Silsoe Spray Applications Unit

THE BREAM2 CALCULATOR

User guidance

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The development of the BREAM2 calculator was funded by the European Crop Protection Association.

The BREAM2 calculator can be downloaded from:

www.ssau.co.uk/BREAM2-calculator

and runs on your own computer, not from the web.

The latest version is dated 1st May 2018

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Please note that technical support for use of this model can only be provided where funding is available.

SUMMARY

The BREAM2 calculator: user guidance

A new calculator for bystander and resident exposure to pesticide spray drift from agricultural applications by a boom sprayer has been developed.

It differs from the original BREAM calculator in the way that the relationship between airborne spray and potential dermal exposure is described, following additional research (Butler Ellis et al, 2018). The uncertainty in this relationship is reduced and the variability is more accurately captured in the model. A statistical comparison between the new model and field data shows that BREAM2 is a better predictor of potential dermal exposures.

The predicted 75th and 95th percentiles of potential dermal exposure are reduced compared with BREAM.

This document provides guidance for the installation and usage of BREAM2, and provides some recommendations and suggestions for how it could be used in a regulatory context.

The effect of different variables on exposure is discussed. Further areas for development, particularly for the inclusion of additional mitigation, are identified.

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The BREAM2 Calculator: User guidance

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1. Introduction

The BREAM (Bystander and Resident Exposure Assessment Model) model (Kennedy et al, 2012) for bystander and resident exposure to spray drift from boom sprayers has recently been incorporated into the European Food Safety Authority (EFSA) guidance for determining non-dietary exposures of humans to plant protection products (EFSA, 2014). The BREAM model has a mechanistic component that predicts airborne spray and ground deposits, and an empirical component that relates airborne spray to deposits on the human body, from which dermal exposure can be calculated. The mechanistic component is based on the Silsoe Spray Drift Model (Butler Ellis and Miller, 2010), which is a particle-tracking model that predicts the movement of individual droplets released from a sprayer. However, instead of incorporating this model directly into BREAM, an emulator is used instead which captures the main behaviour and can be run very rapidly. The empirical component is based on data derived from two sources: Butler Ellis et al (2010) and Glass et al (2002). These are combined into a calculator which runs the algorithms multiple times, sampling inputs from distributions in order to produce a distribution of outputs (Kennedy et al, 2012).

The EFSA guidance requires the 75th and 95th percentiles of exposure distributions to be used to represent long-term and acute exposures respectively, and it is important, therefore, that the predicted distributions are comparable with those that might occur in practice. It was proposed that the relatively high values for the 95th percentile predicted by BREAM could be reduced by addressing some of the uncertainties and the causes of variability.

The empirical component of the model, relating airborne spray concentrations to measured bystander dermal exposure, based on a series of field trials (Butler Ellis et al, 2010; Glass et al, 2002) has a significant level of uncertainty and variability captured within it. A revised description of this relationship, which has reduced the uncertainty and improved the modelling of variability, has been developed.

The original BREAM project and associated model was funded by the UK Government for HSE's Chemical Regulation Division (CRD). This latest software is an implementation of the BREAM2-IP model, developed by SSAU and Fera in the BREAM2 project, and funded by Bayer AG and for which independent regulatory input was provided by CRD. The model and its validation are described in Butler Ellis et al (2018a, and 2018b). It is an update of the original BREAM model of Kennedy et al (2012). The aim is to provide model outputs that are useful for risk-assessors.

2. Installation

The BREAM2 calculator (BREAM2_calc) is provided as a zip file containing all the required files. It runs under Microsoft Windows.

The following steps should be followed:

1) Download the zip file BREAM2_calc.zip and extract to a suitable folder. **A local drive should be used rather than a network drive**. The folder structure is shown below

```
/BREAM2_calc
./app
   ./library
         ./bream2c
   ./shiny
         ./app.R
         ./Data
./GEM files
./correction_factor_samples.RDATA
         ./www
               ./bootstrap.css
               ./cropspraying_banner.jpg
   ./app.R
   ./config.cfg
   ./packages.txt
./dist
   ./R-Portable
   ./script
   ./USAGE.md
/BREAM2_calc.bat
/LICENSE
/README.md
```

2) Double click the BREAM2_calc.bat icon from within the BREAM2_calc folder. The interface will open in the default local web browser. The operating system may ask for permissions to run the program or make changes to the computer, when running the script for the first time. You will need to accept these requests and ignore the warnings.

3. Running Software

On starting the software, a web browser should open as shown in Figure 1. Illustrations shown in this document use Mozilla Firefox web browser, but the calculator should use any standard browser.

