Exploration of potential GB-specific modifications to the EUSES model for UK REACH

Chief Scientist's Group report

December 2025

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Published by:

Environment Agency
Horizon House, Deanery Road,
Bristol BS1 5AH

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Keywords:
Exposure scenarios, EUSES, UK REACH

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Citation:
Environment Agency (2025) Exploration of potential GB-specific modifications to the EUSES model for UK REACH. Environment Agency, Bristol.

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Acknowledgements

The authors thank all the organisations and individuals who contributed to this project, including the Hazardous Substances Advisory Committee (HSAC). In particular, the following people provided invaluable assistance during the preparation of this report:

Atkins:	Carlos Constantino
Environment Agency (EA):	Marta Cattin Charlotte Crossley Mat Davis Richard Davis Ian Dunhill Tony Heany Lottie Hutchinson Adam Malin Ian Martin Neil Murdoch Harriet Orr Laura Thain
Health and Safety Executive (HSE):	Claire Anderson James Hingston
REACH Independent Scientific Expert Pool (RISEP):	Sue Bullock Laura Carter Qintao Liu Richard Murray-Smith
UK Water Industry Research (UKWIR):	Mandy Fletton
Food Standards Agency (FSA):	Andy Axon

Vitis Regulatory Limited produced a first draft of this report, which was subsequently amended by the EA to include updated parameter values from some of those initially proposed following RISEP's review.

Executive summary

The UK REACH (Registration, Evaluation, Authorisation and restriction of CHemicals) Regulation applies to the majority of chemicals that are manufactured in, or imported into, Great Britain (GB; England, Scotland and Wales). UK REACH requires the registrant of hazardous substances supplied at or above 10 tonnes per year to perform an exposure assessment, which is documented in a Chemical Safety Report.

The primary environmental exposure model used in UK REACH is the European Union System for Evaluation of Substances (EUSES). It was developed more than 20 years ago to facilitate standardised environmental risk assessments within the European Union.

The EUSES model uses a series of default values and assumptions to define the properties of the "standard" environment being modelled. These are based on data ranges for the European Union and are intended to represent a "realistic worst-case" situation. The broad aim is to be protective (conservative) for a high percentile of possible situations. The model does not represent a real locality.

A 2018 scoping study identified several potential changes and updates to EUSES. These included targeted parameterisation to make the outputs relevant to UK REACH stakeholders, particularly regulatory authorities. The purpose of this report is to investigate parameterisation options more broadly and to evaluate what impact modifying existing default parameters will have on predicted environmental concentrations (PECs). Consideration was also given to the significance of likely future climate change scenarios and how these could be incorporated into the modelling if necessary.

Proposals for GB-specific values that could be used in the EUSES model to make the results more relevant to the current (and future) environment in GB are:

- A change in the default dilution factor (DF) for sewage effluent entering a river from 10 to 3, in some circumstances, and a corresponding change in the flow rate of the receiving water from 18,000 m^3/d to 13,300 m^3/d.
- Changes in the size of the standard sewage treatment plant (STP) from 2,000 m^3/d to 1,830 m^3/d and in the number of inhabitants feeding one STP from 1.00×10^4 to 8.43×10^3 population equivalents (Eq) and the sewage flow rate from 200 to 218 L/Eq/d.
- A change in the fraction connected to the sewer system from 80% to 95.5%.
- Changes to the characteristics of soil, based on sandy and clay loams.
- Changes in characteristics of the regional and continental systems.
- A change in the windspeed from 3 m/s to 4.9 m/s.
- A change in the annual precipitation from 700 mm/yr to 1,000 mm/yr (regional scale) and 1,300 mm/yr (continental scale).
- Changes to the application rate of sludge onto grassland (from 1,000 kg/ha/yr to 2,500 kg/ha/yr) and the mixing depth of agricultural soil (from 0.2 m to 0.25 m) and grassland soil (from 0.1 m to 0.05 m).

- Changes to the human dietary intake.

Sensitivity analysis was performed using different combinations of intrinsic chemical property values and parameter value changes. The GB-specific parameter values result in PECs that are higher at a local scale for most substances and compartments, when compared to the PECs obtained using the default EUSES values, and are also higher in most cases, except marine compartments, at a regional scale. When a DF of 3 is used, the increase in PECs become more pronounced for surface water compartments and for the human exposure via the environment (HvE). As such, the changes appear to be not only an improvement over the EUSES default values, as they better reflect GB conditions, but are also more conservative and therefore more protective.

The choice of DF depends on the scenario being modelled (i.e. where STP flow accounts for a significant portion of the river flow or where upstream sources of local contamination could influence the PEC), and also on the measure of central tendency (average value), for which a median DF of 3 could be used and is more conservative than a weighted mean DF of 10. A change to the EUSES default DF from 10 to 3 would be the simplest way of achieving more conservatism, but is not as conservative as using the values obtained using the GB-specific parameter values with a DF of 3.

The changes to rainfall and windspeed are expected to account for climate change scenarios at least in the short term. A marine DF of 100 is retained as a pragmatic approach to changes in sea level. The default temperature value of 12 °C was retained as it is reflective of short to medium term predictions in temperature rise, but PECs were found to be insensitive to temperature changes in any case.

The proposed changes to the EUSES default values can be easily overwritten by the user. The simplest way to implement these changes is by saving the relevant changes to the default values as an EUSES export file (.EXF). This can then be imported at the start of a new assessment to preset relevant GB-specific values parameter values.

Additional work to improve the robustness of selected input parameter values and modelling outputs could include:

- Further refinement of STP assumptions, including the analysis of consented versus dry weather flow (DWF) and site-specific DFs.
- Further research to determine the most appropriate value for the organic carbon (OC) content of suspended matter within GB.
- Further investigations to determine a more representative value for the ‘fraction of rainwater infiltrating soil’ and the ‘fraction of rainwater running off soil’ within GB.
- Comparison of model outputs with monitoring data for a range of chemicals with registration data, including substances that are readily or inherently biodegradable which were not included in sensitivity testing.
- Scientific literature should continue to be monitored for future consideration of the potential adaptation of the assessment criteria and/or chemical properties.

1 Introduction

The European Union (Withdrawal) Act 2018 brought the European Union (EU) REACH Regulation (EC) No. 1907/2006 into UK law on the 1st January 2021, with the changes necessary to make them operable in a domestic context (UK Government, 2021). The UK REACH Regulation applies to the majority of chemicals that are manufactured in, or imported into, Great Britain (GB; England, Scotland and Wales). Northern Ireland is subject to EU REACH.

UK REACH retains the main principles of EU REACH. This includes a requirement for registrants of hazardous substances supplied at or above 10 tonnes per year to perform an exposure assessment, which is documented in a Chemical Safety Report (CSR). Exposure assessment is also performed by applicants for authorisation, and the regulator can also explore exposure for specific substances as part of Substance Evaluation activities.

The primary environmental exposure model used in both EU and UK REACH is EUSES. It was initially developed more than 20 years ago to facilitate standardised environmental risk assessments within the EU. It uses a series of default values and assumptions to define the properties of the "standard" environment being modelled. These are based on data ranges for the European Union and are intended to represent a "realistic worst-case" situation. The broad aim is to be protective (conservative) for a high percentile of possible situations. The model does not represent a real locality.

The core principles of the EUSES model were built into the European Chemicals Agency (ECHA) CHEmical Safety Assessment and Reporting (CHESAR) tool (ECHA, 2018a, accessed 17/04/2025). ECHA has also produced guidance for carrying out environmental exposure assessment that is aligned with the EUSES and CHESAR models (ECHA, 2016). CHESAR is currently under review to update its technical content and software functionality and this is expected to result in the release of a new exposure model called CHESAR Platform (ECHA, 2018b, accessed 17/04/2025). The specific details of the update are not currently publicly available, but it is understood that the intention is to better combine the functionality of CHESAR and EUSES within one modelling platform for both the EU REACH Regulation and the EU Biocidal Products Regulation (Regulation (EU) No 528/2012). The first version was not available before Summer 2025. It is anticipated that the ECHA (2016) guidance for environmental exposure assessment will also be updated to accompany this release.

EUSES has been used by regulatory authorities in many European countries for a long time. Nevertheless, EA (2013) found that UK river size relative to treated sewage effluent discharges tends to be smaller than is assumed in EUSES modelling. Therefore, the default dilution factor (DF) of 10 could result in an underestimation of concentrations in UK freshwaters. Subsequently, a scoping study (UKCEH, 2018) identified a number of additional potential changes and updates to the model that could make the outputs more useful and relevant to UK REACH stakeholders, particularly regulatory authorities. These

included delivering spatiotemporal predictions, targeted GB-specific parameterisation, incorporation of sensitivity analysis and probabilistic assessments as well as improvements to the user interface, which were the highest scoring options.

This report has been commissioned to investigate GB-specific parameterisation options in more detail and to evaluate whether modifying existing default parameters will have a significant impact on predicted environmental concentrations (PECs). A second aim is to consider the significance of likely future climate change scenarios and how these could be incorporated in the modelling if necessary.

The current iteration of CHESAR (version (v.) 3.9) does not allow access to many of the default parameters and so they cannot be edited by the user, which limits its adaptability. At present the adaptability of CHESAR Platform to GB-specific parameter values is unknown. For this reason, the focus of this report is solely on EUSES, and the report is set out as follows:

- Section 2 explores how the main parameters used within EUSES could be modified to better reflect GB conditions.
- Section 3 considers how climate change can be dealt with in the model.
- Section 4 presents proposals for GB-specific parameters.
- Section 5 includes a discussion of how PEC values can be interpreted at the scale of GB.
- Section 6 discusses a sensitivity analysis using different combinations of intrinsic chemical properties.
- Section 7 summarises the findings and discusses issues around potential implementation.

2 Key environmental parameters within EUSES

This report discusses EUSES v.2.1.2. Details of the model calculations and principles are given in detail in the EUSES manual (ECB, 2004) and R.16 Guidance (ECHA, 2016). Many of the default values are editable within the model.

A more recent version of EUSES (v.2.2.0) is available. However, the authors of this report have experienced several bugs that limit its useability for this type of project. The main difference of relevance to this project is that EUSES v.2.2.0 includes an updated sewage treatment plant (STP) model (SimpleTreat v.4.0; Struijs (2014)) whereas EUSES v.2.1.2 uses an earlier version (SimpleTreat v.3.1) (see Box 1 for additional details). However, although SimpleTreat v.4.0 has more parameters that can be edited than SimpleTreat v.3.1, the version in EUSES v.2.2.0 has been parameterised to give essentially the same removal estimates as SimpleTreat v.3.1. Other changes in EUSES v.2.2.0 are for the purpose of refining the exposure scenarios and assessment for biocides. The default settings for the STP and other model parameters are similar between the two versions and both give similar results. Although the focus of this report is on EUSES v.2.1.2, the considerations and findings are equally relevant to EUSES v.2.2.0 and CHESAR v.3.9. In particular, EUSES v.2.2.0 can be adapted in exactly the same way as proposed for EUSES v.2.1.2.

The EUSES model calculates PEC values at three different scales:

- Local: This is the concentration immediately downstream of a point of discharge or release. The point source can be an industrial discharge, an STP (this can be related to the point source or, in the case of more widespread uses, an STP serving a local population) or, in the case of the terrestrial environment, the local environment influenced by sewage sludge application or atmospheric deposition resulting from the point source.

- Regional: This is intended to represent the background concentration in a heavily industrialised and populated area. The regional scale is assumed to have inputs of the same substance from numerous sources. In the original EUSES model the regional scale typically receives between 10% and 100% of all the releases of the substance, depending on the use pattern.

- Continental: In the original EUSES model, this is intended to represent the size and population of the EU and receives the total release of the substance in the EU minus the regional releases (this is to avoid double counting of releases).

The local scale receives the background concentration from the regional scale, which in turn receives the inflowing air and water from the continental scale (ECB, 2004). The

local, regional and continental scale conceptualisation in the GB context is discussed in Section 5.

Box 1. SimpleTreat

SimpleTreat is a model developed to estimate chemical emission from STPs and exposure in surface water within the framework of chemical risk assessment (Struijs, 2014). The model is a steady state, multiple box model solving the mass balance of a chemical undergoing treatment in an STP, considers phase partitioning, degradation and volatilization, and is fully implemented in EUSES.

The reliability of SimpleTreat for predicting a chemical's distribution has been subject to previous studies and reports. For example, a recent study (Arthur *et al.*, 2023) concluded that SimpleTreat (v.4.0) may underestimate emissions to sludge and/or effluent for some types of chemicals (e.g. long chain per- and polyfluoroalkyl substances and brominated flame retardants). A review report for SimpleTreat v.3.1 (Struijs, 2013) noted that its performance was satisfactory for modelling the partitioning of chemicals that '*are soluble in water or fat or that are biodegradable*' as the majority of industrial and consumer chemicals fell into these categories at the time. However, it was concluded that the model was less appropriate for modelling substances that are biologically active or surface active. The report prompted a revision of the SimpleTreat model for these types of chemical and led to the development of SimpleTreat v.4.0.

The EUSES model was designed to represent a realistic worst-case scenario for the EU, which is protective of a high percentile of possible scenarios. The proposed GB-specific values are intended to represent the realistic worst case.

To select values for the realistic worst case, several aspects need to be considered:

- Many of the parameters in EUSES are interrelated. For example, in very simple terms, the local concentration in surface water calculated using EUSES is a function of the flow rate from the STP (which is a function of the population served by the STP and the amount of wastewater generated per Eq), and the subsequent dilution in the receiving water (which is related to the flow rate of the receiving water), amongst other factors. Representative average values, as opposed to extreme values, for low flow would be protective without being overly conservative. This is discussed in Section 2.1.4.

- The regional and continental models within EUSES are steady state models assuming that chemical releases are averaged over the year. So, for parameters that vary over the year, such as windspeed, temperature and rainfall, it is most appropriate to use annual average values where these are available rather than 90^{th}, 95^{th} or 98^{th} percentile values.

- The local soil concentrations within EUSES are calculated over a 10-year period. Again, for parameters that vary over the year, it is relevant to consider average values for these parameters for the same reasons as for the regional and continental models above.

- What constitutes a realistic worst case is not always definable for some parameters, because this can differ between substances. Examples are given below. The value chosen for EUSES will necessarily be a compromise.

- The concentration in sediment is dependent upon the OC content of sediment. A high sediment OC content will result in a higher PEC in sediment but a lower PEC in surface water than sediment with a low OC content for neutral organic chemicals. This makes the choice of a worst-case value challenging as the significance of this will depend on whether the substance under consideration adsorbs strongly onto sediments or not. The behaviour of metals and ionisable substances will depend on other parameters (e.g., pH), and therefore these types of substances are normally modelled in EUSES using a specific soil-water partition coefficient (K_d) value (where available) and would not be affected by OC content. Difficulties in modelling these types of substances are a known limitation of EUSES and its underlying methods.

- Similarly, a high soil OC content will lead to higher concentrations in the soil-solid phase (and hence bulk soil) but lower concentrations in soil-porewater and groundwater / drinking water than a low soil OC content for neutral organic chemicals. Again, the significance of this in terms of a worst case is substance-dependent.

2.1 EUSES default values versus GB-specific values

The EUSES model contains a series of default values that define the properties of the “standard” environments being modelled. A complete list of the default values from EUSES v.2.1.2 is given in Appendix A.

The EUSES default values, and possible changes to these to reflect the current situation in GB, are discussed in more detail in the following sections. Sensitivity analysis of the model to adjustment of the values is discussed in Section 6 and Appendix B. The sections reflect the groupings of the default values in the EUSES model. Where appropriate and allowed by the data, different potential values for England, Scotland and Wales are discussed.

The main data sources used for the GB-specific values focused on previous reviews, compilations and surveys for GB. For some values UK data were available and considered; in these cases, the information for Northern Ireland (where available) were also considered and compared against the UK data as a whole to determine if the UK data would be applicable to GB (i.e. to determine if the UK data was heavily influenced by the

Northern Ireland data or whether the GB data value would be expected to be similar to the UK value). Where suitable compilations of data were available from authoritative sources a wider search for other information was not undertaken.

Where information on the statistical basis of the data is available, these are reported.

2.1.1 Characterisation of compartments

2.1.1.1 General

This subsection of EUSES contains the general default values such as density of phases, surface area of aerosol particles and related standard constants. These values are assumed to be applicable to GB and so alternative values have not been investigated.

The subsection also contains the environmental temperature for the EUSES calculations. The default value is 12 °C for all compartments (including marine). This is discussed further in Section 2.1.6.5 and Section 3.

2.1.1.2 Suspended matter

This subsection of EUSES contains the parameters related to suspended matter in surface water, including the volume fractions of solids and water in suspended matter, the weight fraction of OC in suspended matter and the related density. These are used for the local PEC calculations in both freshwater and marine sediment (the calculation assumes that the concentration in freshly deposited sediment is the same as in suspended matter). The same properties are also used to estimate a predicted no-effect concentration (PNEC) for sediment when estimated using the equilibrium partitioning method. According to ECHA (2016), the suspended matter concentration is assumed to be 15 mg/L for freshwater and 5 mg/L for marine water. A higher value for the suspended matter concentration will result in higher PECs in the sediment phase and lower PECs in the water phase. Note: the suspended matter concentration does not appear under the EUSES defaults screen for suspended matter but can be edited for the regional and continental distribution defaults screen.

The assumed suspended matter concentration of freshwater and marine water is also important to the calculation of the PEC in sediment.

Several studies have investigated suspended matter content in UK rivers, including the work of Bilotta *et al.* (2012), which analysed data collated by UK Centre for Ecology & Hydrology (UKCEH) from sources such as the EA, Natural Resources Wales (NRW), Scottish Environment Protection Agency (SEPA), and additional data from Northern Ireland. This comprehensive assessment spanned 42 different river ecosystem types and included a total of 638 reference sites. The study found suspended particulate matter concentrations ranging from 1.7 to 26 mg/L, with 78% of rivers reporting values below 12.5 mg/L and only a few sites recording concentrations exceeding 15 mg/L. Additionally, Grove *et al.* (2015) conducted grab sampling of 10 UK rivers between May 2011 and

2013, encompassing various habitats. Their study found mean suspended sediment concentrations ranging from 1 to 17 mg/L. Although there is evidence that suspended particulate matter concentrations will exceed 15 mg/L in some rivers, this value is likely to be broadly applicable across GB.

Regarding marine waters, Silva *et al.* (2016) published a detailed survey of suspended particulate matter concentrations around the UK, reporting data collected monthly from various locations between 1998 and 2015. Across all seasons, the average concentration of suspended particulate matter was determined to be 2.4 mg/L, with a 90^{th} percentile of 5.7 mg/L (CEFAS, 2018, accessed 24/04/2025). Based on these findings, the default value of 5 mg/L is considered an appropriate benchmark for marine suspended matter in GB.

The EUSES default value for OC content of suspended matter is 10% by weight. Studies suggest that this may be an underestimate for GB. For example, one study found OC values ranging from 2.7% to 38%, with a median of 15.8%, based on organic matter data (Worrall *et al.*, 2014). Other research indicated values of up to 14% (Hillier, 2001; Hope *et al.*, 1997), while Neal (2003) reported variations between 5% and 17%. Although these findings suggest that 10% is low for UK suspended matter, the wide range of values and the lack of precise OC measurements in many studies make it difficult to determine a definitive GB value. Therefore, it is recommended to retain the default value of 10% for now, with further research needed to establish a more accurate and appropriate figure.

Based on the above information and considerations, the EUSES default properties are assumed to be generally applicable to GB and so alternative values are not proposed. When the PNEC is estimated by equilibrium partitioning, any changes would affect both the PEC and the PNEC and cancel each other out, with the net result that the risk characterisation ratio (RCR, i.e. the PEC divided by the PNEC) would be unaffected.

2.1.1.3 Sediment

This subsection of EUSES contains the parameters related to bulk sediment. These include the volume fractions of solids and water in bulk sediment and the weight fraction of OC in bulk sediment. These parameters are used in the regional PEC calculations for both freshwater and marine sediments. Similar to the case with suspended sediment, the OC content in sediment is the most important parameter (the volume fractions of solids and water in bulk sediment are somewhat hypothetical concepts as they depend on the volume of water assumed to be associated with the solid matter). The default OC content of bulk sediment in EUSES is 5% by weight (0.05 kg/kg) and is used for both freshwater and marine sediments (there is currently no option within EUSES to have different values for freshwater and marine water). In terms of the effect on the PECs, a higher organic matter content will lead to a higher regional PEC predicted in both freshwater and marine water sediment, but a lower regional PEC in both freshwater and marine water themselves for neutral organic chemicals.

A Centre for Environment, Fisheries and Aquaculture Science (CEFAS) study (Mason *et al.*, 2017) examined surface marine sediments in England and Wales from 1996 to 2015, with results only accessible through an interactive map. Random spot sampling (of the <2 mm fraction of the sediments) of the map showed OC contents predominantly between 2% and 5%, supporting the default EUSES value of 5% by weight OC content. In Scotland, (Smeaton *et al.*, 2021) analysed 886 samples collected between 1969 and 2019, with OC values ranging from 0.01% to 11%, with a mean of 1.56% and a 95th percentile of 5.3%. These findings further indicate that 5% is suitable as an upper-end value for marine sediments in GB. As noted above, it is not possible to say if this is a worst-case value as the worst case is substance dependent.

In freshwater sediment, Gilbert *et al.* (2014) reported OC levels of 7.68 to 12.86% in uncompacted freshwater sediment from natural ponds with extensive natural vegetation, and lower values of 3.44% in compacted sediments or 3.72% from ponds in arable or pasture fields. Data collected by the EA (2021) showed average OC levels of 4.8% in freshwater sediments and 4.5% in running surface water sediments. Although no detailed analysis of the data was conducted, these studies all suggest that the default value of 5% remains appropriate for GB conditions.

In theory, it is possible to model “mean average OC” (or even “low OC”) and a PEC for “95th percentile OC” for all substances in EUSES. However, given the deterministic nature of the model, entering multiple values for a single parameter would lead to the number of modelled scenarios to grow exponentially and would be difficult to undertake in practice. An ability to model ranges for property values would be a recommendation for any potential future implementations of the model.

The properties of sediment are used by EUSES to estimate the concentration of substances in sediment at the regional and continental scale. Based on the above data and discussion, these properties are assumed to be applicable to the GB situation and so alternative values are not proposed.

2.1.1.4 Soil

This subsection of EUSES contains the general default values for soil. These assume that the soil consists of 60% solids, 20% water and 20% air, by volume. The bulk density of the soil is assumed to be 1,700 kg wet weight (ww)/m^3 and the soil has an organic matter content of 0.034 kg/kg and an OC content of 0.02 kg/kg (2%). The same properties are also used to estimate a PNEC for soil when estimated using the equilibrium partitioning method.

Jeffries and Martin (2009) give default properties for nine of the eleven soil types commonly found in the UK that are used in the Contaminated Land Exposure Assessment (CLEA) model. These are summarised in Table C.1 in Appendix C.

The main differences between the default EUSES assumptions and the values for GB are that the default water content of soil in EUSES (0.2 m^3/m^3) is lower than typically found in

GB soils (0.24-0.51 m^3/m^3) and the fraction of solids (0.6 m^3/m^3 in default EUSES) is correspondingly higher than typically found in GB soils (0.37-0.48 m^3/m^3). This means that the EUSES default values result in a soil that is drier than would appear to be appropriate for GB.

As for other input parameter values, the concept of a worst-case soil is difficult to apply. For example, a high solid content, high OC content soil may be a worst-case soil for certain strongly adsorbing substances (e.g. those with high organic carbon-water partition coefficient (K_{OC}) values) and would result in a higher soil PEC (with a correspondingly lower soil pore water PEC), but would not be worst-case for a more mobile substance. Therefore, the purpose of the calculation needs to be considered, bearing in mind the screening nature of the risk assessment.

To provide more representative coverage of GB soils, two soil types could be considered for the GB-specific exposure scenarios within EUSES, depending on the characteristics of the substance being assessed:

- Sandy loam soil is recommended for substances that pose a potential human health risk. Its texture and composition mean that chemicals are available for diffusion and advection transport processes, making it a conservative choice as it facilitates higher exposure to humans from contaminated land. This is why it is the default soil type for derivation of Soil Guideline Values (SGVs) in the Contaminated Land Exposure Assessment (CLEA) model (Jeffries and Martin, 2009). Furthermore, the use of sandy loam characteristics would enable comparisons to be made between the EUSES and CLEA models.
- In other scenarios, the soil properties of clay loam may be more suitable. Positioned in the mid-range of soil types (Appendix C.1, Table C.1), clay loam is arguably more representative of GB soils, being wetter and having a higher clay and OC content. Additionally, soil type maps suggest that soil types similar to clay loam are more prevalent across England and Wales (LandIS, 2025, accessed 24/04/2025; UKSO, Undated). Whilst this prevalence is challenging to quantify on these maps due to differing categorisation of soils and difficulties interpreting typical values, clay loam, or ‘medium’ soils with similar characteristics (e.g. sandy clay loam and silty clay loam), are more frequently found across GB (EA, 2007; accessed 03/07/2025), particularly in lowland and/or arable farmland areas that receive significant sewage sludge amendments (Cattin and Malin, 2025). It is therefore recommended that the properties of clay loam are used when assessing strongly adsorbing substances for example and those that pose an environmental risk as opposed to human health risks.

According to Jeffries and Martin (2009), the default soil organic matter (SOM) fraction used within the CLEA software is 0.06 (6%), which corresponds to an average value for sandy loam soil. This value was calculated using data from the HORIZON Hydraulics library held by the National Soil Resources Institute and is based on soil property data from a large number of soils sampled across England and Wales (LandIS, 2014). A value

of 6% also aligns with the upper range of the UK benchmark target SOM content for light soils, including sandy loam, under arable conditions receiving 800–1100 mm of rainfall. This value also falls within the mid-range for grassland (AHDB and BBRO, 2022). Whilst SOM fraction for clay loam was not calculated by Jeffries (2009), the target benchmark for medium soils, including clay loam, in the same conditions as above suggests that 7.5% may be an appropriate value (AHDB and BBRO, 2022). Additionally, investigations by Natural Resource Management (NRM) identified the interquartile range of SOM content in clay loam soils to be approximately 4.5-8%, supporting the recommendation of 7.5% for clay loam (Grundy, 2024). These values also fall within the range of SOM recorded in the UK Soil and Herbage Pollutant Survey (UKSHS) for sandy loam and clay loam soils, although the UKSHS values tended to be slightly higher on average (EA, 2007; accessed 03/07/2025).

Jeffries and Martin (2009) and Jeffries (2009) use a factor of 0.58 to convert from organic matter content to total OC content of the soil: a SOM content of 6% therefore corresponds to a soil OC content of 3.5%, whilst 7.5% SOM equates to 4.4%. These are higher than the EUSES default of 2% OC content.

Extensive maps of soil property data are also available for Scotland (SEPA, 1981; The James Hutton Institute, Undated). The agricultural areas of Scotland are predominantly in the lowland regions towards the south and east of the country. Based on these maps, the SOM contents in these regions fall into three bands: low (<1.5% OC), moderate (1.5 - 3% OC), and smaller areas falling into the high (3 - 5% OC) band.

