
Human water ingestion rate (ingRate_wat)	0.6	m^3/y	/Avila and Bergström 2006/
Human food ingestion rate (ingRate_C)	110	kgC/y	/Avila and Bergström 2006/
Human inhalation rate (inhalRate)	1	m^3/h	/Avila and Bergström 2006/
Exposure time (expTime)	8,760	h/y	Conservative value

6.4.5 Average integration time

The time interval over which concentration in vegetables from radionuclides accumulated in soil, as a consequence of irrigation with contaminated water, is described by the parameter "AverTime". A value of 50 years was used, which is the same value used by ICRP /2007/ in the derivation of dose coefficients used in calculation of average dose during the life time of adults. This parameter was kept at a constant value in the probabilistic simulations.

7 Discussion

The discussion below is centred on the approaches applied in this study for selection of K_d and CR values. The K_d and CR reported in the literature are highly variable, often covering several orders of magnitude. Nevertheless, they are widely used in biosphere assessment models for representing radionuclide retention and uptake, respectively. This is largely because the approach is simple. Moreover, the K_ds and CRs are relatively easy to measure, which can explain that numerous values have been reported in the literature covering a wide range of conditions. A common approach to deal with the high variability in K_ds and CRs is to select values that are representative of the biosphere conditions at the studied site, taking into account spatial and time variability within the time frame of the assessments.

7.1 About the approach for selection of CR and K_d values

In SR-Site, site-specific values of K_d and CR have been obtained from the site investigation programs. The measured site data are considered be generally representative of future conditions addressed in the assessment, although it has not been possible to obtain data for all relevant elements and the level of representativeness has varied from case to case. As explained in Chapter 2, several methods have been applied for selecting Best Estimate (BE) values and Probability Distribution Functions (PDFs) of CR and K_d for use in SR-Site biosphere assessments. The selection of one of the other method has been dictated, in each specific case, by the availability of site-specific and literature data.

Best Estimate values

The selected BE values of CR and K_d have been used in deterministic simulations for derivation of LDFs /Avila et al. 2010/ and may, therefore, have direct impact on the dose assessments performed in SR-Site. Tables 7-1–7-4 provide summarising presentations of the information used in the selection of BE values for elements of those radionuclides with the highest potential dose contribution to the doses. It can be seen from these tables, that for many of these elements (denoted with S or S+L in the tables) site-specific values of CR and K_d have been obtained. In several cases (denoted with S in the tables) the site data has been sufficient on their own for deriving BE values, whereas in other cases (denoted with S+L in the tables) it has been combined with literature data using Bayesian updating methods (see Chapter 2 and Appendix C). For a few elements (Am, Np, Pb, Pu and Tc) site-specific data of CR and K_d could not be obtained and therefore the BE of all CR and K_d for these elements are based on literature data. Efforts have been made for selecting representative CR and K_d values also for these elements, for example by selecting literature values obtained for conditions that are representative for the Forsmark site. Nevertheless, it has to be taken into account that for these elements the BE values might be less accurate than for those for which site data is available. The significance of this potential lack of accuracy for the assessments will depend on the contribution of the corresponding radionuclides to the dose estimates and the sensitivity of the model predictions to these parameters.

In cases when only few site data were available, BE values of CR and K_d were derived from combining site specific and literature data using Bayesian Updating methods. The resulting BE values were close to the values that would have resulted from using the site data alone. In part this could be an effect of giving more weight to the site-specific data in the Bayesian updating (see Chapter 2), but nevertheless it increases the confidence in the selected BE values. The use of BE estimate values that are close to the site data has several merits. We consider that the site data obtained is the best information available of representative conditions for the assessment. It is also an advantage that all site data of CR and K_d have been obtained under the same conditions and using the same analytical methods. It is well known that different values of CR and K_d might be obtained for the same site and conditions when different methods are used /IAEA 2010/. Also, it is well known that there are correlations between CRs and K_ds, which might be of important when using several of these parameters in an assessment. For example, using a high K_d value for an element might be in contradiction with using a high CR value for the same element, if these are negatively correlated. The fact that all BE values are close to site data values increases the confident that the different CR and K_d values (i.e. the BE values) used in the deterministic simulations for derivation of Landscape Dose Factors /Avila et al. 2010/ are consistent with each other.

Probability Distribution Functions

The Probability Distribution Functions (PDFs) of CR and K_d were used in the probabilistic simulations for sensitivity and uncertainty analysis /Avila et al. 2010/. The PDFs have no direct impact on the Landscape Dose Conversion Factors, which were derived from deterministic simulations. For all CR and K_d for which site data were available (denoted with S or S+L in Tables 7-1–7-4), the PDFs were derived by combining site and literature data using Bayesian updating methods (see Chapter 2 and Appendix C). The rationale for using Bayesian methods is to complement the site data with other available information, for example literature data, so that selected PDFs cover better the relevant rank of variation of the CRs and K_ds. Although the site data have been sufficient to obtain representative BE values, the number of available values are in most cases too few for giving, a good characterisation on their own of the variation in the distribution (determined by the GSD values). The effect of applying the Bayesian updating methods is that larger GSDs have been assigned to the distributions, than if these had been obtained from the data alone. The ideal situation would be to use only literature data obtained for similar site conditions in the Bayesian updating. In this study, however, compiled literature data have been used and in many cases, and therefore as a rule the GSDs have been overestimated. The same is true for those PDFs that were obtained solely on the basis of literature data. The use of PDFs with overestimated GSD values in the probabilistic simulations will result in overestimation of the uncertainties and sensitivity of the parameters, i.e. it lead to cautious estimates. In very few cases, often when both site and literature data were very scarce, relatively low GSD values have been assigned to the distributions based on the available information. In such cases, depending on their impact on assessment endpoints, it might be necessary to use a cautious generic value of the GSD in the probabilistic simulations, for example the highest values across all GSD of the same parameter. It should be noted that in the case of the CR for terrestrial herbivores the values were derived with the allometric-kinetic model (see Chapter 2) using conservative assumption and have therefore none or very small (small GSDs) associated variation. Therefore, the derived distributions represent uncertainty of a conservative value, which explains why these distributions are generally narrow. For some CRs only a single conservative value could be obtained and therefore these CRs were not varied in the probabilistic simulations.

Table 7-1. Type of information used in the selection of BE values for different types of K_d. "L" indicates that only literature data were used, "S" that only site data were used and "S+L" that both site and literature data were used.

Element	Inorganic deposits	Organic deposits	Suspended matter (freshwater)	Suspended matter (marine)
Am	L	L	L	L
Cl	S+L	S	L	L
Cs	S+L	S+L	S+L	S+L
I	S+L	S	S+L	S+L
Nb	S+L	S+L	S+L	S+L
Ni	S+L	S	S+L	S+L
Np	L	L	L	L
Pd	L	L	L	L
Pu	L	L	L	L
Ra	S	S	L	L
Se	S+L	S	S	S+L
Sn	L	S+L	L	S+L
Tc	L	L	L	L
Th	S+L	S	S+L	S+L
U	S+L	S	S+L	S+L
Zr	S+L	S+L	S+L	S+L

Table 7-2. Type of information used in the selection of BE values of CRs for different types of natural terrestrial biota. "L" indicates that only literature data were used, "S" that only site data were used, "S+L" that both site and literature data were used, "S(pp)" that site data for primary producers were used and "M" that the values were derived with the kinetic-allometric model described in Section 2.4.

Element	Primary producers	Mushrooms	Herbivores
Am	L	L	M
Cl	S	S (pp)	S
Cs	S+L	S+L	S
I	S	S	M
Nb	S	S (pp)	S
Ni	S+L	S	S
Np	L	L	M
Pd	L	L	M
Pu	L	L	M
Ra	S+L	L	M
Se	L	L	M
Sn	S	S (pp)	S
Tc	L	L	M
Th	L	S	S
U	S+L	S	S
Zr	S	S(pp)	S

Table 7-3. Type of information used in the selection of BE values of CRs for different types freshwater biota. "L" indicates that only literature data were used, "S" that only site data were used, "S+L" that both site and literature data were used and "S(macroph)" that site data for macrophytes were used.

Element	Phytoplankton	Microphytobenthos	Macrophytes	Crustacean	Fish
Am	L	L	L	L	L
Cl	S(macroph)	S(macroph)	S+L	S+L	S+L
Cs	S(macroph)	S(macroph)	S+L	S+L	S+L
I	S(macroph)	S(macroph)	S+L	S+L	S+L
Nb	S(macroph)	S(macroph)	S	S+L	S+L
Ni	S(macroph)	S(macroph)	S+L	S+L	L
Np	L	L	L	L	L
Pd	L	L	L	L	L
Pu	L	L	L	L	L
Ra	S(macroph)	S(macroph)	S+L	S+L	S+L
Se	S(macroph)	S(macroph)	S+L	S+L	S+L
Sn	L	L	L	S+L	L
Tc	L	L	L	L	L
Th	S(macroph)	S(macroph)	S+L	S+L	L
U	S(macroph)	S(macroph)	S+L	S+L	S+L
Zr	S(macroph)	S(macroph)	S	S+L	S+L

Table 7-4. Type of information used in the selection of BE values of CRs for different types marine biota. "L" indicates that only literature data were used, "S" that only site data were used, "S+L" that both site and literature data were used and "S(macroph)" that site data for macrophytes were used.

Element	Phytoplankton	Microphytobenthos	Macrophytes	Fish
Am	L	L	L	L
Cl	S	S	S+L	S+L
Cs	S+L	S	S+L	S+L
I	S	S	S+L	S
Nb	S(macroph)	S(macroph)	S+L	S+L
Ni	S	S	S+L	S+L
Np	L	L	L	L
Pd	L	L	L	L
Pu	L	L	L	L
Ra	L	L	L	L
Se	S+L	S	S+L	S+L
Sn	S(macroph)	S(macroph)	S+L	S+L
Tc	L	L	L	L
Th	S+L	S	S+L	S+L
U	S(macroph)	S(macroph)	S+L	S+L
Zr	S+L	S	S+L	S+L

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Appendix A

Compilation of literature data

This appendix contains a compilation of the literature data that was used in the derivation of model parameter values.

Table A-1. Kd for inorganic soil “kD_regoLow”, m³/kg dw, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac	3		1.2E+00	2.0	4.5E-01	2.4E+00	/IAEA 2010/
	4		1.7E+00	3.0	4.5E-01	5.4E+00	/IAEA 2010/[1]
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Ag	5		1.4E-01	3.0	3.6E-02	7.0E-01	/IAEA 2010/
	9		3.7E-01	7.0	3.6E-02	1.5E+01	/IAEA 2010/[1]
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Am	62		2.6E+00	6.0	5.0E-02	1.1E+02	/IAEA 2010/[1]
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Ca	33		7.0E-03	3.0	7.0E-04	8.9E-02	/IAEA 2010/
	34		8.0E-03	3.0	7.0E-04	1.1E-01	/IAEA 2010/[1]
Cd	39		1.1E-01	8.0	2.0E-03	2.7E+00	/IAEA 2010/
	61		1.5E-01	9.0	2.0E-03	7.0E+00	/IAEA 2010/[1]
		1.0E-01			2.0E-03	3.0E+00	/Karlsson and Bergström 2002/
Cl	22		3.0E-04	3.0	4.0E-05	1.2E-03	/IAEA 2010/[1]
		1.0E-03	1.0E-03	3.2	1.0E-04	1.0E-02	/Karlsson and Bergström 2002/
Cm	18		9.3E+00	4.0	1.9E-01	5.2E+01	/IAEA 2010/[1]
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Cs	469		1.2E+00	7.0	4.0E-03	3.8E+02	/IAEA 2010/[1]
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Eu		2.0E+02			2.0E+01	2.0E+03	/Karlsson and Bergström 2002/
Ho	3		6.3E-01	2.0	2.4E-01	1.3E+00	/IAEA 2010/
	4		9.3E-01	3.0	2.4E-01	3.0E+00	/IAEA 2010/[1]
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
I	196		7.0E-03	5.0	1.0E-05	5.4E-01	/IAEA 2010/
	250		7.0E-03	5.0	1.0E-05	5.8E-01	/IAEA 2010/[1]
		3.0E-01			1.0E-01	1.0E+00	/Karlsson and Bergström 2002/
Mo	9		4.0E-02	3.0	7.0E-03	1.3E-01	/IAEA 2010/[1]
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Nb	11		1.5E+00	4.0	1.6E-01	8.4E+00	/IAEA 2010/[1]
		5.0E-01			5.0E-03	5.0E+00	/Karlsson and Bergström 2002/
Ni	64		2.8E-01	7.0	3.0E-03	7.3E+00	/IAEA 2010/[1]
		5.0E-01			5.0E-02	5.0E+00	/Karlsson and Bergström 2002/
Np	22		2.0E-02	4.0	1.3E-03	1.2E-01	/IAEA 2010/
	26		3.5E-01	6.0	1.3E-03	1.2E+00	/IAEA 2010/[1]
		1.0E-01			5.4E-01	6.6E+00	/Karlsson and Bergström 2002/
Pa	3		1.4E+00	2.0	5.4E-01	2.7E+00	/IAEA 2010/
	4		2.0E+00	3.0	5.4E-01	6.6E+00	/IAEA 2010/[1]
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Pb	23		2.1E+00	10	2.5E-02	1.3E+02	/IAEA 2010/[1]
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Pd	4		1.4E-01	2.0	5.5E-02	2.7E-01	/IAEA 2010/
	6		1.8E-01	2.0	5.5E-02	6.7E-01	/IAEA 2010/[1]
		2.0E-01			2.0E-02	2.0E+00	/Karlsson and Bergström 2002/
Po	43		1.9E-01	5.0	1.2E-02	7.0E+00	/IAEA 2010/
	44		2.1E-01	5.0	1.2E-02	7.0E+00	/IAEA 2010/[1]
		5.0E-01			5.0E-02	3.0E+00	/Karlsson and Bergström 2002/
Pu	62		7.4E-01	4.0	3.2E-02	9.6E+00	/IAEA 2010/[1]
		5.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Ra	51		2.5E+00	13	1.2E-02	9.5E+02	/IAEA 2010/[1]
		5.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Se	172		2.0E-01	3.0	4.0E-03	2.1E+00	/IAEA 2010/[1]
		1.0E-02			1.0E-03	1.0E-01	/Karlsson and Bergström 2002/
Sm	3		6.3E-01	2.0	2.4E-01	1.3E+00	/IAEA 2010/
	4		9.3E-01	3.0	2.4E-01	3.0E+00	/IAEA 2010/[1]

Element	N	BE	GM	GSD	Min	Max	Data source
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Sn	4		2.9E-01	2.0	2.0E-03	7.0E+00	/IAEA 2010/
	12		1.6E-01	6.0	1.3E-01	3.1E+01	/IAEA 2010/[1]
		1.0E-01			5.0E-02	5.0E-01	/Karlsson and Bergström 2002/
Sr	255		5.0E-02	6.0	4.0E-04	6.5E+00	/IAEA 2010/[1]
		1.0E-02			1.0E-03	1.0E-01	/Karlsson and Bergström 2002/
Tc	22		6.0E-05	4.0	1.0E-05	1.0E-03	/IAEA 2010/
	33		2.0E-04	9.0	1.0E-05	1.1E-02	/IAEA 2010/[1]
		5.0E-03				1.0E-02	/Karlsson and Bergström 2002/
Th	25		2.6E+00	10	3.5E-02	2.5E+02	/IAEA 2010/
	46		1.9E+00	10	1.9E-02	2.5E+02	/IAEA 2010/[1]
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
U	146		1.8E-01	13	7.0E-04	6.7E+01	/IAEA 2010/
	178		2.0E-01	12	7.0E-04	6.7E+01	/IAEA 2010/[1]
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Zr	11		4.1E-01	21	2.0E-03	1.0E+01	/IAEA 2010/[1]
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/

[1] all soil type.

Table A-2. Kd for organic soil "Ter_regoUp"," Ter_regoMid", "Lake_regoUp"," Lake_regoMid", "Sea_regoUp" and "Sea_regoMid", m³/kg dw, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac	1	5.4E+00					/IAEA 2010/
		5.0E+00			5.0E-01	5.0E+01	/Karlsson and Bergström 2002/
Ag	2	9.7E+00			4.4E+00	1.5E+01	/IAEA 2010/
		2.0E+01			2.0E+00	9.0E+01	/Karlsson and Bergström 2002/
Am	13		2.5E+00	5.0	2.1E-01	1.1E+02	/IAEA 2010/
		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
Ca	1	1.1E-01					/IAEA 2010/
Cd	13		6.5E-01	6.0	1.0E-02	7.0E+00	/IAEA 2010/
		8.0E-01			8.0E-03	8.0E+01	/Karlsson and Bergström 2002/
Cl		1.0E-02			1.0E-03	1.0E-01	/Karlsson and Bergström 2002/
Cm	3		7.4E+00	2.0	5.1E+00	1.2E+01	/IAEA 2010/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Cs	108		2.7E-01	7.0	4.3E-03	9.5E+01	/IAEA 2010/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Eu		1.0E+00			5.0E-02	2.0E+01	/Karlsson and Bergström 2002/
Ho	1						/IAEA 2010/
		3.0E+00			3.0E-01	3.0E+01	/Karlsson and Bergström 2002/
I	11		3.2E-02	3.0	8.5E-03	5.8E-01	/IAEA 2010/
		3.0E-02			3.0E-03	3.0E-01	/Karlsson and Bergström 2002/
Mo		3.0E-02			3.0E-03	3.0E-01	/Karlsson and Bergström 2002/
Nb	1						/IAEA 2010/
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Ni	20		9.8E-01	2.0	2.5E-01	5.0E+00	/IAEA 2010/
		1.0E+00			2.0E-01	7.0E+00	/Karlsson and Bergström 2002/
Np	4		8.1E-01	1.4	5.0E-01	1.2E+00	/IAEA 2010/
		1.0E+00			5.0E-01	3.0E+00	/Karlsson and Bergström 2002/
Pa	1						/IAEA 2010/
		7.0E+00			7.0E-01	7.0E+01	/Karlsson and Bergström 2002/
Pb	5		2.5E+00	3.0	8.8E-01	1.0E+01	/IAEA 2010/
		2.0E+01			8.0E+00	6.0E+01	/Karlsson and Bergström 2002/
Pd	1	6.7E-01					/IAEA 2010/
		7.0E-01			7.0E-02	7.0E+00	/Karlsson and Bergström 2002/
Po	1	6.6E+00					/IAEA 2010/
		7.0E+00			7.0E-01	7.0E+02	/Karlsson and Bergström 2002/
Pu	6		7.6E-01	4.0	9.0E-02	3.0E+00	/IAEA 2010/
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Ra	2	1.3E+00			2.0E-01	2.4E+00	/IAEA 2010/
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Se	2	1.0E+00			2.3E-01	1.8E+00	/IAEA 2010/
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Sm	1	3.0E+00			–	–	/IAEA 2010/
		3.0E+00			3.0E-01	3.0E+01	/Karlsson and Bergström 2002/
Sn	1	1.6E+00			–	–	/IAEA 2010/
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Sr	176		7.0E-02	6.0	2.0E-03	6.5E+00	/IAEA 2010/[1]
	37		1.1E-01	6.0	3.0E-03	6.5E+00	/IAEA 2010/
		2.0E-01			4.0E-03	6.0E+00	/Karlsson and Bergström 2002/
Tc	11		3.0E-03	3.0	9.2E-04	1.1E-02	/IAEA 2010/
		2.0E-03			4.0E-05	6.0E-02	/Karlsson and Bergström 2002/
Th	5		7.3E-01	44	1.8E-02	8.0E+01	/IAEA 2010/
		9.0E+01			9.0E+00	9.0E+02	/Karlsson and Bergström 2002/
U	9		1.2E+00	6.0	3.3E-02	7.6E+00	/IAEA 2010/
		4.0E-01			3.0E-03	4.0E+00	/Karlsson and Bergström 2002/
Zr	2	3.7E+00			2.3E-02	7.3E+00	/IAEA 2010/
		7.0E+00			7.0E-01	7.0E+01	/Karlsson and Bergström 2002/

[1] Loam, Clay, Organic.