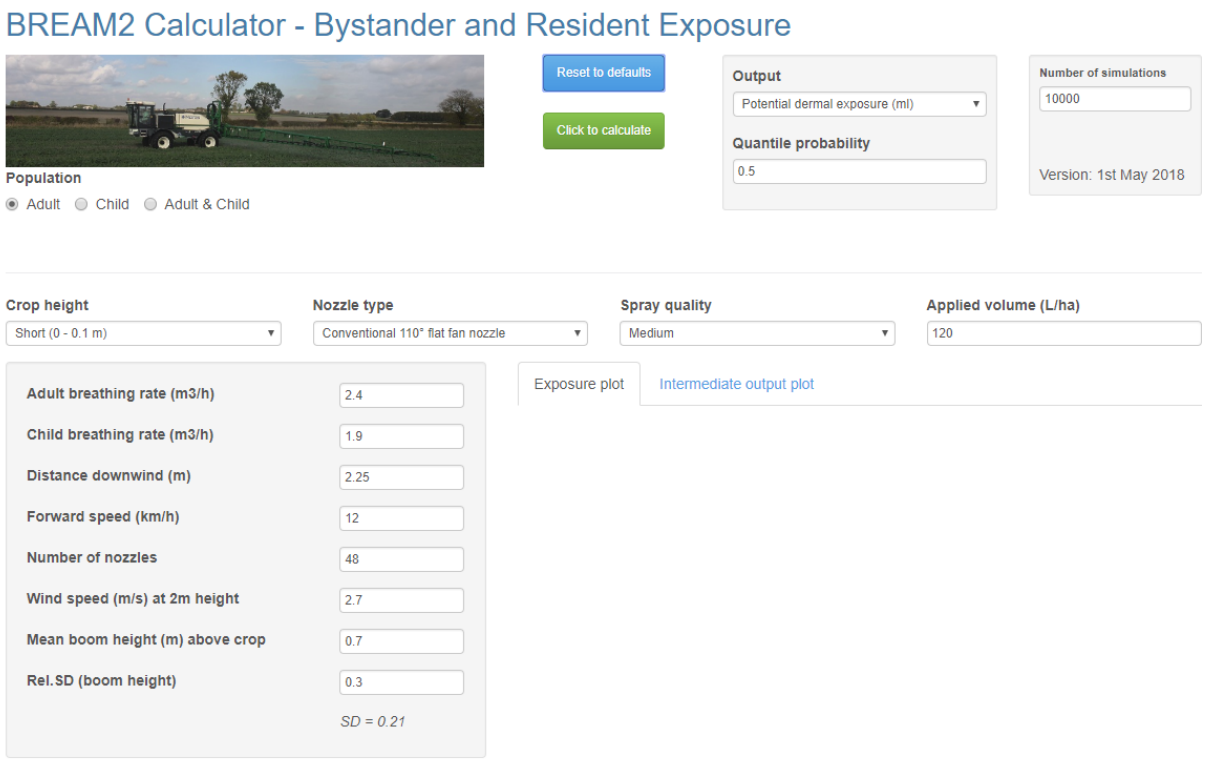


Figure 1. BREAM2 calculator default screen

3.1 Selecting input values

Input values for all required variables can be changed by the user. Some of the default inputs correspond to EFSA guidance values (European Food Safety Authority, 2014) and others are the proposed new defaults. Clicking the blue button 'Reset to defaults' will revert to the startup default values.

Hovering over an input will display information about that input, including any minimum and maximum values allowed. If any input is invalid (such as the example in Figure 2), it will be removed, and an error message will appear once the user attempts to perform the calculation (Figure 3). Replace the missing entries with valid values before retrying.

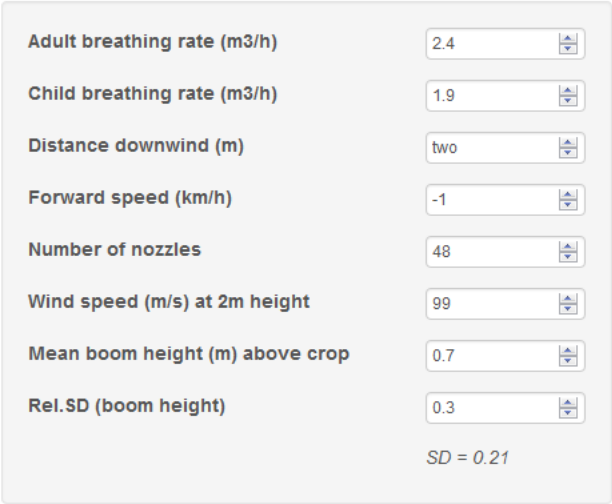


Figure 2. An example with some invalid input values

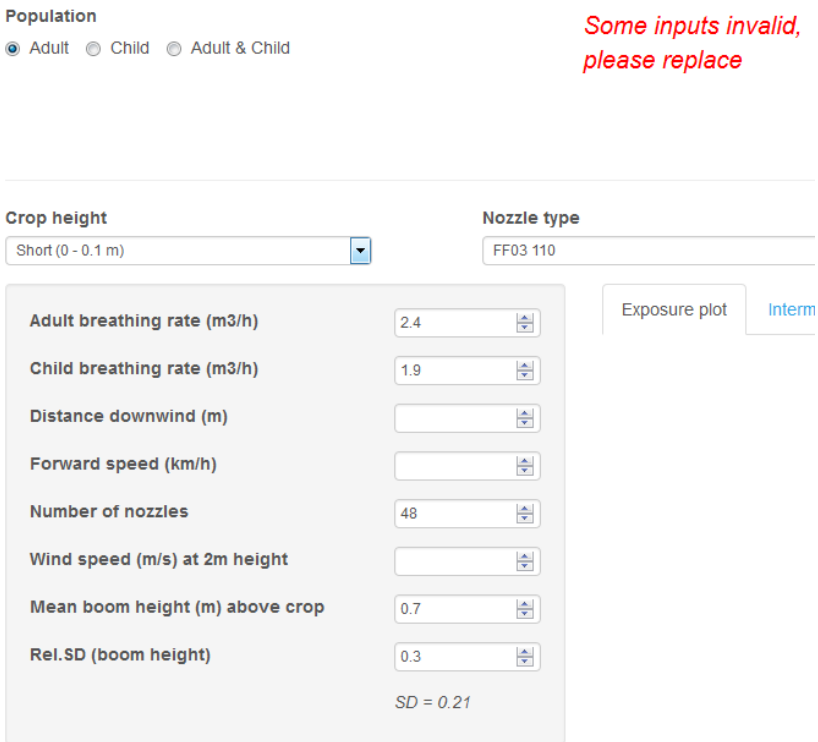


Figure 3. Error message and clearing of invalid inputs

3.2 Simulating and displaying results

There is an option to change the number of simulations for each calculation, which will better define the distribution of outputs. The default is set to 10,000 which is a good compromise between speed and stability This enables the user to evaluate the effect of changing variables relatively quickly when the model is used as part of a computational experiment exercise. However, a greater number of simulations will give a more repeatable result and so to generate regulatory data, a value

of 100,000 or greater is recommended. For a required number of decimal places required, the code can be run repeatedly to check for variations in the result.

Select an output type from the Output dropdown menu and Click the green 'Click to calculate' button. The options are Potential dermal exposure (ml), Ground deposition (% applied) and Inhalation exposure (ml). Each of these outputs can be calculated for Adult, Child or both Adult and Child, according to the Population selection. For potential dermal exposure or inhalation exposure, outputs from the intermediate simulation of airborne spray concentration are also available, and can be selected using the tab Intermediate output plot.

Examples are shown in Figures 4-7. If the selected output is Ground deposits, there is no difference between adult and child simulations, so the child option is removed. Also, in this case there is no intermediate output.

Changes to any of the inputs (except Quantile probability) will not immediately result in updated results being reported. The update will only occur after the Click to calculate button is clicked.

