National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

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RIVM letter report 2020-0165
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Colophon

DOI 10.21945/RIVM-2020-0165

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This report was produced by order, and for the account, of the Ministry of Infrastructure and Water Management, within the framework of the NIBO programme

Published by:
National Institute for Public Health and the Environment, RIVM
P.O. Box 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.nl/en

Synopsis

CSOIL 2020: Exposure model for human health risk assessment through contaminated soil. Technical description

This report describes the CSOIL 2020 model, which calculates human exposure to soil contaminants throughout the entire human lifetime. Exposure can occur through, for example, consuming home grown vegetables and inhalation of soil particles during gardening. CSOIL 2020 is the most recent version of the CSOIL model, which was developed in 1995 and revised in 2000. The Government of The Netherlands uses the results of this model to determine soil quality standards.

CSOIL 2020 was updated to incorporate recent scientific knowledge and allow functionality under newer IT operating systems. Additionally, the exposure results from CSOIL can now be used in the newest version of the risk toolbox for soil (in Dutch: Risicotoolbox Bodem). The toolbox is used to determine whether soil can safely be (re-)used. New modules are currently under development to allow the toolbox to be used in the Environment and Planning act, which will enter into force on the first of January 2022.

Contact with contaminants in soil can be damaging to human health. Information on the extent of human exposure is required to determine the risk to health. CSOIL determines the exposure on the basis of the type of soil use on a location, like 'Residential with garden', the properties of the contaminant, such as solubility, and the local situation.

Keywords: CSOIL 2020, health risk limit, exposure model, human risk assessment

Publiekssamenvatting

CSOIL 2020: blootstellingsmodel voor gezondheidsrisico's door bodemvervuiling. Technische beschrijving

Dit rapport beschrijft de update van het blootstellingsmodel CSOIL 2020. Met dit rekenmodel wordt berekend in welke mate mensen gedurende hun hele leven blootstaan aan bodemvervuiling. Dat kan bijvoorbeeld door groente en fruit uit eigen tuin te eten of gronddeeltjes in te slikken als ze in de tuin werken. Het RIVM heeft dit model, dat in 1995 is ontwikkeld en in 2000 is herzien, nu geactualiseerd. De overheid gebruikt het CSOIL-model om de normen voor de kwaliteit van de bodem te bepalen.

Door de update sluit CSOIL 2020 aan op nieuwe ICT-besturingssystemen en wetenschappelijke kennis. Ook kan het model hierdoor aansluiten op de nieuwste versie van de Risicotoolbox Bodem, die de blootstellingsberekeningen van CSOIL gebruikt. Met deze toolbox kan worden bepaald of de grond veilig mag worden (her-)gebruikt. De toolbox wordt op dit moment uitgebreid met andere tools zodat hij voor de Omgevingswet kan worden ingezet. Deze wet treedt, naar verwachting, op 1 januari 2022 in werking.

Contact met stoffen uit een vervuilde bodem kan schadelijk zijn voor de gezondheid van mensen. Om te weten hoe groot het risico op gezondheidseffecten is, is informatie nodig over de mate waarin mensen blootstaan aan een stof. Voor de blootstelling kijkt CSOIL 2020 welke functie een bodem op een locatie heeft, zoals wonen of natuur, en naar de eigenschappen van een vervuilende stof. Het samenspel van de functie van een bodem, de stofeigenschappen en de lokale situatie zoals de diepte van de vervuiling bepaalt de blootstelling. Een voorbeeld van een stofeigenschap is hoe makkelijk een stof oplost in water.

Kernwoorden: CSOIL 2020, risicogrenswaarden, blootstellingsmodel, humane risicobeoordeling.

Contents

Summary

This report describes the updated CSOIL 2020 model. CSOIL 2020 is a human exposure model that can be used to derive health risk limits for contaminants in soil. CSOIL 2020 was reprogrammed based on the CSOIL 2000 model (Brand et al., 2006) to implement new scientific developments, ensure compatibility with current operating systems and ensure CSOIL 2020 is ready for use when the Environment and Planning act (Government of the Netherlands, 2017) takes effect.

Contaminants in soil can present a risk to humans. This risk depends on the extent of human contact with the soil as well as the extent of contamination and the toxicity of the contaminant. Exposure modelling combined with toxicity of the contaminant results in an expression of risk to humans, which can later be used by local and national authorities to formulate standards for use in legislation. In the Netherlands, the human exposure model CSOIL has been used for this task.

The CSOIL model was originally developed by Van den Berg (1995) and later revised by Otte et al. (2001) and Brand et al. (2006), which resulted in the CSOIL 2000 model (Brand et al., 2006). CSOIL 2000 is currently used in the Risk Toolbox Soil, which provides a framework for the safe (re-)use of soil. The CSOIL 2020 model will be used in an updated version of the Risk Toolbox Soil under the Environment and Planning act (Government of the Netherlands, 2017).

Exposure modelling and human risk
CSOIL 2020 determines the exposure of humans to contaminants in the soil based on human activities and site-specific characteristics. Human exposure to contaminants in soil occurs through different exposure pathways resulting from contact with various environmental compartments (air, soil, water), and vegetables. Physicochemical properties of the contaminant combined with the type of soil use, such as living in a residential area with garden, determine the extent of exposure. The extent of exposure is expressed as a daily dose of contaminant to which an individual is exposed.

Toxicity studies for contaminants provide a Maximum Permissible Risk (MPR) to which humans can be exposed without experiencing any adverse effects. This Maximum Permissible Risk is expressed in a tolerable daily intake (TDI) or a tolerable concentration in air (TCA), depending on whether the exposure to the contaminant is oral, dermal, or respiratory. When combined with the extent of human exposure, this Maximum Permissible Risk provides information about the risks posed by a certain contaminant concentration in the soil.

Updates to the CSOIL model
Reprogramming CSOIL 2000 into a form compatible with new operating systems also provided the opportunity to implement new developments into the model. Most of the updates pertain to exposure pathways, however various updates were implemented in the fate modelling of CSOIL to enable input of ground water concentrations and future

compatibility with the Risk Toolbox Groundwater. The updated exposure pathways are: Consumption of vegetables from the garden, permeation into drinking water, and dermal exposure and exposure inhalation by showering and bathing.

Keywords: CSOIL 2020, health risk limit, exposure model, human risk assessment

Reading guide

This report describes the current state of the CSOIL model and contains an overview of updates performed to update the model. Chapter 2 describes the updates to the CSOIL model. Chapter 3 provides a general overview of the CSOIL model and its concepts. Chapter 4 provides a detailed description of the various exposure pathways, and chapter 5 describes the total human exposure and the soil use scenarios. Detailed descriptions of the updates to the CSOIL model and the formulas can be found in the appendixes.

1 Introduction

1.1 Scope and objectives

The project "NIBO" (Normen en Instrumentarium Bodem en Ondergrond, in English "standards and risk assessment tools for soil and subsoil") has the objective to ensure the soil standards and risk assessment procedures are up to date and ready for deployment when the new Environment and Planning act (Government of the Netherlands, 2017) takes effect. The exposure model CSOIL contains exposure calculations for the health risk assessment of contaminated soil. This report contains an up to date technical description including (technical) improvements, updates, and new functionalities of the CSOIL model.

The CSOIL model, originally developed in 1995 (Van den Berg, 1995), was revised in 2001 (Otte et al., 2001) and a comprehensive description of the model was made in 2006 by Brand et al. (2006). CSOIL is currently used by the Dutch National Institute for Public Health and the Environment (RIVM) to derive human risk limits for contaminated soil, and functions as a reference model for the decision support systems SANSCRIT (Otte et al., 2007) and other modules incorporated in the Risk Toolbox Soil (see figure 1.1). CSOIL was adapted to function with modules in the Toolbox such as the lead module (used to assess the risk of soil with diffuse contamination of lead), Volasoil (used to assess the risk of volatile contaminants evaporating into indoor air)(Bakker et al., 2008), and Sedias (Hin et al., 2010). CSOIL 2000 was programmed in an older version of excel (Microsoft Excel 97-2003), which is not fully compatible with current operating systems. Additionally, new scientific developments and greater data availability warranted a fresh development cycle for CSOIL. CSOIL 2020 will be accessible through various tools in the Risk Toolbox Soil (RTB: www.risicotoolboxbodem.nl, Figure 1.1). The updates are described in this report, which gives a description of the CSOIL 2020 model and contains a detailed explanation of the updated functionality of the model.

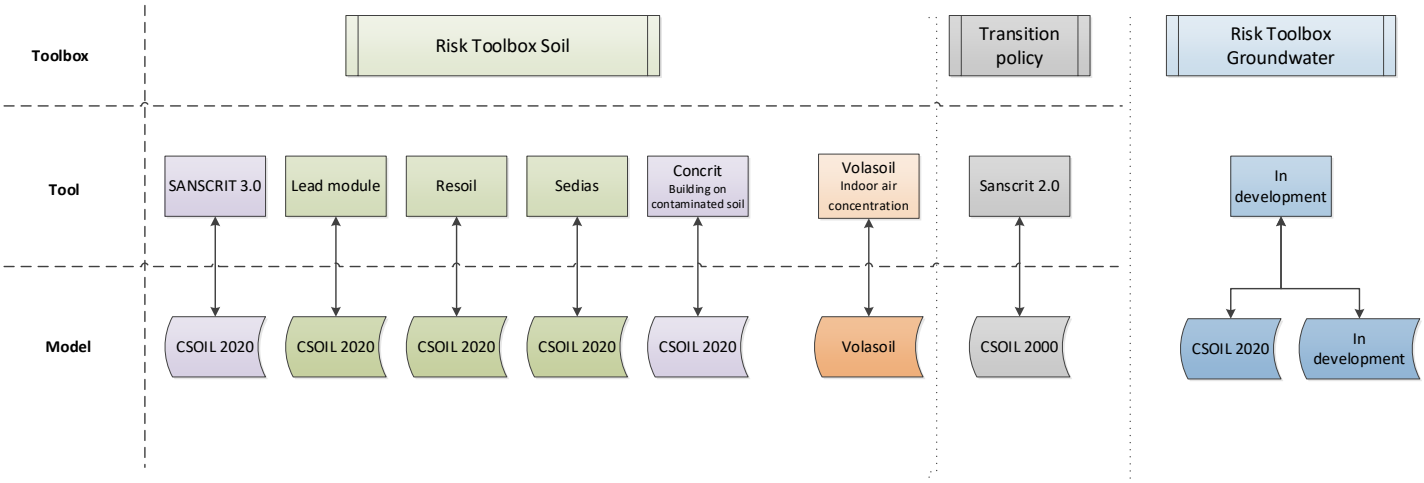

Figure 1.1 The position of CSOIL in the risk toolbox soil and the future risk toolbox groundwater. For more information on the tools in the Risk Toolbox Soil visit www.risicotoolboxbodem.nl.

1.2 Exposure modelling

Due to the production and extensive use of various chemicals and products, (slightly) contaminated soils are now present in large parts of the Netherlands. Contaminated soil can pose risk to humans, plants and animals. The contaminants can accumulate in the ecosystem and may lead to human exposure by ending up in the human food chain (Bontje et al., 2005). However, other pathways, like soil ingestion, dermal contact, or inhalation, can also lead to human exposure. The risks related to human behaviour and soil contamination can be determined using exposure models. Ecological risks are not determined in CSOIL and will therefore not be discussed in this report.

Exposure modelling comprises a set of exposure pathways (inhalation, ingestion or dermal contact) through which contaminants can enter the human body. In essence, exposure models calculate the total human exposure to a contaminant, based on a contaminant concentration in the environment. Exposure is defined as the amount of a contaminant that enters the human body, expressed as contaminant mass, per unit of body weight and time ($mg.kgbw^{-1}.d^{-1}$). In a subsequent step, total exposure can be compared to the Maximum Permissible Risk to elucidate whether risk limits have been exceeded (Swartjes et al., 2013). The chosen set of exposure pathways depends on the aim of the model. An extensive model can include a high level of detail or a large number of pathways, but may not be practical as some exposure pathways may be uncertain or contribute little to nothing to the total exposure. Nonetheless, taking the pathways with a low contribution under normal conditions to the total exposure into account does ensure these pathways are included in the eventuality the pathways do contribute more greatly.

The human exposure model ‘CSOIL’ is embedded in the Risk Toolbox Soil, Sanscrit and several supportive assessment modules (if needed tailored to specific issues). A screening value is derived from a Maximum Permissible Risk (expressed in a maximum daily exposure) and the

human exposure to a contaminant. The human health-based risk limit is the concentration in soil that corresponds to an exposure that equals the Maximum Permissible Risk. Figure 1.2 gives an outline of the derivation of the human health-based risk limit.

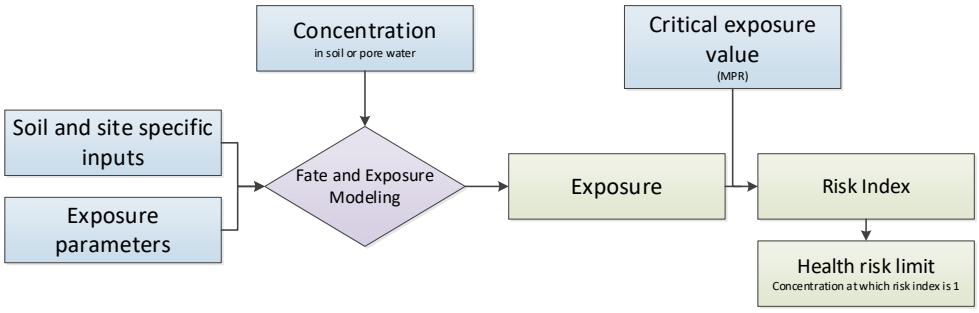

Figure 1.2 Inputs and outputs for CSOIL 2020. Inputs in blue and outputs in green. The risk index is derived from a concentration and a Maximum Permissible Risk. A health risk limit is the concentration at which the risk index is equal to one.

2 Updates to the CSOIL 2020 model

This chapter provides an overview of the updates made to CSOIL. The changes range from updated parameters to adapted exposure pathways. A detailed description of the changes as well as considerations can be found in appendix 3.

2.1 Dissociating contaminants

During the revision of CSOIL attention was placed on preparing the CSOIL model for assessing Contaminants of Emerging Concern (CECs), which sometimes exhibit different properties from the substances that were part of the CSOIL model up till now. Some of the CECs, such as PFAS (Per- and Poly-Fluorinated Alkylated Substances), are organic acids that are mostly dissociated in aqueous environments. Fate and exposure modelling for dissociating contaminants was introduced to CSOIL to enable more robust modelling of these types of contaminants. Some challenges however remain in the modelling of dissociating contaminants, like correcting the solubility values to represent the soil pH.

2.2 Permeation

2.2.1 *Permeation of non-dissociating contaminants*

The revision of the CSOIL model provided an opportunity for harmonisation between CSOIL and the way permeation is modelled for non-dissociating contaminants by the Knowledge and Expertise Centre for Water (KWR). Harmonisation between the CSOIL 2020 model and the guideline on the application of piping materials in contaminated soil of the KWR (Meerkerk et al., 2017) was explored. However, harmonisation between the models was postponed to allow for a further exploration of uncertainties and further coordination with the KWR.

2.2.2 *Permeation of dissociating contaminants*

Dissociation plays a role in the amount of contaminant that can permeate PE water pipelines. A study by Otte et al. (2016) attempted to develop a method to determine the extent of permeation based on substance parameters. However no definitive method could be implemented into CSOIL. In CSOIL 2020 we assume that the dissociated fraction of a soil contaminant will not permeate into PE pipelines, and permeation does not occur at all into metal pipelines.

2.3 Drinking water constant and drinking water usage

The drinking water constant (*dwconst*) is a parameter consisting of several specific constants relevant to the concentration of contaminant in drinking water. These constants are the daily water use, the dimensions of the water pipeline, and the stagnation time of water in the pipeline for an average (model standard) situation. The daily water use (CSOIL2000) was outdated and therefore revised to 126.3 liter per household per day (Vewin, 2017).

Additionally, the length of the water pipeline in contact with contaminated soil or groundwater was reduced from 100 meters to 25

meters in accordance with (Otte et al., 2016; Van der Schans et al., 2016). This concerns so-called PE connection pipes - the connection from the main water pipe to the house.

Moreover, the Vewin statistics provided updated values for water use during showering and bathing which is used to determine the respiratory and dermal exposure during showering and bathing (Vewin, 2017). Based on the Vewin statistics, water use for showering was set at 51 liter per day.

2.4 Exposure through vegetable consumption

2.4.1 *Regression-based bio concentration factors for cadmium and lead*

A bio concentration factor (*BCF*) is used to model the transfer of contaminants to vegetables[1]. The BCF is defined as the contaminant concentration in the vegetable divided by the total contaminant concentration in the soil. Determination of a site-specific BCF can be laborious, therefore for most contaminants the BCF is given as a single value which assumes a linear relationship between vegetable and soil concentration. As of this version, the BCF for lead and cadmium is dependent on the contaminant concentration in soil and soil properties, derived from linear regression in earlier studies (Versluijs et al., 2001; Swartjes et al., 2007; Otte et al., 2011).

2.4.2 *Consumption rates of vegetables*

Consumption rates of vegetables are required to calculate the human exposure to contaminants through vegetable consumption. To comply with the actual food pattern in the Netherlands, consumption rates of different vegetables were updated based on consumption data provided by the Nutrient, Prevention and Health Services (VPZ) department of the RIVM from the 2012-2016 version of the Dutch National Food Consumption Survey (Voedsel Consumptie Peiling, 2019).

2.5 New input options

The option for users to enter a pore water concentration instead of a soil concentration was introduced to CSOIL to facilitate the implementation of CSOIL into the Risk Toolbox groundwater. Additional input options for soil concentrations in developed and non-developed areas, as well as pore water concentrations in developed and non-developed areas, were introduced to ensure CSOIL will still function in SANSCRIT. Soil in non-developed area is defined as soil which is open to outside air (garden, nature), soil in developed area is defined as soil on which buildings are present (e.g. houses).

2.6 Risk values for groundwater

In the newly developed version of CSOIL it is possible to perform a risk assessment based on groundwater concentrations alone, i.e. without the need of entering corresponding soil concentrations. This option is only available for the total concentration in groundwater (meaning differentiation between groundwater in developed and non-developed areas is not possible). The model calculates the corresponding soil

[1] The BCF for metals is based on empirical data. The BCF for organic contaminants is modelled using the Trapp and Matthies model (Trapp and Matthies 1995, Trapp 2002).

concentrations based on equilibrium partitioning. Notably, calculating a soil concentration from a groundwater concentration is only valid for concentrations under the maximum solubility of a contaminant.

Additionally, the exposure pathways in CSOIL were updated to facilitate its implementation in the Risk Toolbox Groundwater, which is currently under development. This allows CSOIL to be used iteratively to derive risk values for groundwater. A health risk limit for groundwater can be derived by iterating on the pore water concentration and only taking the exposure pathways “evaporation of contaminants to air” and “permeation of contaminants into drinking water” into account. However, this option can only be used when the contaminant is known to be located solely in groundwater. If, on the other hand, contaminated groundwater has affected the quality of the contact zone of the soil (or if the possibility cannot be excluded) then the risks of the contaminants in groundwater must be determined separately. Additionally, this method does not take the presence of pure contaminant at concentrations higher than the solubility into account. Therefore, user discretion is advised.

3 The CSOIL model

3.1 Lay-out of the model

The CSOIL model was programmed in Excel and consists of several worksheets. The input sheet stores all user inputs and converts them to common or SI units for later use in the model. The engine sheet uses the converted input values from the input sheet and calculates the various compartment concentrations necessary for calculating the exposure pathways. The output sheet combines the contribution of each exposure pathway and determines a total risk index. Finally, the overview sheet sums up the output sheet and the input sheets as well as some calculation results from the engine sheet. Various extra sheets like the sheets on contaminant data and scenario data are required for the model to function properly. Additionally, a start screen was made which contains command buttons for contaminant selection and allows the model to calculate multiple contaminants in one run.

3.2 Exposure pathways of the model

The CSOIL model distinguishes three processes:

- Calculation of the behavior (fate) of the contaminants in the soil and the partitioning over the soil phases
- Transfer processes and parameterization of the different exposure pathways (direct and indirect)
- Calculation of the lifetime average exposure (Otte et al., 2001)

The first process relates to the fate of contaminants and utilizes input parameters describing contaminant specific physicochemical properties (e.g. K_{ow}). The second process relates to the site specific inputs of the exposure pathways and utilizes input parameters describing the site and soil properties related to potential exposure (e.g. pH). The third process relates to the receptor specific (human) inputs of the exposure pathways and utilizes input parameters describing human behaviour (e.g. breathing volume and consumption of vegetables) (Otte et al., 2001).

For the derivation of national standards, a standard exposure scenario has been defined. In this scenario, all possible exposure pathways in CSOIL are parametrized to reflect exposure to contaminants in a residential situation. The direct and indirect exposure pathways that are considered by CSOIL are described below (also see figure 3.1). The exposure pathways are linked to four distinct media through which contaminants are transferred from soil to human and can therefore be grouped into four transfer pathways. These pathways are Soil, Air, Vegetables, and Drinking water.

Soil
- Ingestion of contaminated soil particles;
- Dermal contact with soil contaminants (indoor);
- Dermal contact with soil contaminants (outdoor);
- Inhalation of contaminated soil particles;

Air
- Inhalation of vapours of contaminants via crawl space (indoor);
- Inhalation of vapours of contaminants (outdoor);

Vegetable
- Ingestion of contaminants via consumption of locally grown vegetables;

Drinking water
- Ingestions of soil contaminants via drinking water;
- Inhalation of vapours of contaminants in the drinking water during showering;
- Dermal contact with contaminants in the drinking water during showering and bathing (Rikken et al., 2001).

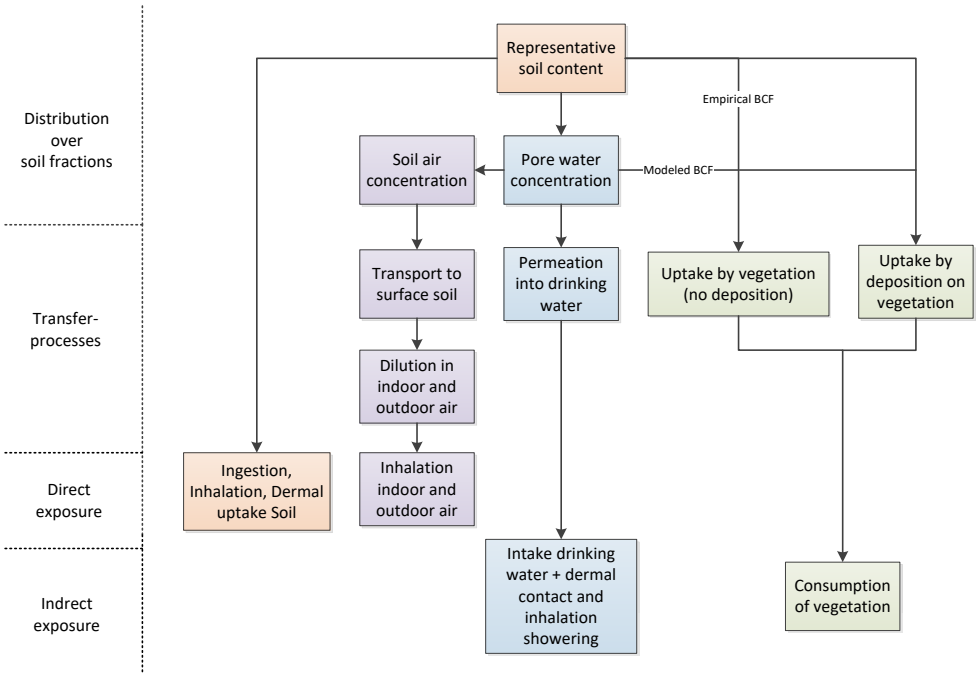

Figure 3.1 Diagram showing the exposure pathways of CSOIL.

The following three exposure pathways account for at least 90% of the total exposure for almost all contaminants. This can be concluded from calculations performed with the CSOIL model by Otte et al. (2001).
The three exposure pathways are:
- The human exposure via ingestion of contaminated soil particles;
- The human exposure to volatile contaminants in the indoor air;
- The human exposure via consumption of contaminated vegetables.

The following exposure pathways contribute very little to the total exposure (Brand et al., 2006).
- Dermal uptake via soil contact (1-7% for 18 contaminants);

- Drinking water intake due to permeation through Low Density Polyethylene (LDPE) (1-13% for 29 contaminants);
- Dermal uptake during bathing (1-5% for 20 contaminants).

Although not every exposure pathway has a significant contribution to the total human exposure, the basic principle is that all possible exposure pathways are considered.

3.3 Exposure scenarios

CSOIL uses a set of pre-defined exposure scenarios, which include a set of parameters representative for a specific type of soil use. The parameters are used in the exposure pathways to calculate the total exposure. There are seven pre-defined exposure scenarios of which "residential with garden" is considered the default scenario. The choice of exposure scenario has a large impact on the risk limits calculated by CSOIL as the amount of direct or indirect contact with soil varies between the different scenarios.

3.3.1 *Aggregated exposure pathways for contaminants in groundwater*

A new set of aggregated exposure pathways were made for the case when contaminants are only present in groundwater. In these aggregated pathways, the transport of contaminants from groundwater to the upper soil layer is not taken into account. This translates into the exposure only being dependent on the exposure pathways inhalation of indoor/outdoor air, permeation into drinking water, and inhalation and dermal uptake during showering and bathing. The pathways not considered are: Inhalation of soil particles, ingestion of soil particles, dermal contact with soil particles indoors and outdoors, and consumption of vegetables. Although this "groundwater only" functionality was added to the model, the preconditions for the use of these aggregated pathways are not fully explored yet.

Additionally, the fate of contaminants in groundwater is more complicated than currently implemented in CSOIL. Therefore, it is advised to only use this specific groundwater scenario when it is certain that the contaminated groundwater has no effect on the top layer of the soil. Another option is to use soil and groundwater concentrations resulting from more detailed groundwater fate models. Figure 3.2 shows the exposure pathways relevant to the groundwater scenario.

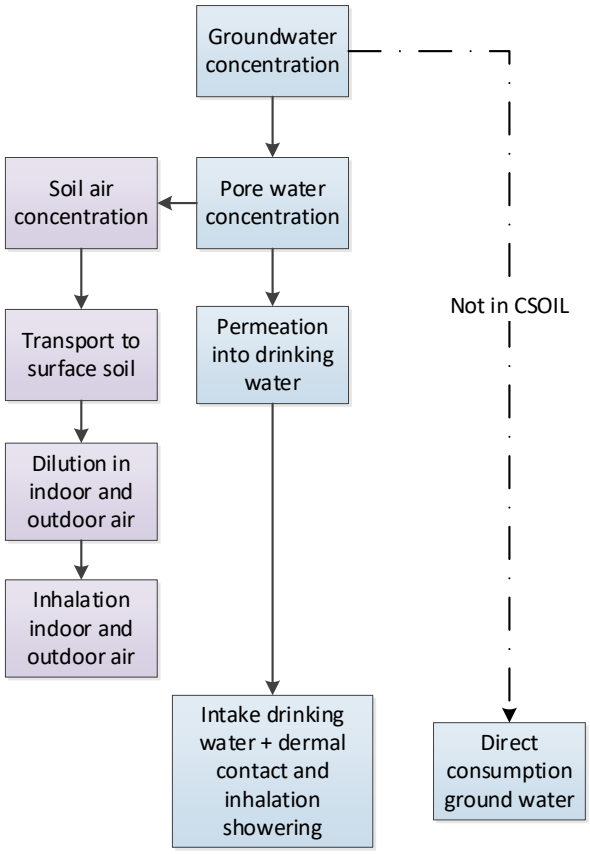

Figure 3.2 Diagram showing the aggregated exposure pathways for groundwater. Direct exposure pathways (soil ingestion, soil inhalation, and dermal uptake) as well as consumption of vegetables are not relevant to the aggregated pathways for groundwater.

3.4 Calculation of the health-based risk limit

CSOIL is used to calculate the human health-based risk limit. The human toxicological definition for health risk limit is as follows: the soil quality which results in an exposure that equals the Maximum Permissible Risk for intake (MPR_{human}). MPR_{human} is defined as the amount of substance that any human individual can be exposed to daily during a full lifetime without significant health risk. However, risk limits are derived for specific aggregated exposure pathways. For example, the risk limit for exposure through inhalation is different from the risk limit for oral and dermal exposure. Therefore, the MPR_{human} can be expressed as a tolerable daily intake (*TDI*) for oral and dermal exposure, and a tolerable concentration in air (*TCA*) for exposure through inhalation.

Due to different modes of toxic action, contaminants can be divided into the threshold and non-threshold groups. For threshold contaminants risks only occur when a certain exposure level is reached, whilst for non-threshold contaminants every additional molecule above 0 results in extra risk. Therefore, for non-threshold contaminants the MPR_{human} can be expressed as an excess carcinogenic risk for oral and dermal exposure (CR_{oral}), and an excess carcinogenic risk via air for exposure through inhalation (CR_{inhal}). Table 3.1 provides an overview of the risk

limits in relation to the aggregated exposure pathways and the mode of toxic action.

Table 3.1 An overview of the various risk limits used in the definition of the MPR_{human}.

MPR_{human}	Threshold	Non-threshold
Oral and dermal exposure	Tolerable daily intake (*TDI*)	Excess carcinogenic risk oral, dermal (CR_{oral})
Exposure through inhalation	Tolerable concentration in air (*TCA*)	Excess carcinogenic risk inhalation (CR_{inhal})

To derive human toxicological risk limits, the oral/dermal exposure and exposure through inhalation is calculated separately under standardized conditions (potential exposure). The oral MPR_{human} (*TDI* or CR_{oral} in $\mu g.kg^{-1}$ bw day^{-1}) are used for the risk assessment of the oral and dermal exposures. The TCA or CR_{inhal} (in $\mu g.m^{-3}$) is used for the risk assessment of exposure via air.

However, TCA and TDI do not have the same units and cannot be used interchangeably. Therefore, for risk assessment purposes, the TCA or CR_{inhal} are converted to the same unit as the TDI/CR_{oral}, namely $\mu g.kg^{-1}$ bw day^{-1} (Lijzen et al., 2001), and two separate $MPR_{human\text{-}inhalation}$ are derived to account for the differences in bodyweight and breathing volumes for children and adults. The oral/dermal exposure, and exposure through inhalation for children and adults, divided by their respective MPR_{human} result in three Risk Indexes (resp. $RI_{oral/dermal}$, $RI_{inhalation,\ child}$, and $RI_{inhalation,\ adult}$) (Equation 1). A weighted summation of the two separate Risk Indexes for inhalation result in a total Risk Index for inhalation (Equation 2). Finally, as shown in Equation 3, the human toxicological risk limit is defined as the concentration of a contaminant in the soil for which the sum of the oral (including dermal) and inhalation risk indexes equal 1 (Lijzen et al., 2001).

Equation 1 Derivation of a Risk Index. Where "y" can either be the total exposure, or the exposure specific to oral/dermal, or inhalation.

$$Risk\ Index_y = \frac{\sum Exposure_y}{MPR_y}$$

Equation 2 Weighted summation of Risk Indexes resulting in a Risk Index specific to lifelong inhalation.

$$Risk\ Index_{inhalation} = \frac{(6 * RI_{inhalation-child}) + (64 * RI_{inhalation-adult})}{70}$$

Equation 3 The human toxicological risk limit is the concentration at which the sum of the Risk Indexes for oral/dermal and inhalation (the total Risk Index) are equal to 1.

$$Risk\ Index_{total} = Risk\ Index_{oral/dermal} + Risk\ Index_{inhalation} = 1$$

Figure 3.3 depicts the general trend of Equation 3 in graph-form for metals and organic contaminants. The orange and yellow lines represent organic contaminants and the blue lines represent metal contaminants. The four dashed lines represent the increasing risk as a result of increasing soil concentration for oral/dermal exposure and exposure through inhalation. The dash-dotted lines represent the total Risk Index. The concentration, which leads to a Risk Index of 1 is called the health risk limit.

The increase in human exposure resulting from an increasing soil concentration is a linear process for metals. However, when the solubility for organic contaminants in water is exceeded, the absolute contribution to human exposure through oral uptake of vegetables and inhalation of evaporated contaminants does not increase further.