This suggests that Scottish agricultural soils generally have a higher OC content than the EUSES defaults, although the values of 3.5% and 4.4% for sandy loam and clay loam would be conservative for Scottish soils.

The EUSES default values for soil and the GB-specific values are summarised in Table 1. Note that calculations and explanations for volume fractions of solids, water and air in soil and determination of bulk density and the wet-dry conversion factor can be found in Appendix C.1. Again, it is important to emphasise that the concept of a worst case is difficult to apply for soil as discussed above.

Table 1 Parameterisation of soil compartment

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value – sandy loam	GB-specific value – clay loam	Units	Notes on GB-value	Source
Volume fraction of solids in soil	$F_{SolidSoil}$	0.6	0.47	0.44	m^3/m^3	GB-specific value dependent on substance being assessed	Jeffries and Martin (2009)
Volume fraction of water in soil	$F_{WaterSoil}$	0.2	0.33	0.43	m^3/m^3	GB-specific value dependent on substance being assessed	Jeffries and Martin (2009)
Volume fraction of air in soil	$F_{AirSoil}$	0.2	0.20	0.14	m^3/m^3	GB-specific value dependent on substance being assessed	Jeffries and Martin (2009)
Weight fraction of OC in soil	F_{ocSoil}	0.02	0.035	0.044	kg/kg	GB-specific value dependent on substance being assessed	Jeffries (2009) AHDB and BBRO (2022)
Weight fraction of organic matter in soil	F_{omSoil}	0.034	0.06	0.075	kg/kg	GB-specific value dependent on	Jeffries (2009) AHDB and BBRO (2022)

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value – sandy loam	GB-specific value – clay loam	Units	Notes on GB-value	Source
						substance being assessed	
Bulk density of wet soil	RHO_{Soil}	1,700	1,500	1,520	kg_{ww}/m^3	GB-specific value dependent on substance being assessed	See Appendix C.1
Conversion factor wet-dry soil	$Conv_{Soil}$	1.13	1.28	1.38	kg_{ww}/kg_{dw}	GB-specific value dependent on substance being assessed	See Appendix C.1

Based on this analysis, it is proposed that the GB-specific values for either sandy loam or clay loam from Table 1 are used to replace the EUSES default values. This change would align EUSES more closely with the approach currently used in the EA CLEA model. As the GB-specific values result in a wetter soil that is richer in OC than the EUSES defaults, the effect of these changes on the PECs will depend upon the properties of the substance, i.e., whether the substance adsorbs strongly or partitions preferentially to the dissolved phase. The impact of the soil properties on the PECs calculated are discussed further in Section 6. However, it is important to note that for assessments which use a PNEC estimated by equilibrium partitioning for soil these changes would affect both the PEC and the PNEC equally, so would cancel out with the net result that the RCR would be unaffected.

2.1.1.5 STP sludge

This subsection of EUSES contains the general default values such as fractions of OC in the different stages of the STP process. In the absence of evidence to the contrary, these values are assumed to be applicable to the GB situation and so alternative values have not been investigated fully. Limited information appears available for the GB situation and what data is available focusses on dissolved organic carbon (O'Keeffe and Akunna, 2022), so may not be directly comparable.

2.1.2 Degradation and transformation rates

This subsection of EUSES contains the default values for abiotic degradation, anaerobic degradation, the fraction of sediment that is aerated and the concentration of hydroxyl radicals in the atmosphere. These values are assumed to be applicable to the GB situation and so alternative values have not been investigated. The degradation parameter values can be overwritten with any available substance-specific data when carrying out EUSES modelling, in accordance with the guidance.

2.1.3 Release estimation

This subsection of EUSES contains the default values related to the fraction of the total tonnage used in the region for industrial uses and widespread (professional and consumer) uses and the fraction connected to the sewer system. The fraction of the total tonnage assumed in the region is discussed in Section 5.2.

The EUSES default for the fraction connected to the sewer system is 80%. According to DIT (2015, accessed 01/11/2022) there are 7,078 STPs in England and Wales, and 10,814 STPs and community septic tanks in Scotland and Northern Ireland. Overall, 98% of urban and rural households in the UK are connected to the UK’s sewerage system. This figure does not account for Combined Sewer Overflows (CSOs) which are discussed further in in Section 2.1.6.1.

Based on this, it is proposed that the fraction connected to the sewer system within EUSES is increased from 80% to 95.5% to better reflect the current situation in GB when accounting for CSO operational time (2.5%, see Section 2.1.6.1). The fraction connected to the sewer system is an input parameter to the regional PEC calculations. Although the available data suggest that 2% of households are not connected to the sewerage system, these are more likely to be in rural areas. The regional model is intended to represent a heavily populated and industrialised area, so it is reasonable to assume that the connection rate to the sewerage system in such areas would be at least 95.5%.

In terms of the effect on the PECs, a higher connection rate will lead to a lower PEC in both fresh / marine water and sediment, due to removal at the STP into sludge, but a higher PEC in soil due to subsequent application STP sludge to land (see Annex B.2).

2.1.4 Sewage treatment

2.1.4.1 General

This subsection of EUSES contains the basic parameters for the size of the local, regional and continental STP. The key default values from EUSES are summarised in Table 2, along with the recommended GB-specific values.

A previous Environment Agency report on dilution modelling for rivers in England and Wales (EA, 2013) contained information on the number of STPs in the various regions of England and Wales, the population each served and the DWFs. From these data an average number of inhabitants per STP (population equivalents, Eq) was calculated (16,800 inhabitants) as well as the average effluent flow rate from an STP (280 L/Eq/d). The report modelled 2,104 STPs (~30% of all STPs) using information from the LF2000-WQX (LowFlows2000 Water Quality eXtension) model database including population served (~29.6 million), which was ~50% of the population of Egland and Wales in 2013.

An unpublished scoping report by UKCEH determined UK-specific environmental exposure models for chemicals (UKCEH, 2018). As a “reasonable worst case”, the report calculated that there were 37,654 inhabitants feeding into one STP based on consented discharges of 50 STPs in the Aire Calder catchment and population data from the 1991 UK Census. From the same data, the average effluent flow rate from an STP was calculated to be 335 L/Eq/d. In EUSES, in the ‘Sewage flow’ dialogue box, the maximum value advised is 300 L/Eq/d.

The most recent data available indicates that there are 7,078 STPs (DIT, 2015) and the population of England and Wales at the time of the last UK Census was 59,597,542 (ONS, 2021). Therefore, the average population served by an STP in England and Wales is 8,420. The most recent EA (2024b) data for STP flows in England and Wales includes mean measured flow data for 4,937 STPs (~70% of all STPs). The sum total of these flows was 11,308 ML/d and the arithmetic mean flow was 2.29 ML/d. Assuming a similar distribution of flows from the other 2,141 STPs, the flow could be scaled up to represent

the total flow of all 7,078 STPs in England and Wales to give a figure of 16,212 ML/d. Dividing this by the total population of England and Wales gives an average effluent flow rate from an STP per number of inhabitants to be 272 L/Eq/d, which is close to the value obtained in EA (2013). Applying the same approach to DWF, which can be calculated as mean STP flow divided by 1.25, the sum total DWF becomes 12,970 ML/d, average DWF from an STP is 1.83 ML/d and average effluent flow rate from an STP per number of inhabitants is 218 L/Eq/d.

As a steady state model, EUSES works with averages over time, so 'national average' values of 8,420 people served by an STP and an effluent flow rate from an STP of 272 L/Eq/d seem appropriate, although the average flow rate of an STP at DWF (218 L/Eq/d) is more consistent with how the DF is calculated (Section 2.1.5.). By default, EUSES models STP flows at 2 ML/d, so the 'national average' flow of 2.29 ML/d is consistent with this scenario and supports the selection of parameter values based on national averages. Similarly, the mean DWF from an STP (1.83 ML/d) is within 10% of the 2 ML/d value, however, is a more conservative value. This reasonable level of conservativeness avoids an unrealistic combination of water flows and dilution factors leading to an overly conservative assessment. Although these figures are very different to the ones proposed by UKCEH (2018), it is not possible to configure different values for effluent flow rate and number of inhabitants served by an STP for local and regional scales. Consideration of the size of the DF is discussed further in Section 2.1.5.

The value of 8,420 people served by an STP is lower than the EUSES default of 10,000, whilst an effluent flow rate from an STP of either 218 or 272 L/Eq/d is higher than EUSES default value of 200. This suggests, on average, that STPs in a significant area of GB are smaller than what is assumed in the EUSES model, but have higher flow rates. This may be due to differences in population densities, climatic conditions and/or higher domestic consumption rates (Water Uk, 2024; accessed 10/07/2025).

The number of inhabitants in the region can be based on the Aire Calder catchment as per the unpublished UKCEH (2018) scoping study carried out for the EA and DEFRA. However, the population should be updated to reflect more recent estimates of population, for example EA (2025; accessed 10/07/2025), which provides a figure of 2,332,469 based on ONS 2020 mid-year local authority estimates. For the continental model, the number of inhabitants is based on the total GB population (ONS, 2021). Further parameterisation of the regional and continental models is discussed in Section 2.1.6.

It is proposed that GB-specific values from Table 2 be used in place of the EUSES default values. The EUSES default values in this subsection also include the temperatures within the STP, the height of the air column above the STP and the windspeed within the system. These values are assumed to be applicable to the GB situation and so alternative values have not been investigated.

Table 2 Parameterisation of the STP

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Number of inhabitants feeding one STP	NLocal	10,000	8,420	Eq	The 2021 population of England and Wales divided by the total number of STPs	DIT (2015); ONS (2021)
Sewage flow	Q_{stp}	200	218	L/Eq/d	Based on STP DWF.	Murdoch (2024)
Effluent discharge rate of local STP	$EffluentLocal_{stp}$	2.00×10^{6}	1.83×10^{6}	L/d	Calculated from the number of inhabitants and sewage flow	
Number of inhabitants of region	NReg	2.00×10^{7}	2.33×10^{6}	Eq	Population of Aire-Calder	EA (2025)
Number of inhabitants of continental system	NCont	3.50×10^{8}	6.34×10^{7}	Eq	Based on GB-population – see Table 6	

2.1.4.1 Raw sewage

This subsection of EUSES has the default values from the raw sewage composition in the STP. These values are assumed to be applicable to the GB situation and so alternative values have not been investigated.

2.1.4.2 Primary settler

This subsection of EUSES has the default values from the primary settler size, retention time and composition in the STP. These values are assumed to be applicable to the GB situation and so alternative values have not been investigated.

2.1.4.3 Activated sludge tank

This subsection of EUSES has the default values for the activated sludge tank size, retention time and composition in the STP. These values are assumed to be applicable to the GB situation and so alternative values have not been investigated.

2.1.4.4 Solids-liquids separator

This subsection of EUSES has the default values for the solids-liquids separator size, retention time and composition. These values are assumed to be applicable to the GB situation and so alternative values have not been investigated.

2.1.5 Local distribution

2.1.5.1 Air and surface water

This subsection of EUSES contains the default values related to the local air calculations (concentration in air at a source strength of 1 kg/d, standard deposition flux of aerosol-bound compounds and gaseous compounds). These values are assumed to be applicable to the GB situation and so alternative values have not been investigated.

The subsection also contains the EUSES parameters related to the dilution in fresh and marine waters. The relevant default EUSES values are summarised in Table 4, alongside the recommended GB-specific values. A sensitivity analysis, discussed in Annex B, was conducted on the changes to several parameter values; the number of inhabitants feeding into the STP and DF was found to have the biggest impacts on the local PEC out of all the parameters tested.

The EUSES default DF for freshwater is 10. A previous EA (2013) study recommended a realistic worst case DF of 3 as being more appropriate for the current GB situation based on data from England and Wales. Nevertheless, a personal communication from internal water quality modelling experts (Murdoch, 2022) confirmed that the average freshwater DF in England is around 10 based on the total STP effluent discharges and the sum of mean river flows, but there is large variability in the actual value between individual STPs.

The communication indicated that a DF of 3 corresponds to the 98th percentile lowest DF for STPs with an Eq above 2,000 inhabitants, which is conservative.

Given the large influence that DF has on local PECs (see Appendix B.3), further evidence was required to corroborate the DF value of 3 for the GB-specific situation. To do this, DFs were calculated from the UKWIR PR24 Source Apportionment Geographical Information System - SIMulation of CATchments (SAGIS-SIMCAT) model (Comber *et al.*, 2013; Murdoch, 2024). This contains an extensive database for >4,000 STPs discharging to freshwater rivers in England (see EA (2024b) for data inputs). The model calculates DFs based on the mean annual STP and river flow and the 95th percentile river flow (Q95) and STP DWF for individual sites (see Equation 1 below).

Q95 river flow is the 5th percentile of the annual river flow (i.e. that is exceeded by 95% of other flows), so represents low flow conditions. Similarly, DWF is the average daily flow to an STP during a 7-day period without rain. The DWF is taken as the 10th percentile of a year's flow, also known as the Q90 value (i.e. it is the total daily flow value that is exceeded by 90% of the measured total daily flows in any period of 12 months). It can be calculated by dividing the mean STP flow by 1.25. For the purposes of calculating DFs, DWF is considered to be equivalent to the discharge from the STP.

Upstream effluent discharges in the catchment may add to chemical concentrations at an individual STP discharge point downstream, and the model deals with this by deriving a cumulative DF (Equation 2).

$$STP\ low\ flow\ dilution(x)_{site} = \frac{(Q95\ river\ flow(x) + DWF(x))}{DWF(x)}$$

(Equation 1)

$$STP\ low\ flow\ dilution(x)_{cumulatve} = \frac{(Q95\ river\ flow(x) + \sum_i^x DWF(i)}{\sum_i^x DWF(i)}$$

(Equation 2)

Where:

Q95 River flow	=	River flow at the 5% percentile of the annual river flow, exceeded by 95% of all other flows (m^3/d)
DWF	=	Dry weather flow to the STP (assumed equivalent to discharge) (m^3/d)
STP Low Flow Dilution$_{Site}$	=	DF from a single STP
STP Low Flow Dilution$_{Cumulative}$	=	DF arising from the contribution of multiple single STPs

To select an appropriate value for DF, datasets from 2019 and 2024 were considered, representing the last data unaffected by the COVID-19 pandemic and the most recent data respectively. These were found to be very similar in terms of their central tendencies (average values), so assessments were generally made on the 2024 data, which also included more STPs. Mean annual STP flow rates in the dataset ranged widely, from very low (9×10^{-5} ML/d) to very high (315 ML/d) as did DWFs (7.2×10^{-5} to 252 ML/d) as DWF is calculated from mean STP flow. DFs calculated on Q95 river flow and STP DWF were also highly variable, ranging from 1 to 69,448. An inversely proportional relationship was observed between STP flow and Q95 DWF DFs; as STP flow increases, DF decreases. Using a generalised additive model (GAM), the relationship was found to be significant (estimated degrees of freedom (edf)= 4.25, $F = 7.61$, $p < 0.001$). This demonstrates the influence of high STP flows on rivers, particularly those with low flow; in some cases, STP DWF accounts for almost all of the river flow.

To adopt a conservative approach and to be consistent with EUSES assumptions, only STPs with flow rates of at least 2 ML/d were used in the DF calculations. These 684 STPs (out of 4,934) accounted for 90% of the total effluent flow for which there was data. Given the relationship between STP flow and DF, the weighted mean (weighted by STP flow) was chosen as the measure of central tendency. The data sets for 2019 and 2024 were combined and the weighted mean was calculated by multiplying the Q95 DWF DF for each site by the STP flow. The sum of these was then divided by the sum of all the STP flows to give the weighted mean, which was 8.2 and has been rounded to 10. The EUSES default DF value is also 10. A similar approach was used for the Cumulative Q95 DWF DF giving a value of 2.9 which has been rounded to 3.

It should be noted that the data was positively skewed with a number of very high values in the righthand side of the distribution. As the mean is prone to influence by extreme values, the median values for Q95 DWF and Cumulative Q95 DWF DFs of 3.1 and 2.2, respectively, could have been chosen. A median Q95 DWF DF of 3 (3.1 rounded down to 3), as opposed to 10, will increase the PEC and the effect is shown in Section 6. Similarly, a median Cumulative Q95 DWF DF of 2 (2.2 rounded down to 2) would increase the PEC further still.

Table 3 Summary of DFs based on STP size

STPs	Total effluent flow (ML/d)	Total Q95 effluent flow (ML/d)	Percentage of total effluent flow	No. STPs	Median Q95 DWF DF	Median Cumulative Q95 DWF DF	Weighted Q95 DWF DF	Weighted Cumulative Q95 DWF DF
All	11,289	7,571	100%	4,934	53	9	24	4
Flow ≥ 1 ML/d	10,664	7,123	94%	1,008	4	2	13	3
Flow ≥ 2 ML/d	10,205	6,807	90%	684	**3**	2	**10**	3
Flow ≥ 10 ML/d	8,074	5,329	72%	207	3	2	6	2

These values are representative of the following conditions:

- Freshwater dilutions only (approximately 66% of treated effluent discharges)
- STPs in England and Wales
- Actual flow (where available), otherwise permitted (DWF)
- Flows based on Low Flows 2000 (LF2000) modelling (UKCEH, 2025)) with the relevant data incorporated into SAGIS-SIMCAT.

Although the weighted Q95 DWF DFs are similar to EUSES defaults for STPs with flow rates ≥ 2 ML/d, there is a further factor to consider. STP effluent can make up a significant proportion of the flow in GB rivers under some conditions. The effluent forms a plume, which gradually mixes with the river water as it moves downstream at a rate that depends on density, turbulence, etc. The freshwater PEC estimated using the DF represents the concentration at the edge of the mixing zone. For small rivers, dilution by a factor of 10 may occur only at a significant distance from the discharge point (in excess of several hundreds of metres downstream). Organisms in the mixing zone will experience higher concentrations than suggested by the PEC, and therefore are potentially at greater risk. For this reason, a lower DF may be more reasonable for the smaller rivers that are generally prevalent in GB, since it will protect a greater proportion of the river.

Given the likelihood for lower dilution, consideration should be given to the median Q95 DWF DF of 3 to be used as the GB-specific value over the weighted Q95 DWF DF of 10. A DF of 3 is consistent with the value proposed by Comber *et al.* (2013). Furthermore, this value, and the weighted mean of the Cumulative Q95 DWF DF of 3 (or 2 if the median cumulative value is selected), should be considered for specific scenarios:

- The higher DF (10) would be appropriate for a generic local assessment for a large river (relative to STP flow) that already takes account of regional background concentrations from the total tonnage of a chemical on the market (together with any natural sources).

- The lower DF (3) would be appropriate for a generic local assessment for a small river (where the STP flow makes up a significant proportion of the river flow) that already takes account of regional background concentrations from the total tonnage of a chemical on the market (together with any natural sources).

- Where all sources are not accounted for (as may happen for local-scale exposure assessments for authorisation or registration), the lower DF would be a way of accounting for cumulative upstream STP inputs, which might not otherwise be adequately captured. This is because EUSES calculates a regional predicted environmental concentration ($PEC_{regional}$) using the company's tonnage for a given substance, usually resulting in a value that is a fraction of the local concentration (C_{local}, derived using the DF). EUSES adds this $PEC_{regional}$ as a background concentration to C_{local} to produce the overall local PEC (PEC_{local}). As the company is not obliged to take account of the tonnage from sources other than their own, EUSES calculations may underestimate background concentrations from upstream STPs in some situations. In other words, the PEC_{local} could be misleadingly low. When other sources are likely to occur, adopting the lower Cumulative Q95 DWF DF of 3 (weighted mean)

acknowledges that some level of existing contamination is likely from upstream sources without the need to quantify it. If the median value for the Cumulative Q95 DWF DF of 2 was used, this would increase the PEC further.

- An additional scenario would be when the company is the sole source of the chemical on the UK market – in that case, the higher DF of 10 should apply for large rivers, and 3 for small rivers relative to STP flow.

The EUSES default DF value for marine water is currently 100. Defining a DF for marine water is challenging as the ultimate dilution in marine water is likely to be very large and will also be affected by tidal ranges. The DF of 100 represents a pragmatic approach to this problem and is best interpreted in terms of the PEC being calculated at a point in marine surface water where the dilution is 100. It is proposed that this same pragmatic approach is also applied to the GB situation and so no change to the EUSES default value of 100 is recommended. More specialised local models may be used to replace this value in specific cases.

Table 4 Parameterisation of the local distribution in surface water

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Suspended solids concentration in STP effluent water	SuspWaterReg	15	15	mg/L	Assume EUSES default is applicable	
DF (rivers)	Dilution	10	10 or 3	-	Determined from weighted mean river Q95 and STP DWF flow, median river Q95 and STP DWF flow and cumulative river Q95 and STP DWF flow respectively.	Comber *et al.* (2013); UKWIR (2024, accessed 22/04/2025)
Flow rate of the receiving river†	Flow	18,000	13,300	m^3/d	Median Q95 river flow of rivers receiving effluent from STPs with discharges of >2 ML/d (data from 2019)	
DF (coastal areas)	DilutionMarine	100	100		Assume EUSES default is applicable	

† This parameter is used by EUSES in the 'Output dilution' screen to calculate DF from the STP flow. If the DF is predetermined (e.g. 10 or 3) this parameter becomes redundant.

2.1.5.2 Soil

This subsection of EUSES gives the parameters related to the local PEC calculations for soil. The default values include the various partial mass transfer coefficients that are used internally within EUSES to estimate the transport of substances through soil. These values are assumed to be applicable to the GB situation and so alternative values have not been investigated.

The other parameters in this subsection are related to the soil mixing depths, rates of application of sewage sludge on soil and the precipitation rate. GB-specific values for these parameters are discussed below and summarised in Table 5, alongside the EUSES default values.

The EUSES default values for application rates of dry sewage sludge are 5,000 kg/ha/yr for agricultural soil and 1,000 kg/ha/yr for grassland as a single annual application, repeated for 10 years. The frequency of application is considered to be a conservative assumption as most biosolids applications are performed once every two to four years as part of a nutrient management plan. Repeat application over the growing season (i.e. 'split application') is more likely to occur on grassland to avoid smothering. The available information on the typical rates of application of sewage sludge to agricultural soil and grassland in GB is limited:

- The phasing out of disposal of sewage sludge at sea was announced in 1990, with a final deadline of 1998 (The Urban Waste Water Treatment Regulations, 1994). The UK sewage sludge survey (EA, 1999) indicated that the average value for sewage sludge application rates in England, Scotland and Wales in 1996/1997 was 3,650 kg/ha/yr for agricultural soil and 2,400 kg/ha/yr for grassland.

- Sludge spreading to land therefore became an important disposal method within GB. A study by EA (2022) suggests that the amount of sewage sludge applied to land in England and Wales has decreased in recent years but the current average application rate to land would be close to the 5,000 kg/ha/yr value; no distinction in the estimate was made between agricultural land and grassland.
- In 2023, nine water companies in England reportedly dispatched a total of 819,001 tonnes (dry solids) of sewage sludge (EA, 2024b). Of this, 93.8% was used in agriculture, covering 151,921 hectares of land, equating to an application rate of 5,057 kg/ha/yr.

- Example 2.4 in AHDB (2023) provides an illustrative calculation for the application of 20,000 kg_{ww}/ha/yr of digested cake on agricultural (arable) soil. Assuming a dry matter content of 25% (value for digested cake in Table 2.14 of the publication), an application rate of 5,000 kg/ha/yr can be calculated. This is taken as a typical application rate for agricultural soil.

- The Biosolids Assurance Scheme (BAS, 2019) suggests that a similar application rate can be assumed for arable and grassland soils. In each example, 20,000 kg_{ww}/ha/yr is applied (Tables 6 to 8 in the guidelines). BAS (2019) estimates that 3.4 million tonnes of biosolids are applied to 150,000 hectares each year in the UK, which ties in with the average application rate of 20,000 kg_{ww}/ha/yr. For grassland, BAS (2019) suggest that 20 t/ha provides 220 kg/ha of nitrogen (N) (Table 8 of the guidelines), yet grassland only requires 100 kg/ha of N. Therefore, an application rate of 10 t/ha would meet this requirement, which when translated to dry matter (25%) equates to 2,500 kg/ha per year.
- The EA Waste Applied to Land: Tool for Environmental Risk (WALTER) model (Martin *et al.*, 2013) (Martin *et al.*, 2013) allows the user to specify the waste application rate (t/ha/year), but the model does not specify values to be used.

Therefore, the current EUSES default application rate of 5,000 kg/ha/yr for agricultural soil is retained as it is considered representative of GB. However, it is not straightforward to decide whether the current EUSES default value for grassland is representative in the absence of recent measured data specific to grassland. The available evidence from the (BAS, 2019) guidelines suggest that the current EUSES default value is too low; a higher value of 2,500 kg/ha/yr is proposed for the GB-specific parameters.

The WALTER model assumes that waste is incorporated in soil to a maximum depth of 25 cm (0.25 m) by ploughing or 5 cm (0.05 m) when applied as a surface dressing. This compares with EUSES defaults of 0.2 m for agricultural (arable) soil and 0.1 m for grassland soil. Although the difference is relatively small, GB-specific EUSES values could be aligned to be consistent with the WALTER model.

Table 5 Parameterisation for the local PECs in soil

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Mixing depth of grassland soil	DepthGrassland	0.1	0.05	m	Value from the WALTER model	Martin *et al.* (2013)
Dry sludge application rate on agricultural (arable) soil	ApplSludgeAgric	5,000	5,000	kg/ha/yr	Current default value supported by the current UK practice	AHDB (2023)
Dry sludge application rate on grassland	ApplSludgeGrassland	1,000	2,500	kg/ha/yr	BAS guidelines	BAS (2019)
Mixing depth of agricultural (arable) soil	DepthAgric	0.2	0.25	m	Value from the WALTER model. This is editable in the EUSES regional and continental distribution defaults screen. The local distribution default automatically updates to match the regional value.	Martin *et al.* (2013)
Fraction of rainwater infiltrating soil	FInfSoil	0.25	0.25	-	Assume EUSES default is applicable to GB	
Average annual precipitation	RainRate	700	1,000	mm/yr	See later section on rainfall; this value is not directly editable in EUSES.	

2.1.6 Regional and continental distribution

2.1.6.1 Configuration

This subsection of EUSES considers the parameters for the regional and continental compartments in terms of population and fractional flows through water into and out of the model at the regional and continental scale. The “regional scale” represents a highly populated industrial area. It is relevant to consider these parameters in terms of the GB environment. The EUSES defaults are shown in Table 6 along with the suggested GB-specific values discussed below.