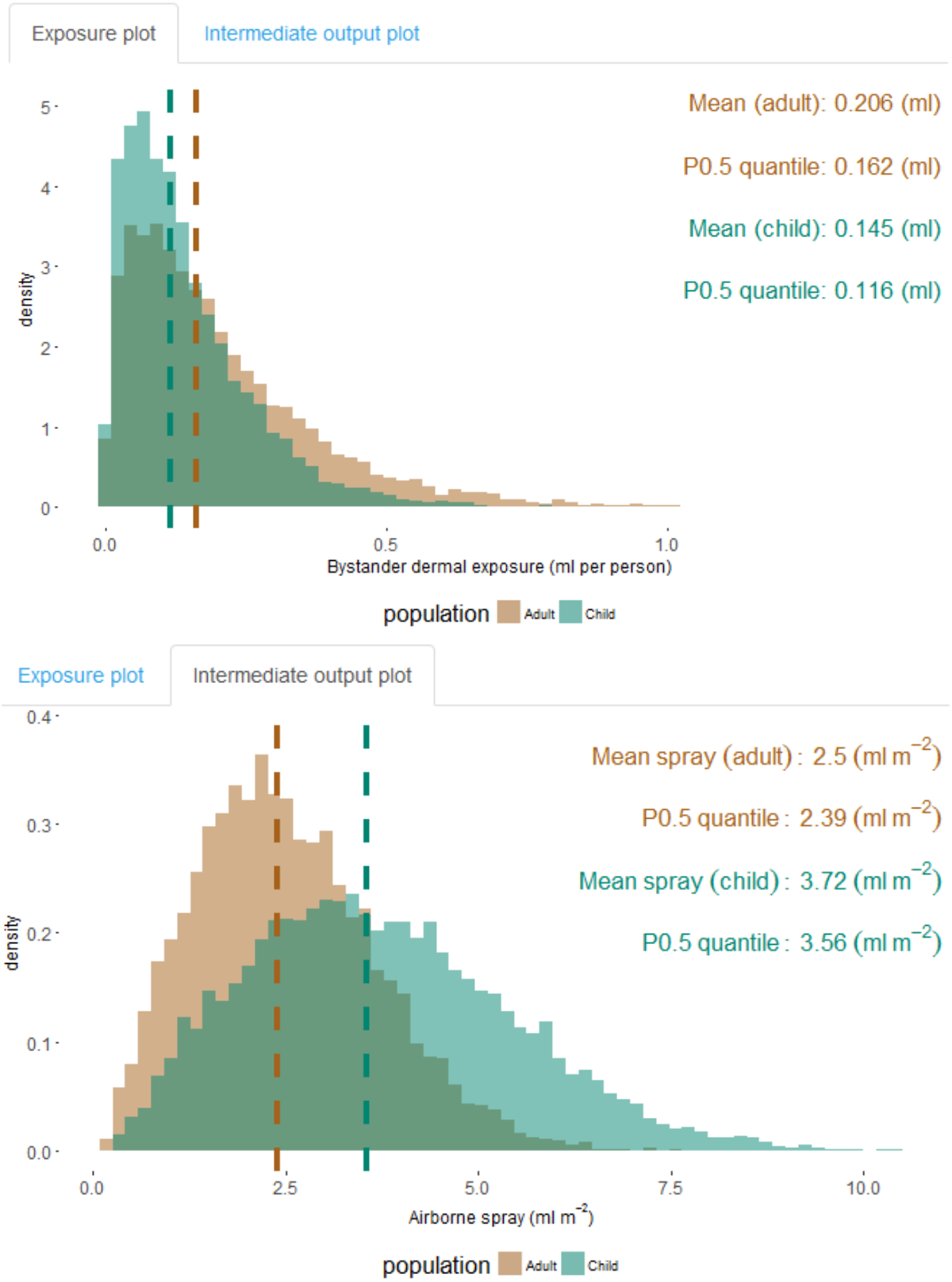


Figure 4: Example results for potential dermal exposure output (ml per person) for adult and child. These were generated based on the default inputs and 10000 simulations. The intermediate calculation airborne spray is also shown (right tab). Vertical lines show the estimated quantile, for user-selected 'Quantile probability' = 0.5.

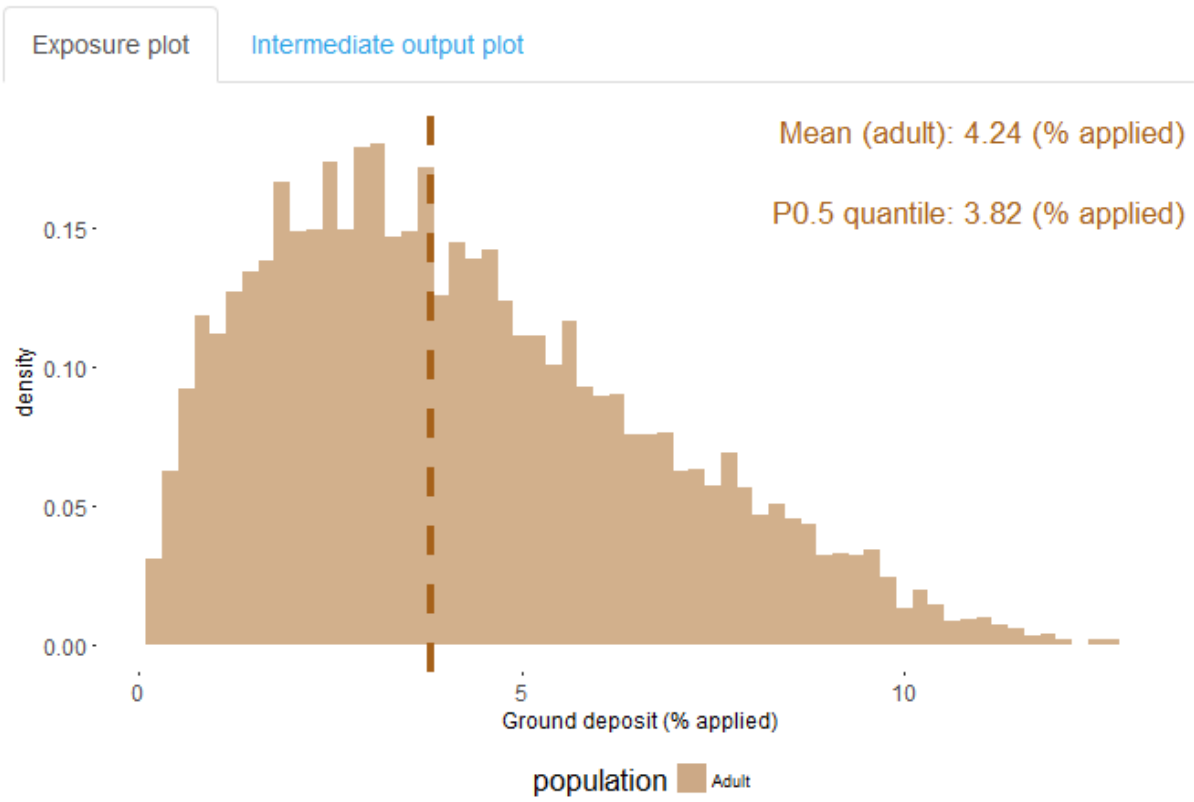


Figure 5: Example results for ground deposit output (as % applied) for adult and child. These were generated based on the default inputs and 10000 simulations. Vertical lines show the estimated quantile, for user-selected 'Quantile probability' = 0.5. In the case of ground deposit, no intermediate output is shown for this output. Note also that ground deposit is identical for adult and child.