Table A-3. Kd values for suspended particulate matter in marine environments “Sea_kD_PM”, m^3/kg dw, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Ag		1.0E+01					/Beresford et al. 2007/
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Am		2.0E+03					/Beresford et al. 2007/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Ca							
Cd		3.0E+01					/Beresford et al. 2007/
		5.0E+00			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Cl		3.0E-05					/Beresford et al. 2007/
		1.0E-03			1.0E-04	1.0E-02	/Karlsson and Bergström 2002/
Cm		2.0E+03					/Beresford et al. 2007/
		1.0E+03			1.0E+01	2.0E+03	/Karlsson and Bergström 2002/
Cs		4.0E+00					/Beresford et al. 2007/
	57		5.4E-01	5.1			/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Eu		2.0E+03					/Beresford et al. 2007/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Ho		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
I		7.0E-02					/Beresford et al. 2007/
	28		3.0E-02				/Sheppard et al. 2009/
		3.0E-01			1.0E-01	1.0E+00	/Karlsson and Bergström 2002/
Mo		1.0E-03			1.0E-04	1.0E-02	/Karlsson and Bergström 2002/
Nb		8.0E+02					/Beresford et al. 2007/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Ni		2.0E+01					/Beresford et al. 2007/
	> 717		1.7E+01	11			/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Np		1.0E+00					/Beresford et al. 2007/
	4		5.0E+00				/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Pa	> 95	1.1E+03	1.1E+03	8.6			/Sheppard et al. 2009/
		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
Pb		1.0E+02					/Beresford et al. 2007/
	> 715		1.8E+02	9.3			/Sheppard et al. 2009/
		5.0E-02			1.0E-02	1.0E-01	/Karlsson and Bergström 2002/
Pd		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Po		2.0E+04					/Beresford et al. 2007/
		2.0E+04			1.0E+02	5.0E+04	/Karlsson and Bergström 2002/
Pu		1.0E+02					/Beresford et al. 2007/
	> 541	1.2E+03	1.2E+03	25.0			/Sheppard et al. 2009/
		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
Ra		2.0E+00					/Beresford et al. 2007/
	12	3.0E-02	3.0E-02	2.4			/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Se		3.0E+00					/Beresford et al. 2007/
	3		2.6E-01	2.8			/Sheppard et al. 2009/
		5.0E+00			1.0E+00	1.0E+01	/Karlsson and Bergström 2002/
Sm		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
Sn			3.3E+01	5.3			/Sheppard et al. 2009/
		5.0E+01			1.0E+01	1.0E+02	/Karlsson and Bergström 2002/
Sr		8.0E-03					/Beresford et al. 2007/
	> 6		5.0E-03	19.0			/Sheppard et al. 2009/
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Tc		1.0E-01					/Beresford et al. 2007/
	12		1.4E+00	4.0			/Sheppard et al. 2009/
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Th		3.0E+03					/Beresford et al. 2007/
	> 125		4.5E+03	3.8			/Sheppard et al. 2009/
		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
U		1.0E+00					/Beresford et al. 2007/
	31		8.6E-01	3.1			/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Zr		2.0E+03					/Beresford et al. 2007/
		5.0E+01			5.0E+00	5.0E+02	/Karlsson and Bergström 2002/

Table A-4. Kd values for suspended particulate matter in limnic environments "Lake_kD_PM", m³/kg dw, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Ag	91		9.5E+01	2.3	2.2E+01	3.3E+02	/IAEA 2010/[1]
	41		4.4E+02	1.7	1.9E+02	1.0E+03	/IAEA 2010/[3]
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Am	99		2.1E+02	3.7	2.5E+01	1.8E+03	//IAEA 2010/[1]
	42		1.2E+02	5.7	6.8E+00	2.0E+03	/IAEA 2010/[3]
		5.0E+00			5.0E-01	5.0E+01	/Karlsson and Bergström 2002/
Ca							
Cd		3.0E+01					/Beresford et al. 2007/
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Cl		1.0E-03					/Beresford et al. 2007/
	> 20		9.8E-02				/Sheppard et al. 2009/
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Cm	1	5.0E+00			1.0E-02	7.0E+01	/IAEA 2010/, /Beresford et al. 2007/
		5.0E+00			1.0E-01	7.0E+01	/Karlsson and Bergström 2002/
Cs	569		9.5E+00	6.7	3.7E-01	1.9E+02	/IAEA 2010/[1]
	119		2.9E+01	2.4	6.8E+00	1.2E+02	/IAEA 2010/[2]
	219		2.9E+01	5.9	1.6E+00	5.2E+02	/IAEA 2010/[3]
	> 69		1.7E+01	5.0			/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Eu	1	5.0E-01			2.0E-01	9.0E-01	/IAEA 2010/, /Beresford et al. 2007/
		5.0E-01			5.0E-02	5.0E+00	/Karlsson and Bergström 2002/
Ho	12		2.3E+02	1.6			/Sheppard et al. 2009/
		3.0E-01			3.0E-02	3.0E+00	/Karlsson and Bergström 2002/
I	124		4.4E+00	14	5.8E-02	3.4E+02	/IAEA 2010/[1]
		3.0E-01					/Beresford et al. 2007/
	39		2.9E-02	9.8			/Sheppard et al. 2009/
		3.0E-01			1.0E-01	1.0E+00	/Karlsson and Bergström 2002/
Mo	79		1.1E+00	18			/Sheppard et al. 2009/
		1.0E-03			1.0E-04	1.0E-02	/Karlsson and Bergström 2002/
Nb		8.0E+02					/Beresford et al. 2007/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Ni		2.0E+01					/Beresford et al. 2007/
	247		1.5E+00	36			/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Np	1	1.0E-02			2.0E-04	1.0E-01	/IAEA 2010/, /Beresford et al. 2007/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Pa		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
Pb		1.0E+02					/Beresford et al. 2007/
	333		1.3E+02	14			/Sheppard et al. 2009/
		5.0E-02			1.0E-02	1.0E-01	/Karlsson and Bergström 2002/
Pd		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Po		2.0E+04					/Beresford et al. 2007/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Pu	37		7.9E+01	2.2	2.1E+01	2.9E+02	/IAEA 2010/[1]
	41		3.0E+02	4.2	2.8E+01	3.2E+03	/IAEA 2010/[2]
	79		2.4E+02	6.6	1.1E+01	5.2E+03	/IAEA 2010/[3]
		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
Ra	75		7.4E+00	3.1	1.1E+00	5.2E+01	/IAEA 2010/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Se		3.0E+00					/Beresford et al. 2007/
	61		4.7E-01				/Sheppard et al. 2009/
		5.0E+00			1.0E+00	1.0E+01	/Karlsson and Bergström 2002/
Sm	> 50		4.3E+02	3.0			/Sheppard et al. 2009/
		5.0E+00			5.0E-01	5.0E+01	/Karlsson and Bergström 2002/
Sn		5.0E+01			1.0E+01	1.0E+02	/Karlsson and Bergström 2002/

Element	N	BE	GM	GSD	Min	Max	Data source
Sr	156		1.9E-01	4.6	1.4E-02	2.2E+00	/IAEA 2010/[1]
	34		6.2E-01	2.1	1.9E-01	2.1E+00	/IAEA 2010/[2]
	13		1.2E+00	2.7	2.3E-01	6.3E+00	/IAEA 2010/[3]
	> 120		4.8E-01	3.1			/Sheppard et al. 2009/
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Tc	1	5.0E-03				1.0E-01	/IAEA 2010/, /Beresford et al. 2007/
	9		0.0E+00	4.9			/Sheppard S et al. 2009/
		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Th	63		1.9E+02	21	1.2E+00	2.7E+04	/IAEA 2010/
	> 40		8.7E+01	2.2			/Sheppard et al. 2009/
		1.0E+02			1.0E+01	1.0E+03	/Karlsson and Bergström 2002/
U	1	5.0E-02			2.0E-02	1.0E+00	/IAEA 2010/, /Beresford et al. 2007/
	> 58		1.5E+01	39			/Sheppard et al. 2009/
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Zr		1.0E+00			1.0E+00	1.0E+01	/IAEA 2010/, /Beresford et al. 2007/
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/

[1] Adsorption.

[2] Desorption.

[3] Field measurements.

Table A-5. CR values for terrestrial primary producers (Ter_cR_pp), kgdw/kgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		9.8E-04			5.9E-05	1.4E-02	/Karlsson and Bergström 2002/[1]
Ag	13	8.9E+00	8.9E+00	2.7	1.4E-02	4.9E+01	/Beresford et al. 2007/[2]
		3.1E+01					/Beresford et al. 2007/[3]
		9.8E-01			9.8E-02	7.9E+00	/Karlsson and Bergström 2002/[1]
Ag, field	> 10	1.2E-01			1.2E-02	1.2E+00	
	> 10	1.3E-02			1.3E-04	1.3E+00	
	> 10	2.2E+00			6.5E-01	2.0E+01	
Am	27		2.9E-03	4.1	2.0E-04	9.4E-02	/IAEA 2010/[7]
	10		1.0E-02	2.6	2.6E-03	5.7E-02	/IAEA 2010/[8]
	11		2.0E-03	5.0	1.0E-03	3.9E-02	/IAEA 2010/[9]
	5		3.3E-04	2.2	2.0E-04	5.9E-04	/IAEA 2010/[10]
	7		6.5E-02	9.0	8.3E-04	5.1E-01	/IAEA 2010/[11]
	40	1.8E-02	1.8E-02	2.3	1.8E-02	8.8E-02	/Beresford et al. 2007/[2]
		2.5E-02					/Beresford et al. 2007/[3]
		2.0E-03			9.8E-04	3.9E-01	/Karlsson and Bergström 2002/[1]
		2.6E-03			2.9E-05	1.5E+00	/Avila 2006a/[4]
Ca, field	28	2.2E+00			2.2E-01	1.8E+01	/Bulgakov A (unpublished)/[4]
Cd	530	7.3E+00	7.3E+00	2.3	1.8E+00	4.7E+01	/Beresford et al. 2007/[2]
	210	1.6E+00	1.6E+00	3.2	1.6E+00	3.2E+00	/Beresford et al. 2007/[3]
		9.8E+00			9.8E-01	9.8E+01	/Karlsson and Bergström 2002/[1]
Cl	22	6.2E+01	6.2E+01	2.2	9.8E-02	2.6E+02	/Beresford et al. 2007/[2]
	79	2.4E+00	2.4E+00	3.5	1.6E+00	5.1E+01	/Beresford et al. 2007/[3]
		5.9E+01			2.0E+01	2.0E+02	/Karlsson and Bergström 2002/[1]
		5.5E+01			5.9E+00	3.3E+02	/Avila 2006a/[4]
Cm	17	2.0E-03	2.0E-03	2.4	2.0E-04	7.1E-03	/IAEA 2010/[7]
	6		4.1E-03	1.7	2.2E-03	7.1E-03	/IAEA 2010/[8]
	8		1.6E-03	1.4	9.0E-04	2.8E-03	/IAEA 2010/[8]
	2	4.9E-04			2.0E-04	7.9E-04	/IAEA 2010/[10]
	20	1.4E-03					/Beresford et al. 2007/[2]
		4.7E-02					/Beresford et al. 2007/[3]
		2.0E-03			2.0E-04	7.9E-03	/Karlsson and Bergström 2002/[1]
Cm, field		2.2E-02			2.2E-04	2.2E+00	
Cs	401		4.9E-01	4.1	2.0E-02	9.8E+00	/IAEA 2010/[7]
	169		5.7E-01	4.1	2.0E-02	9.4E+00	/IAEA 2010/[8]
	124		3.7E-01	4.1	2.0E-02	5.1E+00	/IAEA 2010/[9]
	75		3.5E-01	3.7	2.0E-02	2.4E+00	/IAEA 2010/[10]
	31		1.5E+00	2.2	5.9E-01	9.8E+00	/IAEA 2010/[11]
	64		1.2E-01	36.6	9.4E-03	1.9E+00	/IAEA 2010/[12]
	41		1.7E-01	3.3	2.0E-02	1.9E+00	/IAEA 2010/[13]
	10		9.4E-02	2.3	2.4E-02	4.1E-01	/IAEA 2010/[14]
	9		2.4E-02	2.1	9.4E-03	8.5E-02	/IAEA 2010/[15]
	4		5.5E-01	1.2	4.1E-01	6.7E-01	/IAEA 2010/[16]
	4		1.3E-01	14.9	9.4E-03	5.5E+00	/IAEA 2010/[17]
	433	1.9E+00	1.9E+00	3.0	3.7E-02	1.5E+01	/Beresford et al. 2007/[2]
	196	1.3E+01	1.3E+01	2.6	2.4E-02	8.0E+01	/Beresford et al. 2007/[3]
		3.9E-01			3.9E-02	3.9E+00	/Karlsson and Bergström 2002/[1]
		1.4E+01			2.0E-01	2.0E+02	/Avila 2006a/[4]
		4.5E+00			2.0E-02	4.7E+02	/Avila 2006a/[4]
Eu		2.6E-02					/Beresford et al. 2007/[2]
	12	1.2E+00					/Beresford et al. 2007/[3]
		2.0E-02			2.0E-03	2.0E-01	/Karlsson and Bergström 2002/[1]
Ho		2.0E-03			2.0E-04	2.0E-02	/Karlsson and Bergström 2002/[1]
Ho, field	> 10	6.9E-03			6.9E-04	6.9E-01	
I	25		1.2E+00	3.6			/Robens et al. 1988/
I	12		7.3E-03	6.0	1.8E-03	9.8E-01	/IAEA 2010/[7]
	9		3.5E-03	2.1	1.8E-03	1.7E-02	/IAEA 2010/[8]
	2	1.7E-02			1.7E-02	1.8E-02	/IAEA 2010/[10]
	39	2.7E-01	2.7E-01	4.0	7.1E-01	7.1E-01	/Beresford et al. 2007/[2]
		7.1E-01					/Beresford et al. 2007/[3]
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
		1.2E+00			2.0E-03	2.9E+00	/Avila 2006a/[4]
Mo		1.6E+00			1.6E-01	1.6E+01	/Karlsson and Bergström 2002/[1]
Mo, field		3.1E-01			3.1E-03	3.1E+01	
Nb	1	3.9E-02					/IAEA 2010/[7]
		2.1E-01					/Beresford et al. 2007/[2]

Element	N	BE	GM	GSD	Min	Max	Data source
		1.7E-01					/Beresford et al. 2007/[3]
		9.8E-03			9.8E-04	9.8E-02	/Karlsson and Bergström 2002/[1]
Nb, field		6.3E-02			6.3E-04	6.3E+00	
Ni	38		3.3E-01	2.6	3.54E-02	1.14E+00	/IAEA 2010/[7]
	18		5.1E-01	1.6	1.61E-01	1.00E+00	/IAEA 2010/[8]
	5		2.2E-01	1.6	1.10E-01	3.34E-01	/IAEA 2010/[9]
	10		4.9E-01	1.8	2.16E-01	1.14E+00	/IAEA 2010/[10]
	5		4.7E-02	1.5	3.54E-02	9.83E-02	/IAEA 2010/[11]
	111	2.5E-01	2.5E-01	5.1	9.4E-01	9.4E-01	/Beresford et al. 2007/[2]
	64	7.1E-02	7.1E-02	3.8	1.7E-01	1.7E-01	/Beresford et al. 2007/[3]
		3.9E-01			3.9E-02	3.9E+00	/Karlsson and Bergström 2002/[1]
Ni, field		2.6E-01			2.0E-02	9.2E+00	/Avila 2006a/[4]
Ni, field	111	6.7E-02			4.3E-03	4.3E+01	
Ni, salt	41	4.1E-01			4.3E-02	3.5E+00	
Np	16		1.2E-01	2.7	2.6E-02	9.2E-01	/IAEA 2010/[7]
	5		4.1E-01	2	1.7E-01	9.2E-01	/IAEA 2010/[8]
	10		6.7E-02	1.7	2.6E-02	1.1E-01	/IAEA 2010/[9]
	3		6.1E-02	3.7	1.4E-02	1.7E-01	/IAEA 2010/[12]
	20	8.7E-02					/Beresford et al. 2007/[2]
	13	1.2E-01	1.2E-01	9.7			/Beresford et al. 2007/[3]
		1.4E-01			1.4E-02	1.4E+00	/Karlsson and Bergström 2002/[1]
		1.4E-01			4.5E-05	1.1E+00	/Avila 2006a/[4]
Pa		5.9E-03			5.9E-04	5.9E-02	/Karlsson and Bergström 2002/[1]
		4.9E-04			4.9E-07	4.9E-01	
Pb	34		1.8E-01	4.8	4.3E-03	2.0E+00	/IAEA 2010/[7]
	17		6.1E-01	1.8	2.2E-01	2.0E+00	/IAEA 2010/[12]
	223	9.8E-02	9.8E-02	4.8	2.3E-01	5.7E-01	/Beresford et al. 2007/[2]
	120	7.8E-01	7.8E-01	3.2	6.8E-03	9.7E+00	/Beresford et al. 2007/[3]
		2.0E-03			2.0E-04	2.0E-02	/Karlsson and Bergström 2002/[1]
Pb, field	189	7.5E-02			2.2E-04	2.2E+01	
Pb, salt	133	1.7E-01			1.6E-02	1.2E+01	
		6.7E-01			6.7E-02	6.7E+00	
Pd		3.9E-01			3.9E-02	3.9E+00	/Karlsson and Bergström 2002/
Pd, field		2.4E-01			2.4E-03	2.4E+01	
Po	10		2.4E-01	4.2	4.3E-02	2.0E+00	/IAEA 2010/[7]
	34	2.3E-01	2.3E-01	4.2	1.0E-01	2.0E+00	/Beresford et al. 2007/[2]
	14	4.2E-01	4.2E-01	1.8	9.7E-03	6.7E-01	/Beresford et al. 2007/[3]
		9.8E-02			9.8E-03	9.8E-01	/Karlsson and Bergström 2002/[1]
Pu	22		1.1E-03	3	1.2E-04	7.7E-03	/IAEA 2010/[7]
	5		9.0E-04	1.8	4.1E-04	1.8E-03	/IAEA 2010/[8]
	10		5.9E-04	3	1.2E-04	6.5E-03	/IAEA 2010/[9]
	5		3.9E-03	1.5	2.4E-03	7.7E-03	/IAEA 2010/[10]
	1	2.2E-03					/IAEA 2010/[11]
	2				9.8E-05	5.3E-04	/IAEA 2010/[12]
	73	4.1E-02	4.1E-02	2.9	6.2E-02	8.3E-02	/Beresford et al. 2007/[2]
		1.6E-01					/Beresford et al. 2007/[3]
		7.9E-04			9.8E-05	1.4E+00	/Karlsson and Bergström 2002/[1]
		3.9E-03			9.8E-05	9.8E-02	/Avila 2006a/[4]
Ra	42		1.4E-01	7.6	1.0E-04	3.1E+00	/IAEA 2010/[7]
	3		1.6E-02	3.8	3.5E-03	4.5E-02	/IAEA 2010/[8]
	6		1.7E-02	19	1.0E-04	2.2E-01	/IAEA 2010/[9]
	20		1.4E-01	4.5	1.0E-02	6.5E+00	/IAEA 2010/[17]
	62		2.6E-01	4.0	7.1E-03	3.1E+00	/IAEA 2010/[12]
	24		2.8E-01	4.2	1.1E-02	3.1E+00	/IAEA 2010/[13]
	14		5.1E-01	2.0	1.9E-01	1.4E+00	/IAEA 2010/[14]
	3		8.3E-02	1.5	5.3E-02	1.2E-01	/IAEA 2010/[15]
	32	1.2E-01	1.2E-01	2.7	1.3E-01	2.4E-01	/Beresford et al. 2007/[2]
	10	1.1E-01	1.1E-01	1.4	1.2E-01	3.8E+00	/Beresford et al. 2007/[3]
		1.6E-01			3.9E-02	7.9E-01	/Karlsson and Bergström 2002/[1]
		5.3E+00			1.2E+00	1.5E+01	/Avila 2006a/[4]
Se	158	7.1E-01	7.1E-01	5.3	2.8E+00	2.8E+00	/Beresford et al. 2007/[2]
	73	7.2E+00	7.2E+00	2.0	5.8E+00	1.3E+01	/Beresford et al. 2007/[3]
		3.9E+01			2.0E+00	5.9E+01	/Karlsson and Bergström 2002/[1]
Se, field	158	1.1E+00			3.9E-02	1.5E+02	
Se, salt	64	1.8E+01			7.7E-01	1.2E+03	
Se, organic	15	1.1E+01			4.5E+00	7.1E+01	
Sm, field	0.02	2.0E-02			2.0E-03	2.0E-01	/Karlsson and Bergström 2002/[1]
	> 10	7.1E-03			7.1E-04	7.1E-02	

Element	N	BE	GM	GSD	Min	Max	Data source
Sn, field		2.0E-01			2.0E-02	3.9E+00	/Karlsson and Bergström 2002/[1]
		9.8E-02			9.8E-04	9.8E+00	
Sr	172		2.6E+00	2.2	1.1E-01	1.4E+01	/IAEA 2010/[7]
	87		3.3E+00	5.5	1.9E-01	1.4E+01	/IAEA 2010/[8]
	58		2.2E+00	1.6	7.3E-01	5.1E+00	/IAEA 2010/[9]
	22		1.6E+00	2.2	1.8E-01	5.5E+00	/IAEA 2010/[10]
	4		6.9E-01	3.7	1.1E-01	2.4E+00	/IAEA 2010/[11]
	50		1.8E+00	1.9	4.9E-01	5.5E+00	/IAEA 2010/[12]
	34		2.2E+00	1.7	5.1E-01	5.5E+00	/IAEA 2010/[13]
	6		1.2E+00	2.5	5.7E-01	3.9E+00	/IAEA 2010/[14]
	7		1.6E+00	1.3	9.4E-01	1.9E+00	/IAEA 2010/[15]
	3		5.1E-01	1.1	4.9E-01	5.5E-01	/IAEA 2010/[16]
	1	8.8E+00					/IAEA 2010/[17]
	33	7.6E-02	7.6E-02	9.8	2.5E-01	8.9E+00	/Beresford et al. 2007/[2]
	175	1.7E-01	1.7E-01	2.3	2.4E-02	5.5E+00	/Beresford et al. 2007/[3]
		2.0E+00			7.9E-01	5.9E+00	/Karlsson and Bergström 2002/[1]
		1.4E+00			3.9E-01	7.1E+00	/Avila 2006a/[4]
		2.2E+00			1.3E-01	2.2E+02	/Avila 2006a/[4]
Tc	18		1.5E+02	3.0	1.6E+01	9.2E+02	/IAEA 2010/[7]
	18	8.5E+01	8.5E+01	1.8	1.0E+02	1.0E+02	/Beresford et al. 2007/[2]
		1.0E+02					/Beresford et al. 2007/[3]
		1.6E+01			1.6E+00	1.6E+02	/Karlsson and Bergström 2002/[1]
		2.0E+00			9.8E-01	3.9E+01	/Avila 2006a/[4]
Th	64		1.9E-01	5.5	5.7E-03	5.3E+00	/IAEA 2010/[7]
	1		8.3E-02	3.1	1.5E-03	1.3E+00	/IAEA 2010/[12]
	12	1.1E-01	1.1E-01	3.2	7.6E-02	2.9E-01	/Beresford et al. 2007/[2]
		8.1E-02					/Beresford et al. 2007/[3]
		2.0E-02			2.0E-03	2.0E-01	/Karlsson and Bergström 2002/[1]
		1.8E-01			5.9E-03	3.9E-01	/Avila 2006a/[4]
U	53		9.0E-02	5.3	2.6E-03	2.8E+01	/IAEA 2010/[7]
	3		5.3E-03	1.8	2.6E-03	7.7E-03	/IAEA 2010/[8]
	7		1.4E-01	33	3.5E-03	2.8E+01	/IAEA 2010/[9]
	9		7.1E-02	4.9	1.7E-02	8.1E-01	/IAEA 2010/[17]
	147		3.3E-02	9.4	3.9E-04	1.1E+01	/IAEA 2010/[12]
	19		3.1E-02	17	1.1E-03	3.5E+00	/IAEA 2010/[13]
	34		1.9E-02	8.4	6.1E-04	9.0E-01	/IAEA 2010/[14]
	84	2.3E-02	2.3E-02	4.6	7.6E-03	3.4E-01	/Beresford et al. 2007/[2]
	496	1.6E-02	1.6E-02	3.6	6.8E-05	3.8E-01	/Beresford et al. 2007/[3]
		3.9E-02			3.9E-03	3.9E-01	/Karlsson and Bergström 2002/[1]
		2.8E-01			1.2E-02	1.5E+00	/Avila 2006a/[4]
Zr	1	2.0E-02					/IAEA 2010/[7]
		2.7E-03					/Beresford et al. 2007/[2]
	64	3.6E-04	3.6E-04	2.1	4.8E-04	4.8E-04	/Beresford et al. 2007/[3]
		2.0E-03			2.0E-04	2.0E-02	/Karlsson and Bergström 2002/[1]
Zr, field	> 4	2.8E-02			2.8E-04	2.8E+00	

[1] Pasture.
[2] Grasses & Herbs.
[3] Shrub.
[4] Understory plants.
[5] Ag-110m, salt. Understory plants.
[6] Ag-110m, Chernobyl. Understory plants.
[7] Pasture. All soil.
[8] Pasture. Sand.
[9] Pasture. Loam.
[10] Pasture. Clay.
[11] Pasture. Organic.
[12] Grasses. All soil.
[13] Grasses. Sand.
[14] Grasses. Loam.
[15] Grasses. Clay.
[16] Grasses. Organic.
[17] Herbs. All soil.

