VERMEER Rodenticides (v.5.0)

User Manual

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1.   Model purpose

1.1.   Goal

The VERMEER Rodenticides tool is used to provide exposure and hazard endpoints regarding the release of rodenticides in surface waters.

The VERMEER Rodenticides tool predicts:

1. the concentration of rodenticides in aquatic organisms (expressed in $mg.kg^{-1}$ fresh weight), i.e. in:

    a. phytoplankton;

    b. pelagic and/or benthic invertebrates;

    c. pelagic and/or benthic, herbivorous and/or carnivorous fish;

    d. aquatic mammals (e.g. otter);

2. various ecotoxicological endpoints potentially required for regulatory purposes

1.2.   Potential decision and regulatory framework(s)

In general, rodenticides are considered as Biocidal Products and are then submitted to the related European regulation (Regulation (EU) No 528/2012) with the exclusion of products used in plant growing areas (agricultural field, greenhouse, forest). Several non-agricultural use of rodenticides can be identified, such as e.g. protection of sewer systems, waste dumps and landfills, highways, bank slopes, etc. For facilitating the evaluation of environmental risks associated to rodenticides, ECHA (ECHA, 2018) has defined a set of generic scenarios, i.e. a set of conditions about sources, pathways and use patterns of active compounds. One of these scenarios concerns the application of rodenticides on bank slopes of water courses like rivers, drainage channels, lakes, ponds, lagoons, etc. The aim of measures against rodents close to surface waters is to prevent rodents burrowing activities that accelerates erosion. However, rodenticides can be flushed away due to high rainfall directly into surface waters. For evaluating risks associated to the use of rodenticides for the protection of bank slopes, ECHA (2018) proposed a hypothetical simple scenario, based on application along a drainage channel of wetland marshes. The route of emission in the aquatic system is the flushing away of rodenticide baits into the drainage channel due to high rainfall events. Since it is not considered to be realistic that during such a high-water period baits are laid out repeatedly, only one application is considered.

The VERMEER Rodenticides tool is applicable for testing the abovementioned ECHA scenario, or any other scenario considering release of rodenticides in surface waters.

2.   Model applicability

2.1.   Spatial scale and resolution

Spatial scale and resolution are governed by the homogeneity of the water body under investigation, in which organisms is assumed to live. It is therefore recommended to use the River/Phytoplankton/Invertebrates/Fish models for river zones that show an homogeneous geometry. For water bodies showing significant relative variations in their dimensions (e.g. under the effect of tributaries affecting dilution of chemicals in water), it is possible to build scenarios with several successive and connected river boxes.

The River model assumes that chemicals are homogeneously distributed along the transect of the river (i.e. laterally and vertically). The application of the Fish model just upstream of a lateral point release must then be considered with caution if well-mixing condition is not respected. In such a case, the distribution of Fish among several zones presenting different contamination levels must be defined.

In the VERMEER Rodenticides tool, no migration of organisms among different zones is assumed. In other words, organisms are assumed to stay in the same water box during their entire lifetime.

2.2. Temporal scale and resolution

There is no limitation for temporal scale (i.e. duration of the simulation).

As far as temporal resolution is concerned, several processes included in the model are relevant at daily (or less) exposure resolution. For example, physical exchanges at the water column-sediment interface are highly dependent on water velocity and concomitantly on flow rate. This is especially the case for resuspension processes during flood events. As the flow rate can be subject to rapid variations, especially during flood periods, the estimation of particles resuspension is poorly relevant for large temporal resolution (e.g. weekly or monthly). In conclusion, it is highly recommended to run the model for daily (or less) temporal resolution.

2.3. Chemical considered

The majority of approved active compounds are anticoagulants rodenticides (AR) which either belong to the class of 4-hydroxocoumarines or to 1,3-indandione derivates. With reference to the date of their introduction on the market, AR are subdivided into first- and second-generation compounds. The first ones need to be consumed repeatedly by rodents to cause death, while the second ones have been developed in response to resistance to first-generation compounds and are a priori more toxic and more persistent in the environment.

Rodenticides included in the VERMEER tool are those approved by the EU regulation (European Union, 2012): three first-generation ARs (warfarin, chlorophacinone, coumatetralyl) and five second-generation ARs (brodifacoum, bromadiolone, difenacoum, difethialone, flocoumafen). Alphachloralose and cholecalciferol are also included in the list of compounds available in the VERMEER tool.

Future rodenticide candidates can be included case by case by end-users.

2.4. Steady-state vs dynamic processes

The River/Phytoplankton/Invertebrates/Fish models represent all the exchanges processes dynamically. Processes representing exchanges of contaminants between organisms and their surrounding environment (i.e. overlying water, sediment porewater, other biota systems representing food) are dynamically simulated, with uptake and elimination rates. Kinetics representing uptake and elimination processes are first-order.

3.   Science background

The scientific background of the models included in the VERMEER Rodenticides (River, Phytoplankton, Invertebrates, Fish, Mammals) are presented in detail in the documentation of the MERLIN-Expo tool (available on https://merlin-expo.eu/) and in Ciffroy et al. (2018). Only the main principles on the model are reminded here for a better understanding of the assessment process.

3.1.   The River model

3.1.1. Sorption/desorption between Water and Particles

Exchange of chemicals between surface water and Suspended Particulate Matter (SPM), and between sediment porewater and sediment particles, is assumed to be equilibrated. Such exchanges can thus be described by a distribution (or partition) coefficient, generally noted K_{d_SPM} and K_{d_sed} respectively (in $m^3.g^{-1}$), expressed as the concentration ratio at equilibrium between the particulate phase and the dissolved phase. Under this assumption, chemical concentration in the dissolved and particulate phases can be calculated as follows:

(Equation 1) $$C_{dis\_water} = \frac{C_{water}}{1+K_{d,SPM}.SPM}$$

(Equation 2) $$C_{SPM} = \frac{K_{d,SPM}.C_{water}}{1+K_{d,SPM}.SPM}$$

where C_{dis_water} ($mg.m^{-3}$) is the concentration of the chemical dissolved in river water; C_{SPM} (mg.g-1) is the concentration of the chemical associated to SPM; C_{water} ($mg.m^{-3}$) is the concentration of the chemical in raw river water; SPM ($mg.g^{-1}$) is the Suspended Particulate Matter; $K_{d,SPM}$ ($m^3.g^{-1}$) is the distribution coefficient between SPM and water.

Organic carbon is assumed to be the main particulate media interacting with hydrophobic chemicals. Considering this assumption, distribution coefficients are related to the Water-Organic Carbon partition coefficient K_{oc} (representing the ratio at equilibrium of the chemical between particulate organic carbon and water respectively) and to the fraction of organic matter f_{OM} in particles (when $K_{d,SPM}$ and $K_{d,sed}$ are expressed in $m^3.g^{-1}$):

(Equation 3) $$K_{d,SPM} = 10^{-6}.f_{OM,SPM}.K_{oc}$$

and

(Equation 4) $$K_{d,sed} = 10^{-6}.f_{OM,sed}.K_{oc}$$

where $K_{d,sed}$ ($m^3.g^{-1}$) is the distribution coefficient between sediment particles and sediment porewater; $f_{OM,SPM}$ (dimensionless) is the fraction of organic matter in SPM; $f_{OM,sed}$ (dimensionless) is the fraction of organic matter in sediments; K_{oc} (dimensionless) is the water-organic carbon partition coefficient.

3.1.2. Deposition of SPM and associated chemicals to bed sediment

The ECHA scenario considered in the present study considers a static aquatic pond without water dynamics. In this context, only deposition of contaminated particles is considered here, and no potential resuspension (occurring in running waters and not in static ponds).

Modelling of the deposition of fine cohesive particles (and associated chemicals) is based on the assumption that the gravitational settling velocity of particles (governed by their density and granulometry) plays the

dominant role. It is then assumed that the deposition flux of particles is proportional to the SPM concentration and that the proportionality factor is Settling velocity (W_s, in m.s^{-1}). In running waters, deposition flux of particles increases when flow velocity (reflected by bed shear stress) decreases. But the ECHA scenario considered here assumes stagnant water. As a consequence, dependance to flow velocity is not relevant in our specific case. These assumptions lead to the simplified Krone's relationship:

(Equation 5) $\qquad F_d = SPM.W_s$

where F_d (g particles.m^{-2}.s^{-1}) is the deposition flux of particles.

3.1.3. Diffusion between water and sediment porewater

Deposition and diffusion participate in parallel to the exchanges between the overlying water column and the sediment. The diffusion of chemicals at the interface surface water-sediment porewater is based on a two-film diffusion description, where the transport into the sediment is assumed to happen through two layers of resistance: the first layer represents the laminar water-side film and the second one sediment-side boundary layer. According to these assumptions, the diffusive flux at the surface water-sediment porewater interface can be simulated according to the Fick's law, i.e. by taking into account the concentration gradient between the two compartments and a global mass transfer factor $MTC_{water-sed}$. This latter is estimated according to the assumption that it results from two resistances in series by analogy with the Ohm's law, and considering that a diffusion coefficient is equivalent to the inverse of a resistance.

The first resistance represents the resistance to diffusion on the upper part of the water-sediment interface. For organics, it is calculated by the ratio of the boundary layer thickness below water δ_w by the effective diffusion coefficient of the chemical in pure water D_{water} that is assumed to depend on its molar mass. The boundary layer thickness below water δ_w corresponds to the thickness where diffusion occurs at the water-sediment interface because of the fluid viscosity.

The second resistance represents the resistance to diffusion on the lower part of the water-sediment interface. It is calculated by the ratio of the boundary layer above sediment δ_{sed} by the effective diffusion coefficient of the chemical in pure water corrected by a tortuosity factor according to the Millington and Quirk's law. The boundary layer thickness above sediment δ_{sed} corresponds to the thickness where diffusion occurs within the sediment. Generally speaking, the Millington and Quirk's law states that tortuosity depends on porosity φ_{sed} and water content θ according to:

(Equation 6) $\qquad Tortuosity = \dfrac{\theta^{10/3}}{\varphi_{sed}^2}$

As sediments are water-saturated, the Mass Transfer Coefficient $MTC_{water-sed}$ describing diffusion of chemicals between water and sediment porewater is given by:

(Equation 7) $\qquad MTC_{water-sed} = \left(\dfrac{M_{O_2}}{M_{molar}}\right)^{0.5}.D_{O_2,water}.\dfrac{\varphi_{sed}^{4/3}}{\delta_{sed}+\delta_w.\varphi_{sed}^{4/3}}$

where $MTC_{water-sed}$ (m.d^{-1}) is the Mass Transfer Coefficient from water to sediments; $D_{O_2,water}$ (m^2.d^{-1}) is the diffusion coefficient of dioxygen in water; M_{O_2} (g.mol^{-1}) is the molar mass of dioxygen; M_{molar} (g.mol^{-1}) is the molar mass of the chemical; φ_{sed} (dimensionless) is the porosity of sediment; δ_{sed} (m) is the boundary layer thickness above sediment; δ_w (m) is the boundary layer thickness below water.

3.2. The Phytoplankton, Invertebrate and Fish models

3.2.1. General description of bioaccumulation processes in aquatic food webs

The Phytoplankton, Invertebrates and Fish models are based on the description of the main exchange processes between water and organism compartment, i.e. uptake via respiratory route, uptake via dietary route, elimination via respiratory route (excretion), elimination via gastro-intestinal track (egestion), metabolism, and growth.

While processes involved in bioaccumulation may be assumed to be similar for fish and invertebrate species, for phytoplankton a simpler assumption can be made. The 'Phytoplankton' model can be represented by one compartment and only uptake from water is considered (Figure 1) since phytoplankton includes autotrophic species, and dietary uptake can be disregarded.

The 'Fish' and 'Invertebrate' models include two compartments that correspond to two input/output pathways for chemical accumulation in the organism, i.e. the respiratory system and the gastro-intestinal tract (GIT) system. The media considered are represented in Figure 2.
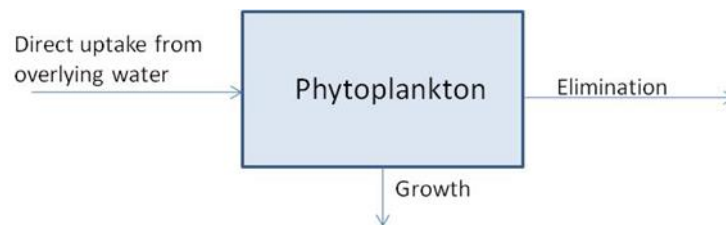

Figure 1 - Main bioaccumulation processes included in 'Phytoplankton' model.
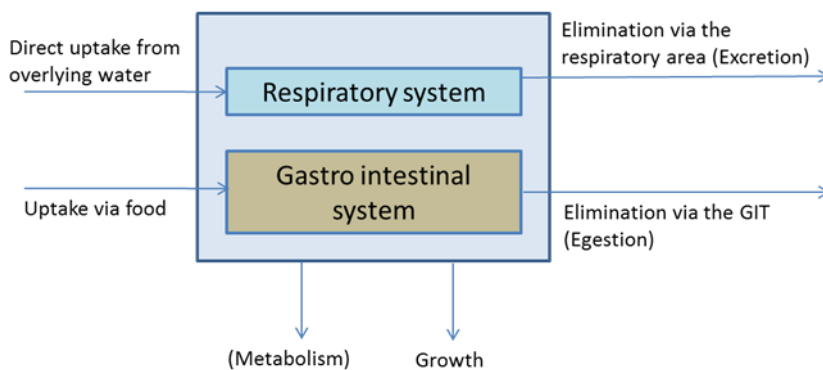

Figure 2 - Main bioaccumulation processes included 'Fish' and 'Invertebrate' model.