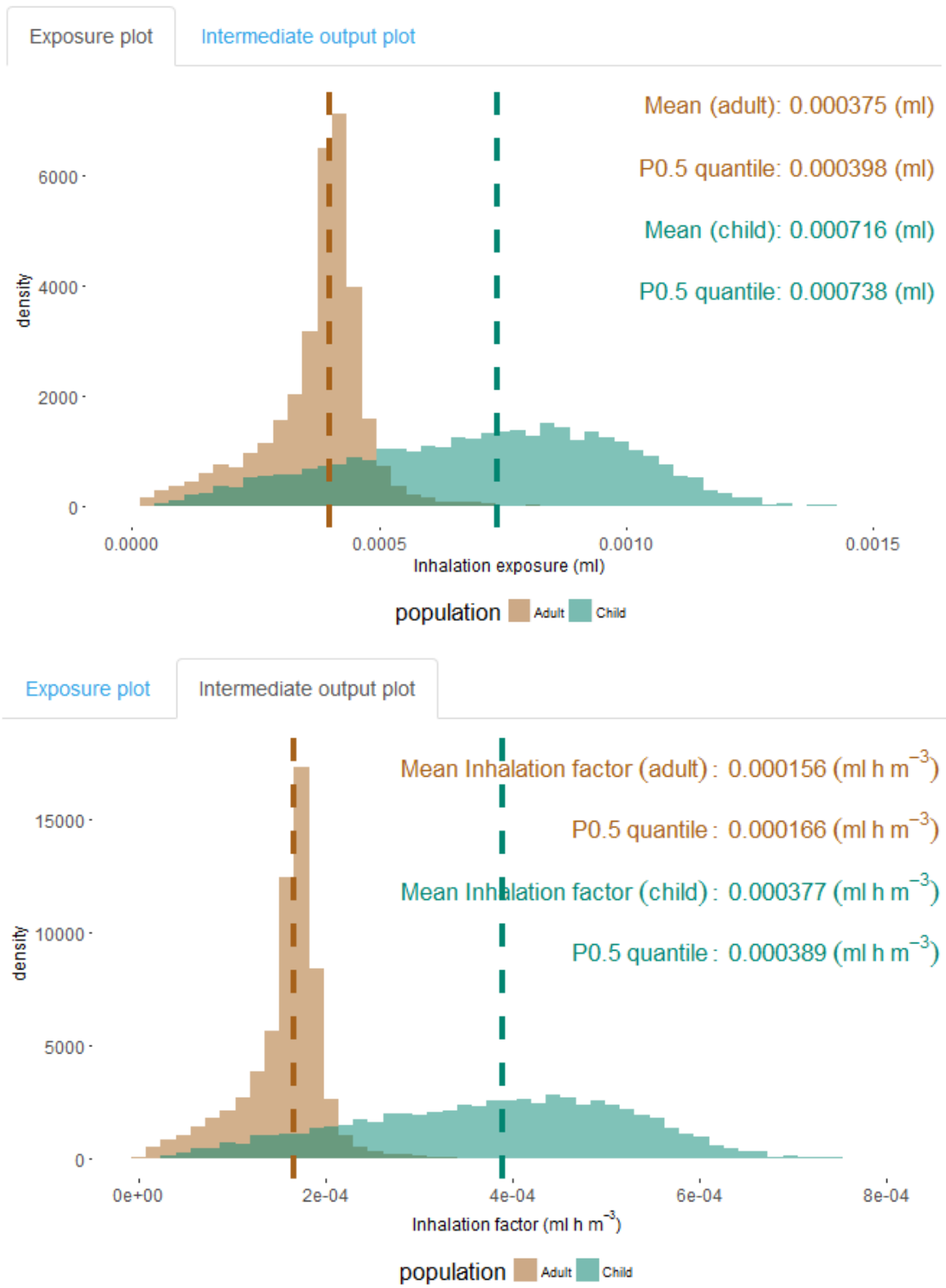


Figure 6: Example results for inhalation output (ml per person) for adult and child. These were generated based on the default inputs and 10000 simulations. The intermediate calculation inhalation factor is also shown (lower panel). Vertical lines show the estimated quantile, for user-selected 'Quantile probability' = 0.5.