Table A-6. CR values for cereals (cR_soilToCereal), kgdw/kgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.0E-03			2.6E-05	2.6E-03	/Karlsson and Bergström 2002/
Ag		1.0E+00			1.0E-01	7.7E+00	/Karlsson and Bergström 2002/
Am	83		4.9E-05	11.0	1.6E-06	7.6E-02	/IAEA 2010/[1]
	66		6.0E-05	4.1	6.0E-06	1.8E-02	/IAEA 2010/[2]
	7		8.9E-04	200	2.2E-06	7.6E-02	/IAEA 2010/[3]
	9		3.6E-05	25	1.6E-06	8.9E-03	/IAEA 2010/[4]
	1	3.3E-07					/IAEA 2010/[5]
		5.1E-05			5.1E-06	5.1E-04	/Karlsson and Bergström 2002/
Ca							
Cd	11		2.0E+00	2.7	3.1E-01	6.5E+00	/IAEA 2010/[1]
	5		2.7E+00	2.1	1.1E+00	5.6E+00	/IAEA 2010/[2]
	4		2.9E+00	2.2	1.2E+00	6.5E+00	/IAEA 2010/[3]
	2		4.7E-01	0.2	3.1E-01	6.2E-01	/IAEA 2010/[4]
		1.3E+01			1.3E+00	1.3E+02	/Karlsson and Bergström 2002/
Cl	7		8.0E+01	1.6	4.5E+01	1.9E+02	/IAEA 2010/[1]
	2	5.6E+01			4.5E+01	6.5E+01	/IAEA 2010/[2]
	3		1.0E+02	1.8	5.8E+01	1.9E+02	/IAEA 2010/[3]
	2	8.2E+01			6.2E+01	1.0E+02	/IAEA 2010/[4]
		7.7E+01			2.3E+01	2.3E+02	/Karlsson and Bergström 2002/
Cm	67		5.1E-05	3.3	3.1E-06	4.5E-04	/IAEA 2010/[1]
	66		5.1E-05	3.3	3.1E-06	6.5E-04	/IAEA 2010/[2]
		5.1E-05			2.6E-06	7.7E-04	/Karlsson and Bergström 2002/
Cs	470		6.5E-02	4.1	4.5E-04	2.0E+00	/IAEA 2010/[1]
	156		8.7E-02	3.3	4.5E-03	1.5E+00	/IAEA 2010/[2]
	158		4.5E-02	4.1	1.8E-03	4.5E-01	/IAEA 2010/[3]
	110		2.5E-02	2.7	4.5E-04	2.0E-01	/IAEA 2010/[4]
	28		9.6E-02	2.7	2.2E-02	1.6E+00	/IAEA 2010/[5]
		5.1E-02			5.1E-03	5.1E-01	/Karlsson and Bergström 2002/
Eu		5.1E-04			5.1E-05	5.1E-03	/Karlsson and Bergström 2002/
Ho		2.6E-04			2.6E-05	2.6E-03	/Karlsson and Bergström 2002/
I	13		1.4E-03	2.3	2.2E-04	2.5E-02	/IAEA 2010/[1]
	2	1.3E-02			2.2E-03	2.5E-02	/IAEA 2010/[2]
	5		8.0E-04	2.5	2.2E-04	2.7E-03	/IAEA 2010/[3]
	6		1.3E-03	2.3	4.5E-04	3.6E-03	/IAEA 2010/[4]
		2.6E-01			2.6E-02	2.6E+00	/Karlsson and Bergström 2002/
Mo	1	1.8E+00					/IAEA 2010/1
		1.8E+00			1.8E-01	1.8E+01	/Karlsson and Bergström 2002/
Nb	2	3.1E-02			4.5E-03	5.6E-02	/IAEA 2010/[1]
		1.0E-02			1.0E-03	1.0E-01	/Karlsson and Bergström 2002/
Ni	44		6.0E-02	2.7	6.9E-03	3.8E-01	/IAEA 2010/[1]
	26		8.2E-02	2.4	1.8E-02	3.8E-01	/IAEA 2010/[2]
	4		1.7E-02	1.7	1.1E-02	3.6E-02	/IAEA 2010/[3]
	9		7.1E-02	2.4	1.4E-02	2.1E-01	/IAEA 2010/[4]
	4		1.4E-02	1.6	6.9E-03	2.2E-02	/IAEA 2010/[5]
		7.7E-02			7.7E-03	7.7E-01	/Karlsson and Bergström 2002/
Np	85		6.5E-03	5.0	5.1E-05	1.6E-01	/IAEA 2010/[1]
	79		7.8E-03	4.1	5.6E-04	1.6E-01	/IAEA 2010/[2]
	2	1.9E-03			6.5E-04	3.1E-03	/IAEA 2010/[3]
	2	8.7E-05			5.1E-05	1.2E-04	/IAEA 2010/[4]
	1	2.2E-04					/IAEA 2010/[5]
		5.1E-03			5.1E-04	5.1E-02	/Karlsson and Bergström 2002/
Pa		7.7E-03			7.7E-04	7.7E-02	/Karlsson and Bergström 2002/
Pb	9		2.5E-02	3.6	4.2E-03	1.1E-01	/IAEA 2010/[1]
		1.0E-02			1.0E-03	1.0E-01	/Karlsson and Bergström 2002/
Pd		7.7E-02			7.7E-03	7.7E-01	/Karlsson and Bergström 2002/
Po	2	5.3E-04			4.9E-04	5.8E-04	/IAEA 2010/[1]
		2.6E-03			2.6E-04	2.6E-02	/Karlsson and Bergström 2002/
Pu	105		2.1E-05	6.7	4.5E-07	2.5E-03	/IAEA 2010/[1]
	76		7.4E-05	0.0	1.1E-06	8.0E-04	/IAEA 2010/[2]
	10		1.1E-05	11.0	7.8E-07	6.9E-04	/IAEA 2010/[3]
	16		1.6E-05	14.9	4.5E-07	1.1E-03	/IAEA 2010/[4]
	2	1.2E-03			5.1E-06	2.5E-03	/IAEA 2010/[5]
		1.8E-05			1.8E-06	1.8E-04	/Karlsson and Bergström 2002/

Element	N	BE	GM	GSD	Min	Max	Data source
Ra	24		3.8E-02	12	1.8E-04	1.5E+00	/IAEA 2010/[1]
	7		6.5E-02	9.7	1.8E-03	1.5E+00	/IAEA 2010/[2]
	10		8.7E-02	9.9	5.3E-04	1.1E+00	/IAEA 2010/[3]
		2.6E-03			5.1E-04	1.3E-02	/Karlsson and Bergström 2002/
Se		5.1E+01			2.3E+00	7.7E+01	/Karlsson and Bergström 2002/
Sm		2.6E-04			2.6E-05	2.6E-03	/Karlsson and Bergström 2002/
Sn		1.0E+00			2.6E-02	2.6E+00	/Karlsson and Bergström 2002/
Sr	282		2.5E-01	2.7	8.0E-03	2.2E+00	/IAEA 2010/[1]
	123		3.1E-01	3.0	8.0E-03	2.2E+00	/IAEA 2010/[2]
	71		2.5E-01	2.4	3.6E-02	1.6E+00	/IAEA 2010/[3]
	72		1.7E-01	2.4	1.2E-02	1.6E+00	/IAEA 2010/[4]
	10		2.2E-01	4.1	2.7E-02	8.0E-01	/IAEA 2010/[5]
		5.1E-01			5.1E-02	2.6E+00	/Karlsson and Bergström 2002/
Tc	2	2.9E+00			4.0E-01	5.3E+00	/IAEA 2010/[1]
		1.5E+00			1.5E-01	7.7E+00	/Karlsson and Bergström 2002/
Th	36		4.7E-03	3.4	3.6E-04	4.9E-02	/IAEA 2010/[1]
	4		9.8E-03	1.4	6.7E-03	1.3E-02	/IAEA 2010/[2]
	18		6.0E-03	3.4	4.7E-04	4.9E-02	/IAEA 2010/[3]
	9		2.7E-03	1.6	1.6E-03	5.8E-03	/IAEA 2010/[4]
		2.6E-02			2.6E-03	2.6E-01	/Karlsson and Bergström 2002/
U	59		1.4E-02	7.7	3.6E-04	1.8E+00	/IAEA 2010/[1]
	6		2.0E-02	11	4.2E-04	1.4E-01	/IAEA 2010/[2]
	20		1.7E-02	5.1	3.6E-04	1.4E-01	/IAEA 2010/[3]
	11		8.5E-03	4.0	1.7E-03	1.1E-01	/IAEA 2010/[4]
		2.6E-03			2.6E-04	2.6E-02	/Karlsson and Bergström 2002/
Zr	1	2.2E-03					/IAEA 2010/[1]
		2.3E-03	2.3E-03	3.2	2.3E-04	2.3E-02	/Karlsson and Bergström 2002/

[1] All soil.
[2] Sand.
[3] Loam.
[4] Clay.
[5] Organic.

Table A-7. CR values used for root crops (cR_soilToTuber), kgdw/kgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		4.9E-04			1.9E-04	9.7E-02	/Karlsson and Bergström 2002/[1]
Ag		1.9E+00			1.9E-01	9.7E+00	/Karlsson and Bergström 2002/[1]
Am	78		4.3E-04	6.0	2.2E-05	6.9E-02	/IAEA 2010/[2]
	65		4.3E-04	5.5	2.2E-05	6.9E-02	/IAEA 2010/[3]
	8		3.1E-04	9.0	2.2E-05	9.6E-03	/IAEA 2010/[4]
	2	6.7E-03			1.8E-04	1.3E-02	/IAEA 2010/[5]
	2	1.7E-03			4.3E-05	3.3E-03	/IAEA 2010/[6]
		3.9E-04			3.9E-05	3.9E-03	/Karlsson and Bergström 2002/[1]
Ca							
Cd		3.1E+00					/IAEA 2010/[2]
		9.7E+00			9.7E-01	9.7E+01	/Karlsson and Bergström 2002/[1]
Cl		5.8E+01	6.1E+01	1.8	1.9E+01	1.9E+02	/Karlsson and Bergström 2002/[1]
Cm	66		3.1E-04	3.7	2.2E-05	4.3E-03	/IAEA 2010/[2]
	65		3.1E-04	4.1	2.2E-05	4.3E-03	/IAEA 2010/[3]
		2.9E-04			1.9E-05	4.9E-03	/Karlsson and Bergström 2002/[1]
Cs	138		1.1E-01	3.0	8.2E-03	1.2E+00	/IAEA 2010/[2]
	69		1.9E-01	3.0	8.2E-03	1.2E+00	/IAEA 2010/[3]
	40		7.1E-02	2.3	9.8E-03	2.9E-01	/IAEA 2010/[4]
	21		5.1E-02	2.2	1.0E-02	1.8E-01	/IAEA 2010/[5]
	7		1.2E-01	3.7	3.3E-02	1.1E+00	/IAEA 2010/[6]
		1.9E-01			1.9E-02	1.9E+00	/Karlsson and Bergström 2002/[1]
Eu		5.8E-04			5.8E-05	5.8E-03	/Karlsson and Bergström 2002/[1]
Ho		8.7E-04			8.7E-05	8.7E-03	/Karlsson and Bergström 2002/[1]
I	1	2.0E-01					/IAEA 2010/[2]
		9.7E-02	3.1E-01	5.8	9.7E-03	9.7E+00	/Karlsson and Bergström 2002/[1]
Mo		1.9E+00			1.9E-01	1.9E+01	/Karlsson and Bergström 2002/[1]

Element	N	BE	GM	GSD	Min	Max	Data source
Nb	1	8.2E-03					/IAEA 2010/[2]
		9.7E-03			9.7E-04	9.7E-02	/Karlsson and Bergström 2002/[1]
Ni		3.9E-01			3.9E-02	3.9E+00	/Karlsson and Bergström 2002/[1]
Np	57		1.2E-02	2.5	1.4E-03	5.5E-02	/IAEA 2010/[2]
	56		1.2E-02	2.5	1.4E-03	5.5E-02	/IAEA 2010/[3]
		1.9E-02			1.9E-03	1.9E-01	/Karlsson and Bergström 2002/[1]
Pa		5.8E-03			5.8E-04	5.8E-02	/Karlsson and Bergström 2002/[1]
Pb	30		3.1E-03	7.4	3.1E-04	5.3E+00	/IAEA 2010/[2]
	5		1.3E-02	3.5	3.3E-03	8.0E-02	/IAEA 2010/[3]
	17		1.1E-03	2.4	3.1E-04	4.7E-03	/IAEA 2010/[4]
		3.9E-02			3.9E-03	3.9E-01	/Karlsson and Bergström 2002/[1]
Pd		3.9E-01			3.9E-02	3.9E+00	/Karlsson and Bergström 2002/[1]
Po	9		5.5E-03	5.8	2.9E-04	6.9E-02	/IAEA 2010/[2]
		3.9E-02			3.9E-03	3.9E-01	/Karlsson and Bergström 2002/[1]
Pu	87		2.2E-04	5.5	7.7E-06	1.0E-02	/IAEA 2010/[2]
	72		2.0E-04	5.0	7.7E-06	4.1E-03	/IAEA 2010/[3]
	9		3.1E-04	11.0	1.3E-05	1.0E-02	/IAEA 2010/[4]
	3		7.3E-04	3.7	1.6E-04	1.9E-03	/IAEA 2010/[5]
	2	8.4E-04			2.7E-05	1.6E-03	/IAEA 2010/[6]
		2.9E-04			2.9E-05	2.9E-03	/Karlsson and Bergström 2002/[1]
Ra	45		2.2E-02	6.8	4.9E-04	8.0E+00	/IAEA 2010/[2]
	8		2.4E-02	11	4.9E-04	1.3E+00	/IAEA 2010/[4]
	24		1.1E-02	2.5	2.7E-03	1.6E-01	/IAEA 2010/[5]
		3.9E-02			3.9E-03	1.9E-01	/Karlsson and Bergström 2002/[1]
Se		3.9E+01			1.9E+00	5.8E+01	/Karlsson and Bergström 2002/[1]
Sm		3.9E-04			3.9E-05	3.9E-03	/Karlsson and Bergström 2002/[1]
Sn		5.8E-01			9.7E-02	9.7E+00	/Karlsson and Bergström 2002/[1]
Sr	106		3.3E-01	3.0	1.5E-02	3.3E+00	/IAEA 2010/[2]
	39		4.5E-01	2.6	5.3E-02	3.3E+00	/IAEA 2010/[3]
	41		2.7E-01	3.0	1.5E-02	9.2E-01	/IAEA 2010/[4]
	21		2.7E-01	2.3	5.3E-02	1.4E+00	/IAEA 2010/[5]
	4		1.2E-01	4.5	1.6E-02	4.7E-01	/IAEA 2010/[6]
		5.8E-01			9.7E-02	2.9E+00	/Karlsson and Bergström 2002/[1]
Tc	8		4.7E-01	3.7	2.7E-02	1.3E+00	/IAEA 2010/[2]
	6		8.0E-01	1.6	3.7E-01	1.3E+00	/IAEA 2010/[3]
	2	1.9E-01			2.7E-02	3.7E-01	/IAEA 2010/[4]
		4.9E-01			4.9E-02	4.9E+00	/Karlsson and Bergström 2002/[1]
Th	24		4.1E-04	9.9	2.7E-05	3.7E-02	/IAEA 2010/[2]
	10		5.1E-04	6.4	2.7E-05	7.3E-03	/IAEA 2010/[4]
	2	2.0E-04			2.7E-05	3.7E-02	/IAEA 2010/[5]
		9.7E-05			9.7E-06	9.7E-04	/Karlsson and Bergström 2002/[1]
U	28		1.0E-02	6.4	3.7E-04	1.6E-01	/IAEA 2010/[2]
	4		3.9E-02	3.8	8.8E-03	1.6E-01	/IAEA 2010/[3]
	3		5.7E-02	3.2	1.7E-02	1.6E-01	/IAEA 2010/[4]
	6		1.9E-03	3.0	3.9E-04	9.8E-03	/IAEA 2010/[5]
		2.9E-02			2.9E-03	2.9E-01	/Karlsson and Bergström 2002/[1]
Zr		4.1E-03					/IAEA 2010/[2]
		1.9E-03			1.9E-04	1.9E-02	/Karlsson and Bergström 2002/[1]

[1] Root crops.
[2] Tuber. All soil.
[3] Tuber. Sand.
[4] Tuber. Loam.
[5] Tuber. Clay.
[6] Tuber. Organic.

Table A-8. CR values used for vegetables (cR_soilToVegetab), kgdw/kgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.3E-01			6.7E-03	2.7E+00	/Karlsson and Bergström 2002/
Ag	5		5.3E-04	3.3	1.7E-04	3.8E-03	/IAEA 2010/[1]
	2	5.0E-04			2.8E-04	7.4E-04	/IAEA 2010/[2]
	3		5.9E-04	5.0	1.7E-04	3.8E-03	/IAEA 2010/[3]
		3.3E+00			3.3E-01	2.7E+01	/Karlsson and Bergström 2002/
Am	10		8.0E-04	3.3	1.2E-04	4.4E-03	/IAEA 2010/[1]
	5		1.6E-03	2.7	5.0E-04	4.4E-03	/IAEA 2010/[2]
	2	4.7E-04			1.8E-04	1.2E-03	/IAEA 2010/[3]
	2	4.4E-07			3.8E-04	6.8E-04	/IAEA 2010/[5]
		2.3E-03			2.3E-04	2.3E-02	/Karlsson and Bergström 2002/
Ca							
Cd		1.7E+01			1.7E+00	1.7E+02	/Karlsson and Bergström 2002/
Cl	6		7.7E+01	1.7	4.1E+01	1.4E+02	/IAEA 2010/[1]
	1	4.7E+01					/IAEA 2010/[2]
	4		7.4E+01	1.7	4.1E+01	1.4E+02	/IAEA 2010/[3]
	1	1.3E+02					/IAEA 2010/[5]
		1.0E+02			3.3E+01	3.3E+02	/Karlsson and Bergström 2002/
Cm	7		4.1E-03	4.5	5.9E-04	2.4E-02	/IAEA 2010/[1]
	6		5.6E-03	3.7	8.9E-04	2.4E-02	/IAEA 2010/[2]
		2.7E-03			2.7E-04	2.7E-02	/Karlsson and Bergström 2002/
Cs	290		1.8E-01	6.0	8.9E-04	2.9E+00	/IAEA 2010/[1]
	96		3.5E-01	4.1	6.2E-03	2.9E+00	/IAEA 2010/[2]
	119		2.2E-01	5.0	8.9E-04	2.2E+00	/IAEA 2010/[3]
	67		5.3E-02	6.7	1.5E-03	2.1E+00	/IAEA 2010/[4]
	7		6.6E-02	7.4	1.2E-02	1.4E+00	/IAEA 2010/[5]
		6.7E-01			6.7E-02	6.7E+00	/Karlsson and Bergström 2002/
Eu		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Ho		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
I	12		1.9E-02	3.7	3.2E-03	3.0E-01	/IAEA 2010/[1]
	1	1.2E-01					/IAEA 2010/[2]
	8		1.2E-02	1.9	3.2E-03	2.4E-02	/IAEA 2010/[3]
	2	1.4E-02			4.7E-03	3.8E-02	/IAEA 2010/[4]
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002
Mo		2.7E+00			2.7E-01	2.7E+01	/Karlsson and Bergström 2002/
Nb	2	5.0E-02			2.4E-02	7.4E-02	/IAEA 2010/[1]
		1.7E-02			1.7E-03	1.7E-01	/Karlsson and Bergström 2002/
Ni		6.7E-01			6.7E-02	6.7E+00	/Karlsson and Bergström 2002/
Np	5		8.0E-02	3.0	1.5E-02	2.4E-01	/IAEA 2010/
		1.3E-01			1.3E-02	1.3E+00	/Karlsson and Bergström 2002/
Pa		1.0E-02			1.0E-03	1.0E-01	/Karlsson and Bergström 2002/
Pb	31		2.4E-01	13.0	9.4E-03	7.4E+01	/IAEA 2010/[1]
	4		2.2E-01	1.5	1.4E-01	3.2E-01	/IAEA 2010/[2]
	3		2.4E+00	1.0	2.3E+00	2.5E+00	/IAEA 2010/[3]
	7		8.3E-02	4.1	1.2E-02	3.5E-01	/IAEA 2010/[4]
		3.3E-02			3.3E-03	3.3E-01	/Karlsson and Bergström 2002/
Pd		6.7E-01			6.7E-02	6.7E+00	/Karlsson and Bergström 2002/
Po	12		2.2E-02	6.9	7.4E-04	1.5E-01	/IAEA 2010/[1]
		3.3E-02			3.3E-03	3.3E-01	/Karlsson and Bergström 2002/
Pu	13		2.4E-04	2.7	3.0E-05	8.6E-04	/IAEA 2010/[1]
	4		3.2E-04	2.7	8.6E-05	8.6E-04	/IAEA 2010/[2]
	1	8.3E-04					/IAEA 2010/[3]
	1	7.8E-05					/IAEA 2010/[4]
		6.7E-04			6.7E-05	6.7E-03	/Karlsson and Bergström 2002/
Ra	77		2.7E-01	6.7	5.3E-03	3.8E+02	/IAEA 2010/[1]
	10		3.5E-01	2.5	4.7E-02	1.3E+00	/IAEA 2010/[3]
	20		1.2E-01	4.5	5.3E-03	1.2E+00	/IAEA 2010/[4]

Element	N	BE	GM	GSD	Min	Max	Data source
	9		1.4E-01	2.1	5.9E-02	4.1E-01	/IAEA 2010/[5]
		1.7E-01			1.0E-02	3.3E+00	/Karlsson and Bergström 2002/
Se		6.7E+01			3.3E+00	1.0E+02	/Karlsson and Bergström 2002/
Sm		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Sn		1.7E+00			3.3E-01	3.3E+01	/Karlsson and Bergström 2002/
Sr	217		2.2E+00	6.0	1.2E-02	2.3E+01	/IAEA 2010/[1]
	72		5.0E+00	4.1	1.9E-01	2.3E+01	/IAEA 2010/[2]
	84		3.5E+00	4.1	1.2E-01	1.5E+01	/IAEA 2010/[3]
	54		4.4E-01	6.0	1.2E-02	6.5E+00	/IAEA 2010/[4]
	6		6.2E-01	1.4	4.4E-01	8.9E-01	/IAEA 2010/[5]
		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Tc	10		5.3E+02	13.5	1.3E+01	1.0E+04	/IAEA 2010/[1]
	4		3.2E+02	33.1	1.3E+01	8.6E+03	/IAEA 2010/[2]
	6		7.4E+02	8.2	7.4E+01	1.0E+04	/IAEA 2010/[3]
		6.7E+02			3.3E+00	2.7E+03	/Karlsson and Bergström 2002/
Th	24		3.5E-03	6.0	2.8E-04	6.2E-01	/IAEA 2010/[1]
	13		2.5E-03	3.3	2.8E-04	1.7E-02	/IAEA 2010/[3]
	7		1.4E-03	2.8	5.6E-04	1.2E-02	/IAEA 2010/[4]
		6.7E-03			6.7E-04	6.7E-02	/Karlsson and Bergström 2002/
U	108		5.9E-02	7.3	2.3E-04	2.6E+01	/IAEA 2010/[1]
	7		5.0E-01	15.0	4.4E-03	2.6E+01	/IAEA 2010/[2]
	14		1.3E-01	3.9	2.3E-02	8.0E-01	/IAEA 2010/[3]
	9		1.1E-02	4.2	2.2E-03	1.3E-01	/IAEA 2010/[4]
	6		5.3E-01	9.7	2.3E-02	2.4E+01	/IAEA 2010/[5]
		3.3E-02			3.3E-03	3.3E-01	/Karlsson and Bergström 2002/[1]
Zr			1.2E-02				/IAEA 2010/[1]
		3.3E-03			3.3E-04	3.3E-02	/Karlsson and Bergström 2002/[1]

[1] All soil.
[2] Sand.
[3] Loam.
[4] Clay.
[5] Organic.

