Guidance on assessment of multiple simultaneous exposure routes of PT21 active substances

Background

This guidance document has been developed following discussion between members of the TM PT21 e-consultation group and presentation of draft versions at TMIII2011 and TMII2013. It specifically addresses the development of scenarios to assess the multiple simultaneous exposure arising from Product Type 21 uses. Within the context of Product Type 21 assessments, the multiple simultaneous exposure routes considered by this guidance include in-service losses combined with losses during application, maintenance and repair activities. The guidance is restricted to considering multiple simultaneous exposure from single chemicals in this product type only. General guidance on assessing the risks from mixtures of substances is also being developed and that guidance should be considered when dealing with multiple substances.

The guidance reflects final agreed positions. However, since the area of PT21 environmental risk assessments is constantly developing, it is expected that this guidance document may need to be updated over time as experience in this area increases. Where existing PT21 assessments are in the process of being finalised in the EU review, the approach to selecting multiple simultaneous exposure scenarios may deviate from this guidance. In this situation it is recommended that additional justification be provided to demonstrate that the scenarios used would not result in an underestimation of predicted exposure levels when compared to the scenarios developed in this guidance. In addition, if large margins of safety exist in the risk assessments performed for all relevant individual exposure routes it may be possible to justify that no additional quantitative assessment of multiple simultaneous exposure routes is required. To determine that a sufficient margin of safety exists to avoid the need for a specific multiple simultaneous exposure assessment, it should be clear that the sum of all individual PEC:PNEC ratios would be less than 1.

Summary bullet points from the guidance (see main text for further details):-

- *For commercial shipping multiple simultaneous losses from **application** and **in-service** activities be assessed together as a conservative first tier scenario*
- *Where this conservative scenario triggers the need for risk mitigation, further consideration of additional multiple simultaneous losses from **removal** and **in-service** should be performed for commercial shipping*
- *For professional and amateur pleasure craft the losses from **removal** and **in-service** activities should be assessed as a conservative first tier*
- *For professional activities on pleasure craft, an additional route via an STP following **application** losses is included at the first tier.*
- *Due to the possible differences in applicability of risk mitigation measures across user groups (e.g. for commercial shipping or pleasure craft, professional or amateur activities), all relevant multiple simultaneous scenarios should be simulated independently for each active substance depending on the proposed use pattern at the first tier.*
- *The MAMPEC v2.5 model is recommended for the implementation of these scenarios*
- *The quantitative effect of risk mitigation for all professional uses should be based on the CEPE (2011) report*
- *To assess multiple exposure in soil, an approach based on deriving a multiple application factor can be used*

1. Introduction

This guidance document outlines scenarios to assess multiple simultaneous environmental exposure arising from the use of antifouling products. The guidance is restricted to considering single chemicals in this product type only. The various application, maintenance and repair activities combined with losses during the in-service period could result in multiple simultaneous exposure routes to the same environmental compartments. Therefore the need for assessment has been identified. It should be clarified that the multiple simultaneous exposure addressed in this guidance will only cover the use of active substances in PT21 products. No consideration of additional sources of these substances via other biocidal product types (or non-biocidal uses) has been made. No consideration of exposure to mixtures of substances is included here either. The assessment of multiple simultaneous exposure across multiple product types (or multiple substances) is outside the scope of this guidance document. However the basic principles and scenarios could easily be applied to mixed active products or substances of concern. Users should also refer to separate guidance on mixtures and/or substances of concern before performing an assessment.

The basic rationale that has been used in developing this guidance is that any multiple simultaneous exposure assessment scheme should ideally be simple, transparent, realistic and consistent with the approaches used to assess the individual exposure routes. The guidance should also cover the full range of users from large scale commercial activities down to amateur users.

The scenarios that have been developed are intended as a simplistic first tier approach. They do not attempt to reflect actual maintenance cycles (e.g. removal followed by application activities on the same boat). Nor do they attempt to accurately reflect the slow release of active substance that may be expected to occur following the loss of intact paint particles during either application or removal activities. The PT 21 e-consultation group considered these aspects and considered that at present the technical difficulties were too great to include these elements in the environmental risk assessment. The main technical difficulties were related to not being able to accurately assessing leaching rates from intact paint. Hence the guidance has been developed to be simple and consistent with the approaches used for individual exposure routes.