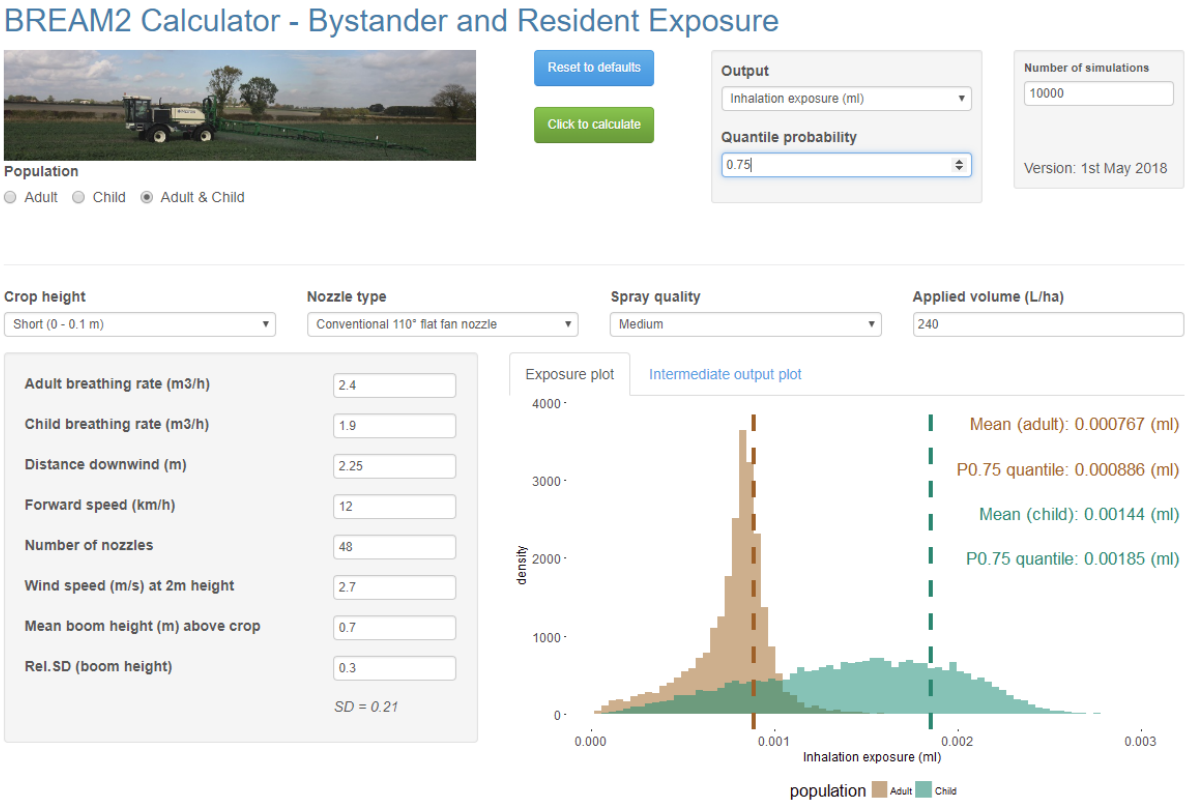


Figure 7: Changing the input 'Quantile probability' updates the vertical lines and the output values in the annotation boxes. In this example the user set the value to 0.75, so the 75th percentile is reported.

4. Model Inputs and use of model outputs

The model outputs relate to the scenario being simulated, which is defined by the model inputs that were used. These inputs include elements of spray application, environment and bystander. The calculator has default input values, but these can be changed, which could then have consequences for predicted exposures. We consider the implications for changing these input variables in the sections below as well as a discussion on possible default values.

Outputs from the current BREAM model are used within the EFSA calculator for bystander exposure, which also has a range of possible inputs. It is important that the inputs to BREAM2 are consistent with the inputs that will be used in the EFSA calculator.

4.1 Spray Application

BREAM2 has limited scope for adjusting spray application. The parameters that can be changed directly in the model are forward speed, boom height, number of nozzles and application volume. Nozzle type and spray quality are fixed.

Nozzle type and spray quality

Spray characteristics (including droplet size and velocity) are important drivers of spray drift and there are many different types of sprays available to spray operators, defined by nozzle size, design and operating pressure.

The spray characteristics of a single nozzle type, size and pressure (flat fan design, F110/1.2/3.0, known colloquially as FF03 110) are available in the model at present, although this is something that could be extended in future developments. This nozzle-pressure combination defines the boundary between 'fine' and 'medium' spray qualities in the BCPC classification scheme, and therefore represents something close to a worst case for drift from a 'medium' quality spray. Many commercially-available plant protection products have an instruction on the label to spray with a 'medium' quality spray and it is therefore protective of a wide range of spray applications across Europe. However, it would not be protective of an application using a 'fine' spray and it is likely that such applications are made in some situations.

Sprayer speed

There is a wide range of sprayer speeds used across the EU, with differences between member states, and also within member states, depending on the scale of the farming operation and the terrain involved.

The nozzle-pressure combination currently in the model has a flow rate of 1.2 l/min. When combined with a given forward speed, this defines the applied volume, which is displayed on the right-hand side of the screen. When using the default speed of 12.0 km/h, this gives an applied volume of 120 l/ha.

Changing the sprayer speed in the model affects the applied volume, which affects the *absolute* amount of spray liquid that the bystander is exposed to, and can also directly affect exposure by changing the *proportion* of the spray that drifts. The relationship between the median adult dermal exposure and sprayer speed is shown in Figure 8. The exposure to spray liquid increases with volume (i.e. reduced speed), as expected.,. Since for a given dose of active substance, the concentration of active substance in the spray liquid reduces with volume, we might expect the exposure to the active substance to remain constant as the sprayer speed reduces and water volume increases. This is only the case below about 150 l/ha (i.e. above 10 km/h). For speeds lower than 10 km/h, the exposure

reduces with reducing speed because there is a direct effect on spray drift. It must be understood that this is an effect of forward speed, not of volume *per se*.

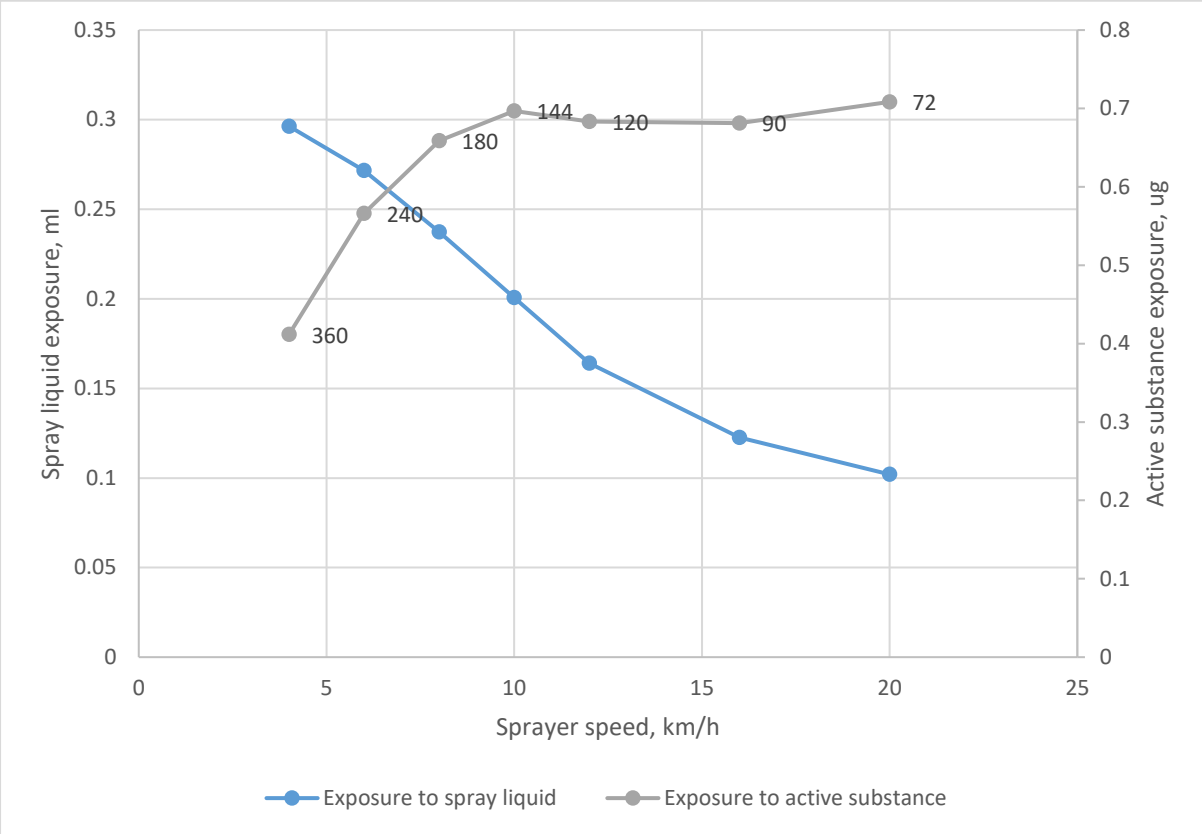


Figure 8. Potential dermal exposure (adult, median values) to both spray liquid and active substance for different sprayer speeds for a constant dose (based on 0.5 kg/ha a.s.). Numbers on graph indicate the corresponding application volume in litres/ha.