Table A-9. CR values for mushrooms in SR-Site (cR_soilToMush), kgdw/kgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.1E-03			6.6E-05	1.5E-02	/Karlsson and Bergström 2002/[1]
Ag		1.1E+00			1.1E-01	8.8E+00	/Karlsson and Bergström 2002/[1]
Am		2.9E-03					/Avila 2006a/
		2.2E-03			1.1E-03	4.4E-01	/Karlsson and Bergström 2002/[1]
Ca							
Cd		1.1E+01			1.1E+00	1.1E+02	/Karlsson and Bergström 2002/[1]
Cl		6.2E+01					/Avila 2006a/
		6.6E+01			2.2E+01	2.2E+02	/Karlsson and Bergström 2002/[1]
Cm		2.2E-03			2.2E-04	8.8E-03	/Karlsson and Bergström 2002/[1]
Cs		2.6E+02	2.8E+01	7.2	5.9E-01	1.4E+03	/Avila 2006a/
		4.4E-01			4.4E-02	4.4E+00	/Karlsson and Bergström 2002/[1]
Eu		2.2E-02			2.2E-03	2.2E-01	/Karlsson and Bergström 2002/[1]
Ho		2.2E-03			2.2E-04	2.2E-02	/Karlsson and Bergström 2002/[1]
I		1.3E+00					/Avila 2006a/
		1.3E+00			1.3E-01	1.3E+01	/Karlsson and Bergström 2002/[1]
Mo		1.8E+00			1.8E-01	1.8E+01	/Karlsson and Bergström 2002/[1]
Nb		1.1E-02			1.1E-03	1.1E-01	/Karlsson and Bergström 2002/[1]
Ni		2.9E-01	3.1E-01	1.2	2.2E-01	4.4E-01	/Avila 2006a/
		4.4E-01			4.4E-02	4.4E+00	/Karlsson and Bergström 2002/[1]
Np		1.5E-01					/Avila 2006a/
		1.5E-01			1.5E-02	1.5E+00	/Karlsson and Bergström 2002/[1]
Pa		6.6E-03			6.6E-04	6.6E-02	/Karlsson and Bergström 2002/[1]
Pb		2.2E-03			2.2E-04	2.2E-02	/Karlsson and Bergström 2002/[1]
Pd		4.4E-01			4.4E-02	4.4E+00	/Karlsson and Bergström 2002/[1]
Po		1.1E-01			1.1E-02	1.1E+00	/Karlsson and Bergström 2002/[1]
Pu			4.4E-03				/Avila 2006a/
		8.8E-04			1.1E-04	1.5E+00	/Karlsson and Bergström 2002/[1]
Ra			5.9E+00				/Avila 2006a/
		1.8E-01			4.4E-02	8.8E-01	/Karlsson and Bergström 2002/[1]
Se		4.4E+01			2.2E+00	6.6E+01	/Karlsson and Bergström 2002/[1]
Sm		2.2E-02			2.2E-03	2.2E-01	/Karlsson and Bergström 2002/[1]
Sn		2.2E-01			2.2E-02	4.4E+00	/Karlsson and Bergström 2002/[1]
Sr		1.5E+00	4.9E-02	1.5	2.2E-02	1.1E-01	/Avila 2006a/
		2.2E+00			8.8E-01	6.6E+00	/Karlsson and Bergström 2002/[1]
Tc		2.2E+00					/Avila 2006a/
		1.8E+01			1.8E+00	1.8E+02	/Karlsson and Bergström 2002/[1]
Th		2.0E-01	1.0E-02	1.5	4.4E-03	2.4E-02	/Avila 2006a/
		2.2E-02			2.2E-03	2.2E-01	/Karlsson and Bergström 2002/[1]
U		3.1E-01	4.2E-02	1.3	2.4E-02	7.5E-02	/Avila 2006a/
		4.4E-02			4.4E-03	4.4E-01	/Karlsson and Bergström 2002/[1]
Zr		2.2E-03			2.2E-04	2.2E-02	/Karlsson and Bergström 2002/[1]

[1] Pasture.

Table A-10. Concentration ratios for freshwater phytoplankton "Lake_cR_pp_plank", m^3/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac							
Ag			1.6E+03				/Beresford et al. 2007/
Am	16		1.1E+02	8.3	2.2E-01	1.1E+03	/IAEA 2010/[1]
Am		1.2E+03					/Beresford et al. 2007/
Ca							
Cd	5		5, 5E+02	6.8	3, 2E+02	6.6E+02	/IAEA 2010/[1]
		2.3E+01					/Beresford et al. 2007/
Cl		1.0E+01					/Beresford et al. 2007/
Cm	1	2, 6E+02					/IAEA 2010/[1]
	2	5.6E+02			5, 5E+02	5.6E+02	/Beresford et al. 2007/
Cs	26		2, 8E+00	16	5, 5E-02	9.5E+01	/IAEA 2010/2
	12	7.9E+01	7.9E+01	2.8	2, 9E+01	7.2E+02	/Beresford et al. 2007/
Eu		6.6E+01					/Beresford et al. 2007/
Ho							
I	3		3.7E+00	3.7	2, 3E+00	7, 8E+00	/IAEA 2010/[1]
	7	3.1E+01	3.1E+01	3.4	1, 6E+00	3, 5E+02	/Beresford et al. 2007/
Mo							
Nb		2.9E+01					/Beresford et al. 2007/
Ni	5		2.2E+01	129	7, 2E+00	3, 2E+01	/IAEA 2010/[1]
	1	1.4E+02					/Beresford et al. 2007/
Np	2	2.1E+02			1.9E+02	2.6E+02	/IAEA 2010/[1]
		1.2E+03	1.2E+03				/Beresford et al. 2007/
Pa							
Pb	5		5.5E+01	76	3.7E+01	6.3E+01	/IAEA 2010/[1]
		1.4E+04					/Beresford et al. 2007/
Pd							
Po	7		7.61E+02	1.2	5.9E+02	1.0E+03	/Beresford et al. 2007/
Pu	40		7, 5E+02	14	3.5E+00	1.4E+06	/IAEA 2010/[1]
	7		1.3E+02	2.0	1.8E+01	4.4E+02	/Beresford et al. 2007/
Ra	9		8.3E+01	4.1	1.8E+01	3.2E+02	/IAEA 2010/[1]
	8		2.6E+01	1.9	1, 2E+00	7, 5E+01	/Beresford et al. 2007/
Se	31		4.0E+01	5.4	2.7E-01	2.6E+02	/IAEA 2010/[1]
		1.0E+02					/Beresford et al. 2007/
Sm							
Sn							
Sr	17		1, 2E+01	3.3	1.1E+00	5.5E+01	/IAEA 2010/[1]
	2		1, 2E+00	1.1	1.1E+00	1.2E+00	/Beresford et al. 2007/
Tc	9		1, 6E-01	4.9	8.6E-03	2.9E+00	/IAEA 2010/[1]
		2.3E-01					/Beresford et al. 2007/
Th		1.2E+02	1.2E+02				/Beresford et al. 2007/
U	4		6.0E+00	1.9	2.6E+00	1.5E+01	/IAEA 2010/[1]
		3.32E+00	3.32E+00	1.3	1.4E+00	4.5E+00	/Beresford et al. 2007/
Zr		9.5E+02					/Beresford et al. 2007/

[1] Edible primary producers.

Table A-11. Concentration ratios for freshwater macrophytes/macroalgae "Lake_cR_pp_macro", m^3/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac							
Ag		2.7E+01			2.7E+01	1.2E+02	/Beresford et al. 2007/
Am	16		5.1E+01	8.3	1.0E-01	5.3E+02	/IAEA 2010/[1]
Am	5	4.7E+01	4.7E+01	1.9	2.7E+01	1.2E+02	Beresford et al. 2007/
Ca							
Cd	5		2.6E+02	6.8	1.5E+02	3.2E+02	/IAEA 2010/[1]
	2	1.0E+01			6.9E+00	1.4E+01	/Beresford et al. 2007/
Cl	6	3.9E+00	3.9E+00	2.0	6.9E-01	1.0E+01	Beresford et al. 2007/
Cm	1	1.2E+02					/IAEA 2010/[1]
	3	2.3E+00	2.3E+00	3.0	2.5E-01	1.0E+01	/Beresford et al. 2007/
Cs	26		1.3E+00	16	2.6E-02	4.5E+01	/IAEA 2010/[1]
	20	8.8E+00	8.8E+00	3.0	6.9E-01	3.3E+01	Beresford et al. 2007/
Eu		4.1E+01					/Beresford et al. 2007/
Ho							
I	3		1.8E+00	3.7	1.1E+00	3.7E+00	/IAEA 2010/[1]
	22	3.0E+00	3.0E+00	2.2	1.6E-01	1.1E+01	/Beresford et al. 2007/
Mo							
Nb	1.00	1.1E+01					/Beresford et al. 2007/
Ni	5		1.1E+01	129	3.4E+00	1.5E+01	/IAEA 2010/[1]
	1	6.9E-01					/Beresford et al. 2007/
Np	2	9.9E+01			8.9E+01	1.2E+02	/IAEA 2010/[1]
		5.8E+01					/Beresford et al. 2007/
Pa							
Pb	5		2.6E+01	76	1.8E+01	3.0E+01	/IAEA 2010/[1]
		1.4E+01	1.4E+01				/Beresford et al. 2007/
Pd							
Po	6		3.3E+01	2.7	1.1E+01	2.0E+02	/Beresford et al. 2007/
Pu	40		3.6E+02	14	1.6E+00	6.7E+05	/IAEA 2010/[1]
	7		2.2E+01	2.7	1.4E+01	1.2E+02	/Beresford et al. 2007/
Ra	9		4.0E+01	4.1	8.8E+00	1.5E+02	/IAEA 2010/[1]
	15		1.7E+01	2.3	2.7E-02	1.2E+02	/Beresford et al. 2007/
Se	31		1.9E+01	5.4	1.3E-01	1.3E+02	/IAEA 2010/[1]
		1.4E+01					/Beresford et al. 2007/
Sm							
Sn							
Sr	17		5.6E+00	3.3	5.3E-01	2.6E+01	/IAEA 2010/[1]
	8		2.6E+00	2.1	4.1E-01	8.8E+00	/Beresford et al. 2007/
Tc	9		7.5E-02	4.9	3.8E-03	1.4E+00	/IAEA 2010/[1]
		1.8E+01					/Beresford et al. 2007/
Th	5		1.5E+01	1.7	1.8E+00	6.9E+01	/Beresford et al. 2007/
U	4		2.9E+00	1.9	1.2E+00	7.1E+00	/IAEA 2010/[1]
	9		2.7E+01	2.4	8.5E-01	2.6E+02	/Beresford et al. 2007/
Zr	2	2.6E+01			1.4E+01	3.8E+01	/Beresford et al. 2007/

[1] Edible primary producers.

Table A-12. Concentration ratios for freshwater crustacean "cR_watToCray_Lake", m^3/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Ag	2	2.8E+00			1.6E+00	4.1E+00	/IAEA 2010/[1]
		2.0E+02					/Beresford et al. 2007/
		9.9E+00			9.9E-01	9.9E+01	/Karlsson and Bergström 2002/[1]
Am			3.0E+01	7.0	7.3E-01	1.1E+03	/IAEA 2010/[1]
	4		1.2E+00	1.2	1.0E+00	1.4E+00	/Beresford et al. 2007/
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Ca	3		4.2E-01	2.5	1.5E-01	8.1E-01	/IAEA 2010/[1]
							/Beresford et al. 2007/
Cd	149		1.2E+00	39	1.7E-04	3.8E+02	/IAEA 2010/[1]
		6.2E+01					/Beresford et al. 2007/
		2.5E+01			2.5E+00	2.5E+02	/Karlsson and Bergström 2002/[1]
Cl	2	2.0E+00			1.6E+00	2.3E+00	/IAEA 2010/[1]
	2	6.2E-01					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Cm	2	1.2E+02			1.1E+02	1.2E+02	/IAEA 2010/[1]
		1.2E+00					/Beresford et al. 2007/
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Cs	29		2.8E-01	75	6.7E-05	7.5E+01	/IAEA 2010/[1]
			8.8E+01	2.4	3.0E+00	2.7E+02	/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Eu	2	2.7E+00			2.5E+00	2.8E+00	/IAEA 2010/[1]
		1.2E+01					/Beresford et al. 2007/
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Ho		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
I	99		2.1E-01	11	4.9E-03	1.6E+01	/IAEA 2010/[1]
	3		4.3E+00	1.7	1.7E+00	7.4E+00	/Beresford et al. 2007/
		6.2E-02			6.2E-03	6.2E-01	/Karlsson and Bergström 2002/[1]
Mo	33		5.6E-03	13	3.6E-04	3.7E+01	/IAEA 2010/[1]
		1.2E-01			1.2E-02	1.2E+00	/Karlsson and Bergström 2002/[1]
Nb		4.3E+00					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Ni		6.8E+00					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Np	2	1.2E+02			1.1E+02	1.2E+02	/IAEA 2010/[1]
		1.4E+01					/Beresford et al. 2007/
		4.9E+00			4.9E-01	4.9E+01	/Karlsson and Bergström 2002/[1]
Pa		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Pb	79		2.7E-01	20	5.6E-04	8.6E+00	/IAEA 2010/[1]
		1.2E+02					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Pd		3.7E+00			3.7E-01	3.7E+01	/Karlsson and Bergström 2002/[1]
Po	2		1.2E+02	1.2	1.1E+02	1.3E+02	/Beresford et al. 2007/
		2.5E+02			2.5E+01	2.5E+03	/Karlsson and Bergström 2002/[1]
Pu	100		9.1E+01	29	4.4E-03	6.8E+04	/IAEA 2010/[1]
	3		1.3E+01	1.5	9.4E+00	2.0E+01	/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Ra	5		1.2E+00	30	2.3E-02	2.3E+01	/IAEA 2010/[1]
	5		1.4E+01	2.1	1.9E+00	4.0E+01	/Beresford et al. 2007/
		3.7E+00			3.7E-01	3.7E+01	/Karlsson and Bergström 2002/[1]
Se	16		7.0E+00	15	1.5E-01	8.5E+02	/IAEA 2010/[1]
		8.8E+01					/Beresford et al. 2007/
		2.5E+00			2.5E-01	2.5E+01	/Karlsson and Bergström 2002/[1]
Sm	2	2.0E+01			6.2E+00	3.3E+01	/IAEA 2010/[1]
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Sn		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Sr	5		3.3E+00	3.2	9.5E-01	1.6E+01	/IAEA 2010/[1]

Element	N	BE	GM	GSD	Min	Max	Data source
	3		1.8E+00	2.2	1.1E+00	4.9E+00	/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Tc	10		3.2E-01	9.8	2.3E-02	4.9E+00	/IAEA 2010/[1]
		1.6E-01					/Beresford et al. 2007/
		6.2E-02			6.2E-03	6.2E-01	/Karlsson and Bergström 2002/[1]
Th	2	3.6E+01			3.6E+01	3.6E+01	/IAEA 2010/[1]
		1.2E+00					/Beresford et al. 2007/
		6.2E+00			6.2E-01	6.2E+01	/Karlsson and Bergström 2002/[1]
U	9		2.1E+00	19	4.4E-02	7.4E+02	/IAEA 2010/[1]
	2	6.2E+00			2.0E-01	1.2E+01	/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Zr	2	2.7E+00					/Beresford et al. 2007/
		8.6E-02			8.6E-03	8.6E-01	/Karlsson and Bergström 2002/[1]

[1] Freshwater invertebrates.

Table A-13. Concentration ratios for freshwater filter feeder "Lake_cR_watToMuss", m³/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Ag	2	2.8E+00			1.6E+00	4.0E+00	/IAEA 2010/[1]
		3.9E+02					/Beresford et al. 2007/
		9.7E+00			9.7E-01	9.7E+01	/Karlsson and Bergström 2002/[1]
Am	17		2.9E+01	7.0	7.1E-01	1.1E+03	/IAEA 2010/[1]
	3		3.9E+00	2.4			/Beresford et al. 2007/
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Ca	3		4.1E-01	2.5	1.4E-01	8.0E-01	/IAEA 2010/[1]
Cd	149		1.2E+00	39	1.7E-04	3.7E+02	/IAEA 2010/[1]
		1.2E+02					/Beresford et al. 2007/
		2.4E+01			2.4E+00	2.4E+02	/Karlsson and Bergström 2002/[1]
Cl	2	1.9E+00			1.6E+00	2.3E+00	/IAEA 2010/[1]
		6.0E-01					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Cm	2	1.1E+02			1.1E+02	1.2E+02	/IAEA 2010/[1]
		4.0E+00					/Beresford et al. 2007/
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Cs	29		2.8E-01	75	6.5E-05	7.4E+01	/IAEA 2010/[1]
			3.4E+00	2.7	1.7E-01	2.7E+01	/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Eu	2	2.7E+00			2.5E+00	2.8E+00	/IAEA 2010/[1]
	2	7.2E+00					/Beresford et al. 2007/
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Ho		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
I	99		2.1E-01	11	4.8E-03	1.6E+01	/IAEA 2010/[1]
	8		2.5E-01	1.9	2.7E-03	2.7E+00	/Beresford et al. 2007/
		6.0E-02			6.0E-03	6.0E-01	/Karlsson and Bergström 2002/[1]
Mo	33	5.4E-03	5.4E-03	13	3.5E-04	3.6E+01	/IAEA 2010/[1]
		1.2E-01			1.2E-02	1.2E+00	/Karlsson and Bergström 2002/[1]
Nb	2		4.1E+00	1.3	3.4E+00	5.1E+00	/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Ni		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
		7.7E+01					/Beresford et al. 2007/
Np	2	1.1E+02			1.1E+02	1.2E+02	/IAEA 2010/[1]
		9.9E+00					/Beresford et al. 2007/
		4.8E+00			4.8E-01	4.8E+01	/Karlsson and Bergström 2002/[1]
Pa		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Pb		7.9E+01	2.7E-01	20			/IAEA 2010/[1]
		2.1E+01					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]

Element	N	BE	GM	GSD	Min	Max	Data source
Pd		3.6E+00			3.6E-01	3.6E+01	/Karlsson and Bergström 2002/[1]
Po	2		2.8E+02	2.7			/Beresford et al. 2007/
		2.4E+02			2.4E+01	2.4E+03	/Karlsson and Bergström 2002/[1]
Pu	100		8.9E+01	29.0	2.3E-02	2.3E+01	/IAEA 2010/[1]
		9.9E+00					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Ra	5		1.2E+00	30	2.3E-02	2.3E+01	/IAEA 2010/[1]
	2		1.2E+01	2.4	4.0E+00	3.3E+01	/Beresford et al. 2007/
		3.6E+00			3.6E-01	3.6E+01	/Karlsson and Bergström 2002/[1]
Se	16		6.9E+00	15.0	1.4E-01	8.3E+02	/IAEA 2010/[1]
		6.0E+01					/Beresford et al. 2007/
		2.4E+00			2.4E-01	2.4E+01	/Karlsson and Bergström 2002/[1]
Sm	2	1.9E+01			6.0E+00	3.3E+01	/IAEA 2010/[1]
		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Sn		1.2E+01			1.2E+00	1.2E+02	/Karlsson and Bergström 2002/[1]
Sr	5		3.3E+00	3.2	9.3E-01	1.6E+01	/IAEA 2010/[1]
	6	3.1E+00	3.1E+00	1.4	1.2E+00	4.5E+00	/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Tc		6.0E-02			6.0E-03	6.0E-01	/Karlsson and Bergström 2002/[1]
	10		3.1E-01	9.8	2.3E-02	4.8E+00	/IAEA 2010/[1]
		2.9E-01					/Beresford et al. 2007/
Th		6.0E+00			6.0E-01	6.0E+01	/Karlsson and Bergström 2002/[1]
	2	3.5E+01			3.5E+01	3.5E+01	/IAEA 2010/[1]
		1.2E+00					/Beresford et al. 2007/
U	9		2.1E+00	19	4.3E-02	7.2E+02	/IAEA 2010/[1]
		2.2E+00					/Beresford et al. 2007/
		1.2E+00			1.2E-01	1.2E+01	/Karlsson and Bergström 2002/[1]
Zr	2	3.0E+00			8.2E-01	5.2E+00	/Beresford et al. 2007/
		8.5E-02			8.5E-03	8.5E-01	/Karlsson and Bergström 2002/[1]

[1] Freshwater invertebrates.