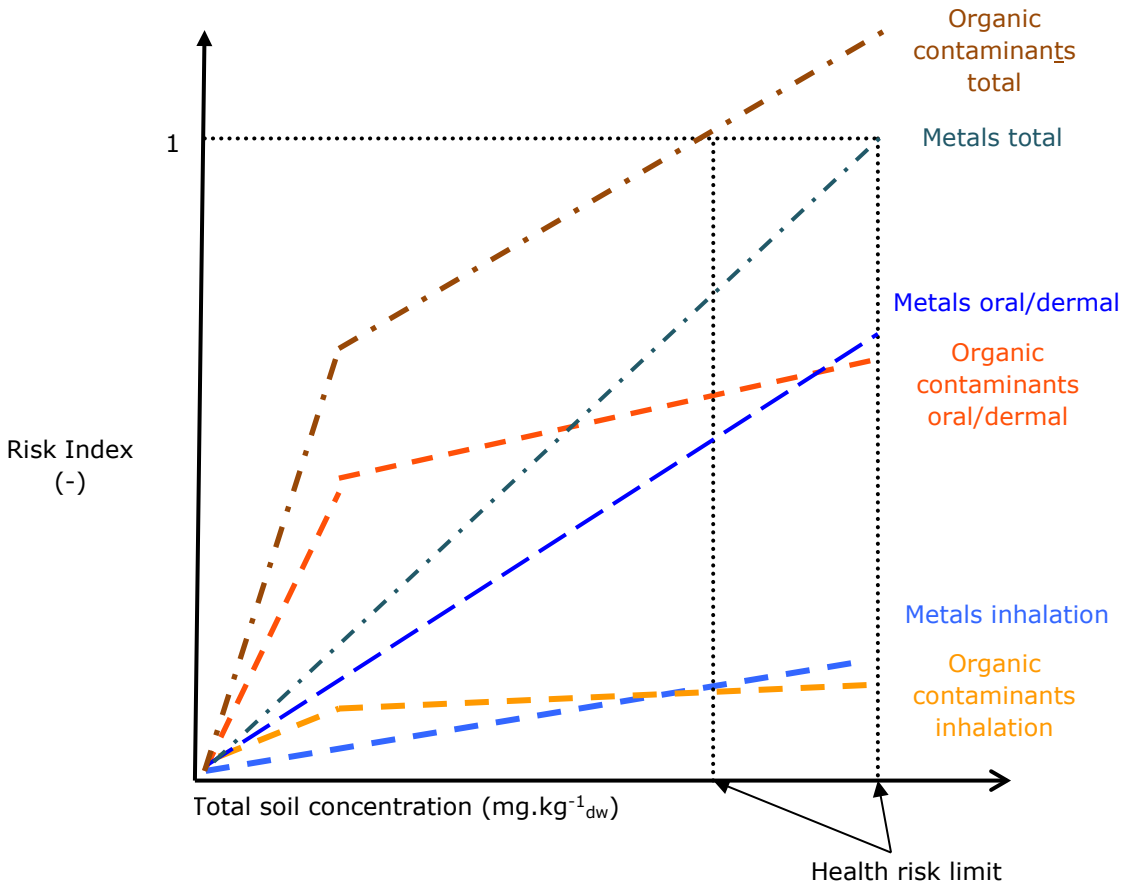

Figure 3.3 The derivation of health risk limits depends on respiratory and oral uptake. The dashed lines represent Risk Indexes for oral/dermal or inhalation, the dash-dotted lines represent the total Risk Index.

4 Model concepts and parameters

Soil consists of three compartments. When a contaminant comes into contact with soil it will partition over pore water, the solid phase (as minerals and organic matter), and air. From these phases the contaminant can enter different transfer pathways, which can result in human exposure.

The first section of this chapter describes the partitioning of contaminants over the different soil phases. The other sections describe the various transfer pathways of a contaminant to human exposure.

Four distinct transfer pathways leading to human exposure are depicted in figure 3.1. These transfer pathways are soil, air, vegetables, and (drinking) water, where air and soil lead to direct exposure and drinking water and vegetables lead to indirect exposure through, for example, consumption. The formulas required for calculating human exposure via these transfer pathways can be found in appendix 1.9.

4.1 Partitioning soil, water & air

The distribution of a contaminant between the different phases in soil is called partitioning. Based on contaminant specific parameters (e.g. the

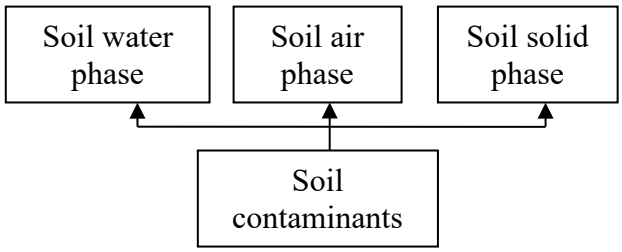

Figure 4.1 Partitioning of soil contaminants.

octanol water partition coefficient) and soil characteristics (e.g. the amount of organic carbon and water) a contaminant will partition over the different soil phases to attain a chemical equilibrium (Van den Berg, 1995). CSOIL uses three soil phases in which an equilibrium of a contaminant is calculated, namely the water phase[2], air phase, and soil (solid) phase (Figure 4.1). The concentration of a contaminant can be calculated from a known soil-water partition coefficient (*Kd*), air-water Henry-coefficient (H), and soil parameters (Van den Berg, 1995). A requirement for the calculation is that the concentration of the contaminant in the water phase does not exceed its solubility. When this is the case the concentration in the water phase is limited the solubility level. Similar measures have been taken for contaminants in the gas phase of soil.

The large amount of distinct contaminants also requires differentiation between a wide range of chemical characteristics. Therefore,

[2] The concentrations in pore water and groundwater are assumed to be equal.

contaminants were split into four groups, namely metals, inorganic contaminants, organic contaminants, and dissociating organic contaminants. Metals are non-volatile and are therefore not present in the gas phase (with the exception of mercury)but will partition over the water phase and the solid phase of the soil. Organic contaminants can be found in all three phases of the soil. Additionally, dissociation (through an acid-base reaction with water) of organic contaminants with a known *pKa* can be calculated in the water phase. Non-volatile, soluble substances like inorganic contaminants partition over the water phase and the solid phase of the soil. The formulas required for the calculation of partitioning can be found in appendix 1.

For partitioning calculations CSOIL uses the fugacity method (Mackay, 2001). Fugacity expresses the tendency of a contaminant to be present in a certain soil phase based on the difference in fugacity capacities with other phases. For each soil phase a fugacity capacity can be calculated. Subsequently, mass fractions of the total amount of contaminant in the different soil phases are calculated. See appendix 1.1 for the fugacity formulas. The presence of organic carbon plays a significant role in the sorption and partitioning of organic contaminants. Therefore, the *Kd* is usually expressed as a soil organic carbon related parameter K_{oc} (appendix 1)(Van den Berg, 1995).

4.1.1 *Dissociating contaminants*

Dissociation in CSOIL is defined as the reaction of an (organic) acid with water into its conjugate base (negatively charged) and an aqueous cation (H_3O^+).

The dissociation of a hydrogen atom from a contaminant in an acid-base reaction is shown in figure 4.2 for perfluorooctanoic acid (PFOA). Dissociated organic contaminants behave differently from non-dissociated organic contaminants, which results in more complex partitioning over the three soil phases. Additionally, some exposure pathways are modelled differently for dissociating contaminants. For example, only non-dissociated contaminants can permeate drinking water pipelines (section 4.5.1). The degree of dissociation in the water phase can be calculated based on the *pKa* of the contaminant and the pH of the soil's water phase. The *pKa* is the logarithm of the equilibrium constant describing the acid-base reaction of the contaminant with water. When the *pKa* value of a contaminant is equal to the pH of the soil, half of the contaminant in water will be dissociated. By rewriting the Henderson-Hasselbalch equation (Po et al., 2001), the non-dissociated fraction (f_{nd}) can be calculated based on the *pKa* and the soil pH (Equation 4).

Figure 4.2: Dissociation of PFOA in water.

Equation 4. Calculating the non-dissociated fraction using the environmental pH and the pKa of the contaminant.

$$f_{nd} = \frac{1}{1 + 10^{pH - pKa}}$$

Dissociation of contaminants also influences the organic carbon partition coefficient (*logK*$_{oc}$), which is used to calculate the fugacity capacity of solid soil (*Zs*). Otte et al. (2001) evaluated the *logK*$_{oc}$ values of the dissociating contaminants in CSOIL and updated the values based on dissociation. The updated values are currently used in CSOIL. Table 4.1 shows the contaminants that are labelled as dissociating in CSOIL.

Table 4.1 List of dissociating contaminants in CSOIL and their pKa values as well as the non-dissociated fraction at standard soil pH of 6.

Contaminant	**pKa**	**f_{nd} (pH 6)**
PFOS	-3.30	$5.01e^{-10}$
PFOA	2.80	$6.31e^{-4}$
GenX	3.82	$6.56e^{-3}$
Pentachlorophenol	4.85	$6.61e^{-2}$
2,3,5,6-tetrachlorophenol	5.21	$1.40e^{-1}$
2,3,4,6-tetrachloorfenol	5.29	$1.63e^{-1}$
2,3,6-trichlorofphenol	5.95	$4.71e^{-1}$
2,3,4,5-tetrachlorophenol	6.07	$5.40e^{-1}$
2,4,6-trichlororphenol	6.22	$6.24e^{-1}$
2,6-dichlorophenol	6.84	$8.74e^{-1}$
2,3,4-trichlorophenol	7.00	$9.09e^{-1}$
2,4,5-trichlorophenol	7.07	$9.22e^{-1}$
3,4,5-trichlorophenol	7.46	$9.66e^{-1}$
2,5-dichlorophenol	7.54	$9.72e^{-1}$
2,3-dichlorophenol	7.66	$9.79e^{-1}$
2,4-dichlorophenol	7.81	$9.85e^{-1}$
3,5-dichlorophenol	8.20	$9.94e^{-1}$
2-chlorophenol	8.43	$9.96e^{-1}$
3,4-dichlorophenol	8.60	$9.97e^{-1}$
3-chlorophenol	9.03	$9.99e^{-1}$
4-chlorophenol	9.20	$9.99e^{-1}$
resorcinol (m-dihydroxybenzene)	9.70	1.00
Phenol	10.00	1.00
m-Cresol	10.00	1.00
p-Cresol	10.10	1.00
o-Cresol	10.20	1.00
catechol (o-dihydroxybenzene)	10.60	1.00
hydrochinon (p-dihydroxybenzene)	10.60	1.00

4.2 Constants, site parameters & partition parameters

CSOIL uses a set of general parameters and constants to calculate the human risk level. Table 4.2 shows the constants and site specific parameters for the user scenario “Residential with garden”. The parameters are only shown for “Residential with garden” because this is

the default scenario for deriving intervention values for soil. More information on user scenarios can be found in section 5.2.

Table 4.2 Constants and parameters for "Residential with garden" (Otte et al., 2001)

Parameters	transfer pathway	Abbreviation/ code	value	Unit
Gas constant	Air	R	8.3144	[$Pa.m^3.mol^{-1}.K^{-1}$]
Viscosity of air	Air	ETA	$5e^{-09}$	[Pa.h]
Mean depth of contamination	Air	dp	1.25	[m]
Air permeability of soil	Air	KAPPA	$1e^{-11}$	[m^2]
Depth of groundwater table	Air	Dg	1.75	[m]
Height of the capillary transition boundary	Air	Z	0.5	[m]
Air pressure difference crawl space	Air	DELTAPCS	1	[Pa]
Fraction dry matter root vegetables	Vegetable	fdwr	0.167	[-]
Fraction dry matter leafy vegetables	Vegetable	fdws	0.098	[-]
Deposition constant	Vegetable	dpconst	0.01	[-]
Temperature bathing water	Water	Tsh	313	[K]
Liquid exchange speed	Water	Kl	0.2	[$m.h^{-1}$]
Gas phase mass transport coefficient	Water	Kg	29.88	[$m.h^{-1}$]

Additionally, CSOIL uses a set of soil parameters to facilitate the partitioning of contaminants over the various phases. Soil characteristics, shown in Table 4.3, are known to have a large effect on the calculated risk limits. Therefore, the parameters were evaluated by Otte et al. (2001) and specifically for lead by Brand et al. (2019). The impact of the following parameters on the exposure can be significant: density of the solid phase; organic matter content; depth of contamination; depth of groundwater table; contribution of vegetable consumption from a vegetable garden to total vegetable consumption; pore air fraction. By default, the model uses the Dutch 'standard soil' consisting of an organic matter content of 10%, clay content of 25% and a pH of 6 (Lijzen et al., 2001).

Table 4.3 Soil parameters for scenario "Residential with garden" (Lijzen et al., 2001; Otte et al., 2001)

Soil parameters	Abbreviation/ code	Value	Unit
Soil temperature	T	283	[K]
Volume fraction air	Va	0.2	[-]
Volume fraction water	Vw	0.3	[-]
Volume fraction soil	Vs	0.5	[-]
Fraction of organic carbon	F_{oc}	0.058*	[-]
Percentage clay	L	25*	[%]
Dry bulk density	S	1.2	[$kg.dm^{-3}$]
pH	pH	6*	[-]

** For background on these values see Lijzen et al. (2001)*

4.3 Soil transfer pathway

4.3.1 *Ingestion of soil particles*

Soil ingestion is a major pathway by which humans are exposed to contaminants in the soil. Adults and especially children ingest soil both on purpose and by accident (Figure 4.3). Ingested soil is then released

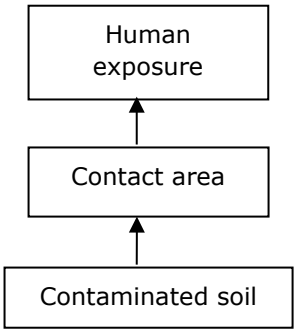

Figure 4.3: Pathway of exposure via soil ingestion.

to the digestive tract where contaminants can be absorbed into the body. Especially for immobile contaminants, this exposure pathway shows a significant contribution to the total human exposure.

Several studies were performed to determine the amounts of soil that adults and children might ingest per day (Calabrese et al., 1989; Calabrese et al., 1990; Wijnen et al., 1990; Calabrese et al., 1997; Stanek III et al., 1997). Otte et al. (2001) performed a review to determine the yearly averaged daily soil ingestion of children and adults. Although the amount of data from direct measurements was limited, the insight in the (distribution) of the parameters was sufficient for exposure modelling. The formulas used for calculating soil ingestion can be found in appendix 1.5.

Parameters
Exposure to contaminants via soil ingestions mainly depends on the daily amount of ingested soil by children/adults ($AID_{c,a}$). Moreover, the amount of ingested contaminant also depends on the concentration in the soil (*Cs*), the relative absorption factor (*Fa*) and the bodyweight of the child or adult ($BW_{c,a}$). More background information on soil ingestion can be found in Otte et al. (2001).
The relative absorption factor represents the relation between the absorption amount assumed in the CSOIL model and the absorption amount in the toxicological study on which the *MPR* was based. By default, the relative absorption factor is set to 1 meaning the absorption amounts between CSOIL and the toxicological study are the same. One exception occurs in the case of lead, where the relative absorption factor is set to a default of 0.74 (VROM, 2008). Table 4.4 shows the default parameters used to calculate exposure via soil ingestion.

Table 4.4 Exposure parameters for soil ingestion for child/ adult for the scenario "residential with garden" (Otte et al., 2001)

parameters soil ingestion	Abbreviation/ code		Value		Unit
	Child	Adult	Child	Adult	
Soil ingestion	AID_c	AID_a	$1.00e^{-4}$	$5.00e^{-5}$	[kg dry weight. day^{-1}]
Relative absorption factor	Fa	Fa	1	1	[-]
Bodyweight	BW_c	BW_a	15	70	[kg]

4.3.2 *Inhalation of soil particles*

Both indoor air and outdoor air contain soil particles. These soil particles can be absorbed into the human body through inhalation (figure 4.4). The relative contribution of soil inhalation to the total exposure depends on the type of contaminant. Volatile contaminants are more likely to evaporate and be inhaled as gases compared to contaminants that are sorbed to soil particles (see section 3.4). The soil inhalation pathway considers the latter category of contaminants, meaning contaminants are released from soil particles after inhalation as is the case for metals and non-volatile contaminants. Soil particles < 10 µm are included in this pathway (Van den Berg, 1995).

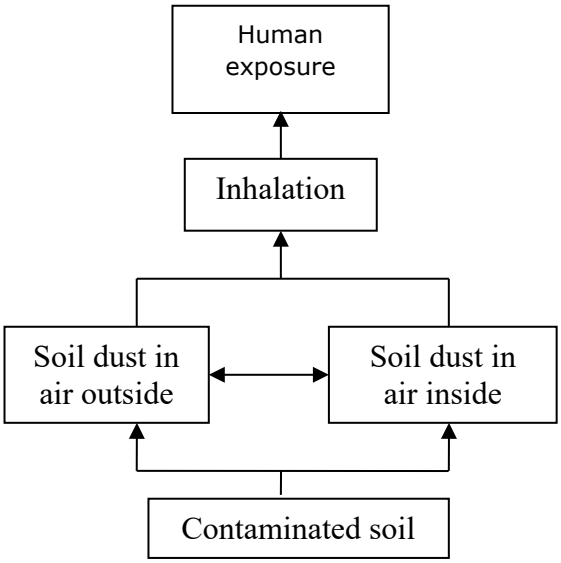

Figure 4.4 Pathways of exposure via soil inhalation.

A distinction between indoor and outdoor air is made as the outdoor concentration of dust particles in the air is higher, but the fraction of soil in these dust particles is lower compared to indoor air (Otte et al., 2001). Only soil dust is considered to be of importance in this pathway. Contaminants from dust particles or other sources are therefore not considered. Appendix 1.5.2 shows the formulas used to calculate soil inhalation.

Parameters
Exposure to contaminants via soil inhalation depends on the concentration of the contaminant in the soil (*Cs*), the amount of inhaled dust particles for a child/adult ($ITSP_c/ITSP_a$), the relative absorption factor (*Fa*), the retention factor of the soil particles in the lungs (*Fr*), and the bodyweight of the child/adult ($BW_{c,a}$). Table 4.5 shows the default parameters used to calculate exposure via soil inhalation.

Table 4.5 Exposure parameters for soil inhalation for child/ adult for the scenario "residential with garden" (Otte et al., 2001).

Parameters soil inhalation	Abbreviation/ code		Value				Unit
	Child	Adult	Child		Adult		
Amount of inhaled dust particles	$ITSP_c$	$ITSP_a$	$3.13e^{-7}$		$8.33e^{-7}$		[$kg.day^{-1}$]
Relative absorption factor	Fa	Fa	1		1		[-]
Retention factor soil in lungs	Fr	Fr	0.75		0.75		[-]
Air volume	AV_c	AV_a	0.317		0.833		[$m^3.h^{-1}$]
Indoor/outdoor			Indoor	Outdoor	Indoor	Outdoor	
Amount of suspended particles in air	TSP	TSP	52.5	70	52.5	70	[$\mu g.m^{-3}$]
Fraction soil particles in air	frs	frs	0.8	0.5	0.8	0.5	[-]
Exposure time	$ti_{(i/o)c}$	$ti_{(i/o)a}$	21.14	2.86	22.86	1.14	[$h.d^{-1}$]

4.3.3 *Dermal uptake of soil contaminants*

The uptake of contaminants through dermal contact with soil is an exposure pathway with a relatively small contribution to the total exposure. Nonetheless, exposure is still a possibility and therefore programmed into the CSOIL model (figure 4.5). Similar to the inhalation of soil particles, the uptake of contaminants through dermal contact is split up in an indoor and an outdoor component. Additionally, the surface area of exposed skin is higher when outdoors compared to

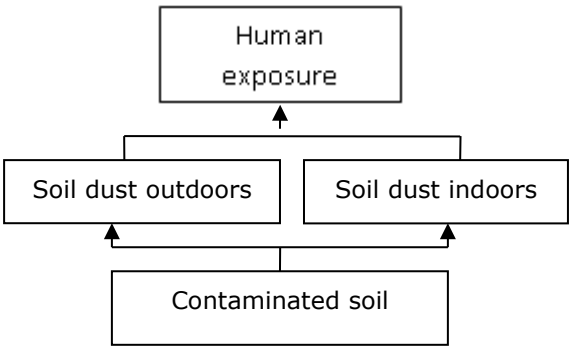

Figure 4.5: Pathways of exposure via dermal contact with soil inhalation.

indoors. Furthermore, the amount of particles covering the skin is higher outdoors compared to indoors (Otte et al., 2001).

The skin consists of an outer layer that protects the body against various external factors. However, it is possible for some contaminants to be absorbed by the skin. After absorption the contaminants enter the blood vessels that are located in the interstitial tissue. Once the contaminants have reached the bloodstream they can cause various health problems depending on their toxicity. The absorption can increase due to damaged skin.

The uptake of contaminants through dermal contact with soil is possible for organic contaminants. For inorganic contaminants (and metals) no absorption is assumed resulting in no contribution to the total exposure for these types of contaminants (Van den Berg, 1995).

Parameters
Exposure through dermal contact with soil depends on the fraction of soil indoors (FRS_i), the concentration in soil (*Cs*), and the surface area of exposed skin for child/adult when indoors/outdoors ($AEXP_{ci,o}/AEXP_{ai,o}$) (which is based on differences in skin coverage of indoor and outdoor clothing). Additional parameters of influence are the degree of skin coverage with soil particles ($DAE_{ci,o}/DAE_{ai,o}$), the dermal absorption rate for a child/adult (DAR_c, DAR_a), the period of exposure through contact with soil indoors/outdoors/ for child/adult, and a matrix factor for dermal uptake (*fm*). Appendix 1.5.3 shows the formulas used to calculate the dermal uptake of soil contaminants

The period of exposure through contact with soil was derived from the exposure time indoors/outdoors for a child/adult and a correction factor for daily to yearly exposure. Table 4.6 shows the exposure parameters for the dermal uptake of soil.

Table 4.6 Exposure parameters for dermal uptake of soil for child/adult when indoors/outdoors for the scenario "residential with garden" (Otte et al., 2001).

Exposure parameters dermal uptake	Abbreviation/ code		Value				Unit
	Child	Adult	Child		Adult		
Fraction of soil indoors	FRS_i	FRS_i	0.8		0.8		[-]
Dermal absorption rate	DAR_c	DAR_a	0.01		0.005		[h^{-1}]
The matrix factor dermal uptake	Fm	Fm	0.15		0.15		[-]
			Indoor	Outdoor	Indoor	Outdoor	
Exposed surface area of skin	$AEXP_{ci,o}$	$AEXP_{ai,o}$	0.05	0.28	0.09	0.17	[m^2]
Degree of coverage skin	$DAE_{ci,o}$	$DAE_{ai,o}$	$5.6e^{-4}$	$5.1e^{-3}$	$5.6e^{-4}$	$3.8e^{-2}$	[$kg.m^{-2}$]
Average period of exposure with soil	$TB_{ci,o}$	$TB_{ai,o}$	9.14	2.86	14.86	1.14	[$h.day^{-1}$]
Duration of exposure	$t_{ci,o}$	$t_{ai,o}$	8	8	8	8	[$h.day^{-1}$]

Exposure parameters dermal uptake	Abbreviation/ code		Value				Unit
	Child	Adult	Child		Adult		
Correction factor daily → yearly	$tf_{ci,o}$	$tf_{ai,o}$	1.143	0.357	1.857	0.143	[h.day^{-1}]

4.4 Air transfer pathway

The air transfer pathway consists of the evaporation of contaminants to air and the resulting exposure to humans through inhalation (Figure 4.6). This pathway differs from the inhalation of soil particles, described in section 4.3.2, because in air the contaminant is not attached to a soil particle but present as a gas. CSOIL describes the transport of contaminants from the soil phases to the air phase as a result of a number of stationary equilibrium processes (Van den Berg, 1995; Waitz et al., 1996).

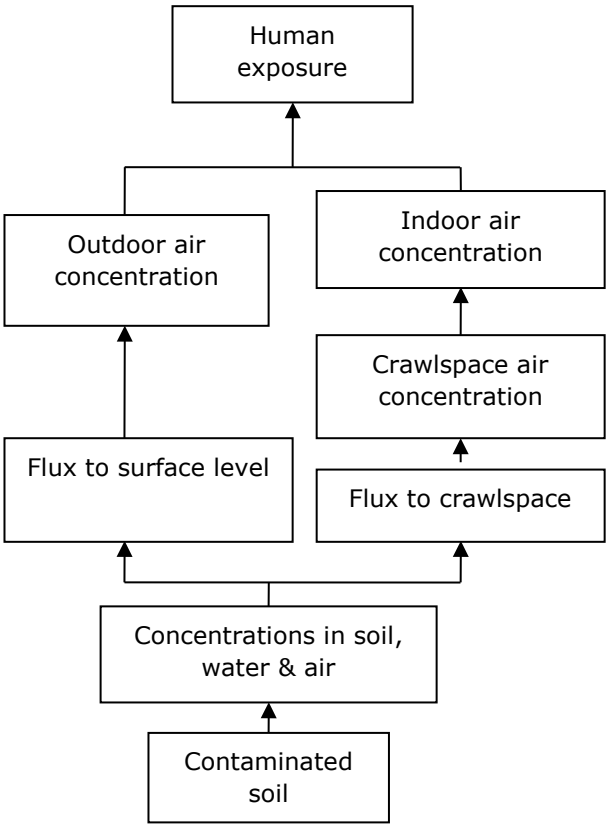

Figure 4.6 Pathways of exposure via inhalation of volatile contaminants.

The model assumes the contaminant is located at a default depth of 1.25 meters. Emission of the contaminant can take place from this depth through vertical transport through the soil. If the contaminant is located in soil in non-developed area the emission will be to outdoor air, which dilutes the emission. If the contaminant is located beneath a building the emission will be to a crawlspace and finally to indoor air, which dilutes the emission to a lesser extent through ventilation of the house (Waitz et al., 1996).

Exposure through the inhalation of volatile contaminants is significant for volatile organic contaminants. Metals, with the exception of mercury, and inorganic contaminants do not evaporate from the soil and will therefore not contribute to exposure through inhalation. Additionally, for organic contaminants it is assumed that only the non-dissociated fraction in the water phase contributes to the concentrations in soil air and subsequently contribute to exposure through inhalation (Wintersen et al., 2019).

Parameters
The amount of contaminant inhaled depends on the concentration in the indoor and outdoor air ($CIA2/COA_{c,a}$). Similar to the inhalation of soil particles, the inhalation of air is split up between inhalation of indoor air and outdoor air due to a concentration difference resulting from the pathway of emission as well as the extent of dilution (Waitz et al., 1996). Additionally, the exposure to contaminants through inhalation of air depends on the time spent indoors and outdoors for child/adult ($TIi_{c,a}/TIo_{c,a}$), the breathing volume of a child/adult ($AV_{c,a}$), the relative absorption factor (Fa), and the bodyweight of a child/adult ($BW_{c,a}$). In the exceptional case that the outdoor air concentration for a child exceeds the indoor air concentration, the outdoor air concentration for child is taken as the indoor air concentration. The choice of taking the outdoor air concentration for child reflects the most sensitive scenario. Table 4.7 shows the exposure parameters for the inhalation of contaminants evaporated to indoor/outdoor air.

Table 4.7 Exposure parameters for the inhalation of contaminant in indoor/ outdoor air for a child/adult for the scenario "residential with garden" (Otte et al., 2001)

Exposure parameters Inhalation of air	Abbreviation/code		Value				Unit
	Child	Adult	Child		Adult		
			Indoor	Outdoor	Indoor	Outdoor	
Inhalation period	TIi_{oc}	TIi_{oa}	21.14	2.86	22.86	1.14	[$h.d^{-1}$]
Air volume	AV_c	AV_a	0.317		0.883		[$m^3.h^{-1}$]
Relative absorption factor	Fa	Fa	1		1		[-]

The concentration of contaminant in outdoor air is determined by the dilution velocity of a child/adult ($VF_{c,a}$) and the diffusion flux from the soil-water phase to surface level (*Dfs*). The dilution velocities for child and adult differ due to the different breathing heights for children and adults. For the indoor air concentration the contaminant is assumed to be the same concentration throughout the entire indoor air volume. The concentration of contaminant in indoor air is determined by the concentration of contaminant in crawlspace air (*CBA*), which in turn depends on the total contaminant flux from the soil to the crawl space air (*Jcs*), the height of the crawlspace (*Bh*), and the ventilation void of the crawlspace air (*Vv*). Lastly, the indoor air concentration of a contaminant can be determined when the fraction of indoor air originating from the crawlspace (*fbi*) is known. Table 4.8 shows the parameters used for calculating the different concentrations in air.

Table 4.8 Exposure parameters for contaminant concentrations in indoor/outdoor air for child/adult for the scenario "residential with garden" (Otte et al., 2001)

Exposure parameters concentration of air	Abbreviation/code		Value		Unit
	Child	Adult	Child	Adult	
Dilution velocity	VF_c	VF_a	161.3	324.6	[$m.h^{-1}$]
Height crawl space	Bh	Bh	0.5	0.5	[m]
Air exchange rate crawlspace	Vv	Vv	1.1	1.1	[h^{-1}]
Contribution of the crawl space air to indoor air	fb_i	fb_i	0.1	0.1	[-]

4.5 Water transfer pathway

Human exposure resulting from the water transfer pathway is contingent on two processes, namely the permeation of a contaminant through water pipelines into drinking water, and the direct consumption of groundwater as drinking water (Figure 4.7). Drinking water, aside from

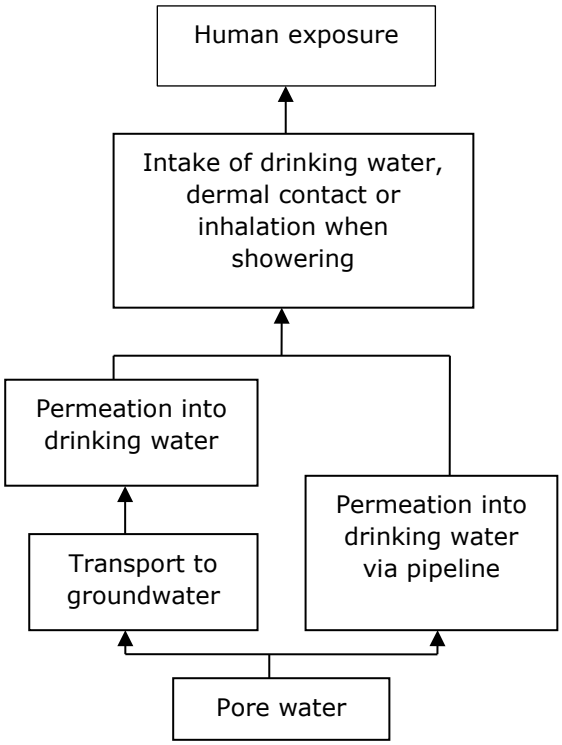

Figure 4.7 Pathways of exposure via drinking, inhalation, dermal contact with drinking water.

consumption, is also used for showering and bathing which results in exposure through dermal uptake as well as inhalation of evaporated volatile contaminants.

4.5.1 *Permeation of contaminants through water pipelines*

When located close to a water pipeline, some contaminants can permeate through a water pipeline made of polyethylene (PE) and dissolve into clean drinking water (Van den Berg, 1995). Contaminants in the pore water or air phases of the soil will generally only permeate if the pipeline is made out of PE. These type of pipelines are often found in the vicinity of houses or other buildings (Van den Berg, 1995). Permeation occurs through a series of interactions between the contaminant, the pore water and drinking water, and the PE pipeline separating the two water reservoirs (Van den Berg, 1995). Furthermore, permeation is only possible for non-dissociated organic contaminants as these can be dissolved into the hydrophobic PE and migrate between the PE polymer layers (Otte et al., 2016; Van der Schans et al., 2016).

Parameters

The concentration in drinking water (*CDW*) depends on the amount of contaminant present in pore water (*CPWo*) that can permeate through water pipelines as well as the amount of water used (*Qwd*). The pore water concentration in non-developed area is used as it is assumed that most of the water pipeline is located in non-developed area. Permeation is a slow process and contaminant concentrations can build up when water usage is low or non-existent (during the night). Moreover, the rate of permeation is not equal for all contaminants. Therefore, a permeation coefficient was derived by Van den Berg (1997) based on Vonk (1985). Additionally, the surface area and thickness of the pipeline as well as the length of the pipeline exposed to the contaminant (*LP*) influences the rate of permeation. In CSOIL, the thickness of the pipeline wall (d2) and the radius of the pipeline (r) are combined with the water usage (*Qwd*) and stagnation period (d1) into a drinking water constant (*dwconst*). The daily drinking water consumption ($QDW_{c,a}$) is used to calculate the exposure to contaminants by drinking tap water. Table 4.9 shows the parameters used to calculate the contaminant concentration in drinking water.