The regional and continental models have default values for the fraction of direct emissions going to seawater and the fraction of the regional and continental STP effluent going direct to seawater. In the absence of any other data the EUSES default values have been assumed to apply to GB. When considering these default values, it is important to note that the regional and continental STP models within EUSES are hypothetical STPs, with one large STP serving the whole of the population/industrial activity in the region and one large STP representing the whole of the population/industrial activity in the continent (in this case GB). They are not intended to correspond to any real STPs. Assuming a low percentage of effluent emitted direct to seawater represents a worst-case approach for the freshwater and sediment: the model will assume the remainder is emitted via the STP effluent which is then assumed to enter either a freshwater system or a coastal area. Direct releases to seawater bypass the STP and are only assessed for marine water and marine sediment, therefore lowering the amount directed to freshwater/freshwater sediment.

The EUSES default fraction of the population connected to sewers is 80%. The fraction bypassing an STP is related to CSOs. In England, most CSOs now have event duration monitoring which captures how much time the CSOs were operating. According to the annual returns, the average percentage of time that CSOs were active between 2020 and 2024 was 2.5%, with a maximum of 5% in a single year (EA, 2024a). It should be noted that the statistics report the duration the CSOs are operating rather than the volume, using a 12/24 hours spill counting method (OFWAT, 2023).

As such, the GB-specific fraction of households connected to the sewer system is adjusted to 95.5% to account for the worst-case scenario and uncertainties associated with the (absence of) data.

Data on regional area and population are provided in the next sub-section.

Table 6 Parameterisation for the configuration of the regional and continental compartments

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Fraction of direct regional emissions to seawater	FEmissWater2Reg	1	1	%	Assume EUSES default is applicable to GB	
Fraction of direct continental emissions to seawater	FemissWater2Cont	0	0	%	Assume EUSES default is applicable to GB	
Fraction of regional STP effluent to seawater	FstpWater2Reg	0	0	%	Assume EUSES default is applicable to GB	
Fraction of continental STP effluent to seawater	FstpWater2Cont	0	0	%	Assume EUSES default is applicable to GB	
Fraction of flow from continental rivers to regional rivers	FflowW1C_W1R	0.034	0.034	-	Assume EUSES default is applicable to GB	

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Fraction of flow from continental rivers to regional sea	FflowW1C_W2R	0	0	-	Assume EUSES default is applicable to GB	
Fraction of flow from continental rivers to continental sea	FflowW1C_W2C	0.966	0.966	-	Assume EUSES default is applicable to GB	
Number of inhabitants of region	Nreg	2.00×10^{7}	2.33×10^{6}	Eq	Population of the Aire-Calder catchment in 2021	EA (2025)
Number of inhabitants in the EU	NEU	3.70×10^{8}	6.52×10^{7}	Eq	Population of England, Scotland and Wales in 2020	ONS (2021)
Number of inhabitants of continental system	Ncont	3.50×10^{8}	6.34×10^{7}	Eq	Calculated as number of inhabitants in England, Scotland and Wales minus number of regional inhabitants	

2.1.6.1 Areas – regional

This subsection of EUSES considers the parameters for the areas of the regional compartment. Table 7 shows the EUSES defaults and the suggested GB-specific values, which are discussed below.

The “regional scale” in EUSES has a default size of 40,000 km² and a population of 20 million inhabitants (so a population density of 500 people/km²). As a result, any alternate region's size should be approximately the same. For comparison, the land areas of GB, England, Scotland and Wales are around 230,000 km², 130,000 km², 89,000 km² and 21,000 km², respectively (ONS, 2024). So, it is not possible to use a single GB nation to represent a region within GB-specific EUSES. Instead, the “continental scale” in GB EUSES can be configured to represent GB, and the “regional scale” can be based on an industrial area with a large population within GB.

An earlier scoping study on UK-specific environmental exposure models proposed the Aire-Calder catchment to represent the regional scale, with an area of 1,960 km² and population of 1.81 million (a population density of around 900 people/km²) (UKCEH, 2018). Based on more recent population data (EA, 2025), this figure would be around 1,200 people/km². The study also suggested that other scenarios be considered to represent a range of catchments typical of the UK environment, such as a mixed rural and urban catchment. However, it is worth noting that finding a complete data set for such small areas is very difficult. The Aire-Calder catchment was included in the Geography-referenced Regional Exposure Assessment Tool for European Rivers (GREAT-ER) model (Fox *et al.*, 2000), which was intended to provide a higher-tier tool if an EUSES assessment needed refinement based on high $PEC_{regional}$ values. The highly populated Aire-Calder catchment is therefore a reasonable choice for the regional scale in a GB-specific EUSES assessment.

Data on the area fraction for freshwater, natural soil, agricultural soil and industrial/urban soil in the Aire-Calder catchment could not be found. Therefore, data on the area fractions from England were used as read across for the catchment area.

As the Aire-Calder catchment is effectively a land locked catchment and GB has a large coastline, considerations were made to make the related parameter values more representative. A value was proposed for the ‘Length of Regional Seawater’ GB parameter of 100 km. This was calculated using the fraction of land that the Aire-Calder catchment represents of the total area of GB (230,000 km²), multiplied by the total GB coastal length (18,226 km). The coastline length of GB is difficult to calculate, so mainland GB was only considered here. This includes England (4,308 km based on the King Charles III coast path), Wales (2,700 km), and Scotland (11,218 km) minus the Orkney Islands, Shetland Islands, and Outer Hebride regions. The default EUSES ‘Width of Regional Seawater’ value of 10 km was assumed to still be applicable to GB. This change caused a consequent change to the value of the EUSES parameters that consider the area of seawater, shown in Table 7.

Table 7 Parameterisation for the area of the regional compartment

EUSES parameter	Parameter name	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Area (land+rivers) of regional system	AreaReg	40,000	1,960	km^2	Aire-Calder catchment	UKCEH (2018)
Area fraction of freshwater, region (excl. sea)	FwaterReg	0.03	0.029	-	Read-across value from England	ONS (2015, accessed 22/04/2025)
Area fraction of natural soil, region (excl. sea)	FnaturalReg	0.27	0.27	-	Read-across value from England	ONS (2015, accessed 22/04/2025)
Area fraction of agricultural soil, region (excl. sea)	FagricReg	0.6	0.52	-	Read-across value from England	ONS (2015, accessed 22/04/2025)
Area fraction of industrial/urban soil, region (excl. sea)	FindReg	0.1	0.17	-	Read-across value from England	ONS (2015, accessed 22/04/2025)

EUSES parameter	Parameter name	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Length of regional seawater	LengthW2_R	40	100	km	Calculated using the fraction of land that the Aire-Calder catchment represents of the total area of GB (230,000 km2), multiplied by the total GB coastal length (18,226 km).	(Marine Scotland Information, 2023; accessed 03/07/2025; ONS, 2021)
Width of regional seawater	WidthW2_R	10	10	km	Assume EUSES default is applicable	
Area of regional seawater	AreaW2_R	400	1000	km^2	Calculated from length and width of regional seawater	
Area (land+rivers+sea) of regional system	Area_R	40,400	$2.96x10^3$	km^2	Calculated as sum of land area and sea area	
Area fraction of freshwater, region (total)	Fwater1_R	0.0297	0.0192	-	Calculated from above data	

EUSES parameter	Parameter name	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Area fraction of seawater, region (total)	Fwater2_R	0.0099	0.338	-	Calculated from above data	
Area fraction of natural soil, region (total)	Fsoil1_R	0.267	0.179	-	Calculated from above data	
Area fraction of agricultural soil, region (total)	Fsoil2_R	0.594	0.344	-	Calculated from above data	
Area fraction of industrial/urban soil, region (total)	Fsoil3_R	0.099	0.112	-	Calculated from above data	

2.1.6.2 Areas – continental

This subsection of EUSES considers the parameters for the areas of the continental compartment. GB is proposed to represent the continental scale for the purposes of a GB-specific EUSES assessment. It is therefore relevant to consider these parameters in terms of the GB environment. The EUSES defaults are show in Table 8 along with the suggested GB-specific values.

2.1.6.3 Areas – moderate, arctic and tropic

The EUSES model contains three further scales for modelling: moderate, arctic and tropic. These models are not used directly for the PEC calculations or the risk characterisation and are intended to represent global scale modelling at moderate, polar and tropical latitudes. The EUSES default values for these scales are assumed to be applicable to the GB situation and so alternative values are not proposed.

2.1.6.4 Temperature

This subsection of EUSES gives the temperature parameters for the regional and continental scale. These are both set to 12 °C by default. Temperature is relevant to both movement of a chemical between compartments and its rate of degradation (see Box 2).

The Met Office (Undated-b) has temperature data published dating back to 1884. However, to remain consistent with the availability of data for other environmental parameters (i.e. windspeed), data from the years 1991-2020 were considered. The average annual temperatures between 1991 to 2020 were:

- GB 9.0 °C
- England 10.0 °C
- Scotland 7.7 °C
- Wales 9.4 °C

It is worth noting that the values for average temperature across GB in more recent years are higher than the averages above. The averages for 2021 to 2024 are 9.6, 10.7, 8.2, and 10.0 °C for GB, England, Scotland, and Wales, respectively. When considered all together (1991 to 2024), the average temperature increases in all cases. As such, a provisional change from the default EUSES value of 12 °C to a more GB-specific value of 10 °C could be proposed.

An annual average surface temperature of soil of 10 °C was selected for the EA CLEA model. This was based on Met Office data from 2007 showing the annual average air temperature ranging between 7 and 11 °C at low altitudes, and an assumption that the temperature of the surface layers of soils responds relatively quickly to changes in ambient air temperature (Jeffries and Martin, 2009). The EUSES model does not allow any distinction between the soil and air temperatures.

It should be recognised that changing the default temperature in the EUSES model is not straightforward. Firstly, the effect on other aspects of the assessment needs to be considered (see text box 2). Secondly, the value of the environmental temperature parameter itself cannot be edited directly in EUSES. A work-around is possible but would require substance-specific information to be calculated separately and entered into the model.

Box 2. Temperature in persistence assessments

The degradation half-lives from simulation studies used to compare against the persistence criteria set out in Annex XIII of UK REACH should correspond to an environmentally relevant temperature. Typically, regulatory assessments have used 12 °C for soil and fresh surface water or 9 °C for marine surface waters.

The relevant test guidelines recommend that simulation tests are carried out at around 20 °C. The data must therefore be extrapolated to a lower temperature for comparison with the Annex XIII criteria. In recent years, ECHA has requested simulation studies at 12 °C, to minimise the uncertainties.

Changing this temperature to the mean GB temperature of 9 or 10 °C in the GB-specific EUSES model raises the question of whether the hazard assessment for persistence should also be carried out at this mean reported temperature. Consideration should be given to the possibility of adding to the inconsistency of the persistence assessment of substances across different regulatory regimes for chemicals (e.g., plant protection products or biocides) if the mean reported GB temperature was used, the socio-economic consequences for testing (e.g., use of air conditioning, and its carbon footprint), and also the impact on the outcome of persistence assessments (since half-lives are likely to be longer, whereas the criteria would remain unchanged).

It should also be noted that ecotoxicity tests are usually conducted around 20 °C or above.

For example, it is possible to overwrite the specific degradation rates and other substance parameter values used for each substance manually within EUSES on a case-by-case basis. The EUSES interface would still indicate that the values represent substance properties at 12 °C as the text on the interface cannot be edited easily, but the value entered should be relevant to a GB-specific temperature of 9 or 10 °C (if implemented).

However, even if these adjustments were performed, it could affect how these parameters are interpreted in EUSES for other calculations. For instance, STP processes are assumed to take place at 15 °C, and thus specifying parameters at 9 or 10 °C instead of 12 °C would affect how these parameters are scaled to the relevant temperature for

modelling. More work would therefore be required to develop a method to make the temperature correction more straightforward within the model, and this is outside of the scope of this review.

Given these complications, changing the temperature should not be undertaken lightly. Whilst a provisional change to the default temperature from 12 °C to 9 or 10 °C could be proposed, it is important to consider longer-term projections due to climate change (as discussed in Section 3.1, the average GB temperature as reported above may soon be out of date) alongside the limited overall sensitivity of the model to temperature (see Section 6).

Considering all of the above, no change to the EUSES default temperature value of 12 °C is proposed.

The temperature subsection of EUSES also contains the default values for the temperatures at the moderate, arctic and tropic scale, along with default values for enthalpy of vaporisation and enthalpy of solution (which are used internally within EUSES to correct certain physico-chemical properties to the temperatures assumed in the model). The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values are not proposed.

Table 8 Parameterisation for the area of the continental compartment

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Total area of EU (continent+region, incl. sea)	AreaEU	7.04×10^{6}	3.50×10^{5}	km^2	Represents total area of GB and is the summation of the regional and continental scale areas.	(ONS, 2015)
Area (land+rivers+sea) of continental system	Area_C	7.00×10^{6}	3.48×10^{5}	km^2	Total area minus the regional area	
Area (land+rivers) of continental system	AreaCont	3.50×10^{6}	2.30×10^{5}	km^2		ONS (2015)
Area fraction of freshwater, continent (excl. sea)	FwaterCont	0.03	0.13	-		ONS (2015)
Area fraction of natural soil,	FnaturalCont	0.27	0.35	-		ONS (2015)

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
continent (excl. sea)						
Area fraction of agricultural soil, continent (excl. sea)	FagricCont	0.6	0.40	-		ONS (2015)
Area fraction of industrial/urban soil, continent (excl. sea)	FindCont	0.1	0.12	-		ONS (2015)
Area fraction of freshwater, continent (total)	Fwater1_C	0.015	0.088	-	Calculated from above data	
Area fraction of seawater, continent (total)	Fwater2_C	0.5	0.32	-		ONS (2015)
Area fraction of natural soil, continent (total)	Fsoil1_C	0.135	0.238	-	Calculated from above data	

EUSES parameter	EUSES parameter code	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Area fraction of agricultural soil, continent (total)	Fsoil2_C	0.3	0.27		Calculated from above data	
Area fraction of industrial/urban soil, continent (total)	Fsoil3_C	0.05	0.082		Calculated from above data	

2.1.6.5 Mass transfer

This subsection of EUSES contains the default values for the various partial mass transfer coefficients used internally within EUSES for modelling transport between the air, water, sediment and soil compartments at the regional and continental scale. The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values are not proposed.

2.1.6.6 Air – general

This subsection of EUSES contains the default values for the regional and continental air compartment for the atmospheric mixing height (default = 1,000 m), windspeed in the system (default = 3 m/s), aerosol deposition velocity (default = 1.0×10^{-3} m/s) and aerosol collection efficiency (default = 2.0×10^{5} m/s).

The Met Office (Undated-a) has published average wind speed data from 1991 to 2020, it is not possible to select a specific time frame from this data. It may be that more recent windspeed averages are higher than this, reflecting the more volatile weather seen in recent years. However, there is no data available to support this. Average wind speeds during this period at a height of 10 m were:

- GB 4.9 m/s
- England 4.2 m/s
- Scotland 5.5 m/s
- Wales 5.0 m/s

It should be noted that the higher the windspeed assumed in the model, the greater will be the air flow into and out of the model resulting in lower predicted concentrations. Furthermore, windspeed will vary daily. Therefore, selecting a reasonable value to represent GB is challenging. The average wind speed for GB is likely to be the best choice to represent the windspeed in the system in the GB-specific EUSES model, and its significance is discussed later in Section 6.

The EUSES default values for atmospheric mixing height, aerosol deposition velocity and aerosol collection efficiency are assumed to be applicable to the GB situation and so alternative values are not proposed.

2.1.6.7 Air – rain

This subsection of EUSES contains the precipitation parameters for the regional, continental, moderate, arctic and tropic scale modelling. It is assumed that the EUSES default values for the moderate, arctic and tropic scale are applicable to the GB situation and so alternative values are not proposed for these parameters.

The EUSES default values for the average precipitation rate at the regional scale and continental scale are both 700 mm/yr. The Met Office (Undated-b) has published rainfall

data dating back to 1836 in GB. However, to remain consistent with the availability of data for other environmental parameters (i.e. windspeed), data from the years 1991-2020 will be considered. The average annual rainfall between 1991 to 2020 was:

- GB 1,302 mm/yr
- England 870 mm/yr
- Scotland 1,573 mm/yr
- Wales 1,465 mm/yr

It is worth noting that the values for average rainfall across GB in more recent years is generally higher than the above averages, due to having more volatile weather. These averages for 2021 to 2024 are 1,332, 936, 1,532, and 1,527 mm/yr for GB, England, Scotland, and Wales, respectively. When considered all together (1991 to 2024), the average rainfall increases in all cases, except Scotland (the data is affected by a lower value of 1,398 mm in 2021).

The Met Office (Undated-c) has published rainfall data for several stations located within the Aire-Calder. The availability of this data is more varied, so to reflect this and for simplicity, the average rainfall between these stations for the last 5 years (2020-2024) was 986 mm/yr.

Similar, to the case with windspeed, selecting a reasonable rainfall value to represent GB conditions is challenging. A rounded figure of 1,000 mm/yr is proposed to be used to represent GB in the regional scale as a compromise between the Aire-Calder and GB averages and for simplicity, with the GB-average value of 1,300 mm/yr used to represent the continental scale. The significance of rainfall is discussed later in Section 6.

2.1.6.8 Air – residence times

This subsection of EUSES displays the residence times of air at the regional, continental, moderate, arctic and tropic scale. These values are output values from EUSES, calculated internally by EUSES from the other parameters discussed above. These cannot be overwritten by the user, but EUSES should calculate the relevant values automatically from the GB-specific values discussed above.

2.1.6.9 Water – depth

This subsection of EUSES gives the default values for the parameters related to the depth of freshwater and seawater at the regional, continental, moderate, arctic and tropic scale. The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values have not been investigated.

2.1.6.10 Water – suspended solids

This subsection of EUSES gives the default values for the parameters related to the suspended solids concentrations in the water phases at the regional, continental, moderate, arctic and tropic scales, along with the concentration in biota. The EUSES

default values for these parameters are assumed to be applicable to the GB situation and so alternative values have not been investigated.

2.1.6.11 Water – residence times

This subsection of EUSES displays the residence times of water at the regional, continental, moderate, arctic and tropic scale. These values are output values from EUSES, calculated internally by EUSES from the other parameters discussed above. These cannot be overwritten by the user, but EUSES should calculate the relevant values automatically from the GB-specific values discussed above.

2.1.6.12 Sediment – depth

This subsection of EUSES gives the default value sediment mixing depth at the regional, continental, moderate, arctic and tropic scales. The EUSES default value for this parameter (0.03 m) is assumed to be applicable to the GB situation and so an alternative value is not proposed.

2.1.6.13 Sediment – suspended solids

This subsection of EUSES gives the default values for the parameters related to the biogenic production of suspended solids concentrations in the water phases at the regional, continental, moderate, arctic and tropic scales. The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values are not proposed.

2.1.6.14 Sediment – sedimentation rates

This subsection of EUSES displays the sedimentation rates in water at the regional, continental, moderate, arctic and tropic scale. These values are output values from EUSES, calculated internally by EUSES from the other parameters discussed above assuming a settling velocity of suspended solids of 2.5 m/d. Except for the settling velocity, these cannot be overwritten by the user, but EUSES should calculate the relevant values automatically from the GB-specific values discussed above.

2.1.6.15 Soil – general

This subsection of EUSES contains default values for the parameters ‘fraction of rainwater infiltrating soil’ (0.25) and ‘fraction of rainwater running off soil’ (0.25) for the regional and continental scale modelling. Obtaining data for these parameters is challenging due to the numerous influencing factors and significant variability that exist, placing it beyond the scope of this project. As such, the EUSES default values are considered applicable to the GB context, and no alternative values are proposed. However, further research might be valuable to establish more representative values for GB.

2.1.6.16 Soil – depth

This subsection of EUSES contains the default values for parameters related to the mixing depths of soils at the regional, continental, moderate, arctic and tropic scales. The EUSES default value for the mixing depth of agricultural soil is 0.2 m. As discussed in Section 2.1.5.2 in relation to the local soil, the EA's WALTER model assumes a mixing depth of 0.25 m for agricultural soil, and it is proposed that the value of 0.25 m is used for the GB-specific parameterisation for both the regional and continental scales, to be consistent.

The EUSES default values for the mixing depths of natural soil and industrial/urban soil at the regional and continental scales, as well as the mixing depth of soil at the moderate, arctic and tropic scales are all 0.05 m (at these scales, only a single soil compartment is considered (i.e., no distinction is made between agricultural, natural or urban/industrial soil). The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values are not proposed.

2.1.6.17 Soil – erosion

This subsection of EUSES gives the default values for the parameters related to the soil erosion rate at the regional, continental, moderate, arctic and tropic scales. The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values have not been investigated.

2.1.7 Characterisation of plants, worms and cattle

2.1.7.1 Plants

This subsection of EUSES gives the default values for the parameters related to the composition of plants assumed in the calculations for concentrations in the food chain for human consumption. This includes parameters such as volume fraction of water in plant tissue, volume fraction of lipids in plant tissue and leaf surface area. The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values are not proposed. The EUSES default values are shown in Appendix A.

2.1.7.2 Worms

This subsection of EUSES gives the default values for the parameters related to the composition of worms assumed in the calculations for concentrations in the food chain for worm-eating organisms (secondary poisoning). This includes parameters such as a worm's water and lipid fractions. The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values are not proposed. The EUSES default values are shown in Appendix A.

2.1.7.3 Cattle

This subsection of EUSES gives the default values for the parameters related to the composition of cattle assumed in the calculations for concentrations in the food chain for

human consumption. This includes parameters such as daily intake of grass, drinking water or soil, and daily inhalation rate. The EUSES default values for these parameters are assumed to be applicable to the GB situation and so alternative values are not proposed. The EUSES default values are shown in Appendix A.

2.1.8 Characteristics of humans

This subsection of EUSES gives the default values for the parameters related to the human diet. These are used within EUSES to estimate the daily intake of substances by humans through the diet. The relevant EUSES default values are summarised in Table 9. It should be noted that the EUSES default food intakes per food group are the highest country-average intake across all EU member states. Considering how varied diets across the EU can be, it is appropriate to review these consumption patterns in a UK context.

Following consultation with experts at the Food Standards Agency (FSA), information on food consumption in the UK is available from the FSA's Total Diet Study (TDS, Lombard (2014)) and the FSA research project 'Total diet study of inorganic contaminants, acrylamide & mycotoxins' (Hamlet *et al.*, 2016). The TDS represents the average UK diet at the time of the study, and so has been previously used to determine trends in exposure levels over time, estimate dietary exposure of the general UK population to a variety of chemicals in food, and evaluate the safety and/or nutritional quality of food. The consumption data used for estimating dietary exposure in Hamlet *et al.* (2016) were from the National Diet and Nutrition Survey Rolling Programme (NDNS).

From this TDS acrylamide study, the reported 97.5th percentile exposure at the population level for the adult population (age 19-64) and level of occurrence in food were used to derive consumption data for each food type. The data for these food types were then grouped into the food categories used in EUSES. The new recommended GB EUSES values are summarised in Table 9. These values represent the highest consumption and therefore a realistic worst-case scenario in the UK, which are assumed to be appropriate for GB.

Whilst a good indicator of GB consumption patterns, there are some uncertainties in using the TDS data:

- The complexity of the food types included in the default EUSES values is not described and so assumptions have to be made when grouping the TDS data. Accordingly, the food types from the TDS that are included in the GB EUSES values are intentionally simplified to avoid making the values too conservative (i.e. canned goods, sandwiches, desserts, and other more complex food groups have not been included).

- The data taken from the TDS are based on food that has been prepared and ready to be consumed. It is not known if this is also the case for the data used for the default EUSES values.

- The NDNS consumption data used in the TDS is from the 2011 – 2014 period. Whilst it is unlikely that the current average UK diet differs much from this period, the data used will not reflect more current food trends.

Table 9 Parameterisation for human intake via diet

EUSES parameter	Parameter name	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Daily intake of drinking water	IhDrW	2	2	L/d	Assumed to be applicable to GB	
Daily intake of fish	IhFish	0.115	0.124	kg/d		Lombard (2014)
Daily intake of leaf crops (incl. fruit and cereals)	IhLeaf	1.2	1.3	kg/d		Lombard (2014)
Daily intake of root crops	IhRoot	0.384	0.541	kg/d		Lombard (2014)
Daily intake of meat	IhMeat	0.301	0.392	kg/d		Lombard (2014)
Daily intake of dairy products	IhMilk	0.561	0.700	kg/d		Lombard (2014)

EUSES parameter	Parameter name	EUSES default value	GB-specific value	Units	Notes on GB-value	Source
Inhalation rate for humans (consumers, environment)	IhAir	0.833	0.833	m^3/hr	Assumed to be applicable to GB	Typical adult inhalation rate is 20 m^3/d
Inhalation rate for humans (worker exposure)[a]	IhAirWorker	1.5	1.5	m^3/hr	Assumed to be applicable to GB	
Bodyweight of the human considered	Bw	70	70	kg	Mean adult bodyweight of 85.4 kg and 72.1 kg reported for men and women, respectively (Moody and Neave, 2020). Default value retained as it is conservative, and used by other UK groups, e.g. the Committee on Toxicity of Chemicals (COT)	ECB (2004)
Correction factor for duration and frequency of exposure[a]	CFOccup	2.8	2.8	-	Assumed to be applicable to GB	

Note: a) These parameters are related to worker exposure parts of EUSES only and do not affect the environmental exposure.

3 Effect of future projected climate change scenarios on EUSES parameters

The default values in the EUSES model include an average temperature of 12 °C, an annual precipitation rate of 700 mm/yr and an average windspeed of 3 m/s. As discussed in Section 2.2, an average temperature of 10 °C, annual precipitation rate of 1,000 mm/yr and an average windspeed of 4.9 m/s can be proposed as GB-specific values for the local and regional scales, with a precipitation rate of 1,300 mm/yr used for the continental scale. These parameters may be affected by climate change in the future.

Projections for future climate change scenarios are readily available (Met Office, 2018, accesssed 02/11/2022) for temperature and rainfall. No projections are given for average windspeed. The current Met Office UK climate projections are known as UKCP18 (Fung and Gawith, 2018). The projections are based on four Representative Concentration Pathways (RCP), which specify the concentrations of greenhouse gases that would result in target amounts of radiative forcing at the top of the atmosphere by 2100, relative to pre-industrial levels. The forcing levels used in the projections have been set to 2.6, 4.5, 6.0 and 8.5 W/m^2, referred to as RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5.

3.1 Temperature projections

The UKCP18 probabilistic projections for mean annual temperature by country/region are summarised in Table 10. The data are taken from Met Office (2022b) and the associated summary spreadsheet (Met Office, 2022a, accessed 02/11/2022). The overall findings are summarised below:

- All areas of GB are projected to experience warming.
- The warming is greater in the summer than the winter, but both winters and summers will become warmer.
- The extent of warming depends on the amounts of greenhouse gases emitted globally.
    - The RCP2.6 scenario predicts that the highest rate of increase in temperature will occur in the early part of the century.
    - The RCP8.5 scenario predicts that the highest rate of increase in temperature will occur towards the end of the century.