Table A-14. Concentration ratios for freshwater fish "cR_watToFish_Lake", m^3/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.1E+00			1.1E-01	2.2E+00	/Karlsson and Bergström 2002/
Ag	27		1.2E+00	1.5	4.4E-01	2.3E+00	/IAEA 2010/
	5		4.5E-01	3.8	2.2E-03	5.5E+00	/Beresford et al. 2007/
		1.1E+00					/Beresford et al. 2007/
		5.5E-02			2.2E-03	1.1E-01	/Karlsson and Bergström 2002/
Am	2	2.6E+00			7.9E-01	4.4E+00	/IAEA 2010/
	7		2.6E+00	2.5	3.3E-01	1.1E+01	/Beresford et al. 2007/
	1	2.0E-02					/Beresford et al. 2007/
		3.3E-01			1.1E-01	3.3E+00	/Karlsson and Bergström 2002/
Ca	104		1.3E-01	2.5	2.2E-02	1.1E+00	/IAEA 2010/
Cd	4		1.9E+00	2.1	2.2E-01	5.5E+00	/Beresford et al. 2007/
		2.5E+00					/Beresford et al. 2007/
		2.2E-01			2.2E-02	2.2E+00	/Karlsson and Bergström 2002/
Cl	16		5.1E-01	2.2	1.1E-01	1.3E+00	/IAEA 2010/
	7		8.3E-01	1.5	5.5E-01	1.4E+00	/Beresford et al. 2007/
		9.0E-01					/Beresford et al. 2007/
		5.5E-01			2.2E-02	2.2E+00	/Karlsson and Bergström 2002/
Cm		1.6E+00					/Beresford et al. 2007/
	2	1.6E+00			5.5E-01	2.7E+00	/Beresford et al. 2007/
		3.3E-01			1.1E-01	3.3E+00	/Karlsson and Bergström 2002/
Cs	106		2.7E+01	2.4	1.5E+00	1.6E+02	/IAEA 2010/
	100		4.0E+01	2.8	9.4E-01	3.2E+02	/Beresford et al. 2007/
	13	5.9E+01	5.9E+01	2.1	5.1E-01	2.1E+02	/Beresford et al. 2007/
		1.1E+02			5.5E+01	2.2E+02	/Karlsson and Bergström 2002/
Eu	24		1.4E+00	4.9	1.2E-01	7.9E+00	/IAEA 2010/
	3		5.5E-01	1.0			/Beresford et al. 2007/

Element	N	BE	GM	GSD	Min	Max	Data source
		5.5E-01					/Beresford et al. 2007/
		5.5E-01			1.1E-01	2.2E+00	/Karlsson and Bergström 2002/
Ho		3.3E-01			3.3E-02	3.3E+00	/Karlsson and Bergström 2002/
I	50		3.3E-01	2.5	1.2E-03	4.4E+00	/IAEA 2010/
	10		9.0E-01	3.5	8.8E-02	8.8E+00	/Beresford et al. 2007/
	10		9.0E-01	3.5	8.8E-02	8.8E+00	/Beresford et al. 2007/
		2.2E+00			1.1E-01	5.5E+00	/Karlsson and Bergström 2002/
Mo			2.1E-02	2.1	4.4E-05	2.2E-01	/IAEA 2010/
		1.1E-01			1.1E-02	1.1E+00	/Karlsson and Bergström 2002/
Nb	3		2.3E+00	1.6	3.3E-01	3.3E+00	/Beresford et al. 2007/
	3		2.3E+00	1.6	3.3E-01	3.3E+00	/Beresford et al. 2007/
		3.3E+00			1.1E+00	3.3E+02	/Karlsson and Bergström 2002/
Ni	5		2.3E-01	1.9	1.2E-01	4.8E-01	/IAEA 2010/
	3	1.1E+00	1.1E+00	1.0			/Beresford et al. 2007/
	3		1.1E+00	1.0			/Beresford et al. 2007/
		1.1E+00			1.1E-01	1.1E+01	/Karlsson and Bergström 2002/
Np		1.6E+00					/Beresford et al. 2007/
	2		1.2E+00	2.2	5.5E-01	2.7E+00	/Beresford et al. 2007/
		5.5E-01	1.9E+00	4.3	1.1E-01	3.3E+01	/Beresford et al. 2007/
Pa		1.1E-01			1.1E-02	1.1E+00	/Karlsson and Bergström 2002/
Pb	39		2.7E-01	2.9	1.1E-03	3.0E+00	/IAEA 2010/
		3.3E+00					/Beresford et al. 2007/
		3.3E+00					/Beresford et al. 2007/
		3.3E+00			1.1E+00	4.4E+00	/Karlsson and Bergström 2002/
Pd		1.1E+00			1.1E-01	1.1E+01	/Karlsson and Bergström 2002/
Po	5		3.9E-01	4.3	6.6E-02	1.9E+00	/IAEA 2010/
		2.6E+00					/Beresford et al. 2007/
	13		2.0E+00	2.1	1.1E-01	5.5E+00	/Beresford et al. 2007/
		5.5E-01			5.5E-02	5.5E+00	/Karlsson and Bergström 2002/
Pu	3		2.3E+02	2.6	8.4E+01	5.5E+02	/IAEA 2010/
	45		2.8E-01	3.7	4.4E-03	6.1E+00	/Beresford et al. 2007/
	45		2.8E-01	3.7	4.4E-03	6.1E+00	/Beresford et al. 2007/
		3.3E-01			4.4E-02	3.3E+00	/Karlsson and Bergström 2002/
Ra	21		4.4E-02	6.8	6.6E-04	1.6E+00	/IAEA 2010/
	17		4.9E-01	3.0	3.3E-03	8.9E+00	/Beresford et al. 2007/
	17		4.9E-01	3.0	3.3E-03	8.9E+00	/Beresford et al. 2007/
		5.5E-01			1.1E-01	2.2E+00	/Karlsson and Bergström 2002/
Se	14		6.6E+01	1.3	3.8E+01	1.0E+02	/IAEA 2010/
	1	2.2E+00					/Beresford et al. 2007/
	1	2.2E+00					/Beresford et al. 2007/
		2.2E+01			5.5E+00	5.5E+01	/Karlsson and Bergström 2002/
Sm		3.3E-01			3.3E-02	3.3E+00	/Karlsson and Bergström 2002/
Sn		3.3E+01			3.3E+00	3.3E+02	/Karlsson and Bergström 2002/
Sr	99		3.2E-02	3.8	1.5E-03	7.5E-01	/IAEA 2010/
	14		1.1E-01	2.8	4.4E-03	9.8E-01	/Beresford et al. 2007/
	14		1.1E-01	2.8	4.4E-03	9.8E-01	/Beresford et al. 2007/
		6.6E-01			1.1E-02	1.1E+01	/Karlsson and Bergström 2002/
Tc	3		3.3E-01	2.1	1.6E-01	8.5E-01	/Beresford et al. 2007/
	3		3.3E-01	2.1	1.6E-01	8.5E-01	/Beresford et al. 2007/
		2.2E-01			2.2E-02	8.8E-01	/Karlsson and Bergström 2002/
Th	3		6.6E-02		6.6E-02	6.6E-02	/IAEA 2010/
	5		8.5E-01	2.3	1.6E-01	6.1E+00	/Beresford et al. 2007/
	5		8.5E-01	2.3	1.6E-01	6.1E+00	/Beresford et al. 2007/
		1.1E+00			3.3E-01	1.1E+01	/Karlsson and Bergström 2002/
U	9		1.1E-02	12.0	2.2E-04	2.2E-01	/IAEA 2010/
	11		1.5E-01	3.6	3.3E-03	2.2E+00	/Beresford et al. 2007/
	11		1.5E-01	3.6	3.3E-03	2.2E+00	/Beresford et al. 2007/
		1.1E-01			2.2E-02	5.5E-01	/Karlsson and Bergström 2002/
Zr	10		2.4E-01	2.4	1.0E-01	1.3E+00	/IAEA 2010/
		3.3E+00					/Beresford et al. 2007/
		3.3E+00					/Beresford et al. 2007/
		2.2E+00			3.3E-02	3.3E+00	/Karlsson and Bergström 2002/

Table A-15. Concentration ratios for marine phytoplankton "Sea_cR_pp_plank", m³/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac							
Ag	8		1.1E+03	2.4	3.7E+02	5.8E+03	/Beresford et al. 2007/
Am	15		4.3E+03	2.3	2.0E+02	2.0E+04	/Beresford et al. 2007/
Ca							
Cd	56		1.5E+01	2.5	6.3E-01	1.7E+02	/Beresford et al. 2007/
Cl		2.9E-02					
Cm	5		6.0E+03	2.0	3.5E+03	1.8E+04	/Beresford et al. 2007/
Cs	21		1.1E+00	4.9	2.9E-02	5.8E+01	/Beresford et al. 2007/
Eu		2.6E+03					
Ho							
I		2.8E+01					
Mo							
Nb		2.9E+01					
Ni		4.0E+01					
Np	12		3.7E+00	1.5	8.6E-01	6.9E+00	/Beresford et al. 2007/
Pa							
Pb	35		6.7E+03	3.4	3.5E+01	7.5E+04	/Beresford et al. 2007/
Pd							
Po	18		4.5E+02	2.8	8.1E+01	3.5E+03	/Beresford et al. 2007/
Pu	52		2.2E+03	2.5	1.2E+01	1.8E+04	/Beresford et al. 2007/
Ra	10		2.2E+01	2.1	2.6E+00	8.6E+02	/Beresford et al. 2007/
Se	94		2.8E+01	5.1	3.2E-01	3.2E+03	/Beresford et al. 2007/
Sm							
Sn							
Sr	27		3.2E+00	3.1	2.6E-01	4.6E+01	/Beresford et al. 2007/
Tc	14		5.8E-02	2.9	0.0E+00	4.9E-01	/Beresford et al. 2007/
Th	25		1.5E+04	2.4	2.3E+02	5.8E+04	/Beresford et al. 2007/
U	8		3.1E+00	2.1	2.9E-01	8.6E+00	/Beresford et al. 2007/
Zr	4		7.5E+02	2.0	2.9E+01	2.9E+03	/Beresford et al. 2007/

Table A-16. Concentration ratios for marine macrophytes/macroalgae "Sea_cR_pp_macro", m³/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		7.9E+01			1.6E+00	1.6E+02	/ Karlsson and Bergström 2002/[1]
Ag	16		1.5E+01	2.3	1.6E+01	7.9E+01	/Beresford et al. 2007/[2]
		2.1E+01					/Beresford et al. 2007/[3]
		3.2E+00			3.2E-01	3.2E+01	Karlsson and Bergström 2002/[1]
Am	15	7.9E+00	7.9E+00	2.7	3.0E+00	6.0E+01	/Beresford et al. 2007/[2]
		1.3E+01					/Beresford et al. 2007/[3]
		7.9E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Ca							
Cd	63	9.4E+00	9.4E+00	2.3	1.7E-01	7.5E+01	/Beresford et al. 2007/[2]
		1.3E+01					/Beresford et al. 2007/[3]
		1.6E+01			1.6E+00	1.6E+02	/Karlsson and Bergström 2002/
Cl	35		1.2E-02	1.6	9.5E-04	3.2E-02	/Beresford et al. 2007/[2]
		1.3E-02					/Beresford et al. 2007/[3]
		1.6E-03			1.6E-04	1.6E-02	Karlsson and Bergström 2002/[1]
Cm	23		1.3E+02	2.3	2.1E+01	8.3E+02	/Beresford et al. 2007/[2]
		1.9E+02					/Beresford et al. 2007/[3]
		7.9E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Cs	579		3.1E-01	6.8	7.9E-02	1.2E+02	/Beresford et al. 2007/[2]
	9		2.9E-01	1.9	3.2E-02	7.3E-01	/Beresford et al. 2007/[2]
		7.9E-01			7.9E-02	7.9E+00	Karlsson and Bergström 2002/[1]
Eu	4		1.8E+01	1.9	4.8E+00	4.1E+01	/Beresford et al. 2007/[2]

Element	N	BE	GM	GSD	Min	Max	Data source
		2.2E+01					/Beresford et al. 2007/[3]
		7.9E+01			7.9E+00	7.9E+02	Karlsson and Bergström 2002/[1]
Ho		7.9E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
I	62	2.3E+01	2.3E+01	4.3	7.3E-01	1.4E+03	/Beresford et al. 2007/[2]
		6.5E+01					/Beresford et al. 2007/[3]
		1.6E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Mo		1.6E-01			1.6E-02	1.6E+00	Karlsson and Bergström 2002/[1]
Nb	20	7.1E+00	7.1E+00	2.2	1.6E-01	3.2E+01	/Beresford et al. 2007/[2]
		9.7E+00					/Beresford et al. 2007/[3]
		1.6E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Ni	14	9.8E+00	9.8E+00	2.0	7.9E-01	4.5E+01	/Beresford et al. 2007/[2]
		1.3E+01					/Beresford et al. 2007/[3]
		4.8E+00			4.8E-01	4.8E+01	Karlsson and Bergström 2002/[1]
Np	52	7.2E-01	7.2E-01	1.8	2.4E-01	2.4E+00	/Beresford et al. 2007/[2]
		8.4E-01					/Beresford et al. 2007/[3]
Pa		9.5E-02			9.5E-03	9.5E-01	Karlsson and Bergström 2002/[1]
Pb	54		8.8E+00	3.0	1.6E-01	9.7E+01	/Beresford et al. 2007/[3]
			1.6E+01				/Beresford et al. 2007/2
		1.6E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Pd		3.2E+01			3.2E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Po	13	1.3E+01	1.3E+01	2.0	1.1E+00	4.1E+01	/Beresford et al. 2007/[2]
		1.6E+01					/Beresford et al. 2007/[3]
		3.2E+01			3.2E+00	3.2E+02	Karlsson and Bergström 2002/[1]
Pu	225	2.9E+01	2.9E+01	3.5	1.4E+00	1.6E+02	/Beresford et al. 2007/[2]
		6.5E+01					/Beresford et al. 2007/[3]
		4.8E+00			4.8E-01	4.8E+01	Karlsson and Bergström 2002/[1]
Ra	7		1.2E+00	1.7	1.6E-02	7.9E+00	/Beresford et al. 2007/[2]
		1.4E+00					/Beresford et al. 2007/[3]
		1.6E+00			1.6E-01	1.6E+01	Karlsson and Bergström 2002/[1]
Se	35	2.1E+00	2.1E+00	2.8	3.2E+00	1.8E+01	/Beresford et al. 2007/[2]
		3.5E+00					/Beresford et al. 2007/[3]
		1.6E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Sm		7.9E+01			1.6E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Sn		1.6E+00			1.6E-01	1.6E+01	Karlsson and Bergström 2002/[1]
Sr	97		4.4E-01	2.5	1.6E-03	2.9E+00	/Beresford et al. 2007/[2]
		6.7E-01					/Beresford et al. 2007/[3]
	–	1.6E-01			1.6E-02	1.6E+00	Karlsson and Bergström 2002/[1]
Tc	124		3.9E+02	1.9	1.3E+01	1.4E+03	/Beresford et al. 2007/[2]
		4.8E+02					/Beresford et al. 2007/[3]
		6.4E+01			6.4E+00	1.6E+02	Karlsson and Bergström 2002/[1]
Th	6		1.8E+01	2.9	3.7E+00	1.2E+02	/Beresford et al. 2007/[2]
		3.2E+01					/Beresford et al. 2007/[3]
		4.8E+01			4.8E+00	4.8E+02	Karlsson and Bergström 2002/[1]
U	33		1.4E+00	2.2	2.5E-01	7.9E+00	/Beresford et al. 2007/[2]
	2		3.4E+00	1.5	2.7E+00	4.8E+00	/Beresford et al. 2007/[3]
		1.1E+00			1.1E-01	1.1E+01	Karlsson and Bergström 2002/[1]
Zr	44		1.8E+01	2.5	1.4E-01	1.6E+02	/Beresford et al. 2007/[2]
	1	1.9E+01					/Beresford et al. 2007/[3]
		3.2E+01			3.2E+00	1.6E+02	Karlsson and Bergström 2002/[1]

[1] Marine plant.

[2] Macroalgae.

[3] Vascular plant.

Table A-17. Concentration ratios for marine fish "cR_watToFish_Sea", m³/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac		1.0E+00			1.0E-01	2.0E+00	/Karlsson and Bergström 2002/
Ag	4		1.7E+01	2.9	3.0E+00	1.0E+02	/Beresford et al. 2007/[1]
	4		1.7E+01	2.9	3.0E+00	1.0E+02	/Beresford et al. 2007/[2]
		5.0E+00			1.0E+00	1.0E+01	/Karlsson and Bergström 2002/
Am	33		3.7E-01	2.6	8.0E-02	3.0E+00	/Beresford et al. 2007/[1]
	33		3.7E-01	2.6	8.0E-02	3.0E+00	/Beresford et al. 2007/[2]
		1.0E+00	4.5E-01	2,	1.0E-01	2.0E+00	/Karlsson and Bergström 2002/
Ca							
Cd	5		1.1E+01	2.3	1.0E-01	3.0E+01	/Beresford et al. 2007/[1]
	5		1.1E+01	2.3	1.0E-01	3.0E+01	/Beresford et al. 2007/[2]
		2.0E+00			2.0E-01	2.0E+01	/Karlsson and Bergström 2002/
Cl		5.6E-04					/Beresford et al. 2007/[1]
		5.6E-04					/Beresford et al. 2007/[2]
		1.0E-02			1.0E-03	1.0E-01	/Karlsson and Bergström 2002/
Cm		1.0E+00					/Beresford et al. 2007/[1]
		1.0E+00					/Beresford et al. 2007/[2]
		5.0E-01			1.0E-01	3.0E+00	/Karlsson and Bergström 2002/
Cs	1173		5.0E-01	2.8	5.0E-02	1.8E+01	/Beresford et al. 2007/[1]
	1173		5.0E-01	2.8	5.0E-02	1.8E+01	/Beresford et al. 2007/[2]
		2.0E+00			1.0E+00	5.0E+00	/Karlsson and Bergström 2002/
Eu	3		3.6E+00	1.9	1.3E+00	7.3E+00	/Beresford et al. 2007/[1]
	3		3.6E+00	1.9	1.3E+00	7.3E+00	/Beresford et al. 2007/[2]
		1.0E+00			1.0E-01	1.0E+01	/Karlsson and Bergström 2002/
Ho		3.0E-01			3.0E-02	3.0E+00	/Karlsson and Bergström 2002/
I		3.6E-02					/Beresford et al. 2007/[1]
		3.6E-02					/Beresford et al. 2007/[2]
		3.0E-01			1.0E-01	1.0E+00	/Karlsson and Bergström 2002/
Mo		1.0E-01			1.0E-02	5.0E-01	/Karlsson and Bergström 2002/
Nb		8.3E-01					/Beresford et al. 2007/[1]
		8.3E-01					/Beresford et al. 2007/[2]
		1.0E+00			1.0E-01	5.0E+00	/Karlsson and Bergström 2002/
Ni	7		1.0E+00	2.7	1.0E-01	6.7E+00	/Beresford et al. 2007/[1]
	7		1.0E+00	2.7	1.0E-01	6.7E+00	/Beresford et al. 2007/[2]
		3.0E+00			3.0E-01	5.0E+00	/Karlsson and Bergström 2002/
Np		1.0E-02					/Beresford et al. 2007/[1]
		1.0E-02					/Beresford et al. 2007/[2]
		5.0E-01			1.0E-01	3.0E+01	/Karlsson and Bergström 2002/
Pa		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Pb		2.0E+00					/Beresford et al. 2007/[1]
		2.0E+00					/Beresford et al. 2007/[2]
		1.0E+00			5.0E-01	2.0E+00	/Karlsson and Bergström 2002/
Pd		1.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Po	16		1.9E+01	2.0	2.0E+00	9.6E+01	/Beresford et al. 2007/[1]
	16		1.9E+01	2.0	2.0E+00	9.6E+01	/Beresford et al. 2007/[2]
		2.0E+01			2.0E+00	2.0E+02	/Karlsson and Bergström 2002/
Pu	110		5.0E-01	3.7	3.3E-04	1.5E+01	/Beresford et al. 2007/[1]
	110		5.0E-01	3.7	3.3E-04	1.5E+01	/Beresford et al. 2007/[2]
		3.0E-01			5.0E-02	5.0E-01	/Karlsson and Bergström 2002/
Ra	29		7.3E-01	3.1	1.0E-02	9.5E+00	/Beresford et al. 2007/[1]
	29		7.3E-01	3.1	1.0E-02	9.5E+00	/Beresford et al. 2007/[2]
		5.0E-01			1.0E-01	1.0E+00	/Karlsson and Bergström 2002/
Se	3		8.3E+01	1.6	4.0E+01	1.2E+02	/Beresford et al. 2007/[1]
	3		8.3E+01	1.6	4.0E+01	1.2E+02	/Beresford et al. 2007/[2]
		4.0E+01			2.0E+01	8.0E+01	/Karlsson and Bergström 2002/
Sm		3.0E-01			3.0E-02	3.0E+00	/Karlsson and Bergström 2002/
Sn		1.0E+01			1.0E+00	1.0E+02	/Karlsson and Bergström 2002/
Sr	103		6.3E-02	3.0	1.0E-03	9.5E-01	/Beresford et al. 2007/[1]

Element	N	BE	GM	GSD	Min	Max	Data source
	103		6.3E-02	3.0	1.0E-03	9.5E-01	/Beresford et al. 2007/[2]
		3.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Tc	92		1.5E-01	3.3	1.0E-01	4.0E+00	/Beresford et al. 2007/[1]
	92		1.5E-01	3.3	1.0E-01	4.0E+00	/Beresford et al. 2007/[2]
		3.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
Th	1	6.0E+00					/Beresford et al. 2007/[1]
	1	6.0E+00					/Beresford et al. 2007/[2]
		3.0E-01			1.0E-02	1.0E+00	/Karlsson and Bergström 2002/
U	25		9.6E-02	2.4	6.0E-04	9.0E-01	/Beresford et al. 2007/[1]
	25		9.6E-02	2.4	6.0E-04	9.0E-01	/Beresford et al. 2007/[2]
		5.0E-01			1.0E-01	1.0E+00	/Karlsson and Bergström 2002/
Zr	7		6.8E-01	1.9	3.7E-01	2.0E+00	/Beresford et al. 2007/[1]
	7		6.8E-01	1.9	3.7E-01	2.0E+00	/Beresford et al. 2007/[2]
		1.0E+00			1.0E-01	2.0E+00	/Karlsson and Bergström 2002/

Table A-18. Concentration ratios for marine filter feeder “Sea_cR_watToMuss”, m^3/KgC, literature data.