Table 4.9 Exposure parameters for permeation in drinking water for "residential with garden" (Otte et al., 2001)

Exposure parameters permeation in drinking water	Abbreviation/code	Value		Unit
Drinking water constant	dwconst	178.48*		[-]
Diameter contaminated area	LP	25*		[m]
Duration of water stagnation	d1	0.33		[d]
Radius of pipeline	r	0.0098		[m]
Thickness of pipe wall	d2	0.0027		[m]
Average daily water use	Qwd	0.1263*		[m^3]
		Child	Adult	
Drinking water consumption	$QDW_{c,a}$	1	2	[$dm^3.d^{-1}$]

*revised values, more information can be found in appendix 3.1.3.

4.5.2 *Drinking water*

As mentioned in the previous section, contaminants can enter drinking water by permeation through drinking water pipelines. Drinking water that originates from surface water (e.g. rivers and lakes) is not part of

the CSOIL model and will therefore not be discussed in this report. The formulas that are used to calculate the exposure via drinking water are described in appendix 1.7.2.

Parameters
Consumption of drinking water after a contaminant has permeated the drinking water pipeline leads to exposure. The daily drinking water consumption for adult or child ($QDW_{c,a}$) is given in table 4.9.

4.5.3 *Showering and bathing*
Contaminants enter the tap water used for showering and bathing through permeation of drinking water pipelines as mentioned in the previous sections. Exposure to contaminants through showering or bathing can occur via two pathways, namely through dermal contact with water and through inhalation of contaminants evaporated from the water (fig 4.8).

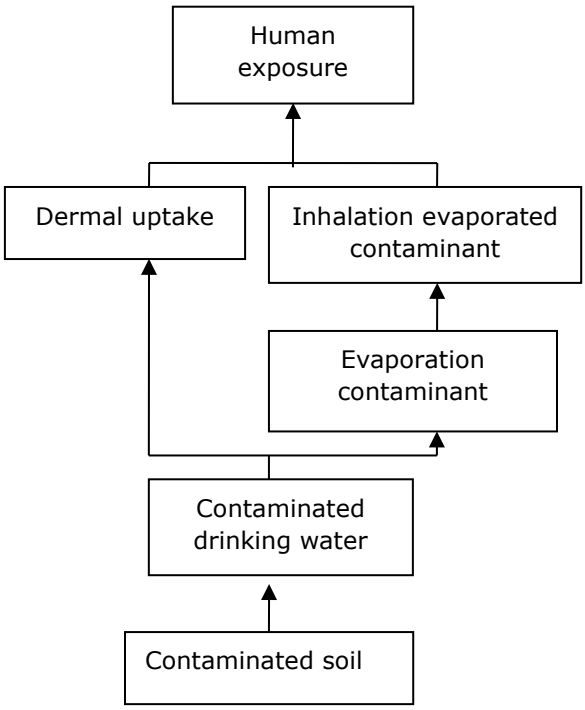

Figure 4.8: Pathways of exposure via showering.

Inhalation of vapours
During showering and bathing volatile organic contaminants can evaporate from the tap water and be inhaled together with water vapours. Water droplet formation during showering will increase the surface to volume ratio which increases the evaporation rate of the contaminant from water. Additionally, the relatively high water temperatures used during showering also serves to increase the evaporation rate (Bontje et al., 2005).

Dermal contact
Contaminants in drinking water can be absorbed through the skin when showering and bathing (Van den Berg, 1995). The contribution of this exposure pathway is generally small compared to the total human

exposure (Brand et al., 2006). The rate of absorption is mainly determined by the contaminant concentration in drinking water, the fraction of exposed skin during showering or bathing, the time spent in the shower, and the dermal absorption speed. The formulas used to calculate the exposure through dermal contact during showering are described in appendix 1.7.5.

Parameters
The concentration in bathroom air *(CBK*) resulting from evaporation of a contaminant is determined by the contaminant concentration in drinking water (*CDW*), the rate of evaporation (K_{wa}), the volume of the bathroom (*Vbk*), and the volume of water used for showering. The rate of evaporation is corrected for the water temperature of water used for showering. Subsequently, the exposure through inhalation is calculated using the residence time in the bathroom (*Td*) and the breathing volume of a child/adult ($AV_{c,a}$). Table 4.10 shows the parameters for exposure through inhalation of contaminants during showering.

Table 4.10 Exposure parameters for the inhalation of contaminant during showering for "residential with garden" (Otte et al., 2001).

Exposure parameters inhalation of water vapours during showering	Abbreviation/code		Value		Unit
	Child	Adult	Child	Adult	
Air volume	AV_c	AV_a	0.317	0.833	[$m^3.h^{-1}$]
Residence time bathroom	Td	Td	0.5	0.5	[$h.d^{-1}$]
Volume of the bathroom	Vbk		15.0		[m^3]
Volume of water used for showering	Vwb		51*		[dm^3]

** Revised values, for more information see appendix 3.1.3.*

The exposure through dermal contact with water during showering depends on the concentration in drinking water (*CDW*), the body surface of a child/adult ($ATOT_{c,a}$), the fraction of exposed skin during showering/bathing (*Fexp*), the time spent showering (*tdc*), the dermal absorption speed while showering (*DARw*), the relative absorption factor (Fa), and the bodyweight of a child/adult ($BW_{c,a}$). Time spent showering is not the same as residence time in the bathroom. After showering is finished there is little to no contact with water anymore, yet breathing of vapours still continues. Table 4.11 shows the parameters for exposure through dermal contact during showering.

Table 4.11 Exposure parameters for uptake of contaminant through dermal contact with water while showering for the scenario "residential with garden" (Otte et al., 2001)

Exposure parameters dermal contact during showering	Abbreviation/code		Value		Unit
	Child	Adult	Child	Adult	
Body surface	$ATOT_c$	$ATOT_a$	0.95	1.80	[m^2]
Fraction exposed skin	Fexp	Fexp	0.40	0.40	[-]
Showering time	tdc	tdc	0.25	0.25	[$h.d^{-1}$]
Bathing time	td	td	0.5	0.5	[$h.d^{-1}$]
Relative absorption factor	Fa	Fa	1	1	[-]

4.5.4 *Direct consumption of contaminated groundwater*

The direct consumption of contaminated ground water as drinking water is included in the CSOIL model (figure 3.1 and 3.2). Groundwater is occasionally used as a drinking water source at camp sites. However, groundwater should also be considered as a strategic source of drinking water. Therefore, the groundwater *should* be of drinkable quality without treatment.

The exposure of humans via drinking contaminated groundwater in the Netherlands occurs very rarely but is nonetheless included in CSOIL. It is, however, not included in the total human exposure of the CSOIL model as direct consumption of groundwater only occurs in very rare cases. Appendix 1.10 gives the formula that are used to determine the maximal permissible concentration in groundwater.

4.6 Vegetable consumption pathway

Exposure to contaminants can occur through the consumption of home-grown vegetables. Contaminants enter home-grown vegetables via two pathways, namely the uptake of contaminants through roots and the uptake of contaminants through leaves (via air) (Figure 4.9). A Bioconcentration Factor (*BCF*) is derived to determine the contaminant concentration in vegetables. A *BCF* is defined as the quotient of the

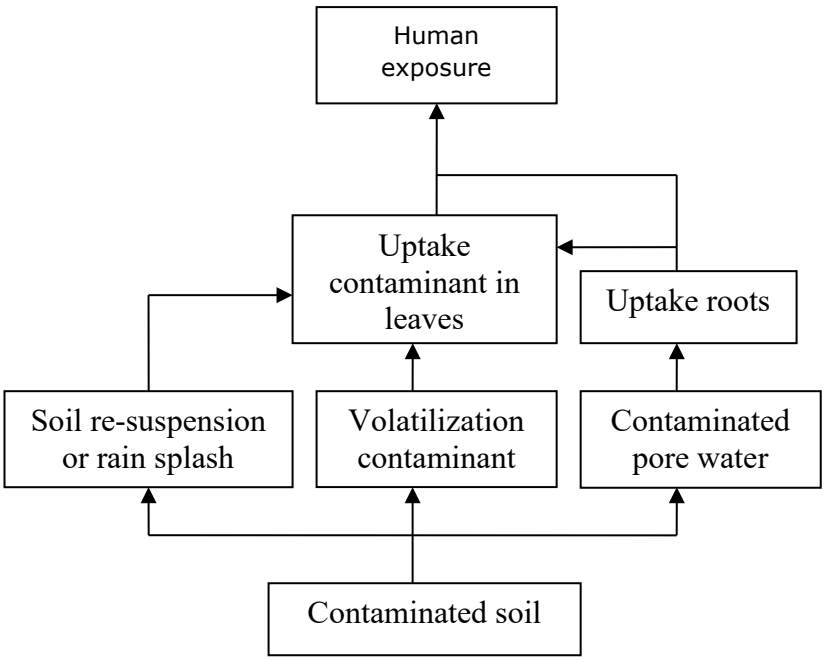

Figure 4.9: Pathways of exposure via vegetation.

contaminant concentration in the edible part of the vegetable and the contaminant concentration in soil (Versluijs and Otte, 2001).
In the CSOIL exposure model, the consumption of vegetables is split into consumption of above ground vegetables and underground vegetables such as root and bulbous vegetables. For organic contaminants, CSOIL calculates the transport of a contaminant from the roots to the leaves of the plant. The term 'leaves' includes all parts of the plant situated above ground, including the stem. The term 'root' includes all parts of the plant situated below ground (Trapp et al., 1995; Trapp, 2002; Bontje et al., 2005). Using daily consumption rates of individual underground and above ground vegetables for a child/adult ($QK_{c,a}/QB_{c,a}$) and the fraction of contaminated underground/above ground vegetables (*fvk/fvb*) that are consumed from the contaminated site, overall exposure through vegetable consumption can be calculated. All formulas related to exposure through vegetable consumption can be found in appendix 1.8. The relevant parameters can be found in table 4.12.

Table 4.12 Exposure parameters for exposure via vegetable consumption for adult/child for the scenario "residential with garden" (Otte et al., 2001).

Exposure parameters vegetable consumption	Abbreviation/ code				Value				Unit
	underground		above ground		underground		above ground		
Deposition constant	Dpconst		Dpconst		0.01		0.01		[kg dw soil. kg^{-1}dw plant]
Fraction contaminated vegetables	fvk		fvb		0.1		0.1		[-]
Organic contaminants	child	adult	child	adult	child	adult	child	adult	
Consumption of vegetables (underground/ above ground)	QK_c	QK_a	QB_c	QB_a	48.1*	99.9*	55.4*	111.0*	[g fw.d^{-1}]
Relative sorption factor	FA				1				[-]
Dilution velocity plant	VFp				84				[m.h^{-1}]
Metals	child	adult	child	adult	child	adult	child	adult	
Consumption of vegetables (potato/other)	Qa_c	Qa_a	Qo_c	Qo_a	39.1*	73.7*	64.4*	137.3*	[g fw. d^{-1}]
Dry weight vegetables	fdwr		fdws		0.167		0.098		[-]

* Revised values, see appendix 3.1.5.

4.6.1 *Uptake by roots and leaves*

The uptake of contaminants by the roots of a plant is generally the most important process for exposure through vegetable consumption. The uptake of contaminants from soil is largely a passive process driven by the transpiration stream in the xylem (vascular tissues transporting fluid) of the plant (Versluijs and Otte, 2001). Water soluble contaminants pass the root membranes and can be transported upwards to the leaves of the plant by the transpiration stream. A fraction of the total amount of contaminant will remain in the roots. Contaminants can accumulate in leaves due to water evaporation from leaves (Bromilow et al., 1995; Rikken et al., 2001). Due to different uptake mechanisms, different methods were used to calculate the *BCF* for metals, organic, and inorganic contaminants.

Method to calculate a BCF for metals

BCFs for metals are based on regression performed on a "basket" filled with typical vegetables grown in local gardens. Deriving a *BCF* through regression allows the *BCF* to vary based on soil concentrations and soil properties. For all metals, either a generic *BCF* was derived based on this regression or, when no regression was possible, a *BCF* was derived by taking the geometric mean from *BCF* values reported in literature (Versluijs and Otte, 2001; Swartjes et al., 2007; Otte et al., 2011). Generic BCF values were determined at soil intervention values. For lead

and cadmium the regression was built into the CSOIL model, allowing for a more site-specific *BCF*. For the remaining metals a fixed *BCF* for each metal was used due to the insufficient quality of the regression.

The data used by Versluijs and Otte (2001) to derive the *BCFs* for most metals included in the CSOIL 2020 model stems from the years 1990-2000. It is advised to use data from new or more recent empirical studies when the exposure through vegetable consumption is found to be critical to the total exposure.

Parameters
The regression makes use of Freundlich-type equations, including coefficients which represent the influence of soil properties and soil concentration. For cadmium, the following regression parameters were taken into account: (a) intercept, (b) soil concentration, (c) *pH*, (d) percentage of organic carbon in soil, (e) Percentage of clay in soil. For lead only (a) and (b) were taken into account. The values of the regression parameters, as well as the formulas used, can be found in Versluijs and Otte (2001), Swartjes et al. (2007), and Otte et al. (2011).

Method to calculate BCF for organic contaminants
For organic contaminants, the relation between contaminant concentration in the soil and the concentrations in the roots (Trapp, 2002) and leaves of the plant is calculated according to Trapp and Matthies (1995), and assessed by Rikken et al. (2001). The BCF for organic contaminants was derived from various plant specific characteristics as well as contaminant specific parameters such as the octanol water partition coefficient (K_{ow}) using the Trapp and Matthies (1995) model (Trapp, 2002; Swartjes et al., 2007). Due to different uptake mechanisms for root and bulbous vegetables compared to leafy vegetables, the BCFs are split into a *BCF root* and a *BCF leaf*. The latter also takes deposition of soil particles onto leaves due to rain splash into account. The lipid fraction in plants is considered to behave like octanol, and the pore water concentration is assumed to be in equilibrium with the concentration in roots. (Rikken et al., 2001).

For dissociating organic contaminants, the *BCF* is ideally an experimental *BCF*, which is split into roots and leaves to ensure compatibility with CSOIL 2020. If an experimental *BCF* is not available, the uptake model of Trapp and Matthies (Trapp and Matthies, 1995; Trapp, 2002) can be used to approximate the *BCF*. However, calculating plant uptake for dissociated contaminants through Trapp and Matthies leads to greater uncertainty as the Trapp and Matthies model is designed for non-dissociating organic contaminants. Therefore, modelling the *BCF* of dissociating contaminants requires additional research.

Parameters
The *BCF* for roots and bulbous vegetables was calculated from the volume fraction of lipids (*Flipid*) and water in root (*Fwater*) as well as the density of root tissue (*RHO_root*), the octanol water partition coefficient (K_{ow}) and a correction factor for differences between root lipids and octanol (*b_root*). The *BCF* for leafy vegetables was calculated using similar parameters as the *BCF* for roots but also accounts for

deposition and other processes that occur above ground in the plant through a differential equation. The parameters are shown in table 4.12.

Inorganic contaminants
Most inorganic contaminants modelled in CSOIL are readily soluble in water. Therefore, it is assumed that the contaminant concentration in roots equals the contaminant concentration in pore water. This relation between roots and pore water assumes a worst-case scenario. A study by Köster (1999) on cyanides shows this is indeed a worst-case approach, as cyanides will degrade in plants. The parameters are shown in table 4.12.

4.6.2 *Consumption rate of vegetables*

The consumption rate of vegetables is based on the Dutch National Food Consumption Survey (VCP) (Voedsel Consumptie Peiling, 2019)(C. van Rossum, M. Beukers, Email communication, 2019). For organic contaminants with no empirical *BCF* the total vegetable consumption is split into the root vegetables and leafy vegetables. In the scenario "Kitchen Garden", a person is assumed to consume 100% of the daily consumption of vegetables from their own kitchen garden. However, due to the amount of land required to grow 100% of a person's daily consumption of potatoes, the daily intake of potatoes is assumed to be 50% from the own kitchen garden. Therefore, the *BCF* for metals is split into a *BCF* for potatoes and a *BCF* for other vegetables instead. The parameters for vegetable consumption are shown in table 4.12.

4.6.3 *Soil re-suspension and rain splash (organic contaminants)*

Contaminated soil and dust particles can be deposited onto the leaves of plants under influence of the wind, in a process called re-suspension, or rain splash (Rikken et al., 2001). The influence of re-suspension on contaminant concentration in leaves is hard to estimate as wind quickly dilutes the amount of soil and dust particles especially for high growing plants (Rikken et al., 2001). Therefore, CSOIL only takes locally contaminated soil into account (Rikken et al., 2001). Moreover, consumption of improperly washed vegetables leads to increased exposure through this pathway due to the involuntary consumption of attached soil particles (Rikken et al., 2001; Versluijs and Otte, 2001). The amount of dust deposited on plant leaves also depends on the geometry of the plant. The parameters are shown in table 4.12.

4.6.4 *Deposition of volatile contaminants (organic contaminants)*

Volatile contaminants in the local soil can evaporate and be absorbed by the aboveground parts of the plant. Under influence of the wind, the contaminant concentration in air quickly dissipates. However, for low growing vegetables this pathway can have a substantial contribution to the plant concentration. For example, PCDD/F's (polychlorinated dibenzodioxin and dibenzofuran) are poorly transported via the xylem of the plant but do reach the plant through deposition (Rikken et al., 2001). The parameters are shown in table 4.12.

4.6.5 *Empirical and modelled BCF*

CSOIL gives users the option to provide the model with a custom *BCF*. For metals, the calculation already occurs with an empirical *BCF*, but for most organic contaminants the *BCF* is modelled through the Trapp-Matthies model (Trapp and Matthies, 1995; Trapp, 2002; Swartjes et al., 2007). When an empirical *BCF* is used, the *BCF* is split up in a *BCF* for potatoes and a *BCF* for all other vegetables.

5 Human exposure

5.1 Total Risk Index

The total Risk Index is determined by the combined Risk Indexes of the aggregated oral/dermal and inhalation pathways. The Risk Indexes for these aggregated pathways are derived through the following steps.

1. Individual exposure per pathway
CSOIL first calculates the individual exposure for each pathway separately. The separation of these pathways can be used to determine important exposure pathways for a contaminant. The exposures are calculated for children, adults and a lifelong exposure resulting from a weighted summation of the separate exposures for children and adults.

2. Summation of individual exposure pathways into two aggregated exposure pathways.
The aggregated pathways are exposure through inhalation, and through oral and dermal contact. Table 5.1 shows which individual pathways contribute to the aggregated inhalation and oral/dermal pathways. The aggregated exposure pathways are calculated for children, adults and a lifelong exposure based on a weighted summation of the separate exposures for children and adults.

3. Derivation of Risk Indexes for the aggregated pathways.
A risk index is derived by dividing the aggregated exposure by its respective MPR_{human} (see Equation 1 in section 3.4). In the Netherlands the aggregated lifelong exposure via oral and dermal contact relates to the MPR_{oral}, which in turn is based on a *TDI* (Maximum Permissible Risk = Tolerable Daily Intake). However, the *TCA* and MPR do not share the same units and the *TCA* therefore requires a conversion to the same units (from *TCA* = [$mg.m^{-3}$] to *MPR* = [$mg.kg^{-1}bw.day^{-1}$]). This conversion is based on the body weight and breathing volume of children and adults which results in two separate $MPR_{inhalation}$ for children ($MPR_{inahaltion\text{-}child}$) and adults ($MPR_{inhalation\text{-}adult}$). Therefore, the Risk Index for the aggregated exposure via inhalation is calculated from a weighted summation of the two Risk Indexes for inhalation for adults and children (see Equation 2).

4. Derivation of the total Risk Index.
The total risk index is the sum of the Risk Indexes for lifelong exposure via inhalation, and oral and dermal uptake. The aggregated risk indexes are summed to prevent a situation where individually the risk indexes for the aggregated exposure pathways are lower than 1, but combined show a risk index larger than 1.

Table 5.1 The aggregated exposure pathways and their respective individual exposure pathways.

Aggregated inhalation pathway	Aggregated oral/dermal pathway
Inhalation of soil particles	Ingestion of soil particles
Inhalation of indoor air	Dermal contact soil indoors
Inhalation of outdoor air	Dermal contact soil outdoors
Inhalation during showering	Consumption of vegetables
	Permeation of drinking water
	Dermal contact during showering

5.2 Soil use scenarios

5.2.1 *Standard soil use scenario*

"Residential with garden" is the standard soil use scenario in CSOIL. This scenario is used in the derivation of the Intervention Values for soil. The scenario "residential with garden" assumes a house with a garden of which *some* part is used for growing vegetables for consumption. However, the garden is assumed to have a predominantly recreational purpose, and is therefore not a vegetable garden. Exposure using the standard scenario is possible through the exposure pathways described in chapter 3. Default parameters for the standard scenario are listed in table 5.2

Table 5.2 Default parameters for the standard use scenario "Residential with garden" (Otte et al., 2001)

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	100	50	[mg.day^{-1}]
Time spent indoors	21.14	22.86	[h.day^{-1}]
Time spent outdoors	2.86	1.14	[h.day^{-1}]
Time of soil contact indoors	9.14	14.86	[h.day^{-1}]
Time of soil contact outdoors	2.86	1.14	[h.day^{-1}]
Percentage rooty vegetables from own garden	10	10	[%]
Percentage leafy vegetables from own garden	10	10	[%]
Daily consumption rooty vegetables[1*]	48	100	[g.day^{-1}]
Daily consumption leafy vegetables[1*]	55	111	[g.day^{-1}]
Daily consumption potatoes[2*]	39	74	[g.day^{-1}]
Daily consumption other vegetables[2*]	64	137	[g.day^{-1}]

1) Calculated from the daily consumption of vegetables for the BCF of metals
2) Only used when the contaminant is a metal.
**) Updated values based on the Food Consumption Survey.*

5.2.2 *All soil use scenarios*

Aside from the standard scenario CSOIL also includes 6 other use scenarios. The complete list of user scenario is as follows.

1. Residential with garden;
2. Places where children play;
3. Residential with vegetable/kitchen garden;
4. Agricultural area;
5. Nature;
6. Green with nature value, sports, recreation and city parks;
7. Other greens, buildings, infrastructure and industry.

The user scenarios were developed by the policy workgroup NoBo (Policy workgroup on Soil quality standards and Soil quality assessment). A short description of the use scenarios can be found below.

1. Residential with garden
See chapter 5.3.1. for a description of the standard scenario

2. Places where children play
This scenario includes places that children often visit to play where children come in contact with soil in non-developed area. Examples are playgrounds, grass plots, playing fields, gardens near schools and other green places. The exposure pathway "consumption of vegetables" does not contribute to this scenario as no vegetables are grown and eaten in places where children play. Ornamental gardens can also be part of this scenario as long as no plants are grown that are intended for consumption. Therefore, this scenario can also apply to homes in urban areas with small gardens where cultivation of vegetables is unlikely.

3. Residential with vegetable/kitchen garden
Residential with vegetable/kitchen garden is similar to the standard scenario with the exception of the garden being a vegetable garden from which more plants are consumed. This scenario also applies to communal vegetable gardens. The consumption rate of vegetables as well as the fraction of the consumed vegetables originating from the vegetable garden are increased in this scenario.

4. Agriculture
The user scenario agriculture includes the production area of a farmer without a farm or premises. The soil contact frequency is equal to the scenario 'Residential with garden'. It must be mentioned that the soil contact frequency for the farmer can be much higher. However, this is seen as an occupational hazard (internal document).

5. Nature
The user scenario nature assumes contact with soil occurs in the ecological main structure (i.e. national parks, forests etc.). The scenario assumes that exposure only occurs outdoors. Moreover, in this scenario humans are not exposed through the consumption of drinking water and vegetables. People remain in a nature reserve on average 1 hour per day. Ingestion of soil is, therefore, 5 times lower compared to the scenario 'Residential with garden'.

6. Green with nature value, sports, recreation and city parks
Many recreational utilities are included in this use scenario. No exposure is assumed through consumption of vegetables as no vegetables are grown in these areas. Additionally, the scenario assumes a lower ingestion of soil (5 times lower than standard). When nature areas contain places designated for children to play in, these places should be treated as scenario 2 (places where children play).

7. Other greens, buildings, infrastructure and industry
This scenario includes green areas with low ecological value and parts of cities where soil is mostly sealed. This scenario assumes no vegetable

consumption as no vegetables are grown in industrial areas. Moreover, the time spent in industrial areas is very diverse as people can use this area in an occupational fashion (40h work weeks inside and 7 hours outside). Both time spent indoor and outdoor are therefore reduced in this scenario compared to 'Residential with garden'.

5.2.3 *Parameters soil use scenarios*

The parameters listed in table 5.2, to some extent, also apply to the other use scenarios. The full list of parameters and their values for all scenarios can be found in appendix 2.

5.3 Determination of risk indexes and risk values

CSOIL provides the option to determine a set of health risk limits for contaminants for each use scenario. Additionally, CSOIL can determine a risk index resulting from a contaminant concentration in soil or pore water. A health risk limit in CSOIL is defined as the concentration at which the risk index of the selected soil use scenario for a given contaminant equals 1. The health risk limit is determined by iterating the soil concentration using the "goal seek" function in excel. The goal seek function is allowed to make 200 iterations and stops iterating after the risk index reaches 1.0000000 ±0.0000001.

The updated version of CSOIL also provides the option to derive a health risk limit for groundwater. In this scenario, only exposure pathways that are relevant to groundwater are considered. Therefore, the exposure pathways ingestion of soil, dermal uptake of soil, and inhalation of soil are set to zero. Table 6.1 shows the exposure pathways and their relevance to the derivation of the groundwater health risk limit.

Deriving a health risk limit for groundwater through CSOIL is meant for situations where the contamination is only present in the groundwater to determine the quality requirements for groundwater given a specific use, function and/or to exclude or manage risks for soil functions.
In situations where the influence of groundwater on the top-layer of the soil cannot be excluded, the topsoil should be evaluated on the basis of measured total soil concentrations of contaminants. However the assessment of the groundwater quality and associated risks can be of added value to obtain a complete overview of the risks.

Table 6.1 The exposure pathways relevant to determining the groundwater health risk limit.

Exposure pathway	Relevance to groundwater health risk limit
Ingestion of soil particles	No
Dermal contact soil indoors	No
Dermal contact soil outdoors	No
Inhalation of soil particles	No
Inhalation of indoor air	Yes
Inhalation of outdoor air	Yes
Consumption of vegetables	No
Permeation into drinking water	Yes
Inhalation during showering	Yes
Dermal contact during showering	Yes

6 Abbreviations

BCF	Bioconcentration Factor: the ratio of the contaminant concentration in (part of) an organism (e.g. plant, fish) to the concentration in a medium (e.g. soil, water) at steady state
CEC	Contaminant of Emerging Concern
$CR_{oral/inhal}$	Excess carcinogenic risk via oral, dermal intake or intake through inhalation
CSOIL	Exposure model used to determine human exposure to contaminants in soil. CSOIL 2020 refers to the most recent version of the model.
LDPE	Low Density Polyethylene: a plastic that is used to make water pipelines
MPR_{human}	Maximal Permissible Risk: For toxicity, substances can be divided into two categories: the threshold substances and the non-threshold (carcinogenic) substances. For the threshold substances the MPR_{human} is set at the No Observed Adverse Effect Level (NOAEL). For the non-threshold substances the MPR_{human} is set at the concentration at which 1 in ten thousand individuals develops a tumor after lifelong exposure.
NIBO	Normen en Instrumentarium Bodem en Ondergrond, Standards and risk assessment tools for soil and subsoil
PFAS	PerFluorinated Alkylated Substances
RI	Risk index. The value derived from comparing the calculated dose with the intake limits (MPR_{human} and TCA).
RIVM	Rijksinstituut voor Volksgezondheid en Milieu, National Institute for Public Health and the Environment
RTB	RisicoToolbox Bodem, Risk toolbox soil.
TCA	Tolerable Concentration in Air: Estimate of the concentration in air, based on the amount of contaminant that can be inhaled over a specified period of time without appreciable health risk.
TDI	Tolerable Daily Intake: Estimate of the amount of contaminant that can be ingested or absorbed over a specified period of time without appreciable health risk.

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1 Appendix 1 – Formulas

1.1 Fugacity calculations

For background information in the fugacity concept see (Mackay et al., 1985; Mackay, 2001)

Organic contaminants

- Za =1/R*T

Za	: fugacity constant air	[mol.m^{-3}.Pa^{-1}]
R	: gas constant	[8.3144 Pa.m^{3}.mol^{-1}.K^{-1}]
T	: temperature	[283 K]

- Zw =S/Vp

Zw	: fugacity constant water	[mol.m^{-3}.Pa^{-1}]
S	: solubility at soil temperature	[mol.m^{-3}]
Vp	: vapour pressure pure product	[Pa]

- Zs =Kd*SD/1000*Zw/Vs

Zs	: fugacity constant soil	[mol.m^{-3}.Pa^{-1}]
Kd	: partition constant soil-water	[(mol.kg^{-1}dw)/ (mol.dm^{-3})]
SD	: dry bulk density	[kg dw.m^{-3} soil]
Vs	: volume fraction soil	[-]

Vs =1-porosity
=1-Va-Vw

Va	= volume fraction air	[-]
Vw	= volume fraction water	[-]

- Kd = K_{oc}*Foc

Kd	: partition coefficient soil-water	[(mol.kg^{-1}dw)/ (mol.dm^{-3})]
K_{oc}	: distribution coefficient soil-water corrected for organic carbon	[mol.kg^{-1}org.C) / mol.dm^{-3}]
Foc	: fraction organic carbon	[kg org.C .kg^{-1} dw]

K_{oc} =0.411*K_{ow}*f_{nd}

K_{ow}	: octanol-water partition coefficient	[-]
f_{nd}	: fraction not dissociated contaminant	[-]

- Klw = Vp/(S*R*T) or = Za/Zw [-]

Klw	: air-water partition coefficient	[-]
S	: solubility at soil temperature	[mol.m^{-3}]
R	: gas constant	[8.3144 Pa.m^{3}.mol^{-1}.K^{-1}]
T	: temperature	[283 K]
Za	: fugacity constant air	[mol.m^{-3}.Pa^{-1}]
Zw	: fugacity constant water	[mol.m^{-3}.Pa^{-1}]

1.2 Mass fraction calculations

1.2.1 *Organic and some inorganic contaminants*

- Pa = (Za*Va)/(Za*Va+Zw*Vw+Zs*Vs)
- Pw = (Zw*Vw)/(Za*Va+Zw*Vw+Zs*Vs)
- Ps = (Zs*Vs)/(Za*Va+Zw*Vw+Zs*Vs)

Pa	: mass fraction soil air	[-]
Pw	: mass fraction soil moisture	[-]
Ps	: mass fraction solid phase	[-]
Za	: fugacity constant air	[mol.m^{-3}.Pa^{-1}]
Zw	: fugacity constant water	[mol.m^{-3}.Pa^{-1}]
Zs	: fugacity constant soil	[mol.m^{-3}.Pa^{-1}]
Va	: volume fraction air	[-]
Vw	: volume fraction water	[-]
Vs	: 1-Va-Vw	[-]

1.2.2 *Metals and some inorganic contaminants*

- Pa = 0 [-]
- Pw = Vw/(Vw+Kd/1000*SD) [-]
- Ps = (1-PW) [-]

Pa	: mass fraction in soil air	[-]
Pw	: mass fraction in soil moisture	[-]
Ps	: mass fraction in soil solid	[-]
Vw	: volume fraction water	[-]
Kd	: partition coefficient soil-water	[(mol.kg^{-1}dw soil)/ (mol.dm^{-3} water)]
Constants:		
SD	: dry bulk density (1200)	[kg dw.m^{-3} soil]

1.3 Dissociation

f_nd : non dissociated fraction [-]

- f_nd = 1/(1+10^(pH-pKa))

f_nd : non dissociated fraction [-]
pKa : acid dissociation constant [-]
pH : acidity of solution [-]

1.4 Concentrations in air, water, and soil

1.4.1 *Organic contaminants in air*

- Csa = (Cgb*SD/1000*Pa)/Va

Csa : concentration in soil air [$kg.m^{-3}$] or [$g.dm^{-3}$]

Cgb : initial concentration in soil in developed area (total concentration in soil gas-, water and solid) [$mg.kg^{-1}$]

Pa : mass fraction in soil air [-]

Constants
SD : dry bulk density (1200) [$kg.m^{-3}$]
Va : volume fraction air (0.2) [-]

If the solubility is exceeded:
If CPWb > (S/1000)*M then

$$CSA = \frac{S * \frac{M}{1000} * Vw * Pa}{Pw * Va}$$

Csa : concentration in soil air [$kg.m^{-3}$]
S : solubility [$mol.m^{-3}$]
M : molecular weight [$g.mol^{-1}$]
Vw : volume fraction water [-]
Pa : mass fraction in soil air [-]
Pw : mass fraction in soil moisture [-]
Va : volume fraction air [-]

1.4.2 *Inorganic contaminants*

Csa = 0

Csa : concentration in soil air [$kg.m^{-3}$]

1.4.3 *Metals*

Csa = 0

Csa : concentration in soil air [$kg.m^{-3}$]

1.4.4 *Metals and organic contaminants in water*

- Cpw = (Cs/1000)*SD*Pw/Vw

  Cpw : concentration in soil moisture [$kg.m^{-3}$]

  Cs : initial concentration in soil (total concentration in gas-, water and solid) [$g.kg^{-1}$]

  Pw : mass fraction in soil moisture [-]

  Constants:
  SD : dry bulk density (1200) [$kg.m^{-3}$]
  Vw : volume fraction in water (0.3) [-]

- The pore water concentrations for soil in developed (CPWb) and non-developed (CPWo) areas are derived according to the formula for CPW. Instead of Cs, the respective soil concentrations in developed (Cgb) and non-developed (Cgo) areas are used

If the solubility is exceeded (verification only for organic contaminants)
If Cpw >S*M then:

- Cpw = S*M/1000

  Cpw : concentration in soil moisture [$kg.m^{-3}$]
  S : solubility [$mol.m^{-3}$]
  M : molecular weight [$g.mol^{-1}$]

If a soil concentration is calculated from user input of concentration in pore water (example given for Cs, similar procedure for Cgo and Cgb):

- Cs = CPW *1000/SD * Vw/Pw

1.5 Soil ingestion, inhalation, and dermal uptake

1.5.1 *Exposure through soil ingestion*

Conventions:

c	: child	
a	: adult	
L	: lifelong	
Fa	: relative sorption factor	[-]
$BW_{c,a}$	: bodyweight (child 15, adult 70)	[kg]
Cs	: initial soil concentration (total concentration in gas-, water- and solid phase)	[$g.kg^{-1}$]
	Exposure, the lifelong average exposure	[$g.kg^{-1}$ $bw.d^{-1}$]
	Lifelong: 70 years	[year]

CHILD

♦ DIc = AID_c*Cgo*Fa/BW_c
= AID_c*Cgo*Fag/BW_c

DIc	: exposure via ingestion of soil - child	[$g.kg^{-1}$ $bw.d^{-1}$]
AID_c	: daily intake soil – child (1.0 *10^{-4})	[kg $dw.d^{-1}$]
Cgo	: initial concentration soil in non-developed area (total concentration in gas-, water- and solid phase)	[$g.kg^{-1}$]
Fa	: relative absorption factor (general)	[-]
Fag	: relative absorption factor soil	[-]
BW_c	: bodyweight child (15kg)	[kg]

ADULT

♦ DIa = AID_a*Cgo*Fa/BW_a
= AID_a*Cgo*Fag/BW_a

DIa	: exposure via ingestion of soil – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
AID_a	: daily intake soil - adult (5.0 *10^{-5})	[kg $dw.d^{-1}$]
Cgo	: initial concentration in soil in non-developed area (total concentration in gas-, water- and solid phase)	[$g.kg^{-1}$]
Fa	: relative absorption factor (general)	[-]
Fag	: relative absorption factor soil	[-]
BW_a	: bodyweight adult (70 kg)	[kg]

LIFELONG AVERAGE

♦ DIL =(l_c*DIc+l_a*DIa)/(l_c+l_a)

DIL	: exposure via ingestion of soil lifelong average	[$mg.kg^{-1}$ $bw.d^{-1}$]
DIc	: exposure via ingestion of soil lifelong average - child	[$mg.kg^{-1}$ $bw.d^{-1}$]
DIa	: exposure via ingestion of soil – adult	[$mg.kg^{-1}$ $bw.d^{-1}$]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

Groundwater health risk limit

When a groundwater health risk limit is derived through CSOIL this pathway is set to zero. However, this can only be done when contaminants in groundwater are certain to have no effect on the top layer of the soil. Therefore, user discretion is advised.