3.2.2. Respiratory uptake and excretion of chemicals

Bioconcentration in invertebrates and fish partially results from chemical uptake via the respiratory surface (fish's gill) of the organism. The Invertebrates and Fish VERMEER models are based on the Hendrik's model (Hendriks et al., 2001), which assumes that chemical uptake is driven by resistances in water and lipid membranes respectively. The resistances for diffusion through water layers can be considered the same for different chemicals because molecular weights and volumes are in the same order of magnitude.

The resistance during permeation through lipid layers was considered to decrease with the hydrophobicity of the compound. In addition to resistances in lipid and water layers, fluxes can also be limited by delays in the flow of water through organisms. However, the delay imposed by the water flow can be ignored for aquatic species because ventilation and filtration are sufficiently fast in these organisms.

Uptake of chemicals through the gill membrane also depends on the volume of water flowing across the gill membrane, i.e. on the ventilation rate. Assuming that ventilation rates essentially depend on organism body weight, they can also be estimated by allometric scaling (see Paragraph 3.5).

In conclusion, the Invertebrates and Fish VERMEER models consider that respiratory uptake rate of a chemical depends on K_{ow}, body weight W, and resistances ρ_{water_layer} and ρ_{lipid_layer} that substances encounter in lipid and water layers of the organism:

(Equation 8) $$k_{uptake\_resp} = \frac{W^{-\kappa}}{\rho_{water\_layer} + \frac{\rho_{lipid\_layer}}{K_{ow}}}$$

where k_{uptake_resp} (L.kg^{-1} fw.d^{-1}) is the respiratory uptake rate; W (kg fw) is the organism weight; κ (dimensionless) is the allometric factor; ρ_{water_layer} (kg.d.kg^{-1}) is the water layer diffusion resistance for uptake of chemicals from water; ρ_{lipid_layer} (kg.d.kg^{-1}) is the lipid layer permeation resistance; K_{ow} (dimensionless) is the octanol-water partition coefficient.

The respiratory pathway includes chemical uptake, as described above, but also chemical excretion. Excretion can be seen as a release of chemicals from fish's water compartment via respiratory route. Chemical uptake via the respiratory surface (fish's gill) of the organism is indeed associated to chemical excretion associated to the outflux of water via the respiratory surface. Both processes are influenced by the same factors connected with respiration. Many experiments were conducted under controlled laboratory conditions where dietary uptake is considered negligible. Under such conditions, equilibrium between concentration of the chemical in fish tissues and surrounding water can be reached. The bioconcentration factor (BCF), defined as the ratio at equilibrium of biota concentration of the substance to water concentration, can then be defined. As equilibrium condition is assumed to be reached, BCF also represents the ratio between respiratory uptake rate and excretion rate. BCF can then be used in combination with the respiratory uptake rate k_{uptake_resp} to estimate the excretion rate $k_{excretion\_resp}$ and to reflect affinity of the substance for staying in the lipid compartment of the organism.

3.2.3. Dietary uptake and egestion of chemicals

The rate at which chemicals are assimilated from the diet via the gastro-intestinal tract (GIT) is expressed by the dietary uptake rate constant (kg.kg^{-1}.d^{-1}), and the rate at which chemicals are eliminated from the organism body via the gastro-intestinal tract (GIT) is expressed by the egestion rate constant (kg.kg^{-1}.d^{-1}).

In complement to what proposed for the respiratory pathway, Hendriks et al. (2001) proposed formulations to simulate uptake and egestion of chemicals via diet ingestion. It is assumed that chemical exchanges across the gastro-intestinal tract (GIT) are driven by diffusion gradients, i.e. the concentration differences between phases within the fish and its food/feces. These exchanges are assumed to be mainly simple molecular diffusions.

The distribution of food between digested and undigested fractions respectively can be represented by an Assimilation Fraction AF_{food}. As the chemical can be both transported in food water and/or food lipids, the assimilation fraction of the chemical $AF_{chemical}$ can be different of those applied for food AF_{food}. For this

purpose, food is assumed to be composed of lipids and water only, in respective proportions $p_{lipid,food}$ and (1- $p_{lipid,food}$). The assimilation fraction of the chemical contained in water is directly related to the assimilation fraction of food AF_{food}; the assimilation fraction of the chemical contained in lipids is assumed to be related to the assimilation fraction of food AF_{food} corrected by the octanol-water partition coefficient K_{OW}.

Similar to what assumed for Hendrik's respiratory uptake model, the dietary uptake is limited by two resistances in series reflecting transport across the water GIT layer and the lipid GIT membrane respectively. As for respiratory uptake, the resistance for diffusion through the water layer is considered to be the same for different chemicals, while partial resistance from the lipid layer (encountered to and from food) is inversely proportional to K_{ow}. A flow delay of food and feces, depending on the fraction of undigested chemical contained in lipids, can also be considered. The mathematical formulation respecting these assumptions can be found in Hendriks et al. (2001):

(Equation 9)

$$k_{uptake\_diet}$$
$$= \frac{AF_{food}}{1 - AF_{food}} \cdot \frac{1}{p_{lipid,food} \cdot (K_{ow} - 1) + 1} \cdot \frac{W^{-\kappa}}{\rho_{water\_layer\_food} + \frac{\rho_{lipid\_layer}}{K_{ow}} + \frac{1}{p_{lipid,food} \cdot K_{ow} \cdot (1 - AF_{food}) \cdot \gamma_{food}}}$$

where k_{uptake_diet} (kg fw.kg^{-1} fw.d^{-1}) is the dietary uptake rate; AF_{food} (dimensionless) is the food assimilation efficiency; $p_{lipid,food}$ (dimensionless) is the proportion of lipids in food; W (kg fw) is the organism weight; κ (dimensionless) is the allometric factor; $\rho_{water\_layer\_food}$ (kg.d.kg^{-1}) is the water layer diffusion resistance for uptake of chemicals from food; ρ_{lipid_layer} (kg.d.kg^{-1}) is the lipid layer permeation resistance; K_{ow} (dimensionless) is the octanol-water partition coefficient; γ_{food} (dimensionless) is the food transport coefficient (that represents delay in advective transport of chemical substances through organism due to limited supply of new food).

3.2.4. Metabolic biotransformation

One of the routes of chemical elimination in invertebrates and fish is metabolic transformation (or biotransformation), defined as a change of the parent substance to another molecule or a conjugated form of the parent substance.

The biotransformation model included in the VERMEER tool assumes a first-order process. Biotransformation half-lives and rate constants ($\lambda_{metabolism}$) for organic chemicals in fish are from the QSAR model developed by Arnot et al., 2009 (under applicability domain limitations). QSAR predictions of metabolic biotransformation are functions of structural properties, and can be presented as normalised values (e.g. to 0.01 kg fish and 15°C). In this latter case, for comparison of models' estimates and use in mass balance models, convert QSAR predicted values are converted to body weight and temperature specific values.

3.4　The Mammals model

The goal of the 'Mammals' model is to dynamically simulate the concentration of chemicals in mammals organs (i.e. muscle, liver, kidney, milk). The model is described in detail in Radomyski et al (2018) and briefly reminded here.

3.4.1.　General description of the Mammals pharmaco-kinetic model

The Mammals model is a Physiologically-based Pharmaco-kinetic (PBPK) model. Mammals body is subdivided in five organs: (i) blood (arterial and venous); (ii) muscle; (iii) liver; (iv) kidney; (v) milk. Uptake of chemicals occurs via diet in the gastro-intestinal tract (GIT). Chemicals diffuse between the GIT and blood according to the concentration gradient and are then distributed in organs submitted to arterial blood input and venous blood output. Chemicals are eliminated through excretion in feces, metabolism, urinary elimination and milk extraction.
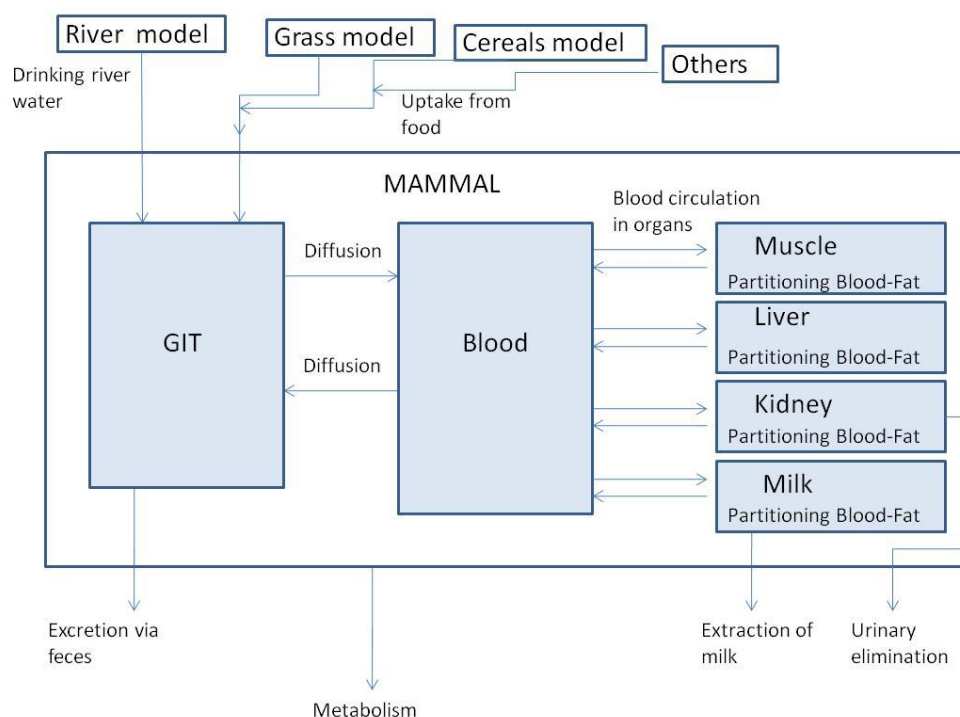
3.4.2.　Advective transport and diffusion of chemicals in/across the GIT membrane

Uptake of chemicals via food depends on advective transport along the GIT and passive diffusion of digested food across the GIT epithelium membrane towards the blood system.

Bioaccumulation first depends on the distribution of food between digested and undigested fractions respectively, which can be represented by the assimilated fraction of food AE_{food}. For estimating the assimilation fraction of food, food may be assumed to be composed of lipids and water only, in respective proportions p_{lipid_food} and (1- p_{lipid_food}). The assimilation fraction of the chemical contained in water is directly related to the assimilation fraction of food water; the assimilation fraction of the chemical contained in lipids is related to the assimilation fraction of food lipids but also to the octanol-water partition coefficient K_{OW}.

The fraction of chemical able to be transport across the GIT membrane is driven by diffusion gradients, i.e. the concentration differences between phases within the animal blood and its food/feces. These exchanges are assumed to be mainly simple and passive molecular diffusions. The VERMEER tool is based on the model of O'Connor et al. (2013), where the lipid membrane separating GIT and the blood system is assumed to be a bilayer structure with an apolar membrane centre and an outer membrane with polar groups (Figure 3). The driving force for the transport of chemicals is the concentration gradient across this bilayer membrane.
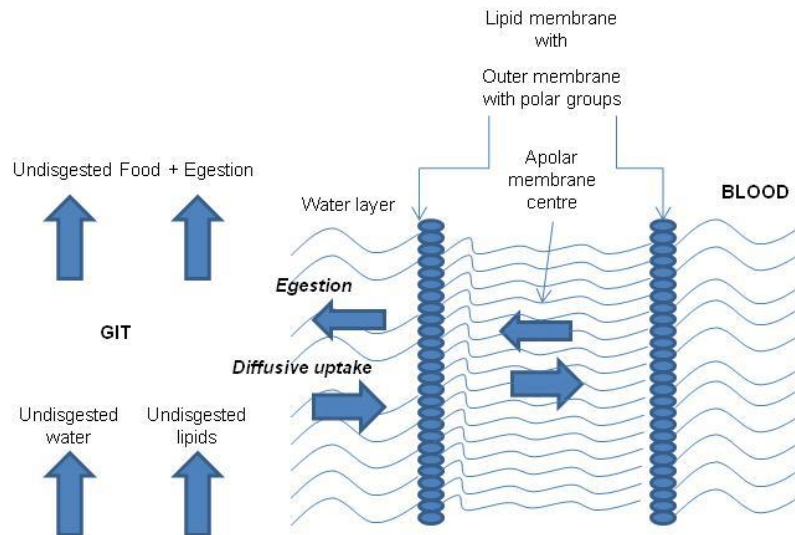
Figure 3 – Exchange processes and resistances taking place across gastro-intestinal tract (GIT)

Considering this background related to the GIT membrane structure, O'Connor's model assumes that ingestion rate constant of chemicals is related to two resistances to diffusion in series or in parallel corresponding to different layers in the membrane[1] (Figure 3):

- the partial resistance from water layer. Resistance for diffusion through water layer is considered to be the same for different chemicals because molecular weights and volumes are in the same order of magnitude;

- the partial resistance for passive diffusion from inner apolar lipid layer, assumed to be inversely proportional to octanol-water partition coefficient K_{ow};

Time delay associated to advective transport of food and feces in the GIT is also represented by a flow delay, depending on the fraction of undigested chemical contained in water and lipids.

In summary, the total resistance to diffusion ρ_{tot} for the chemical present in digested food is given by the sequence of resistance from water layer, resistance from membrane and time delay for advective transport (if carrier-mediated transport is not considered):

(Equation 10)

$$\rho_{tot} = \rho_{water\_layer} + \frac{\rho_{outer\_membrane}}{K_{ow}} + \frac{1}{\gamma_{ingestion}\left(p_{undigested\_lipid} + p_{undigested\_water}\right)}$$

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[1] In this version, the partial resistance for passive diffusion from outer polar lipid layer, assumed to be inversely proportional to heptane-water partition coefficient K_{hw}, was not considered because there is a lack of QSAR model for predicting K_{hw}.

where ρ_{water_layer} (d.kg$^{-\kappa}$) is the resistance for diffusion in the water layer; $\rho_{outer\_membrane}$ (d.kg$^{-\kappa}$) is the resistance for diffusion in the outer membrane; $\gamma_{ingestion}$ (kg$^{\kappa}$.d^{-1}) is the food ingestion coefficient; $p_{undigested\_lipid}$ (dimensionless) is the chemical fraction contained in undigested food lipids; $p_{undigested\_water}$ (dimensionless) is the chemical fraction contained in undigested food water.