Element	N	BE	GM	GSD	Min	Max	Data source
Ac							
Ag	15		3.3E+02	2.8	1.7E+00	3.5E+03	/Beresford et al. 2007/
Am	28		8.4E+01	2.8	3.5E+00	1.5E+02	/Beresford et al. 2007/
Ca							
Cd	80		4.1E+02	5.1	1.7E-01	4.0E+04	/Beresford et al. 2007/
Cl		8.1E-04					
Cm	10		4.3E+02	2.1	2.1E+02	9.9E+02	/Beresford et al. 2007/
Cs	172		8.5E-01	2.2	3.5E-02	3.0E+00	/Beresford et al. 2007/
Eu	1	1.2E+02					/Beresford et al. 2007/
Ho							
I		2.4E-01					/Beresford et al. 2007/
Mo							
Nb	2		1.4E+01	1.3	1.3E+01	1.7E+01	/Beresford et al. 2007/
Ni	12	7.1E+01	7.1E+01	2.6	5.2E-01	7.0E+02	/Beresford et al. 2007/
Np	12	5.4E+00	5.4E+00	2.2	4.5E-01	1.6E+01	/Beresford et al. 2007/
Pa							
Pb	57		6.1E+00	5.9	1.9E-01	1.1E+03	/Beresford et al. 2007/
Pd							
Po	70		4.3E+02	2.3	3.0E+01	3.0E+03	/Beresford et al. 2007/
Pu	159	1.2E+01	1.2E+01	2.7	3.5E-02	1.6E+02	/Beresford et al. 2007/
Ra	20	8.1E-01	8.1E-01	2.3	3.5E-02	4.2E+00	/Beresford et al. 2007/
Se	3	7.0E+01	7.0E+01	1.9	2.3E+01	1.5E+02	/Beresford et al. 2007/
Sm							
Sn							
Sr	8		1.2E+00	3.0	3.5E-02	8.7E+00	/Beresford et al. 2007/
Tc	58		1.1E+02	2.3	2.6E+00	3.5E+02	/Beresford et al. 2007/
Th	4		7.7E+00	1.7	1.6E+00	1.2E+01	/Beresford et al. 2007/
U	22		4.1E-01	2.2	7.0E-02	1.7E+00	/Beresford et al. 2007/
Zr	5		3.8E+01	3.4	1.7E+00	3.5E+02	/Beresford et al. 2007/

Appendix B

Compilation of site data of K_d for Radium

A extensive site investigation in the Forsmark area was conducted during the summer of 2010, comprising K_d measurements for 70 element, including Ra. The sampling was carried out in arable lands located in areas where discharge of radionuclides may occur. Five different types of Quaternary Deposits (QD), suitable as arable land, were distinguished and sampled : 1) clayey till, 2) glacial clay, 3) gyttja clay/clay gyttja, 4) peat and 5) cultivated peat. The peat in wetlands has different properties than the cultivated peat and was therefore sampled separately. For each QD five sites were choosen giving a total of 25 sites. Samples were taken from five spade dug holes at each site which were then lumped in order to obtain a representative sample for the site. Samples were taken at 20 cm depth and at 50 cm depth given a total of 50 samples.

The soil samples were saturated with Milli-Q water and incubated at room temperature for one week before the samples were centrifuged and pore water was filtered and analysed. ^{226}Ra analysis was carried out with ICP-SFMS after single-column, ion-exchange separation. Solid samples were analysed following digestion according to a method proposed by Activation Laboratories Ltd, involving aqua regia leaching of 0.5 g solid for 2 h in a heating block held at 90°C. Leachates were diluted and then analysed using ICP-SFMS after three-column ion exchange procedures.

The results of the soil and pore water analysis and the calculated K_d values for Ra at each sampling site are presented in Table B-1. To derive K_d values for inorganic and organic soils the calculated K_d values were categorised based on soil type. The K_d for inorganic soil was derived by calculate the GM and GSD of K_d values from the two inorganic soil types; glacial clay and clayey till. The K_d value for organic soil was estimated by calculating the GM and GSD of the K_ds for three organic soils; gyttja clay, peat and cultivated peat. The values of GM and GSD for the K_d of inorganic and organic deposits derived from the measured K_ds (Table B-1) are presented in Table B-2.

Table B-1. Results from measurements of Ra concentration in soils and pore water for the different soil types and also the calculated K_d value for each sample. Idcode represents the sampling site in the Forsmark.

Idcode	Soil type	Sampling depth (cm)	Concentration solid phase (Bq/kg dw)	Concentration pore water (Bq/m^3)	K_d (m^3/kg dw)
AFM001356	Clayey till	20	53.3	4.2	12.7
AFM001356	Clayey till	50	77.1	2.7	28.2
AFM001357	Clayey till	20	48.4	4.6	10.4
AFM001357	Clayey till	50	55.3	13.5	4.1
AFM001359	Clayey till	20	36.4	1.6	22.7
AFM001359	Clayey till	50	43.2	2.2	19.7
AFM001361	Clayey till	20	41.1	7.9	5.2
AFM001361	Clayey till	50	45.5	8.5	5.4
AFM001362	Gyttja clay	20	26.4	30.4	0.9
AFM001362	Gyttja clay	50	56.7	31.2	1.8
AFM001363	Gyttja clay	20	40.5	20.8	1.9
AFM001363	Gyttja clay	50	99.7	10.1	9.8
AFM001365	Gyttja clay	20	47.6	30.0	1.6
AFM001365	Gyttja clay	50	55.4	18.7	3.0
AFM001367	Gyttja clay	20	71	21.3	3.3
AFM001367	Gyttja clay	50	58.1	16.7	3.5
AFM001368	Gyttja clay	20	62.1	14.4	4.3
AFM001368	Gyttja clay	50	72.2	11.0	6.6
AFM001369	Glacilal clay	20	55.9	22.0	2.5
AFM001369	Glacilal clay	50	70.1	14.7	4.8
AFM001371	Glacilal clay	20	80.4	*	
AFM001371	Glacilal clay	50	131.4	*	
AFM001372	Glacilal clay	20	45.6	16.9	2.7
AFM001372	Glacilal clay	50	71.6	11.2	6.4
AFM001373	Glacilal clay	20	58.7	12.8	4.6
AFM001373	Glacilal clay	50	76.8	4.8	15.9
AFM001374	Glacilal clay	20	75.4	17.6	4.3
AFM001374	Glacilal clay	50	107.8	4.9	22.0
AFM001376	Clayey till	20	43.2	8.5	5.1
AFM001376	Clayey till	50	36.5	15.5	2.4
AFM001379	Cultivated peat	20	25	16.4	1.5
AFM001379	Cultivated peat	50	16.8	20.7	0.8
AFM001381	Cultivated peat	20	31.7	36.2	0.9
AFM001381	Cultivated peat	50	16.8	30.7	0.5
AFM001382	Peat	20	27.5	13.6	2.0
AFM001382	Peat	50	34.9	11.7	3.0
AFM001383	Cultivated peat	20	23.5	4.3	5.4
AFM001383	Cultivated peat	50	16.1	3.7	4.3
AFM001384	Cultivated peat	20	22.7	6.5	3.5
AFM001384	Cultivated peat	50	34.2	9.4	3.7
AFM001385	Peat	20	15	1.9	8.0
AFM001385	Peat	50	15.6	3.9	4.0
AFM001387	Peat	20	37.7	15.0	2.5
AFM001387	Peat	50	35	19.0	1.8
AFM001388	Peat	20	19.2	17.6	1.1
AFM001388	Peat	50	28.7	12.1	2.4
AFM001389	Peat	20	24.3	31.3	0.8
AFM001389	Peat	50	15.7	14.4	1.1
AFM001391	Peat	20	18.9	7.5	2.5
AFM001391	Peat	50	21.4	10.4	2.1

* Too small sample volume for analysis.

Table B-2. K_d values for Ra in organic and inorganic deposits calculated from the site-specific data in Table A-1. The number of samples is also presented (N).

	GM	GSD	N
kD_regoLow (m^3/kg dw)	7.3	2.2	18
Ter_kD_regoUp (m^3/kg dw)	2.3	2.1	30

Appendix C

Bayesian updating methods fo combining site and literature data

The procedure for deriving a probability distribution for a model parameter, such as a CR or K_d, can be divided in two main steps: i) selection of a probability model or distribution type and ii) estimating the distribution parameters. In this Appendix we discuss how Bayesian updating was used in this study for estimating distribution parameters using a combination of literature and site data. We assume that the CR and K_d follow a Lognormal distribution. The 2-parameter Lognormal distribution takes its name from the fundamental property that the logarithm of the random variable (X) is distributed according to Normal distribution /Evans et al. 2000/:

$$\log(X) \sim N(\mu, \sigma) \qquad \text{(C-1)}$$

where log(X) denotes the natural or Napierian logarithm of the random variable and N(μ, σ) denotes a Normal distribution with two parameters, the mean μ and the standard deviation σ.

Bayesian updating

Bayesian inference is the process of fitting a probability model to various sets of data and estimating probability distributions for the parameters of the probability model. The essential characteristic of Bayesian methods is their explicit use of probability for quantifying uncertainty in model parameters. This is achieved by applying the Bayes' theorem /Bayes 1763/, which in its present-day form, due to /Laplace 1812/, is expressed with the following equation:

$$prob\ (hypothesis|data,\ I) = \frac{prob\ (data|hypothesis,\ I) * prob\ (hypothesis|I)}{prob\ (data|I)} \qquad \text{(C-2)}$$

The various terms in the Bayes' theorem have formal names /Sivia 1996/. The quantity on the far right, prob(hypothesis|I), is called the **prior distribution.** It represents our stage of knowledge (or ignorance) about the truth of the hypothesis before we have analysed the current data, given all available background information (I). This is modified by the experimental measurements through the **likelihood function**, or prob(data|hypothesis), and yields the **posterior diistribution**, prob(hypothesis|data, I). This distribution represents our stage of knowledge about the truth of the hypothesis in the light of the data and all available background information. In parameter estimation problems the term prob(data|I) is simply a normalisation constant (not depending explicitly on the hypothesis) and therefore does not play an important role. However, in some situations, such as model selection, this term plays a crucial role. For that reason, it is sometimes given the special name of **evidence**.

In applications of the Bayes theorem for estimation of distribution parameters, the hypothesis is the value that we would assign to the distribution parameter, for example the GM of a lognormal distribution, given the measured data and other available information. The power of the Bayes' theorem lies in the fact that it relates the quantity of interest (the probability of each specific value of the distribution parameter given the measured data) to a term that we have a better chance of being able to assign (the probability of the measured data given that the distribution parameter has a specific value). Note that this way we are implicitly recognizing that the value of the distribution parameter is an uncertain quantity, meaning that different values are possible with different probabilities.

The Bayes theorem can be directly applied to estimate distribution parameters in situations where there is limited site data, but where other prior information is available, for example literature data. The aim is to obtain an estimate of the distribution parameters that takes into account all available information, including prior information and new relevant data. Such direct applications of the Bayes theorem are hereafter called *Bayesian Updating* and include the following basic steps:

1. Definition of *prior* distributions.
2. Definition of *likelihood functions*.
3. Derivation of *posteriors* distributions for the parameters of the probability model.
4. Generation of a *predictive posterior* distribution for the parameter of interest (CR or K_d in this case).

Below we present a description of each of these steps, which we also illustrate with one example dealing with updating of the probability distribution for a CR.

Step 1 – Defining prior distributions

The first step for *Direct Bayesian Updating* is to define *prior* distributions for the parameters μ and σ. The priori distributions should take into account all available information that is relevant for the parameter of interest. We will describe an approach for defining prior distributions for μ and σ which relies on the concepts of *population* and *sub-population*.

In statistics, a population is a set for which statistical inferences are to be drawn. For example if we are interested in generalisations about a CR from soil to a specific plant type, then we would include in the population all CRs for this specific plant type, independently of soil type. A sub-set of a population is called a sub-population. If there are reasons to believe that different sub-sets in a population have different properties, then these might be easier studied and understood if they are further divided into sub-populations. For example, if we know that the CRs from soil to the specific plant type depend on soil type, then we may want to define different sub-populations of CRs for different soil types. One of these sub-populations might be the sub-population of interest for a given problem. For example if we are dealing with inferences for a given site and we know the soil type in this site, then the CR sub-population of interest would be the one corresponding to this soil type. The combination of distributions of different sub-populations, including the sub-population of interest, defines the distribution of the whole population. The concept of population and sub-population is graphically illustrated in Figure 2-2.

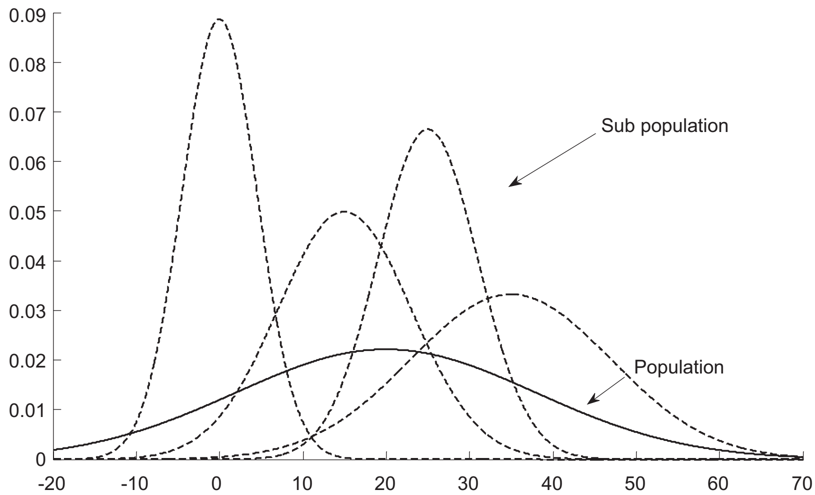

Figure C-1. *Illustration of the concept of population and sub-population. In this example the population distribution (filled curve) is defined by the combination of four sub-populations (dotted curves).*

Prior distributions from available data for a suitable sub-population

If there are sufficient reasons to assume that the random variable of interest belongs to a specific sub-population (-2), then we can use prior data from this sub-population to define prior distributions for μ and σ. Given existing statistics from previous measurements for the sub-population, summarized with mean μ_0, variance σ_0^2 and number of data points n_0, the prior distributions for μ and σ^2 can be defined as /Gelman et al. 2004/:

$$\mu|\sigma^2 = N(\mu_0, \frac{\sigma^2}{n_0}) \quad \text{(C-3)}$$

$$\sigma^2 = Inv\text{–}\,\mathrm{X}^2(n_0, \sigma_0^2) \quad \text{(C-4)}$$

where,

Inv-χ^2 denotes the scaled Inverse Chi Square distribution and is a convenient notation for the distribution of the random variable

$$X = \frac{n_0\sigma_0^2}{\chi_n^2} \quad \text{(C-5)}$$

where,

χ_n^2 indicates a random variable that is chi squared distributed with n_0 degrees of freedom.

The joint prior distribution for μ and σ can then be written as:

$$p(\mu, \sigma^2) = \sigma^{-1}(\sigma^2)^{-(\frac{n_0}{2}+1)}\exp(-\frac{0.5}{\sigma^2}[n_0\sigma_0^2 + n_0(\mu_0 - \mu)^2]) \quad \text{(C-6)}$$

This distribution is commonly labelled as:

$$Normal\text{–}Inv\text{–}\mathrm{X}^2(\mu_0, \frac{\sigma_0^2}{n_0}; n^0, \sigma_0^2) \quad \text{(C-7)}$$

The special choice of the prior distribution (6) has the property of being conjugate to the normal data model with unknown mean and variance. A conjugate prior distribution will result in a posterior distribution that has the same functional form as the prior. That is, the resulting posterior distribution will also be *Normal – Inv –* X^2 distributed, but with updated parameters.

The prior distribution based on the sub-population carries information about both parameters: μ and σ, of the distribution of interest. The number of samples n_0 used for estimating μ_0 and σ_0 is also required. If this information was lost, then value of n_0 will have to be assumed by interpreting this value as subjective weight between the prior information and the data. For example, assigning a value of 1 for n_0 is equivalent to giving the lowest possible weight to the prior information, whereas assigning a value equal to the number of data points available for the variable of interest is equivalent to giving equal weights to the prior information and the new data.

Prior distributions from available data for a suitable population

Assume now that we only have *a priori* data for the whole population. This could be the case if more specific data for sub-populations composing the population are not available or are very scarce, or if we cannot choose which sub-population is closest to the case of interest. The available statistics for the population provides prior information about the logarithmic mean, μ, of the sub-population that is relevant for the case of interest. However, it does not bear information about σ representing the variability within the sub-population. Given existing statistics from previous measurements for the population, summarized with mean μ_0 and variance τ_0^2, the prior distribution for μ is defined as:

$$\mu = Normal\ (\mu_0, \tau_0^2) \quad \text{(C-8)}$$

No prior distribution for σ can be defined from the population data and therefore it will have to be assumed known or estimated directly from the data.

Step 2 – Defining the likelihood function

The likelihood function is the probability of observing the *n* data points conditioned to the μ and σ values, i.e. the unknown parameters that we want to estimate. For a lognormal probability model and assuming independence between the measures, the likelihood function can be obtained by multiplying the *n* individual normal likelihoods /Gelman et al. 2004/:

$$p(y;\mu,\sigma^2)=\frac{1}{\sqrt{2\pi\sigma}}\Pi_i^n\left(-\frac{1}{2\sigma^2}(y_i-\mu)^2\right) \qquad \text{(C-9)}$$

where,

y (without subscript) denotes the vector of all n individual samples (y_i).

Step 3 – Deriving posterior distributions

The joint posterior distribution is given as multiplication of the appropriate prior distribution (Equation C-6 or Equation C-8) and the corresponding data likelihood (Equation C-9).

1. Posterior distribution for priors from available data for a suitable sub-population

For the case when the prior distribution is based on available data for a suitable sub-population, the joint posterior distribution for the sub-population is given by:

$$p(\mu,\sigma^2|y)=\sigma^{-1}(\sigma^2)^{\frac{(n_0+1)}{2}}\exp\left(-\frac{0.5}{\sigma^2}(n_0\sigma_0^2+n_0(\mu_0-\mu)^2)\right)$$

$$\times(\sigma^2-\frac{n}{2}\exp(-\frac{0.5}{\sigma^2}((n-1)s^2+n(\bar{y}-\mu)^2) \qquad \text{(C-10)}$$

$$=Normal\text{–}Inv\text{–}X^2(\mu_n,\frac{\sigma_n^2}{n_n};n_n,\sigma_n^2)$$

where the updated parameters for the sub-population are:

$$\mu_n=\frac{1}{n_0+n}(n_0\mu_0+n\bar{y})$$

$$n_n=n_0+n \qquad \text{(C-11)}$$

$$\sigma^2=\frac{1}{n_n}\left(n_0\sigma_n^2+(n-1)s^2+\frac{(y-\mu_0)^2}{\frac{1}{n_0}+\frac{1}{n}}\right)$$

where,

$$\bar{y}=\frac{1}{n}\sum_{i=1}^n y_i$$

$$s^2=\frac{1}{n-1}\sum_{i=1}^n(y_i-\bar{y})^2$$

are the mean and variance of the observed data.

The joint two-dimensional posterior distribution (Equation C-10) is of the same form as the joint prior (Equation C-6) and can be thus be factored as:

$$\mu|\sigma^2=N(\mu_n,\frac{\sigma_n^2}{n_n}) \qquad \text{(C-12)}$$

$$\sigma^2=Inv-X^2(n_n,\sigma_n^2) \qquad \text{(C-13)}$$

Samples from the joint posterior distribution are most easily obtained by first generating a sample of from (Equation C-13) and then a sample of μ from (Equation C-12) using the obtained sample for σ^2.

The parameters of the posterior distribution (Equation C-10) combine the prior information and the information contained in the observed data. The mean μ_n is a weighted average of the prior mean and the observed data mean, with weights equal to the number of prior samples and the number of observed data samples, respectively. The variance σ_n^2 is also a weighted combination of the prior variance and the observed data, but with an additional term estimating the uncertainty caused by the difference between the prior and observed data means.

Posterior distribution for priors from available data for a suitable population

The posterior distribution of the mean (μ), after updating using the observed data for the case of interest, is:

$$p(\mu|\sigma^2, y) = Normal\ (\mu_n, \tau_n^2 \qquad \text{(C-14)}$$

$$\mu_n = \frac{\frac{1}{\tau_0^2}\mu_0 + \frac{n}{\sigma^2}\bar{y}}{\frac{1}{\tau_0^2} + \frac{n}{\sigma^2}} \qquad \text{(C-15)}$$

$$\tau_n^2 = \frac{1}{\frac{1}{\tau_0^2} + \frac{n}{\sigma^2}} \qquad \text{(C-16)}$$

The mean is thus a weighted combination of the prior mean (μ0) and the data mean $\bar{y}$. The variance of the sub-population (σ^2) of interest is estimated from the variance of the observed data, either as a point estimate (S^2) or as a scaled inverse chi squared distribution centred around the sample variance S^2 with degrees of freedom $n - 1$:

$$\sigma^2 = Inv - \mathrm{X}^2\ (n{-}1, s^2) \qquad \text{(C-17)}$$

Step 4 – Deriving posterior predictive distributions

The posteriors of the distribution parameters (Equations C-10 and C-14) can be used to generate a predictive posterior distribution of the parameter of interest y (for example the CR). This can be done by taking K samples (μ_k and σ_k, $k = 1, ..., K$) of μ and σ from their posterior distributions and use these for generating K predictions (y_k^{pred}y, $k = 1, ..., K$) of the variable of interest (y):

$$y_k^{pred} \sim N(\mu_k, \sigma_k^2),\ k = 1, ..., K\mathrm{Y} \qquad \text{(C-18)}$$

The predictive distribution of y can be summarized by calculating the mean, standard deviation or percentiles of the obtained predicted samples $y_1^{pred}, y_2^{pred},...,. y_k^{pred}$y.