1.5.2 *Exposure through inhalation of soil particles*

CHILD

- $IPc = Cgo*ITSP_c*fr*Fa/BW_c$

IPc	: exposure via inhalation of soil particles – child	[$g.kg^{-1}$ $bw.d^{-1}$]
Cgo	: initial concentration in soil in non-developed area (total concentration in gas-, water- and solid phase)	[$g.kg^{-1}$]
$ITSP_c$	: inhaled amount of soil particles – child ($3.13 *10^{-7}$)	[$kg.d^{-1}$]
fr	: retention factor soil particles in lungs (0.75)	[-]
Fa	: relative absorption factor	[-]
BW_c	: bodyweight child (15)	[g]

$ITSP_c = TSPi * frsi * AV_c * tiic + TSPo * frso *AV_c * tioc$

Constants:

TSPi,o	: amount of suspended particles in air Indoors 0.75 * 70 = 52.5 $ug.m^{-3}$ Outdoors 70 $ug.m^{-3}$	[$kg.m^{-3}$]
Frsi,o	: fraction soil particles in air Indoors 0.8 Outdoors 0.5	[-]
AV_c	: air volume child (0.317)	[$m^3.h^{-1}$]
Tiic	: Inhalation time indoors (21.14)	[h]
Tioc	: Inhalation time outdoors (2.86)	[h]

ADULT

- $IPa = Cgo*ITSPa*Fr*Fa/BW_a$

IPa	: exposure via inhalation of soil particles – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
Cgo	: initial concentration in soil in non-developed area (total concentration in gas-, water- and solid phase)	[$g.kg^{-1}$]
$ITSP_a$	: inhaled amount of soil particles – adult ($8.33 * 10^{-7}$)	[$kg.d^{-1}$]
Fr	: retention factor soil particles in lungs (0.75)	[-]
Fa	: relative absorption factor	[-]
BW_a	: bodyweight adult (70)	[kg]

Constants:

$ITSP_a = TSPi * frsi * AV_a * tiia + TSPo * frso * AV_a * Tioa$

TSPi,o	: amount of suspended particles in air Indoors 0.75 * 70 = 52.5 $\mu g.m^{-3}$ Outdoors 70 $ug.m^{-3}$	[$kg.m^{-3}$]
Frsi,o	: fraction soil particles in air Indoors 0.8 Outdoors 0.5	[-]
AV_a	: air volume adult (0,833)	[$m^3.h^{-1}$]
Tiia	: Inhalation time indoors (22.86)	[h]
Tioa	: Inhalation time outdoors (1.14)	[h]

LIFELONG AVERAGE

- IPL = (l_c*IPc+l_a*IPa)/(l_c+l_a)

IPL	: exposure via inhalation of soil particles lifelong average	[$g.kg^{-1}$ $bw.d^{-1}$]
IPc	: exposure via inhalation of soil particles – child	[$g.kg^{-1}$ $bw.d^{-1}$]
IPa	: exposure via inhalation of soil particles – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

Groundwater health risk limit

When a groundwater health risk limit is derived through CSOIL this pathway is set to zero. However, this can only be done when contaminants in groundwater are certain to have no effect on the top layer of the soil. Therefore, user discretion is advised.

1.5.3 *Exposure through dermal uptake*

Dermal contact soil indoors (DAc,a i)

CHILD

♦ DAci =AEXPci*fm*DAEci*DARc*Cgo*TBci*FRSi*Fa/BW_c

DAci : exposure via dermal contact soil child – indoors [$g.kg^{-1}$ $bw.d^{-1}$]
AEXPci: exposed surface skin – child – indoors (0.05) [m^2]
fm : matrix factor dermal uptake (0.15) [-]
DAEci : degree of skin covered – child – indoors (5.6 *10^{-4}) [kg $soil.m^{-2}$]

DARc : dermal absorption velocity – child (0.01) [h^{-1}]

Cgo : initial concentration in soil in non-developed area (total concentration in gas-, water- and solid phase) [$g.kg^{-1}$]

Constants
TBci : period of exposure through contact soil – child – indoors (9.14) [$h.d^{-1}$]
FRSi : fraction soil in dust – indoors (0.8) [-]
Fa : relative absorption factor [-]
BW_c : bodyweight child (15) [kg]

TBci = t_ci * tf_ci
t_ci : duration of the exposure – child – indoors (8) [$h.d^{-1}$]
tf_ci : correction factor exposure daily → yearly – child (1.143) [-]

ADULT

♦ DAai =AEXPai*Fm*DAEai*DARa*Cgo*TBai*FRSi*Fa/BW_a

DAai : exposure via dermal contact soil – adult - indoors [$g.kg^{-1}$ $bw.d^{-1}$]
AEXPai: exposed surface surface skin – adult – indoors (0.09) [m^2]
fm : matrix factor dermal uptake (0.15) [-]
DAEai : degree of skin covered – adult - indoors (5.6 * 10^{-4}) [kg $soil.m^2$]
DARa : dermal absorption velocity - adult (0.005) [h^{-1}]
Cgo : initial concentration in soil in non-developed area (total concentration in gas-, water- and solid phase) [$mg.kg^{-1}$]

Constants
TBai : period of exposure through contact soil – adult – indoors(14.9) [$h.d^{-1}$]
FRSi : fraction soil in dust – indoors (0.8) [-]
Fa : relative absorption factor [-]
BW_a : bodyweight adult (70) [kg]

TBai = t_ai * tf_ai
t_ai : duration of the exposure – adult – indoors (8) [$H.d^{-1}$]
tf_ai : correction factor exposure daily → yearly – adult (1.857) [-]

LIFELONG AVERAGE

♦ DALi =(l_c*DAci+l_a*DAai)/(l_c+l_a)

DALi : exposure via dermal contact soil lifelong average- indoors [$g.kg^{-1}$ $bw.d^{-1}$]
DAci : exposure via dermal contact soil – child – indoors [$g.kg^{-1}$ $bw.d^{-1}$]
DAci : exposure via dermal contact soil – adult – indoors [$g.kg^{-1}$ $bw.d^{-1}$]

l_c : Duration child phase (6) [year]
l_a : Duration adult phase (64) [year]

Groundwater health risk limit

When a groundwater health risk limit is derived through CSOIL this pathway is set to zero. However, this can only be done when contaminants in groundwater are certain to have no effect on the top layer of the soil. Therefore, user discretion is advised.

Dermal contact soil outdoors

CHILD

♦ DAco = Cgo*AEXPco*Fm*DAEco*DARc*TBco*Fa/BW_c

DAco : exposure via dermal contact soil – child – outdoors [$g.kg^{-1}$ $bw.d^{-1}$]
Cgo : initial soil concentration (total concentration in gas-, water- and solid phase) [$g.kg^{-1}$]

Constants
AEXPco: exposed surface skin – child – outdoors (0.28) [m^2]

Fm : matrix factor dermal uptake (0.15) [-]
DAEco : degree of skin covered – child – outdoors ($5.1 * 10^{-3}$) [kg $soil.m^{-2}$]
DARc : dermal absorption velocity – child kind (0.01) [h^{-1}]
TBco : period of exposure through soil –child –outdoors (2.86) [$h.d^{-1}$]
Fa : relative absorption factor [-]
BW_c : bodyweight child (15) [kg]

TBco = t_co * tf_co
t_co : duration of the exposure – child – outdoors (8) [$h.d^{-1}$]
tf_co : correction factor exposure daily → yearly – child (0.357) [-]

ADULT

- DAao = Cgo*AEXPao*Fm*DAEao*DARa*TBao*Fa/BW_a

  DAao : exposure via dermal contact soil – adult – outdoors [$g.kg^{-1}$ $bw.d^{-1}$]
  Cgo : initial soil concentration (total concentration in gas-, water- and solid phase) [$g.kg^{-1}$]

  Constants
  AEXPao: exposed surface skin – adult – outdoors (0.17) [m^2]
  Fm : matrix factor dermal uptake (0.15) [-]
  DAEao : degree of skin covered – adult –outdoors (3.75 * 10^{-2}) [kg $soil.m^{-2}$]
  DARa : dermal absorption velocity – adult (0.005) [h^{-1}]
  TBao : period of exposure through soil – adult – outdoors (1.14) [$h.d^{-1}$]
  Fa : relative absorption factor [-]
  BW_a : bodyweight adult (70) [kg]

  TBao = t_ao * tf_ao
  t_ao : duration of the exposure – adult – outdoors (8) [$h.d^{-1}$]
  tf_ao : correction factor exposure daily → yearly – adult (0.143) [-]

LIFELONG AVERAGE

- DALo = (l_c*DAco+l_a*DAao)/(l_c+l_a)

  DALo : exposure via dermal contact soil lifelong average – outdoors [$g.kg^{-1}$ $bw.d^{-1}$]
  DAco : exposure via dermal contact soil – child – outdoors [$g.kg^{-1}$ $bw.d^{-1}$]
  DAao : exposure via dermal contact soil – adult – outdoors [$g.kg^{-1}$ $bw.d^{-1}$]
  l_c : Duration child phase (6) [year]
  l_a : Duration adult phase (64) [year]

Groundwater health risk limit
When a groundwater health risk limit is derived through CSOIL this pathway is set to zero. However, this can only be done when contaminants in groundwater are certain to have no effect on the top layer of the soil. Therefore, user discretion is advised.

1.6 Formulas Air transfer pathway

1.6.1 *Air flux from soil to crawlspace (indoor)*

Organic contaminants

- Jsc =(-Fsc*Csa)/(EXP(-Fsc*Ls/Dsa)-1)

  Jsc : total contaminant flux from soil to crawl space [$kg.m^{-2}.h^{-1}$]

  Fsc : air flux from soil to crawl space [$m^3.m^{-2}.h^{-1}$]

  Csa : concentration in the soil air [$kg.m^{-3}$]
  Ls : length of soil column [m]
  Dsa : diffusion coefficient in the soil gas phase [$m^2.h^{-1}$]

- Dsa =$(Va^{10/3} * Da)/(1-Vs)^2$

  Da: Diffusion coefficient in free air [$m^2.h^{-1}$]
  Vs: Volume fraction soil [-]
  Va: Volume fraction air [-]

- Da = $0.036 *(76/M)^{1/2}$

- FSC = Ks*DELTAPCS/Ls

  Fsc : air flux from soil to crawl space [$m^3.m^{-2}.h^{-1}$]
  Ks : conductivity soil air [$m^2.Pa^{-1}.h^{-1}$]

  Constants
  Ks = KAPPA/ETA
  KAPPA : air permeability of the soil ($1 *10^{-11}$) [m^2]
  ETA : viscosity of air ($5 *10^{-9}$) [$Pa.h^{-1}$]
  DELTAPCS : air pressure difference between crawl space and soil (1) [Pa]

  Ls : length of soil column [m]

  If Dp.L – Dc < 0.01 then:
- Ls = 0.01

  If Dp-Dc > 0.01 then:
- Ls = Dp-Dc

  Ls : length of soil column [m]
  Dp.L : depth of contamination 1.25 (=Dg-Z) [m]

Dc	: depth of crawl space below ground surface	[m]
Dg	: depth of ground water table	[m]
Z	: Ht of cap. trans. boundary above groundwater table	[m]

1.6.2 *Concentration in crawlspace and indoor air*

Organic contaminants

- Cba = (Jsc/(Bh*Vv)

Cba	: concentration in the crawl space air	[kg.m^{-3}]
Jsc	: total contaminant flux from soil to crawl space	[g.m^{-2}.h^{-1}]
Bh	: height of crawl space (0.5)	[m]
Vv	: air exchange rate crawlspace (1.1)	[h^{-1}]

If Cba*fbi < COAc then:

- CIA2 = COAc

If Cba*fbi > COAc then:

- CIA2 = fbi*Cba *f_nd

CIA2	: concentration in indoor air according to revised concept	[kg.m^{-3}]
COAc	: concentration in air outdoors - child	[kg.m^{-3}]
fbi	: fraction indoor air/crawl space air (0.1)	[-]
Cba	: concentration in the crawl space air	[kg.m^{-3}]
F_nd	: non-dissociated fraction	[-]

1.6.3 *Air flux from soil to soil surface (outdoor)*

Organic contaminants

- Dfs = Du*(Cpw*Vw)/(Dp*Pw) or (Du*Cgo*SD)/Dp)

Dfs	: diffusion flux from water-soil to the surface	[kg.m^{-2}.h^{-1}]
Du	: diffusion coefficient in the soil	[m^2.h^{-1}]
Cpwo	: concentration in soil moisture/groundwater	[kg.m^{-3}] or [g.dm^{-3}]
Vw	: volume fraction water	[-]
Dp	: depth of contamination 1.25 (=Dg-Z)	[m]
Dg	: depth of ground water table	[m]
Z	: Height of capillary transfer boundary above groundwater table [m]	
Pw	: mass fraction in the soil moisture	[-]
Cgo	: initial soil concentration (total concentration in gas-, water- and solid phase)	[g.kg^{-1}]
SD	: dry bulk density	[kg.dm^{-3}]

- Du = (Pa*Dsa/Va) + (Pw*Dsw/Vw)

Pa,w	: mass fraction in soil air,water	[-]
Dsa	: diffusion coefficient in the soil gas phase	[m^2.h^{-1}]
Va,w	: volume fraction air, water	[-]

Dsw : diffusion coefficient in the soil water phase [$m^2.h^{-1}$]

- Dsw = $Vw^{10/3} * Dw(1-Vs)^2$

Dw : Diffusion coefficient in free water [$m^2.h^{-1}$]

- Dw = 0.0001 * Da
- Da = $0.036 * (76/M)^{1/2}$

Da : Diffusion coefficient in free air [$m^2.h^{-1}$]
M : Molecular weight

1.6.4 Dilution speed child, adult, plant (constant)

Vfc : Dilution velocity outdoor air child (161.3) [$m.h^{-1}$]
Vfa : Dilution velocity outdoor air adult (324.6) [$m.h^{-1}$]
Vfp : Dilution velocity outdoor air plant (84) [$m.h^{-1}$]

- VF = Vg*Sz/Lp

VF : dilution velocity (plant, child or adult) [$m.h^{-1}$]
Vg : average windspeed [$m.h^{-1}$]
Sz : Pasquill dispersion coefficient vertical, related to Pasquil weather stability class D [m]
Lp : diameter contaminated area [m]

- Vg =(Vx+V')/2

Vx : wind speed at x meter high [$m.h^{-1}$]
V' : friction speed [$m.h^{-1}$]

- Vx = ln(Z/Zo)*V'/k

Z : height when breathing [m]
Zo : roughness surface living area (1.0) [-]
k : Karman constant (0.4) [-]

- V' k*V10/ln(Z10/Zo)

k : Karman constant (0.4) [-]
Z10 : height (10) [m]
V10 : wind speed at 10 m height (18000) [$m.h^{-1}$]
Zo : roughness surface living area (1.0) [-]

- Sz = $Co*0.2*Lp^{0.76}$

Sz : Pasquill dispersion coefficient vertical, related to Pasquil weather stability class D [m]

Co	= (10*Zo)^(0.53*$Lp^{-0.22}$)	
Co	: correction factor for roughness length	[-]
Zo	: roughness surface living area (1.0)	[-]
Lp	: diameter contaminated area	[m]

Example calculation if Lp = 100 (van den Berg 1995)

		Child	Adult	
Z	=	1.0	1.5	[m]
V'	=	3127	3127	[$m.h^{-1}$]
Vg	=	1563	3148	[$m.h^{-1}$]
Co	=	1.56	1.56	[-]
Sz	=	10.31	10.31	[m]

1.6.5 *Concentration in outdoor air*

Organic contaminants

PLANT

♦ Cair = Dfs/VFp *f_nd

Cair	: the concentration in air outdoors - plant	[$kg.m^{-3}$]
Dfs	: diffusion flux water-soil to surface level	[$kg.m^{-2}.h^{-1}$]
VFp	: dilution velocity plant (84)	[$m.h^{-1}$]
F_nd	: Non-dissociated fraction	[-]

CHILD

♦ COAc = Dfs/VFc *f_nd

COAc	: the concentration in air outdoors - child	[$kg.m^{-3}$]
Dfs	: diffusion flux water – soil to surface level	[$kg.m^{-2}.h^{-1}$]
VFc	: dilution velocity – child (161.3)	[$m.h^{-1}$]
F_nd	: Non-dissociated fraction	[-]

ADULT

♦ COAa =Dfs/VFa *f_nd

COAa	: concentration in air outdoors adult	[$kg.m^{-3}$]
Dfs	: diffusion flux water-soil to surface level	[$kg.m^{-2}.h^{-1}$]
VFa	: dilution velocity – adult (324.6)	[$m.h^{-1}$]
F_nd	: Non-dissociated fraction	[-]

1.6.6 *Exposure through inhalation of indoor air*

CHILD

- IVci = TIic*CIA2*AV_c*Fa*1000/BW_c

IVci	: exposure via inhalation of vapours – child – indoors	[$g.kg^{-1}$ $bw.d^{-1}$]
TIic	: inhalation period – child – indoors (21.1)	[$h.d^{-1}$]
CIA2	: concentration in indoor air	[$kg.m^{-3}$]
AV_c	: air volume – child (0.317)	[$m^3.h^{-1}$]
Fa	: relative sorption factor	[-]
BW_c	: bodyweight child (15)	[kg]

ADULT

- IVai = TIia*CIA2*AV_a*Fa*1000/BW_a

IVai	: exposure via inhalation of vapours – adult – indoors	[$g.kg^{-1}$ $bw.d^{-1}$]
TIia	: inhalation period – adult – indoors (22.9)	[$h.d^{-1}$]
CIA2	: concentration in indoor air	[$kg.m^{-3}$]
AV_a	: air volume – adult (0.833)	[$m^3.h^{-1}$]
Fa	: relative sorption factor	[-]
BW_a	: bodyweight adult (70)	[kg]

LIFELONG AVERAGE

- IVLi = (l_c*IVci+l_a*IVai)/(l_c+l_a)

IVLi	: exposure via inhalation of vapours lifelong average	[$g.kg^{-1}$ $bw.d^{-1}$]
IVci	: exposure via inhalation of vapours – child - indoors	[$g.kg^{-1}$ $bw.d^{-1}$]
IVai	: exposure via inhalation of vapours – adult – indoors	[$g.kg^{-1}$ $bw.d^{-1}$]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

1.6.7 *Exposure through inhalation of outdoor air*

Child

- IVco = TIoc*COac*Fa*AV_c*1000/BW_c

IVco	: exposure via inhalation of vapours – child - outdoors	[$g.kg^{-1}$ $bw.d^{-1}$]
TIoc	: inhalation period – child – outdoor (2.86)	[$h.d^{-1}$]
COac	: concentration in outdoor air - child	[$kg.m^{-3}$]
Fa	: relative sorption factor	[-]
AV_c	: air volume child (0.317)	[$m^3.h^{-1}$]
BW_c	: bodyweight child (15)	[kg]

Adult

- IVao = TIoa*COaa*Fa*AV_a*1000/BW_a

IVao	: exposure via inhalation of vapours – adult - outdoors	[g.kg^{-1} bw.d^{-1}]
TIoa	: inhalation period – adult – outdoors (1.14)	[h.d^{-1}]
COaa	: concentration in outdoor air - adult	[kg.m^{-3}]
Fa	: relative sorption factor	[-]
AV_a	: air volume adult (0.833)	[m^3.h^{-1}]
BW_a	: bodyweight adult (70)	[kg]

LIFELONG AVERAGE

- IVLO = (l_c*IVco+l_a*IVao)/(l_c+l_a)

IVLO	: exposure via inhalation of vapours lifelong average	[g.kg^{-1} bw.d^{-1}]
IVco	: exposure via inhalation – child – outdoors	[g.kg^{-1} bw.d^{-1}]
IVao	: exposure via inhalation of vapours – adult – outdoors	[g.kg^{-1} bw.d^{-1}]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

1.7 Permeation of contaminants into drinking water through PE pipeline

1.7.1 *Concentration in drinking water*

- Cdw =Dwconst*Dpe*Cpwo*LP*f_nd

Cdw	: concentration in the drinking water	[kg.m^{-3}]
Dwconst	: drinking water constant (178.76)	[d.m^{-3}]
Dpe	: permeation coefficient PE pipeline	[m^2.d^{-1}]
Cpwo	: porewater concentration in non-developed area	[kg.m^{-3}]
LP	: diameter contaminated area (25)	[m]
f_nd	: Non-dissociated fraction	[-]

- Dwconst = (2 * d1* 3 * π * r) / (d2 * Qwd)

d1	: time of water stagnation (0.33)	[d]
r	: radius of pipeline (0.0098)	[m]
d2	: thickness of the pipeline wall (0.0027)	[m]
Qwd	: average daily water use (0.1263)	[m^3]

1.7.2 *Exposure through permeation in drinking water*

CHILD

- DIWc = QDW_c*Cdw*Fa/BW_c

DIWc	: exposure via permeation of drinking water – child	[$g.kg^{-1}$ $bw.d^{-1}$]
QDW_c	: consumption of drinking water – child (1)	[$dm^3.d^{-1}$]
Cdw	: concentration in drinking water	[$kg.dm^{-3}$]
Fa	: relative sorption factor	[-]
BW_c	: bodyweight child (15)	[kg]

ADULT

- DIWa = QDW_a*Cdw*Fa/BW_a

DIWa	: exposure via permeation of drinking water – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
QDW_a	: consumption of drinking water – adult (2)	[$dm^3.d^{-1}$]
Cdw	: concentration in drinking water	[$kg.dm^{-3}$]
Fa	: relative sorption factor	[-]
BW_a	: bodyweight adult (70)	[kg]

LIFELONG AVERAGE

- DIWL = (l_c*DIWc+l_a*DIWa)/(l_c+l_a)

DIWL	: exposure via permeation of drinking water lifelong average	[$mg.kg^{-1}$ $bw.d^{-1}$]
DIWc	: exposure via permeation of drinking water – child	[$mg.kg^{-1}$ $bw.d^{-1}$]
DIWa	: exposure via permeation of drinking water – adult	[$mg.kg^{-1}$ $bw.d^{-1}$]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

1.7.3 *Concentration in bathroom air*

Organic contaminants

- Cbk = Cdw*Kwa*Vwb/(2*Vbk)

Cbk	: concentration in bathroom air	[$kg.dm^{-3}$]
Cdw	: concentration in the drinking water	[$kg.dm^{-3}$]
Kwa	: measure of evaporation of contaminant	[-]
Vwb	:Volume water usage shower (0.051)	[m^3]
Vbk	:Volume bathroom (15)	[m^3]

- Kwa = (KLW_SH*KL*KG) / (KLW_SH*KG+KL)*(Ad/Vd)*tf

KLW_SH	: air - water partition coefficient at bathroom temperature	[-]
KL	: water mass transport coefficient	[$m.s^{-1}$]
KG	: vapour mass transport coefficient	[$m.s^{-1}$]
Ad	: Surface area water droplet	[m^2]
Vd	: Volume water droplet	[m^3]
Tf	: Fall time water droplet	[s]
(Ad/Vd)*tf = 6000		[s/m]

♦

$$KLW_{SH} = \frac{e^{\ln(\mathrm{Klw}*\mathrm{R}*\mathrm{T})+0.024*(Tsh-T)}}{R*Tsh}$$

KLW	: air – water partition coefficient at soil temperature	[-]
R	: gas constant	[Pa.m^3·mol^{-1}.K^{-1}]
T	: soil temperature (283)	[K]
Tsh	: temperature bathing water (313)	[K]

♦ KL = Kl*(44/M)^0.5/3600

♦ KG = Kg*(18/M)^0.5/3600

M	: molecular weight	[g.mol^{-1}]

Constants:

Kl	: exchange speed liquid phase (0.2)	[m.h^{-1}]
Kg	: mass transport coefficient gas phase (29.88)	[m.h^{-1}]

♦ Ad = 4 * π * r^2 [m^2]

♦ VD = 4/3 * π * r^3 [m^3]

r	: radius of water droplet (0,0005)	[m]

1.7.4 *Exposure through inhalation of vapours during showering*

CHILD

♦ IVWc = Cbk*AV$_c$*Td*Fa *1000/BW$_c$

IVWc	: exposure via inhalation of vapours during showering – child	[g.kg^{-1} bw.d^{-1}]
Cbk	: concentration in bathroom air	[kg.m^{-3}]
AV$_c$	: air volume – child (0.317)	[m^3.h^{-1}]
Td	: bathing period (0.5)	[h.d^{-1}]
Fa	: relative sorption factor	[-]
BW$_c$	: bodyweight child (15)	[kg]

ADULT

♦ IVWa = Cbk*AV$_a$*Td*Fa*1000/BW$_a$

IVWa	: exposure via inhalation of vapours during showering – adult	[g.kg^{-1} bw.d^{-1}]
Cbk	: concentration in bathroom air	[kg.m^{-3}]
AV$_a$	: air volume – adult (0.833)	[m^3.h^{-1}]
Td	: bathing period (0.5)	[h.d^{-1}]
Fa	: relative sorption factor	[-]
BW$_a$	: bodyweight adult (70)	[kg]

LIFELONG AVERAGE.

- IVWL = (l_c*IVWc+l_a*IVWa)/(l_c+l_a)

IVWL : exposure via inhalation of vapours during showering lifelong average [$g.kg^{-1}$ $bw.d^{-1}$]
IVWc : exposure via inhalation of vapours during showering – child [$g.kg^{-1}$ $bw.d^{-1}$]
IVWa : exposure via inhalation of vapours during showering – adult [$g.kg^{-1}$ $bw.d^{-1}$]

l_c : Duration child phase (6) [year]
l_a : Duration adult phase (64) [year]

1.7.5 *Exposure through dermal contact with drinking water during showering*

CHILD

- DAWc = ATOTc*Fexp*Tdc*DARw*(1-Kwa)*Cdw*DWexp*Fa/BW_c

DAWc : exposure via dermal contact with drinking water during showering – child [$g.kg^{-1}bw.d^{1}$]
ATOTc: body surface – child (0.95) [m^2]
Fexp : fraction exposed skin during showering (0.40) [-]
Tdc : showering period (0.25) [$h.d^{-1}$]
Kwa : evaporation of a contaminant [-]
Cdw : concentration in drinking water [$kg.m^{-3}$]
Fa : relative sorption factor [-]
BW_c : bodyweight child (15) [kg]
DARw : dermal absorption velocity during showering [$(mg.m^{-2})/(mg.dm^3).h^1$]

$$DARw = \frac{5000 * (0.038 + 0.153 * 10^{\log KOW})}{(5000 + (0.038 + 0.153 * 10^{\log KOW})) * e^{-0.016 * \frac{M}{1.5}}}$$

ADULT

- DAWa = ATOTa*Fexp*Tdc*DARw*(1-Kwa)*Cdw*Fa/BW_a

DAWa : exposure via dermal contact with drinking water during showering – adult [$g.kg^{-1}bw.d^{-1}$]
ATOTa: body surface – adult (1.80) [m^2]
Fexp : fraction exposed skin during showering (0.40) [-]
Tdc : showering period (0.25) [$h.d^{-1}$]
Kwa : evaporation of a contaminant [-]
Cdw : concentration in drinking water [$kg.dm^{-3}$]
Fa : relative sorption factor [-]
BW_a : bodyweight adult (70) [kg]
DARw : dermal absorption velocity during showering [$(mg.m^{-2})/(mg.dm^3).h^{-1}$]

LIFELONG AVERAGE

- DAWL = (l_c*DAWc+l_a*DAWa)/(l_c+l_a)

DAWL : exposure via dermal contact with drinking water during showering lifelong average [$g.kg^{-1}$ $bw.d^{-1}$]
DAWc : exposure via dermal contact with drinking water during showering – child [$g.kg^{-1}$ $bw.d^{-1}$]
DAWa : exposure via dermal contact with drinking water during showering – adult [$g.kg^{-1}$ $bw.d^{-1}$]

l_c : Duration child phase (6) [year]
l_a : Duration adult phase (64) [year]

1.8 Vegetable transfer pathway

1.8.1 *Calculation vapour pressure of a Sub-cooled liquid (organic)*

TEMPmelt is set to 283 by default which effectively disables these formulas

If TEMPmelt > T then;

- VP_L =Vp/(EXP(6.79*(1-TEMPmelt/T)))

VP_L : vapour pressure of sub-cooled liquid [Pa]
Vp : vapour pressure pure product [Pa]
TEMPmelt: melting point (283) [K]
T : soil temperature (283) [K]

If TEMPmelt < T then;

VP_L = Vp

VP_L : vapour pressure of sub-cooled liquid [Pa]
TEMPmelt : melting point (283) [K]
T : soil temperature (283) [K]

1.8.2 *Calculation of BCF for organic contaminants*

- K_plantwater =Fwater_plant+Flipid_plant*K_{ow}^{b}

K_plantwater: partition coefficient plant-water [-]
Fwater_plant: volume fraction water in plant tissue (0.65) [-]
Flipid_plant: volume fraction lipid in plant tissue (0.01) [-]
K_{ow} : octanol-water partition coefficient [-]
b : correction exponent for differences between plant lipid/octanol (0.95) [-]

- K_rootwater = Fwater_root+Flipid_root*$K_{ow}^{b\_root}$

K_rootwater: partition coefficient root-water [-]
Fwater_root: volume fraction water in root (=1-Fdwr) (0.833) [-]
Fdwr : fraction dry matter root (0.167) [kg $dw.kg^{-1}$ fw]
Flipid_root: volume fraction lipid in root (0.005) [-]
K_{ow} : octanol-water partition coefficient [-]

b_root : correction exponent for differences between root lipid/octanol (0.8) [-]

- K_leafair = K_plantwater/Klw

K_leafair: partition coefficient leaf - air [-]
K_plantwater: partition coefficient plant - water [-]
Klw : air-water partition coefficient [-]
Klw = Vp/(S*R*T) or = Za/Zw [-]

S : solubility at soil temperature [mol.m^{-3}]
R : gas constant (8.3144) [Pa.m^3.mol^{-1}.K^{-1}]
T : temperature (283) [K]
Za : fugacity constant air [mol.m^{-3}.Pa^{-1}]
Zw : fugacity constant water [mol.m^{-3}.Pa^{-1}]

- $$Tscf_1 = 0.784 * e^{-\frac{(\log K_{OW} - 1.78)^2}{2.44}}$$

Tscf : transpiration-stream concentration factor [-]
Tscf_1 : according to Briggs (et al 1982) [-]
K_{ow} : octanol-water partition coefficient [-]

- $$Tscf_2 = 0.7 * e^{\frac{(-\log K_{OW} - 3.07)^2}{2.78}}$$

Tscf : transpiration-stream concentration factor [-]
Tscf_2 : according to Hsu (et al 1991) [-]
K_{ow} : octanol-water partition coefficient [-]

The highest result of both equations (Tscf_1,_2) will be used.