During the development of any risk assessment some consideration of the overarching protection goals should also be made to ensure the final scheme provides an appropriate level of protection. However this is considered beyond the scope of this guidance. It has therefore been assumed that the schemes to assess the individual exposure routes (i.e. via application, maintenance, repair or in-service activities) do provide an appropriate level of protection. Therefore by ensuring the multiple exposure schemes are consistent with the approaches used to assess the individual routes the same or similar levels of protection should be achieved.

The guidance follows the structure of the PT21 OECD ESD and utilises the MAMPEC v2.5 model to perform the assessments. Separate scenarios for either commercial shipping or pleasure craft, and amateur or professional activities only are considered. Although it is reasonable to assume that situations exist where there is a mix of commercial and pleasure craft and/or professional and amateur activities taking place, the guidance has been developed on the basis that the existing scenarios for either commercial or pleasure craft or professional or amateur activities are sufficiently conservative. Where the need for risk mitigation is triggered on the basis of these separate scenarios, the level of mitigation will be conservative compared with the level of mitigation needed in any mixed scenario. It has therefore been assumed that any mixed scenario that could be developed would not necessarily improve decision making in the environmental risk assessment and such scenarios have not been included in this guidance.

2. Scenarios for the multiple simultaneous exposure assessment

Active substances may be supported at Annex I for the full range of uses covered by the OECD ESD (e.g. professional and amateur, commercial and pleasure craft). Alternatively substances may only be supported for use by professionals or be limited to large commercial craft only (i.e. restricting the use on pleasure craft). Because of these potential restricted use patterns, the simplest possible selection of scenarios for multiple simultaneous exposure needs to cover 3 separate use patterns: (1) commercial shipping, (2) professional pleasure craft and (3) amateur pleasure craft. To keep the guidance simple and to allow for a tiered assessment approach a single scenario is recommended for each of the three use categories listed above at the first tier:-

> For commercial shipping the guidance proposes that multiple simultaneous losses from application and in-service activities be assessed as a conservative first tier scenario. For commercial shipping the losses from application activities calculated according to the PT21 OECD ESD will be higher than the losses from removal activities. Hence a single scenario at the first tier is appropriate.
>
> For professional and amateur pleasure craft the guidance proposes that multiple simultaneous losses from removal and in-service activities be assessed as a conservative first tier scenarios. For pleasure craft activities the losses from removal activities calculated according to the PT21 OECD ESD will be higher than the losses from application activities. Hence again a single scenario at the first tier is appropriate.
>
> For professional users an additional route via an STP following application losses is included at the first tier. Significant losses via an STP are only assumed to occur following professional pleasure craft activities based on the OECD ESD defaults and again this single scenario is selected for the first tier.

Due to the possible differences in applicability of risk mitigation measures across these user groups, all relevant multiple simultaneous scenarios should be simulated for each active substance depending on the proposed use pattern at the first tier. This is necessary because it is possible that in some cases the 'worst case' multiple simultaneous scenario could be, for example, the commercial shipping scenario which may be acceptably refined by adopting risk mitigation measures to obtain acceptable PEC:PNEC ratios. However once this 'worst case' scenario is subject to risk mitigation, the remaining multiple simultaneous scenarios which may not be subject to the same degree of risk mitigation may become critical to the environmental risk assessment. Hence all multiple simultaneous scenarios that are relevant to the proposed use pattern should be considered. In addition, where these conservative scenarios trigger the need for risk mitigation, further consideration of additional multiple simultaneous losses will be needed at the next tier. For example where the multiple simultaneous commercial shipping scenario based on application and in-service losses triggers the need for risk mitigation, further consideration of multiple simultaneous removal and in-service losses for commercial shipping will be required. This is explained further in the worked examples provided below.

The following figure summarises the proposed tiered approach to the multiple simultaneous exposure scenarios. Please refer to the detailed guidance below to further explain the rationale behind selection of the different scenarios for different user groups at the different tiers.

Tier	Commercial shipping	Professional pleasure craft	Amateur pleasure craft
Worst case multiple simultaneous exposure scenario to be performed for all relevant use patterns.	Application (new build or M&R) **plus** In-service losses [realistic worst case and typical case defaults inside and adjacent to the harbour]	Application (M&R) via STP **plus** Removal **plus** In-service losses [realistic worst case default only; inside and adjacent to marina]	Removal **plus** In-service losses [realistic worst case default only; inside and adjacent to marina]
Where the worst case scenario results in an unacceptable risk assessment, risk mitigation or refinement is required			
Additional scenario to be performed where worst case scenario requires risk mitigation or refinement only	Removal **plus** In-service losses [realistic worst case and/or typical case defaults inside and adjacent to the harbour depending on scenarios failing above]	No additional scenarios required	Adapted M&R amateur scenario for soil exposure if soil DT_{90} > 1 year and single year PEC;PNEC >0.1

Figure 1: Summary of proposed tiered approach to assessing multiple simultaneous exposure scenarios.