The chemical fractions contained in undigested food lipids $p_{undisgested\_lipid}$ and in undigested food water $p_{undigested\_water}$ are calculated from the lipid and water assimilation efficiencies AE_{lipid} and AE_{water} :

(Equation 11) $p_{undigested\_lipid} = (1 - AE_{lipid}) \cdot f_{lipid\_food} \cdot K_{ow}$

(Equation 12) $p_{undigested\_water} = (1 - AE_{water}) \cdot f_{lipid\_food} \cdot$

where f_{lipid_food} (dimensionless) is the fraction of lipids in food.

The rate at which chemicals are assimilated from the diet via the gastro-intestinal tract (GIT) can then be expressed by the dietary uptake rate constant $k_{absorption}$ (kg.kg^{-1}.d^{-1}), that is assumed to be related to an allometric rate exponent describing the effect of species weight on physiological rate constants.

(Equation 13) $k_{absorption} = \frac{W^{-\kappa}}{\rho_{tot}} \cdot \frac{1}{(p_{undigested\_lipid} + p_{undigested\_water})}$

where $k_{absorption}$ (kg.kg^{-1}.d^{-1}) is the dietary uptake rate constant; W is the animal weight (kg); κ (dimensionless) is the allometric factor; ρ_{tot} (d.kg$^{-\kappa}$) is the total resistance for diffusion; $p_{undigested\_lipid}$ (dimensionless) is the undigested food lipids; $p_{undigested\_water}$ (dimensionless) is the undigested food water.

The rate at which chemicals are eliminated from blood to feces via the GIT can be expressed by the egestion rate constant $k_{egestion}$ (kg.kg^{-1}.d^{-1}). The combination of absorption and egestion allows calculating the chemical assimilation efficiency $E_{assimilation}$ (O'Connor et al., 2013):

(Equation 14) $E_{assimilation} = \frac{1}{\rho_{tot} \cdot \gamma_{ingestion} \cdot (p_{undigested\_lipid} + p_{undigested\_water})}$

Considering this background, the mass balance equation for estimating the concentration C_{blood} of the chemical in blood is (in case of no metabolism):

(Equation 15) $\frac{dC_{blood}}{dt} = k_{absorption} \cdot (C_{diet} - E_{assimilation} \cdot C_{blood})$

where C_{blood} (mg.L^{-1}) is the concentration of the chemical in blood; C_{diet} (mg.kg^{-1}ww) is the concentration of the chemical in diet.

3.4.3. Circulation of blood in tissues and partition of chemicals between blood and fat/tissue

Once chemicals have crossed the GIT barrier, their accumulation in animal organs is mainly governed by two processes:

• the circulation of blood fluids through organs, with input from arterial blood and output to venous blood;

• when blood is circulating within the organ, the partition of chemicals between blood and fat contained in the organ. Partition coefficients are used for representing such distribution of compounds.

The transport of chemicals from blood to organs depends on the perfusion rate of the tissues. Blood flow is assumed to be constant and non-pulsatile. The chemical is assumed to distribute evenly and homogeneously throughout the tissue volume. Moreover, the compound distribution into all compartments is assumed to be limited by perfusion, i.e. the tissue membranes present no barrier to diffusion. Perfusion rate of meat tissues (e.g. muscle, liver, kidneys) can be estimated from the cardiac output and the relative blood flow to organs (i.e. the fraction of total blood flow crossing over each organ). For mammal glands, perfusion flow highly depends on lactating stage of the animal and it is assumed to depend on milk volume production.

Once crossing through the tissue, chemical present in blood is distributed between blood and fat of tissues. Tissue-Blood partition coefficient, associated with assumed available fractions of water and lipids in each tissue, is used for simulating the accumulation of chemicals in tissues.

Considering this background, the mass balance equation for estimating the concentration of the chemical in a given organ tissue is (in case of no metabolism):

(Equation 16) $\quad \frac{dC_{tissue,i}}{dt} = Flow_{blood-organ,i} \cdot \left(C_{blood} - \frac{C_{tissue,i}}{K_{blood-tissue}} \right)$

where C_{blood} (mg.L^{-1}) is the concentration of the chemical in blood; $C_{tissue,i}$ (mg.kg^{-1}ww) is the concentration of the chemical in tissue i; $Flow_{blood-organ,i}$ (L.kg^{-1}ww.d^{-1}) is the blood flow though organ i; $K_{blood-tissue}$ (L.kg^{-1}ww) is the Blood-Tissue partition coefficient.

3.5   Allometric scaling

As described above, Invertebrates, Fish and Mammals models are based on allometric scaling. A short introduction to allometric scaling is then proposed here.

Allometric relationships provide body-size specific parameters instead of values that are arbitrary or taken from a well-known species. Allometry, or the biology of scaling, is the study of size and its consequences. In the VERMEER tool, several allometric coefficients that relate body size to many parameters, like ingestion rate, blood flows in organs, urine elimination, metabolism, are used. These coefficients are taken from meta-analysis, in particular those presented in Hendriks (2007).

4. The ECHA scenario

The VERMEER Rodenticides tool proposes a scenario that is consistent with the recommendations in ECHA (2018).

The ECHA scenario assumes that rodenticides are applied along bank slopes of a drainage channel of wetland marshes. The drainage channel is assumed to be 500 meters long, and has a trapezoidal section with a width at the bottom of 0.3 m, a width at the surface of 1.5 m, and a water depth of 1 m, corresponding to a volume of 450 m^3. The channel water is assumed stagnant; that means that the channel is a close system without any upstream inputs and downstream outputs.

The route of emission in the aquatic system is the flushing away of rodenticide baits into the drainage channel due to high rainfall events. Since it is not considered to be realistic that during such a high water period baits are laid out repeatedly, only one application is considered. The release is then a pulse input occurring during a unique rainfall event (assumed to occur during one day in our scenario).

The quantity of rodenticides release during this unique daily event is driven by: (i) the number of application baits sites. Baits are assumed to be placed on both sides of the channel with a distance of 100 m, resulting in 12 baiting sites; (ii) the fraction of active rodenticide released during the event, assumed to be 0.4 in the ECHA scenario; (iii) the amount of product used for one bait station (in g) and the fraction of active rodenticide in the product. Data related to these amounts and fractions are taken from ECHA (https://echa.europa.eu/fr/information-on-chemicals/biocidal-products). All these default values allow to calculate the quantity of rodenticide discharged in the close channel, and then its initial concentration in raw water (Table 1).

Chemical (active rodenticide substance)	Concentration of active substance (%)	Maximum quantity in bait station (g)	Maximum quantity during a flood event according to ECHA assumptions (12 baits; fraction of active substance released = 40%) (mg.d^{-1})
Brodifacoum	from 0.12 to 0.5	from 50 to 200	4800
Bromadiolone	from 0.25 to 0.5	from 100 to 200	4800
Chlorophacinone	0.5	from 100 to 200	4800
Coumatetralyl	from 0.27 to 3.75	from 100 to 200	36000
Difenacoum	from 0.3 to 0.5	from 100 to 200	4800
Difethialone	0.25	200	2400
Flocoumafen	from 0.25 to 0.5	from 50 to 75	1800
Warfarin	from 4 to 8	from 200 to 220	84480

Table 1 – Concentration of active substance and maximum quantity of rodenticide in bait station

A generic food web (representative of riverine or lake systems) is proposed. It is inspired from Campfens and Mackay (1997) and Lim and Lastoskie (2001). It is based on eight organisms:

1. a generic phytopkankton species;
2. a pelagic invertebrate species (mysid-type species), with a diet composed exclusively of phytoplankton;
3. a benthic invertebrate species (oligochaete-type species), with a diet composed of sediment exclusively;
4. a small pelagic fish species (golden shiner-type species), with a diet composed of pelagic invertebrates exclusively;
5. a small bentho-pelagic fish species (bluntnose minnow-type species), with a diet composed of pelagic invertebrates (50%) and benthic invertebrates (50%);
6. a small carnivorous bentho-pelagic fish species (yellow perch-type species), with a diet composed of pelagic invertebrates (10%), benthic invertebrates (30%), pelagic fish (30%) and bentho-pelagic fish (30%);
7. a big carnivorous bentho-pelagic fish species (lake trout-type species), with a diet composed of benthic invertebrates (10%), pelagic fish (20%), bentho-pelagic fish (20%) and small carnivorous fish (50%);
8. an aquatic mammal, i.e. otter.

5.   How to build an assessment with the VERMEER Rodenticides tool

The VERMEER Rodenticides tool is based on the MERLIN-Expo platform. All the potential features of the MERLIN-Expo platform are described in detail on https://wiki.merlin-expo.eu/doku.php.

Only the main features are described in this chapter to facilitate the use of the VERMEER Rodenticides tool, but issues that are not covered in the present chapter can be found in more detail on https://wiki.merlin-expo.eu/doku.php.

5.1 Describing your assessment: the Information tab

Let's start building an assessment!

You can first read some information about the your assessment:

- Go to the 'Information' tab;

- Click on 'Edit' to open the Description window;

- Write what you want in the Description window: Title of the assessment; Name of the assessor; Characteristics of the assessment, etc…
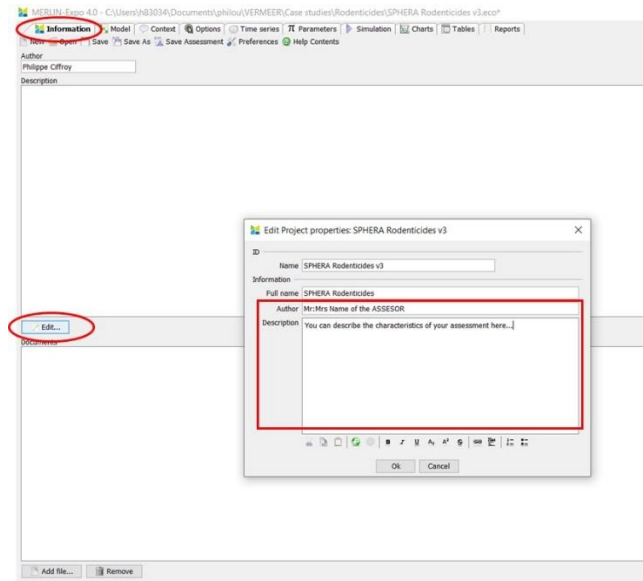
The information you have written are visible on the 'Description' window:
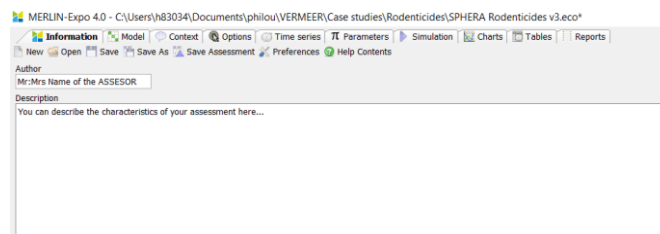
You can also attach any file that is associated to your assessment (e.g. database, report, etc) :

- Go to 'Add file';

- Attach your file
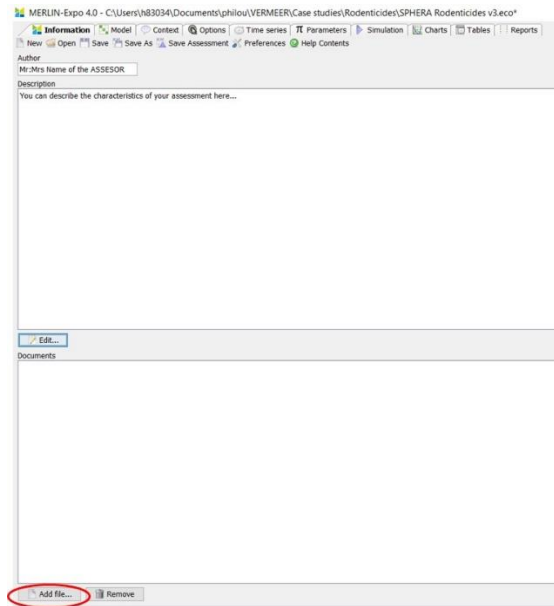
Don't forget to save ('Save as' the first time, and then 'Save') your assessment regularly when building it:
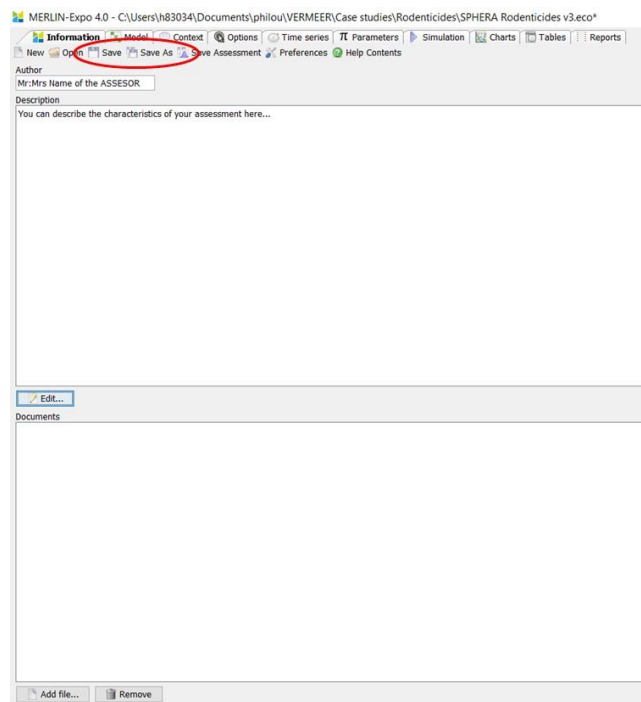
5.2   Selecting the MERLIN-Expo models: the Model tab

We have already downloaded all the models required for running a Rodenticide aquatic scenario from the MERLIN-Expo library. You can anyway select which parts of the model you want to simulate.