Elimination by plant
kelim_plant = kmetab_plant+kphoto_plant

kelim_plant: rate constant for total elimination in plants [d^{-1}]

Constants: set to zero
kmetab_plant: rate constant for metabolism in plants (0) [d^{-1}]
kphoto_plant: rate constant for photolysis in plants (0) [d^{-1}]

- $$ALPHA = \frac{AREA_{plant} * g_{plant}}{K_{leafair} * V_{leaf}} + Kelim_{plant} + Kgrowth_{plant}$$

ALPHA: sink term of differential equation [d^{-1}]
AREA_plant: leaf surface plant (5) [m^2]
g_plant : conductivity plant (80) [m.day^{-1}]
K_leafair: partition coefficient leaf-air [-]

V_leaf: leaf volume (0.002) [m^3]
kelim_plant: rate constant for total elimination in plants [d^{-1}]
kgrowth_plant : rate constant for dilution by growth (0.035) [d^{-1}]

♦

$$BETA = \frac{Cpwo*Tscf*Qtransp}{V\_leaf} + (1 - Fass_{aer}) * \frac{C_{air}*g_{plant}*AREA_{plant}}{V_{leaf}}$$

BETA : source term for differential equation for vegetables [$kg.m^{-3}.day^{-1}$]
Cpwo: porewater concentration in non-developed area soil moisture [$kg.m^{-3}$]
Tscf : transpiration stream concentration factor [-]
Qtransp: transpiration stream (0.001) [$m^3.day^{-1}$]
V_leaf : leaf volume (0.002) [m^3]
Fass_aer: fraction of chemical associated with aerosol particles [-]
COAp : the concentration in air outdoors – plant [$kg.m^{-3}$]
g_plant : conductivity plant (80) [$m.day^{-1}$]
AREA_plant: leaf surface plant (5) [m^2]

♦

$$Fass_{aer} = \frac{CONjunge * surf_{aer}}{VP_L + CONjunge * SURF_{aer}}$$

Fass_aer: fraction of chemical associated with aerosol particles [-]
CONjunge: constant of junge (0.4) [-]
SURF_aer: surface area of aerosol particles (0.00025) [-]
VP_L : vapour pressure pure product [Pa]

♦

$$BCFleafTM = \frac{\frac{Beta}{ALPHA * RHO_{plant}}}{Cpwo} * 1000$$

BCFleafTM: Bio concentration factor leaf (fresh weight) [(g. kg^{-1} fw)/ ($kg.m^{-3}$)]
BETA : source term for differential equation for vegetables [$kg.m^{-3} \cdot day^{-1}$]
ALPHA: sink term of differential equation [d^{-1}]
RHO_plant: density plant tissue (800) [$kg.m^{-3}$]
RHO_water: density of water (1000) [$kg.m^{-3}$]
Cpwo : porewater concentration in non-developed area [$kg.m^{-3}$]

♦

$$BCFrootTM = \frac{K_{rootwater}}{RHO\_root} * 1000$$

BCFrootTM	[(g.m^{-3})/ (kg.m^{-3})]
K_rootwater: partition coefficient root-water	[-]
RHO_root: density root tissue (1000)	[kg.m^{-3}]
RHO_water: density of water (1000)	[kg.m^{-3}]

1.8.3 *Concentration in vegetables*

Organic contaminants

- C_root = Cpwo*BCFroot

C_root: amount in the root on basis of fresh weight (fw)	[g.kg^{-1} fw]
Cpwo : porewater concentration in non-developed area	[kg.m^{-3}]
BCF_root: bioconcentration factor root	[(g.kg^{-1} fw)/ (kg.m^{-3})]

- C_blad = BCF_blad*Cpwo + C_dep_blad

BCF_blad: bioconcentration factor leaf	[(g.kg^{-1} fw)/ (kg.m^{-3})]
Cpwo : porewater concentration in non-developed area	[kg.kg^{-1}]
C_dep_blad : Concentration in leaf due to deposition	[g/kg fw]

Concentration in vegetables due to local deposition

- C_dep_blad= Dpconst*Cgo*Fdws

C_dep_blad: concentration in leaf due to deposition	[g.kg^{-1} fw]
Dpconst : deposition constant (0.01)	[-]
Cgo : initial soil concentration in non-developed area (total concentration in gas-, water- and solid phase)	[kg.kg^{-1}]
Fdws : fraction dry matter leafy vegetables (0.098)	[kg dw.kg^{-1}fw]

Inorganic contaminants

- C_root = Cpwo*(1-Fdwr)

C_root : concentration in the root on basis of fresh weight (fw)	[g.kg^{-1} fw]
Cpwo : porewater concentration in non-developed area	[kg.dm^{-3}]
Fdwr : dry matter fraction in root vegetables (0.167)	[kg dw.kg^{-1}fw]

- C_blad = Cpwo*(1-Fdws)+Dpconst*Cgo*Fdws)

C_blad : concentration in leaves on basis of fresh weight (fw)	[g.kg^{-1} fw]
Cpwo : porewater concentration in non-developed area	[kg.dm^{-3}]
Fdws : dry matter fraction in root vegetables (0.098)	[kg dw.kg^{-1} fw]
Dpconst: deposition constant (0.01)	[-]

Cgo : initial soil concentration in non-developed area (total concentration in gas-, water- and solid phase) [kg.kg^{-1}]

Metals
Empirical data is taken for the BCF value of metals in both root and leaf. For lead and cadmium the BCF can be derived through regression. An in depth explanation can be found in Versluijs and Otte (2001) and Swartjes et al. (2007)

1.8.4 *Exposure through consumption of vegetables*
Since the BCF for organic, inorganic, and metal contaminants are split between root and leaf for organic and inorganic, and potatoes and other vegetabels for metals and empirical BCFs, the exposure pathways use different consumption quantities based on their respective consumption groups.

Organic and inorganic contaminants:
CHILD
♦

$$VIC = \left(QK_C * C_{root} * fvkc + QB_c * C_{leaf} * fvbc\right) * \frac{Fa}{BW_c}$$

VIc	: exposure via ingestion of vegetables – child	[g.kg^{-1} bw.d^{-1}]
QK_c	: consumption root vegetables – child (0.048)	[kg fw.d^{-1}]
C_root	: concentration in root vegetables or potatoes	[g.kg^{-1} fw]
fvkc	: fraction contaminated root vegetables – child (0.1)	[-]
QB_c	: consumption leafy vegetables – child (0.055)	[kg fw.d^{-1}]
C_leaf	: concentration in leafy or other vegetables	[g.kg^{-1} fw]
fvbc	: fraction contaminated root vegetables - child	[-]
Fa	: relative sorption factor	[-]
BW_c	: bodyweight child	[15 kg]

ADULT
♦

$$VIa = QK_A * C_{root} * fvk + QB_a * Cp_{leaf} * fvb) * \frac{FA}{BW\_a}$$

VIa	: exposure via ingestion of vegetables – adult	[g.kg^{-1} bw.d^{-1}]
QK_a	: consumption root vegetables – adult (0.100)	[kg fw.d^{-1}]
C_root	: concentration in root vegetables or potatoes	[g.kg^{-1} fw]
fvka	: fraction contaminated root vegetable – adult (0.1)	[0.1 -]
QB_a	: consumption of leafy vegetables – adult (0.111)	[kg fw.d^{-1}]
C_leaf	: concentration in leafy or other vegetables	[g/kg fw]
fvba	: fraction contaminated leafy vegetables – adult (0.1)	[-]
Fa	: relative sorption factor	[-]
BW_a	: bodyweight adult	[70 kg]

Metals and empirical BCF

CHILD

♦

$$VIc = \left(QK_c * C_{root} * fvkc + QB_c * C_{leaf} * fvbc\right) * \frac{Fa}{BW_c}$$

VIc	: exposure via ingestion of vegetables – child	[g.kg^{-1} bw.d^{-1}]
Qa_c	: consumption root vegetables – child (0.039)	[kg fw.d^{-1}]
C_root	: concentration in root vegetables or potatoes	[g.kg^{-1} fw]
fvkc	: fraction contaminated root vegetables – child (0.1)	[-]
Qo_c	: consumption other vegetables – child (0.064)	[kg fw.d^{-1}]
C_leaf	: concentration in leafy or other vegetables	[g.kg^{-1} fw]
fvbc	: fraction contaminated root vegetables - child	[-]
Fa	: relative sorption factor	[-]
BW_c	: bodyweight child	[15 kg]

ADULT

♦

$$VIA = \left(QK_A * C_{root} * fvk + QB_a * Cp_{leaf} * fvb\right) * \frac{Fa}{BW_a}$$

VIa	: exposure via ingestion of vegetables – adult	[g.kg^{-1} bw.d^{-1}]
Qa_a	: consumption potatoes – adult (0.074)	[kg fw.d^{-1}]
C_root	: concentration in root vegetables or potatoes	[g.kg^{-1} fw]
fvka	: fraction contaminated root vegetable – adult (0.1)	[0.1 -]
Qo_a	: consumption of other vegetables – adult (0.137)	[kg fw.d^{-1}]
C_leaf	: concentration in leafy or other vegetables	[g/kg fw]
fvba	: fraction contaminated leafy vegetables – adult (0.1)	[-]
Fa	: relative sorption factor	[-]
BW_a	: bodyweight adult	[70 kg]

LIFELONG AVERAGE

♦ VIL_{org} = (l_c*VIc+l_a*VIa)/(l_c+l_a)

VIL	= exposure via ingestion of vegetables lifelong average	[g.kg^{-1} bw.d^{-1}]
VIc	: exposure via ingestion of vegetables - child	[g.kg^{-1} bw.d^{-1}]
VIa	: exposure via ingestion vegetables - adult	[g.kg^{-1} bw.d^{-1}]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

Groundwater health risk limit
When a groundwater health risk limit is derived through CSOIL the vegetable pathway is set to zero.

1.9 Aggregated exposure

1.9.1 *Aggregated exposure through inhalation*

CHILD

- SUMac = IPc + IVci+ IVco +IVWc

SUMac: total exposure via inhalation – child [$g.kg^{-1}$ $bw.d^{-1}$]
IPc : exposure via inhalation of soil particles – child [$g.kg^{-1}$ $bw.d^{-1}$]
IVci : exposure via inhalation of indoor air – child [$g.kg^{-1}$ $bw.d^{-1}$]
IVco : exposure via inhalation of outdoor air – child [$g.kg^{-1}$ $bw.d^{-1}$]
IVWc : exposure via inhalation of vapours during showering – child [$g.kg^{-1}$ $bw.d^{-1}$]

ADULT

- SUMao = IPa + IVai + IVao + IVWa

SUMao: total exposure via inhalation - adult [$g.kg^{-1}$ $bw.d^{-1}$]
IPa : exposure via inhalation of soil particles – adult [$g.kg^{-1}$ $bw.d^{-1}$]
IVai : exposure via inhalation of indoor air – adult [$g.kg^{-1}$ $bw.d^{-1}$]
IVao : exposure via inhalation of outdoor air – adult [$g.kg^{-1}$ $bw.d^{-1}$]
IVWa : exposure via inhalation of vapour during showering – adult [$g.kg^{-1}$ $bw.d^{-1}$]

LIFELONG AVERAGE

- SUMAL = (l_c*SUMac+l_a*SUMao)/(l_c+l_a)

SUMAL: total exposure via inhalation lifelong average [$g.kg^{-1}$ $bw.d^{-1}$]
SUMac: total exposure via inhalation – child [$g.kg^{-1}$ $bw.d^{-1}$]
SUMao: total exposure via inhalation – adult [$g.kg^{-1}$ $bw.d^{-1}$]

Although CSOIL 2020 does not calculate a risk index based on a lifelong average exposure, it can be of value to derive a lifelong exposure. Therefore, these formulas are still included in CSOIL 2020

1.9.2 *Aggregated exposure oral and dermal*

CHILD

- SUMOc = DIc + DAci + DAco +Vic + DIWc + DAWc

SUMOc: total exposure oral and dermal – child [$g.kg^{-1}$ $bw.d^{-1}$]
DIc : exposure via ingestion of soil – child [$g.kg^{-1}$ $bw.d^{-1}$]
DAci : exposure via dermal contact indoors – child [$g.kg^{-1}$ $bw.d^{-1}$]
DAco : exposure via dermal contact soil outdoors – child [$g.kg^{-1}$ $bw.d^{-1}$]
VIc : exposure via ingestion of vegetables – child [$g.kg^{-1}$ $bw.d^{-1}$]
DIWc : exposure via permeation in drinking water – child [$g.kg^{-1}$ $bw.d^{-1}$]
DAWc : exposure via dermal uptake with drinking water during showering – child [$g.kg^{-1}$ $bw.d^{-1}$]

ADULT

- SUMOo = DIa + DAai + DAao + Via + DIWa + DAWa

SUMOo:	total exposure oral and dermal – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
DIa	: exposure via ingestion of soil – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
DAai	: exposure via dermal contact soil indoors – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
DAao	: exposure via dermal contact outdoors – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
VIa	: exposure via ingestion of vegetables – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
DIWa	: exposure via permeation of drinking water – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
DAWa	: exposure via dermal contact with drinking water during showering – adult	[$g.kg^{-1}bw.d^{-1}$]

LIFELONG AVERAGE

- SUMOL = (l_c*SUMOc+l_a*SUMOo)/(l_c+l_a)

SUMOL:	total exposure oral and dermal lifelong average	[$g.kg^{-1}$ $bw.d^{-1}$]
SUMOc:	total exposure oral and dermal – child	[$g.kg^{-1}$ $bw.d^{-1}$]
SUMOo:	total exposure oral and dermal – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

1.9.3 *Risk indexes for the aggregated exposure pathways inhalation, and oral and dermal uptake*

The MPR_{human} covers both oral and inhalation exposure (and if necessary also dermal exposure), and classical toxic risks as well as carcinogenic risks. The MPR_{human} can be expressed as a tolerable daily intake (TDI) or an excess carcinogenic risk via intake (CR_{oral}) ($mg.kg^{-1}$ $bw.d^{-1}$). The MPR_{human} can also be expressed as a tolerable concentration in air (TCA) or an excess carcinogenic risk via air (CR_{inhal}) ($\mu g.m^{-3}$) (Baars et al. 2001). In order to combine both aggregated pathways into one risk index, the TCA is converted to the $MPR_{inhalation}$ for child and adult. The lifelong risk index for inhalation is calculated from a 'weighted' summation.

In CSOIL the risk is defined as exposure/MPR

$MPR_{inhalation}$

CHILD

- $MPR_{inhalation\text{-}child}$ = TCA*24*(AVc/BWc)

$MPR_{inhalation\text{-}child}$		[$g.kg^{-1}$ $bw.d^{-1}$]
TCA	: Tolerable concentration air	[$g.m^{-3}$]
AVc	: Breathing volume child (0.317)	[$m^3.h^{-1}$]
BWc	: Bodyweight child (15)	[kg]

ADULT

- $MPR_{inhalation\text{-}adult}$ = TCA*24*(AVa/BWa)

$MPR_{inhalation\text{-}adult}$ [$g.kg^{-1}$ $bw.d^{-1}$]
TCA : Tolerable concentration air [$g.m^{-3}$]
AVc : Breathing volume child (0.833) [$m^3.h^{-1}$]
BWc : Bodyweight child (70) [kg]

RISK INDEX – INHALATION

CHILD

$RI_{child\ -\ inhalation}$ = SUMAc / $MPR_{inhalation\text{-}child}$

SUMAc: total exposure via inhalation – child [$g.kg^{-1}bw.day^{-1}$]
$MPR_{inhalation\text{-}child}$: [$g.kg^{-1}bw.day^{-1}$]

ADULT

$RI_{adult\ -\ inhalation}$ = SUMAo / $MPR_{inhalation\text{-}adult}$

SUMAo: total exposure via inhalation – adult [$g.kg^{-1}bw.day^{-1}$]
$MPR_{inhalation\text{-}adult}$: [$g.kg^{-1}bw.day^{-1}$]

LIFELONG

$$RI_{lifelong-inhalation} = \frac{6*RI_{child-inhalation}+64*RI_{adult-inhalation}}{70}$$

RISK INDEX – ORAL AND DERMAL

CHILD

- Risk – child = SUMOc/MPR

SUMOc: total exposure oral and dermal child [$g.kg^{-1}$ $bw.d^{-1}$]
MPR : Maximum Permissible Risk [$g.kg^{-1}$ $bw.d^{-1}$]

ADULT

- Risk – adult = SUMOo/MPR

SUMOo: total exposure oral- and dermal – adult [$g.kg^{-1}$ $bw.d^{-1}$]
MPR : Maximum Permissible Risk [$g.kg^{-1}$ $bw.d^{-1}$]

LIFELONG

$$RI_{lifelong-oral/dermal} = \frac{6 * RI_{child-\ oral/dermal} + 64 * RI_{adult-\ oral/dermal}}{70}$$

OR

$RI_{lifelong\text{-}oral/dermal}$ = SUMOL/MPR

SUMOL : total exposure oral/dermal lifelong average [$g.kg^{-1}$ $bw.d^{-1}$]
MPR : Maximum Permissible Risk [$g.kg^{-1}$ $bw.d^{-1}$]

In the case of oral and dermal uptake, both calculation methods are valid although only the first is used in CSOIL 2020. In the first method the weighted summation occurs after the Risk indixes for child and adult are derived. In the second method, the total exposure through oral and dermal uptake is calculated through a weighted summation, leading directly to the lifelong Risk Index for oral and dermal uptake.

CORRECTED TOTAL DOSE

Although CSOIL does not use the total dose in the derivation of the risk index, some specific situations may require insight in the total dose and the corrected total dose.

The corrected total dose is required to properly derive a risk index from the total exposure. The total risk index is calculated from the exposure and the MPR. CSOIL 2020 uses both an $MPR_{oral/dermal}$ and an $MPR_{inhalation}$ which can differ in value. Therefore, before deriving a total exposure, the exposure for inhalation must first be corrected for this difference between the MPR for oral and inhalation (see below).

With exposure = risk *MPR
Corrected exposure – child = (~~MPR~~*SUMOc/~~MPR)~~ +(MPR* SUMAc/MPR_AC)
Corrected exposure – adult = (~~MPR~~*SUMOo/~~MPR~~) +(MPR*SUMAo/MPR_AA)

Using these formulas, the total exposure can be calculated as follows.

CHILD

- Tch_{org} = SUMOc+(MPR/MPR_Ac)*SUMAc

Tch_{org}	: total exposure (dose) – child	[$g.kg^{-1}$ $bw.d^{-1}$]
SUMOc	: total exposure oral and dermal child	[$g.kg^{-1}$ $bw.d^{-1}$]
MPR	: Maximum Permissible Risk	[$g.kg^{-1}$ $bw.d^{-1}$]
SUMAc	: total exposure via inhalation – child	[$g.kg^{-1}$ $bw.d^{-1}$]
MPR_Ac	: TDI inhalation child	[$g.kg^{-1}$ $bw.d^{-1}$]

MPR_Ac = TCA*AV_c*24/BW_c

TCA	: acceptable concentration air	
AV_c	: air volume – child (0.317)	[$m^3.h^{-1}$]
BW_c	: bodyweight child (15)	[kg]

ADULT

- Tad_{org} = SUMOo+(MPR/MPR_Aa)*SUMAo

Tad_{org}	: total exposure (or dose) – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
SUMOo	: total exposure oral- and dermal – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
MPR	: maximal permissible risk	[$g.kg^{-1}$ $bw.d^{-1}$]
SUMAo	: total exposure via inhalation – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
MPR_Aa	: TDI inhalation – adult	[$g.kg^{-1}$ $bw.d^{-1}$]

MPR_Aa = TCA*AV_a*24/BW_a

TCA	: acceptable concentration air	
AV_a	: air volume – adult (0.833)	[$m^3.h^{-1}$]
BW_a	: bodyweight adult (70)	[kg]

LIFELONG AVERAGE

- DOSE = (l_c*Tch_{org}+l_a*Tad_{org})/(l_c+l_a)

DOSE	: total exposure (or dose) lifelong average	[$g.kg^{-1}$ $bw.d^{-1}$]
Tch_{org}	: total exposure (or dose) – child	[$g.kg^{-1}$ $bw.d^{-1}$]
Tad_{org}	: total exposure (or dose) – adult	[$g.kg^{-1}$ $bw.d^{-1}$]
l_c	: Duration child phase (6)	[year]
l_a	: Duration adult phase (64)	[year]

1.10 Exposure through direct consumption of contaminated drinking water

Maximum concentration at which the MPR is not exceeded

$$C_{max} = \frac{MPR * 70}{(6 * \frac{QDWc}{BWc} + 64 * \frac{QDWa}{BWa})}$$

C_{max}	: Maximum concentration	[$kg.m^{-3}$]
MPR	: Maximal permissible risk	[$g.kg^{-1}bw.d^{-1}$]
QDWa	: Consumption of groundwater – adult (2)	[$dm^3.d^{-1}$]
QDWc	: Consumption of groundwater – child (1)	[$dm^3.d^{-1}$]
BW_a	: Bodyweight adult (70)	[kg]
BW_c	: Bodyweight child (15)	[kg]

This exposure does not contribute to the total human exposure calculated by CSOIL (this exposure route is not part of a standard exposure scenario in CSOIL and must be calculated separately).

2 Appendix 2 – Parameters of soil use scenarios

The superscript [1] and [2] on the consumption data in the following tables distinguishes between consumption data when modelling 1: organic contaminants; 2: metals and empirically determined BCF's.

Residential with garden:

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	100	50	[mg.day^{-1}]
Time spent indoors	21.14	22.86	[h.day^{-1}]
Time spent outdoors	2.86	1.14	[h.day^{-1}]
Time of soil contact indoors	9.14	14.86	[h.day^{-1}]
Time of soil contact outdoors	2.86	1.14	[h.day^{-1}]
Percentage root vegetables from own garden	10	10	[%]
Percentage leafy vegetables from own garden	10	10	[%]
Daily consumption root vegetables[1]	48	100	[g.day^{-1}]
Daily consumption leafy vegetables[1]	55	111	[g.day^{-1}]
Daily consumption potatoes[2]	39	74	[g.day^{-1}]
Daily consumption other vegetables[2]	64	137	[g.day^{-1}]

Places where children play

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	100	50	[mg.day^{-1}]
Time spent indoors	9.14	14.86	[h.day^{-1}]
Time spent outdoors	2.86	1.14	[h.day^{-1}]
Time of soil contact indoors	9.14	14.86	[h.day^{-1}]
Time of soil contact outdoors	2.86	1.14	[h.day^{-1}]
Percentage root vegetables from own garden	0	0	[%]
Percentage leafy vegetables from own garden	0	0	[%]
Daily consumption root vegetables[1]	48	100	[g.day^{-1}]
Daily consumption leafy vegetables[1]	55	111	[g.day^{-1}]
Daily consumption potatoes[2]	39	74	[g.day^{-1}]
Daily consumption other vegetables[2]	64	137	[g.day^{-1}]

Residential with vegetable/kitchen garden

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	100	50	[mg.day^{-1}]
Time spent indoors	21.14	22.86	[h.day^{-1}]
Time spent outdoors	2.86	1.14	[h.day^{-1}]
Time of soil contact indoors	9.14	14.86	[h.day^{-1}]
Time of soil contact outdoors	2.86	1.14	[h.day^{-1}]
Percentage root vegetables from own garden	50	50	[%]
Percentage leafy vegetables from own garden	100	100	[%]
Daily consumption root vegetables[1]	53	110	[g.day^{-1}]
Daily consumption leafy vegetables[1]	66	189	[g.day^{-1}]
Daily consumption potatoes[2]	39	81	[g.day^{-1}]
Daily consumption other vegetables[2]	64	233	[g.day^{-1}]

Agricultural area

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	100	50	[mg.day^{-1}]
Time spent indoors	21.14	22.86	[h.day^{-1}]
Time spent outdoors	2.86	1.14	[h.day^{-1}]
Time of soil contact indoors	9.14	14.86	[h.day^{-1}]
Time of soil contact outdoors	2.86	1.14	[h.day^{-1}]
Percentage root vegetables from own garden	10	10	[%]
Percentage leafy vegetables from own garden	10	10	[%]
Daily consumption root vegetables[1]	48	100	[g.day^{-1}]
Daily consumption leafy vegetables[1]	55	111	[g.day^{-1}]
Daily consumption potatoes[2]	39	74	[g.day^{-1}]
Daily consumption other vegetables[2]	64	137	[g.day^{-1}]

Nature

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	20	10	[mg.day^{-1}]
Time spent indoors	0	0	[h.day^{-1}]
Time spent outdoors	1	1	[h.day^{-1}]
Time of soil contact indoors	0	0	[h.day^{-1}]
Time of soil contact outdoors	1	1	[h.day^{-1}]
Percentage root vegetables from own garden	0	0	[%]
Percentage leafy vegetables from own garden	0	0	[%]
Daily consumption root vegetables[1]	48	100	[g.day^{-1}]
Daily consumption leafy vegetables[1]	55	111	[g.day^{-1}]
Daily consumption potatoes[2]	39	74	[g.day^{-1}]
Daily consumption other vegetables[2]	64	137	[g.day^{-1}]

Green with nature value, sports, recreation and city parks

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	20	10	[mg.day^{-1}]
Time spent indoors	0	0	[h.day^{-1}]
Time spent outdoors	1	1	[h.day^{-1}]
Time of soil contact indoors	0	0	[h.day^{-1}]
Time of soil contact outdoors	1	1	[h.day^{-1}]
Percentage root vegetables from own garden	0	0	[%]
Percentage leafy vegetables from own garden	0	0	[%]
Daily consumption root vegetables[1]	48	100	[g.day^{-1}]
Daily consumption leafy vegetables[1]	55	111	[g.day^{-1}]
Daily consumption potatoes[2]	39	74	[g.day^{-1}]
Daily consumption other vegetables[2]	64	137	[g.day^{-1}]

Other greens, buildings, infrastructure and industry

Default parameters	Child	Adult	Unit
Soil ingestion yearly average	20	10	[mg.day^{-1}]
Time spent indoors	6	6	[h.day^{-1}]
Time spent outdoors	1	1	[h.day^{-1}]
Time of soil contact indoors	6	6	[h.day^{-1}]
Time of soil contact outdoors	1	1	[h.day^{-1}]
Percentage root vegetables from own garden	0	0	[%]
Percentage leafy vegetables from own garden	0	0	[%]
Daily consumption root vegetables[1]	48	100	[g.day^{-1}]
Daily consumption leafy vegetables[1]	55	111	[g.day^{-1}]
Daily consumption potatoes[2]	39	74	[g.day^{-1}]
Daily consumption other vegetables[2]	64	137	[g.day^{-1}]

3 Appendix 3 – New and updated functionality

This appendix contains a more detailed description of the most recent updates and changes made in CSOIL. Additionally, updates that were discontinued or postponed are also described in each section where relevant. The updates to CSOIL and their status as postponed or implemented are shown in table A3.1.

Table A3.1, Status of the updates explored in CSOIL 2020

Update	Nr	Status
Dissociation of contaminants	1	implemented
Permeation of contaminants based on permeation coefficient	2	implemented
Drinking water usage (and constant)	3	implemented
BCF regression for lead and cadmium	4	implemented
Consumption rates of vegetables	5	implemented
New input options	6	implemented
Fugacity and dissociation	7	postponed
modelled BCF for dissociating contaminants	8	postponed[1]
Permeation of contaminants based on permeation factor	9	postponed

1. The BCF for dissociating contaminants could not be modelled, therefore an empirical BCF should be used.

3.1 Implemented updates

3.1.1 *Dissociating contaminants (1)*

Dissociation of contaminants was introduced to CSOIL to enable more robust modelling of dissociating contaminants like those in the PFAS group. Some challenges however still remain in the proper fate and exposure modelling of dissociating contaminants.

As mentioned in section 4.1.1, the dissociated fraction can be calculated from the pKa of the contaminant and the pH of the soil (equation 2). This method assumes contaminants behave like monoprotic acids and dissociation through other pathways than acid-base reactions were not taken into account. The effects of limiting the model to monoprotic acids or bases is assumed to be small as within the range of soil relevant pH levels, pH 3.0 tot pH 8.0[3] (Otte et al., 2001; Mol et al., 2012; Wamelink et al., 2019), the polyprotic character of acids and bases is usually not relevant. When multiple pKa values are given, the lowest should be used (Webster et al., 2005).

3.1.2 *Permeation of contaminants based on permeation coefficient (2)*

Similar to non-dissociating contaminants, the permeation of dissociating contaminants is only possible for the non-dissociated fraction. Therefore, the CSOIL 2000 method was adapted to only include the non-dissociated fraction as described in section 2.2.2. By multiplying the pore water concentration with the non-dissociated fraction (see section 4.1.1,

[3] The Geochemical soil Atlas mentions a pH range of 2.6 to 7.9 for various soil types, Wamelink et al. modelled pH from plant uptake data with most data points between pH of 3.6 and 8.0. Taking the pKa of the contaminants in the CSOIL database into account, a pH range of 3.0 to 8.0 was deemed appropriate.

equation 2) the pore water concentration for only the non-dissociated fraction can be calculated. This non-dissociated pore water concentration is then used to calculate the drinking water concentration using the formulas shown in appendix 1.7.1.

3.1.3 *Drinking water constant and drinking water usage (3)*

The effect of updating the daily water use for a household was explored before implementation in CSOIL 2020. The update of CSOIL provided an opportunity for harmonization between CSOIL and the model used by KWR to determine the risk limits for permeation found in the permeation guideline (Meerkerk and Van der Schans, 2017). KWR derived the risk limits for permeation based on a daily water usage of 500 liter. KWR is exploring the effect of updating the daily drink water usage on the permeation risk limits. CSOIL 2020 can be further harmonized with the KWR model after new risk limits are derived based on the lower daily drink water usage.

Since the daily drink water usage in CSOIL is only used in the calculation of the drinking water concentration using the permeation coefficient (the secondary method), the updated values for drinking water usage were introduced to CSOIL. As mentioned in section 2.2, the daily water use for a household was revised to 126.3 Liter per day based on Vewin statistics (Vewin, 2017). The Vewin statistics show data for a wide range of water applications split into statistics for (among other) gender and family composition. The water use of a one-person household was used in CSOIL 2020 as this reflects the most sensitive scenario. Lower water consumption (in comparison with a larger household) leads to a higher drinking water concentration as the same amount of contaminant is now permeated into a smaller volume of water. Additionally, all water is used by one person whereas in a larger household the water usage is split between several individuals.

This revision increases the drinking water constant from 45.6 to 178.8 (an increase of a factor ~3.9). The drinking water constant is used together with other constants such as the length of the water pipeline to calculate the contaminant concentration in drinking water (CDW). Because the length of the pipeline was reduced from 100 to 25 (by a factor 0.25; see section 2.3), the net influence of these changes on the drinking water concentration therefore remains small.