Table 10 UKCP18 probabilistic projections for mean annual temperature

Time horizon (relative to 1981-2000)	Country/region	50th percentile increase in temperature (°C; figures in brackets are the 5th percentile-95th percentile change)			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2020-2039	England	+1 (+0.2 to +1.7)	+0.8 (+0.1 to +1.5)	+0.7 (+0.1 to +1.5)	+0.9 (+0.2 to +1.7)
	Scotland	0.8 (0-1.5)	0.7 (0-1.4)	0.6 (-0.1-1.3)	0.8 (0-1.5)
	Wales	0.9 (0.2-1.7)	0.8 (0.1-1.5)	0.7 (0.1-1.4)	0.9 (0.2-1.7)
2050-2069	England	1.2 (0.2-2.2)	1.5 (0.4-2.7)	1.4 (0.4-2.6)	2.2 (0.8-3.6)
	Scotland	0.9 (0-1.8)	1.1 (0.2-2.2)	1.1 (0.1-2.1)	1.7 (0.4-3)
	Wales	1.1 (0.2-2.2)	1.4 (0.4-2.6)	1.4 (0.3-2.5)	2.1 (0.7-3.5)
2080-2099	England	1.3 (0.2-2.6)	2.4 (0.9-4.1)	2.8 (1.1-4.7)	4 (1.8-6.3)
	Scotland	0.9 (-0.1-2.1)	1.8 (0.5-3.3)	2.2 (0.7-3.7)	3.1 (1.2-5.2)
	Wales	1.3 (0.2-2.5)	2.4 (0.9-4)	2.8 (1.1-4.5)	3.9 (1.8-6.2)

The following overall increases in temperature are suggested in the short- (i.e., 2020-2039), medium- (i.e., 2050-2069) and long-term (i.e., 2080-2099) (Table 11). These are based on the projections in Table 10 for GB. The range represents the 5th percentile projection from the RCP2.6 scenario to the 95th percentile of the RCP8.5 scenario. The 50th percentile value is from the RCP4.5 scenario (the 50th percentile values from the RCP6.0 scenario are relatively similar to these).

Table 11 Suggested increase in temperature (°C) for use in EUSES to take account of climate change

Projection	Projected increase in GB average temperature					
	5th Percentile from RCP2.6	50th Percentile from RCP4.5	95th Percentile from RCP8.5	Current average temperature	Projected average temperature	Range
Short-term projection (2020-2039)	0.2	0.8	1.7	9.0	9.8	9.2-10.7
Medium-term projection (2050-2069)	0.2	1.4	3.6	9.0	10.4	9.2-12.6
Long-term projection (2080-2099)	0.2	2.4	6.2	9.0	11.3	8.9-15.2

The temperature predictions suggest that the current average temperature in GB of 9.0 °C could rise to 9.8 °C (range 9.2-10.7 °C) in the short-term, 10.4 °C (range 9.2-12.6 °C) in the medium-term and 11.3 °C (RCP4.5) to 11.8 °C (RCP6.0) (range 8.9-15.2 °C) in the long-term. These averages are still below the current EUSES default temperature but may be expected to exceed the default in parts of GB. The proposed value of 10 °C would account for predicted temperatures over the short term, but the current default (12 °C) would be more appropriate for the medium- and longer-term scenarios, supporting the decision to not alter the current default EUSES value.

The sensitivity of EUSES to the temperature and the implications of future temperature predictions on EUSES modelling for GB are considered in Section 6.

3.2 Precipitation projections

The overall findings from UKCP18 climate projections for precipitation are that winter precipitation is expected to increase significantly, and summer rainfall is expected to decrease significantly. However, there may be more intense storms in summer when it does rain. The precipitation data are summarised in Appendix C in Table C.2.

The precipitation predictions show that although increased rainfall is expected to occur in winter, this is approximately balanced by a decrease in the rainfall in summer. The net effect of this is that the overall average rainfall would be relatively unchanged. With increasing rainfall intensity, more flash flooding could be expected leading to more storm overflow discharges. This may impact assumptions about the contribution of direct discharges.

There are two potential effects of a future change in average rainfall within the simplistic approach within EUSES. The first is on the rain-out of substances from the atmosphere to soil and the second is on potential changes to river flow rates and dilutions. The sensitivity of EUSES to rainfall and the implications of future temperature predictions on EUSES modelling for GB are considered in Appendix B.

A personal communication (Constantino, 2022) from an expert in the climate change scenarios being developed within the UKWIR SAGIS-SIMCAT model (UKWIR, 2024) has indicated that climate change will impact on river dilution as it will result in lower overall flow volumes but more extreme high and low flows. The SAGIS-SIMCAT model is being developed to implement the climate change modifications to the parameter values controlling river flow within the model, but the actual effects of this are currently uncertain as this has not yet been modelled nationally. Based on the work done so far, the magnitude of the likely impact on dilution will vary both spatially and with the time frame being considered. The overall trend expected is towards a lower level of dilution.

3.3 Windspeed

Future climate predictions are not available for average windspeed. The climate predictions do however indicate that there may be more intense storms which could imply more extremes in windspeed. The global projections over the UK show an increase in near-surface wind speeds over the UK for the second half of the 21st century for the winter season when more significant impacts of wind are expected. This is accompanied by an increase in frequency of winter storms over the UK. However, it is noted that wind speed is not available for the probabilistic projections as they did not pass the Met Office credibility checks (Met Office, 2019).

The sensitivity of EUSES to windspeed is considered in the later sensitivity analysis (Section 6 and Appendix B).

3.4 Projected sea level rise

UKCP18 also gives predictions for sea level rise. The sea level is projected to rise for all emission scenarios and at all locations around the UK. The 95th percentile projection for RCP 8.5 suggest a sea level rise of 0.4 m in London, 0.39 m in Cardiff and 0.28 m in Edinburgh by 2050 and 1.14 m in London, 1.13 m in Cardiff and 0.9 m in Edinburgh by the year 2100 (all compared with the 1981-2000 average). The future increase in sea level could potentially increase dilution in the marine environment, if current discharge points remain the same. However, as discussed in Section 2.2.3.1, selecting an appropriate DF in marine water is challenging for generic exposure modelling and a pragmatic approach of assuming a DF of 100 would also be appropriate for future climate change scenarios.

3.5 Indirect effects of climate change

Climate change is expected to affect a chemical's persistence, bioavailability, environmental distribution and mobility (e.g., Val *et al.* (2016)). It is also expected to affect toxicity as it has been shown to affect the vulnerability of aquatic organisms (e.g., Bethke *et al.* (2023); Swelam *et al.* (2022)), exacerbating the more direct effects of climate change on wildlife. Nevertheless, most ecotoxicity testing takes place around room temperature or higher, so the data used for PNEC derivation will not change.

While a full review of the indirect effects of climate change on chemicals was outside the scope of this report, it is recommended that the scientific literature continues to be monitored and potential adaptation of the assessment criteria and/or chemical properties be considered in future.

3.6 Summary of predicted climate change implications for a GB-specific EUSES

The climate change predictions suggest that the current average GB temperature of 9.0 °C could rise to 9.8 °C (range 9.2-10.7 °C) in the short-term, 10.4 °C (range 9.2-12.6 °C) in the medium-term and 11.3 °C (range 9.3-15.2 °C) in the long-term. The merit of modifying the current default temperature (12 °C) is therefore subject to the overall significance of temperature to EUSES modelling outputs (considered in Section 6).

In addition, there are predicted to be changes to precipitation patterns, with winter precipitation expected to increase significantly and summer rainfall expected to decrease significantly. The net effects of the changes in the precipitation pattern on the average precipitation is unclear but is likely to balance out across the year. There is also predicted to be an increasing incidence of more intense storms with the associated increase in strong winds, although the overall impact of future climate change on average windspeed is unclear.

In terms of EUSES modelling, it is relevant to consider the timescales of the projections. This is particularly relevant for the regional modelling which is a steady-state model. The time to steady-state in the EUSES regional model depends on the substance removal rate (e.g., rates of (bio)degradation) and how the substance partitions between environmental compartments). So, the time to steady-state is substance specific but can be in the order of hundreds if not thousands of years for substances that are persistent and relatively immobile in the environment. The regional model therefore provides a snapshot of likely concentrations that could occur many years in the future, assuming that the release rate stays constant. Furthermore, the regional EUSES model works on annual averages and so is not capable of modelling extreme events in any detail. Therefore, any impacts of future climate change on the regional modelling would not necessarily be apparent until many hundreds of years into the future, depending on the substance. This limits the usefulness of EUSES for estimating the effects of future climate change over relatively short timescales (e.g., 20-80 years) at the regional level.

In contrast, the local model within EUSES is, with the exception of the soil compartment, an instantaneous model. The local PECs for the soil compartment are estimated over a 10-year period, which is relatively short or comparable with the predicted climate change timescales. Therefore, in principle the local model in EUSES could be used to model the effects of climate change over relevant timescales.

The emerging future climate change predictions using the SAGIS-SIMCAT model, although not yet published, are suggesting that the average dilution in the UK may change in the future. There is currently insufficient information available on these predictions to make recommendations for including them in the GB-specific EUSES beyond the changes proposed in Section 2.1.5.1.

The changes to rainfall and windspeed as detailed in Section 2 are expected to account for climate change scenarios at least in the short term. The overall change in average rainfall (and windspeed) is expected to be relatively low, but updated GB-specific values are nonetheless considered to be an improvement over EUSES default values. A marine DF of 100 is retained as a pragmatic approach to changes in sea level. As a steady state model, EUSES works with averages over time, so the model is not appropriate for addressing the potential impacts of extreme weather.

4 Summary of initial proposals for GB-specific parameters

The initial proposals for GB-specific parameterisation of EUSES are summarised in Table 12. The sensitivity of EUSES to the values of the parameters in Table 12 is discussed in Section 6 and Appendix B.

Table 12 Initial proposals for GB-specific parameterisation of EUSES

EUSES parameter	EUSES default value		GB-specific value (% of default)	Units
Characterisation of compartments – Soil				
Volume fraction of solids in soil	0.6	Clay Loam: 0.44 (73%)	Sandy Loam: 0.47 (78%)	m^3/m^3
Volume fraction of water in soil	0.2	Clay Loam: 0.42 (210%)	Sandy Loam: 0.33 (165%)	m^3/m^3
Volume fraction of air in soil	0.2	Clay Loam: 0.14 (70%)	Sandy Loam: 0.2 (N/A)	m^3/m^3
Weight fraction of OC in soil	0.02	Clay Loam: 0.044 (220%)	Sandy Loam: 0.035 (175%)	kg/kg
Weight fraction of organic matter in soil	0.034[a]	Clay Loam: 0.075 (221%)	Sandy Loam: 0.06 (176%)	kg/kg
Bulk density of wet soil	1,700	Clay Loam: 1520 (89%)	Sandy Loam: 1,500 (88%)	kg_{ww}/m^3
Conversion factor wet-dry soil	1.13	Clay Loam: 1.38 (122%)	Sandy Loam: 1.28 (113%)	kg_{ww}/kg_{dw}
Release estimation				
Fraction connected to sewer system	80		95.5 (119%)	%
Sewage treatment – General				

EUSES parameter	EUSES default value	GB-specific value (% of default)	Units
Number of inhabitants feeding one STP	$1.00x10^4$	$8.42 x10^3$ (84%)	Eq
Sewage flow	200	218 (109%)	L/Eq/d
Effluent discharge rate of local STP	$2.00 x10^6$	$1.83 x10^6$ (92%)	L/d
Number of inhabitants of region	$2.00 x10^7$	$2.33 x10^6$ (12%)	Eq
Number of inhabitants of continental system	$3.50 x10^8$	$6.34 x10^7$ (18%)	Eq
Windspeed in the system	3	4.9 (163%)	m/s
Local distribution - Air and surface water			
DF (rivers)	10	3 (30%)	-
Flow rate of receiving water	18,000	13,300 (74%)	m^3/d
Local distribution – Soil			
Mixing depth of grassland soil	0.1	0.05 (50%)	m
Dry sludge application rate on agricultural soil	5,000	5,000 (N/A)	kg/ha/yr
Dry sludge application rate on grassland	1,000	2,500 (250%)	kg/ha/yr
Mixing depth of agricultural soil	0.2	0.25 (125%)	m
Average annual precipitation	700	1,000 (regional) (143%) 1300 (continental) (186%)	mm/yr
Regional and continental distribution – Configuration			
Number of inhabitants of region	$2.00 x10^7$	$2.33 x10^6$ (12%)	Eq

EUSES parameter	EUSES default value	GB-specific value (% of default)	Units
Number of inhabitants in the EU (for the GB-specific model this represents the total population of GB rather than the EU)	3.70 x10^8	6.52 x10^7 (18%)	Eq
Number of inhabitants of continental system	3.50 x10^8	6.34 x10^7 (18%	Eq
Regional and continental distribution – Areas			
Area (land+rivers) of regional system	40,000	1,960 (5%)	km^2
Area fraction of freshwater, region (excl. sea)	0.03	0.019 (63%)	-
Area fraction of natural soil, region (excl. sea)	0.27	0.27 (N/A)	-
Area fraction of agricultural soil, region (excl. sea)	0.6	0.52 (87%)	-
Area fraction of industrial/urban soil, region (excl. sea)	0.1	0.17 (17%)	-
Total area of EU (continent+region, incl. sea)	7.04×10^6	3.50×10^5 (5%)	km^2
Area (land+rivers+sea) of continental system	7.00×10^6	3.48×10^5 (5%)	km^2
Area (land+rivers) of continental system	3.50×10^6	2.30×10^5 (7%)	km^2

EUSES parameter	EUSES default value	GB-specific value (% of default)	Units
Area fraction of freshwater, continent (excl. sea)	0.03	0.13 (433%)	-
Area fraction of natural soil, continent (excl. sea)	0.27	0.35 (130%)	-
Area fraction of agricultural soil, continent (excl. sea)	0.6	0.40 (67%)	-
Area fraction of industrial/urban soil, continent (excl. sea)	0.1	0.12 (120%)	-
Regional and continental distribution – Air			
Windspeed in the system	3	4.9 (163%)	m/s
Average precipitation, regional system	700	1,000 (143%)	mm/yr
Average precipitation, continental system	700	1,300 (186%)	mm/y
Humans - Characteristics of humans			
Daily intake of fish	0.115	0.124 (108%)	kg/d
Daily intake of leaf crops (incl. fruit and cereals)	1.2	1.32 (110%)	kg/d
Daily intake of root crops	0.384	0.541 (141%)	kg/d
Daily intake of meat	0.301	0.474 (157%)	kg/d
Daily intake of dairy products	0.561	0.793 (141%)	kg/d

EUSES parameter	EUSES default value	GB-specific value (% of default)	Units
Length of regional seawater	40	100 (250%)	km

5 Interpretation of PEC values at a GB scale

For PEC calculations under UK REACH, it is assumed that the tonnage and use information available will be specific to GB rather than the EU. The tonnage per site in the local PEC calculation may be the same as the EU, depending on the specific modelled scenario (e.g., a site-specific versus widespread use scenario). Therefore, the tonnage and emission inputs, and the PECs calculated, for UK REACH should be verified as they may be different from those currently used and modelled in CSRs prepared by registrants under EU REACH, regardless of any GB-specific changes to the modelling assumptions.

Changes to tonnage and use information notwithstanding, this section gives recommendations for how the PECs are calculated and interpreted using the GB-specific EUSES model.

The EUSES model calculates PEC values at three different scales as outlined in Section 2. In the GB-specific model the local, regional and continental scales are conceptualised as follows:

- The conceptualisation of the local scale is the same as the EU, representing the concentration immediately downstream of a point of discharge or release.
- The regional scale is suggested to be based on the size and population of the industrialised and highly populated Aire-Calder catchment.
- It is proposed that the continental model is based on the size and properties of GB.

The local model used in EUSES is a simple dilution model that assumes instantaneous mixing and partitioning between compartments (e.g., between water, sludge, sediment and soil). The regional and continental models are both multi-compartment steady-state models based on the fugacity concept (Mackay, 1979).

5.1 Interpretation at the local scale

For the local scale, the main changes that will need to be made to the EUSES model to make it more specific for GB relate to the properties of the local environment (e.g., water flow, dilution, etc.) rather than the local tonnage or local release from the point source. The properties of the local environment are already accounted for in the recommended GB-specific values. Therefore, in principle, the local PECs will be appropriate for GB. The recommended tonnage inputs into the GB-specific local model are summarised below.

- Point sources: For industrial sources, the local tonnage should represent the realistic worst-case tonnage of the substance used at an individual site, as in the original EUSES model.
- Widespread uses: These usually include professional and consumer uses, and in some cases also service life releases from articles. The service life is intended to represent the timescale over which emissions could occur from substances present in articles. In

the original EUSES model this is based on an STP serving a population of 10,000 people. For the GB-specific model it is recommended that a similar approach is used but that the population served by the STP is decreased from 10,000 people to 8,420 people so it reflects the national average of England and Wales.

Further guidance on how to estimate the local tonnage is given in ECHA (2016) and it is recommended that the same approach is used for GB.

The other part of the local emission estimate is the emission factor to air, water and industrial soil assumed in EUSES. The current approach to emission estimation under UK REACH is outlined in the ECHA (2016) R.16 guidance and is based on Life Cycle Stage (LCS), Sector of Use (SU), Chemical Product Category (PC), Environmental Release Categories (ERCs), Article Category (AC) and Technical Function (TF). Further details of these descriptors are given in ECHA (2015). R.16 gives recommended default emission factors for each ERC that can be used in the absence of actual emission data, and for the purpose of this report it is assumed that a similar system of default emission factors will be used under UK REACH. These ERCs, and associated default emission factors, are not currently incorporated into the EUSES model, but are built into the CHESAR model. The EUSES model uses an older system based on Industry Category and Use Category (the Use Category is similar to the Product Category) with the default release factors coming from the A- and B-Tables in European Commission (2003). To use the ERC emission factors in EUSES the relevant emission factors need to be manually input into EUSES; there is no difference in this respect to how EUSES is currently used to model exposure under UK or EU REACH.

5.2 Interpretation at the regional scale

The regional model proposed for the GB-specific EUSES model is based on the Aire-Calder catchment. For modelling purposes, it is assumed that this catchment has a population of 2.33×10^6 Eqs (see Table 6) and a total area of 1,960 km^2 (see Table 7). The total population of GB is 6.52×10^7 Eqs (see Table 6) and the total area of GB is 2.30×10^5 km^2 (see Table 8). So, the GB-specific regional model represents 3.6% of the total GB population and 0.85% of the GB land area. For comparison, the regional model within the default EUSES model represents 5.4% of the total EU population and 0.56% of the total EU area.

The regional model is intended to represent a heavily industrialised area with a higher-than-average amount of a substance being made or used there. Based on ECHA (2016), the normal assumption for the tonnage of a substance used in the regional assessment should be between 10% and 100% of the total EU tonnage of the substance. For the GB-specific EUSES the total tonnage assessed will be that for GB rather than the EU. Therefore, for a worst-case assessment, it is appropriate to assume that the regional tonnage would be between 10% and 100% of the total GB-tonnage. The decision over the actual regional tonnage to be used will need to be taken on a case-by-case basis, using

the R.16 guidance (as is currently the case under EU REACH). This will need to consider the number of sites of use (a limited number of point sources versus a large number of point sources, and the spatial distribution of these sources).

As well as the regional tonnage, similar to the case with the local scale model, the regional scale model also requires emission factors to be used. These need to be manually overwritten within EUSES if the ERC emission factors are being used. Again, there is no difference here between how EUSES is currently used to model exposure under UK or EU REACH.

The regional PECs calculated in EUSES have two main uses in the risk assessment: firstly, they are used to carry out the regional risk characterisation; secondly, they are used as the industrial background level that is taken into account for the local PECs. Both of these are automatically included in EUSES and there is no need for further modifications to make those calculation applicable to GB-EUSES.

In summary:

- ECHA (2016) should be followed to determine the appropriate percentage of the regional tonnage, which should typically be 10-100% of the total GB tonnage.
- The regional PECs obtained from the GB-specific EUSES are directly applicable to both a) the regional risk characterisation and b) the GB-specific regional background concentration (this is automatically included in the local PECs estimated by GB-EUSES).

5.3 Interpretation at the continental scale

For the GB-specific EUSES it is proposed that the continental scale represents the whole of GB. The continental tonnage used in the GB-specific continental model should therefore be the total GB tonnage minus the regional tonnage. This is directly analogous to the approach take in the default EUSES model (where the continental tonnage is the total EU tonnage minus the regional tonnage).

Like the local and regional scale models, the continental model also requires emission factors to be used. These need to be manually overwritten within EUSES if the ERC emission factors are being used. There is no difference in this respect to how EUSES is currently used for modelling exposure under UK and EU REACH.

The continental PECs obtained using the GB-specific EUSES are representative of the overall background concentration present in the GB environment. In addition, the EUSES model also provides information on the mass of substance remaining in the continental environment at steady-state; this approximates to the steady-state mass of the substance in the GB environment that results from a specific annual emissions rate of the substance assuming that the total GB emission of the substance (inputs) is balanced by degradation and/or transport out of GB (outflows).

6 Sensitivity analysis

The sensitivity analysis was undertaken using hypothetical physico-chemical properties of four example substances (A, B, C and D) spanning a range of high and low volatility, solubility and lipophilicity (properties are presented in Table B.1 of Appendix B). The analysis consisted of several parts:

- A comparison of the PECs obtained using the GB-specific values (at DF of both 10 and 3), and for the soil types ‘clay loam’ and ‘sandy loam’, with those obtained using the EUSES default values for different compartments.
- A comparison of the GB-specific values at a range of different temperatures to account for climate change predictions.
- A comparison of the effect of changing the EUSES default value for DF only from 10 to 3, leaving all other values unchanged.
- A comparison of the PECs obtained using the GB-specific values at DF 3 with those using EUSES defaults at DF 3.
- Examination of which parameters have the largest impact on the PECs.

6.1 PECs obtained using GB-specific parameters compared with current EUSES defaults

The results of the first stage are summarised in Table 13 for local PECs and Table 14 for regional PECs. The comparisons are based on the ‘sandy loam’ soil type and the effect of ‘clay loam’ is discussed separately. Further details of the methodology and results are included in Appendix B.

As described in Section 2.1.5.1, a DF of 3 is the scenario accounting for upstream STP releases where a suitable background concentration cannot be ascertained, or for large STPs flowing into small rivers.

The scale of the difference between the local PECs obtained using a DF of 3 with GB-specific values versus the EUSES defaults is generally identical to the scale of change when a DF of 10 is used (Table 13), resulting in an average of 1.5 times higher PECs across soil types when the GB-specific values are used. Dilution only affects local freshwater PECs (and the associated sediment/fish PECs), so as there is a factor of 3.3 difference between the DFs it is not surprising that a DF of 3 results in local PECs that are 3.3 times higher than those derived using a DF of 10. There are some discrepancies for HvE (± 10%) for substances B, C and D and for substance B as a function of soil type (sandy loam) for agricultural soil and terrestrial predator’s prey, where these values are more divergent from the EUSES defaults.

Table 13 Effects of GB-specific parameterisation on local PECs for different compartments compared to standard EUSES defaults

Local PEC	GB-specific PEC as a percentage of the EUSES default PEC	
	DF of 10	DF of 3
Freshwater and freshwater sediment	109% to 127% (i.e. 1.09 to 1.27 times higher)	363% to 435% (i.e. 3.63 to 4.35 times higher)
Secondary poisoning of predators associated with freshwater	110% and 127% (i.e. 1.10 to 1.27 times higher).	363% and 422% (i.e. 3.63 to 4.22 times higher).
Marine water and sediment	109% (i.e. 1.09 times higher)	109% (i.e. 1.09 times higher)
Agricultural soil	105% to 135% (i.e. 1.05 to 1.35 times higher)	105% to 120% (i.e. 1.05 to 1.20 times higher)
Secondary poisoning (marine and terrestrial environments)	109% (i.e. 1.09 times higher) and 67% to 131% (i.e. 6.7 times lower to 1.31 times higher)	109% (i.e. 1.09 times higher) and 67% to 131% (i.e. 6.7 times lower to 1.31 times higher)
Air	100% to 166% (i.e. 1 to 1.66 times higher)	100% to 166% (i.e. 1 to 1.66 times higher)
Humans via the environment exposure	103% to 150% (i.e. 1.03 to 1.5 times higher)	117% to 292% (i.e.1.17 to 2.92 times higher)

When the GB-specific soil characteristics are replaced with clay loam (Appendix C.1), the PECs tend to be the same as to those obtained with sandy loam soil characteristics (reported in Table 13), other than in agricultural soil, terrestrial predator's prey and HvE. Depending on the substance, agricultural soil PECs tend to change by between -1 to 7%, with 3 out of the 4 substances showing increases. Changes to PECs are also observed in terrestrial predator's prey, with substances B and C showing slight decreases whereas substance D shows an increase of ~50% with clay loam. Similar changes are seen for HvE, supporting the choice of sandy loam characteristics for a more conservative HvE assessment, although substance D shows only a very minor increase in PEC.

Where increases are seen for HvE, this is a combination of the increased PECs in air and water as well as fish.

Table 14 Effects of GB-specific parametrisation on regional PECs for different compartments

Regional PEC	Effect of GB-specific parametrisation (GB-specific PEC as a percentage of the EUSES default PEC)	
	DF of 10	DF of 3
Freshwater and freshwater sediment	527% to 1,048% (5.27 to 10.48 times higher) and 323% to 1,047% (3.23 to 10.47 times higher)	527% to 1,048% (5.27 to 10.48 times higher) and 323% to 1,047% (3.23 to 10.47 times higher)
Marine water and sediment	44% to 153% (0.44 times lower to 1.53 times higher)	44% to 153% (0.44 times lower to 1.53 times higher)
Agricultural soil	1,390% to 11,133% (13.9 to 111 times higher)	1,390% to 2,480% (13.9 to 24.8 times higher)
Air	19% to 858% (0.19 times lower to 8.58 times higher)	116% to 804% (1.16 to 8.04 times higher)
Total daily intake for humans	167% to 1,967% (1.67 to 19.67 times higher)	167% to 1,967% (1.67 to 19.67 times higher)

The GB-specific parameterisation has a greater effect on the regional PECs than what is seen at the local scale for all compartments except marine (other than substance A for marine). For example, freshwater-related endpoints have regional PECs that are between 3.2 and 10.5 times higher than obtained using the current defaults. This is caused in part by the ratio between the default EUSES area (400,000 km^2) being around 2,000% of (20 times) the GB regional area (1,960 km^2), and a standard mass release rate of 1 kg/d resulting in a much higher loading (in kg/km^2) in the GB region than the EU region.

When the DF is changed to 3, the regional PECs are the same as when using the DF of 10 for most compartments but differences are observed in agricultural soil and air. For marine compartments, the PECs are actually lower than those obtained using EUSES defaults for substances B, C and D (44 to 71 %), reflecting changes to the coastline length to land area ratio (an increase of 2.5 times), windspeed and connectivity to the sewer system, but is not clear why a lower DF causes the regional PEC to decrease and the local PEC to increase. In the case of surface water and marine compartments, the regional PEC accounts for up to 0.3% of the local PECs, which is a modest increase in absolute

terms over the contribution of the EUSES defaults of ~0.03%, but approximately 10 times higher in relative terms. Similarly, for agricultural soil, the regional PECs modelled with GB-specific values contribute to up 1.4% of the local PEC versus the contribution of the EUSES defaults of 0.1%. A small increase of <1% to the contribution of the regional air PEC to the local air PEC was seen using the GB-specific values versus the EUSES defaults. Therefore, the increases to the regional scale PECs as a result of the GB-specific parameter changes has only a limited impact on the local PEC.