Commercial shipping scenario

For the commercial shipping scenario it is reasonable to assume that simultaneous exposure from periodic application or removal activities could occur to a commercial harbour that also receives daily inputs via in-service losses from working ships. Based on the standard defaults in the OECD ESD losses following application to either a new build ship or as part of the maintenance and repair of a commercial ship are identical based on the Elocalwater. These losses are also in excess of losses during removal activities when comparing either realistic worst case or typical case default situations. This is true even when the $Fa.s._{old\ paint}$ parameter[1] is increased to 0.9 based on TM discussions (see Tables 0.8, 0.12 and 0.18 of OECD ESD and also the worked example in Appendix 1).

For applications to a new build ship this equates to a painting period of 1 d, occurring twice per year. Application as part of maintenance and repair activity would involve painting periods of 2 d, with a frequency of 20 painting periods per year. The total time spent applying paint according to the ESD is therefore 42 d and this is considered a sufficiently significant period to warrant consideration of the potential multiple simultaneous exposure levels. The

[1] The Fa.s.old paint parameter describes the fraction of active substance remaining in old paint. Together with the concentration of active ingredient in the original paint this fraction is necessary to be able to calculate the concentration in the paint layers that are to be removed from the hull.

inputs to the commercial harbour arising from application to commercial ships (new build or maintenance and repair) should be combined with the in-service scenarios to provide an assessment of potential multiple simultaneous exposure. This scenario assumes that simultaneous losses arising from application and removal activities do not occur. Assessing repeated cumulative exposure from application and in-service routes alone within the existing MAMPEC modelling framework is considered to be sufficiently conservative based on the simple PT21 ESD defaults. Further consideration of additional inputs via removal activities at the same time at same conservative default levels assumed in the ESD would not be realistic and consistent with the original rationale outlined at the start of this document. This proposal was agreed at TMIII2011.

Where the above commercial shipping application plus in-service scenario results in acceptable PEC:PNEC ratios (i.e. < 1) without the need for any form of risk mitigation for both worst case and typical case defaults, no further consideration of cumulative removal and in-service losses is required. However due to differences in applicability of risk mitigation measures across activities, where the above scenario triggers the need for risk mitigation or refinement for either the worst case or typical case, further consideration of the multiple simultaneous removal and in-service losses should also be performed to confirm whether additional risk mitigation for removal activities is triggered. This aspect is further discussed in the section on risk mitigation.

To illustrate the commercial shipping application/in-service multiple simultaneous scenario the following worked example is presented using a dummy substance and MAMPEC model (v2.5).

The following substance properties were used:-

Molecular weight = 350 g/mol
Log Koc = 2.699 L/kg
Henrys law constant = 5.25 x 10^{-7} Pa m^3 mol^{-1}
Water phase biological degradation rate, DT_{50} = 2.7 d
Sediment phase biological degradation rate, DT_{50} = 26.4 d
All other degradation rates set to 0.

With regard to the MAMPEC scenarios, the in-service losses were simulated assuming a dummy leach rate of 5µg cm^{-2} d^{-1} for all boats, the sediment mixing depth was set at 3cm and the organic carbon degradation rate was set to 0 d^{-1}. Results are expressed as the TGD default temperature of 9°C for the marine environment.