3.1.4 *BCF Regression for lead and cadmium (4)*

For lead and cadmium, the option exists to derive a site-specific BCF using a Freundlich-type equation, including soil concentration and soil properties. This equation is based on linear regression Versluijs and Otte (2001) and Swartjes et al. (2007); in the case of lead this regression is based on Versluijs and Otte (2001), Swartjes et al. (2007) and Otte et al. (2011) .The derivation of a site-specific BCF for other metals was not possible, due to the lack of appropriate equations.

Table A3.2 shows the BCF through regression of lead and cadmium at various soil concentrations to delineate the range of the BCF. In the table the overall BCF values are shown. In the regression the BCF is split in a BCF for potatoes and a BCF for other vegetables in line with the BCF for the other metals.

Table A3.2, BCF regression values for lead and cadmium at lowest, highest and half concentration values. The BCF is inversely related to the soil concentration.

Lead	**min**	**half**	**max**
BCF [mg.kg-^{1} fw/ mg.kg^{-1} dw]	0.0049	0.0035	0.0021
conc. Soil [mg/kg dw]	<16.1	77.4	>393
Cadmium	**min**	**half**	**max**
BCF [mg.kg-^{1} fw/ mg.kg^{-1} dw]	0.62	0.38	0.14
Conc. Soil [mg/kg dw]	<0.07	0.32	>6.90

3.1.5 *Consumption rates of vegetables (5)*

The BCF for organic contaminants based on Trapp and Matthies uses consumption rates for vegetables that grow underground and vegetables that grow above ground to determine the exposure through consumption of vegetables (Trapp and Matthies, 1995; Trapp, 2002). However, for metals a different distribution of vegetables was taken, which requires updated consumption rates. The BCF for metals is based on empirical data. Therefore, a different grouping of vegetables is used. Due to potatoes requiring vastly more land to grow than any kitchen garden can realistically provide, the grouping for metal consists of potatoes on the one hand, and all other vegetables on the other. The BCF values are derived accordingly.

In cooperation with the Dutch National Food Consumption Survey (VCP)(Voedsel Consumptie Peiling, 2019), new consumption rates for the relevant vegetables were selected. The consumption data from the VCP survey was grouped in nine different age groups and split for male and female. The consumption data for children and adults was derived from the combined weighted average of consumption for males and females for the age groups between 1 and 6 years old (child), and 7 and 70 years old (adult). These revised values can be found in table A3.3. The vegetable groups and their contribution to the average vegetable consumption can be found in table A3.4.

The VCP consumption data showed the contribution of each vegetable type to the total vegetable consumption for children and adults (table 3.4). Based on these contributions the consumption rates for the vegetable groups “potatoes” and “other”, used for the BCF for metals, was made. For example, the vegetable group potato for adults contributes 35% to the total vegetable consumption of adults, as this group consists of potatoes (34.7%) and unclassified and other tubers (0.3%). In contrast, the vegetable group for underground vegetables for adults (46.6%), used for organic contaminants, consists of potatoes (34.7%), unclassified and other tubers (0.3%), root vegetables (5.8%), and leek, onion, and garlic (5.8%).

Additionally, as kitchen gardeners often consume more vegetables in their diet, consumption data for the use scenario “kitchen garden” was derived from the consumption data for residential with garden and a correction factor derived by Swartjes et al. (2007)

Table A3.3, Daily vegetable consumption of vegetables for children and adults in two use scenarios.

Daily vegetable consumption quantities	kitchen garden		Residential with garden		Unit
	adult	child	adult	child	
$Q_{underground}$	109.9	52.9	100	48.1	[g fw. day^{-1}]
$Q_{above\ ground}$	188.8	66.4	111	55.4	[g fw. day^{-1}]
Total	297.8	119.3	211	103.5	[g fw. day^{-1}]

Table A3.4, Contribution of vegetables to the average vegetable consumption

Vegetable	**Contribution child %**	**contribution adult %**
potatoes	37.5%	34.7%
unclassified and other tubers	0.3%	0.3%
unclassified, mixed salads/ vegetables	3.5%	5.9%
leafy vegetables (except cabbages)	6.1%	9.2%
fruiting vegetables	27.0%	23.3%
root vegetables	7.1%	5.8%
cabbages	11.7%	9.1%
mushrooms	0.7%	1.4%
grain and pod vegetables	1.7%	1.1%
leek, onion, garlic	2.5%	5.8%
stalk vegetables, sprouts	0.3%	1.2%
legumes	1.7%	2.1%

3.1.6 *New input options (6)*

The input for soil concentration was split to inputs for soil concentrations in non-developed area and developed area. Soil in developed area is soil on which houses or other buildings are built. Moreover, an input option for concentration in pore water (both developed and non-developed areas) was added. When a total soil concentration is given, the developed and non-developed area soil concentrations are set as the same given value and the pore water concentrations are calculated from the soil concentrations in the developed and non-developed area. Vice versa soil concentrations can be calculated from a given pore water concentration with notably one uncertainty: when a pore water concentration exceeds the maximum solubility level, no reliable soil concentrations can be calculated and the results of CSOIL become unreliable. Nonetheless, users are still able to give pore water concentrations but will be notified of the limitations of the model when solubility is exceeded.

The new inputs were already introduced to Sanscrit in order to separate soil in open areas from soil under buildings in which case the exposure pathway inhalation of indoor air is enabled. The exposure pathways in CSOIL, previously dependent on the total soil concentration are now dependent on their relevant developed and non-developed inputs. For example, the exposure pathway “Ingestion of soil particles” depends on the soil concentration in non-developed area as in this exposure

pathway, ingestion of soil occurs outdoors. However, the relevance of soil concentrations in developed and non-developed areas to exposure pathways is less clear when dealing with exposure pathways dependent on concentrations in drinking water. For any pathway depending on concentration in drinking water (which is subsequently reliant on the pore water concentration), the concentrations for soil or porewater in the non-developed area were deemed most relevant. This is because the largest part of the water conduit is situated in non-developed area. Table A3.5 shows on which type of concentration the exposure pathways depend.

Table A3.5, Exposure pathways and preceding concentrations.

Exposure pathway	Type of concentration
Ingestion of contaminated soil particles	Non-developed area
Non-developed area	Non-developed area
Dermal contact with soil contaminants (outdoor)	Non-developed area
Inhalation of contaminated soil particles	Non-developed area
Inhalation of vapors of contaminants via crawl space (indoor)	Developed area
Inhalation of vapors of contaminants (outdoor)	Developed area
Ingestion of contaminants via consumption of locally grown vegetables	Non-developed area
ingestion of soil contaminants via drinking water	Non-developed area
Inhalation of vapors of contaminants in the drinking water during showering	Non-developed area
Dermal contact with contaminants in the drinking water during showering and bathing	Non-developed area

3.2 Postponed updates

3.2.1 *Fugacity and dissociation (7)*

The effect of dissociation on the fate modelling through the fugacity modelling was explored using two methods. However, due to time constraints the full implementation of these methods was postponed as uncertainties could not fully be explored. The first method multiplied the mass fractions (Ps, Pw, Pa) with the non-dissociated fraction (f_{nd}) however, this method is only valid when solubility values are available for the non-dissociated and dissociated form of the contaminant. In the case of CSOIL 2020 these solubility values were unavailable, which led to an over estimation of the amount of contaminant in the water phase. The second method corrects for pH differences between the environment and the pH at which solubility was measured. Future implementation of dissociation in the CSOIL 2020 model can build on the second tested method, which is described below.

Dissociation can be introduced in a level 1 fugacity model (Parnis et al., 2020) like CSOIL by correcting the fugacity capacity of the water phase (Mackay, 2001; Webster et al., 2005). The fugacity capacity of the water phase is given by the Henry coefficient, which is a function of the solubility and vapour pressure of the contaminant (see appendix 1.1).

The solubility of dissociating contaminants is dependent on the environmental pH and is given as a combined value for both the dissociated and non-dissociated forms at a certain pH. For acids, this translates into a higher solubility at increasing environmental pH levels.

According to OECD guideline 105 (OECD, 1995) solubility is measured in pure water, assuming a pH of 7. Therefore, the solubility values of dissociating contaminants are only valid for an environmental pH of 7. However, CSOIL uses a standard environmental pH of 6. This leads to an over estimation of the solubility of dissociating contaminants, which in turn leads to an overestimation of the fugacity capacity in water. Therefore, the fugacity capacity for water should be corrected for the difference between the environmental pH and the pH at which the solubility values were measured. This correction can be done based on Mackay (2001) and Webster et al. (2005) by separating the fugacity capacity for water in two separate fugacity capacities for the dissociated and non-dissociated form of the contaminant (see equation 3).

Equation 3. Correction of the fugacity capacity of the water phase for dissociation.

$$Zw_{corrected} = \frac{(1 + 10^{pH_e - pKa})}{1 + 10^{pH_d - pKa}} * Zw_d$$

$Zw_{corrected}$: the fugacity capacity corrected for pH difference between soil and the measured Henry coefficient

pH_e: The pH of the soil (environment)

pH_d: The pH at which the Henry coefficient was measured

pKa: The pKa of the contaminant

Zw_d: The fugacity capacity of water before correction

The effect of this correction was explored by implementing this formula into a beta version of the CSOIL 2020 model. The pore water concentration (CPW) was used to determine the effect of the correction. Additionally, the pH at which the Henry coefficient was determined is assumed to be 7 (1 above the pH of standard soil, and in line with the OECD guidelines). The effect was tested for pentachlorophenol (pKa of 4.85) and 4-chlorophenol (pKa of 9.23). The ratios of corrected to non-corrected porewater concentrations (CPW), fugacity capacities (Zw) and mass fractions (Pw) are shown in tables A3.6 and A3.7.

Table A3.6, Ratios of Zw, Pw, and CPW for pentachlorophenol. Soil relevant pH levels highlighted in blue

pH	$Zw_{corrected}/Zw$	$Pw_{corrected}/Pw$	$CPW_{corrected}/CPW$
0	0.01	0.01	0.01
1	0.01	0.01	0.01
2	0.01	0.01	0.01
3	0.01	0.01	0.01
4	0.01	0.01	0.01
5	0.02	0.02	0.02
6	0.11	0.11	0.11
7	1.00	1.00	1.00
8	9.94	9.70	9.70
9	99.30	78.40	78.40
10	992.98	269.08	269.08
11	9929.71	355.56	355.56
12	99297.04	367.36	367.36
13	992970.32	368.59	368.59
14	9929703.09	368.71	368.71

Table A3.7, ratios of Zw, Pw, and CPW for 4-chlorophenol. Soil relevant pH levels highlighted in blue

pH	$Zw_{corrected}/Zw$	$Pw_{corrected}/Pw$	$CPW_{corrected}/CPW$
0	0.01	0.01	0.01
1	0.01	0.01	0.01
2	0.01	0.01	0.01
3	0.01	0.01	0.01
4	0.01	0.01	0.01
5	0.02	0.02	0.02
6	0.11	0.11	0.11
7	1.00	1.00	1.00
8	9.94	9.70	9.70
9	99.30	78.40	78.40
10	992.98	269.08	269.08
11	9929.71	355.56	355.56
12	99297.04	367.36	367.36
13	992970.32	368.59	368.59
14	9929703.09	368.71	368.71

Pentachlorophenol and 4-chlorophenol have pKa values that are at the outer ranges of pKa values for the dissociating contaminants in CSOIL (4.85 and 9.23 resp.) currently in CSOIL (excluding PFAS). Both contaminants show the same trend in the ratios of Zw, Pw, and CPW with increasing pH. This is as expected since in this implementation of equation 3 in the CSOIL model, only the environmental pH functions as a variable and is not dependent on the contaminant. To further

illustrate: the logarithm of the organic carbon partition coefficient ($LogK_{oc}$) for pentachlorophenol and 4-chlorophenol is 3.2 and 1.93 resp. This suggests that the effect of the pH correction on the fugacity capacity was not influenced by contaminant parameters like the $logK_{oc}$.

Nonetheless, the correction for dissociating contaminants has, at the outer ranges of soil relevant pH levels, an effect of almost a factor 100 (table A3.7) on the soil pore water concentration. The soil pore water concentration affects several exposure pathways: the exposure through inhalation of indoor/ outdoor air of contaminants after volatilization from soil pore water, drinking and other uses of water containing contaminants that permeated through water pipelines, and the exposure through vegetable consumption. Especially inhalation and vegetable consumption are important pathways where dissociating contaminants are concerned. Assuming that Henry coefficients were measured at pH 7 whereas standard soil pH is set at 6, this correction would introduce a factor of 0.11 to the porewater concentration and subsequently to pore water relevant exposure pathways. This reduced porewater concentration increases the human health risk limit (a higher soil concentration at which the risk index is 1) for dissociating contaminants.

Additionally, the fugacity capacity of soil is influenced by the pH of the soil due to its dependency on the organic carbon partition coefficient. Otte et al. (2001) performed a correction for the K_{oc} values for the dissociating contaminants currently in CSOIL, and the values implemented in CSOIL correspond to a standard soil pH of 6. Further implementation of dissociation in CSOIL should, therefore, also correct the K_{oc} values based on the soil pH selected by the users in a similar fashion as done by (Otte et al., 2001) for a pH of 6.

3.2.2 *Dissociation and BCF (8)*

The BCF for organic contaminants is based on the Trapp and Matthies (1995) model which was evaluated by Swartjes et al. (2007). However, this model is only valid for non-dissociating organic contaminants. Dissociating contaminants represent a substantial fraction of the total amount of contaminants of emerging concern (CEC) in the environment. Therefore, dissociation adds an extra challenge to the determination of the BCF for these contaminants.

One possibility is to calculate the dissociated and non-dissociated fractions using the Henderson-Hasselbalch equation (as explained in section 4.1.1) and calculate a BCF through the Trapp and Matthies model for the non-dissociated fraction only. This can be achieved by simply deriving a pore water concentration for the non-dissociated form by multiplying the total pore water concentration with the non-dissociated fraction. From this non-dissociated BCF a plant concentration can be calculated. The dissociated fraction can then be assumed to behave like the inorganic contaminants, which are assumed to be completely dissociated. The dissociated fraction in the pore water would then translate directly into the plant concentration similar to the inorganic contaminants. The highest of the two plant concentrations can then be used to derive the exposure through consumption of vegetables.

However, it is uncertain how both uptake mechanisms would interact with each other. Therefore, the determination of a BCF for dissociating contaminants and the interplay with the dissociated fraction should be further explored before dissociation can be fully implemented into CSOIL. An empirical BCF for dissociating contaminants is required to enable CSOIL to determine risk indexes for dissociating contaminants until a BCF model for dissociating contaminants is implemented.

3.2.3 *Permeation of contaminants into drinking water pipelines based on permeation factor (9)*

Permeation of contaminants from groundwater into drinking water through drinking water pipes depends on the likelihood of a contaminant to permeate into the pipeline wall, as well as the speed at which the contaminant is distributed through the pipeline wall. Especially the distribution of contaminants in a pipeline wall is a challenging process to model as it depends on the concentration in the groundwater as well as the concentration in drinking water at standstill resulting from already permeated contaminant. Permeation is therefore a process that slows down as the drinking water concentration rises over time.

RIVM and the Knowledge and Expertise centre for water (KWR) developed a model in 2016 that, among other things, accounted for the stagnation time of water in pipelines and concentration gradients of contaminants in groundwater and drinking water (Otte et al., 2016; Van der Schans et al., 2016). Based on this model, KWR derived a set of risk limits for various types of pipelines at which the drinking water norm was exceeded (Meerkerk and Van der Schans, 2017). Based on this risk limit and the corresponding drinking water norm, a permeation factor was derived for use in CSOIL as shown in equation 4 and 5. The drinking water concentration was calculated by multiplying this permeation factor with the contaminant concentration in the soil. Care must be taken that the maximum solubility is not exceeded.

Equation 4. Deriving the Linear permeation coefficient from the permeation risk limit for soil.

$$PF_s = \frac{DW\ norm}{RGW_{soil}}$$

With PF_s = the lineair permeation factor soil [$\mu g.L^{-1}$/ $mg.kg^{-1}$], Dw norm = the drinking water norm [$\mu g.L^{-1}$], and RGW_{soil} is the risk limit for permeation based on a soil concentration [$mg.kg^{-1}$].

Equation 5. Calculating the drinking water concentration from the permeation factor for soil.

$$CDW = PE_l * Cs$$

With CDW = the drinking water concentration [$\mu g.L^{-1}$], PE_l = permeation factor [$\mu g.L^{-1}/mg.kg^{-1}$], and Cs the total soil concentration [$mg.kg^{-1}$]

A similar method can be followed to derive the permeation factors based on permeation risk limits for groundwater. However, KWR used an assessment factor of 3 in the derivation of the groundwater risk limits. Therefore, the permeation factor for groundwater should be multiplied by this assessment factor of 3.

For new non-dissociating contaminants, the linear permeation coefficient (PE_l) may not be available. Before permeation of new non-dissociating contaminants can be calculated the permeation factor must be derived from a risk limit (GWR) and drinking water norm. When these too are unavailable, the permeation method of CSOIL 2000 can be used as a placeholder until KWR and RIVM have derived new norms and risk limits.

4 Appendix 4 – Contribution of exposure pathways to the total exposure for all contaminants in CSOIL

The following tables provide an overview of the relative and absolute contribution to the total exposure for contaminants listed in CSOIL 2020[4] using the Soil use scenario 'Residential with garden'. A total soil concentration of 1 mg/kg dry weight was used for all contaminants.

Abbreviations:

DI	:	Soil Ingestion	[$g.kg^{-1}$ $bw.day^{-1}$]
DA	:	Dermal uptake soil	[$g.kg^{-1}$ $bw.day^{-1}$]
IP	:	Inahaltion of soil particles	[$g.kg^{-1}$ $bw.day^{-1}$]
IV	:	Inhalation of air	[$g.kg^{-1}$ $bw.day^{-1}$]
VI	:	Consumption of vegetables	[$g.kg^{-1}$ $bw.day^{-1}$]
DI	:	Permeation drinking water	[$g.kg^{-1}$ $bw.day^{-1}$]
IV	:	Inhalation during showering	[$g.kg^{-1}$ $bw.day^{-1}$]
DA	:	Dermal uptake during showering	[$g.kg^{-1}$ $bw.day^{-1}$]
L	:	Lifelong	
A	:	Adult	
C	:	Child	
I	:	Indoor	
O	:	Outdoor	

[4] The set of contaminants for which soil standards are included in the Environment and Planning Act

Table A4.1 relative contribution [%] of contaminants to the total lifelong exposure.

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
3.22E-08	4	0	0	0	0	0	96	0	0	0	antimony
1.62E-09	77	0	0	1	0	0	23	0	0	0	arsenic
2.29E-09	53	0	0	0	0	0	46	0	0	0	barium
1.05E-08	12	0	0	0	0	0	88	0	0	0	cadmium
1.68E-09	73	0	0	1	0	0	27	0	0	0	chromium (III)
6.41E-08	73	0	0	1	0	0	27	0	0	0	chromium (VI)
5.98E-08	2	0	0	0	0	0	98	0	0	0	cobalt
1.50E-08	12	0	0	0	0	0	88	0	0	0	copper
1.37E-08	9	0	0	0	0	0	91	0	0	0	mercury (inorganic)
1.88E-09	48	0	0	1	0	0	51	0	0	0	lead
7.90E-09	16	0	0	0	0	0	84	0	0	0	molybdenum
3.39E-08	45	0	0	0	0	0	54	0	0	0	nickel
9.45E-09	13	0	0	0	0	0	87	0	0	0	zinc
1.17E-06	0	0	0	0	0	0	100	0	0	0	cyanides (free)
1.17E-06	0	0	0	0	0	0	100	0	0	0	cyanides (complex)
1.17E-06	0	0	0	0	0	0	100	0	0	0	thiocyanate
2.86E-06	0	0	0	0	98	0	1	1	0	0	benzene
8.95E-07	0	0	0	0	97	0	1	1	0	1	ethylbenzene
6.89E-06	0	0	0	0	98	0	1	1	0	1	toluene
1.37E-06	0	0	0	0	95	0	2	1	0	2	o-xylene
1.06E-06	0	0	0	0	96	0	2	1	0	2	m-xylene
6.01E-07	0	0	0	0	96	0	1	1	0	2	p-xylene
2.50E-07	0	0	0	0	91	0	3	2	0	3	styrene
8.57E-08	2	0	0	0	2	0	96	1	0	0	phenol
1.38E-07	1	0	0	0	3	0	49	41	0	6	o-cresol
1.06E-07	1	0	0	0	3	0	48	41	0	6	m-cresol
1.26E-07	1	0	0	0	1	0	51	41	0	6	p-cresol
4.38E-08	3	0	0	0	68	0	20	3	0	6	naphthalene
5.55E-09	22	0	2	0	3	0	60	1	0	10	phenanthrene
4.81E-09	25	0	2	0	2	0	58	1	0	10	anthracene

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
2.81E-09	44	0	4	0	1	0	50	0	0	1	fluoranthene
2.69E-09	45	0	4	0	0	0	50	0	0	0	chrysene
2.14E-09	57	0	5	0	0	0	37	0	0	0	benzo(a)anthracene
3.19E-09	38	0	3	0	0	0	58	0	0	0	benzo(a)pyrene
2.13E-09	57	0	5	0	0	0	37	0	0	0	benzo(k)fluoranthene
5.61E-09	22	0	2	0	0	0	76	0	0	0	indeno(1,2,3-cd) pyrene
2.00E-09	61	0	5	0	0	0	33	0	0	0	benzo(ghi)perylene
2.79E-04	0	0	0	0	100	0	0	0	0	0	monochloroethene
8.49E-07	0	0	0	0	98	0	1	1	0	0	dichloromethane
9.01E-06	0	0	0	0	99	0	1	0	0	0	1,1-dichloroethane
2.16E-06	0	0	0	0	96	0	3	1	0	0	1,2-dichloroethane
2.30E-05	0	0	0	0	98	0	0	1	0	0	1,1-dichloroethene
4.94E-05	0	0	0	0	100	0	0	0	0	0	1,2-dichloroethene (cis)
3.33E-05	0	0	0	0	100	0	0	0	0	0	1,2-dichloroethene (trans)
4.17E-05	0	0	0	0	100	0	0	0	0	0	1,2-dichloroethene (cis,trans)
9.04E-05	0	0	0	0	97	0	1	1	0	0	1,2-dichloropropane
6.46E-05	0	0	0	0	97	0	1	1	0	0	1,3-dichloropropane
5.37E-06	0	0	0	0	98	0	1	1	0	0	trichloromethane
1.01E-05	0	0	0	0	99	0	0	0	0	0	1,1,1-trichloroethane
6.59E-07	0	0	0	0	90	0	3	6	0	0	1,1,2-trichloroethane
4.77E-06	0	0	0	0	99	0	1	1	0	0	trichloroethene
5.79E-06	0	0	0	0	99	0	0	0	0	0	tetrachloromethane
1.82E-06	0	0	0	0	99	0	0	0	0	0	tetrachloroethene
1.74E-06	0	0	0	0	92	0	2	3	0	3	monochlorobenzene
2.06E-07	0	0	0	0	90	0	4	2	0	4	1,4-dichlorobenzene
8.93E-07	0	0	0	0	85	0	6	3	0	5	1,2-dichlorobenzene
1.32E-07	1	0	0	0	88	0	8	1	0	3	1,2,3-trichlorobenzene
9.39E-08	1	0	0	0	87	0	9	1	0	3	1,2,4-trichlorobenzene
6.19E-07	0	0	0	0	99	0	0	0	0	0	1,3,5-trichlorobenzene
1.77E-08	7	0	1	0	31	0	51	2	0	8	1,2,3,4-tetrachlorobenzene
5.50E-08	2	0	0	0	53	0	37	1	0	6	1,2,3,5-tetrachlorobenzene

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
2.36E-07	1	0	0	0	94	0	5	0	0	1	1,2,4,5-tetrachlorobenzene
6.92E-08	2	0	0	0	62	0	34	0	0	2	pentachlorobenzene
4.90E-08	2	0	0	0	3	0	93	0	0	1	hexachlorobenzene
6.76E-08	2	0	0	0	52	0	46	0	0	0	2-chlorophenol
1.27E-08	10	0	1	0	7	0	82	0	0	0	3-chlorophenol
4.40E-08	3	0	0	0	5	0	92	0	0	0	4-chlorophenol
2.20E-08	6	0	0	0	29	0	61	3	0	1	2,3-dichlorophenol
2.22E-08	6	0	0	0	5	0	84	3	0	2	2,4-dichlorophenol
1.71E-08	7	0	1	0	35	0	54	2	0	1	2,5-dichlorophenol
1.71E-08	7	0	1	0	27	0	61	3	0	1	2,6-dichlorophenol
1.61E-08	8	0	1	0	19	0	68	2	0	3	3,4-dichlorophenol
1.01E-07	1	0	0	0	46	0	50	1	0	2	3,5-dichlorophenol
1.37E-08	9	0	1	0	12	0	64	7	0	7	2,3,4-trichlorophenol
1.29E-08	9	0	1	0	2	0	73	7	0	9	2,3,5-trichlorophenol
1.19E-08	10	0	1	0	1	0	80	3	0	5	2,3,6-trichlorophenol
1.01E-08	12	0	1	0	2	0	71	5	0	9	2,4,5-trichlorophenol
7.47E-09	16	0	1	0	2	0	70	3	0	6	2,4,6-trichlorophenol
1.04E-08	12	0	1	0	3	0	71	3	0	10	3,4,5-trichlorophenol
6.96E-09	18	0	2	0	3	0	69	3	0	6	2,3,4,5-tetrachlorophenol
2.65E-08	5	0	0	0	0	0	91	1	0	3	2,3,4,6-tetrachlorophenol
1.11E-08	11	0	1	0	1	0	83	1	0	2	2,3,5,6-tetrachlorophenol
1.13E-07	1	0	0	0	0	0	98	0	0	1	pentachlorophenol
1.22E-08	9	0	1	0	7	0	83	0	0	0	PCB 28
2.94E-08	4	0	0	0	4	0	91	0	0	0	PCB 52
1.37E-08	9	0	1	0	5	0	86	0	0	0	PCB101
4.55E-09	27	0	2	0	0	0	70	0	0	0	PCB 118 (dioxines)
4.54E-09	27	0	2	0	0	0	70	0	0	0	PCB 118 (indicator PCB)
2.58E-08	5	0	0	0	0	0	95	0	0	0	PCB138
1.80E-08	7	0	1	0	0	0	92	0	0	0	PCB153
4.86E-08	3	0	0	0	0	0	97	0	0	0	PCB180
1.77E-08	7	0	1	0	2	0	47	39	0	4	monochloroaniline

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
1.08E-08	11	0	1	0	0	0	87	0	0	0	2,3,7,8-TCDD
1.07E-08	11	0	1	0	0	0	87	0	0	0	PCDD
7.57E-09	16	0	1	0	0	0	82	0	0	0	HxCDD
6.29E-09	19	0	2	0	0	0	79	0	0	0	HpCDD
2.67E-09	46	0	4	0	0	0	49	0	0	0	OCDD
3.84E-09	32	0	3	0	0	0	65	0	0	0	1,2,3,4,6,7,8-HeptaCDF
1.05E-08	12	0	1	0	0	0	87	0	0	0	1,2,3,4,7,8,9-HeptaCDF
1.06E-08	12	0	1	0	1	0	86	0	0	0	1,2,3,4,7,8-HexaCDF
1.05E-08	12	0	1	0	1	0	86	0	0	0	1,2,3,6,7,8-HexaCDF
1.06E-08	12	0	1	0	0	0	87	0	0	0	1,2,3,7,8,9-HexaCDF
1.08E-08	11	0	1	0	0	0	87	0	0	0	1,2,3,7,8-PentaCDF
1.05E-08	12	0	1	0	0	0	87	0	0	0	2,3,4,6,7,8-HexaCDF
1.08E-08	11	0	1	0	1	0	87	0	0	0	2,3,4,7,8,-PentaCDF
1.09E-08	11	0	1	0	0	0	87	0	0	0	2,3,7,8-TetraCDF
2.24E-09	55	0	5	0	0	0	40	0	0	0	OctaCDF
5.42E-09	23	0	2	0	0	0	75	0	0	0	PCB 77
5.41E-09	23	0	2	0	0	0	75	0	0	0	PCB 105
1.11E-08	11	0	1	0	0	0	88	0	0	0	PCB 126
1.05E-08	12	0	1	0	0	0	87	0	0	0	PCB 156
1.05E-08	12	0	1	0	0	0	87	0	0	0	PCB 157
1.28E-08	10	0	1	0	0	0	89	0	0	0	PCB 169
4.27E-06	4	0	0	0	51	0	35	1	0	8	1-chloronaphatalene
1.76E-06	5	0	0	0	29	0	51	2	0	12	2-chloronaphatalene
3.15E-08	7	0	1	0	1	0	91	0	0	0	chlorodane
1.36E-08	9	0	1	0	0	0	90	0	0	0	DDT
2.41E-08	5	0	0	0	0	0	94	0	0	0	DDE
1.01E-08	12	0	1	0	0	0	86	0	0	0	DDD
2.54E-07	0	0	0	0	2	0	98	0	0	0	aldrin
9.25E-09	13	0	1	0	0	0	84	1	0	0	dieldrin
1.04E-08	12	0	1	0	0	0	85	1	0	0	endrin
4.89E-08	10	0	1	0	24	0	59	5	0	2	a-HCH

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
1.14E-08	11	0	1	0	23	0	58	5	0	2	b-HCH
2.51E-08	5	0	0	0	0	0	87	5	0	2	g-HCH
2.75E-08	6	0	1	0	38	0	55	0	0	0	heptachlor
1.91E-07	1	0	0	0	81	0	15	2	0	0	heptachloro epoxide
3.44E-09	36	0	3	0	0	0	57	3	0	1	tri-butyltinoxide
1.55E-09	79	0	7	1	0	0	13	0	0	0	trifenyltin hydroxide
6.22E-07	0	0	0	0	0	0	100	0	0	0	MCPA
2.26E-07	1	0	0	0	0	0	98	1	0	0	atrazine
2.42E-08	5	0	0	0	8	0	75	11	0	1	carbaryl
2.92E-07	0	0	0	0	0	0	96	4	0	0	carbofuran
2.14E-05	0	0	0	0	51	0	44	5	0	0	cyclohexanone
4.50E-08	3	0	0	0	5	0	32	60	0	1	dimethyl phthalate (DMP)
2.30E-08	5	0	0	0	5	0	37	48	0	4	diethyl phthalate (DEP)
4.11E-08	3	0	0	0	1	0	78	7	0	11	diisobutyl phthalate (DIBP)
1.09E-07	1	0	0	0	4	0	80	5	0	10	dibuthyl phthalate (DBP)
1.86E-08	7	0	1	0	0	0	85	3	0	5	butyl benzyl phthalate
9.50E-08	1	0	0	0	1	0	97	0	0	0	dihexyl phthalate (DHP)
5.46E-08	2	0	0	0	0	0	97	0	0	0	bis(2-ethylhexyl)phthalate
6.61E-07	0	0	0	0	100	0	0	0	0	0	aliphatic >EC10-EC12
8.42E-08	0	0	0	0	99	0	1	0	0	0	aliphatic >EC12-EC16
4.96E-08	2	0	0	0	96	0	1	0	0	0	aliphatic >EC16-EC21
5.75E-05	0	0	0	0	100	0	0	0	0	0	aliphatic >EC5-EC6
1.83E-05	0	0	0	0	100	0	0	0	0	0	aliphatic >EC6-EC8
3.53E-06	0	0	0	0	100	0	0	0	0	0	aliphatic >EC8-EC10
1.29E-07	1	0	0	0	91	0	4	1	0	4	aromatic >EC10-EC12
2.46E-08	4	0	0	0	61	0	18	2	0	14	aromatic >EC12-EC16
1.13E-08	11	0	1	0	34	0	38	2	0	13	aromatic >EC16-EC21
4.62E-09	27	0	2	0	5	0	62	1	0	3	aromatic >EC21-EC35
6.93E-06	0	0	0	0	99	0	0	0	0	0	aromatic >EC5-EC7
3.20E-06	0	0	0	0	99	0	0	0	0	1	aromatic >EC7-EC8
6.76E-07	0	0	0	0	98	0	1	0	0	1	aromatic >EC8-EC10

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
8.34E-08	1	0	0	0	3	0	31	64	0	1	pyridine
1.38E-06	0	0	0	0	28	0	23	48	1	0	tetrahydrofuran
7.35E-07	0	0	0	0	65	0	11	21	1	2	tetrahydrothiophene
2.12E-07	0	0	0	0	90	0	9	1	0	0	tribromomethane
2.51E-09	49	0	4	0	0	0	44	2	0	0	tri-fenyltin (compounds)

Table A4.2. Absolute contribution of contaminants to the lifelong exposure.