A full comparison of the PECs is given in Appendix B and the effect of DF is discussed in the next sub-section.

6.2 Parameters with the greatest effect on GB-specific PECs

The parameters with the largest influence vary across compartments and scale (local or regional). For instance, at the local scale, the “dilution factor”, “number of inhabitants feeding one STP” and “sewage flow rate per inhabitant” were the most significant parameters for the water and sediment compartments and secondary poisoning (both freshwater and marine). Increasing “number of inhabitants feeding one STP” and “sewage flow rate per inhabitant” both decrease the PEC, so as one is decreased and the other increased, they have an antagonistic effect on the overall PEC. “Sludge application rate onto soil” and “mixing depth of agricultural soil” were found to be impactful for agricultural soil and terrestrial secondary poisoning PECs. “Bulk density of wet soil” was also found to be an impactful parameter for agricultural soil PECs.

At the regional scale “windspeed in the system” along with “fraction connected to sewer system” were found to be the most impactful input parameters when determining PEC values for freshwater, freshwater sediment, marine water and marine sediment. The “area (land + rivers)” for both the regional and continental system, “area fraction of freshwater, region”, “sewage flow rate per inhabitant” and “average precipitation, continental system” are also impactful parameters for freshwater and freshwater sediment, while the “width of regional seawater” is an impactful parameter for the marine water and sediment PECs.

For agricultural soil, the “area fraction of agricultural soil” and the “average precipitation” were found to be the two most important input parameters in determining the regional PEC. For the regional air PEC, the most important parameters identified were the “windspeed in the system”, “area (land + rivers) of regional system”, “average precipitation, regional system” and “fraction of rainwater infiltrating soil”.

A summary of the most sensitive parameters and proposed changes to values is shown in Table 15 below. Further details are included in Appendix B. Sensitivity analysis.

Table 15 Summary of the parameters with the largest influence on calculated PECs in the GB-specific model

Parameter	EUSES default value	GB-specific value	Unit
Local scale			
Number of inhabitants feeding one STP	10,000	8,420	Eq
DF for freshwater	10	10 or 3	-
Sewage flow rate per inhabitant	200	218	L/Eq/d
Bulk density wet soil	1,700	1,500	kg_{ww}/m^3
Dry sludge application rate on agricultural soil	5,000	5,000	kg/ha/yr
Mixing depth of agricultural soil	0.2	0.25	m
Regional scale			
Windspeed in the system	3	4.9	m/s
Area (land + rivers) of regional system	40,000	1,960	km^2
Average precipitation, regional system	700	1,000	mm/yr
Fraction connected to sewer system	80	95.5	%
Area fraction of freshwater, region (excluding sea)	0.03	0.029	-

6.3 Country-specific PECs and climate change

Separate PECs were not calculated for England, Scotland or Wales. Country-specific data such as tonnage are generally not available. It is therefore assumed that the PECs obtained using the GB-specific EUSES model are sufficiently representative of GB for the purposes of a generalised regulatory assessment approach. Sensitivity testing was therefore not undertaken.

The effects of climate change on average windspeed and rainfall have not been subject to sensitivity testing. The impact of changes to these parameter values on the calculated PECs is expected to be relatively small. A comparison of the GB-specific values at both

the EUSES default temperature (12 °C) and the uppermost predicted temperature in GB from Table 11 (15 °C) has been completed to account for the predicted changes in temperature from climate change.

The general trend across both the local and regional scale indicate that increasing the temperature from 12 °C to 15 °C whilst using the GB-specific values causes the PECs to decrease, approaching values closer to that of those achieved using the EUSES default parameters (but not falling below). There is only one instance in which the PECs increase, and that is at both the local (substance D only) and regional scale for the air compartment. The merit of modifying the current default temperature (12 °C) is therefore subject to the overall significance of temperature to EUSES modelling outputs (considered in Section 6). This consolidates the decision to not alter the EUSES default value of 12 °C.

Regarding the increased probability of extreme weather events, it should be noted that EUSES takes a relatively simplistic approach to modelling. In particular, the input parameter values are averages over time as is the model output (calculated PECs). Therefore, the model is not appropriate for addressing the potential impacts of extreme weather. This is discussed further in Appendix B.

7 Discussion and conclusions

7.1 Proposed changes and their effects

Currently, EUSES (or the related CHESAR model) is used for two purposes relevant to the Environment Agency:

- the preparation of CSRs by registrants as part of REACH registration or applicants for authorisation; and
- regulators' assessments for evaluation activities or preparation of a REACH restriction dossier.

This report presents a series of GB-specific values for the EUSES model to make the modelling results more relevant to the GB environment (see Table 12). The method for estimating releases in EUSES is not fully aligned with the ECHA (2016) R.16 guidance, so adjustment for emission fractions is still required.

The parameters with the largest overall impact on the local PECs using the GB-specific model are the DF, the size and flows of the STP, the sewage sludge application rate to soil, the soil mixing depth and the soil density. The extent of change in the outputs is influenced by the properties of the substance, and varies between compartments. For the example substances subject to sensitivity analysis, the net effect is that, for a given release rate, the local PECs obtained using the GB-specific values are generally higher than those obtained with the EUSES defaults. For freshwater, freshwater sediment, secondary poisoning for freshwater and HvE these increases are more pronounced and are between 109% to 127% (or 363% to 435% if using a DF of 3) of those obtained using the default EUSES parameter values. For marine water and sediment, agricultural soil, and secondary poisoning for the marine and terrestrial environments, the local PECs obtained using the GB-specific values are also generally 105% to 135 % of those derived using the default EUSES values. For HvE, the total local exposure obtained using the GB-specific values generally varies between 103% to 150% (117% to 292% for a DF of 3) of the value obtained using the default EUSES values; the higher value was obtained for one of the example substances (Substance D), which also had a higher PEC for air. These effects are more pronounced when the DF is changed from 10 to 3.

The changes that have the largest overall impact on the regional PECs are the areas in the regional model, the rainfall and windspeed, the connection rate to STPs and the sewage flow rate. The effect of the GB-specific values is to produce higher regional PECs in all compartments for all substances except for marine water and sediment for Substances B, C and D, where the PECs are up to 19% lower than those obtained with the current default EUSES parameter values. The level of increase varies by substance and compartment, but is generally >530% for fresh surface water/sediment and agricultural soil. For HvE, the increase ranges from 167% to 1967%.

Nevertheless, since regional PECs are incorporated into the local PECs, the increase does not make a significant difference as the contribution to the local PEC increases only by a small amount in percentage terms (typically <1%).

In summary, the result of the GB-specific parameter value changes appears to be that the PECs will generally be higher (on average 1.5 times higher) at a local scale for most substances when compared to the PECs obtained using the default EUSES parameter values. The increases are further pronounced (up to 4.3 times depending on soil type and associated retention) when a DF of 3 is used, for those compartments related to surface water. The values are not only a better reflection of GB conditions over the EUSES default values, but are more conservative and so more protective. Only a small subset of property values could be tested in the sensitivity analysis, which may limit the applicability of these conclusions. In addition, it must also be remembered that the EUSES model is essentially a screening tool – if risks are identified, the calculations can usually be refined in various ways, such as through improved testing of degradation rates or monitoring to refine release estimates or for comparison with PECs.

7.2 Implementation options

The GB-specific values listed in Table 12 can be relatively easily implemented in EUSES as the current defaults can be overwritten by the user. The relevant changes to the default values can be saved as an EUSES export file, which could be hosted on the UK Government website or otherwise made available to EUSES users in GB by the regulatory authorities. When this file is imported at the start of a new assessment, the relevant default values will be automatically set to the GB-specific values. Although the local parameters for flow rate of receiving water and annual average precipitation rate for the local assessment cannot be directly overwritten by the user, flow rate can be edited for each exposure scenario individually from the STP screens within EUSES.

As explained in Section 2.1.6.4, the value of the environmental temperature parameter itself cannot be edited directly in EUSES. A work-around is possible but would require substance-specific information to be calculated separately and entered into the model. However, climate change considerations (discussed in Section 3.1) mean that the average UK temperature may soon be approaching the EUSES default of 12 °C. In any case, the EUSES model is relatively insensitive to the temperature parameter.

For these reasons, changing the default temperature for the purposes of UK REACH assessments is unlikely to be helpful. Whilst there is a possibility that degradation rates for organic chemicals could be somewhat underestimated for average GB conditions, a difference of 2°C is unlikely to make a significant difference overall, given the other uncertainties and broad assumptions included in the model. Thus, the decision to not change the default EUSES value of 12 °C to a more GB specific value of 10 °C.

Given that a temperature change is not required, and the other changes are simple to make, the decision about whether to implement the changes (in whole or in part) comes

down to consideration of the significance of the net effect of the changes, and the policy desire to diverge from an approach that has been in existence for a very long time. At the local scale only, and without counting the seven changes to soil parameters, 11 changes to values are proposed, some of which are antagonistic of each other in terms of their individual effect of increasing or lowering the PEC. Additional optional changes to the selection of DF and soil type are also proposed dependant on the scenario being modelled (e.g. sandy loam for HvE assessments). The net effect of these GB-specific changes is that the local PECs are typically higher than the values obtained with the EUSES defaults (Table 13). This ranges from between 1.2 to 1.8 times higher depending on the soil type. If a DF of 3 is used, then the local PECs are generally 4 times higher (for freshwater-related compartments).

Given the impact of the DF, if the aim of introducing changes was solely to increase conservatism, the obvious 'shortcut' would be to retain the EUSES defaults and adjust the DF from 10 to 3 (i.e. in scenarios where other local sources need to be considered or there are high STP flows relative to river flows). This generally increases surface water, surface water sediment and freshwater predator's prey PECs by ~3.3 times. The scale of the difference between the PECs obtained using GB-specific values versus the EUSES defaults is generally identical to the scale of change when a DF of 10 is used, but there are some discrepancies for HvE (± 10%) for substances B, C and D and for substance B as a function of soil type (sandy loam) for agricultural soil and terrestrial predator's prey, where these values are more divergent from the EUSES defaults.

Nevertheless, as described in Section 2.1.5.1, the choice of DF should reflect the nature of the assessment. It is recommended that a DF of 3 is used for scenarios where STP flow accounts for a significant portion of the river flow or where upstream sources of local contamination have not been taken into account (e.g. at sites which could be influenced by other sites locally) If used with the other GB-specific parameters, this leads to local PECs in fresh surface water and sediment (and the related secondary poisoning scenario) that are 3.63 to 4.35 times higher than those obtained using current EUSES defaults. It should be noted that using the median cumulative Q95 DWF value of 2 for the DF (as opposed to the weighted average cumulative Q95 DWF DF of 3), would increase PECs further.

A further consideration is how these changes could be implemented using the CHESAR model, which is widely used by industry. The exposure module in the CHESAR model is better aligned with the ECHA R.16 guidance than EUSES and is also integrated with the IUCLID database (ECHA, 2025). It is therefore able to generate a full CSR in the appropriate format. However, CHESAR is much less flexible over which default values can easily be changed by the user: in practice these are effectively limited to the size of the STP (in terms of effluent flow), and the dilution in, or flow rate of, the receiving water. This limits the current utility of the CHESAR model to implement the full range of GB-specific values recommended in this report. Nevertheless, STP effluent flow and the flow rate of the receiving water (collectively driving the dilution factor) are important parameters in determining PECs in surface water compartments at either the local and/or regional level.

In CHESAR, it is possible to modify dilution factors for both freshwater and marine water scenarios, provided the contributing scenario represents a manufacturing, formulation or industrial use. However, for wide dispersive uses, such as professional and consumer scenarios, the dilution factor is fixed and cannot be altered due to standardised assumptions embedded in the default town model. Additional limitations also apply within industrial scenarios. For example, CHESAR requires the receiving water flow rate condition to be disabled before a dilution factor can be manually entered, since the two parameters are interdependent. Furthermore, use map templates such as Specific Environmental Release Categories (SPERCs) may restrict DF modification unless the contributing scenario is first converted to a user-defined version.

It seems likely that in many cases, the current EUSES defaults lead to a less conservative worst-case scenario than is produced using GB-specific values (up to 1.8 times except for air and marine environments), depending on substance properties. However, asking GB companies to re-calculate PECs using a GB-specific EUSES model would reduce the utility of assessments already performed with CHESAR (e.g. for the purposes of compliance with EU REACH) and could therefore create a lot of work as well as disparities with assessments used in Northern Ireland (where EU REACH applies). The impact of this may be undesirable, and would need a thorough assessment prior to any implementation, together with detailed guidance. This suggests that a GB-specific EUSES assessment would be useful as a refinement in scenarios where RCRs exceed 0.5, but are less than 1 when using the current defaults.

There is perhaps more scope for regulators to consider using a GB-specific EUSES model for evaluations and restrictions, to present the range of potential risk and gain more experience about the potential benefits and drawbacks for individual cases. This could be done in a targeted way, such as using the characteristics of clay loam when assessing strongly adsorbing substances for environmental exposure (as opposed to HvE). Changing the area and/or population at the regional scale would generally increase PECs for surface water compartments and agricultural soil due to a concentrating effect.

The use of a lower DF could also be particularly relevant when considering guidance for applicants for authorisation, since they usually do not consider additional sources to their own.

It is also important to note that there may be other implications arising from the use of some of the GB-specific parameter values. For example, the PNEC for sediment or soil derived using the equilibrium partitioning method depends on properties such as the OC content and bulk density. This means that if the GB-specific values were implemented, the PNEC derived by equilibrium partitioning would be slightly different to that derived using the EU default values. Whilst this would not matter for the purposes of risk assessment (since the PECs would be derived using the same assumptions, cancelling out the effect), it could be relevant for standard setting in other contexts.

Potential implementation options are given below in Table 16. For simplicity, the effect of the changes on the aquatic PEC only is shown.

Table 16 Implementation options for the different parameter values

Implementation option	Aquatic PEC as a percentage of EUSES default	Comment
Keep EUSES defaults	100%	No change; maintains business as usual
GB-specific values in full at DF10	127%	Better reflection of GB situation and modestly more conservative
Keep EUSES defaults and reduce DF to 3	330%	Increased conservatism; easy to implement; generally compatible with CHESAR; can be used situationally* (e.g. applications for Authorisation)
GB-specific values in full at DF3	435%	Better reflection of GB situation and much more conservative; can be used situationally* (e.g. applications for Authorisation)

7.3 Other models

The EUSES model itself is over 20 years old, and ECHA intends to replace both it and CHESAR with a new software package called CHESAR Platform during 2025. It is likely that the modelling will be updated in some respects, making it more difficult to replicate calculations using EUSES. In addition, the software may be less easy to modify for local conditions. Further GB-specific refinements may therefore not be easy, and could be impossible.

If a stand-alone higher tier GB model were desired to deliver more realistic spatiotemporal predictions for regulatory purposes in the longer-term, an Excel® spreadsheet-based model would allow the default values to be edited more easily as required, with the added advantage of allowing ranges of input parameter values to be included (e.g. median and 95th percentile). This would enable sensitivity testing to be undertaken more easily. User support, updates (e.g. to take account of changes to linked models, such as SimpleTreat) and version control could be managed more readily too. The costs of such a project may be significant.

In this regard, it is relevant to note that other UK models are available, for example the SAGIS-SIMCAT model. These models are typically expert systems, requiring detailed knowledge of the actual locations where the chemical inputs occur, and expert knowledge of the model to both set up and run simulations. Although such models are of great utility in carrying out detailed site-specific assessments of chemical inputs into specific watersheds, they are not suitable for the worst-case generic-type assessments that are undertaken under UK REACH. Although information from SAGIS-SIMCAT was useful in

determining DF values, linking the EUSES model with this type of model would not be beneficial.

7.4 Recommendations for further work

Suggestions for further work to improve the robustness of selected input parameter values and modelling outputs could include:

- Further refinement of STP assumptions, including the analysis of consented versus DWF and site-specific DFs.
- Further research to determine the most appropriate value for the OC content of suspended matter within GB.
- Further investigations to determine a more representative value for the ‘fraction of rainwater infiltrating soil’ and the ‘fraction of rainwater running off soil’ within GB.
- Comparison of model outputs with monitoring data for a range of chemicals with registration data, including substances that are readily or inherently biodegradable which were not included in sensitivity testing.
- Scientific literature should continue to be monitored for future consideration of the potential adaptation of the assessment criteria and/or chemical properties.

8 Glossary

AC	Article category
BAS	Biosolids Assurance Scheme
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CHESAR	Chemical Safety Assessment and Reporting
CLEA	Contaminated Land Exposure Assessment
CSO	Combined sewage overflow
CSR	Chemical Safety Report
DEFRA	Department for Environmental Food and Rural Affairs
DF	Dilution factor
dw	dry weight
DWF	Dry weather flow
EA	Environment Agency
ECHA	European Chemicals Agency
Edf	Estimated degrees of freedom
Eq(s)	Population equivalent(s)
ERC	Environmental release category
EU	European Union
EUSES	European Union System for Evaluation of Substances
F	F-statistic
FSA	Food Standards Agency
GAM	Generalised Additive Model
GREAT-ER	Geography Regional Exposure Assessment Tool for European Rivers
GB	Great Britain
HSAC	Hazardous Substances Advisory Committee
HSE	Health & Safety Executive
HvE	Human exposure via the environment
IUCLID	International Uniform Chemical Information Database
LCS	Lifecycle stage
K_{OC}	Organic carbon water partition coefficient
K_{OW}	Octanol water partition coefficient
NDNS	National Diet and Nutrition Survey Rolling Programme
NHS	National Health Service
NRM	National Resource Management
NRW	Natural Resources Wales
OC	Organic carbon
P	P-value
Pa	Pascals
PC	Chemical product category
PEC	Predicted environmental concentration
PNEC	Predicted no-effect concentration
Q95	5^{th} Percentile river flow
QSAR	Quantitative structure-activity relationship

RCP	Representative concentration pathways
RCR	Risk characterisation ratio
REACH	Registration, Evaluation, Authorisation and restriction of CHemicals
RISEP	REACH Independent Scientific Expert Pool
SAGIS-SIMCAT	Source Apportionment Geographical Information System - SIMulation of CATchments
SEPA	Scottish Environment Protection Agency
SGV	Soil guideline values
SOM	Soil organic matter
SPERCS	Specific Environmental Release Categories
STP	Sewage treatment plant
SU	Sector of use
TF	Technical function
UK	United Kingdom
UKCEH	United Kingdom Centre for Ecology & Hydrology
UKCP18	UK Climate Projections
UKSHS	UK Soil and Herbage Pollutant Survey
UKWIR	UK Water Industry Research
WALTER	Waste Applied to Land Tool for Environmental Risk
ww	wet weight

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Appendix A. Default values from EUSES v.2.1.2

The default value from EUSES v.2.1.2 are shown below. The sub-headings relate to the sub-headings in the EUSES v.2.1.2 outputs and the same terminology as in EUSES is used.

Section/Parameter	Actual value	Unit	Status[a]
DEFAULT IDENTIFICATION			
General name	Default EUSES 2.1		D
Description	According to TGDs		D
CHARACTERISTICS OF COMPARTMENTS			
GENERAL			
Density of solid phase	2.5	kg/L	D
Density of water phase	1	kg/L	D
Density of air phase	1.30×10^{-3}	kg/L	D
Environmental temperature	12	°C	D
Standard temperature for Vp and Sol	25	°C	D
Temperature correction method	Temperature correction for local distribution		D
Constant of Junge equation	0.01	Pa/m	D
Surface area of aerosol particles	0.01	m^2/m^3	D
Gas constant	8.314	Pa m^3/mol/K	D

Section/Parameter	Actual value	Unit	Status[a]
SUSPENDED MATTER			
Volume fraction solids in suspended matter	0.1	m^3/m^3	D
Volume fraction water in suspended matter	0.9	m^3/m^3	D
Weight fraction of OC in suspended matter	0.1	kg/kg	D
Bulk density of suspended matter	$1.15x10^3$	kg_{ww}/m^3	O
Conversion factor wet-dry suspended matter	4.6	kg_{ww}/kg_{dw}	O
SEDIMENT			
Volume fraction solids in sediment	0.2	m^3/m^3	D
Volume fraction water in sediment	0.8	m^3/m^3	D
Weight fraction of OC in sediment	0.05	kg/kg	D
SOIL			
Volume fraction solids in soil	0.6	m^3/m^3	D
Volume fraction water in soil	0.2	m^3/m^3	D
Volume fraction air in soil	0.2	m^3/m^3	D
Weight fraction of OC in soil	0.02	kg/kg	D
Weight fraction of organic matter in soil	0.034	kg/kg	O

Section/Parameter	Actual value	Unit	Status[a]
Bulk density of soil	1.70x10^3	kg_{ww}/m^3	O
Conversion factor wet-dry soil	1.13	kg_{ww}/kg_{dw}	O
STP SLUDGE			
Fraction of OC in raw sewage sludge	0.3	kg/kg	D
Fraction of OC in settled sewage sludge	0.3	kg/kg	D
Fraction of OC in activated sewage sludge	0.37	kg/kg	D
Fraction of OC in effluent sewage sludge	0.37	kg/kg	D
DEGRADATION AND TRANSFORMATION RATES			
Rate constant for abiotic degradation in STP	0	/d	D
Rate constant for abiotic degradation in bulk sediment	0	/d (12°C)	D
Rate constant for anaerobic biodegradation in sediment	0	/d (12°C)	D
Fraction of sediment compartment that is aerated	0.1	m^3/m^3	D
Concentration of OH-radicals in atmosphere	5.00 x10^5	molec/cm^3	D
Rate constant for abiotic degradation in bulk soil	0	/d (12°C)	D
RELEASE ESTIMATION			
Fraction of EU production volume for region	100	%	D

Section/Parameter	Actual value	Unit	Status[a]
Fraction of EU tonnage for region (private use)	10	%	D
Fraction connected to sewer systems	80	%	D
SEWAGE TREATMENT			
GENERAL			
Number of inhabitants feeding one STP	1.00 x10^4	Eq	D
Sewage flow	200	L/ Eq/d	D
Effluent discharge rate of local STP	2.00 x10^6	L/d	O
Temperature correction for STP degradation	No		D
Temperature of air above aeration tank	15	°C	D
Temperature of water in aeration tank	15	°C	D
Height of air column above STP	10	m	D
Number of inhabitants of region	2.00x10^7	Eq	D
Number of inhabitants of continental system	3.50x10^8	Eq	O
Windspeed in the system	3	m/s	D
RAW SEWAGE			
Mass of O2 binding material per person per day	54	g/Eq/d	D

Section/Parameter	Actual value	Unit	Status[a]
Dry weight solids produced per person per day	0.09	kg/Eq/d	D
Density solids in raw sewage	1.5	kg/L	D
Fraction of OC in raw sewage sludge	0.3	kg/kg	D
PRIMARY SETTLER			
Depth of primary settler	4	m	D
Hydraulic retention time of primary settler	2	hr	D
Density suspended and settled solids in primary settler	1.5	kg/L	D
Fraction of organic carbon in settled sewage sludge	0.3	kg/kg	D
ACTIVATED SLUDGE TANK			
Depth of aeration tank	3	m	D
Density solids of activated sludge	1.3	kg/L	D
Concentration solids of activated sludge	4	kg/m	D
Steady state O2 concentration in activated sludge	$2.00x10^{-3}$	kg/m	D
Mode of aeration	Surface		D
Aeration rate of bubble aeration	$1.31x10^{-5}$	$m^3/s/Eq$	D
Fraction of OC in activated sewage sludge	0.37	kg/kg	D

Section/Parameter	Actual value	Unit	Status[a]
Sludge loading rate	0.15	kg/kg/d	D
Hydraulic retention time in aerator (9-box STP)	6.9	hr	O
Hydraulic retention time in aerator (6-box STP)	10.8	hr	O
Sludge retention time of aeration tank	9.2	d	O
SOLIDS-LIQUIDS SEPARATOR			
Depth of solids-liquid separator	3	m	D
Density suspended and settled solids in solids-liquid separator	1.3	kg/L	D
Concentration solids in effluent	30	mg/L	D
Hydraulic retention time of solids-liquid separator	6	hr	D
Fraction of OC in effluent sewage sludge	0.37	kg/kg	D
LOCAL DISTRIBUTION			
AIR AND SURFACE WATER			
Concentration in air at source strength 1 kg.d-1	$2.78x10^{-4}$	mg/m	D
Standard deposition flux of aerosol-bound compounds	0.01	$mg/m^2/d$	D
Suspended solids concentration in STP effluent water	15	mg/L	D
DF (rivers)	10	-	D

Section/Parameter	Actual value	Unit	Status[a]
Flow rate of the river	$1.80x10^{4}$	m^3/d	D
Calculate dilution from river flow rate	No		D
DF (coastal areas)	100	-	D
SOIL			
Mixing depth of grassland soil	0.1	m	D
Dry sludge application rate on agricultural soil	$5.00x10^{3}$	kg/ha/yr	D
Dry sludge application rate on grassland	1,000	kg/ha/yr	D
Averaging time soil (for terrestrial ecosystem)	30	d	D
Averaging time agricultural soil	180	d	D
Averaging time grassland	180	d	D
PMTC, air side of air-soil interface	$1.05x10^{-3}$	m/s	O
Soil-air PMTC (air-soil interface)	$5.56x10^{-6}$	m/s	D
Soil-water film PMTC (air-soil interface)	$5.56x10^{-10}$	m/s	D
Mixing depth agricultural soil	0.2	m	D
Fraction of rainwater infiltrating soil	0.25	-	D
Average annual precipitation	700	mm/yr	D

Section/Parameter	Actual value	Unit	Status[a]
REGIONAL AND CONTINENTAL DISTRIBUTION			
CONFIGURATION			
Fraction of direct regional emissions to seawater	1	%	D
Fraction of direct continental emissions to seawater	0	%	D
Fraction of regional STP effluent to seawater	0	%	D
Fraction of continental STP effluent to seawater	0	%	D
Fraction of flow from continental rivers to regional rivers	0.034	-	D
Fraction of flow from continental rivers to regional sea	0	-	D
Fraction of flow from continental rivers to continental sea	0.966	-	O
Number of inhabitants of region	$2.00x10^{7}$	Eq	D
Number of inhabitants in the EU	$3.70x10^{8}$	Eq	D
Number of inhabitants of continental system	$3.50x10^{8}$	Eq	O
AREAS			
REGIONAL			