Example of Bayesian Updating

We illustrate the methods described in the previous sections by applying them in updating the probability distribution for the CR of an element from water to a specific species of fish, hereafter called the reference species. We assume that CRs are well described with a lognormal distribution and want to update the distribution parameters μ and σ. Table C-1 shows the statistics obtained from 5 measurements of the reference species, prior values obtained from 10 measurements of species that we consider belong to the same sub-population as the reference species, and 50 prior values obtained from measurements of species that we consider belong to the same population as the reference species.

Table C-1. Statistics for the available data of CR from water to fish for the reference species and prior data for species belonging to the same sub-population or population as the reference species.

Available information	N	GM	GSD	μ	σ²
Prior data for species from the same sub-population	10	0.20	3.0	–1.6	1.2
Prior data for species from the same population	50	0.50	6.0	–0.7	3.2
Data for the reference species	5	0.10	2.0	–2.3	0.48

Note: μ and σ^2 are obtained from the GM and GSD deviation respectively using standard conversion equations (μ = In(GM), σ^2 = In(GSD)^2).

We derive predictive posterior distributions for two cases with different data being used to define the prior distributions, i.e. data for species of the same sub-population and data for species from the same population. The application of steps 1 to 3, described above, using the prior and observed data presented in Table C-1, give the values for the parameters of the posterior distributions, n_n, μ_n, σ^2 $_n$ and τ_n^2μ, presented in Table C-2. In the case when data for species from the same population is used to define the priors, the values of μ_n and τ_n^2 in Table C-2 were obtained assuming that σ^2 is known and the value of 0.48 given in Table C-1 is directly used in Equations C-15 and C-16. Applying Equation C-17 for generating several σ^2 values would result in several estimates of μ_n and τ_n^2. The parameter values in Table C-2 are then used in the final step of the direct updating procedure to obtain predictive posterior distributions of the CR. The results are presented in Table C-3 and illustrated in Figure C-2 and Figure C-3.

Table C-2. Parameter values of the posterior distributions obtained for two cases where different priors are used, derived from data for the same sub-population and population, respectively.

Prior based on	n_n	μ_n	σ_n^2
Data for species from the same sub-population	15	–1.8	1.0
Data for species from the same population	5	–2.3	0.093

Table C-3. Parameter values of the predictive posterior distributions obtained for two cases where different priors are used, derived from data for the same sub-population and population, respectively.

Prior based on	n_n	GM	GSD	μ	σ^2
Prior data for species from the same sub-population	15	0.16	3.1	–1.8	1.3
Prior data for species from the same population	5	0.11	3.0	–2.2	1.2

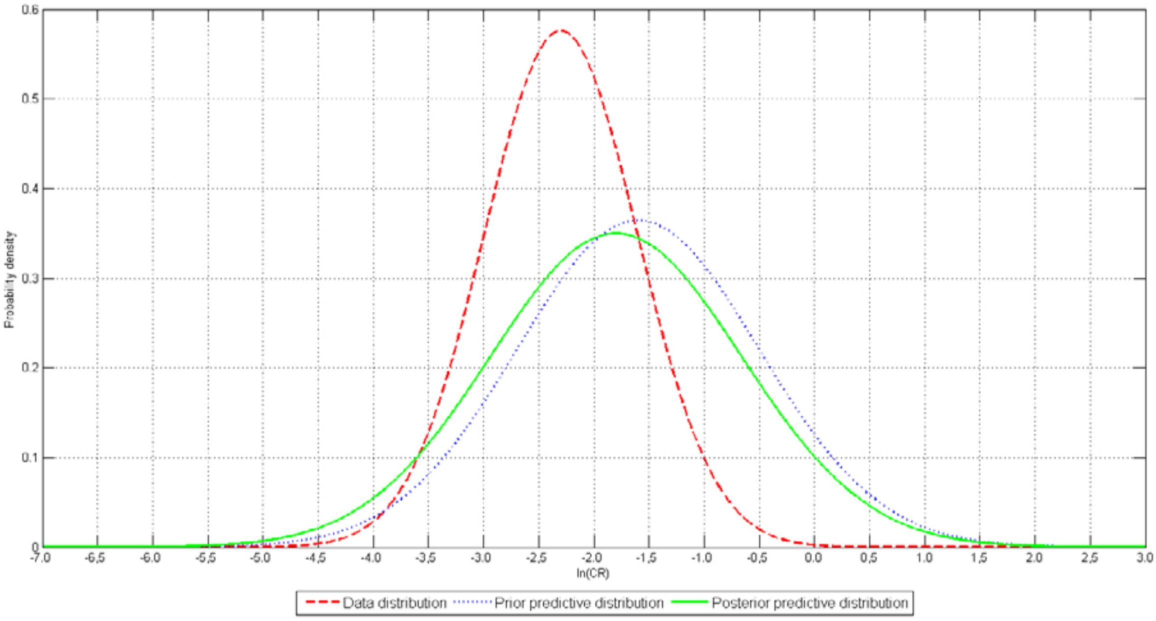

__Figure C-2.__ Predictive posterior distribution of the CR (shown on logarithmic scale) for the reference species obtained by direct Bayesian updating using prior data from the same sub-population.

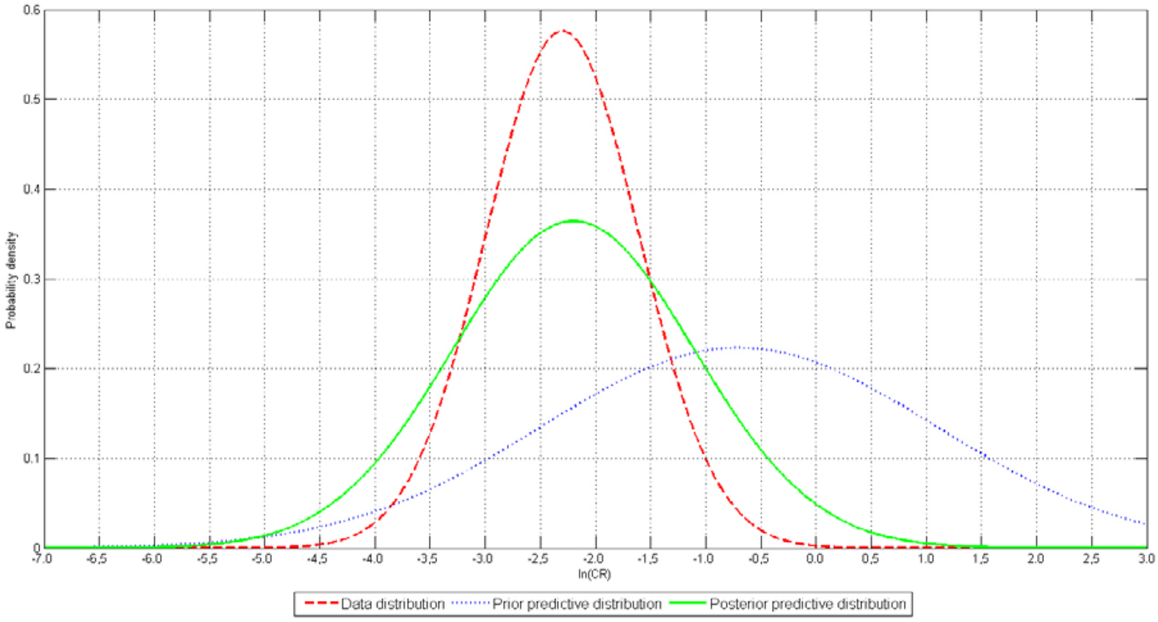

Figure C-3. *Predictive posterior distribution of the CR (shown on logarithmic scale) for the reference species obtained by direct Bayesian updating using prior data from the same population.*

Appendix D

Results from Bayesian updating

This appendix presents the results from Bayesian updating methods used to combine site-specific and literature data.

Table D-1. K_d values for inorganic soil ("kD_regoLow"), m^3/kg dw resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	5	3.6E-02	1.4	33	7.0E-03	3.0	8.6E-03	3.4	3.4E-02	1.7	3.4E-02	3.4E-02	1.7
Cd	5	2.7E-01	4.1	39	1.1E-01	8.0	1.2E-01	8.2	2.4E-01	8.4	2.4E-01	2.4E-01	8.4
Cl	3	6.9E-03	1.8	22	3.0E-04	3.0	4.4E-04	4.7	3.7E-03	8.0	4.4E-04	4.4E-04	4.7
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	5	4.8E+01	2.5	469	1.2E+00	7.0	1.3E+00	7.4	3.6E+01	4.1	3.6E+01	3.6E+01	4.1
Eu	4	5.4E+00	2.4	10	2.0E+02	3.2	–	–	1.1E+01	5.5	1.1E+01	1.1E+01	5.5
Ho	5	1.8E+01	3.2	3	6.3E-01	2.0	5.2E+00	9.7	4.3E+00	6.0	5.2E+00	5.2E+00	9.7
I	2	2.5E-02	3.1	196	7.0E-03	5.0	7.1E-03	5.1	-	-	7.1E-03	7.1E-03	5.1
Mo	5	1.6E-01	2.2	10	1.0E-01	3.2	–	–	1.5E-01	3.3	1.5E-01	1.5E-01	3.3
Nb	2	7.9E+00	4.9	11	1.5E+00	4.0	1.9E+00	5.3	–	–	1.9E+00	1.9E+00	5.3
Ni	4	2.0E+00	2.1	64	2.8E-01	7.0	3.1E-01	7.5	1.8E+00	4.0	3.1E-01	1.8E+00	4.0
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	5	8.5E+00	3.0	23	2.1E+00	10.0	2.7E+00	10.0	7.7E+00	5.4	7.7E+00	7.7E+00	5.4
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	4	1.7E-02	1.6	172	2.0E-01	3.0	1.9E-01	3.2	2.2E-02	2.6	2.2E-02	2.2E-02	2.6
Sm	4	2.3E+01	4.1	3	6.3E-01	2.0	5.0E+00	13.3	2.9E+00	12.3	5.0E+00	5.0E+00	13.3
Sn	–	–	–	4	2.9E-01	2.0	–	–	–	–	–	–	–
Sr	5	3.5E-01	2.0	255	5.0E-02	6.0	5.3E-02	6.1	3.2E-01	2.9	3.2E-01	3.2E-01	2.9
Tc	–	–	–	22	6.0E-05	4.0	–	–	–	–	–	–	–
Th	5	5.0E+01	6.1	25	2.6E+00	10.0	4.2E+00	13.3	3.2E+01	15.3	3.2E+01	3.2E+01	15.3
U	5	1.6E+00	2.2	146	1.8E-01	13.0	1.9E-01	13.3	1.5E+00	3.3	1.5E+00	1.5E+00	3.3
Zr	5	4.7E-01	1.3	11	4.1E-01	21.0	4.3E-01	16.3	4.7E-01	1.6	4.7E-01	4.7E-01	1.6

Table D-2. K_d values for organic soil (“Ter_regoUp”,” Ter_regoMid”, “Lake_regoUp”,” Lake_regoMid”, “Sea_regoUp” and “Sea_regoMid”), m^3/kg dw resulting from the Bayesian updating.

							Results						
	Site-specific data			Prior (Literature data)			POSTERIOR_Subp		POSTERIOR_Pop		Selected values		
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	11	6.2E+01	3.0	9	3.8E-01	7	6.1E+00	24.3	5.2E+01	3.5	6.2E+01	5.2E+01	3.5
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	26	3.1E-02	5.9	34	8.0E-03	3	1.5E-02	5.0	2.8E-02	6.6	3.1E-02	1.5E-02	5.0
Cd	29	4.3E+00	21.1	13	6.5E-01	6	2.4E+00	18.6	3.7E+00	24.5	4.3E+00	2.4E+00	19
Cl	20	1.3E-02	3.2	22	3.0E-04	3	1.8E-03	9.9	1.1E-02	3.5	1.3E-02	1.1E-02	3.5
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	23	2.7E+01	2.1	108	2.7E-01	7	6.0E-01	12.5	2.6E+01	2.2	2.6E+01	2.6E+01	2.2
Eu	24	8.6E+00	5.4	10	1.0E+00	4.6	–	–	7.7E+00	6.1	8.6E+00	8.6E+00	5.4
Ho	23	1.2E+01	3.3	4	9.3E-01	3	8.2E+00	4.7	1.0E+01	3.6	1.2E+01	8.2E+00	4.7
I	20	7.1E-01	3.8	11	3.2E-02	3	2.4E-01	7.6	5.6E-01	4.3	7.1E-01	2.4E-01	7.6
Mo	27	1.1E+00	5.2	9	4.0E-02	3	4.8E-01	8.8	8.3E-01	5.8	1.1E+00	4.8E-01	8.8
Nb	20	4.6E+01	3.5	11	1.5E+00	4	1.4E+01	8.9	4.0E+01	3.8	4.0E+01	4.0E+01	3.8
Ni	27	3.0E+00	5.0	20	9.8E-01	2	1.9E+00	4.3	2.5E+00	5.5	3.0E+00	1.9E+00	4.3
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	28	4.3E+01	4.1	5	2.5E+00	3	2.8E+01	5.8	3.6E+01	4.4	4.3E+01	2.8E+01	5.8
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	27	5.3E-01	9.2	172	2.0E-01	3	2.3E-01	3.8	4.6E-01	10.4	5.3E-01	2.3E-01	3.8
Sm	28	1.1E+01	4.1	4	9.3E-01	3	7.8E+00	5.3	9.3E+00	4.4	1.1E+01	7.8E+00	5.3
Sn	16	8.5E+00	3.2	12	1.6E+00	6	4.1E+00	5.8	8.0E+00	3.6	8.0E+00	8.0E+00	3.6
Sr	25	1.2E-01	2.5	176	7.0E-02	6	7.5E-02	5.7	1.2E-01	2.7	1.2E-01	1.2E-01	2.7
Tc	–	–	–	–	–	–							
Th	25	4.2E+01	3.4	5	7.3E-01	44	2.1E+01	12.8	4.2E+01	3.7	4.2E+01	4.2E+01	3.7
U	25	6.5E+00	3.2	9	1.2E+00	6	4.2E+00	5.0	6.3E+00	3.4	6.5E+00	6.3E+00	3.4
Zr	26	6.1E+00	13.8	11	4.1E-01	21	2.7E+00	22.2	5.6E+00	16.4	5.6E+00	5.6E+00	16.4

Table D-3. K_d values for suspended particulate matter in marine environments ("Sea_kD_PM), m^3/kg dw resulting from the Bayesian updating.

Element	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	8	2.7E-01	8.6	–	–	–	–	–	–	–	–	–	–
Cd	8	1.8E+02	6.9	10	1.0E+01	3.2	–	–	7.7E+01	11.0	7.7E+01	7.7E+01	11
Cl	1	4.5E-04	1.4	–	1.0E-03	3.2	–	–	–	–	–	–	–
Cm	-	-	–	–	–	–	–	–	–	–	–	–	–
Cs	5	1.9E+01	3.4	57	5.4E-01	5.1	7.2E-01	6.7	1.1E+01	6.7	1.1E+01	1.1E+01	6.7
Eu	4	2.6E+02	1.6	10	1.0E+01	3.2	–	–	2.0E+02	2.5	2.0E+02	2.0E+02	2.5
Ho	5	1.4E+02	2.4	10	1.0E-01	3.2	–	–	4.6E+01	5.1	4.6E+01	4.6E+01	5.1
I	5	5.1E+00	1.6	10	3.2E-01	1.8	–	–	3.3E+00	2.1	3.3E+00	3.3E+00	2.1
Mo	8	2.3E+00	8.7	10	1.0E-03	3.2	–	–	1.6E-01	16.8	1.6E-01	1.6E-01	17
Nb	5	3.8E+02	2.7	10	1.0E+01	3.2	–	–	2.0E+02	4.7	2.0E+02	2.0E+02	4.7
Ni	8	1.4E+01	1.3	717	1.7E+01	11	1.7E+01	10.8	1.4E+01	1.4	1.4E+01	1.4E+01	1.4
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	8	2.5E+02	2.2	715	1.8E+02	9.3	1.8E+02	9.3	2.5E+02	2.7	2.5E+02	2.5E+02	2.7
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	5	1.5E+01	3.4	3	2.6E-01	2.8	3.4E+00	15.8	4.6E+00	7.0	3.4E+00	3.4E+00	16
Sm	5	4.6E+02	1.7	10	1.0E+02	3.2	–	–	4.2E+02	2.2	4.2E+02	4.2E+02	2.2
Sn	3	4.8E+01	1.3	10	3.3E+01	5.3	–	–	4.7E+01	2.6	4.7E+01	4.7E+01	2.6
Sr	5	9.4E-02	1.3	6	5.0E-03	19	1.9E-02	21.2	9.3E-02	1.5	1.9E-02	1.9E-02	21
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	5	7.5E+02	2.9	125	4.5E+03	3.8	4.2E+03	4.0	1.0E+03	4.9	1.0E+03	1.0E+03	4.9
U	5	1.2E+00	1.9	31	8.6E-01	3.1	9.0E-01	3.1	1.2E+00	2.7	1.2E+00	1.2E+00	2.7
Zr	5	3.6E+02	2.5	10	5.0E+01	3.2	–	–	2.6E+02	4.3	2.6E+02	2.6E+02	4.3

Table D-4. K_d values for suspended particulate matter in limnic environments ("Lake_kD_PM"), m^3/kg dw resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	2	3.6E+01	1.6	91	9.5E+01	2.3	9.3E+01	2.3	–	–	9.3E+01	9.3E+01	2.3
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	7	7.0E-01	3.2	–	–	–	–	–	–	–	–	–	–
Cd	6	2.2E+02	2.4	10	1.0E-01	3.2	–	–	–	4.0	8.6E+01	8.6E+01	4.0
Cl	–	–	–	–	–	–	–	–	–	–	–	–	–
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	7	1.0E+02	2.4	219	2.9E+01	5.9	3.1E+01	5.9	9.7E+01	3.2	9.7E+01	9.7E+01	3.2
Eu	7	9.0E+01	2.2	10	5.0E-01	3.2			5.8E+01	2.9	5.8E+01	5.8E+01	2.9
Ho	7	8.6E+01	2.1	12	2.3E+02	1.6	1.6E+02	2.2	1.2E+02	2.5	1.6E+02	1.6E+02	2.2
I	6	1.0E+01	2.6	124	4.4E+00	14.0	4.5E+00	13.8	1.0E+01	3.7	1.0E+01	1.0E+01	3.7
Mo	7	7.2E+00	3.6	79	1.1E+00	18.0	1.3E+00	17.9	6.8E+00	5.3	6.8E+00	6.8E+00	5.3
Nb	7	3.3E+02	2.4	10	1.0E+01	3.2	–	–	2.3E+02	3.2	2.3E+02	2.3E+02	3.2
Ni	7	2.6E+01	1.9	247	1.5E+00	36	1.7E+00	37.2	2.6E+01	2.3	2.6E+01	2.6E+01	2.3
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	7	5.6E+02	2.2	333	1.3E+02	14	1.4E+02	14.1	5.4E+02	2.9	5.4E+02	5.4E+02	2.9
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	7	8.4E+00	2.1	10	3.2E+00	1.8	–	–	6.6E+00	2.6	8.4E+00	8.4E+00	2.1
Sm	7	1.2E+02	2.7	50	4.3E+02	3	3.7E+02	3.3	1.4E+02	3.6	1.4E+02	1.4E+02	3.6
Sn	–	–	–	–	–	–	–	–	–	–	–	–	–
Sr	7	8.5E-01	3.0	13	1.2E+00	2.7	1.1E+00	3.0	9.1E-01	4.1	1.1E+00	1.1E+00	3.0
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	7	3.0E+02	3.2	63	1.9E+02	21	2.0E+02	19.8	3.0E+02	4.6	3.0E+02	3.0E+02	4.6
U	7	6.1E+00	5.5	58	1.5E+01	39	1.3E+01	37.2	6.3E+00	9.3	6.3E+00	6.3E+00	9.3
Zr	7	1.2E+02	3.0	10	1.0E+00	3.2	–	–	5.7E+01	4.4	5.7E+01	5.7E+01	4.4

Table D-5. CR values for terrestrial primary producers (Ter_cR_pp), kg dw/kg C resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	13	8.9E+00	2.7	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	19	2.0E+00	2.8	10	2.0E+00	3.1	–	–	2.0E+00	3.0	2.0E+00	2.0E+00	3.0
Cd	19	7.6E-01	3.1	210	1.6E+00	3.2	1.5E+00	3.3	7.9E-01	3.4	7.9E-01	7.9E-01	3.4
Cl	19	3.4E+01	5.3	22	6.2E+01	2.2	4.7E+01	3.8	3.9E+01	6.1	3.4E+01	4.7E+01	3.8
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	19	1.8E-01	3.7	401	4.9E-01	4.1	4.7E-01	4.2	1.9E-01	4.2	1.9E-01	1.9E-01	4.2
Eu	19	3.5E-03	2.5	10	2.0E-02	3.2	6.5E-03	3.9	3.7E-03	2.7	3.7E-03	3.7E-03	2.7
Ho	19	2.9E-03	2.3	10	2.0E-03	3.2			2.9E-03	2.5	2.9E-03	2.9E-03	2.5
I	19	5.6E-01	5.8	25	1.2E+00	3.6	8.6E-01	4.8	6.2E-01	6.7	5.6E-01	8.6E-01	4.8
Mo	19	1.7E-01	3.1	10	1.6E+00	3.2	3.7E-01	5.1	1.9E-01	3.4	1.9E-01	1.9E-01	3.4
Nb	19	4.0E-03	3.5	–	–	–	–	–	–	–	–	–	–
Ni	19	1.8E-01	2.5	111	2.5E-01	5.1	2.4E-01	4.8	1.8E-01	2.7	1.8E-01	1.8E-01	2.7
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	19	2.0E-02	2.3	34	1.8E-01	4.8	8.2E-02	5.8	2.1E-02	2.4	2.1E-02	2.1E-02	2.4
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	5	1.4E-01	2.7	42	1.4E-01	7.6	1.4E-01	7.3	1.4E-01	4.6	1.4E-01	1.4E-01	4.6
Se		–	–	–	–	–	–	–	–	–	–	–	–
Sm	19	2.6E-03	4.5	10	2.0E-02	3.2	-	-	3.1E-03	5.2	2.6E-03	2.6E-03	4.5
Sn	19	5.0E-02	2.1	–	–	–	–	–	–		–	–	–
Sr	19	4.8E-01	2.5	172	2.6E+00	2.2	2.1	2.6	5.5E-01	2.8	4.8E-01	2.1E+00	2.6
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	–	–	–	–	–	–	–	–	–	–	–	–	–
U	19	1.5E-03	3.7	53	9.0E-02	5.3	3.1E-02	11.7	1.7E-03	4.1	1.7E-03	1.7E-03	4.1
Zr	19	3.0E-03	2.5	64	3.6E-04	2.1	5.8E-04	3.3	2.5E-03	2.8	3.0E-03	5.8E-04	3.3