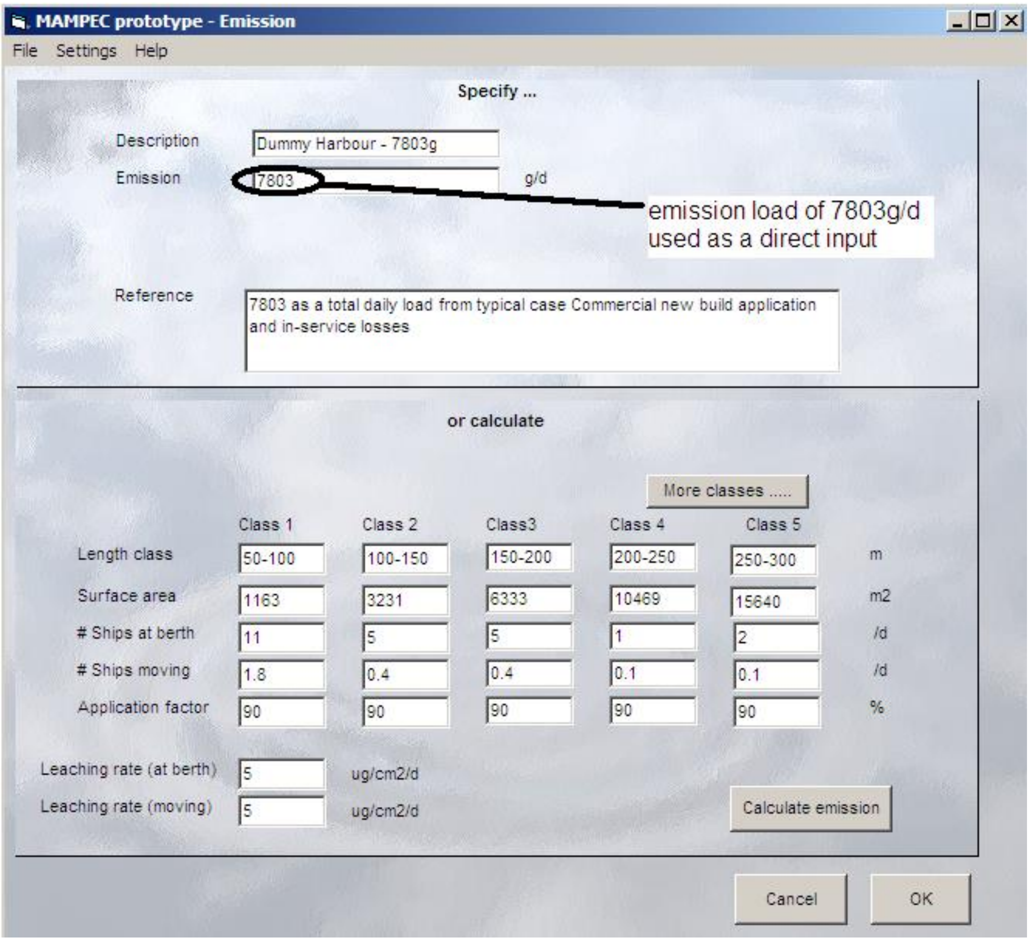
Example calculation no. 1: Application to a new build ship in a commercial shipyard **plus** in-service losses.

To demonstrate the multiple simultaneous assessment, assuming the typical case scenario and a theoretical coverage of paint of 5 m^2 l^{-1} and a concentration of the dummy active substance in the paint of 75 g l^{-1}, the emission load is calculated as shown in the table below. [Note that for example purposes only the 'typical' case scenario defaults have been presented here. However both the 'typical' and 'realistic worst case' defaults should be used in any complete assessment of potential cumulative losses, to reflect the broad range of practices that may be in operation across EU boatyards. In line with the descriptions used in the OECD ESD, the realistic worst case is assumed to involve application of paint on an exposed slipway, in the open air on a hard standing area near or above water, compared with the typical case where application is carried out in a dock, which is less exposed than the slipway.]