The comprehensive VERMEER Rodenticides tool is subdivided in six main blocks:

- Block 1: the 'River model' block, which simulates the partition of chemicals between water and Suspended Particulate Matter, as well as the concentration of chemicals in bottom sediments;

- Block 2: the 'Phytoplankton model' block. The main outpout of this model is the kinetic evolution of the concentration of chemical in phytoplankton (in mg.kg^{-1} fw);

- Block 3: the 'Invertebrates model' block. The main outpout of this model is the kinetic evolution of the concentration of chemical in invertebrate species (in mg.kg^{-1} fw);

- Block 4: the 'Fish model' block. The main outpout of this model is the kinetic evolution of the concentration of chemical in fish species (in mg.kg^{-1} fw);

- Block 5: the 'Mammals model' block. The main outpout of this model is the kinetic evolution of the concentration of chemical in organs (blood, muscle, liver, kidney, milk) of mammal species (in mg.kg^{-1} fw).

- Block 6: the 'Ecotoxicity' block. It contains QSAR predictions extracted from VEGA of ecotoxicological endpoints for phytoplankton, invertebrates and fish.
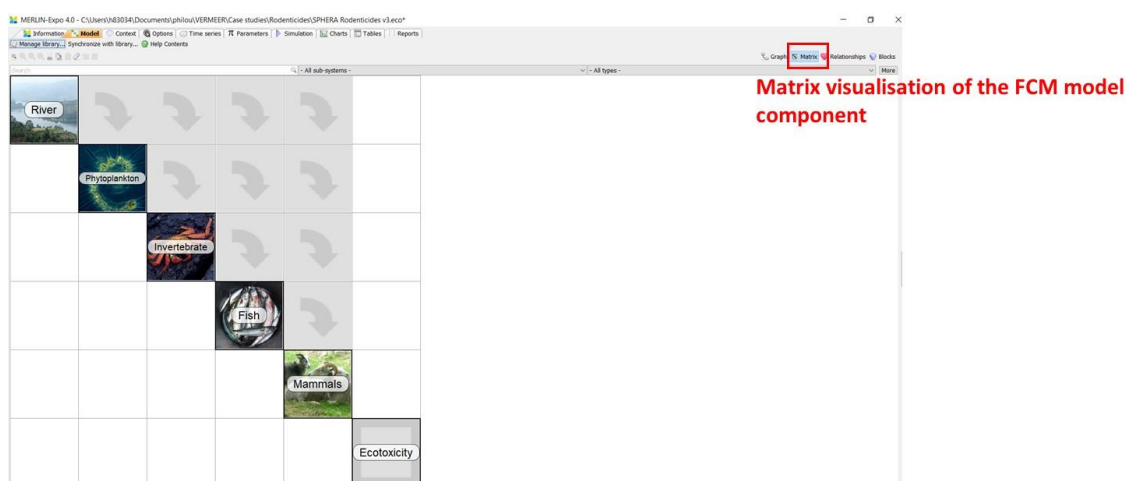
You can select one or more blocks or sub-blocks for the simulation[2]. For this purpose,

- right click on the block you want to deselect (in the picture below, the 'Ecotoxicity' block);

- click on Enable/Disable;

- the block you have chosen for this operation will be removed from the simulation (and therefore, you don't have to inform parameter values required for this block).

---

[2] Obviously, if you want to simulate the 'Mammals' block and if you define that the mammal species eats fish, you can deselect the 'Fish' block'. The selection/unselection choices must be consistent with your assumptions
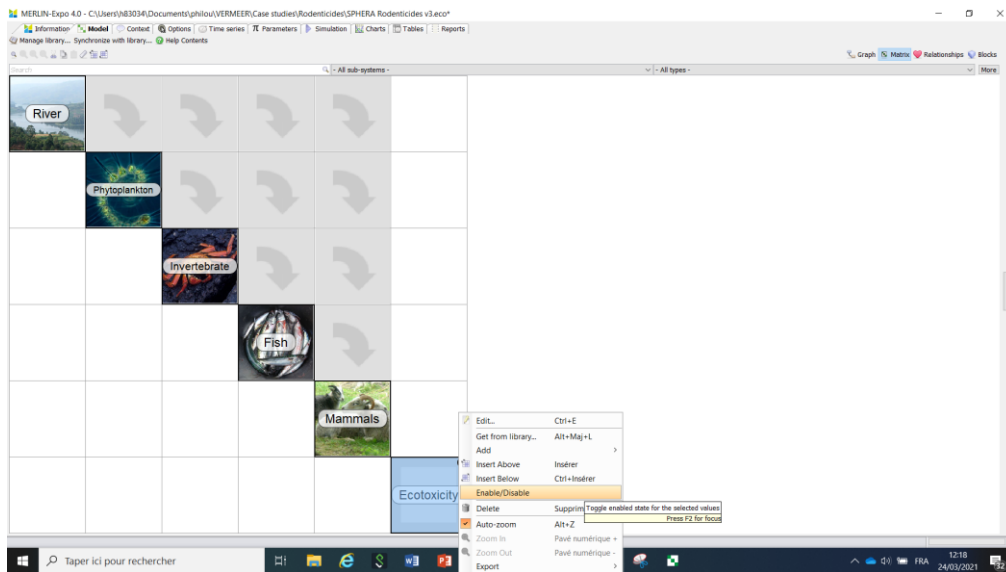
Unselected blocks are then indicated by a red cross:
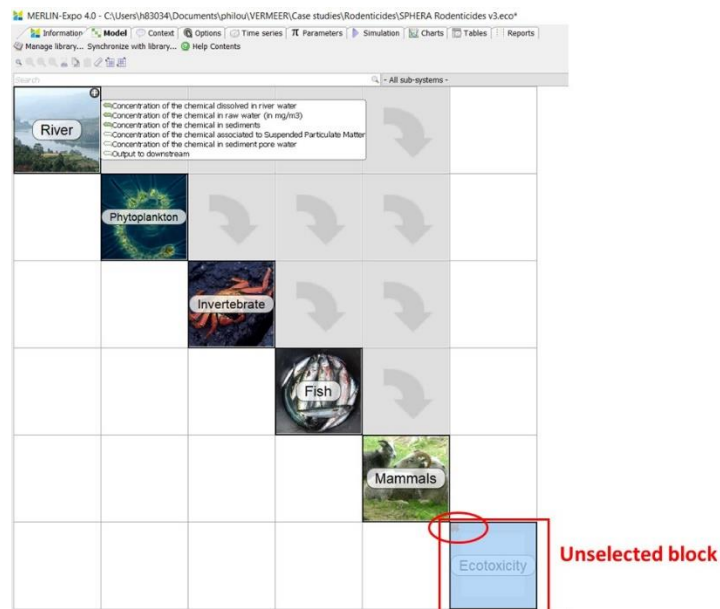
For selecting a block which had been previously unselected, do the same operation:

- right click on the block you want to deselect (in the picture below, the 'Hazard data level 3' block;

- click on Enable/Disable;

- the block you have chosen for this operation will be selected again for the simulation.

You can do the same operation for sub-blocks, for example the 'Algae_toxicity' sub-block. For this purpose:

- open the 'Ecotoxicity' block with the '+' indicated at the top right;
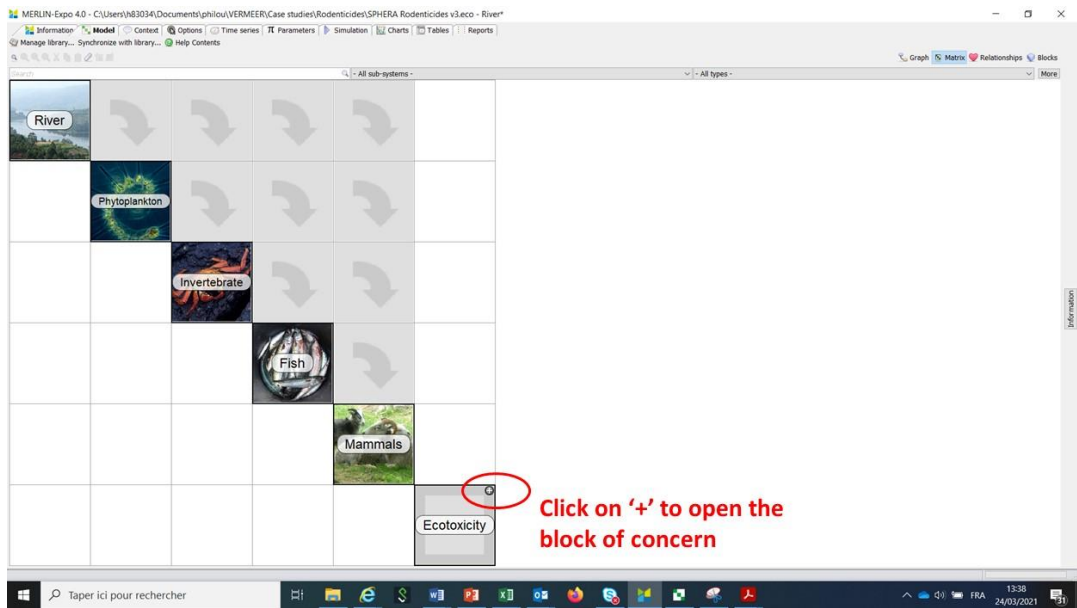
- the sub-blocks included in the block of concern are now visible:
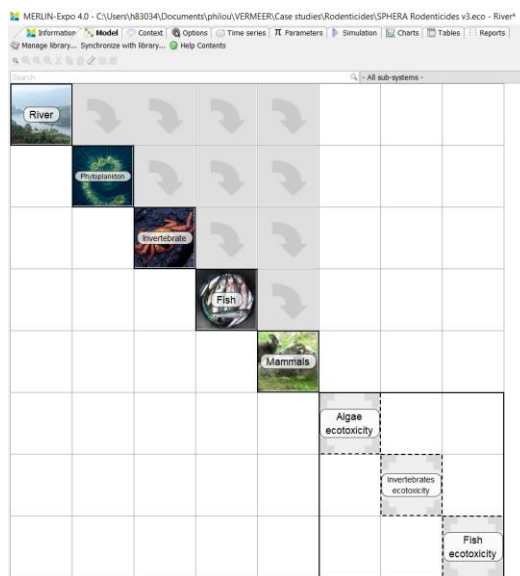
- You can proceed as indicated above for deselecting/reselecting, e.g. the 'Algae_ecotoxicity' sub-block.

5.3 Selecting the chemicals and the species of concern: the Context tab

In the Context tab, you can select the chemicals and the species you want to assess.

5.3.1 Selecting the chemical(s)

A comprehensive list of chemicals is proposed in the VERMEER Rodenticides tool. Each chemical is described by its name and ECAS number:
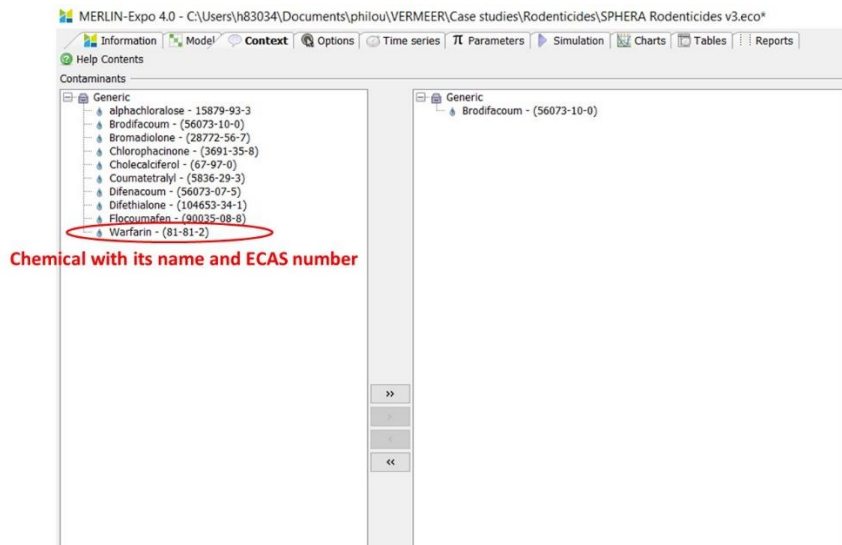
You can search a specific chemical with the Filter option, specifying e.g. an ECAS number:
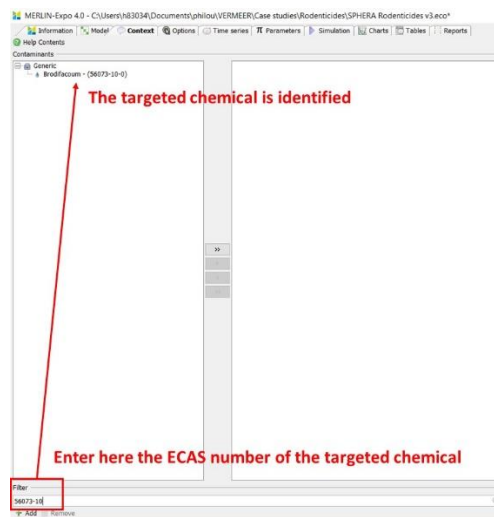
To select the chemical(s) you want to assess, choose it/them in the left window and move them to the right window (or inversely from the right to the left to deselect) :
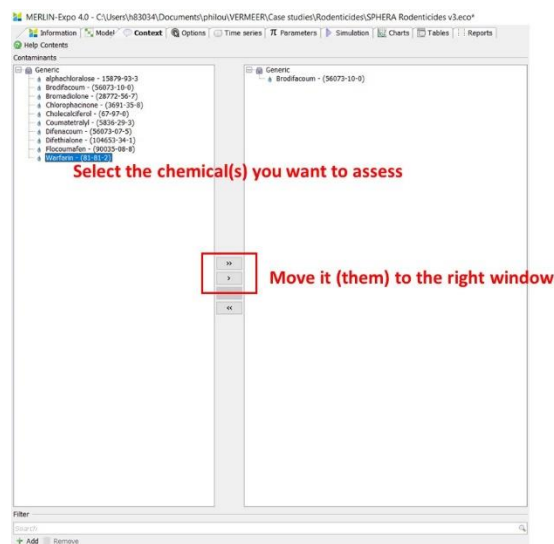
5.3.2 Creating a new chemical

If the chemical you want to assess is not in the list proposed by the VERMEER Rodenticides tool, you can create it:

- Click on 'Add' for creating a new chemical:

- In the Add Contaminant window, indicate a short name, a full name (eventually the same), and the chemical SMILES; Choose 'Organic'.