Section/Parameter	Actual value	Unit	Status[a]
Area (land+rivers) of regional system	$4.00x10^{4}$	km^2	D
Area fraction of freshwater, region (excl. sea)	0.03	-	D
Area fraction of natural soil, region (excl. sea)	0.27	-	D
Area fraction of agricultural soil, region (excl. sea)	0.6	-	D
Area fraction of industrial/urban soil, region (excl. sea)	0.1	-	D
Length of regional seawater	40	km	D
Width of regional seawater	10	km	D
Area of regional seawater	400	km^2	O
Area (land+rivers+sea) of regional system	$4.04x10^{4}$	km^2	O
Area fraction of freshwater, region (total)	0.0297	-	O
Area fraction of seawater, region (total)	$9.90x10^{-3}$	-	O
Area fraction of natural soil, region (total)	0.267	-	O
Area fraction of agricultural soil, region (total)	0.594	-	O
Area fraction of industrial/urban soil, region (total)	0.099	-	O
CONTINENTAL			

Section/Parameter	Actual value	Unit	Status[a]
Total area of EU (continent+region, incl. sea)	$7.04x10^6$	km^2	D
Area (land+rivers+sea) of continental system	$7.00x10^6$	km^2	O
Area (land+rivers) of continental system	$3.50x10^6$	km^2	O
Area fraction of freshwater, continent (excl. sea)	0.03	-	D
Area fraction of natural soil, continent (excl. sea)	0.27	-	D
Area fraction of agricultural soil, continent (excl. sea)	0.6	-	D
Area fraction of industrial/urban soil, continent (excl. sea)	0.1	-	D
Area fraction of freshwater, continent (total)	0.015	-	O
Area fraction of seawater, continent (total)	0.5	-	D
Area fraction of natural soil, continent (total)	0.135	-	O
Area fraction of agricultural soil, continent (total)	0.3	-	O
Area fraction of industrial/urban soil, continent (total)	0.05	-	O
MODERATE			
Area of moderate system (incl. continent, region)	$8.50x10^7$	km^2	D

Section/Parameter	Actual value	Unit	Status[a]
Area of moderate system (excl. continent, region)	$7.80x10^{7}$	km^2	O
Area fraction of water, moderate system	0.5	-	D
ARCTIC			
Area of arctic system	$4.25x10^{7}$	km^2	D
Area fraction of water, arctic system	0.6	-	D
TROPIC			
Area of tropic system	$1.275x10^{8}$	km^2	D
Area fraction of water, tropic system	0.7	-	D
TEMPERATURE			
Environmental temperature, regional scale	12	°C	D
Environmental temperature, continental scale	12	°C	D
Environmental temperature, moderate scale	12	°C	D
Environmental temperature, arctic scale	-10	°C	D
Environmental temperature, tropic scale	25	°C	D
Enthalpy of vaporisation	50	kJ/mol	D
Enthalpy of solution	10	kJ/mol	D

Section/Parameter	Actual value	Unit	Status[a]
MASS TRANSFER			
PMTC, air side of air-soil interface	1.05×10^{-3}	m/s	O
Soil-air PMTC (air-soil interface)	5.56×10^{-6}	m/s	D
Soil-water film PMTC (air-soil interface)	5.56×10^{-10}	m/s	D
Water-film PMTC (sediment-water interface)	2.78×10^{-6}	m/s	D
Pore water PMTC (sediment-water interface)	2.78×10^{-8}	m/s	D
AIR			
GENERAL			
Atmospheric mixing height	1,000	m	D
Windspeed in the system	3	m/s	D
Aerosol deposition velocity	1.00×10^{-3}	m/s	D
Aerosol collection efficiency	2.00×10^{5}	-	D
RAIN			
Average precipitation, regional system	700	mm/yr	D
Average precipitation, continental system	700	mm/yr	D

Section/Parameter	Actual value	Unit	Status[a]
Average precipitation, moderate system	700	mm/yr	D
Average precipitation, arctic system	250	mm/yr	D
Average precipitation, tropic system	$1.30x10^3$	mm/yr	D
RESIDENCE TIMES			
Residence time of air, regional	0.687	d	O
Residence time of air, continental	9.05	d	O
Residence time of air, moderate	30.2	d	O
Residence time of air, arctic	22.3	d	O
Residence time of air, tropic	38.6	d	O
WATER			
DEPTH			
Water depth of freshwater, regional system	3	m	D
Water depth of seawater, regional system	10	m	D
Water depth of freshwater, continental system	3	m	D
Water depth of seawater, continental system	200	m	D
Water depth, moderate system	1,000	m	D

Section/Parameter	Actual value	Unit	Status[a]
Water depth, arctic system	1,000	m	D
Water depth, tropic system	1,000	m	D
SUSPENDED SOLIDS			
Suspended solids conc. freshwater, regional	15	mg/L	D
Suspended solids conc. seawater, regional	5	mg/L	D
Suspended solids conc. freshwater, continental	15	mg/L	D
Suspended solids conc. seawater, continental	5	mg/L	D
Suspended solids conc. seawater, moderate	5	mg/L	D
Suspended solids conc. seawater, arctic	5	mg/L	D
Suspended solids conc. seawater, tropic	5	mg/L	D
Concentration solids in effluent, regional	30	mg/L	D
Concentration solids in effluent, continental	30	mg/L	D
Concentration biota	1	mg_{ww}/L	D
RESIDENCE TIMES			
Residence time of freshwater, regional	43.3	d	O
Residence time of seawater, regional	4.64	d	O

Section/Parameter	Actual value	Unit	Status[a]
Residence time of freshwater, continental	172	d	O
Residence time of seawater, continental	365	d	O
Residence time of water, moderate	$2.69x10^3$	d	O
Residence time of water, arctic	$5.84x10^3$	d	O
Residence time of water, tropic	$1.09x10^4$	d	O
SEDIMENT			
DEPTH			
Sediment mixing depth	0.03	m	D
SUSPENDED SOLIDS			
(Biogenic) prod. susp. solids in freshwater, regional	10	$g/m^2/yr$	D
(Biogenic) prod. susp. solids in seawater, regional	10	$g/m^2/y^r$	D
(Biogenic) prod. susp. solids in freshwater, continental	10	$g/m^2/yr$	D
(Biogenic) prod. susp. solids in seawater, continental	5	$g/m^2/yr$	D
(Biogenic) prod. susp. solids in water, moderate	1	$g/m^2/yr$	D
(Biogenic) prod. susp. solids in water, arctic	1	$g/m^2/yr^1$	D
(Biogenic) prod. susp. solids in water, tropic	1	$g/m^2/yr^1$	D

Section/Parameter	Actual value	Unit	Status[a]
SEDIMENTATION RATES			
Settling velocity of suspended solids	2.5	m/d	D
Net sedimentation rate, freshwater, regional	2.8	mm/yr	O
Net sedimentation rate, seawater, regional	1.53	mm/yr	O
Net sedimentation rate, freshwater, continental	2.75	mm/yr	O
Net sedimentation rate, seawater, continental	$6.69x10^{-3}$	mm/yr	O
Net sedimentation rate, moderate	$2.8x10^{-3}$	mm/yr	O
Net sedimentation rate, arctic	$2x10^{-3}$	mm/yr	O
Net sedimentation rate, tropic	$2x10^{-3}$	mm/yr	O
SOIL			
GENERAL			
Fraction of rainwater infiltrating soil	0.25	-	D
Fraction of rainwater running off soil	0.25	-	D
DEPTH			
Chemical-dependent soil depth	No		D

Section/Parameter	Actual value	Unit	Status[a]
Mixing depth natural soil	0.05	m	D
Mixing depth agricultural soil	0.2	m	D
Mixing depth industrial/urban soil	0.05	m	D
Mixing depth of soil, moderate system	0.05	m	D
Mixing depth of soil, arctic system	0.05	m	D
Mixing depth of soil, tropic system	0.05	m	D
EROSION			
Soil erosion rate, regional system	0.03	mm/yr	D
Soil erosion rate, continental system	0.03	mm/yr	D
Soil erosion rate, moderate system	0.03	mm/yr	D
Soil erosion rate, arctic system	0.03	mm/yr	D
Soil erosion rate, tropic system	0.03	mm/yr	D
CHARACTERISTICS OF PLANTS, WORMS AND CATTLE			
PLANTS			
Volume fraction of water in plant tissue	0.65	m^3/m^3	D
Volume fraction of lipids in plant tissue	0.01	m^3/m^3	D

Section/Parameter	Actual value	Unit	Status[a]
Volume fraction of air in plant tissue	0.3	m^3/m^3	D
Correction for differences between plant lipids and octanol	0.95	-	D
Bulk density of plant tissue (ww)	0.7	kg/L	D
Rate constant for metabolism in plants	0	/d	D
Rate constant for photolysis in plants	0	/d	D
Leaf surface area	5	m^2	D
Conductance	$1.00x10^{-3}$	m/s	D
Shoot volume	2	L	D
Rate constant for dilution by growth	0.035	/d	D
Transpiration stream	1	L/d	D
WORMS			
Volume fraction of water inside a worm	0.84	m^3/m^3	D
Volume fraction of lipids inside a worm	0.012	m^3/m^3	D
Density of earthworms	1	kg_{ww}/L	D

Section/Parameter	Actual value	Unit	Status[a]
Fraction of gut loading in worm	0.1	kg/kg	D
CATTLE			
Daily intake for cattle of grass (dw)	16.9	kg/d	D
Conversion factor grass from dry weight to wet weight	4	kg/kg	D
Daily intake of soil (dw)	0.41	kg/d	D
Daily inhalation rate for cattle	122	m^3/d	D
Daily intake of drinking water for cattle	55	L/d	D
CHARACTERISTICS OF HUMANS			
Daily intake of drinking water	2	L/d	D
Daily intake of fish	0.115	kg/d	D
Daily intake of leaf crops (incl. fruit and cereals)	1.2	kg/d	D
Daily intake of root crops	0.384	kg/d	D
Daily intake of meat	0.301	kg/d	D
Daily intake of dairy products	0.561	kg/d	D
Inhalation rate for humans (consumers, environment)	0.833333	m^3/hr	D
Inhalation rate for humans (worker exposure)	1.5	m^3/hr	D
Bodyweight of the human considered	70	kg	D

Section/Parameter	Actual value	Unit	Status[a]
Correction factor for duration and frequency of exposure	2.8	-	D

Notes: a) D = Default value. O = Output value – these are calculated by EUSES from the default values entered.

Appendix B. Sensitivity analysis

The sensitivity of the PECs calculated with EUSES to the various GB-specific parameters values has been examined. This sensitivity analysis is based on four example substances and consists of two parts. Part 1 is a comparison of the PECs obtained using the GB-specific values with those obtained using the EU default parameter values. This part was conducted using two different DFs (10 and 3). Part 2 examines which parameters have the largest impact on the PECs. Combining the results of these two different analyses allows the GB-specific parameter value changed that have the largest impact on the PECs to be identified.

The sensitivity analysis has not investigated how changes in parameter values may affect substance properties (e.g., the effect of temperature on degradation rates).

The properties of the example substances are shown in Table B.1. They cover combinations of “high” and “low” values for vapour pressure and water solubility / log K_{ow} (these last two properties tend to co-vary in an inverse manner, so it would be unreasonable to use both a high-water solubility and a high log K_{ow} for example). They are not intended to represent any specific substance.

Table B.1 Properties of the four example substances for the sensitivity analysis

Property	Substance A	Substance B	Substance C	Substance D
Vapour pressure at 25 °C (Pa)	0.001	1,000	0.001	1,000
Water solubility at 25 °C (mg.L^{-1})	1,000	1,000	0.001	0.001
Log K_{ow}	1	1	5	5

Note: a) For simplicity, all substances have the same molecular weight (200 g/mol).

b) All substances were considered to be ‘not readily biodegradable’ to avoid potential complications resulting from temperature correction of degradation rates.

c) The K_{OC} was estimated from the log K_{OW} using the default “non-hydrophobics" quantitative structure-activity relationship (QSAR).

B.1 Part 1: PEC comparison between GB-specific EUSES and default EUSES

The PECs obtained using the GB-specific values in EUSES are shown in Table B.2, alongside the PECs obtained using the default EUSES parameter values. To keep the comparison relatively simple, the following standard release scenario was used:

- Local release: 1 kg/d to wastewater and 1 kg/d to air
- Regional release 1 kg/d to wastewater and 1 kg/d to air
- Continental release 1 kg/d to wastewater and 1 kg/d to air

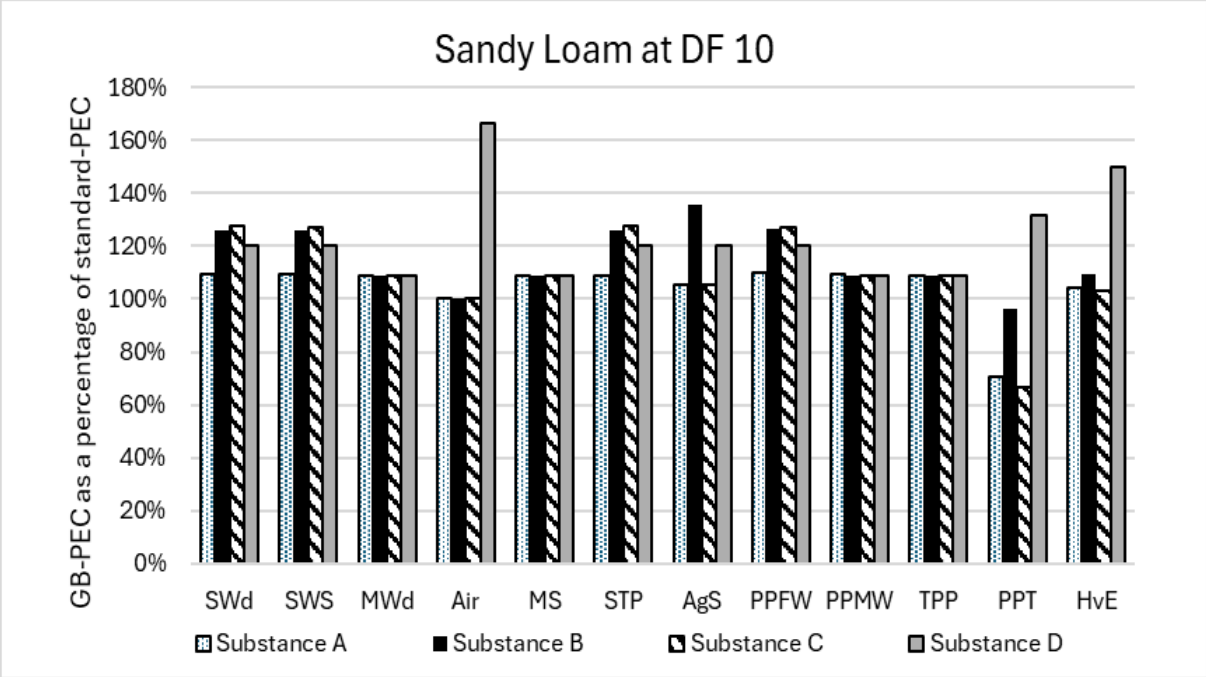

Figure B.1 shows the local PECs estimated using the GB-specific values (Sandy Loam soil type and a DF of 10) as a percentage of the PECs estimated using the default EUSES values.

Output concentrations are: SWd (surface water dissolved), SWS (surface water sediment), MWd (marine water dissolved), Air, MS (marine water sediment), STP (sewage treatment plant), AgS (agricultural soil), PPFW (predator's prey secondary poisoning freshwater), PPMW (predator's prey secondary poisoning marine), TPP (top predator secondary poisoning marine), PPT (predator's prey secondary poisoning terrestrial), and HvE (humans via the environment).

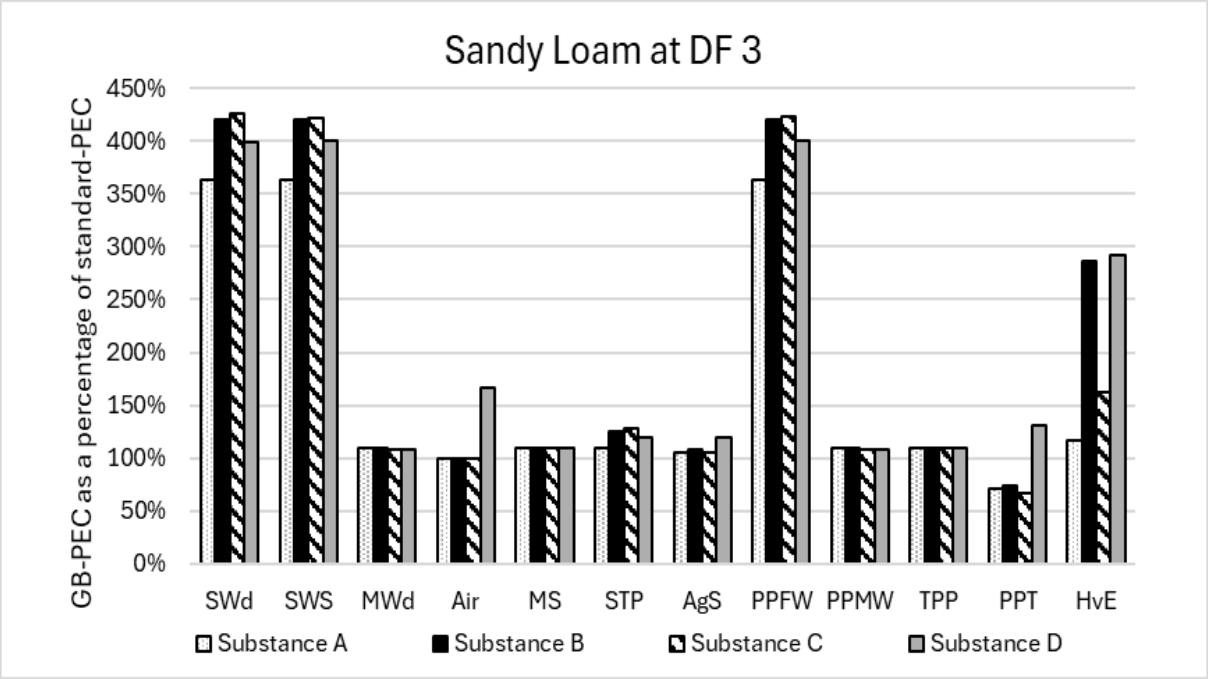

Figure B.2 shows the local PECs estimated using the GB-specific values (Sandy Loam soil type and a DF of 3) as a percentage of the PECs estimated using the default EUSES values.

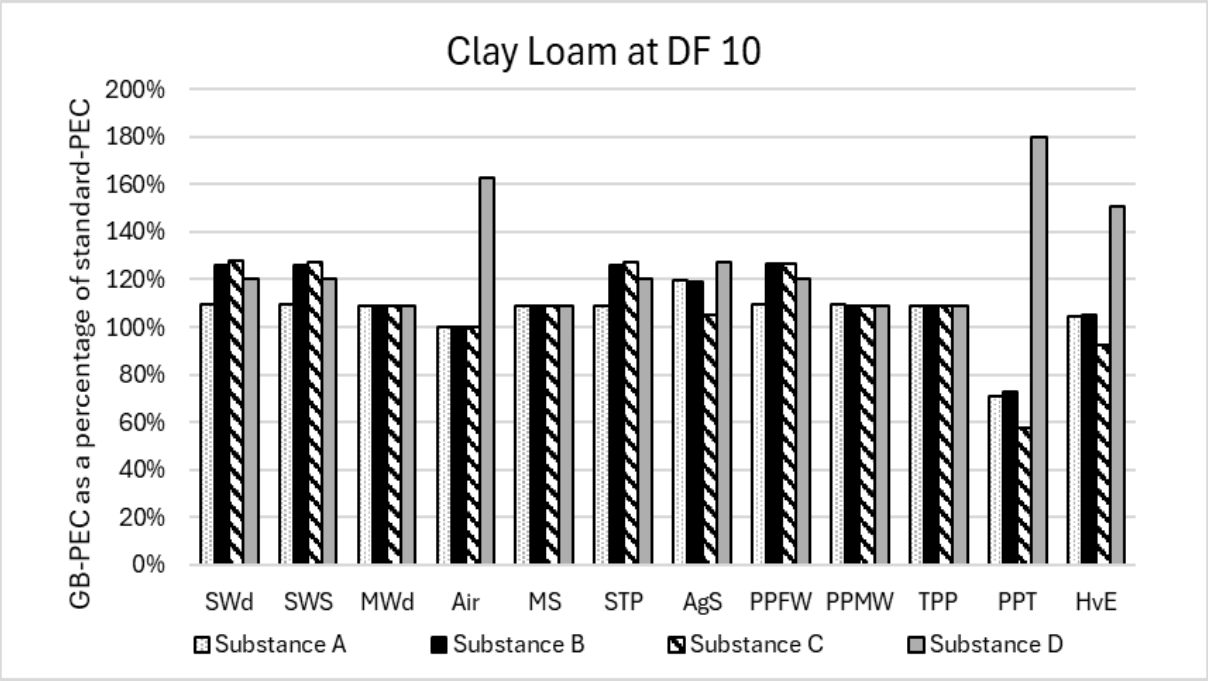

Figure B.3 shows the local PECs estimated the GB-specific values (Clay Loam soil type and a DF of 10) as a percentage of the PECs estimated using the default EUSES values.

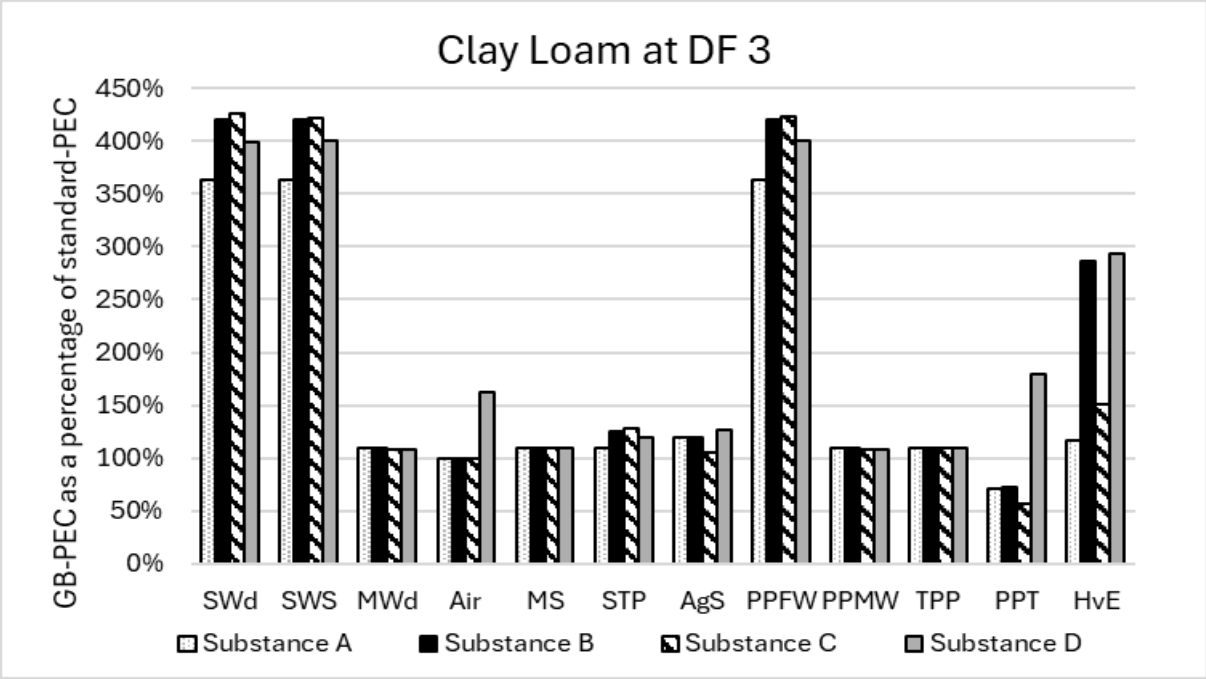

Figure B.4 shows the local PECs estimated the GB-specific values (Clay Loam soil type and a DF of 3) as a percentage of the PECs estimated using the default EUSES values.

Table B.2 Comparison of PECs calculated using the GB-specific values with those obtained using the default EUSES parameter values. Where multiple values are displayed, the differing values between using a sandy loam soil type at a DF of 10 (indicated by a *), a sandy loam soil type with a DF of 3 (indicated by a **), a clay loam soil type with a DF of 10 (indicated by †), and a clay loam soil type with a DF of 3 (indicated by ‡) are being shown.

PEC	Substance A		Substance B		Substance C		Substance D	
	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES
Local PECs during emission period								
Surface water (mg/L)	0.0544* and † 0.181** and ‡	0.0498	0.0230* and † 0.0768** and ‡	0.0183	0.0175* and † 0.0583** and ‡	0.0137	0.00245* and † 0.00815** and ‡	0.00204
Sediment (mg/kg_{ww})	0.0836* and † 0.278** and ‡	0.0765	0.0354* and † 0.118** and ‡	0.0281	1.60* and † 5.32** and ‡	1.26	0.224* and † 0.745** and ‡	0.186
Marine water (mg/L)	0.00545	0.005	0.00545	0.005	0.00541	0.00541	0.00216	0.00497
Marine sediment (mg/kg_{ww})	0.00837	0.00768	0.00837	0.00768	0.00495	0.454	0.00495	0.454

PEC	Substance A		Substance B		Substance C		Substance D	
	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES
STP (mg/L)	0.543	0.498	0.230	0.183	0.176	0.138	0.0246	0.0205
Agricultural soil (mg/kg$_{ww}$)[a]	0.0193* and ** 0.0219† and ‡	0.0183	0.0117* 0.00935** 0.0103† and ‡	0.00864	5.08* and ** 5.07† and ‡	4.83	0.942* and ** 0.997† and ‡	0.784
Secondary poisoning – fish (freshwater) (mg/kg)	0.0317* and † 0.105** and ‡	0.0289	0.0134* and † 0.0446** and ‡	0.0106	255* and † 850** and ‡	201	35.7* and † 119** and ‡	29.7
Secondary poisoning – fish (marine) (mg/kg)	0.00317	0.0029	0.00316	0.0029	78.9	72.5	78.9	72.5
Secondary poisoning – fish-eating marine top predator (mg/kg$_{ww}$)	0.000636	0.000583	0.000633	0.000581	158	145	158	145

PEC	Substance A		Substance B		Substance C		Substance D	
	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES
Secondary poisoning – earthworms (mg/kg)[a]	0.00740* and † 0.00744** and ‡	0.0105	0.00410* 0.00312** 0.0309† and ‡	0.00425	23.7* and ** 20.4† and ‡	35.5	0.142* and ** 0.194† and ‡	0.108
Total daily intake for humans (mg/kg bw/d)	0.0268* and † 0.0300** and ‡	0.0257	0.000451* 0.00118** and ‡ 0.000434†	0.000412	0.367* 0.578** 0.328† 0.539‡	0.356	0.0312* 0.0607** 0.0314† 0.0609‡	0.0208
Regional PECs during emission period								
Surface water (mg/L)	1.52×10^{-4}	1.45×10^{-5}	9.03×10^{-6}* 8.88×10^{-6}**, † and ‡	8.67×10^{-7}	8.49×10^{-6}	8.93×10^{-7}	1.28×10^{-6}	3.92×10^{-7}
Sediment (mg/kg_{ww})	2.21×10^{-4}	2.11×10^{-5}	1.31×10^{-5}* 1.29×10^{-5}**, † and ‡	1.26×10^{-6}	1.35×10^{-3}	1.43×10^{-4}	2.03×10^{-4}* and ** 2.04×10^{-4}† and ‡	6.29×10^{-5}

PEC	Substance A		Substance B		Substance C		Substance D	
	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES
Marine water (mg/L)	2.69×10^{-6}	1.76×10^{-6}	7.01×10^{-8}* 7.11×10^{-8}**, † and ‡	9.98×10^{-8}	6.65×10^{-8}	9.45×10^{-8}	2.32×10^{-8}* and ** 2.29×10^{-8}† and ‡	5.21×10^{-8}
Marine sediment (mg/kg_{ww})	3.90×10^{-6}	2.55×10^{-6}	1.02×10^{-7}* 1.03×10^{-7}**, † and ‡	1.45×10^{-7}	9.15×10^{-6}* and ** 9.16×10^{-6}† and ‡	1.31×10^{-5}	3.20×10^{-6}* and ** 3.15×10^{-6}† and ‡	7.21×10^{-6}
Air (mg/m^3)	5.39×10^{-9}	6.28×10^{-10}	8.96×10^{-8}* 5.34×10^{-7}**, † and ‡	4.61×10^{-7}	8.69×10^{-8}* and ** 8.68×10^{-8}† and ‡	3.60×10^{-8}	6.02×10^{-2}* and ** 5.89×10^{-2}† and ‡	3.60×10^{-2}
Agricultural soil (mg/kg_{ww})[a]	2.53×10^{-4}* and ** 2.98×10^{-4}† and ‡	1.82×10^{-5}	8.35×10^{-6}* 1.86×10^{-6}** 2.19×10^{-6}† and ‡	7.50×10^{-8}	1.21×10^{-2}* and ** 1.41×10^{-2}† and ‡	5.14×10^{-4}	3.51×10^{-4}* and ** 3.78×10^{-4}† and ‡	2.05×10^{-5}

PEC	Substance A		Substance B		Substance C		Substance D	
	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES	GB-EUSES	Default EUSES
Total daily intake for humans (mg/kg bw/d)	4.82×10^{-5}	4.95×10^{-6}	3.09×10^{-7}* 3.15×10^{-7}**, † and ‡	1.47×10^{-7}	7.12×10^{-4}* and ** 7.14×10^{-4}† and ‡	3.62×10^{-5}	1.74×10^{-2}* and ** 1.70×10^{-2}† and ‡	1.04×10^{-2}

GB-specific parameter values at a local scale using a DF of 10

Figures B.1 to B.4 show the local PECs estimated using the GB-specific parameter values as a percentage of the PECs estimated using the default EUSES values.