Table D-6. CR values for mushrooms ("cR_soilToMush") kg dw/kg C, resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag													
Am				–	–	–	–	–	–	–	–	–	–
Ca	8	6.0E-02	3.2	–	–	–	–	–	–	–	–	–	–
Cd	9	1.5E+01	3.1	–	–	–	–	–	–	–	–	–	–
Cl	–	–	–	–	–	–	–	–	–	–	–	–	–
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	9	2.9E+01	4.7	10	2.8E+01	7.2	–	–	3.0E+01	6.5	3.0E+01	3.0E+01	6.5
Eu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ho	–	–	–	–	–	–	–	–	–	–	–	–	–
I	9	6.7E-02	2.3	–	–	–	–	–	–	–	–	–	–
Mo	–	–	–	–	–	–	–	–	–	–	–	–	–
Nb	–	–	–	–	–	–	–	–	–	–	–	–	–
Ni	9	3.2E-01	2.4	10	3.1E-01	1.2			3.2E-01	2.8	3.2E-01	3.2E-01	2.4
Np													
Pa													
Pb	9	2.6E-02	2.4										
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	–	–	–	–	–	–	–	–	–	–	–	–	–
Sm	–	–	–	–	–	–	–	–	–	–	–	–	–
Sn	–	–	–	–	–	–	–	–	–	–	–	–	–
Sr	9	9.1E-02	3.4	10	4.9E-02	1.5	–	–	6.7E-02	4.1	9.1E-02	9.1E-02	3.4
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	9	8.1E-03	3.1	10	1.0E-02	1.5	–	–	9.0E-03	3.9	8.1E-03	8.1E-03	3.1
U	9	1.3E-02	9.1	10	4.3E-02	1.3	–	–	3.5E-02	13.0	1.3E-02	1.3E-02	9.1
Zr	–	–	–	–	–	–	–	–	–	–	–	–	–

Table D-7. CR values for freshwater macrophytes ("Lake_cR_pp_macro") m^3/kgC resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	7	7.6E+00	1.1	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	9	8.5E+00	3.7	–	–	–	–	–	–	–	–	–	–
Cd	9	2.8E+01	2.4	5	2.6E+02	6.8	6.1E+01	6.6	3.0E+01	2.885973	6.1E+01	6.1E+01	6.6
Cl	9	6.1E-01	7.5	6	4.0E+00	1.9	1.3E+00	7.2	1.7E+00	10.7	1.3E+00	1.3E+00	7.2
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	9	1.3E+01	3.9	26	1.3E+00	16	2.4E+00	16.3	1.2E+01	5.3	1.2E+01	1.2E+01	5.3
Eu	9	1.9E+01	5.6	–	–	–	–	–	–	–	–	–	–
Ho	9	8.6E+00	5.3	–	–	–	–	–	–	–	–	–	–
I	9	3.6E+00	2.7	3	1.8E+00	3.7	3.0E+00	3.4	3.5E+00	3.3	3.0E+00	3.0E+00	3.4
Mo	9	4.4E+00	3.4	–	–	–	–	–	–	–	–	–	–
Nb	7	2.7E+01	3.4	–	–	–	–	–	–	–	–	–	–
Ni	9	5.4E+00	2.4	5	1.1E+01	129	7.0E+00	28.5	5.5E+00	3.0	7.0E+00	5.5E+00	3.0
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	9	3.8E+01	4.0	5	2.60E+01	76	3.3E+01	23.0	3.8E+01	5.3	3.3E+01	3.8E+01	5.3
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	4	9.6E+00	2.5	9	4.0E+01	4.1	2.6E+01	4.9	1.2E+01	5.3	2.6E+01	2.6E+01	4.9
Se	7	6.8E+00	1.3	31	1.9E+01	5.4	1.6E+01	5.1	6.8E+00	1.5	6.8E+00	6.8E+00	1.5
Sm	9	2.0E+01	6.6	–	–	–	–	–	–	–	–	–	–
Sn	–	–	–	–	–	–	–	–	–	–	–	–	–
Sr	9	2.3E+00	3.5	17	5.6E+00	3.3	4.1E+00	3.8	2.6E+00	4.4	4.1E+00	4.1E+00	3.8
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	9	9.1E+00	6.1	5	1.5E+01	1.7	1.1E+01	4.9	1.2E+01	8.6	1.1E+01	1.1E+01	4.9
U	9	2.6E+00	3.2	4	2.9E+00	1.9	2.7E+00	3.0	2.7E+00	4.0	2.7E+00	2.7E+00	3.0
Zr	9	7.5E+00	3.8	–	–	–	–	–	–	–	–	–	–

Table D-8. CR values for freshwater filter feeders (“Lake_cR_watToMuss”) m³/kgC resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	6	8.7E+01	2.3	2	4.5E-01	6.7	2.4E+01	22.8	6.8E+01	3.1	2.4E+01	2.4E+01	23
Am	–	–	–	–	–	–	–	–	–		–	–	–
Ca	6	6.7E+00	2.8	3	4.1E-01	2.5	2.6E+00	6.8	3.7E+00	4.2	2.6E+00	2.6E+00	6.8
Cd	6	1.2E+03	2.0	149	1.2E+00	39	1.6E+00	49.5	1.1E+03	2.6	1.1E+03	1.1E+03	2.6
Cl	6	5.3E-01	6.6	3	1.9E+00	1.2	8.2E-01	6.1	1.7E+00	11.6	8.2E-01	8.2E-01	6.1
Cm	–	–	–	–	–	–	–	–	–		–	–	–
Cs	6	6.3E+00	3.0	29	2.8E-01	75	4.8E-01	77.7	6.0E+00	4.7	6.0E+00	6.0E+00	4.7
Eu	6	4.1E+01	6.0	2	2.6E+00	1.1	2.1E+01	9.5	2.7E+00	10.2	2.1E+01	2.1E+01	9.5
Ho	6	7.3E+00	5.8	10	1.2E+01	3.2	–	–	8.6E+00	10.5	7.3E+00	7.3E+00	5.8
I	6	1.9E+00	2.4	99	2.1E-01	11	2.3E-01	11.5	1.8E+00	3.5	1.8E+00	1.8E+00	3.5
Mo	6	3.5E+00	2.6	33	5.4E-03	13	1.5E-02	31	2.8E+00	3.8	2.8E+00	2.8E+00	3.8
Nb	6	9.6E+00	2.0	2	4.1E+00	1.3	7.8E+00	2.3	6.0E+00	2.5	7.8E+00	7.8E+00	2.3
Ni	6	3.7E+00	1.9	10	1.2E+00	3.2	–	–	3.4E+00	2.4	3.4E+00	3.4E+00	2.4
Np	–	–	–	–	–	–	–	–	–		–	–	–
Pa	–	–	–	–	–	–	–	–	–		–	–	–
Pb	6	5.5E+01	3.0	79	2.7E-01	20	3.8E-01	26.2	4.6E+01	4.6	4.6E+01	4.6E+01	4.6
Pd	–	–	–	–	–	–	–	–	–		–	–	–
Po	–	–	–	–	–	–	–	–	–		–	–	–
Pu	–	–	–	–	–	–	–	–	–		–	–	–
Ra	2	1.3E+01	1.4	5	4.9E-02	13	2.4E-01	65	1.2E+01	1.5	2.4E-01	1.2E+01	1.5
Se	6	4.6E+01	1.1	16	6.9E+00	15	1.2E+01	14.0	4.6E+01	1.2	4.6E+01	4.6E+01	1.2
Sm	6	2.2E+01	10.8	2	1.4E+01	2.3	1.9E+01	10.6	1.6E+01	24.4	1.9E+01	1.9E+01	11
Sn	–	–	–	–	–	–	–	–	–		–	–	–
Sr	6	4.4E+00	2.7	5	3.3E+00	3.2	3.9E+00	3.3	4.2E+00	4.0	3.9E+00	3.9E+00	3.3
Tc	–	–	–	–	–	–	–	–	–		–	–	–
Th	6	8.9E+00	4.7	2	3.5E+01	1.0	1.2E+01	5.2	3.5E+01	7.4	1.2E+01	1.2E+01	5.2
U	6	1.6E+00	3.0	9	2.1E+00	19	1.9E+00	13.9	1.6E+00	4.6	1.9E+00	1.6E+00	4.6
Zr	6	2.9E+00	2.7	10	8.5E-02	3.2	–	–	1.7E+00	4.1	1.7E+00	1.7E+00	4.1

Table D-9. CR values for freshwater fish ("cR_watToFish_Lake") m^3/kgC resulting from the Bayesian updating.

							Results						
	Site-specific data			Prior (Literature data)			POSTERIOR_Subp		POSTERIOR_Pop		Selected values		
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	9	2.2E-01	3.1	104	1.3E-01	2.5	1.4E-01	2.6	2.0E-01	4.0	1.4E-01	1.4E-01	2.6
Cd	–	–	–	4	–	–	–	–	–	–	–	–	–
Cl	9	1.4E-01	5.9	16	5.1E-01	2.2	3.2E-01	4.1	2.3E-01	8.1	3.2E-01	3.2E-01	4.1
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	9	1.6E+01	4.8	106	2.7E+01	2.4	2.6E+01	2.6	1.9E+01	6.4	2.6E+01	2.6E+01	2.6
Eu	–	–	–	24	1.4E+00	4.9	–	–	–	–	–	–	–
Ho	–	–	–	–	–	–	–	–	–	–	–	–	–
I	9	1.7E-01	4.0	50	3.3E-01	2.5	3.0E-01	2.8	2.0E-01	5.3	3.0E-01	3.0E-01	2.8
Mo	9	6.6E-02	2.6E+00	64	2.1E-02	2.1	2.4E-02	2.4	5.3E-02	3.2	2.4E-02	2.4E-02	2.4
Nb	7	7.7E-02	2.2	3	2.3E+00	1.6	2.2E-01	7.3	2.6E-01	3.0	2.2E-01	2.2E-01	7.3
Ni	–	–	–	–	–	–	–	–	–	–	–	–	–
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	–	–	–	–	–	–	–	–	–	–	–	–	–
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	4	2.3E-01	2.5	21	4.4E-02	6.9	5.8E-02	7.5	1.9E-01	5.5	5.8E-02	1.9E-01	5.5
Se	7	8.9E+00	1.7	14	6.6E+01	1.3	3.4E+01	2.9	2.1E+01	2.1	3.4E+01	3.4E+01	2.9
Sm	–	–	–	–	–	–	–	–	–	–	–	–	–
Sn	–	–	–	–	–	–	–	–	–	–	–	–	–
Sr	9	3.3E-02	3.4	99	3.2E-02	3.9	3.2E-02	3.9	3.3E-02	4.3	3.3E-02	3.3E-02	4.3
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	–	–	–	–	–	–	–	–	–	–	–	–	–
U	9	2.0E-03	4.6	9	1.1E-02	12	4.6E-03	11.0	2.1E-03	6.3	4.6E-03	2.1E-03	6.3
Zr	9	8.1E-02	3.7	10	2.4E-01	2.4	1.4E-01	3.6	1.0E-01	4.8	1.4E-01	1.4E-01	3.6

Table D-10. CR values for marine phytoplankton (“Sea_cR_pp_plank”) m^3/kgC, resulting from the Bayesian updating.

	Site-specific data			Prior (Literature)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	3	2.5E-01	1.1	–	–	–	–	–	–	–	–	–	–
Cd	3	6.6E+01	1.3	56	1.5E+01	2.5	1.6E+01	2.7	5.8E+01	2.7	1.6E+01	1.6E+01	2.7
Cl	2	1.3E-01	1.0	–	–	–	–	–	–	–	–	–	–
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	3	7.3E+01	1.3	21	1.1E+00	4.9	1.8E+00	8.9	6.4E+01	3.5	1.8E+00	7.3E+01	1.3
Eu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ho	–	–	–	–	–	–	–	–	–	–	–	–	–
I	2	6.2E+00	1.6	–	–	–	–	–	–	–	–	–	–
Mo	3	–	–	–	–	–	–	–	–	–	–	–	–
Nb	–	–	–	–	–	–	–	–	–	–	–	–	–
Ni	3	3.5E+01	1.3	–	–	–	–	–	–	–	–	–	–
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	3	1.7E+02	7.3	35	6.7E+03	3.4	5.0E+03	5.3	–	–	5.0E+03	5.0E+03	5.3
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	3	4.1E+01	1.6	94	2.8E+01	5.1	2.8E+01	5.1	4.0E+01	4.2	2.8E+01	2.8E+01	5.1
Sm	–	–	–	–	–	–	–	–	–	–	–	–	–
Sn	–	–	–	–	–	–	–	–	–	–	–	–	–
Sr	–	–	–	–	–	–	–	–	–	–	–	–	–
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	3	2.7E+03	1.2	25	1.5E+04	2.4	1.2E+04	2.8	2.9E+03	1.9	1.2E+04	1.2E+04	2.8
U	–	–	–	–	–	–	–	–	–	–	–	–	–
Zr	3	1.4E+03	1.1	4	7.5E+02	2.0	9.9E+02	2.2	1.4E+03	1.4	9.9E+02	9.9E+02	2.2

Table D-11. CR values for marine macrophytes ("Sea_cR_pp_macro") m³/kgC resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	10	8.3E-01	3.3	–	–	–	–	–	–	–	–	–	–
Cd	10	1.0E+02	3.0	63	9.4E+00	2.3	1.3E+01	3.4	6.6E+01	3.7	1.0E+02	1.3E+01	3.4
Cl	9	3.2E-02	1.6	35	1.1E-02	1.9	1.3E-02	2.2	3.0E-02	1.8	3.0E-02	3.0E-02	1.8
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	10	5.9E+00	3.4	579	3.1E-01	6.8	3.3E-01	7.0	4.9E+00	4.3	4.9E+00	4.9E+00	4.3
Eu	10	8.4E+00	12.3	4	1.8E+01	1.9	1.0E+01	10.2	1.4E+01	18.4	8.4E+00	1.0E+01	10.2
Ho	10	5.7E+00	9.8	10	1.6E+01	3.2			7.7E+00	14.5	5.7E+00	5.7E+00	9.8
I	9	1.2E+01	1.9	62	2.3E+01	4.3	2.1E+01	4.1	1.2E+01	2.1	1.2E+01	1.2E+01	2.1
Mo	10	7.0E-01	2.1	10	1.6E-01	3.2			6.5E-01	2.4	6.5E-01	6.5E-01	2.4
Nb	5	5.5E+01	2.3	20	7.1E+00	2.2	1.1E+01	3.3	3.3E+01	3.5	1.1E+01	1.1E+01	3.3
Ni	10	1.8E+01	1.9	14	9.9E+00	2.0	1.3E+01	2.2	1.7E+01	2.1	1.7E+01	1.7E+01	2.1
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	10	1.9E+01	7.8	54	8.8E+00	3.0	9.9E+00	3.8	1.5E+01	11.2	1.9E+01	9.9E+00	3.8
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	8	1.3E+01	1.8	35	2.1E+00	2.8	2.9E+00	3.5	1.2E+01	2.1	1.2E+01	1.2E+01	2.1
Sm	10	7.7E+01	4.6	10	1.6E+01	3.2	–	–	5.8E+01	6.0	7.7E+01	7.7E+01	4.6
Sn	5	1.9E+01	2.3	10	1.6E+00	3.2	–	–	1.3E+01	3.7	1.3E+01	1.3E+01	3.7
Sr	7	1.1E+00	2.5	97	4.4E-01	2.5	4.7E-01	2.6	9.8E-01	3.3	4.7E-01	4.7E-01	2.6
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	10	1.2E+02	6.0	6	1.8E+01	2.9	5.8E+01	6.9	7.1E+01	8.2	1.2E+02	5.8E+01	6.9
U	7	2.5E+00	1.8	33	1.4E+00	2.2	1.6E+00	2.2	2.4E+00	2.1	2.4E+00	2.4E+00	2.1
Zr	10	9.1E+01	4.4	44	1.7E+01	2.5	2.3E+01	3.5	6.1E+01	5.8	9.1E+01	2.3E+01	3.5

Table D-12. CR values for marine fish (“cR_watToFish_Sea”) m^3/kgC resulting from the Bayesian updating.

							Results						
	Site-specific data			Prior (Literature data)			POSTERIOR_Subp		POSTERIOR_Pop		Selected values		
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	10	2.3E-01	3.0	–	–	–	–	–	–	–	–	–	–
Cd	10	6.7E-01	3.4	5	1.1E+01	2.3	1.7E+00	6.5	1.2E+00	4.3	6.7E-01	1.7E+00	6.5
Cl	9	1.4E-03	1.7	10	1.0E-02	3.2	–	–	1.4E-03	1.9	1.4E-03	1.4E-03	1.9
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	10	2.2E+00	1.8	1,773	5.0E-01	2.8	5.1E-01	2.8	2.1E+00	2.0	2.1E+00	2.1E+00	2.0
Eu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ho	–	–	–	–	–	–	–	–	–	–	–	–	–
I	9	1.1E-01	2.1	10	3.2E-01	1.8	–	–	1.3E-01	2.4	1.1E-01	1.1E-01	2.1
Mo	10	2.1E-02	1.8	10	1.9E-01	3.1	–	–	2.3E-02	2.0	2.3E-02	2.3E-02	2.0
Nb	5	1.6E-01	1.6	10	7.1E-01	2.7	–	–	1.7E-01	2.1	1.7E-01	1.7E-01	2.1
Ni	10	9.8E-02	2.3	7	1.0E+00	2.7	2.6E-01	4.9	1.2E-01	2.6	9.8E-02	2.6E-01	4.9
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	10	4.7E-01	6.1	10	1.0E+00	1.4	–	–	8.3E-01	8.0	4.7E-01	4.7E-01	6.1
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	8	3.9E+01	1.6	3	8.3E+01	1.6	4.8E+01	1.9	4.4E+01	1.8	4.8E+01	4.8E+01	1.9
Sm	10	2.0E-01	2.8	10	3.0E-01	3.2	–	–	2.0E-01	3.5	2.0E-01	2.0E-01	3.5
Sn	5	3.6E+00	1.8	10	1.0E+01	3.2	–	–	3.9E+00	2.5	3.9E+00	3.9E+00	2.5
Sr	7	4.7E-03	2.5	103	1.3E-01	3.0	1.0E-01	3.9	7.1E-03	3.3	7.1E-03	7.1E-03	3.3
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	10	1.3E+00	2.7	10	1.0E-01	3.2	–	–	1.1E+00	3.3	1.1E+00	1.1E+00	3.3
U	7	1.4E-03	1.7	25	9.6E-02	2.4	3.8E-02	7.4	1.9E-03	2.1	1.9E-03	1.9E-03	2.1
Zr	10	4.1E-01	6.3	7	6.8E-01	1.9	5.1E-01	4.8	5.3E-01	8.6	4.1E-01	5.1E-01	4.8

Table D-13. CR values for marine filter feeder (“Sea_cR_watToMuss”) m^3/kgC resulting from the Bayesian updating.

	Site-specific data			Prior (Literature data)			Results				Selected values		
							POSTERIOR_Subp		POSTERIOR_Pop				
Element	N	GM	GSD	N	GM	GSD	GM	GSD	GM	GSD	BE	GM	GSD
Ag	–	–	–	–	–	–	–	–	–	–	–	–	–
Am	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca	7	8.2E+00	4.9	–	–	–	–	–	–	–	–	–	–
Cd	7	9.3E+01	2.8	80	4.1E+02	5.1	3.7E+02	5.3	1.0E+02	3.9	1.0E+02	1.0E+02	3.9
Cl	4	1.5E-02	4.5	–	–	–	–	–	–	–	–	–	–
Cm	–	–	–	–	–	–	–	–	–	–	–	–	–
Cs	7	2.8E+00	2.9	172	8.5E-01	2.2	8.8E-01	2.3	2.1E+00	4.0	8.8E-01	8.8E-01	2.3
Eu	7	5.6E+00	2.4	–	–	–	–	–	–	–	–	–	–
Ho	7	4.1E+00	1.8	–	–	–	–	–	–	–	–	–	–
I	4	1.6E+00	2.5	–	–	–	–	–	–	–	–	–	–
Mo	7	4.9E-01	1.9	–	–	–	–	–	–	–	–	–	–
Nb	2	4.8E+00	1.4	2	1.4E+01	1.3	8.2E+00	2.6	–	–	8.2E+00	8.2E+00	2.6
Ni	7	6.7E+00	2.3	12	7.2E+01	2.6	3.0E+01	4.8	9.2E+00	3.0	9.2E+00	9.2E+00	3.0
Np	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa	–	–	–	–	–	–	–	–	–	–	–	–	–
Pb	7	1.5E+01	6.1	57	6.1E+00	5.9	6.8E+00	6.3	1.3E+01	10.3	6.8E+00	6.8E+00	6.3
Pd	–	–	–	–	–	–	–	–	–	–	–	–	–
Po	–	–	–	–	–	–	–	–	–	–	–	–	–
Pu	–	–	–	–	–	–	–	–	–	–	–	–	–
Ra	–	–	–	–	–	–	–	–	–	–	–	–	–
Se	7	4.3E+01	2.1	3	7.0E+01	1.9	5.0E+01	2.3	4.6E+01	2.6	5.0E+01	5.0E+01	2.3
Sm	7	1.4E+01	3.3	–	–	–	–	–	–	–	–	–	–
Sn	2	6.8E+00	1.2	–	–	–	–	–	–	–	–	–	–
Sr	2	1.6E-01	1.2	8	1.2E+00	3.0	7.8E-01	4.3	–	–	7.8E-01	7.8E-01	4.3
Tc	–	–	–	–	–	–	–	–	–	–	–	–	–
Th	7	7.0E+01	4.2	4	7.7E+00	1.7	3.1E+01	5.9	2.1E+01	6.1	3.1E+01	3.1E+01	5.9
U	2	1.1E+00	1.1	22	4.1E-01	2.2	4.5E-01	2.3	–	–	4.5E-01	4.5E-01	2.3
Zr	7	4.8E+01	5.9	5	3.8E+01	3.4	4.3E+01	5.5	4.4E+01	9.6	4.3E+01	4.3E+01	5.5