- Click OK.

The new chemical is created and added to the list of Rodenticides.
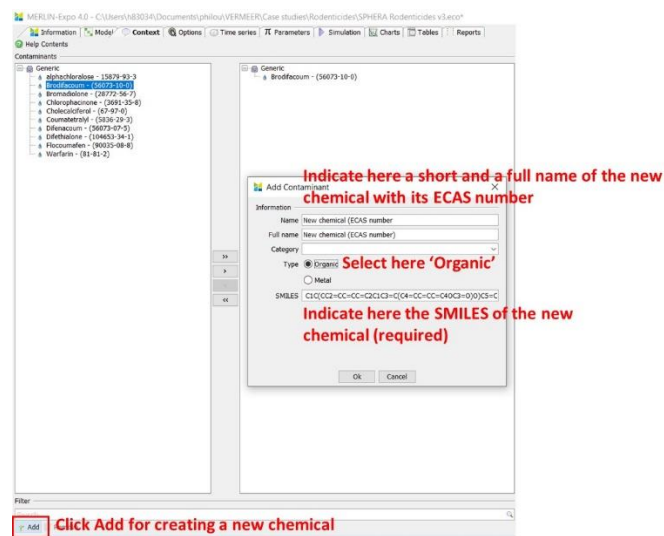
5.3.3 Selecting the species to assess

Several phytoplankton/invertebrates/fish/mammal species are proposed and parameterized in the VERMEER Rodenticides tool (corresponding to the ECHA scenario presented in Chapter 4). These species are connected through their respective food diet items (see Chapter 4).

5.3.4 Creating a new species and removing an existing species

If the species you want to assess is not in the list proposed by the VERMEER Rodenticides tool, you can create it:

- Click on 'Add' +select 'Phytoplankton species' or 'Invertebrates' or 'Fishes' or 'Mammals' for creating a new species belonging to one of the predefined categories;

- A new species is created in the list of species;

- Write the name of the new species (since it is a new food, you will have to inform the value of the several parameters in the Parameter tab – see below)
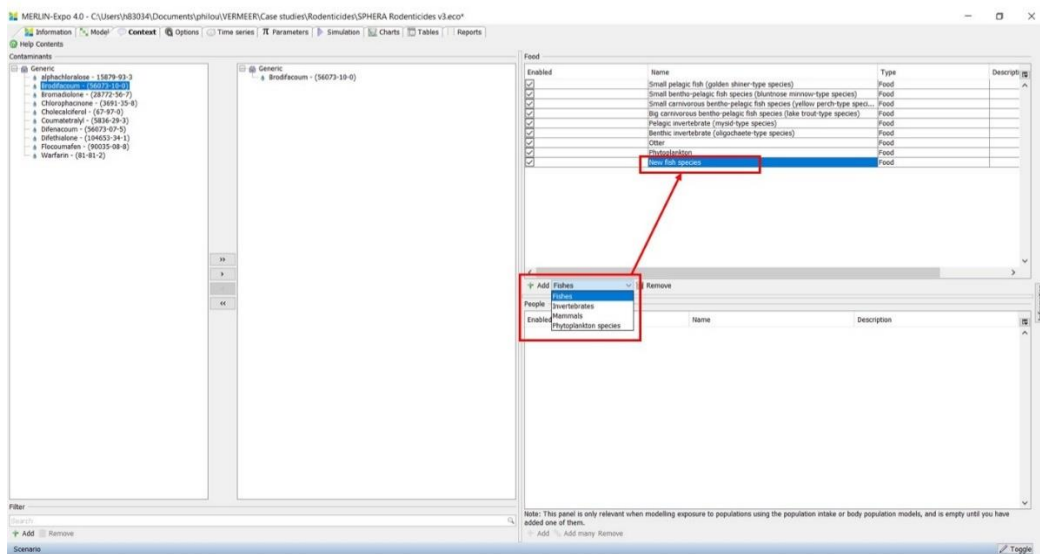
If you want to remove a species present in the list, select the targeted species and use the 'Remove' button.
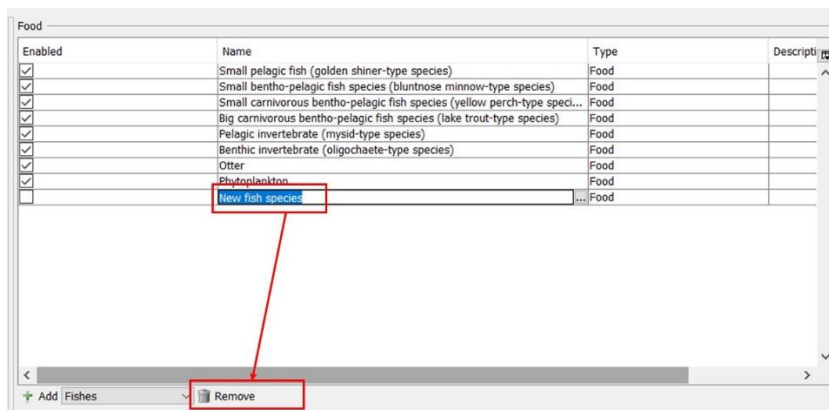
5.4   Selecting the Calculated vs Measured options: the Option tab

In the Context tab, you can select if some parameters are calculated or if you define them as measured data.

The VERMEER Rodenticides tool can calculate the two following parameters (among many others):

- the Concentration of chemical in raw river water. If you define flux of chemical from point source(s) (in mg.d^{-1}) and/or inputs of chemicals from the upstream river (in mg.d^{-1}), additionally to

data related to the river flow rate (in $m^3.d^{-1}$), the River model calculates the concentration of the chemical(s) in raw water;

- the Suspended Particulate Matter concentration. SPM can be calculated by a rating curve relating SPM to river flow rate (see 3.1).

But if you have measured values for one of these parameters, or for both, you can use these measured experimental values instead of calculated values. For this purpose:

- For SPM, select the "Calculated vs Measured" option for the SPM parameter of concern (If you choose 'Measured', default values are proposed for the SPM in the 'Time series' window, but they obviously do not correspond to your own measured value. Therefore, you will have to provide a value in the Time series tab – see 4.5);
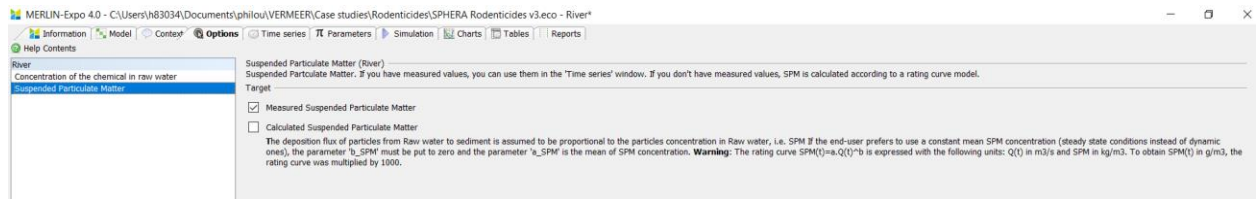
- For the Concentration of chemical in raw river water, select the targeted chemical and then select "Calculated vs Measured" option (If you choose 'Measured', default values are proposed for the Concentration in raw river water' in the 'Time series' window, but they obviously do not correspond to your own measured value. Therefore, you will have to provide a value in the Time series tab – see 4.5)
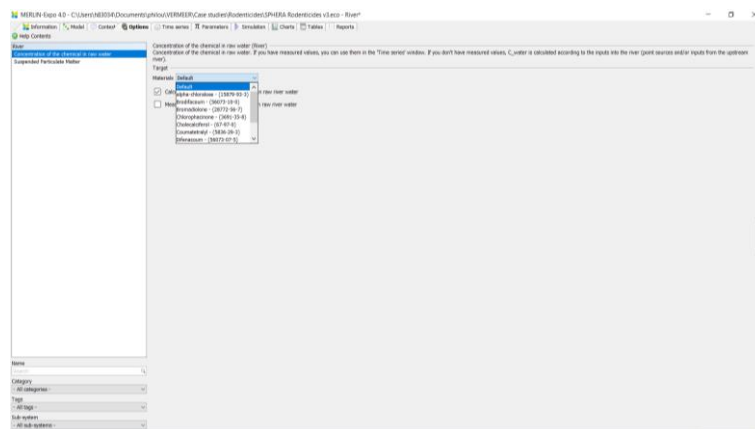
5.5   Selecting the forcing variables of the assessment: the Time series tab

In the Time series tab, you can select all the forcing variables that show temporal variations, i.e.

- temperature in the investigated surface water;
- the concentration of the chemical in raw water entering into the zone of interest from the upstream river zone (in $mg.m^{-3}$);
- the flux of chemical from point source(s) (e.g. industry, sewage water treatment plant, etc) (in $mg.d^{-1}$);
- the flow rate of the river (in $m3.s^{-1}$);

- the measured concentration of the chemical in raw river water (required only if the Measured option has been chosen – see 5.4);
- the measured SPM concentration (required only if the Measured option has been chosen – see 5.4);
- wind speed.

5.5.1 Defining a constant value for a forcing variable

We consider here temperature as an example of forcing variable.

For defining a constant temperature:

- Go to 'Data'

- Define for Time=0, the chosen temperature (in °C).
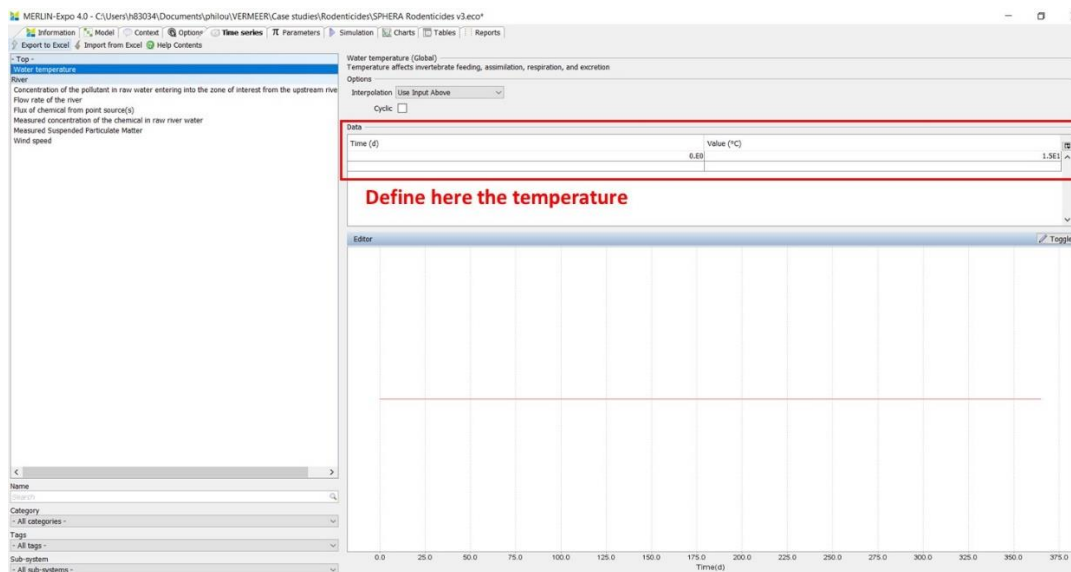
5.5.2 Defining a variable temperature

For defining a variable temperature:

- Go to 'Data'

- Define the sequence of the chosen temperatures (in °C) (e.g. in the figure below: 15°C from 0 to 10 days; 5°C from 10 to 20 days; 20°C from 20 days to infinity)

- Define the 'Option' for the interpolation between dates (e.g. in the figure below: constant temperature from 0 to 10 days; constant temperature from 10 to 20 days; constant temperature from 20 days to infinity). You can test other 'Options'; the corresponding sequence will appear on the figure.