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
3.22E-08	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	3.09E-08	0.00E+00	0.00E+00	0.00E+00	antimony
1.62E-09	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	3.61E-10	0.00E+00	0.00E+00	0.00E+00	arsenic
2.29E-09	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	1.06E-09	0.00E+00	0.00E+00	0.00E+00	barium
1.05E-08	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	9.22E-09	0.00E+00	0.00E+00	0.00E+00	cadmium
1.68E-09	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	4.51E-10	0.00E+00	0.00E+00	0.00E+00	chromium (III)
6.41E-08	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	4.51E-10	0.00E+00	0.00E+00	0.00E+00	chromium (VI)
5.98E-08	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	5.85E-08	0.00E+00	0.00E+00	0.00E+00	cobalt
1.50E-08	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	9.38E-09	0.00E+00	0.00E+00	0.00E+00	copper
1.37E-08	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	1.22E-08	0.00E+00	0.00E+00	0.00E+00	mercury (inorganic)
1.88E-09	9.06E-10	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	9.66E-10	0.00E+00	0.00E+00	0.00E+00	lead
7.90E-09	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	6.65E-09	0.00E+00	0.00E+00	0.00E+00	molybdenum
3.39E-08	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	1.47E-09	0.00E+00	0.00E+00	0.00E+00	nickel
9.45E-09	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	8.22E-09	0.00E+00	0.00E+00	0.00E+00	zinc
1.17E-06	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	1.16E-06	0.00E+00	0.00E+00	0.00E+00	cyanides (free)
1.17E-06	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	1.16E-06	0.00E+00	0.00E+00	0.00E+00	cyanides (complex)
1.17E-06	1.22E-09	0.00E+00	0.00E+00	9.50E-12	0.00E+00	0.00E+00	1.16E-06	0.00E+00	0.00E+00	0.00E+00	thiocyanate
2.86E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.08E-06	1.30E-09	3.77E-08	4.35E-08	3.56E-09	1.18E-08	benzene
8.95E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.94E-06	4.34E-10	1.99E-08	1.50E-08	1.07E-09	2.72E-08	ethylbenzene
6.89E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.70E-06	8.82E-10	3.42E-08	2.30E-08	1.75E-09	2.00E-08	toluene
1.37E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.21E-06	4.95E-10	4.21E-08	2.51E-08	1.76E-09	4.29E-08	o-xylene
1.06E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.74E-06	3.89E-10	2.77E-08	1.50E-08	1.06E-09	3.04E-08	m-xylene
6.01E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	9.86E-07	2.21E-10	1.49E-08	8.50E-09	6.00E-10	1.54E-08	p-xylene
2.50E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.68E-07	1.06E-10	1.42E-08	1.28E-08	8.69E-10	1.55E-08	styrene
8.57E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.33E-09	6.38E-12	7.48E-08	5.51E-10	1.51E-13	3.36E-11	phenol
1.38E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.15E-09	5.82E-12	6.74E-08	5.68E-08	5.20E-11	8.29E-09	o-cresol
1.06E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.59E-09	4.52E-12	5.12E-08	4.32E-08	4.49E-11	6.46E-09	m-cresol
1.26E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.55E-09	4.76E-12	6.45E-08	5.11E-08	1.96E-11	7.32E-09	p-cresol
4.38E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.99E-08	6.34E-12	8.75E-09	1.28E-09	5.71E-11	2.49E-09	naphthalene
5.55E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.92E-10	4.35E-14	3.35E-09	7.22E-11	7.82E-13	5.81E-10	phenanthrene

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
4.81E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.20E-10	2.94E-14	2.79E-09	6.15E-11	5.15E-13	4.86E-10	anthracene
2.81E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.60E-11	5.33E-15	1.40E-09	3.24E-12	3.83E-14	3.03E-11	fluoranthene
2.69E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.18E-14	2.81E-16	1.34E-09	9.35E-13	3.89E-17	6.99E-12	chrysene
2.14E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.79E-15	2.37E-16	7.81E-10	7.96E-13	1.21E-17	5.71E-12	benzo(a)anthracene
3.19E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.82E-14	2.18E-16	1.83E-09	7.43E-13	9.90E-17	3.88E-12	benzo(a)pyrene
2.13E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.82E-15	8.03E-17	7.82E-10	2.82E-13	6.51E-18	1.47E-12	benzo(k)fluoranthene
5.61E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.21E-15	1.27E-16	4.26E-09	4.69E-13	4.40E-18	1.70E-12	indeno(1,2,3-cd) pyrene
2.00E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.84E-15	4.96E-17	6.54E-10	1.82E-13	4.63E-18	6.51E-13	benzo(ghi)perylene
2.79E-04	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.07E-04	1.42E-07	2.68E-08	2.62E-08	2.48E-09	2.15E-09	monochloroethene
8.49E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.02E-05	2.53E-09	1.14E-07	5.80E-08	4.43E-09	1.93E-09	dichloromethane
9.01E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.25E-05	2.88E-09	6.69E-08	3.10E-08	2.27E-09	2.86E-09	1,1-dichloroethane
2.16E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.15E-06	5.01E-10	7.03E-08	2.08E-08	1.33E-09	9.58E-10	1,2-dichloroethane
2.30E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.18E-05	7.40E-09	4.43E-08	3.66E-07	2.77E-08	7.52E-08	1,1-dichloroethene
4.94E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.81E-05	6.53E-09	3.33E-08	1.35E-09	1.02E-10	3.88E-11	1,2-dichloroethene (cis)
3.33E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.05E-05	1.18E-08	3.26E-08	1.34E-09	1.02E-10	2.57E-11	1,2-dichloroethene (trans)
4.17E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.95E-05	9.19E-09	3.41E-08	1.39E-09	1.05E-10	3.41E-11	1,2-dichloroethene (cis,trans)
9.04E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.69E-06	1.02E-09	6.60E-08	5.76E-08	3.80E-09	6.89E-09	1,2-dichloropropane
6.46E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.69E-06	1.02E-09	6.60E-08	5.76E-08	3.80E-09	6.89E-09	1,3-dichloropropane
5.37E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.31E-06	1.13E-09	5.55E-08	4.87E-08	3.18E-09	5.04E-09	trichloromethane
1.01E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.43E-05	2.89E-09	4.69E-08	4.94E-08	3.17E-09	2.72E-08	1,1,1-trichloroethane
6.59E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	7.39E-07	1.51E-10	2.79E-08	5.02E-08	2.74E-09	3.59E-09	1,1,2-trichloroethane
4.77E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.68E-06	1.15E-09	3.30E-08	3.27E-08	2.10E-09	1.21E-08	trichloroethene
5.79E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.58E-05	4.87E-09	7.66E-08	3.14E-08	1.88E-09	1.36E-08	tetrachloromethane
1.82E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	8.36E-06	1.52E-09	3.51E-08	7.27E-09	4.20E-10	9.18E-09	tetrachloroethene
1.74E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.24E-06	2.72E-10	2.28E-08	3.84E-08	2.58E-09	3.58E-08	monochlorobenzene
2.06E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.43E-07	6.63E-11	1.52E-08	7.37E-09	4.30E-10	1.37E-08	1,4-dichlorobenzene
8.93E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.52E-07	6.82E-11	2.46E-08	1.22E-08	6.87E-10	2.23E-08	1,2-dichlorobenzene
1.32E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.99E-07	3.49E-11	1.79E-08	1.44E-09	7.70E-11	5.99E-09	1,2,3-trichlorobenzene
9.39E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.38E-07	2.42E-11	1.38E-08	1.28E-09	6.79E-11	4.60E-09	1,2,4-trichlorobenzene

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
6.19E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.16E-06	2.03E-10	3.61E-09	2.56E-10	1.42E-11	1.15E-09	1,3,5-trichlorobenzene
1.77E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.44E-09	8.91E-13	9.09E-09	3.02E-10	1.18E-11	1.46E-09	1,2,3,4-tetrachlorobenzene
5.50E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.94E-08	4.76E-12	2.04E-08	6.59E-10	2.99E-11	3.19E-09	1,2,3,5-tetrachlorobenzene
2.36E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.20E-07	3.54E-11	1.16E-08	4.16E-10	2.10E-11	1.86E-09	1,2,4,5-tetrachlorobenzene
6.92E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.31E-08	6.46E-12	2.33E-08	2.95E-10	1.35E-11	1.16E-09	pentachlorobenzene
4.90E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.33E-09	1.98E-13	4.59E-08	2.14E-10	5.03E-12	5.96E-10	hexachlorobenzene
6.76E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.53E-08	9.21E-12	3.08E-08	1.25E-10	1.66E-12	2.01E-11	2-chlorophenol
1.27E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	8.83E-10	7.09E-13	1.04E-08	3.34E-11	5.07E-14	1.23E-11	3-chlorophenol
4.40E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.20E-09	2.62E-12	4.02E-08	1.37E-10	1.27E-13	3.95E-11	4-chlorophenol
2.20E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.32E-09	1.62E-12	1.34E-08	6.53E-10	5.66E-12	2.95E-10	2,3-dichlorophenol
2.22E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.01E-09	6.69E-13	1.86E-08	6.88E-10	1.04E-12	5.19E-10	2,4-dichlorophenol
1.71E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.93E-09	1.34E-12	9.18E-09	3.50E-10	4.79E-12	2.55E-10	2,5-dichlorophenol
1.71E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.57E-09	1.19E-12	1.05E-08	4.97E-10	4.12E-12	1.83E-10	2,6-dichlorophenol
1.61E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.07E-09	7.79E-13	1.10E-08	3.06E-10	2.74E-12	4.09E-10	3,4-dichlorophenol
1.01E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.61E-08	9.23E-12	5.05E-08	1.09E-09	2.76E-11	2.08E-09	3,5-dichlorophenol
1.37E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.71E-09	4.05E-13	8.79E-09	9.26E-10	7.03E-12	9.44E-10	2,3,4-trichlorophenol
1.29E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.25E-10	1.46E-13	9.39E-09	8.46E-10	1.05E-12	1.13E-09	2,3,5-trichlorophenol
1.19E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	8.04E-11	5.21E-14	9.57E-09	3.03E-10	3.77E-13	5.92E-10	2,3,6-trichlorophenol
1.01E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.15E-10	9.89E-14	7.16E-09	4.92E-10	9.94E-13	8.71E-10	2,4,5-trichlorophenol
7.47E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.74E-10	6.21E-14	5.26E-09	2.59E-10	7.86E-13	4.30E-10	2,4,6-trichlorophenol
1.04E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.30E-10	9.88E-14	7.35E-09	3.41E-10	1.46E-12	1.03E-09	3,4,5-trichlorophenol
6.96E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.89E-10	3.98E-14	4.82E-09	1.79E-10	1.41E-12	4.29E-10	2,3,4,5-tetrachlorophenol
2.65E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.26E-10	3.83E-14	2.40E-08	3.17E-10	1.05E-12	6.69E-10	2,3,4,6-tetrachlorophenol
1.11E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.25E-10	2.85E-14	9.25E-09	1.56E-10	9.66E-13	2.14E-10	2,3,5,6-tetrachlorophenol
1.13E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.26E-11	8.89E-15	1.10E-07	2.29E-10	4.05E-13	7.79E-10	pentachlorophenol

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
1.22E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	8.51E-10	1.29E-13	1.07E-08	1.20E-11	4.04E-13	4.95E-11	PCB 28
2.94E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.37E-09	1.92E-13	2.79E-08	9.79E-12	3.58E-13	2.43E-11	PCB 52
1.37E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.93E-10	9.11E-14	1.23E-08	1.45E-12	5.68E-14	2.08E-12	PCB101
4.55E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.74E-12	9.39E-16	3.20E-09	2.19E-13	4.79E-15	3.34E-13	PCB 118 (dioxines)
4.54E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.74E-12	9.39E-16	3.20E-09	2.19E-13	4.79E-15	3.34E-13	PCB 118 (indicator PCB)
2.58E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.44E-12	7.80E-16	2.44E-08	2.39E-12	1.36E-14	2.21E-12	PCB138
1.80E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.18E-11	4.12E-15	1.66E-08	1.65E-12	4.14E-14	1.44E-12	PCB153
4.86E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.67E-11	3.29E-15	4.72E-08	1.26E-12	3.11E-14	6.31E-13	PCB180
1.77E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.38E-10	6.25E-13	8.43E-09	6.99E-09	3.95E-12	6.38E-10	monochloroaniline
1.08E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.79E-12	8.02E-16	9.44E-09	6.05E-13	2.57E-15	1.04E-12	2,3,7,8-TCDD
1.07E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.17E-13	1.21E-16	9.31E-09	1.98E-13	1.53E-16	2.00E-13	PCDD
7.57E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.18E-12	1.69E-16	6.22E-09	6.26E-14	6.03E-16	3.53E-14	HxCDD
6.29E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.89E-14	1.70E-17	4.94E-09	3.41E-14	1.23E-17	1.15E-14	HpCDD
2.67E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.61E-14	4.17E-18	1.32E-09	5.69E-15	9.73E-18	1.09E-15	OCDD
3.84E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	7.46E-12	8.83E-16	2.49E-09	1.92E-14	6.23E-16	7.53E-15	1,2,3,4,6,7,8-HeptaCDF
1.05E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.19E-12	3.11E-16	9.14E-09	1.20E-13	1.11E-15	5.07E-14	1,2,3,4,7,8,9-HeptaCDF
1.06E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.39E-10	1.71E-14	9.14E-09	9.11E-14	3.40E-15	6.10E-14	1,2,3,4,7,8-HexaCDF
1.05E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	9.73E-11	1.19E-14	9.10E-09	7.41E-14	2.75E-15	4.96E-14	1,2,3,6,7,8-HexaCDF
1.06E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.99E-11	2.50E-15	9.26E-09	1.41E-13	3.93E-15	9.75E-14	1,2,3,7,8,9-HexaCDF
1.08E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.11E-11	5.55E-15	9.39E-09	5.49E-13	1.28E-14	6.65E-13	1,2,3,7,8-PentaCDF
1.05E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.92E-11	3.61E-15	9.10E-09	7.41E-14	2.52E-15	5.01E-14	2,3,4,6,7,8-HexaCDF
1.08E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	7.16E-11	9.46E-15	9.39E-09	5.49E-13	1.57E-14	6.54E-13	2,3,4,7,8,-PentaCDF
1.09E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.43E-11	3.81E-15	9.49E-09	9.99E-13	1.31E-14	2.16E-12	2,3,7,8-TetraCDF
2.24E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	7.64E-13	8.74E-17	8.88E-10	3.06E-15	8.91E-17	6.99E-16	OctaCDF
5.42E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.12E-11	1.74E-15	4.05E-09	6.93E-13	1.12E-14	1.86E-12	PCB 77
5.41E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.36E-12	7.93E-16	4.05E-09	3.64E-13	5.25E-15	5.67E-13	PCB 105
1.11E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	8.48E-12	1.25E-15	9.69E-09	5.63E-13	8.24E-15	8.79E-13	PCB 126
1.05E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.59E-12	7.51E-16	9.18E-09	5.61E-13	1.05E-14	4.98E-13	PCB 156
1.05E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.72E-12	9.03E-16	9.18E-09	6.74E-13	1.26E-14	5.99E-13	PCB 157
1.28E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	8.13E-13	2.15E-16	1.15E-08	1.20E-12	2.74E-15	1.12E-12	PCB 169
4.27E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.61E-08	3.03E-12	1.09E-08	4.66E-10	2.07E-11	2.53E-09	1-chloronaphatalene

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
1.76E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.59E-09	1.28E-12	1.17E-08	4.66E-10	1.53E-11	2.80E-09	2-chloronaphatalene
3.15E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.72E-10	2.29E-14	1.52E-08	3.08E-11	3.83E-13	1.21E-11	chlorodane
1.36E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.80E-12	5.33E-16	1.23E-08	3.23E-12	6.16E-15	3.33E-12	DDT
2.41E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.52E-12	7.53E-16	2.27E-08	5.48E-12	5.65E-15	1.02E-11	DDE
1.01E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.70E-13	9.01E-16	8.72E-09	8.10E-12	2.52E-15	1.44E-11	DDD
2.54E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.05E-09	5.15E-13	2.48E-07	1.41E-10	3.99E-12	1.12E-10	aldrin
9.25E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.92E-12	1.20E-14	7.73E-09	1.25E-10	1.36E-14	4.46E-11	dieldrin
1.04E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.17E-12	1.28E-14	8.84E-09	1.38E-10	4.06E-15	4.89E-11	endrin
4.89E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.97E-09	4.73E-13	7.29E-09	5.73E-10	8.04E-12	2.19E-10	a-HCH
1.14E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.68E-09	4.26E-13	6.66E-09	5.22E-10	7.27E-12	2.00E-10	b-HCH
2.51E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.39E-11	1.40E-13	2.19E-08	1.25E-09	2.53E-13	4.99E-10	g-HCH
2.75E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	7.66E-09	9.45E-13	1.09E-08	4.35E-11	1.59E-12	2.68E-11	heptachlor
1.91E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.64E-08	8.11E-12	1.24E-08	1.40E-09	4.32E-11	6.61E-11	heptachloro epoxide
3.44E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.68E-12	1.06E-14	1.96E-09	9.74E-11	1.06E-14	3.36E-11	tri-butyltinoxide
1.55E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.19E-14	1.69E-16	1.98E-10	1.72E-12	2.19E-16	1.38E-13	trifenyltin hydroxide
6.22E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.09E-11	2.41E-12	6.21E-07	3.80E-11	1.12E-18	6.71E-12	MCPA
2.26E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.33E-11	9.20E-13	2.21E-07	3.01E-09	1.77E-15	3.57E-10	atrazine
2.42E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.90E-09	1.13E-12	1.82E-08	2.58E-09	3.52E-12	2.17E-10	carbaryl
2.92E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	7.82E-11	3.09E-12	2.80E-07	1.02E-08	4.64E-14	1.18E-10	carbofuran
2.14E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.90E-07	5.97E-11	1.66E-07	1.74E-08	2.11E-10	2.17E-10	cyclohexanone
4.50E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.11E-09	1.22E-12	1.42E-08	2.69E-08	3.96E-11	4.06E-10	dimethyl phthalate (DMP)
2.30E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.20E-09	5.25E-13	8.43E-09	1.11E-08	2.10E-11	8.58E-10	diethyl phthalate (DEP)
4.11E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.33E-10	1.09E-13	3.21E-08	2.82E-09	3.68E-12	4.64E-09	diisobutyl phthalate (DIBP)
1.09E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.29E-09	7.46E-13	8.78E-08	5.11E-09	5.35E-11	1.08E-08	dibuthyl phthalate (DBP)
1.86E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	6.08E-12	1.61E-14	1.58E-08	6.03E-10	9.30E-14	8.79E-10	butyl benzyl phthalate
9.50E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.07E-09	1.42E-13	9.24E-08	1.10E-10	3.51E-12	1.42E-10	dihexyl phthalate (DHP)
5.46E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.01E-11	1.69E-15	5.32E-08	2.09E-11	1.18E-13	1.20E-11	bis(2-ethylhexyl)phthalate
6.61E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.99E-06	3.68E-10	2.50E-09	3.90E-11	2.31E-12	7.15E-10	aliphatic >EC10-EC12

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
8.42E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.47E-07	4.11E-11	1.45E-09	1.96E-12	1.04E-13	2.03E-11	aliphatic >EC12-EC16
4.96E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.76E-08	6.85E-12	6.16E-10	9.81E-15	4.47E-16	3.42E-14	aliphatic >EC16-EC21
5.75E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.60E-04	4.03E-08	8.47E-09	1.00E-08	8.36E-10	3.53E-08	aliphatic >EC5-EC6
1.83E-05	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.11E-05	1.17E-08	5.72E-09	2.32E-09	1.74E-10	2.54E-08	aliphatic >EC6-EC8
3.53E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.07E-05	2.18E-09	3.72E-09	3.06E-10	2.01E-11	6.58E-09	aliphatic >EC8-EC10
1.29E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.71E-07	3.50E-11	6.90E-09	1.36E-09	8.69E-11	6.66E-09	aromatic >EC10-EC12
2.46E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.89E-08	3.65E-12	5.71E-09	6.85E-10	3.66E-11	4.34E-09	aromatic >EC12-EC16
1.13E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.90E-09	6.76E-13	4.36E-09	2.17E-10	9.65E-12	1.48E-09	aromatic >EC16-EC21
4.62E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.37E-10	3.72E-14	2.86E-09	2.73E-11	9.06E-13	1.45E-10	aromatic >EC21-EC35
6.93E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	4.18E-06	1.07E-09	9.38E-09	3.40E-09	2.88E-10	1.55E-08	aromatic >EC5-EC7
3.20E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	1.92E-06	4.58E-10	8.63E-09	2.71E-09	2.11E-10	1.26E-08	aromatic >EC7-EC8
6.76E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	9.95E-07	2.11E-10	7.98E-09	2.16E-09	1.46E-10	8.16E-09	aromatic >EC8-EC10
8.34E-08	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.88E-09	3.50E-12	2.64E-08	5.49E-08	8.24E-11	6.73E-10	pyridine
1.38E-06	1.22E-09	7.62E-12	1.06E-10	9.50E-12	3.90E-07	1.39E-10	3.17E-07	6.75E-07	9.84E-09	6.05E-09	tetrahydrofuran
7.35E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.05E-07	1.30E-10	8.63E-08	1.67E-07	6.83E-09	1.36E-08	tetrahydrothiophene
2.12E-07	1.22E-09	7.62E-12	1.06E-10	9.50E-12	2.76E-07	4.19E-11	2.73E-08	1.61E-09	5.74E-11	1.08E-10	tribromomethane
2.51E-09	1.22E-09	7.62E-12	1.06E-10	9.50E-12	5.39E-13	5.44E-15	1.10E-09	5.61E-11	1.95E-15	3.46E-12	tri-fenyltin (compounds)

Table A4.3. Absolute contribution of contaminants to the exposure during the child phase.

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
7.07E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	6.40E-08	0.00E+00	0.00E+00	0.00E+00	antimony
7.42E-09	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	7.21E-10	0.00E+00	0.00E+00	0.00E+00	arsenic
8.80E-09	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	2.12E-09	0.00E+00	0.00E+00	0.00E+00	barium
2.53E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	1.86E-08	0.00E+00	0.00E+00	0.00E+00	cadmium
7.61E-09	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	9.42E-10	0.00E+00	0.00E+00	0.00E+00	chromium (III)
6.94E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	9.42E-10	0.00E+00	0.00E+00	0.00E+00	chromium (VI)
1.23E-07	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	1.16E-07	0.00E+00	0.00E+00	0.00E+00	cobalt
3.03E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	1.93E-08	0.00E+00	0.00E+00	0.00E+00	copper
3.16E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	2.46E-08	0.00E+00	0.00E+00	0.00E+00	mercury (inorganic)
6.87E-09	4.93E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	1.92E-09	0.00E+00	0.00E+00	0.00E+00	lead
2.00E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	1.33E-08	0.00E+00	0.00E+00	0.00E+00	molybdenum

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
4.05E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	2.99E-09	0.00E+00	0.00E+00	0.00E+00	nickel
2.31E-08	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	1.65E-08	0.00E+00	0.00E+00	0.00E+00	zinc
2.41E-06	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	2.40E-06	0.00E+00	0.00E+00	0.00E+00	cyanides (free)
2.41E-06	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	2.40E-06	0.00E+00	0.00E+00	0.00E+00	cyanides (complex)
2.41E-06	6.67E-09	0.00E+00	0.00E+00	1.56E-11	0.00E+00	0.00E+00	2.40E-06	0.00E+00	0.00E+00	0.00E+00	thiocyanate
2.77E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.89E-06	6.92E-09	7.65E-08	9.12E-08	5.93E-09	2.58E-08	benzene
9.12E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.02E-06	2.31E-09	4.04E-08	3.14E-08	1.77E-09	5.94E-08	ethylbenzene
6.51E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.76E-06	4.70E-09	6.95E-08	4.82E-08	2.90E-09	4.39E-08	toluene
1.41E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.43E-06	2.63E-09	8.54E-08	5.27E-08	2.92E-09	9.39E-08	o-xylene
1.08E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.70E-06	2.07E-09	5.63E-08	3.14E-08	1.76E-09	6.66E-08	m-xylene
6.11E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.53E-06	1.18E-09	3.02E-08	1.78E-08	9.97E-10	3.38E-08	p-xylene
2.88E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.27E-07	5.64E-10	2.88E-08	2.67E-08	1.45E-09	3.39E-08	styrene
1.69E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.07E-09	3.39E-11	1.52E-07	1.15E-09	2.51E-13	7.36E-11	phenol
2.85E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.45E-09	3.10E-11	1.37E-07	1.19E-07	8.65E-11	1.82E-08	o-cresol
2.19E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.58E-09	2.41E-11	1.04E-07	9.04E-08	7.47E-11	1.41E-08	m-cresol
2.63E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.42E-09	2.53E-11	1.31E-07	1.07E-07	3.26E-11	1.60E-08	p-cresol
7.96E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.65E-08	3.38E-11	1.78E-08	2.68E-09	9.50E-11	5.45E-09	naphthalene
1.57E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.99E-10	2.32E-13	6.82E-09	1.51E-10	1.30E-12	1.27E-09	phenanthrene
1.42E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.87E-10	1.57E-13	5.68E-09	1.29E-10	8.57E-13	1.06E-09	anthracene
1.01E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.04E-11	2.84E-14	2.86E-09	6.79E-12	6.36E-14	6.64E-11	fluoranthene
9.85E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.38E-14	1.50E-15	2.72E-09	1.96E-12	6.47E-17	1.53E-11	chrysene
8.72E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.06E-14	1.26E-15	1.60E-09	1.67E-12	2.02E-17	1.25E-11	benzo(a)anthracene
1.09E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	9.06E-14	1.16E-15	3.73E-09	1.55E-12	1.65E-16	8.48E-12	benzo(a)pyrene
8.71E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.94E-15	4.27E-16	1.60E-09	5.91E-13	1.08E-17	3.22E-12	benzo(k)fluoranthene
1.58E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.99E-15	6.75E-16	8.65E-09	9.81E-13	7.32E-18	3.72E-12	indeno(1,2,3-cd) pyrene
8.45E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.42E-15	2.64E-16	1.34E-09	3.82E-13	7.70E-18	1.42E-12	benzo(ghi)perylene
2.60E-04	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.89E-04	7.56E-07	5.44E-08	5.48E-08	4.13E-09	4.70E-09	monochloroethene
9.91E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.59E-05	1.35E-08	2.31E-07	1.21E-07	7.36E-09	4.22E-09	dichloromethane
8.51E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.94E-05	1.54E-08	1.36E-07	6.49E-08	3.78E-09	6.26E-09	1,1-dichloroethane
2.12E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.34E-06	2.67E-09	1.43E-07	4.37E-08	2.20E-09	2.10E-09	1,2-dichloroethane
2.20E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.95E-05	3.94E-08	9.00E-08	7.66E-07	4.60E-08	1.64E-07	1,1-dichloroethene

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
4.61E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.37E-05	3.48E-08	6.77E-08	2.82E-09	1.70E-10	8.50E-11	1,2-dichloroethene (cis)
3.11E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.85E-05	6.26E-08	6.62E-08	2.81E-09	1.69E-10	5.62E-11	1,2-dichloroethene (trans)
3.89E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.14E-05	4.89E-08	6.92E-08	2.91E-09	1.75E-10	7.47E-11	1,2-dichloroethene (cis,trans)
8.43E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.29E-06	5.45E-09	1.34E-07	1.21E-07	6.32E-09	1.51E-08	1,2-dichloropropane
6.03E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.29E-06	5.45E-09	1.34E-07	1.21E-07	6.32E-09	1.51E-08	1,3-dichloropropane
5.13E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	8.26E-06	6.02E-09	1.13E-07	1.02E-07	5.29E-09	1.10E-08	trichloromethane
9.54E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.23E-05	1.54E-08	9.52E-08	1.03E-07	5.28E-09	5.95E-08	1,1,1-trichloroethane
7.13E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.15E-06	8.03E-10	5.67E-08	1.05E-07	4.55E-09	7.86E-09	1,1,2-trichloroethane
4.53E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	8.84E-06	6.15E-09	6.70E-08	6.85E-08	3.49E-09	2.65E-08	trichloroethene
5.54E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.01E-05	2.59E-08	1.56E-07	6.58E-08	3.13E-09	2.98E-08	tetrachloromethane
1.76E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.30E-05	8.10E-09	7.12E-08	1.52E-08	6.99E-10	2.01E-08	tetrachloroethene
1.74E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.93E-06	1.45E-09	4.64E-08	8.05E-08	4.30E-09	7.83E-08	monochlorobenzene
2.41E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.33E-07	3.53E-10	3.08E-08	1.54E-08	7.15E-10	3.00E-08	1,4-dichlorobenzene
9.07E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.47E-07	3.63E-10	4.99E-08	2.55E-08	1.14E-09	4.88E-08	1,2-dichlorobenzene
1.58E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.10E-07	1.86E-10	3.64E-08	3.02E-09	1.28E-10	1.31E-08	1,2,3-trichlorobenzene
1.16E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.15E-07	1.29E-10	2.79E-08	2.69E-09	1.13E-10	1.01E-08	1,2,4-trichlorobenzene
5.88E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.81E-06	1.08E-09	7.35E-09	5.37E-10	2.37E-11	2.51E-09	1,3,5-trichlorobenzene
3.79E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	8.46E-09	4.74E-12	1.85E-08	6.32E-10	1.96E-11	3.20E-09	1,2,3,4-tetrachlorobenzene
1.03E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.57E-08	2.53E-11	4.14E-08	1.38E-09	4.97E-11	6.98E-09	1,2,3,5-tetrachlorobenzene
3.78E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.42E-07	1.88E-10	2.36E-08	8.71E-10	3.49E-11	4.08E-09	1,2,4,5-tetrachlorobenzene
1.25E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.71E-08	3.44E-11	4.72E-08	6.17E-10	2.24E-11	2.54E-09	pentachlorobenzene
1.03E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.07E-09	1.06E-12	9.32E-08	4.47E-10	8.37E-12	1.30E-09	hexachlorobenzene
1.25E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.49E-08	4.90E-11	6.26E-08	2.62E-10	2.76E-12	4.39E-11	2-chlorophenol
2.98E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.37E-09	3.77E-12	2.12E-08	6.98E-11	8.43E-14	2.70E-11	3-chlorophenol
9.28E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.42E-09	1.39E-11	8.18E-08	2.87E-10	2.12E-13	8.64E-11	4-chlorophenol
4.62E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	9.83E-09	8.62E-12	2.72E-08	1.37E-09	9.42E-12	6.45E-10	2,3-dichlorophenol

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
4.92E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.57E-09	3.56E-12	3.79E-08	1.44E-09	1.73E-12	1.14E-09	2,4-dichlorophenol
3.63E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	9.23E-09	7.11E-12	1.86E-08	7.34E-10	7.96E-12	5.58E-10	2,5-dichlorophenol
3.71E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.10E-09	6.32E-12	2.14E-08	1.04E-09	6.86E-12	4.01E-10	2,6-dichlorophenol
3.58E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.77E-09	4.15E-12	2.24E-08	6.42E-10	4.55E-12	8.95E-10	3,4-dichlorophenol
1.88E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.17E-08	4.92E-11	1.03E-07	2.29E-09	4.59E-11	4.54E-09	3,5-dichlorophenol
3.16E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.66E-09	2.15E-12	1.79E-08	1.94E-09	1.17E-11	2.07E-09	2,3,4-trichlorophenol
3.08E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.50E-10	7.76E-13	1.91E-08	1.77E-09	1.75E-12	2.47E-09	2,3,5-trichlorophenol
2.86E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.25E-10	2.77E-13	1.95E-08	6.34E-10	6.27E-13	1.30E-09	2,3,6-trichlorophenol
2.50E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.35E-10	5.27E-13	1.46E-08	1.03E-09	1.65E-12	1.91E-09	2,4,5-trichlorophenol
1.96E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.70E-10	3.31E-13	1.07E-08	5.42E-10	1.31E-12	9.42E-10	2,4,6-trichlorophenol
2.55E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.12E-10	5.26E-13	1.49E-08	7.15E-10	2.42E-12	2.26E-09	3,4,5-trichlorophenol
1.85E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.94E-10	2.12E-13	9.79E-09	3.74E-10	2.34E-12	9.39E-10	2,3,4,5-tetrachlorophenol
5.82E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.97E-10	2.04E-13	4.88E-08	6.64E-10	1.74E-12	1.46E-09	2,3,4,6-tetrachlorophenol
2.69E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.94E-10	1.52E-13	1.88E-08	3.27E-10	1.61E-12	4.69E-10	2,3,5,6-tetrachlorophenol
2.34E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.52E-11	4.73E-14	2.24E-07	4.79E-10	6.73E-13	1.70E-09	pentachlorophenol
2.90E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.32E-09	6.85E-13	2.18E-08	2.52E-11	6.72E-13	1.08E-10	PCB 28
6.39E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.12E-09	1.02E-12	5.67E-08	2.05E-11	5.96E-13	5.32E-11	PCB 52
3.22E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.08E-09	4.85E-13	2.50E-08	3.03E-12	9.44E-14	4.56E-12	PCB101
1.36E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.05E-11	5.00E-15	6.50E-09	4.59E-13	7.97E-15	7.32E-13	PCB 118 (dioxines)
1.36E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.05E-11	5.00E-15	6.50E-09	4.59E-13	7.97E-15	7.32E-13	PCB 118 (indicator PCB)
5.67E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.91E-12	4.15E-15	4.96E-08	5.01E-12	2.26E-14	4.84E-12	PCB138
4.09E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.94E-11	2.19E-14	3.38E-08	3.46E-12	6.89E-14	3.15E-12	PCB153
1.03E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.14E-11	1.75E-14	9.59E-08	2.63E-12	5.18E-14	1.38E-12	PCB180
4.05E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.26E-10	3.32E-12	1.72E-08	1.46E-08	6.57E-12	1.40E-09	monochloroaniline
2.63E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	5.89E-12	4.27E-15	1.92E-08	1.27E-12	4.28E-15	2.28E-12	2,3,7,8-TCDD
2.60E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.37E-13	6.45E-16	1.89E-08	4.14E-13	2.54E-16	4.39E-13	PCDD
1.97E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.83E-12	9.02E-16	1.26E-08	1.31E-13	1.00E-15	7.74E-14	HxCDD
1.71E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.94E-14	9.07E-17	1.00E-08	7.15E-14	2.05E-17	2.52E-14	HpCDD