For freshwater, freshwater sediment and secondary poisoning of predators associated with freshwater, the local PECs obtained using the GB-specific values are between 109% and 128% of those obtained using the default EUSES parameter values (i.e. 1.09 to 1.28 times higher).

The local PECs obtained using the GB-specific values are generally a fraction more of those using the default EUSES values for marine water (109%) and sediment (109%), agricultural soil (105% to 135%), and secondary poisoning in the marine (109%) and terrestrial (57% to 180%) environments.

The local PECs in air obtained using the GB-specific values are similar to the PECs obtained using the default EUSES values for three of the substances, and 163% to 166% higher for the fourth.

For HvE, the total local exposure obtained using the GB-specific parameter values is between 92% and 151% of the value obtained using the default EUSES values, depending on the substance (i.e. 0.92 times lower or 1.51 times higher).

It is notable that the differences between the GB-specific local PECs and the default local EUSES PECs were relatively consistent across the different chemicals for some compartments (e.g. marine water, or agricultural soil). For other compartments (e.g. freshwater or HvE larger differences between substances were noted, particularly between Substance A representing a hydrophilic substance with low volatility and Substance D, a volatile hydrophobic substance. This suggests that the effects of the GB-specific values on the modelling vary between different compartments and are sensitive to the substance properties. With the exception of air and HvE, the effect of GB-specific parametrisation was consistent for all four substances, i.e. freshwater, marine and soil local PECs for all substances were higher in the GB-specific model compared to EUSES default. This is logical for compartments such as water as the flow rates and DFs used would be expected to affect each substance in a similar way relative to the EUSES default values. Inconsistency in effects on HvE can be explained by contributions from varied exposure routes. For instance, lower air exposure of a substance may be compensated by higher exposure via drinking water and/or food intake depending on specific properties of the substance. The effects of adopting the GB-specific input values on HvE will depend on how the specific substance properties affect exposure via different routes (e.g. air exposure, drinking water exposure, etc).

GB specific parameters at a local scale using a DF of 3

The local PEC values obtained using the GB-specific parameter values and a DF of 3 were largely the same as those obtained using a DF of 10 (described above). The only

differences here were in the values obtained for the compartments considering freshwater and for HvE (though the trends across the substances were still generally the same as with a DF of 10).

For freshwater, freshwater sediment, and secondary poisoning of predators associated with freshwater, the local PECs obtained using the GB-specific values are between 363% and 426% of those obtained using the default EUSES values (i.e. 3.63 to 4.26 times higher).

For HvE, the total local exposure obtained using the GB-specific values is between around 117% and 293% of the value obtained using the default EUSES values, depending on the substance (i.e. 1.17 to 2.93 times higher).

GB-specific values at a regional scale

Figures B.5 to B.8 show the regional PECs estimated using the GB-specific values as a percentage of the PECs estimated using the default EUSES parameter values. Note that the scale on the y-axis is different to Figures B.1 to B.4. The difference is more significant at the regional level and the differences between GB-specific modelling using a DF of 10 and 3 are negligible in most cases:

- The regional PECs in freshwater and freshwater sediment are at least 3 times (and in most cases greater than 10 times) higher using the GB-specific values.

- In contrast, the regional PECs for marine water and marine sediment obtained using the GB-specific values are less pronounced (between 44% and 153%) to those obtained using the default EUSES value, and they are lower for Substances B, C and D.

- For agricultural soil, the regional PECs using the GB-specific values vary depending on the substance, the soil type, and the DF. Generally, the PEC values are between 1,300% to 3,000% of the EUSES default. There is an instance where the PEC is approximately 11,000% higher, where the soil type is Sandy Loam and the DF is 10.

- The PECs for regional air are at least 116% higher in all but one instance (19% with a Sandy Loam soil type and a DF of 10) and go up to 858% higher).

- For the regional estimates of total human daily intake, the GB-specific values result in PECs between 163% and 1,973% higher than those obtained using the default EUSES values.

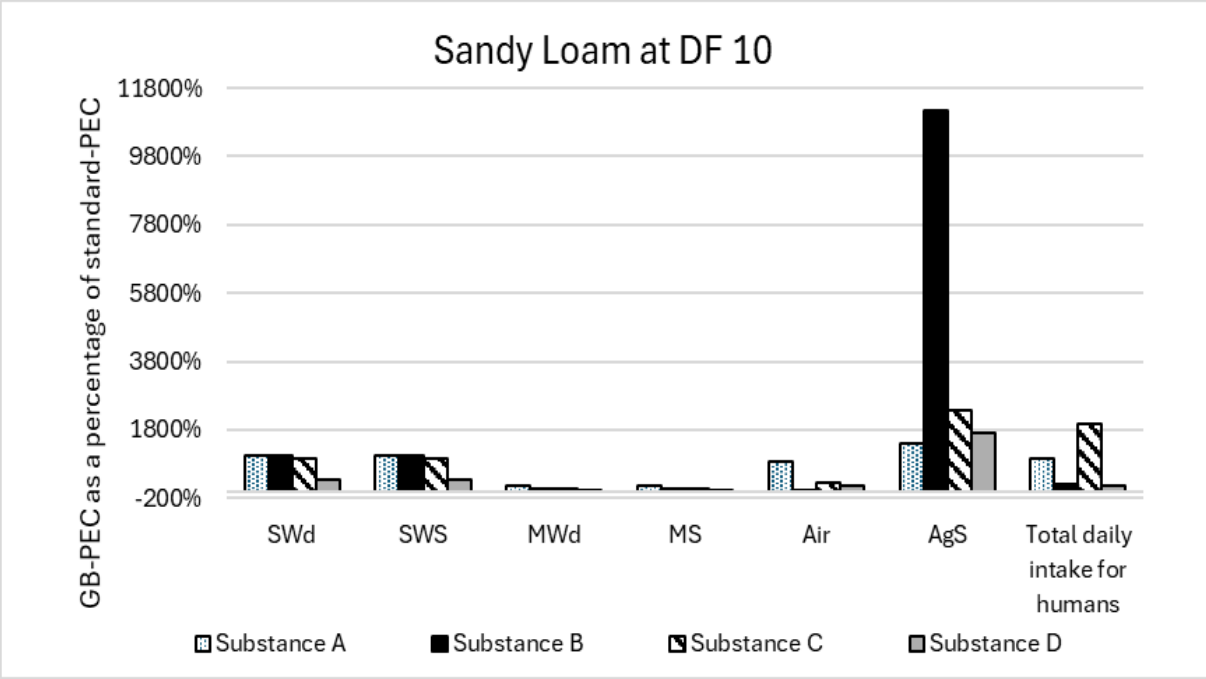

Figure B.55 Regional PECs estimated using the GB-specific values (Sandy Loam soil type at a DF of 10) as a percentage of the PECs estimated using the default EUSES values.

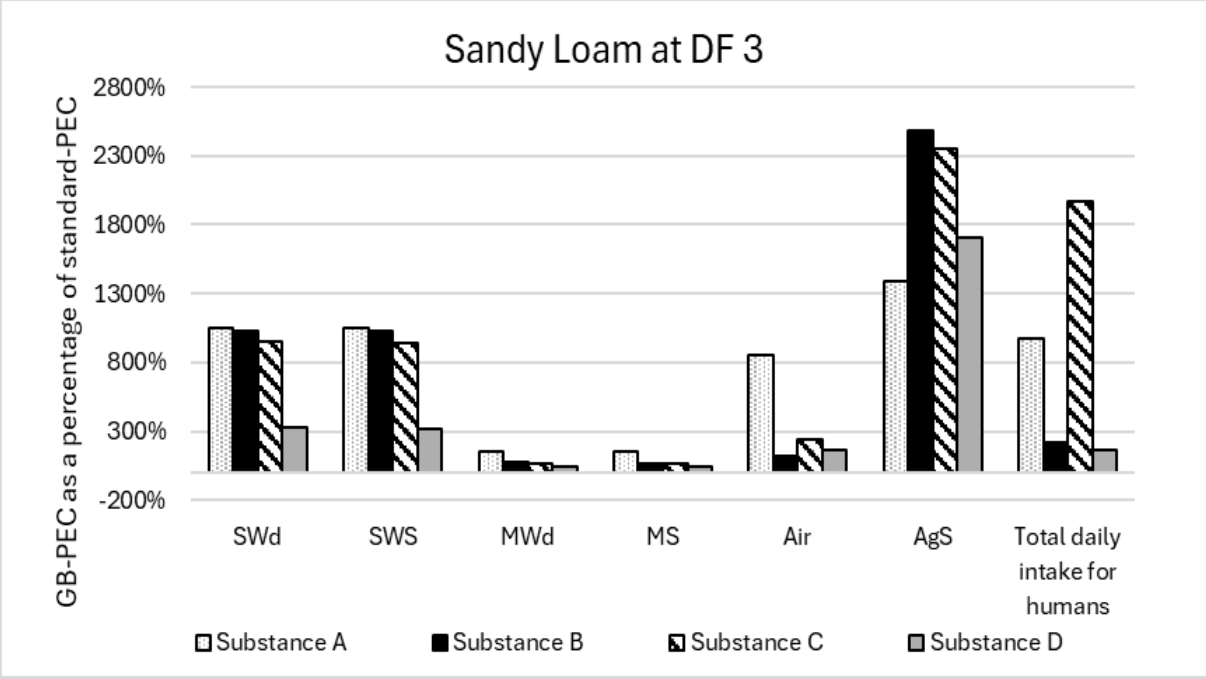

Figure B.66 Regional PECs estimated using the GB-specific values (Sandy Loam soil type at a DF of 3) as a percentage of the PECs estimated using the default EUSES values.

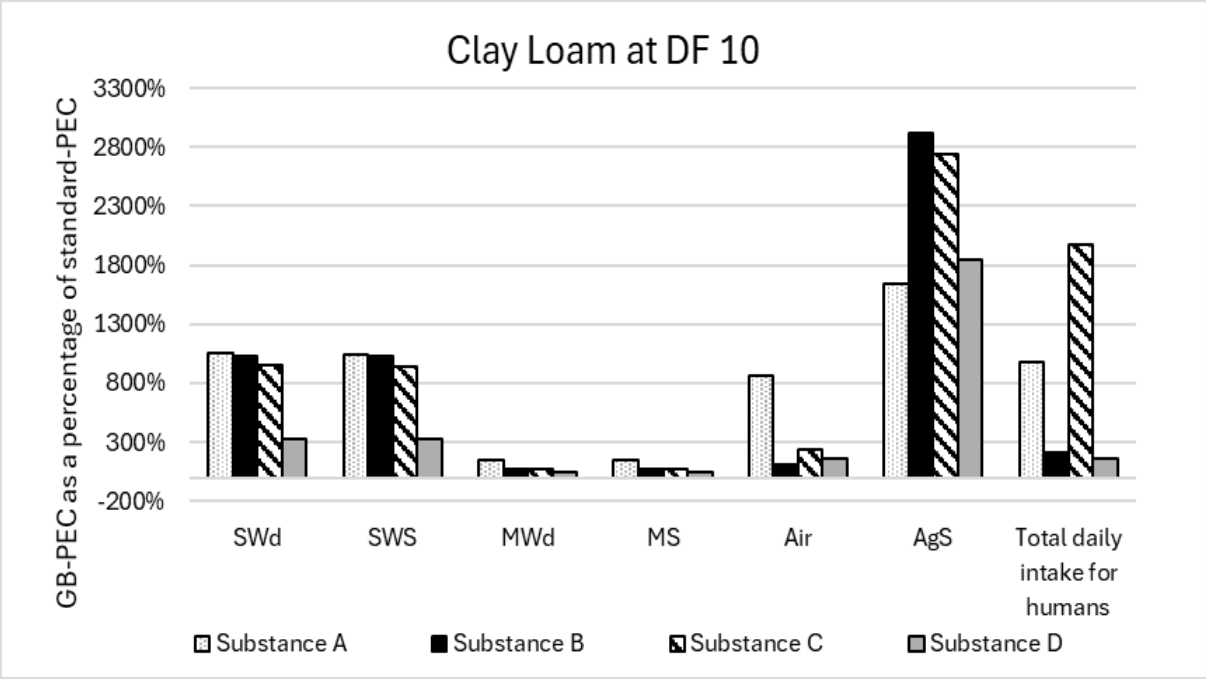

Figure B.77 Regional PECs estimated using the GB-specific values (Clay Loam soil type at a DF of 10) as a percentage of the PECs estimated using the default EUSES values.

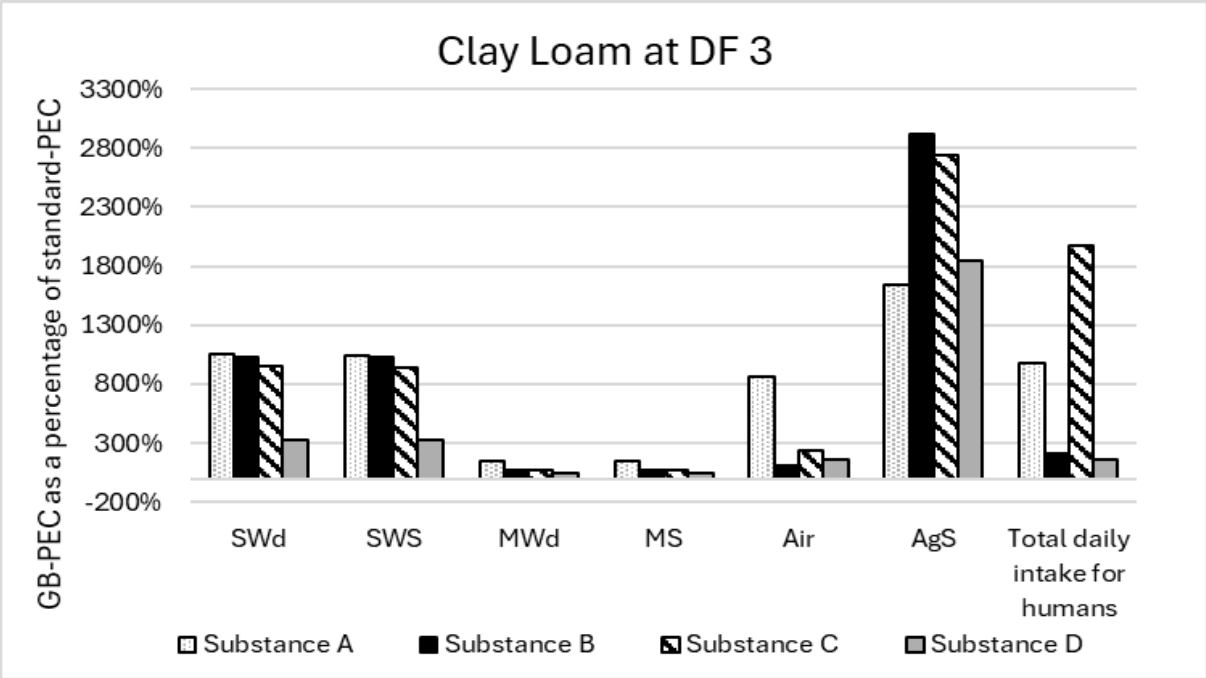

Figure B.88 Regional PECs estimated using the GB-specific values (Clay Loam soil type at a DF of 3) as a percentage of the PECs estimated using the default EUSES values.

When considering the comparison at the regional level it is important to note that these were carried out using a standard release estimate. As noted within Section 6, the default EUSES area (400,000 km^2) is around 2,000% (20 times) of the GB regional area (1,960 km^2), a standard mass release rate of 1 kg/d results in a much higher loading (in kg/km^2) in the GB region than the EU region. This may, in large part, explain why the regional PECs obtained using the GB-specific model are generally higher than those obtained using the default EUSES model in these example calculations. In practice the actual regional tonnage, and hence regional emissions, will be very important to the regional calculations (the regional concentrations are generally directly proportional to the regional emissions). In particular, the EU default values are intended to be used with the total EU tonnage, whereas the GB-specific values are intended to be used with the GB-tonnage. In most cases the GB tonnage of a given substance will be lower (and hence regional emissions lower) than the EU tonnage. Therefore, in practice, the regional PECs obtained using the GB-specific values and GB tonnages may be closer to the regional PECs obtained for the EU, when using the default EUSES parameter values and total EU tonnage, than may be suggested by this analysis as the effect of the lower tonnage and smaller area are antagonistic of each other.

For the regional marine water compartment, the increase in length of regional seawater (to reflect GB being an island) does not lead to an equivalent increase in marine PECs for all substances. This is largely due to the substance physico-chemical dependant interactions (i.e. solubility, mobility and vapour pressure). Therefore, for a given release rate the GB-specific EUSES model will lead to similar PECs as the default EUSES model, i.e., both models will give similar PECs if the GB-tonnage is assessed in them.

B.2 Part 2: Sensitivity of PECs to the different GB-specific parameters

This part of the analysis considered the sensitivity of the PECs to uncertainty within the EUSES parameter values. This is used to identify which parameters have the largest impacts on the PECs relative to the other parameters. To do this, the EUSES model with the GB-specific values was run approximately 24,000 times with each of the GB-specific values varying within a set range of ±10% and sampled randomly within that range. Although ±10% variability is a relatively low value and may not necessarily reflect the actual uncertainty in many of the values, the analysis is still useful as it allows the parameters that have the largest impact on the PECs to stand out.

The outputs from the EUSES runs were analysed using Sobol analysis, a variance-based sensitivity analysis method. Using this method, the GB-specific values that had the highest influence on the PECs can be identified based on the magnitude of the first-order Sobol sensitivity index (values above 0.1). The results of the analysis are shown in Table B.3.

At the local scale, the “number of inhabitants feeding one STP” and “sewage flow rate per inhabitant” were found to have an impact on all the PEC values (see Table B.3), and were

the most significant parameters for the water and sediment compartments and secondary poisoning (both freshwater and marine).

For the PECs related to freshwater (i.e., freshwater, freshwater sediment and secondary poisoning), the DF also had a relatively large impact on the PEC values compared to other input parameters.

“Sludge application rate onto soil” and “mixing depth of agricultural soil” were found to be impactful for agricultural soil and terrestrial secondary poisoning PECs. “bulk density of wet soil” was also found to be an impactful parameter for agricultural soil PECs.

For secondary poisoning PECs, the EUSES calculation includes a significant contribution from the regional concentrations, so some of the parameters that affect the regional concentrations in freshwater, marine water and agricultural soil also impact the PECs for secondary poisoning (see below). In addition, the PECs for secondary poisoning for terrestrial predators are impacted by the parameters “volume fraction of air in soil”, “weight fraction of organic carbon in soil” and “volume fraction of solids in soil”. These appear to impact on the regional PEC in natural soil which also feeds into the PEC calculations for secondary poisoning.

With the exception of “sludge application rate onto soil” and “weight fraction of organic carbon in soil”, increasing the value of the parameters that most influence the local PECs resulted in decreasing PECs.

Table B.3 Summary of main findings from the sensitivity analysis

PEC	Parameters having the largest influence	Change in PECs with increasing parameter value[a]
Local PECs		
Freshwater	Number of inhabitants feeding one STP	Decreased PEC
	DF for freshwater	Increased PEC
	Sewage flow rate per inhabitant	Decreased PEC
Freshwater sediment	Number of inhabitants feeding one STP	Decreased PEC
	DF for freshwater	Increased PEC
	Sewage flow rate per inhabitant	Decreased PEC
Marine water	Number of inhabitants feeding one STP	Decreased PEC

PEC	Parameters having the largest influence	Change in PECs with increasing parameter value[a]
	Sewage flow rate per inhabitant	Decreased PEC
Marine sediment	Number of inhabitants feeding one STP	Decreased PEC
	Sewage flow rate per inhabitant	Decreased PEC
Agricultural soil	Sludge application rate onto soil	Increased PEC
	Number of inhabitants feeding one STP	Decreased PEC
	Bulk density of wet soil	Decreased PEC
	Mixing depth of agricultural soil	Decreased PEC
	Sewage flow rate per inhabitant	Decreased PEC
	Fraction of rainwater infiltrating soil	Decreased PEC
Secondary poisoning – fish (freshwater)	Number of inhabitants feeding one STP	Decreased PEC
	DF for freshwater	Increased PEC
	Sewage flow rate per inhabitant	Decreased PEC
Secondary poisoning – fish (marine)	Number of inhabitants feeding one STP	Decreased PEC
	Sewage flow rate per inhabitant	Decreased PEC
Secondary poisoning – fish-eating marine top predator	Number of inhabitants feeding one STP	Decreased PEC
	Sewage flow rate per inhabitant	Decreased PEC
Secondary poisoning – earthworms	Sludge application rate onto soil	Increased PEC
	Number of inhabitants feeding one STP	Decreased PEC
	Volume fraction of air in soil	Decreased PEC

PEC	Parameters having the largest influence	Change in PECs with increasing parameter value[a]
	Weight fraction of organic carbon in soil	Increased PEC
	Volume fraction of solids in soil	Decreased PEC
	Sewage flow rate per inhabitant	Decreased PEC
	Mixing depth of agricultural soil	Decreased PEC
	Fraction of rainwater infiltrating soil	Decreased PEC
	Annual average precipitation	Decreased PEC (can only easily test at regional scale)
Regional PECs		
Freshwater	Windspeed in the system	Decreased PEC
	Area (land + rivers) of regional system	Increased PEC
	Area fraction of freshwater, region (excluding sea)	Decreased PEC
	Fraction connected to sewer system	Decreased PEC
	Sewage flow rate per inhabitant	Increased PEC
	Area (land+rivers+sea) of continental system	Decreased PEC
	Average precipitation, continental system	Decreased PEC
Freshwater sediment	Windspeed in the system	Decreased PEC
	Area (land + rivers) of regional system	Decreased PEC
	Area fraction of freshwater, region (excluding sea)	Decreased PEC
	Fraction connected to sewer system	Decreased PEC
	Sewage flow rate per inhabitant	Increased PEC

PEC	Parameters having the largest influence	Change in PECs with increasing parameter value[a]
	Area (land+river+sea) of continental system	Decreased PEC
	Average precipitation, continental system	Decreased PEC
Marine water	Windspeed in the system	Decreased PEC
	Width of regional seawater	Decreased PEC
	Fraction connected to sewer system	Decreased PEC
Marine sediment	Windspeed in the system	Decreased PEC
	Width of regional seawater	Decreased PEC
	Fraction connected to sewer system	Decreased PEC
Agricultural soil	Average precipitation, regional system	Decreased PEC
	Area (land + rivers) of regional system	Decreased PEC
	Sewage flow rate per inhabitant	Decreased PEC
	Area fraction of agricultural soil, region (excluding sea)	Decreased PEC
Air	Windspeed in the system	Decreased PEC
	Area (land + rivers) of regional system	Decreased PEC
	Average precipitation, regional system	Increased PEC
	Fraction of rainwater infiltrating soil	Decreased PEC

Note: a) This was checked manually within EUSES.

“Windspeed in the system” along with “fraction connected to sewer system” were found to be the most impactful input parameters when determining PEC values for freshwater, freshwater sediment, marine water and marine sediment at the regional scale. The “area (land + rivers)” for both the regional and continental system, “area fraction of freshwater, region”, “sewage flow rate per inhabitant” and “average precipitation, continental system”

are also impactful parameters for freshwater and freshwater sediment, while the “width of regional seawater” is an impactful parameter for the marine water and sediment PECs.

For agricultural soil, the “area fraction of agricultural soil” and the “average precipitation” were found to be the two most important input parameters in determining the regional PEC. “Area (land + rivers) of regional system” and “sewage flow rate per inhabitant” were also important.

For secondary poisoning, the PECs for freshwater and marine predators were affected by the same parameters that impacted the local concentrations in freshwater and marine water. Similarly, the PECs for terrestrial predators were influenced by similar parameters as for the agricultural soil. In addition, the PECs for terrestrial predators were influenced by other soil-related parameters such as the “volume fraction of air in soil”, the “Volume fraction of solids in soil” and the “weight fraction of organic carbon in soil”.

For the regional air PEC, the most important parameters identified were the “windspeed in the system”, “area (land + rivers) of regional system”, “average precipitation, regional system” and “fraction of rainwater infiltrating soil”.

Increasing the value of parameters that influence the regional PECs the most resulted in decreased PECs. The main exceptions to this were the “sewage flow rate per inhabitant”, which increased the PECs for freshwater and freshwater sediment with increasing value but decreased the PEC for agricultural soil, and the “average precipitation, regional system”, which increased the PEC for air slightly.