- The 'Cyclic' option can be selected if you want to repeat the same sequence several times.
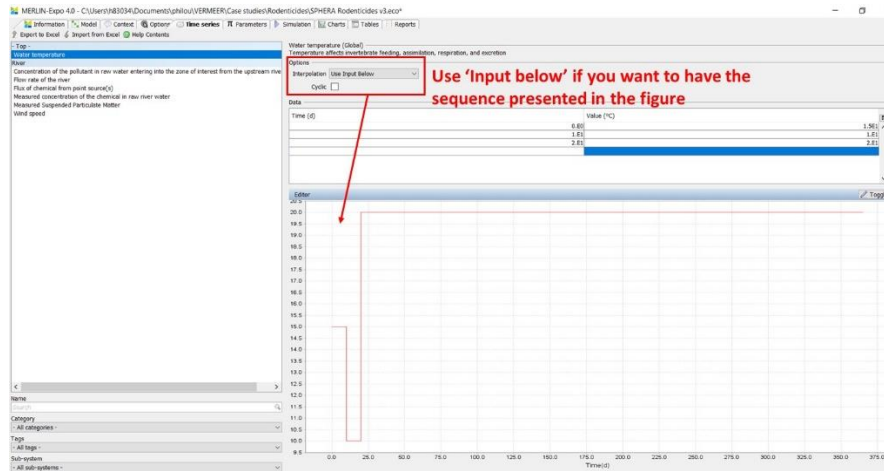
For the forcing variables that depend on the chemical (i.e. concentration of the chemical in raw water entering into the zone of interest from the upstream river zone; flux of chemical from point source(s); flow rate of the river), don't forget to select the targeted chemical:
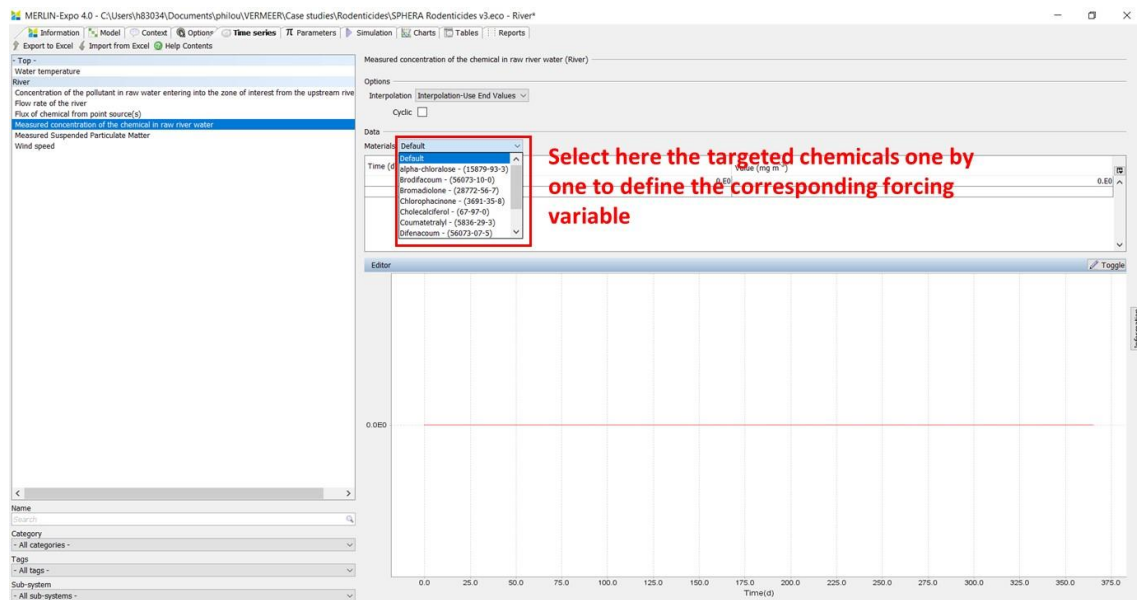
5.6   Selecting the parameter values: the Parameters tab

For running the model, we have to set values for each of the parameters. Parameters were subdivided in several categories.

5.6.1 Generic presentation of parameters

When you select a parameter, you automatically open a window which contains the following information:

- Name of the parameter, and eventually comments about the parameter;

- Unit

- Best estimate (or default) value. For most of the parameters, best estimates are proposed by the VERMEER Rodenticides tool. You can change the proposed value with your own value if available and relevant;

- Probability Density Function (PDF). PDF is optional and is used when parameter values are uncertain. Uncertainty is described by a PDF (e.g. normal PDF, log-normal PDF, uniform PDF, etc). PDFs are used for probabilistic simulations (see 5.7.4).
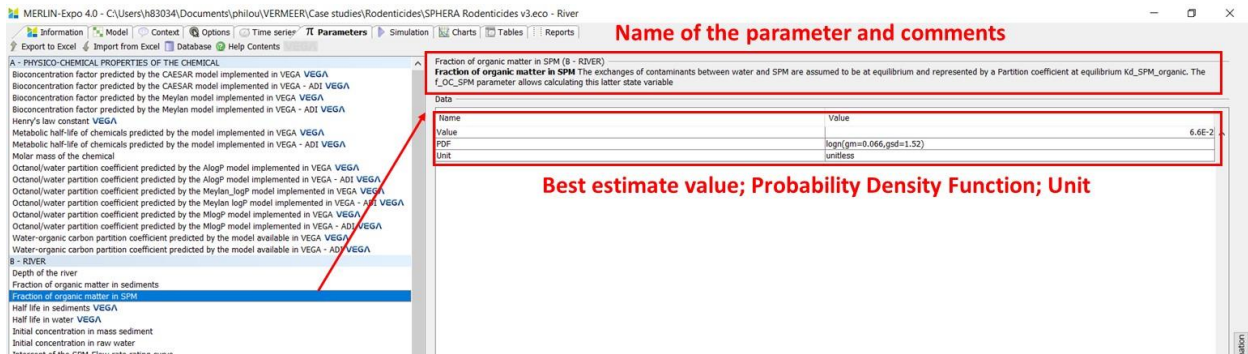
If you want to change the PDF:

- Click on the PDF box;

- Select the PDF type you want to use (a large list of potential PDF types is available);

- Indicate the parameters of the chosen PDF (e.g. arithmetic mean and standard deviation for normal PDF; geometric mean and geometric standard deviation for log-normal PDF; minimum and maximum values for uniform PDF; mean and degrees of freedom for Student PDF, etc).
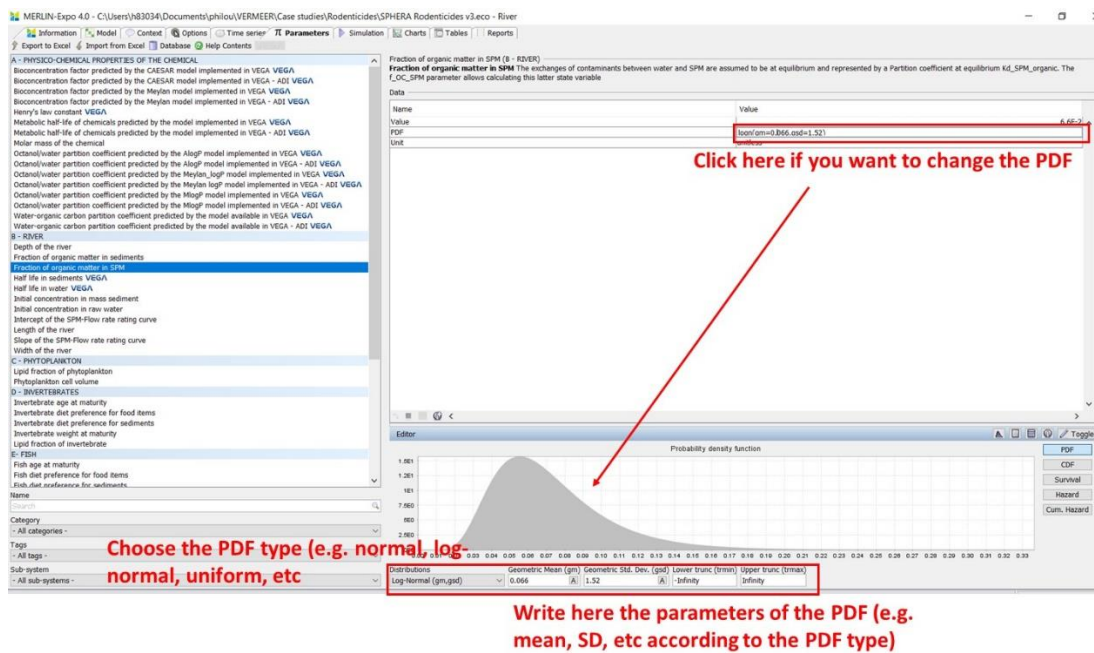
5.6.2 Parameter values calculated by a VEGA model

Some parameters are chemical-specific, i.e. their value depends on the chemical that is targeted by the assessment. For such parameters, specifying the parameter value can be done through a direct access to the VEGA tool, which is a library of QSAR models for the prediction of values for an extended list of endpoints. All the parameters that are linked to a relevant QSAR model available in VEGA are indicated by the VEGA tag:

All these parameters with a 'VEGA' tag are linked to a QSAR model available in the VEGA tool

Each model available in the VEGA platform provides two kinds of information for a given parameter: 1) the quantitative or qualitative value of the prediction; 2) the Applicability Domain Index (ADI) of the prediction for the chemical of concern, on a [0;1] scale. ADI is a summary index indicating the confidence related to the prediction: 0 means that the chemical is outside of the applicability domain; 1 means that the chemical is integrally within the applicability domain. For this reason, each parameter associated to a VEGA model is described by two lines in the VERMEER Rodenticides interface:

- 'Name of the parameter'. This line refers to the parameter (quantitative or qualitative) prediction from the VEGA model;

- 'Name of the parameter – ADI'. This line refers to the ADI of the prediction for the chemical of concern. ADI is taken into account for probabilistic simulations aimed at uncertainty/sensitivity analysis.

Prediction with a QSAR model available in VEGA

ADI of the prediction with a QSAR model available in VEGA

When a data is missing for a given chemical, you can generate a relevant value calling the corresponding VEGA model as follows:

- Click on the VEGA button at the top of the window to run the corresponding VEGA model;

- The corresponding VEGA model returns the prediction for the requested parameter and chemical(s). If you accept the prediction, it is automatically written in the corresponding cell.

Click on the VEGA button for running the corresponding VEGA model

Missing value for the selected parameter and the selected chemical

When you have clicked on the VEGA button, the VEGA model runs for the requested parameter and chemical(s)

The relevant VEGA model returns a value for the requested parameter and chemical(s).
If you accept the prediction, the value is automatically written in the corresponding cell,

You have to follow the same process for the ADI of the targeted parameter (line just below).

5.6.3 Parameters describing the physico-chemical properties of the chemical(s)

Several parameters describing the physico-chemical properties of the chemical(s) are required for running a simulation. These parameters are:

- the Bioconcentration factor, predicted by two VEGA models;

- the Metabolic half-life, predicted by one VEGA model;

- the molar mass of the chemical;

- the Octanol-Water partition coefficient, predicted by three VEGA models;

- the Water-Organic carbon partition coefficient.
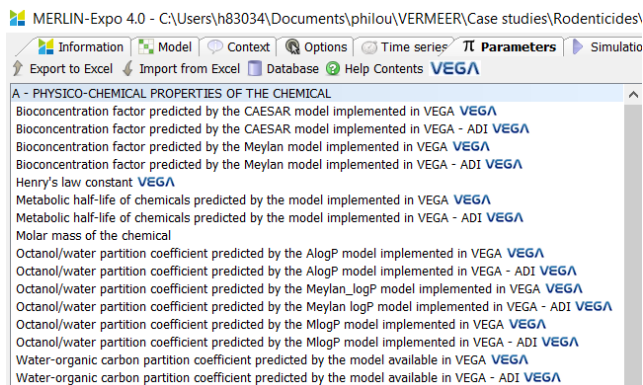
5.6.4 Parameters required by the River model

Several parameters are required for running the River model:

- Parameters describing the geometry of the system, i.e. the length, width and depth of the river. Default values are proposed in the VERMEER Rodenticides tool, corresponding to the ECHA scenario described above (see 4). By definition however, the geometry of the system is specific to each assessment and the assessor have to correct them if necessary;

- Parameters describing the initial state of the system, i.e. the initial concentrations in raw water and in sediments. By default, initial concentrations in raw water and sediments are set at zero in the current VERMEER Rodenticides tool, but it can be corrected by end-users if necessary;

- Parameters describing the physico-chemistry of the river system, i.e. the fraction of organic matter in SPM and sediments, and the parameters of the rating curve model allowing to relate flo rate and SPM concentration. Such parameters must be updated by end-users according to the specificities of the investigated river system.

4.6.5 Parameters describing the Phytoplankton, Invertebrates, Fish and Mammals models

In the Phytoplankton, Invertebrates and Fish blocks, parameters related to physiology of the targeted organisms must be informed, i.e. lipid fraction of organisms, organisms weight or length, organisms age at maturity, and organisms diet preference. All these parameters are specific to the selected species.

For informing or correcting parameter values, select the targeted parameter and enter the parameter values for each phytoplankton, invertebrate and/or fish species.

The 'Diet preference for food items' parameter is presented in a matrix form: for a given species (represented on a line), enter the fraction of food item i (in columns) in the diet composition. The sum of a given line must then be unity.


For the Mammals block, two additional parameters are required by the PBPK model, i.e. the Adipose tissue-Blood partition coefficient and Hydrogen bond donor strength.

5.7   Running a simulation: the Simulation tab

The simulation page lets you run deterministic, probabilistic (Monte Carlo) or sensitivity analysis simulations. The error section lists problems that must be solved before a simulation can be performed.