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
9.80E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.51E-14	2.22E-17	2.69E-09	1.19E-14	1.62E-17	2.39E-15	OCDD
1.22E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.16E-11	4.70E-15	5.06E-09	4.02E-14	1.04E-15	1.65E-14	1,2,3,4,6,7,8-HeptaCDF
2.57E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.41E-12	1.65E-15	1.86E-08	2.52E-13	1.84E-15	1.11E-13	1,2,3,4,7,8,9-HeptaCDF
2.59E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.17E-10	9.11E-14	1.86E-08	1.91E-13	5.66E-15	1.34E-13	1,2,3,4,7,8-HexaCDF
2.57E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.51E-10	6.36E-14	1.85E-08	1.55E-13	4.58E-15	1.09E-13	1,2,3,6,7,8-HexaCDF
2.60E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.09E-11	1.33E-14	1.88E-08	2.96E-13	6.53E-15	2.13E-13	1,2,3,7,8,9-HexaCDF
2.63E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.39E-11	2.95E-14	1.91E-08	1.15E-12	2.14E-14	1.45E-12	1,2,3,7,8-PentaCDF
2.56E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.55E-11	1.92E-14	1.85E-08	1.55E-13	4.18E-15	1.10E-13	2,3,4,6,7,8-HexaCDF
2.63E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.11E-10	5.04E-14	1.91E-08	1.15E-12	2.61E-14	1.43E-12	2,3,4,7,8,-PentaCDF
2.64E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.79E-11	2.03E-14	1.93E-08	2.09E-12	2.18E-14	4.72E-12	2,3,7,8-TetraCDF
8.93E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.19E-12	4.65E-16	1.81E-09	6.41E-15	1.48E-16	1.53E-15	OctaCDF
1.54E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.74E-11	9.24E-15	8.24E-09	1.45E-12	1.87E-14	4.06E-12	PCB 77
1.54E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	8.34E-12	4.22E-15	8.24E-09	7.62E-13	8.73E-15	1.24E-12	PCB 105
2.68E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.32E-11	6.66E-15	1.97E-08	1.18E-12	1.37E-14	1.92E-12	PCB 126
2.58E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	8.70E-12	4.00E-15	1.86E-08	1.17E-12	1.75E-14	1.09E-12	PCB 156
2.58E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.05E-11	4.81E-15	1.86E-08	1.41E-12	2.10E-14	1.31E-12	PCB 157
3.04E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.26E-12	1.14E-15	2.33E-08	2.51E-12	4.55E-15	2.45E-12	PCB 169
4.00E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.51E-08	1.61E-11	2.21E-08	9.75E-10	3.44E-11	5.53E-09	1-chloronaphatalene
1.66E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.03E-08	6.80E-12	2.37E-08	9.75E-10	2.54E-11	6.14E-09	2-chloronaphatalene
5.20E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.67E-10	1.22E-13	3.08E-08	6.45E-11	6.37E-13	2.65E-11	chlorodane
3.21E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.79E-12	2.84E-15	2.49E-08	6.76E-12	1.03E-14	7.29E-12	DDT
5.32E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.37E-12	4.01E-15	4.61E-08	1.15E-11	9.40E-15	2.23E-11	DDE
2.49E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.04E-12	4.80E-15	1.77E-08	1.70E-11	4.19E-15	3.14E-11	DDD
5.15E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.29E-09	2.74E-12	5.04E-07	2.95E-10	6.63E-12	2.46E-10	aldrin
2.32E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.10E-12	6.39E-14	1.58E-08	2.63E-10	2.26E-14	9.76E-11	dieldrin
2.56E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.81E-12	6.81E-14	1.81E-08	2.88E-10	6.74E-15	1.07E-10	endrin
6.03E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.62E-09	2.52E-12	1.48E-08	1.20E-09	1.34E-11	4.80E-10	a-HCH
2.64E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.16E-09	2.27E-12	1.35E-08	1.09E-09	1.21E-11	4.38E-10	b-HCH
5.58E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	9.94E-11	7.47E-13	4.49E-08	2.62E-09	4.21E-13	1.09E-09	g-HCH
4.36E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.19E-08	5.03E-12	2.22E-08	9.11E-11	2.64E-12	5.88E-11	heptachlor
1.99E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.03E-07	4.32E-11	2.52E-08	2.93E-09	7.18E-11	1.45E-10	heptachloro epoxide

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
1.14E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.17E-12	5.66E-14	4.03E-09	2.04E-10	1.77E-14	7.34E-11	tri-butyltinoxide
7.53E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	9.62E-14	8.99E-16	4.13E-10	3.60E-12	3.63E-16	3.02E-13	trifenyltin hydroxide
1.30E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	9.47E-11	1.28E-11	1.29E-06	7.96E-11	1.87E-18	1.47E-11	MCPA
4.75E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.62E-11	4.90E-12	4.61E-07	6.31E-09	2.95E-15	7.81E-10	atrazine
5.16E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.95E-09	6.01E-12	3.69E-08	5.39E-09	5.85E-12	4.74E-10	carbaryl
6.11E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.22E-10	1.64E-11	5.82E-07	2.14E-08	7.72E-14	2.58E-10	carbofuran
2.01E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.95E-07	3.18E-10	3.37E-07	3.65E-08	3.51E-10	4.75E-10	cyclohexanone
9.66E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.27E-09	6.51E-12	2.89E-08	5.64E-08	6.59E-11	8.89E-10	dimethyl phthalate (DMP)
5.13E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.87E-09	2.80E-12	1.71E-08	2.33E-08	3.49E-11	1.88E-09	diethyl phthalate (DEP)
8.87E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.63E-10	5.79E-13	6.52E-08	5.90E-09	6.12E-12	1.01E-08	diisobutyl phthalate (DIBP)
2.26E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.68E-09	3.97E-12	1.78E-07	1.07E-08	8.90E-11	2.36E-08	dibuthyl phthalate (DBP)
4.24E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	9.46E-12	8.58E-14	3.21E-08	1.26E-09	1.55E-13	1.92E-09	butyl benzyl phthalate
1.97E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.67E-09	7.54E-13	1.88E-07	2.30E-10	5.83E-12	3.11E-10	dihexyl phthalate (DHP)
1.15E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.57E-11	8.99E-15	1.08E-07	4.38E-11	1.97E-13	2.63E-11	bis(2-ethylhexyl)phthalate
6.25E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.09E-06	1.96E-09	5.09E-09	8.16E-11	3.84E-12	1.57E-09	aliphatic >EC10-EC12
8.59E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.84E-07	2.19E-10	2.96E-09	4.10E-12	1.72E-13	4.45E-11	aliphatic >EC12-EC16
8.24E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.40E-08	3.65E-11	1.26E-09	2.05E-14	7.44E-16	7.49E-14	aliphatic >EC16-EC21
5.36E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.49E-04	2.15E-07	1.72E-08	2.10E-08	1.39E-09	7.74E-08	aliphatic >EC5-EC6
1.71E-05	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.94E-05	6.24E-08	1.16E-08	4.85E-09	2.89E-10	5.56E-08	aliphatic >EC6-EC8
3.31E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.66E-05	1.16E-08	7.56E-09	6.42E-10	3.35E-11	1.44E-08	aliphatic >EC8-EC10
1.44E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.66E-07	1.86E-10	1.40E-08	2.86E-09	1.45E-10	1.46E-08	aromatic >EC10-EC12
4.13E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.94E-08	1.94E-11	1.16E-08	1.43E-09	6.09E-11	9.49E-09	aromatic >EC12-EC16
2.58E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.07E-09	3.60E-12	8.86E-09	4.54E-10	1.60E-11	3.24E-09	aromatic >EC16-EC21
1.37E-08	6.67E-09	2.05E-11	4.08E-10	1.56E-11	3.68E-10	1.98E-13	5.82E-09	5.71E-11	1.51E-12	3.17E-10	aromatic >EC21-EC35
6.49E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.51E-06	5.69E-09	1.91E-08	7.13E-09	4.79E-10	3.40E-08	aromatic >EC5-EC7
3.01E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	2.99E-06	2.44E-09	1.75E-08	5.68E-09	3.50E-10	2.75E-08	aromatic >EC7-EC8
6.57E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	1.55E-06	1.12E-09	1.62E-08	4.52E-09	2.43E-10	1.79E-08	aromatic >EC8-EC10
1.77E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.48E-09	1.86E-11	5.36E-08	1.15E-07	1.37E-10	1.47E-09	pyridine

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
2.43E-06	6.67E-09	2.05E-11	4.08E-10	1.56E-11	6.06E-07	7.37E-10	6.44E-07	1.41E-06	1.64E-08	1.32E-08	tetrahydrofuran
9.97E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	7.85E-07	6.94E-10	1.75E-07	3.49E-07	1.14E-08	2.97E-08	tetrahydrothiophene
2.36E-07	6.67E-09	2.05E-11	4.08E-10	1.56E-11	4.29E-07	2.23E-10	5.55E-08	3.37E-09	9.54E-11	2.36E-10	tribromomethane
9.52E-09	6.67E-09	2.05E-11	4.08E-10	1.56E-11	8.38E-13	2.90E-14	2.28E-09	1.17E-10	3.25E-15	7.57E-12	tri-fenyltin (compounds)

Table A4.4. Absolute contribution of contaminants to the exposure during the adult phase.

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
2.86E-08	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	2.79E-08	0.00E+00	0.00E+00	0.00E+00	antimony
1.07E-09	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	3.27E-10	0.00E+00	0.00E+00	0.00E+00	arsenic
1.68E-09	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	9.57E-10	0.00E+00	0.00E+00	0.00E+00	barium
9.06E-09	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	8.34E-09	0.00E+00	0.00E+00	0.00E+00	cadmium
1.12E-09	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	4.05E-10	0.00E+00	0.00E+00	0.00E+00	chromium (III)
6.36E-08	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	4.05E-10	0.00E+00	0.00E+00	0.00E+00	chromium (VI)
5.39E-08	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	5.31E-08	0.00E+00	0.00E+00	0.00E+00	cobalt
1.35E-08	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	8.45E-09	0.00E+00	0.00E+00	0.00E+00	copper
1.20E-08	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	1.10E-08	0.00E+00	0.00E+00	0.00E+00	mercury (inorganic)
1.41E-09	5.29E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	8.76E-10	0.00E+00	0.00E+00	0.00E+00	lead
6.77E-09	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	6.03E-09	0.00E+00	0.00E+00	0.00E+00	molybdenum
3.33E-08	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	1.33E-09	0.00E+00	0.00E+00	0.00E+00	nickel
8.17E-09	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	7.45E-09	0.00E+00	0.00E+00	0.00E+00	zinc
1.05E-06	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	1.05E-06	0.00E+00	0.00E+00	0.00E+00	cyanides (free)
1.05E-06	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	1.05E-06	0.00E+00	0.00E+00	0.00E+00	cyanides (complex)
1.05E-06	7.14E-10	0.00E+00	0.00E+00	8.93E-12	0.00E+00	0.00E+00	1.05E-06	0.00E+00	0.00E+00	0.00E+00	thiocyanate
2.87E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.81E-06	7.72E-10	3.40E-08	3.91E-08	3.34E-09	1.05E-08	benzene
8.93E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.84E-06	2.58E-10	1.80E-08	1.34E-08	1.00E-09	2.41E-08	ethylbenzene
6.92E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.51E-06	5.25E-10	3.09E-08	2.07E-08	1.64E-09	1.78E-08	toluene
1.36E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.09E-06	2.94E-10	3.80E-08	2.26E-08	1.65E-09	3.81E-08	o-xylene
1.06E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.65E-06	2.32E-10	2.51E-08	1.35E-08	9.92E-10	2.70E-08	m-xylene
6.00E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	9.35E-07	1.31E-10	1.34E-08	7.63E-09	5.62E-10	1.37E-08	p-xylene
2.46E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.43E-07	6.30E-11	1.28E-08	1.14E-08	8.15E-10	1.38E-08	styrene
7.78E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.26E-09	3.79E-12	6.76E-08	4.94E-10	1.41E-13	2.99E-11	phenol

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
1.24E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.93E-09	3.46E-12	6.08E-08	5.09E-08	4.88E-11	7.37E-09	o-cresol
9.51E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.40E-09	2.69E-12	4.62E-08	3.88E-08	4.21E-11	5.74E-09	m-cresol
1.13E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.47E-09	2.83E-12	5.82E-08	4.59E-08	1.84E-11	6.50E-09	p-cresol
4.05E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.84E-08	3.77E-12	7.90E-09	1.15E-09	5.36E-11	2.21E-09	naphthalene
4.60E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.82E-10	2.59E-14	3.03E-09	6.48E-11	7.33E-13	5.16E-10	phenanthrene
3.93E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.14E-10	1.75E-14	2.52E-09	5.52E-11	4.83E-13	4.32E-10	anthracene
2.13E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.46E-11	3.17E-15	1.26E-09	2.91E-12	3.59E-14	2.70E-11	fluoranthene
2.02E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.06E-14	1.67E-16	1.21E-09	8.39E-13	3.65E-17	6.21E-12	chrysene
1.52E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.44E-15	1.41E-16	7.05E-10	7.14E-13	1.14E-17	5.07E-12	benzo(a)anthracene
2.47E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.52E-14	1.30E-16	1.66E-09	6.66E-13	9.28E-17	3.44E-12	benzo(a)pyrene
1.51E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.62E-15	4.77E-17	7.05E-10	2.53E-13	6.11E-18	1.31E-12	benzo(k)fluoranthene
4.65E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.04E-15	7.54E-17	3.84E-09	4.20E-13	4.13E-18	1.51E-12	indeno(1,2,3-cd) pyrene
1.40E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.69E-15	2.95E-17	5.90E-10	1.64E-13	4.34E-18	5.79E-13	benzo(ghi)perylene
2.81E-04	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.81E-04	8.44E-08	2.42E-08	2.35E-08	2.33E-09	1.91E-09	monochloroethene
8.35E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	9.68E-06	1.50E-09	1.03E-07	5.20E-08	4.15E-09	1.71E-09	dichloromethane
9.05E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.18E-05	1.72E-09	6.04E-08	2.78E-08	2.13E-09	2.54E-09	1,1-dichloroethane
2.16E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.03E-06	2.98E-10	6.35E-08	1.87E-08	1.24E-09	8.51E-10	1,2-dichloroethane
2.31E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.02E-05	4.40E-09	4.00E-08	3.28E-07	2.59E-08	6.68E-08	1,1-dichloroethene
4.97E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.66E-05	3.89E-09	3.01E-08	1.21E-09	9.56E-11	3.45E-11	1,2-dichloroethene (cis)
3.36E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.79E-05	6.99E-09	2.95E-08	1.20E-09	9.54E-11	2.28E-11	1,2-dichloroethene (trans)
4.20E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.74E-05	5.47E-09	3.08E-08	1.25E-09	9.87E-11	3.03E-11	1,2-dichloroethene (cis,trans)
9.09E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.44E-06	6.09E-10	5.97E-08	5.17E-08	3.56E-09	6.13E-09	1,2-dichloropropane
6.50E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.44E-06	6.09E-10	5.97E-08	5.17E-08	3.56E-09	6.13E-09	1,3-dichloropropane
5.39E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.04E-06	6.72E-10	5.01E-08	4.37E-08	2.98E-09	4.48E-09	trichloromethane
1.01E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.36E-05	1.72E-09	4.24E-08	4.43E-08	2.98E-09	2.42E-08	1,1,1-trichloroethane
6.53E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.01E-07	8.97E-11	2.52E-08	4.51E-08	2.57E-09	3.19E-09	1,1,2-trichloroethane
4.79E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.39E-06	6.87E-10	2.98E-08	2.94E-08	1.97E-09	1.08E-08	trichloroethene

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
5.81E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.44E-05	2.89E-09	6.92E-08	2.82E-08	1.77E-09	1.21E-08	tetrachloromethane
1.82E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.92E-06	9.05E-10	3.17E-08	6.52E-09	3.94E-10	8.16E-09	tetrachloroethene
1.74E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.18E-06	1.61E-10	2.06E-08	3.45E-08	2.42E-09	3.18E-08	monochlorobenzene
2.03E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.25E-07	3.94E-11	1.37E-08	6.62E-09	4.03E-10	1.22E-08	1,4-dichlorobenzene
8.92E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.33E-07	4.05E-11	2.22E-08	1.09E-08	6.44E-10	1.98E-08	1,2-dichlorobenzene
1.29E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.89E-07	2.07E-11	1.62E-08	1.29E-09	7.22E-11	5.32E-09	1,2,3-trichlorobenzene
9.19E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.31E-07	1.44E-11	1.24E-08	1.15E-09	6.37E-11	4.09E-09	1,2,4-trichlorobenzene
6.22E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.10E-06	1.20E-10	3.26E-09	2.30E-10	1.34E-11	1.02E-09	1,3,5-trichlorobenzene
1.58E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.16E-09	5.30E-13	8.21E-09	2.71E-10	1.10E-11	1.30E-09	1,2,3,4-tetrachlorobenzene
5.05E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.79E-08	2.83E-12	1.84E-08	5.92E-10	2.81E-11	2.83E-09	1,2,3,5-tetrachlorobenzene
2.22E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.09E-07	2.10E-11	1.05E-08	3.73E-10	1.97E-11	1.66E-09	1,2,4,5-tetrachlorobenzene
6.40E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.09E-08	3.84E-12	2.10E-08	2.65E-10	1.26E-11	1.03E-09	pentachlorobenzene
4.40E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.26E-09	1.18E-13	4.15E-08	1.92E-10	4.72E-12	5.29E-10	hexachlorobenzene
6.23E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.35E-08	5.48E-12	2.79E-08	1.12E-10	1.55E-12	1.78E-11	2-chlorophenol
1.11E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	8.38E-10	4.21E-13	9.42E-09	2.99E-11	4.75E-14	1.10E-11	3-chlorophenol
3.94E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.09E-09	1.56E-12	3.63E-08	1.23E-10	1.19E-13	3.51E-11	4-chlorophenol
1.98E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.99E-09	9.63E-13	1.21E-08	5.86E-10	5.31E-12	2.62E-10	2,3-dichlorophenol
1.97E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	9.60E-10	3.98E-13	1.68E-08	6.18E-10	9.73E-13	4.61E-10	2,4-dichlorophenol
1.53E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.63E-09	7.94E-13	8.29E-09	3.14E-10	4.49E-12	2.26E-10	2,5-dichlorophenol
1.53E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.33E-09	7.06E-13	9.51E-09	4.46E-10	3.87E-12	1.63E-10	2,6-dichlorophenol
1.43E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.91E-09	4.63E-13	9.95E-09	2.75E-10	2.57E-12	3.63E-10	3,4-dichlorophenol
9.30E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.37E-08	5.49E-12	4.56E-08	9.80E-10	2.59E-11	1.84E-09	3,5-dichlorophenol
1.20E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.62E-09	2.41E-13	7.94E-09	8.31E-10	6.60E-12	8.39E-10	2,3,4-trichlorophenol
1.13E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.13E-10	8.66E-14	8.48E-09	7.59E-10	9.88E-13	1.00E-09	2,3,5-trichlorophenol
1.03E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.63E-11	3.10E-14	8.64E-09	2.72E-10	3.53E-13	5.26E-10	2,3,6-trichlorophenol

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
8.70E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.04E-10	5.88E-14	6.47E-09	4.42E-10	9.32E-13	7.74E-10	2,4,5-trichlorophenol
6.33E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.65E-10	3.70E-14	4.75E-09	2.32E-10	7.37E-13	3.82E-10	2,4,6-trichlorophenol
8.98E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.13E-10	5.88E-14	6.63E-09	3.06E-10	1.36E-12	9.19E-10	3,4,5-trichlorophenol
5.88E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.79E-10	2.37E-14	4.35E-09	1.60E-10	1.32E-12	3.81E-10	2,3,4,5-tetrachlorophenol
2.35E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.20E-10	2.27E-14	2.17E-08	2.84E-10	9.82E-13	5.94E-10	2,3,4,6-tetrachlorophenol
9.61E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.18E-10	1.69E-14	8.36E-09	1.40E-10	9.06E-13	1.90E-10	2,3,5,6-tetrachlorophenol
1.02E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.15E-11	5.29E-15	9.98E-08	2.05E-10	3.79E-13	6.92E-10	pentachlorophenol
1.06E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	8.07E-10	7.65E-14	9.68E-09	1.08E-11	3.79E-13	4.40E-11	PCB 28
2.61E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.30E-09	1.14E-13	2.52E-08	8.78E-12	3.36E-13	2.16E-11	PCB 52
1.20E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.57E-10	5.42E-14	1.11E-08	1.30E-12	5.32E-14	1.85E-12	PCB101
3.70E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.39E-12	5.58E-16	2.89E-09	1.97E-13	4.49E-15	2.97E-13	PCB 118 (dioxines)
3.69E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.39E-12	5.58E-16	2.89E-09	1.97E-13	4.49E-15	2.97E-13	PCB 118 (indicator PCB)
2.29E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.21E-12	4.64E-16	2.21E-08	2.15E-12	1.27E-14	1.96E-12	PCB138
1.58E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.01E-11	2.45E-15	1.50E-08	1.48E-12	3.89E-14	1.28E-12	PCB153
4.35E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.53E-11	1.96E-15	4.27E-08	1.13E-12	2.92E-14	5.61E-13	PCB180
1.55E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.21E-10	3.71E-13	7.61E-09	6.27E-09	3.71E-12	5.67E-10	monochloroaniline
9.34E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.59E-12	4.77E-16	8.53E-09	5.43E-13	2.41E-15	9.26E-13	2,3,7,8-TCDD
9.21E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.05E-13	7.20E-17	8.41E-09	1.77E-13	1.43E-16	1.78E-13	PCDD
6.43E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.12E-12	1.01E-16	5.62E-09	5.62E-14	5.65E-16	3.14E-14	HxCDD
5.27E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.79E-14	1.01E-17	4.46E-09	3.06E-14	1.16E-17	1.02E-14	HpCDD
2.00E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.53E-14	2.48E-18	1.19E-09	5.11E-15	9.12E-18	9.70E-16	OCDD
3.06E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.08E-12	5.25E-16	2.25E-09	1.72E-14	5.84E-16	6.69E-15	1,2,3,4,6,7,8-HeptaCDF
9.06E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.08E-12	1.85E-16	8.25E-09	1.08E-13	1.04E-15	4.50E-14	1,2,3,4,7,8,9-HeptaCDF
9.19E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.32E-10	1.02E-14	8.25E-09	8.18E-14	3.19E-15	5.42E-14	1,2,3,4,7,8-HexaCDF
9.12E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	9.23E-11	7.11E-15	8.22E-09	6.65E-14	2.58E-15	4.41E-14	1,2,3,6,7,8-HexaCDF

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
9.19E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.89E-11	1.49E-15	8.37E-09	1.27E-13	3.68E-15	8.66E-14	1,2,3,7,8,9-HexaCDF
9.33E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.90E-11	3.30E-15	8.49E-09	4.93E-13	1.20E-14	5.91E-13	1,2,3,7,8-PentaCDF
9.05E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.77E-11	2.15E-15	8.22E-09	6.65E-14	2.36E-15	4.46E-14	2,3,4,6,7,8-HexaCDF
9.36E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.79E-11	5.63E-15	8.48E-09	4.93E-13	1.47E-14	5.81E-13	2,3,4,7,8,-PentaCDF
9.40E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.31E-11	2.26E-15	8.57E-09	8.97E-13	1.23E-14	1.92E-12	2,3,7,8-TetraCDF
1.61E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.25E-13	5.20E-17	8.01E-10	2.75E-15	8.36E-17	6.21E-16	OctaCDF
4.48E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.06E-11	1.03E-15	3.66E-09	6.22E-13	1.05E-14	1.65E-12	PCB 77
4.47E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.08E-12	4.72E-16	3.66E-09	3.26E-13	4.92E-15	5.04E-13	PCB 105
9.57E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	8.04E-12	7.44E-16	8.76E-09	5.06E-13	7.73E-15	7.81E-13	PCB 126
9.11E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.30E-12	4.46E-16	8.29E-09	5.03E-13	9.85E-15	4.43E-13	PCB 156
9.11E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.38E-12	5.37E-16	8.29E-09	6.05E-13	1.18E-14	5.32E-13	PCB 157
1.12E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.71E-13	1.28E-16	1.04E-08	1.08E-12	2.57E-15	9.95E-13	PCB 169
4.30E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.53E-08	1.80E-12	9.85E-09	4.18E-10	1.94E-11	2.25E-09	1-chloronaphatalene
1.77E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.25E-09	7.59E-13	1.05E-08	4.18E-10	1.43E-11	2.49E-09	2-chloronaphatalene
2.96E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.63E-10	1.36E-14	1.37E-08	2.76E-11	3.59E-13	1.08E-11	chlorodane
1.19E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.70E-12	3.17E-16	1.11E-08	2.90E-12	5.78E-15	2.96E-12	DDT
2.13E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.44E-12	4.48E-16	2.05E-08	4.92E-12	5.30E-15	9.04E-12	DDE
8.71E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.35E-13	5.36E-16	7.88E-09	7.27E-12	2.37E-15	1.28E-11	DDD
2.29E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.84E-09	3.06E-13	2.24E-07	1.26E-10	3.74E-12	9.99E-11	aldrin
7.94E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.72E-12	7.14E-15	6.97E-09	1.13E-10	1.28E-14	3.96E-11	dieldrin
8.95E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.11E-12	7.60E-15	7.97E-09	1.23E-10	3.80E-15	4.35E-11	endrin
4.78E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.82E-09	2.81E-13	6.58E-09	5.14E-10	7.54E-12	1.95E-10	a-HCH
1.00E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.54E-09	2.54E-13	6.02E-09	4.69E-10	6.82E-12	1.78E-10	b-HCH
2.22E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.06E-11	8.34E-14	1.98E-08	1.12E-09	2.37E-13	4.44E-10	g-HCH
2.60E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.27E-09	5.62E-13	9.87E-09	3.90E-11	1.49E-12	2.39E-11	heptachlor
1.90E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	6.30E-08	4.82E-12	1.12E-08	1.26E-09	4.05E-11	5.87E-11	heptachloro epoxide
2.69E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.54E-12	6.32E-15	1.76E-09	8.74E-11	9.98E-15	2.98E-11	tri-butyltinoxide
9.87E-10	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.87E-14	1.00E-16	1.78E-10	1.54E-12	2.05E-16	1.22E-13	trifenyltin hydroxide
5.59E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.77E-11	1.43E-12	5.58E-07	3.41E-11	1.05E-18	5.96E-12	MCPA
2.03E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.21E-11	5.47E-13	1.99E-07	2.70E-09	1.66E-15	3.17E-10	atrazine
2.16E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.80E-09	6.72E-13	1.64E-08	2.31E-09	3.30E-12	1.92E-10	carbaryl

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
2.62E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	7.41E-11	1.84E-12	2.52E-07	9.18E-09	4.35E-14	1.05E-10	carbofuran
2.15E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.80E-07	3.55E-11	1.50E-07	1.56E-08	1.98E-10	1.93E-10	cyclohexanone
4.02E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.00E-09	7.27E-13	1.28E-08	2.42E-08	3.72E-11	3.61E-10	dimethyl phthalate (DMP)
2.03E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.14E-09	3.12E-13	7.61E-09	9.99E-09	1.97E-11	7.62E-10	diethyl phthalate (DEP)
3.66E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.21E-10	6.47E-14	2.90E-08	2.53E-09	3.45E-12	4.12E-09	diisobutyl phthalate (DIBP)
9.84E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.07E-09	4.44E-13	7.93E-08	4.59E-09	5.02E-11	9.57E-09	dibuthyl phthalate (DBP)
1.64E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.77E-12	9.59E-15	1.42E-08	5.41E-10	8.72E-14	7.81E-10	butyl benzyl phthalate
8.55E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.02E-09	8.42E-14	8.34E-08	9.86E-11	3.29E-12	1.26E-10	dihexyl phthalate (DHP)
4.89E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	9.60E-12	1.00E-15	4.81E-08	1.88E-11	1.11E-13	1.07E-11	bis(2-ethylhexyl)phthalate
6.64E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.89E-06	2.19E-10	2.26E-09	3.50E-11	2.17E-12	6.36E-10	aliphatic >EC10-EC12
8.40E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.34E-07	2.44E-11	1.31E-09	1.76E-12	9.73E-14	1.81E-11	aliphatic >EC12-EC16
4.65E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.51E-08	4.07E-12	5.56E-10	8.81E-15	4.20E-16	3.04E-14	aliphatic >EC16-EC21
5.79E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.52E-04	2.40E-08	7.65E-09	9.01E-09	7.84E-10	3.14E-08	aliphatic >EC5-EC6
1.84E-05	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.84E-05	6.97E-09	5.16E-09	2.08E-09	1.63E-10	2.26E-08	aliphatic >EC6-EC8
3.55E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.01E-05	1.29E-09	3.36E-09	2.75E-10	1.89E-11	5.85E-09	aliphatic >EC8-EC10
1.28E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.62E-07	2.08E-11	6.24E-09	1.22E-09	8.15E-11	5.92E-09	aromatic >EC10-EC12
2.30E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.80E-08	2.17E-12	5.16E-09	6.14E-10	3.43E-11	3.85E-09	aromatic >EC12-EC16
9.97E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.70E-09	4.02E-13	3.94E-09	1.94E-10	9.05E-12	1.32E-09	aromatic >EC16-EC21
3.77E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.25E-10	2.21E-14	2.58E-09	2.45E-11	8.50E-13	1.29E-10	aromatic >EC21-EC35
6.97E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.97E-06	6.36E-10	8.47E-09	3.05E-09	2.70E-10	1.38E-08	aromatic >EC5-EC7

Dose	DIL	DALI	DALO	IPL	IVLI	IVLO	VIL	DIWL	IVWL	DAWL	Contaminant
3.22E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	1.82E-06	2.72E-10	7.80E-09	2.43E-09	1.98E-10	1.12E-08	aromatic >EC7-EC8
6.78E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	9.43E-07	1.25E-10	7.21E-09	1.94E-09	1.37E-10	7.25E-09	aromatic >EC8-EC10
7.46E-08	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.73E-09	2.08E-12	2.38E-08	4.92E-08	7.73E-11	5.98E-10	pyridine
1.28E-06	7.14E-10	6.42E-12	7.79E-11	8.93E-12	3.69E-07	8.24E-11	2.87E-07	6.06E-07	9.23E-09	5.37E-09	tetrahydrofuran
7.11E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	4.79E-07	7.75E-11	7.80E-08	1.50E-07	6.40E-09	1.21E-08	tetrahydrothiophene
2.10E-07	7.14E-10	6.42E-12	7.79E-11	8.93E-12	2.62E-07	2.49E-11	2.47E-08	1.45E-09	5.38E-11	9.60E-11	tribromomethane
1.85E-09	7.14E-10	6.42E-12	7.79E-11	8.93E-12	5.11E-13	3.24E-15	9.91E-10	5.03E-11	1.83E-15	3.07E-12	tri-fenyltin (compounds)

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