Application volume

An alternative approach to changing the volume would be to change the nozzle size and/or pressure. A different nozzle which has a greater flow rate but identical spray characteristics will give drift, and therefore exposure levels, that are in proportion to the applied volume. For example, the default inputs with a speed of 12 km/h, which gives an applied volume of 120 l/ha, result in a median adult dermal exposure of 0.164 ml. Changing the nozzle from one delivering 1.2 l/min to one which delivers 2.4 l/min, but with the same spray characteristics (i.e. approximate worst case medium quality spray) will double the volume to 240 l/ha, and double the median adult exposure to 0.328 ml. For the same applied dose of active substance, the concentration of the higher volume will be half that of the lower volume and so the exposure to active substance will be the same in both cases. Of course in practice, a different nozzle and pressure is likely to change the spray characteristics too, either increasing or decreasing its drift potential, but this is not yet captured in the model.

The calculator allows the user to override the default volume based on nozzle flow rate and sprayer speed and specify a different value. This assumes exactly the same drift characteristics, but a different flow rate.

Once the 'Applied volume' input box has been updated by the user, changing the speed will no longer influence its value, which will remain at the input value at all speeds. If the 'reset to defaults' button is pressed, then the relationship between speed and volume will be reinstated.

Boom height

Boom height is another strong driver of spray drift. 'Best practice' aims to achieve a boom height of 0.5 m above the target, but any terrain which is not perfectly flat will result in a variation in actual height, and for fast speeds and bumpy terrain, boom stability can be inadequate to prevent the boom making contact with the crop or ground. Booms are therefore often raised. The boom height of 0.7 m which was adopted in the original BREAM model was chosen as a reasonable compromise between supposed best practice and reality.

Active boom suspension and levelling is becoming increasingly widely available on modern sprayers and therefore it may be possible to reduce the value of 0.7 m as a mitigation measure where such technology is used. However, the model also assumes that there will be some boom fluctuations, which are captured in a distribution of boom heights around the nominal value, and boom levelling systems are likely to reduce the width of this distribution which would have an impact on the 75th and 95th quantiles. The input box labelled **Rel. SD (boom height)** is a factor which alters the standard deviation of boom fluctuations based on boom height. The standard deviation used in the model simulations is given just below the last input box. While there is no basis at present for adjusting this parameter, there is potential in the future, with appropriate performance data from real sprayers, particularly those with boom levelling systems, to amend this value to be less conservative.

Crop height

The only crop height in the current model is a "short crop" which we would estimate would be reliable for bare soil and crops up to around 0.15 m tall. The original BREAM calculator also included a variable crop height option, but some problems were identified, with the emulators being unable to correctly predict drift with taller crops in some situations, and so this facility was not recommended without further work. This was addressed during the BROWSE project, with an improved emulation method. BREAM2 uses the same emulators as BREAM, but future developments could replace them with the BROWSE emulators.

Number of nozzles

The number of nozzles does not relate solely to the width of the boom, but to the width of the sprayed area. Therefore, a single swath sprayed by a 24 m sprayer (with the fixed nozzle spacing of 0.5 m) will have 48 nozzles. Two successive upwind swaths would be 96 nozzles, as would be a single swath sprayed by a 48 m boom.

The current default is 48 nozzles, which was used in the EFSA guidance, and there tends to be an assumption that subsequent upwind swaths contribute a negligible quantity to exposure. Figure 9 shows model predictions for the 95th percentiles of adult and child dermal exposures and ground deposits for different numbers of nozzles (i.e. widths of sprayed area) up to almost 100 m. This suggests that, according to model predictions, a wider sprayed area will make a significant difference to exposure. The data is expressed relative to the value achieved with the default of 48 nozzles. The effect of the number of nozzles is greater for dermal exposure than for ground deposits because the airborne spray declines less quickly with distance than does sedimenting spray. Similar relationships occur with the 75th percentile values.

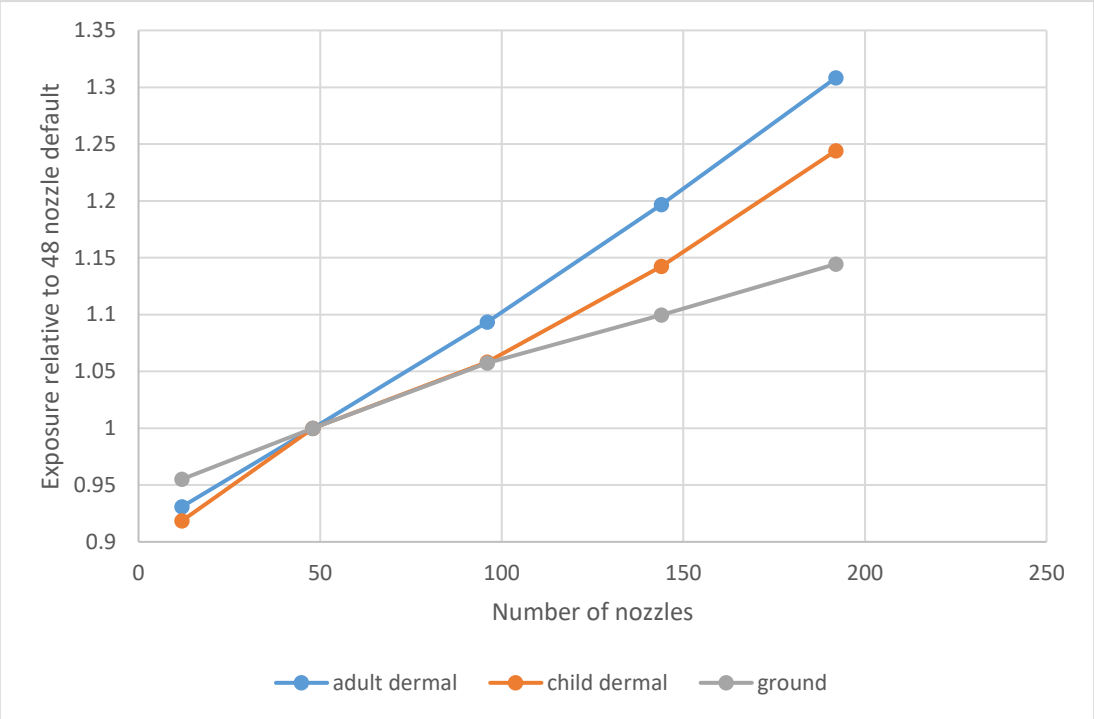


Figure 9. Effect of number of nozzles (width of area sprayed) on 95th percentile exposures for adult, child and ground, from 12 nozzles (6 m) to 192 nozzles (96 m).