5.7.1 Visualizing errors before running a simulation

For running a simulation, all the parameters must be informed, i.e. a quantitative value must be affected to each of them. If values are missing, the VERMEER Rodenticides tool indicates them in the Simulation tab:

Error messages to be solved before running a simulation (here 'Value is missing')
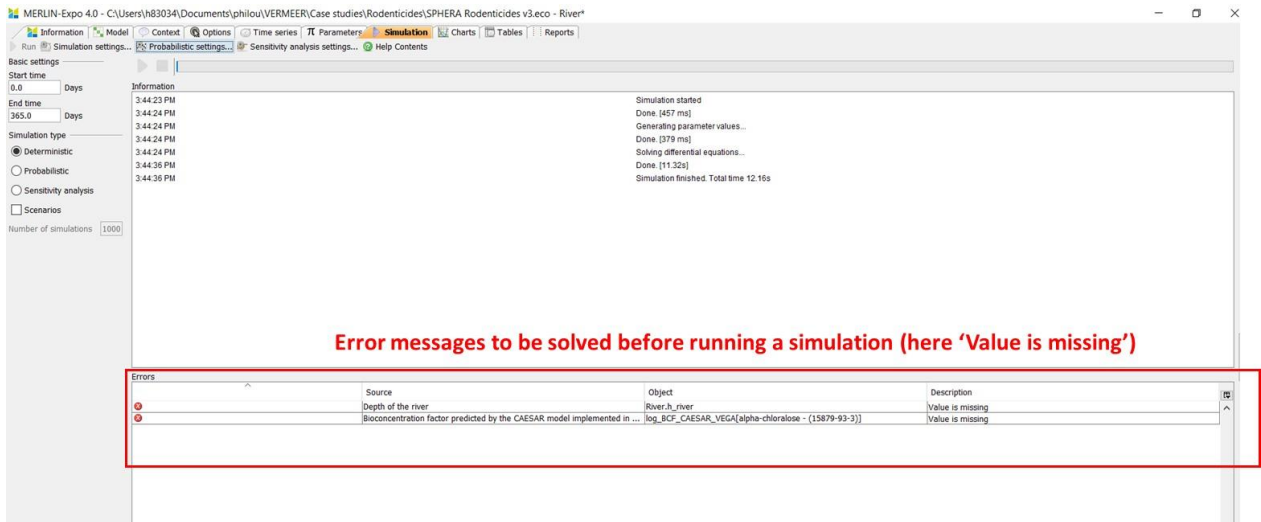
If such information appears, you have to fill the data gaps.

5.7.2 Defining the simulation settings

Before running a simulation, you have to define some simulation settings in the 'Simulation settings' window:

- **Duration of the exposure assessment**. For this purpose:

  o Define 'Start time' at 0;

 o Define 'End time' at the maximum contact time you have chosen;

Define here the duration of the simulation
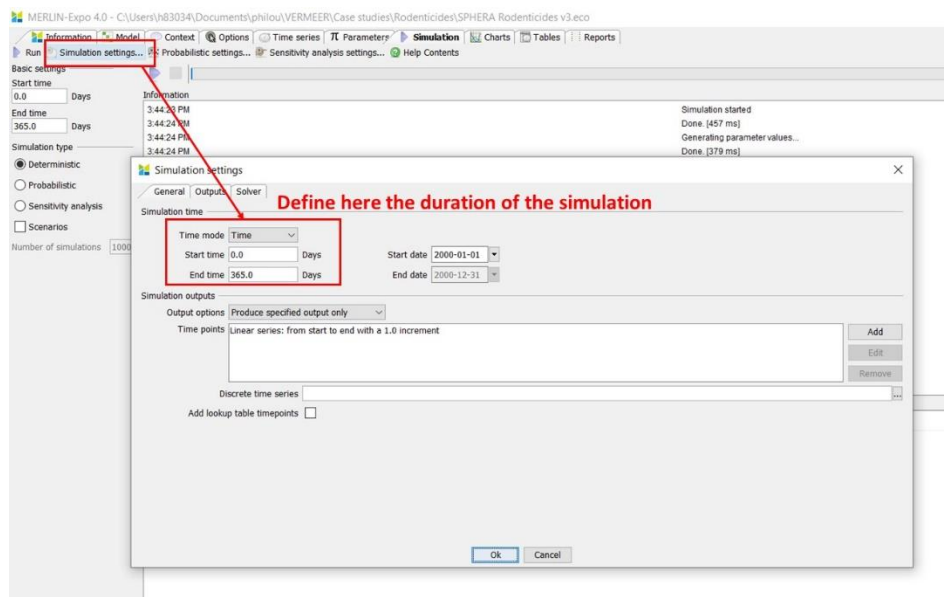
- **The time points for which you want to see the simulation results**. For this purpose, go to 'Simulation outputs' and:

  o If you want to see the results only for some specific pre-defined time points,

    ▪ select 'Produce specified output only',

    ▪ select 'Add',

- Select 'Custom',

- define the chosen 'Time points' (for example, in the simulation shown below, results will be shown at nine time points: 0.042 d (=1 h), 0.083 d (=2 h); 0.25 d (6 h); 1d; 2 d; 4 d; 10 d; 20 d; 48 d);

- Click on 'OK';
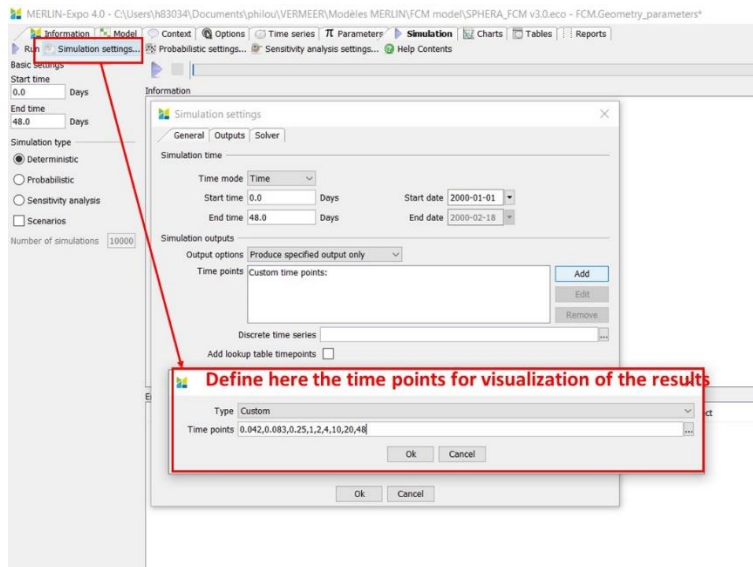
o If you want to see the results at a regular linear time increment,

- select 'Produce specified output only',

- select 'Add',

- Select 'Linear increment',

- define the chosen Start time, End time and 'Increment' (for example, in the simulation shown below, results will be shown every day from 0 to 48 d);

- Click on 'OK';

Define here the linear increment for visualization of the results
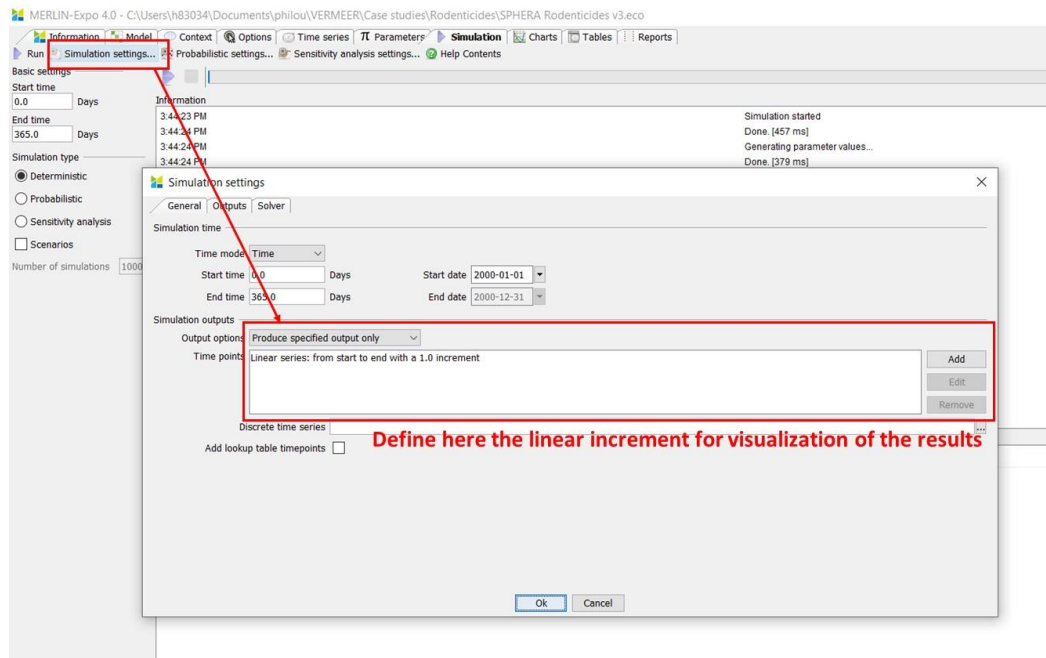
o If you want to see the results at a geometric time increment (i.e. more results at short times and less results at longer times),

- select 'Produce specified output only',

- select 'Add',

- Select 'Geometric',

- define the chosen Start time, End time and 'N', number of data points to be visualized (for example, in the simulation shown below, results will be shown every from 0 to 48 d according to a geometric scale);

- Click on 'OK'.

Define here the number of data for visualization of the results according to a geometric scale
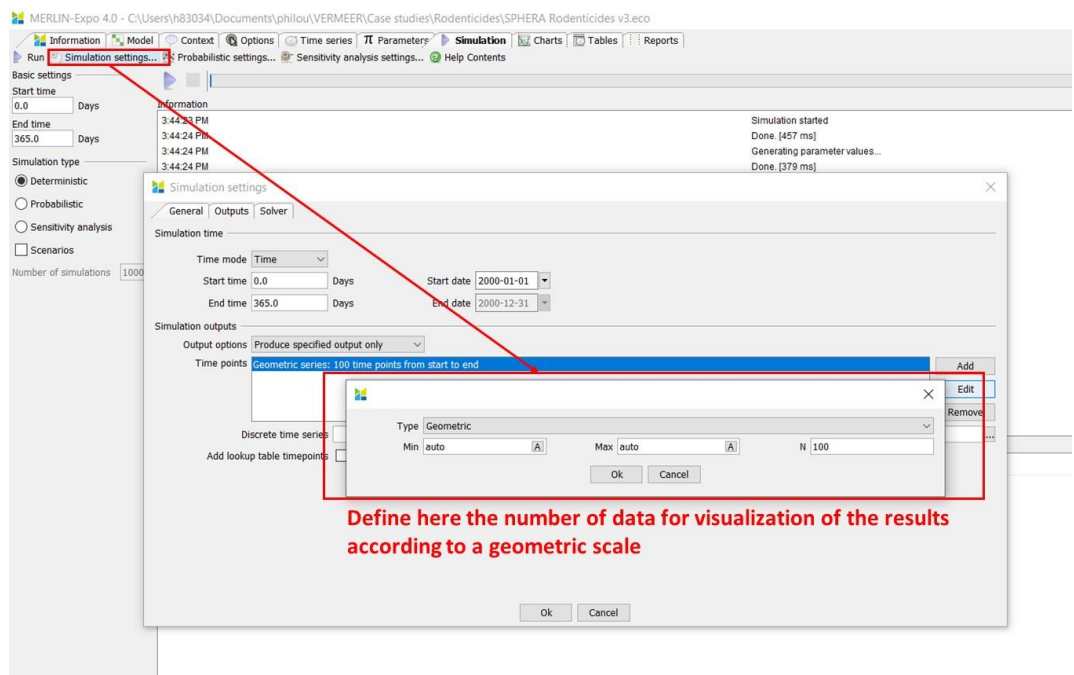
- **Outputs to be visualized**. All the state variables (i.e. variables calculated by the model) can be visualized by end-users. Some of them are however are of poor interest for regulatory purposes since they are intermediate variables in the simulation process. For regulatory purpose, the most important variables are the chemical concentrations in the different media and organisms (in mg.kg^{-1}) and the ecotoxicological endpoints.

  All these outputs are selected by default for results visualization. But you can add or remove endpoints by moving the corresponding endpoints from the left to the right bow (and inversely).
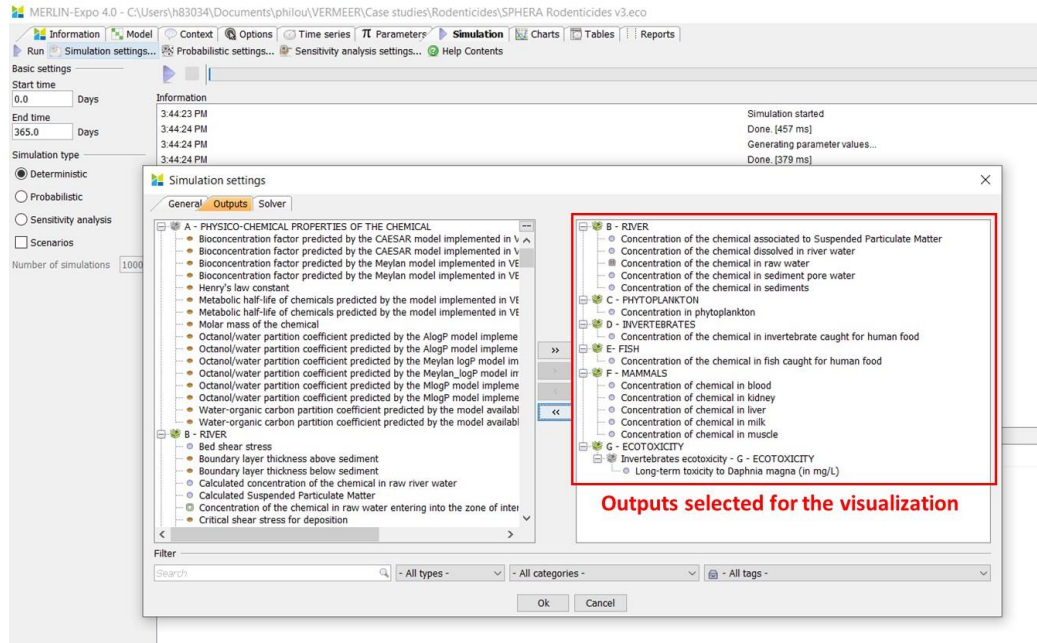
5.7.3 Running a deterministic simulation

Running a 'deterministic simulation' means that each parameter (defined at the previous step in the 'Parameters' tab – see 4.6) is described by its best estimate value. Eventual PDFs are therefore ignored.