It should be noted that several PECs were influenced by the parameter “fraction of rainfall infiltrating soil”. This value of this parameter is not proposed to change for the GB-EUSES model as it is very difficult to define a meaningful value for GB.

The magnitude of the effect on the PECs of increasing the EUSES parameter values is also dependent to some extent upon the properties of the substance. The properties chosen for the study reflected a range of substance types:

Substance A: highly water soluble, low volatility with low adsorption and bioaccumulation potential

Substance B: highly water soluble, high volatility with low adsorption and bioaccumulation potential

Substance C: low water solubility, low volatility with high adsorption and bioaccumulation potential

Substance D: low water solubility, high volatility with high adsorption and bioaccumulation potential

All substances are considered to be ‘not readily biodegradable’ for the analysis to avoid potential complications resulting from temperature correction of degradation rates.

Therefore, the properties covered included substances that will partition mainly to the water phase, substances that will partition mainly to the sediment/soil/biota phases and substances that will partition significantly to the air. The magnitude of the effect of changing the EUSES parameter values that are significant for a given environmental compartment (e.g., water, sediment, soil or biota) depend to some extent on how relevant that compartment is to the substance under consideration.

B.3 Part 3: Sensitivity analysis summary

This section draws together the two parts of the analysis to identify the main GB-specific parameter values that lead to the observed differences in PECs between two versions of the EUSES model.

B.3.1 Local PECs for water and sediment

Part 2 of the sensitivity analysis shows that the parameters that have the greatest impact on the PECs for water and sediment are the number of inhabitants feeding one STP, the sewage flow rate per inhabitant and (for freshwater and freshwater sediment), the DF for sewage effluent in rivers.

Part 1 of the sensitivity indicates that the local PECs for freshwater and freshwater sediment obtained using GB-specific values are around 0.7 times lower to 1.8 times higher (DF of 10) or 0.7 times lower to 4.4 times higher (DF of 3) than the default EUSES model. For local PECs for marine water and marine sediment the values obtained using GB-specific values are around half the values obtained using default EUSES parameter values. These differences are driven mainly by the following:

- Although antagonistic of each other in terms of their individual effects on the PEC, a change in number of inhabitants feeding one STP from 10,000 (default) to 8,420 (GB-specific) combined with the sewage flow of 218 (GB-specific) from 200 (default) L/Eq/d results in a net effective decrease in the water flow through the local STP from 2,000 m^3/d (default) to 1,830 m^3/d (GB-specific). So, the concentrations in effluent from the STP are a factor of around 0.92 times higher using the GB-specific values compared to those within the default EUSES model. This is the main reason why the concentrations in marine water and marine sediments using GB-specific values are around a tenth higher than those obtained using default EUSES values.
- A decrease in DF from 10 to 3 results in a proportional reduction in the dilution of the effluent in the receiving freshwater. A decrease in DF to 2 similarly results in a proportional reduction in the dilution.
- The net result of these changes is that the overall dilution (taking into account the higher concentrations in the STP effluent and the lower dilution in the subsequent receiving water) using the GB-specific parameter values is higher than when using

the EUSES defaults, resulting in an equivalent increase in the PECs for freshwater and freshwater sediment by a factor of around 1.3 to 4.4 depending on the DF.

B.3.2 Local PECs in agricultural soil

Part 2 of the sensitivity analysis shows that the parameters that have the highest impact on the PECs calculated in agricultural soil are the sludge application rate onto soil, the number of inhabitants feeding one STP, the bulk density of wet soil, the mixing depth of agricultural soil, sewage flow rate per inhabitant and the fraction of rainwater infiltrating soil. No GB-specific value is proposed for the fraction of rainwater infiltrating soil, so this parameter is not considered further here.

Part 2 of the sensitivity analysis shows that the net effect of the proposed GB-specific values is that the local PECs obtained using the GB-specific parameter values in agricultural soil are around 105% to 130% of the values derived using the default EUSES model. The main drivers for this increase are described below, but it is important to note that the PEC calculations for agricultural soil are complex and take into account various removal processes, and include significant contributions from the concentrations in air and the regional PECs in soil. Therefore, it is only possible to discuss the impact of the changes in the parameter values in very general terms.

- As discussed above for the local PECs in water and sediment, the number of inhabitants feeding one STP and the sewage flow rate per inhabitant have the effect of decreasing the water volume (and hence dilution) in the STP compared with the default EUSES parameter values. This effectively increases the concentrations in the STP water flow, and hence the sewage sludge, for the GB-specific values compared with the EUSES defaults. At the same time the decrease in the number of inhabitants feeding one STP will decrease the sludge generation rate in the STP (the sludge generation rate is estimated by EUSES on a per inhabitant basis). The net effect is that the predicted concentration in sewage sludge using the GB-specific values is larger than that obtained using EUSES defaults.
- Antagonistically, the mixing depth of agricultural soil is proposed to change from 0.2 m (default EUSES) to 0.25 (GB-specific). This results in a larger volume of soil in which the sewage sludge is mixed for the GB-specific values compared to the default EUSES values. This results in initial concentrations in soil using the GB specific values that are around 80% of (or 1.3 times lower than) the concentrations obtained using the EUSES defaults.
- The bulk density of wet soil depends on a combination of factors including the volume fractions of water, air and solids in soil. The GB-specific value of 1,500 kg_{ww}/m^3 is lower than the EUSES default value of 1,700 kg_{ww}/m^3. This is used internally within EUSES to convert from a volume of soil to a mass of soil. The net result is that the initial concentrations in soil on a mg/kg_{ww} basis using the GB-

specific parameter values will be around 110% of (or 1.1 times higher than) the values obtained using default EUSES parameter values.

- As discussed earlier, there is some uncertainty over the appropriate sewage sludge application rate that is appropriate for GB and if the EUSES default of 5,000 kg/ha/yr is used, the net effect would be a PEC in agricultural soil that is close to, but slightly lower than, that obtained using the default EUSES model.

B.3.3 Secondary poisoning

Based on Part 2 of the sensitivity analysis, the PECs calculated for secondary poisoning in fish (freshwater), fish (marine) and fish-eating marine top predators are mainly influenced by the same parameters that affect the local PECs for freshwater and marine water.

Similarly for secondary poisoning in earthworms, Part 2 of the sensitivity analysis shows that the PECs are mainly influenced by the same parameters that affect the local PECs in agricultural soil.

Furthermore, Part 2 of the sensitivity analysis shows that the magnitude of the change in PECs for secondary poisoning mirror those obtained for surface water, marine water and agricultural soil. The reason for this is that the basis of the calculations for secondary poisoning is the concentration in freshwater, marine water or agricultural soil. Therefore, the discussions under the local PECs for water and local PECs for agricultural soil above are equally applicable here.

B.3.4 Regional PECs

The regional PECs in EUSES are calculated using a complex multimedia steady-state model. This model contains many processes, interactions and transport between compartments. For this reason, it is not easy to summarise quantitively the contribution of each parameter separately on the final regional PECs calculated and they can only be discussed in very general terms.

Based on Part 2 of the sensitivity analysis, the main parameters affecting the regional PECs include the “windspeed in the system”, the “area (land + rivers) of the regional system”, the “area fraction of freshwater, region (excluding sea)”, “area fraction of agricultural soil, region (excluding sea)”, “fraction connected to the sewer system”, “sewage flow per inhabitant”, “width of regional seawater”, “average precipitation, regional system”, “area (land+rivers+sea) of continental system”, “average precipitation, continental system” and “fraction of rainwater infiltrating soil”. As no GB-specific values for the “fraction of rainwater infiltrating soil” and “width of regional seawater” are proposed these parameters are not considered further here.

Part 1 of the sensitivity analysis showed that the GB-specific parameter values resulted in marked differences in the regional PECs compared with those obtained using the EUSES defaults with the regional PECs obtained using the GB-specific values being, in the case

of agricultural soil, up to approximately 11,133% of (or 111 times higher than) the PECs obtained using the EUSES defaults. These differences result from combinations of the following elements:

- “Windspeed in the system”: For the GB-specific values it is proposed to increase the windspeed from 3 m/s (EUSES default) to 4.9 m/s. Part 2 of the sensitivity analysis shows that an increase in the value for this parameter results in a decrease in the PECs in freshwater, freshwater sediment, marine water, marine sediment and air. The regional model in EUSES takes into account the residence time of air in the regional system, and an increased windspeed in the system results in a lower residence time of air with subsequent increased removal of the substance from the regional system.
- “Area (land+rivers) of regional system”: For the GB-specific value it is proposed to decrease this area from 40,000 km^2 to 1,960 km^2. Part 2 of the sensitivity analysis shows that a decrease in this area results in an increase in the regional PEC for freshwater, freshwater sediment, and air. The main reason for this decrease is that a decreased area results in a lower volume or mass of environment into which a substance will partition and so, for a given release rate, will result in increased concentrations. In very simple terms the increase in concentration will be inversely proportional to the decrease in air. So, for the GB-specific value a decrease in area to 1,960 km^2 (a decrease of 20 times) will lead to an approximate 20 times increase in the concentration in the relevant media compared to default EUSES, all other things being equal. Therefore, it can be concluded that this parameter is a major driver for the increased regional concentrations obtained using the GB-specific values compared to the default EUSES values.
- “Area fraction of freshwater, region (excluding sea)”: For the GB-specific value it is proposed to decrease this fraction from 0.03 to 0.029. Part 2 of the sensitivity analysis shows that a decrease in this fraction results in an increase in the PEC for freshwater and freshwater sediment. Similar to the case with the “area (land+rivers) of the regional system”, this increase in the regional PEC results from a decrease in the volume of water as the fraction decreases so that, for a given release rate, higher concentrations in water result. As a rough estimate a decrease in the fraction from 0.03 to 0.029 would result in an increase in regional PECs in these compartments of around 1.03 times.
- “Area fraction of agricultural soil, region (excluding sea)”: For the GB-specific parameter value it is proposed to decrease this area from 0.62 to 0.52. Part 2 of the sensitivity analysis shows that a decrease in this fraction results in an increase in the regional PEC for agricultural soil. Similar to the case above for the area fraction of freshwater this can be interpreted in terms of a decrease in the volume of soil which, for a given release rate, results in higher concentrations in soil as the area fraction decreases. As a rough estimate a decrease in the fraction from 0.62 to 0.52 would result in an increase in the regional PEC of around 1.2 times.
- “Area (land+river+sea) of continental system”: For the GB-specific parameter value it is proposed to decrease this area from 7.00×10^6 km^2 to 3.48×10^5 km^2. Part 2 of

the sensitivity analysis shows that a decrease in this fraction results in an increase in the PECs for freshwater and freshwater sediment. This area is used by EUSES in the continental model and the effect is best interpreted as a decrease in the area resulting in increased concentrations in the continental model. The continental PECs act as background concentrations for the regional model and so this increase in continental PECs results indirectly in an increase in the regional PECs through this contribution.

- “Fraction connected to sewer”: For the GB-specific parameter value it is proposed to increase this fraction from 80% to 95.5%. Part 2 of the sensitivity analysis shows that an increase in this parameter results in a decrease in the regional PEC for freshwater, freshwater sediment, marine water and marine water sediment. The reason for this is that as the connection fraction increases, a higher proportion of the release to water is assumed to be treated in an STP at the regional scale resulting in a reduced concentration in water and sediment.
- “Sewage flow rate per inhabitant”: For the GB-specific parameter value it is proposed to increase this value from 200 to 218 L/Eq/d. Part 2 of the sensitivity analysis shows that an increase in this value results in an increase in the regional PEC for freshwater and freshwater sediment, but a decrease in the regional PEC for agricultural soil. The reasons for this are not obvious but may be related to changes to the regional STP flows and dilutions. As the region PECs for agricultural soil increase using the GB-specific values, the effect of this change is outweighed by the effect of changes to other parameter values.
- “Average precipitation, regional system”: For the GB-specific parameter value it is proposed to increase the average precipitation from 700 mm/yr to 1,000 mm/yr. Part 2 of the sensitivity analysis shows that an increase in the value of this parameter results in a decrease in the regional PECs for agricultural soil and variations in the regional PEC for air. The reason for this is not obvious but may be related to changes in the steady-state partitioning between environmental compartments within the regional steady-state model. Again, the individual effect of this change is outweighed by the overall changes.
- “Average precipitation, continental system”: For the GB-specific parameter value it is proposed to increase the average precipitation from 700 mm/yr to 1,300 mm/yr. Part 2 of the sensitivity analysis shows that an increase in this parameter results in a decrease in the regional concentration for freshwater and freshwater sediment. This parameter is used in the continental model within EUSES. As with the case with the precipitation in the regional system discussed above, an increased rate of precipitation will result in changes in the steady-state partitioning within the model. This then feeds back indirectly as changes in background concentration to the regional PECs.

Overall, for the regional compartment, based on the analysis done, the parameter that has the highest impact on the PECs using the GB-specific values compared with the default EU values is the “area (land+rivers) of the regional system”.

B.3.5 Discussion of different values for England, Scotland and Wales

As noted previously, differences in the values for certain parameters, notably average windspeed and average rainfall between England, Scotland and Wales exist. Of these parameters, the PECs calculated are significantly influenced by the average windspeed and average rainfall. This raises the possibility of using different values for different countries within GB.

In terms of the significance of this to EUSES modelling for different countries within GB, it is important to consider the following.

- The regional and continental models are particularly sensitive to the average windspeed and average rainfall parameters, and it would be possible to define different values for England, Scotland and Wales. However, there would appear to be only limited benefit for defining England-, Scotland- and Wales-specific parameters for the following reasons.
    - An increase in average windspeed tends to lower the predicted PECs, therefore a worst-case approach would imply the use of a lower average windspeed than a higher average windspeed.
    - The registered tonnage of the substance would need to be split across England, Scotland and Wales. Specific data are not generally available leading to increased uncertainty in modelled predictions.
    - Given the many other uncertainties and simplifications within the EUSES model, introducing England-, Scotland- and Wales-specific parameter values into the model may imply a degree of modelling specificity that is not warranted in practice.

B.3.6 Climate change considerations

The future climate change predictions indicate that the average GB temperature will increase, with the possibility of more extreme rainfall events and storms.

In terms of the significance of this, it is important to note that the EUSES model is relatively insensitive to the temperature parameter, as shown in Table B. 4 which displays the effects on PECs of modelling conducted at a temperature of 15 °C compared to the EUSES default of 12 °C, changes to the PEC were within the same order of magnitude. To take account of possible future climate change it would be possible to increase the average temperature within the model from the current GB average of 9.0 °C to 9.8 °C in the short-term, 10.4 °C in the medium term and 11.3 °C in the long-term (see discussion in Section 3, although the impact of this would be expected to be relatively small). By keeping the default EUSES value of 12 °C, all future climate change considerations are accounted for.

For the average windspeed and average rainfall parameters, future climate predictions indicate an overall change to wetter winters and dryer summers, but the overall change in

average rainfall (and windspeed) is expected to be relatively low. Therefore, there would appear to be only limited benefit for adapting the parameters for future climate change. In particular, the EUSES regional and continental models use a very simplistic approach to modelling at these scales, which works with averages over time. Therefore, the model is not appropriate for addressing the potential impacts of extreme weather.

The emerging future climate change predictions using the SAGIS-SIMCAT model, although not yet published, are suggesting that the average dilution in the UK may change in the future. There is currently insufficient information available on these predictions to make recommendations for their inclusion in a GB-specific EUSES model at this stage.

Table B.4 Comparison of the effects on PECs as a result of an increase in temperature to 15 °C when using GB Specific Values (DF of 10)

Scale	Compartment	Effect on the PEC
Local	SWd	Substance A: none Substance B: decrease Substance C: decrease Substance D: none
	SWS	Substance A: none Substance B: decrease Substance C: decrease Substance D: none
	MWd	None
	Air	Substance A: none Substance B: none Substance C: none Substance D: increase
	MS	None
	STP	Substance A: none Substance B: decrease Substance C: decrease Substance D: none
	AgS	Substance A: decrease (SL only) Substance B: decrease Substance C: decrease Substance D: decrease
	PPFW	Substance A: none Substance B: decrease Substance C: decrease Substance D: none
	PPMW	None
	TPP	None
	PPT	Substance A: decrease (SL only) Substance B: decrease Substance C: decrease Substance D: decrease
	HvE	Substance A: decrease (SL only) Substance B: decrease

Scale	Compartment	Effect on the PEC
		Substance C: decrease Substance D: decrease
Regional	SWd	Substance A: none Substance B: decrease Substance C: decrease Substance D: none
	SWS	Substance A: decrease Substance B: decrease Substance C: decrease Substance D: decrease (CL only)
	MWd	Substance A: decrease Substance B: decrease Substance C: decrease Substance D: decrease
	MS	Substance A: decrease Substance B: decrease Substance C: decrease Substance D: decrease
	Air	Substance A: increase Substance B: increase Substance C: increase Substance D: none
	AgS	Substance A: decrease Substance B: decrease Substance C: decrease Substance D: decrease
	Total daily intake for humans	Substance A: decrease Substance B: decrease Substance C: decrease Substance D: none

Appendix C. Supporting Data for Parameter Value Selection

C.1 Soil

Table C.1 Default properties by soil type used in the EA CLEA model (Jeffries and Martin, 2009)

Soil type	Dry soil bulk density[a] (g/cm^3)	Air-filled Porosity[b] ($cm^3.cm^{-3}$)	Water-filled Porosity[b] ($cm^3.cm^{-3}$)	Total Porosity[b] ($cm^3.cm^{-3}$)	Solid phase[c] (cm^3/cm^3)
Clay	1.07	0.12	0.47	0.59	0.41
Silty clay	0.94	0.12	0.51	0.63	0.37
Silty clay loam	1.07	0.12	0.46	0.58	0.42
Clay loam	**1.14**	**0.14**	**0.42**	**0.56**	**0.44**
Sandy clay loam	1.20	0.16	0.37	0.53	0.47
Silt loam	1.09	0.14	0.44	0.58	0.42
Sandy silt loam	1.19	0.14	0.38	0.52	0.48
Sandy loam	**1.21**	**0.20**	**0.33**	**0.53**	**0.47**
Sand	1.18	0.30	0.24	0.54	0.46
Loamy sand	No data given	No data given	No data given	No data given	No data
Sandy clay	No data given	No data given	No data given	No data given	No data

The porosity values from Jeffries and Martin (2009) are expressed in terms of a volume fraction; these can be used directly within EUSES as it also uses volume fractions. However, the bulk density of the solid phase is based on dry weight soil per unit volume whereas EUSES requires a value based on wet weight soil per unit volume. It is possible to estimate a wet weight soil per unit volume value from the data using Equation 3 from (ECHA, 2016) (which is also the basis of the calculations in EUSES).

Notes: a) Dry soil bulk density is the apparent density of field soil calculated from the oven-dry mass divided by the volume occupied in the field.

b) Porosity is the volume of the soil not occupied by solid material. Water-filled porosity is the amount of pore space occupied by water based on a suction head at 50 cm H_2O. Air-filled porosity is the remainder of the pore space.

c) Volume of solid phase is estimated by difference.

$$\boldsymbol{RHO_{Soil} = F_{Solid} \times RHO_{Solid} + F_{Water} \times RHO_{Water} + F_{Air} \times RHO_{Air}}$$

(Equation 3)

Where:

RHO_{Soil} = bulk density of soil (kg_{ww}/m^3)

F_{Solid} = volume fraction of solids in soil (m^3/m^3) = 0.47 (sandy loam) or 0.44 (clay loam) (from Jeffries and Martin (2009))

RHO_{Solid} = density of the solid phase (kg/m^3) = 2500 (default value from EUSES)

F_{Water} = volume fraction of water in soil (m^3/m^3) = 0.33 (sandy loam) or 0.42 (clay loam) (from Jeffries and Martin (2009))

RHO_{Water} = density of the water phase (kg/m^3) = 1000 (default value from EUSES)

F_{Air} = volume fraction of air in soil (m^3/m^3) = 0.2 (sandy loam) or 0.14 (clay loam) (from Jeffries and Martin (2009))

RHO_{Air} = density of the air phase (kg/m^3) = 1.3 (default value from EUSES)

Therefore, using the EA values for porosity in place of the fractions of solids, water and air in soil, the bulk density on a kg_{ww}/m^3 basis can be estimated as approximately 1,500 kg_{ww}/m^3 for sandy loam and 1,500 kg_{ww}/m^3 for clay loam. It is important to note that this calculation still uses the default values from EUSES for density of the solid phase of the soil.

EUSES also requires a conversion factor to convert from kg_{ww} soil to kg_{dw} soil. For sandy loam for example, this can be estimated for the default GB soil based on Jeffries and Martin (2009) as follows using the densities to convert from m^3 to kg: the soil is assumed to be 33% water by volume and 47% solid by volume with a bulk density of 1,500 kg_{ww}/m^3. Therefore, the mass of 1 m^3 of wet soil is 1,500 kg; the mass of water in 1 m^3 soil is 0.33 × 1,000 kg/m^3 = 330 kg; the weight percentage of water in the soil is 330/1500 × 100% = 22%. So, to convert from 1 mg/kg_{ww} of soil to the equivalent mg/kg_{dw} of soil the factor is 1/(1-0.22) or 1.28 kg_{ww}/kg_{dw} based on these assumptions. Using the estimated bulk density of 1,500 kg_{ww}/m^3 and the dry weight bulk density for sandy loam of 1.21 g_{dw}/cm^3 (equivalent to 1,210 kg_{dw}/m^3) reported in Jeffries and Martin (2009), a similar conversion factor of 1,500/1,210 or 1.24 kg_{ww}/kg_{dw} can be estimated. The same calculation was also carried out for clay loam using values from Jeffries and Martin (2009). As noted above, this calculation is partly dependent upon the EUSES default value for the density of the solid phase.

C.2 Precipitation Projections

Table C.2 UKCP18 probabilistic projections for mean summer and winter precipitation

Time horizon (relative to 1981-2000)	Country/region	50th percentile change (%: figures in brackets are the 5th percentile-95th percentile change)							
		Summer				Winter			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2020-2039	England	-6 (-29 to +17)	-3 (-25 to +19)	-3 (-25 to +20)	-4 (-28 to +20)	+6 (-6 to +19)	+5 (-6 to +18)	+5 (-6 to +17)	+6 (-6 to +19)
	Wales	-8 (-30 to +14)	-5 (-27 to +17)	-5 (-26 to +18)	-6 (-29 to +17)	+5 (-8 to +18)	+4 (-8 to +17)	+4 (-9 to +17)	+5 (-8 to +19)
	England and Wales	-7 (-29 to +16)	-3 (-25 to +18)	-3 (-25 to +19)	-5 (-28 to +19	+5 (-7 to +19)	+5 (-6 to +18)	+5 (-6 to +17)	+6 (-6 to +19)
	Scotland	-4 (-20 to +12)	-1 (-16 to +14)	-1 (-16 to +14)	-2 (-17 to +14)	+7 (-6 to +21)	+6 (-7 to +21)	+6 (-7 to +21)	+7 (-7 to +24)
	Northern Ireland	-8 (-26 to +10)	-5 (-22 to +13)	-4 (-22 to +13)	-5 (-23 to +12)	+7 (-6 to +21)	+6 (-8 to +21)	+6 (-8 to +20)	+7 (-8 to +22)

Time horizon (relative to 1981-2000)	Country/region	50th percentile change (%: figures in brackets are the 5th percentile-95th percentile change)							
		Summer				Winter			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
	United Kingdom	-4 (-22 to +13)	-2 (-19 to +15)	-2 (-18 to +16)	-3 (-20 to +15)	+5 (-5 to +16)	+5 (-5 to +15)	+5 (-5 to +15)	+5 (-5 to +16)
2050-2069	England	-15 (-37 to +8)	-15 (-40 to +9)	-15 (-39 to +11)	-20 (-49 to +9)	+7 (-7 to +24)	+8 (-8 to +26)	+7 (-8 to +25)	+11 (-7 to +33)
	Wales	-16 (-38 to +8)	-16 (-41 to +10)	-15 (-40 to +12)	-21 (-50 to +9)	+8 (-8 to +26)	+9 (-8 to +28)	+9 (-9 to +28)	+12 (-8 to +36)
	England and Wales	-15 (-38 to +8)	-15 (-40 to +9)	-15 (-39 to +11)	-20 (-49 to +9)	+8 (-7 to +24)	+8 (-7 to +26)	+8 (-8 to +26)	+11 (-7 to +34)
	Scotland	-7 (-24 to +13)	-7 (-27 to +14)	-7 (-27 to +15)	-11 (-34 to +17)	+10 (-5 to +26)	+11 (-5 to +30)	+11 (-4 to +29)	+15 (-3 to +40)
	Northern Ireland	-12 (-31 to +8)	-12 (-32 to +10)	-11 (-32 to +10)	-16 (-39 to +9)	+6 (-8 to +22)	+7 (-8 to +25)	+7 (-9 to +23)	+10 (-7 to +32)

Time horizon (relative to 1981-2000)	Country/region	50th percentile change (%: figures in brackets are the 5th percentile-95th percentile change)							
		Summer				Winter			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
	United Kingdom	-12 (-29 to +6)	-12 (-31 to +7)	-11 (-30 to +8)	-16 (-38 to +7)	+7 (-5 to +21)	+8 (-5 to +23)	+7 (-6 to +23)	+11 (-5 to +29)
2080-2099	England	-16 (-40 to +8)	-23 (-49 to +2)	-27 (-55 to +3)	-35 (-66 to +3)	+7 (-9 to +25)	+12 (-7 to +35)	+14 (-7 to +40)	+20 (-6 to +54)
	Wales	-16 (-41 to +8)	-24 (-51 to +3)	-27 (-56 to +4)	-36 (-67 to +3)	+7 (-9 to +24)	+13 (-6 to +36)	+15 (-6 to +41)	+22 (-6 to +57)
	England and Wales	-16 (-40 to +7)	-23 (-50 to +2)	-27 (-55 to +3)	-36 (-66 to +3)	+7 (-9 to +25)	+12 (-7 to +34)	+14 (-7 to +39)	+20 (-6 to +54)
	Scotland	-13 (-29 to +5)	-17 (-38 to +7)	-19 (-43 to +9)	-24 (-52 to +13)	+7 (-7 to +24)	+13 (-6 to +37)	+15 (-6 to +42)	+22 (-6 to +61)
	Northern Ireland	-12 (-33 to +10)	-18 (-41 to +7)	-21 (-47 to +6)	-28 (-56 to +6)	+9 (-7 to +27)	+15 (-4 to +38)	+17 (-4 to +43)	+24 (-3 to +58)

Time horizon (relative to 1981-2000)	Country/region	50th percentile change (%: figures in brackets are the 5th percentile-95th percentile change)							
		Summer				Winter			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
	United Kingdom	-13 (-32 to +6)	-18 (-39 to +2)	-21 (-44 to +3)	-28 (-54 to +2)	+6 (-7 to +22)	+11 (-6 to +29)	+12 (-6 to +34)	+17 (-5 to +46)

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