Spray drift mitigation

Drift reduction measures are not currently included in BREAM2. However, drift-reducing nozzles are widely available and commonly used in many member states and therefore it would be advantageous to take this into account. These nozzles have a specific set of spray characteristics which reduce their drift potential, and ideally would be included as options in BREAM2. This could be added in future work.

An alternative approach is to use the classification of drift reduction which is undertaken for surface water, using one of the existing protocols – either Germany, the Netherlands or UK. These protocols are based on measurement of sedimenting spray (i.e. ground deposits) rather than airborne spray. Therefore the current drift reduction classification does not give a measure of exposure reduction relevant to dermal exposure or inhalation. In addition, it is known that drift reduction depends upon distance downwind. However, the continued use of 50% reduction in exposure for all nozzles with 50% drift-reducing status or more is a reasonable compromise until further work can be undertaken to robustly include 75% drift reduction and greater.

4.2 Environmental conditions

Mean wind speed is the only environmental parameter that can be varied in BREAM2. This value is the wind speed measured at 2 m height above the ground. A default value of 2.7 m/s was proposed by EFSA. Reducing wind speed can reduce exposure.

The model assumes that there will be fluctuations in both wind speed and direction. The distributions are based on real meteorological data obtained during spray drift experiments and depend upon mean wind speed. These cannot be changed. The mean wind direction is always 90 degrees to the sprayer direction.

4.3 Bystander

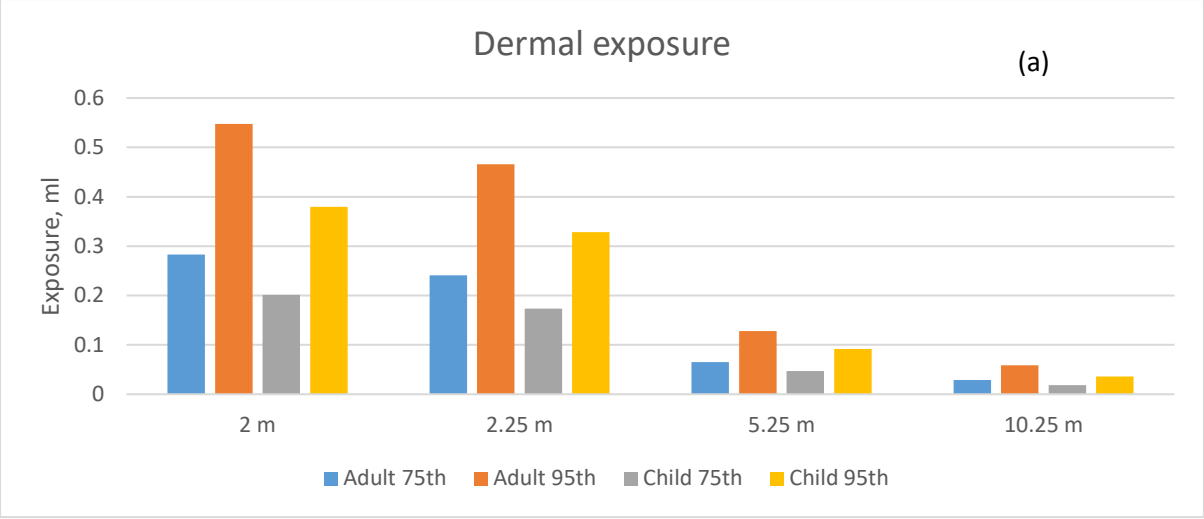
Bystander variables are distance from the sprayed area and breathing rates. Breathing rates are the defaults given in the EFSA guidance. The edge of the sprayed area (i.e. zero distance) was defined in the original BREAM model as the location of the centre of the downwind nozzle. Other models and data have defined this 'zero' value as 0.25 m (half the nozzle spacing) downwind of the centre of the final nozzle, representing the edge of the treated area. Thus, to be consistent with other exposure assessments, a default value of 2.25 m, which would be equivalent to 2.0 m from the treated area, might be more appropriate than the 2.0 m from the downwind nozzle currently used.

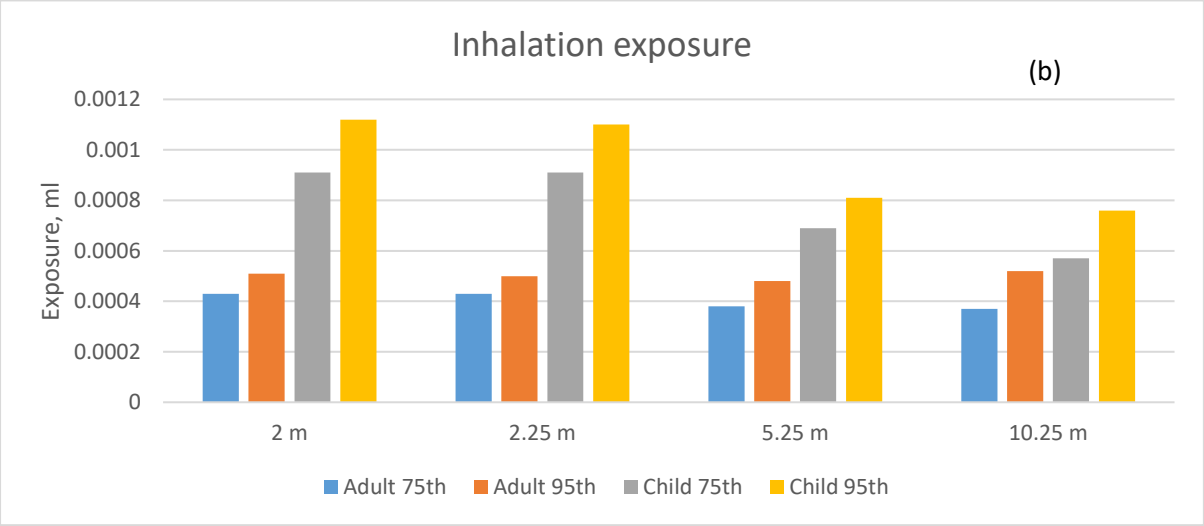
Figure 10 shows the predicted effect of distance on the different exposure routes, with dermal exposure having the greatest reduction and inhalation the least. The biggest impact comes from increasing the distance from 2 to 5 m, with diminishing returns from increasing the distance further.