For running a deterministic simulation:

- Select 'Deterministic' in the 'Simulation type';

- Click on the arrow for starting the simulation;

- When the simulation is finished, it is indicated in the 'Information' window. You can see the results (see 5.8).
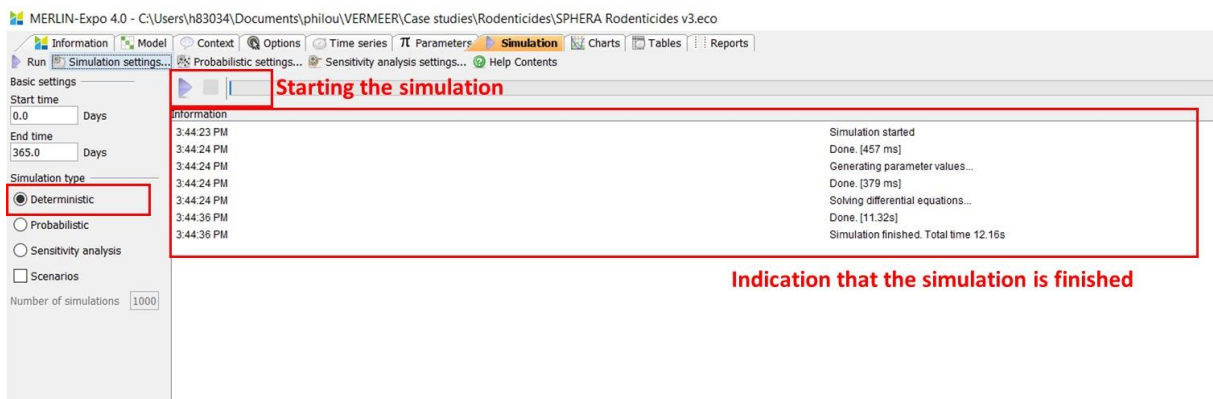
5.7.4 Running a probabilistic simulation

Running a 'probabilistic simulation' means that each parameter (defined at the previous step in the 'Parameters' tab – see 4.6) is described by its PDF. A Monte Carlo generator randomly samples a given number of parameter combinations according to the respective PDFs and the model runs for each of these combinations. This allows to generate a great number of simulations and associated results, and summary statistics describing the parametric uncertainty can be calculated (e.g. mean, standard deviation, percentiles, etc).

To run a probabilistic simulation, it is first necessary to define the 'Probabilistic settings' in the ad hoc window. For this purpose:

- Open the 'Probabilistic settings' window;

- In the 'General' window, you have to define:

  o the 'Number of simulations'. This setting specifies how many simulations will be performed during a probabilistic simulation.

  o the 'Seed'[3]. The seed initializes the seed value for the random number generator. If you set the same seed, then the sequence will be the same each run. If you don't need this option, you can use the default selection 'auto';

  o the 'Sampling' scheme, either Monte Carlo (pseudo random numbers) or Latin hypercube sampling. For the applications of the VERMEER Rodenticides tool, the Monte Carlo scheme is sufficient.
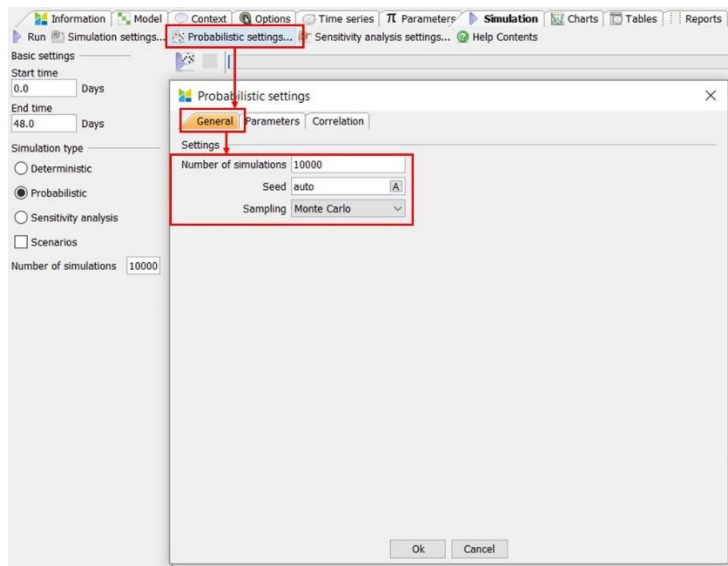

- The 'Parameters' window lets you select the parameters that will be included in the uncertainty analysis. Only parameters that have been assigned PDFs can be selected. Note that you must select at least one parameter to run a probabilistic simulation.

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[3] The seed is an initial number of the random number generator which returns a sequence of numbers that always generates the same sequence for given value.
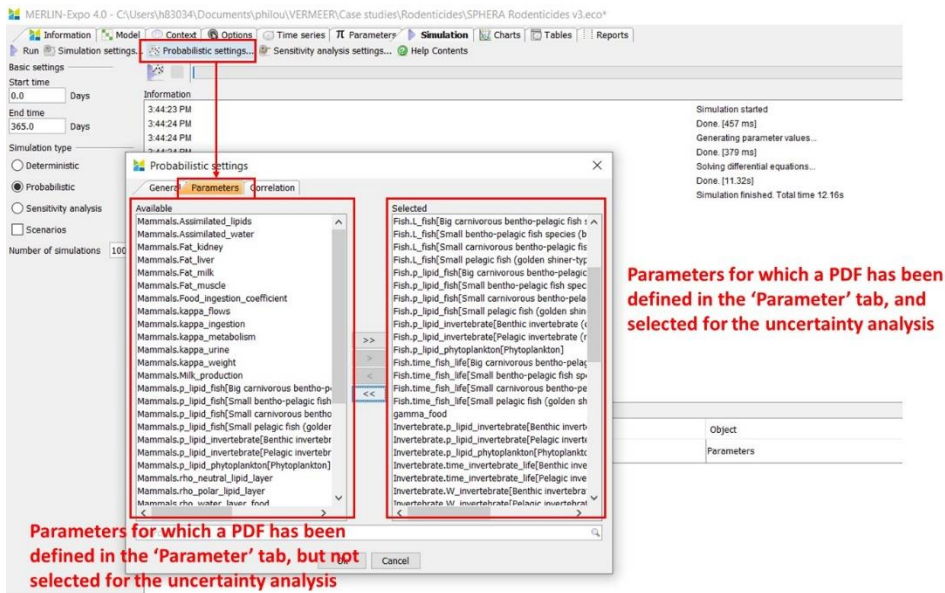
- In the 'Correlations' window, correlations between parameters can be assigned in order to reduce noise and to avoid impossible parameter combinations. A priori, this option is not necessary for the VERMEER Rodenticides tool.

When the 'Probabilistic settings' have been defined, you can start the probabilistic simulation:
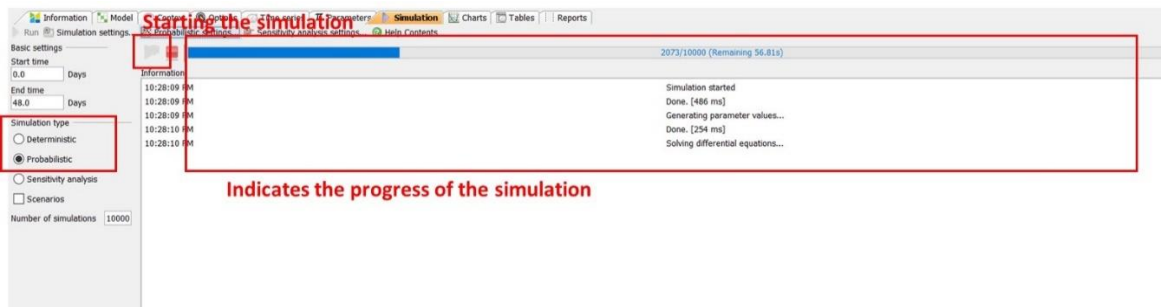
## 5.8   Analysing results: the Charts and Tables tabs

Results can be analysed in the Charts or in the Tables tabs. Whatever the results are displayed on the Charts or Tables tabs, the process in the selection of endpoints is similar.

4.8.1 Selecting the endpoints

To analyse the results of the simulation, you have first to select which results are relevant for you. For this purpose:

- Select the targeted endpoint in the list of endpoints you have selected in 5.7.4;

- Select the food(s) you want to analyse;

- Select the chemical(s) you want to analyse.

You can create all the possible endpoint-food(s)-chemical(s) combinations simultaneously (i.e. all together) or sequentially (one by one).
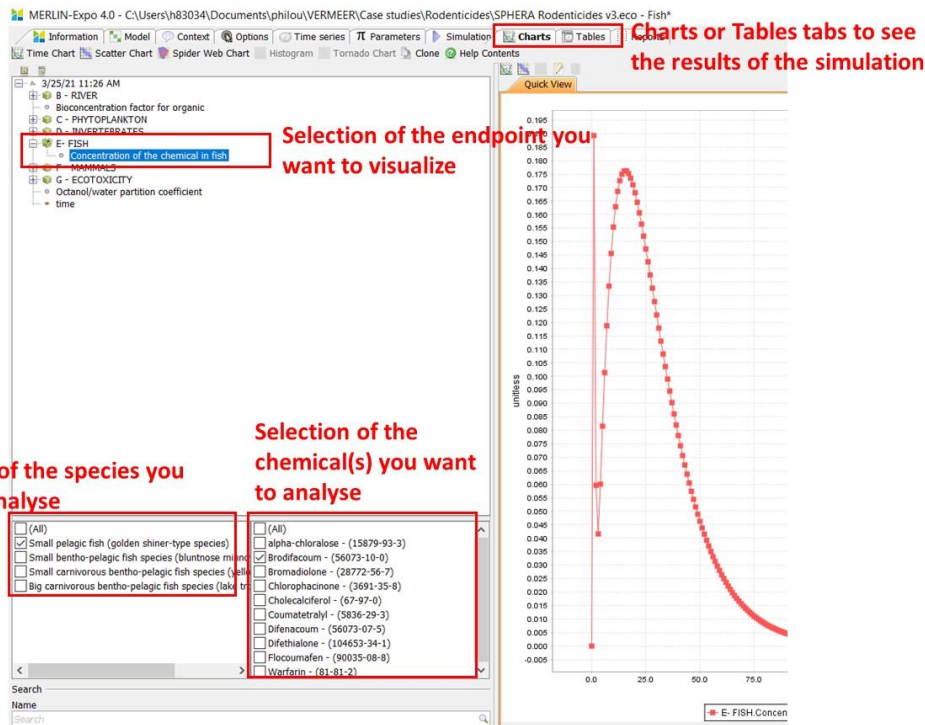
4.8.2 Creating a chart

The VERMEER Rodenticides tool generates figures to visualize results. For example, temporal figures can be generated as showed below.

All the options to generate figure (generic options for all the models included in the MERLIN-Expo platform) are described in detail on https://wiki.merlin-expo.eu/doku.php?id=charts_screen.
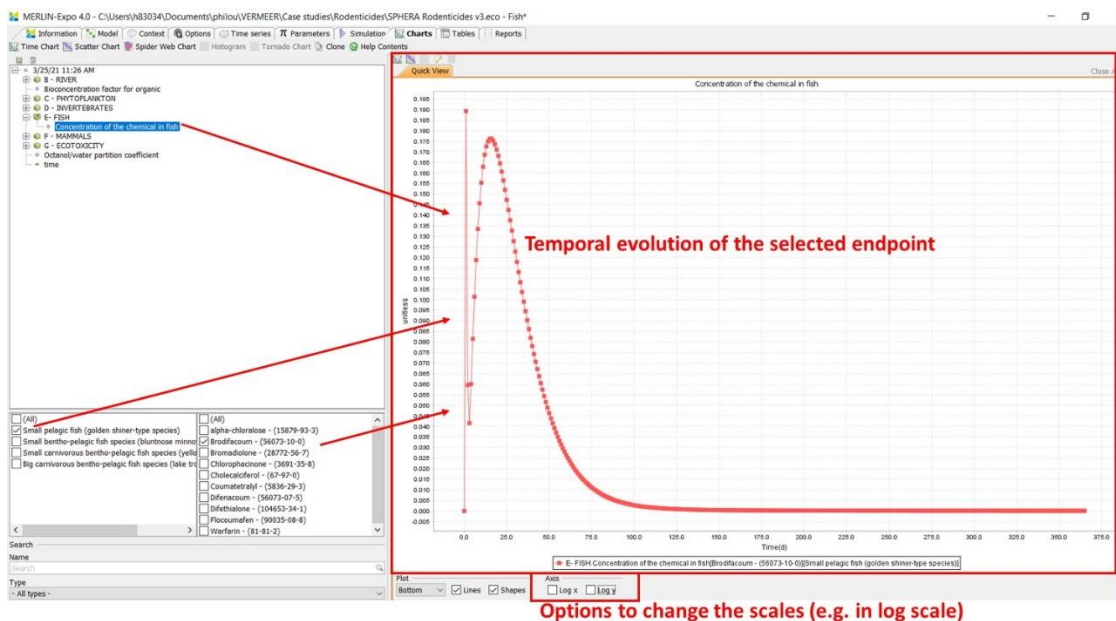
4.8.3 Creating tables

The VERMEER Rodenticides tool generates tables to visualize results. For example, tables describing the evolution of the selected endpoint in time can be generated as showed below.

All the options to generate tables (generic options for all the models included in the MERLIN-Expo platform) are described in detail on https://wiki.merlin-expo.eu/doku.php?id=tables_screen.

Note that you can export data for a given table either to a text or an Excel file. Right-click the table and select 'Export data…'.

Temporal evolution of the selected endpoint

References

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Lim, D. H., & Lastoskie, C. M. (2011). A dynamic multimedia environmental and bioaccumulation model for brominated flame retardants in Lake Huron and Lake Erie, USA. Environmental Toxicology and Chemistry, 30(5), 1018-1025