5. Recommendations

The following recommendations are made.

1. The BREAM2 calculator should be used to generate new outputs that can be used in the existing EFSA calculator, replacing the values currently used. The model has been shown to be able to predict field measurements of bystander dermal exposure more reliably than the previous version (BREAM).
2. For input to the EFSA calculator,
    a. the default value for distance is changed to 2.25 m to be consistent with other exposure assessments relating to spray drift, and
    b. the default value for sprayer speed is changed to 12.0 km/h to result in a more meaningful applied volume as well as a more commonly used sprayer speed.
3. Some consideration is given to changing the default number of nozzles to ensure that sufficient protection is achieved for larger fields and/or wider booms
4. Mitigation of spray drift can be achieved through
    a. use of drift reducing nozzles and other engineering controls;
    b. Use of no-spray zones; but
    c. Not combining no-spray zones and drift-reducing nozzles, without further research to establish if the effects on exposure are robustly additive.
5. Consideration is given to further mitigation methods that could be included in future developments (BREAM3), which could include
    a. Nozzles producing 75% drift reduction and more;
    b. Combining drift reduction technology and no-spray zones;
    c. Reducing sprayer speed;
    d. Improved boom height control;
    e. The effect of different crop canopies.





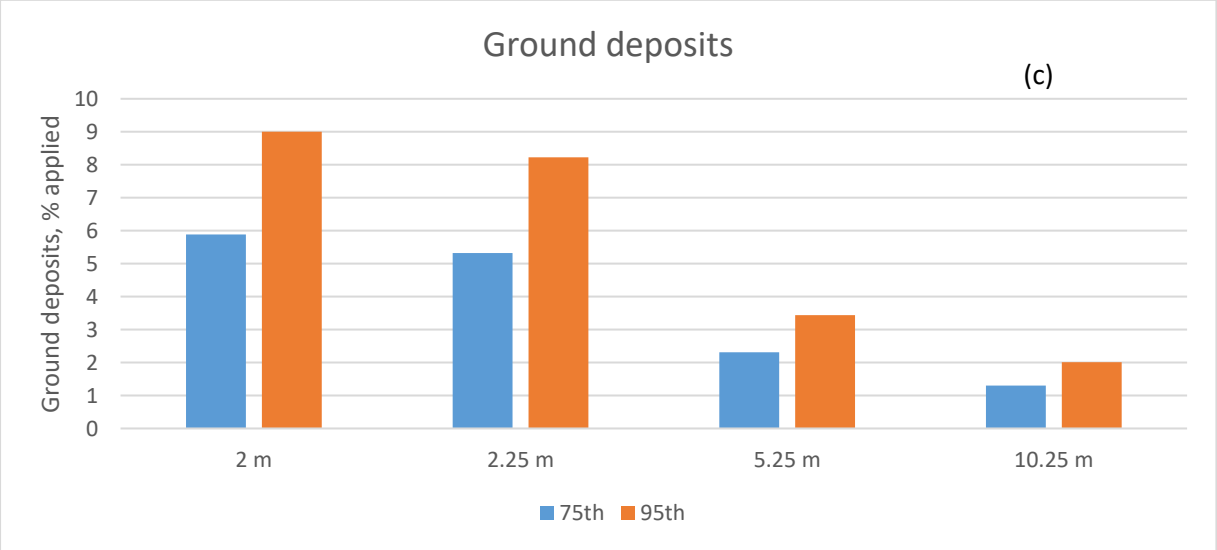


Figure 10. The effect of distance on exposure for (a) dermal exposure, (b) inhalation exposure and (c) ground deposits.

5.1 Example calculations for updating EFSA guidance

The component relating to arable/ground boom sprayer in Table 16 in the EFSA guidance would be replaced by Table 1, the 'field crops' component of Table 18 by Table 2 and the arable/ground boom sprayer component of Table 19, for bystander exposure would be replaced by Table 3.

Table 1. 75th percentile of dermal and inhalation exposure from BREAM2

Distance from sprayed area, m*	Dermal (ml spray per person)		Inhalation (ml spray per person)	
	Adult	Child	Adult	Child
2	0.252	0.183	0.000443	0.000926
5	0.068	0.049	0.000397	0.000710
10	0.030	0.019	0.000378	0.000593

*Determined by using a model input of distance + 0.25 m

Table 2. Mean and 75th percentile of ground deposits from BREAM2

Distance from sprayed area, m*	Ground deposits, % applied volume	
	Mean	P75
2.5	3.85	5.30
5	1.72	2.26
10	1.01	1.28

*Determined by using a model input of distance + 0.25 m

Table 3. 95th percentile of dermal and inhalation exposure from BREAM2

Distance from sprayed area, m*	Dermal (ml spray per person)		Inhalation (ml spray per person)	
	Adult	Child	Adult	Child
2	0.492	0.342	0.000525	0.00112
5	0.137	0.097	0.000504	0.000829
10	0.061	0.038	0.000539	0.000790

*Determined by using a model input of distance + 0.25 m

Note that the calculation of ground deposits and inhalation exposure has not changed, but there are small differences due to small adjustments to the recommended inputs (distance and sprayer speed). These data all relate to an applied volume of 120 L/ha.

5.2 Use of BREAM2 model outputs in EFSA calculator

The current EFSA calculator is based on the erroneous assumption that exposure to spray liquid is independent of applied spray volume, and therefore the exposure to active substance is dependent on the concentration of active substance in the sprayed tank mix.

The BREAM2 calculator now allows the volume to be adjusted explicity, and the volume used to run the BREAM2 calculator to derive values for the EFSA calculator *must* match the volume used in the EFSA calculator.

It is therefore currently not possible to run the EFSA calculator for different volumes because it has only one set of values embedded in it, which relate to 114.6 L/ha. (If these embedded values are changed for those suggested above in Tables 1 – 3, then these relate to an applied volume of 120 L/ha). Therefore, the EFSA calculator can currently be run for only one volume. However, the exposure to the *active substance* is independent of volume and therefore these results will apply to all other volumes.

It is further recommended, therefore, that the EFSA calculator is modified, either to enable the appropriate relationship between volume and exposure to be predicted, or to constrain the volume to be the same as that used to generate the embedded exposure data.

6. References

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