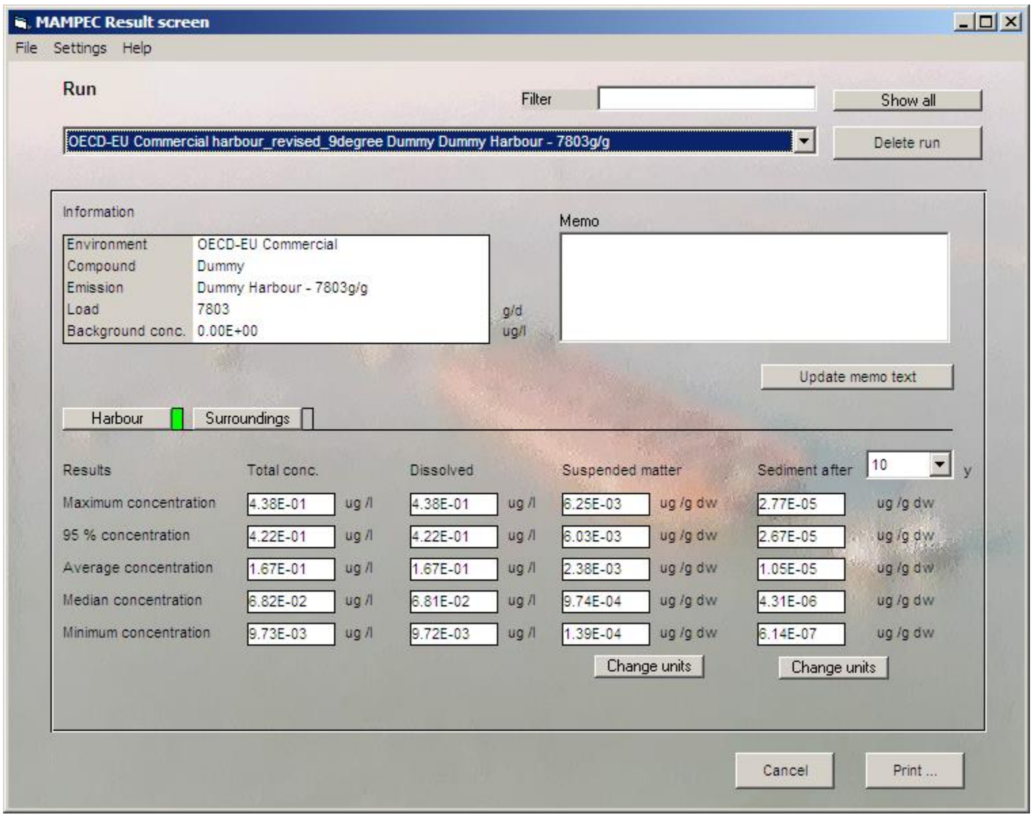
(a) Commercial application [see Table 0.8 in the PT 21 ESD]				
Variable/ parameter	**Unit**	**Symbol**	**Value for typical case**	**S/D/ O/P**
Input:				
The painting period	**[d]**	T_{paint}	1	D
Number of ships treated in an EU/US shipyard per painting period	**[-]**	N_{ship}	1	D
The average hull surface of a ship	**[m^2]**	$AREA_{ship}$	2500	D
Theoretical coverage of the paint	**[m^2 l^{-1}]**	**COVERAGE**	5	S
Number of coats applied on the hull	**[-]**	N_{coats}	1 (only the final coat)	D
The concentration of a.s. in the paint	**[g l^{-1}]**	$Ca.s.$	75	S
Fraction to surface water	**[-]**	F_{water}	0.075	D
Fraction to soil	**[-]**	F_{soil}	0	D
Output:				
The theoretical amount of paint applied per ship	**[l]**	V_{paint}	500	O
Total emission to surface water	**[g d^{-1}]**	$Elocal_{water}$	**2813**	O
Intermediate calculations:				
Vpaint = Ncoats * (AREAship / COVERAGE)				
End calculations:				
Elocalwater = Vpaint * Nship * Fwater * Ca.i.) / Tpaint				

For the in-service losses which were simulated assuming a dummy leach rate of 5 µg cm^{-2} d^{-1} for all boats, this resulted in a daily emission load of **4990 g/d** to the commercial harbour. Running this in a standard MAMPEC simulation gave an average total concentration within the commercial harbour of **0.105µg/l**.

Using the MAMPEC model, the Elocalwater value from the commercial application activity can be added to the daily emission load from the in-service losses to give a total of 2813 + 4990 = **7803 g/d** which can be used as an input parameter on the Emission input screen, as shown in the screenshot below[2]. This can be combined with the OECD commercial harbour scenario and dummy substance compound parameters to generate a PECsw (see further screen shot over page).



[2] Note that in MAMPEC v2.5 for the commercial harbour emissions are entered into the last row of cells in the simulated matric. Greater control on the location of emissions is possible in MAPEC v3.0



As can be seen above, using the MAMPEC model for a multiple simultaneous daily emission load of **7803 g d^{-1}** to the OECD commercial harbour results in an average total PECsw of **0.167 µg l^{-1}** within the Commercial harbour. Note that in a full assessment it would be appropriate to present the result from both within the harbour and in the area adjacent to the harbour.

Since the simulation of in-service loss only resulted in a PECsw of 0.105 µg/l, the effective PECsw arising from the application losses alone can be calculated by simple subtraction i.e. 0.167 – 0.105 = **0.062 µg/l**. This separate PECsw value may be useful when risk mitigation is required, since only the application losses can be easily mitigated (see example in risk mitigation section).

Although the approach described above does not explicitly consider complete maintenance cycles of removal followed by re-application, the assumption of constant daily application releases can be used to effectively address this situation in a conservative manner.

If the multiple simultaneous scenario based on application and in-service losses requires risk mitigation in order to achieve acceptable PEC:PNEC ratios, an additional scenario based on multiple simultaneous removal and in-service losses should also be assessed. This is necessary because the forms of mitigation proposed to reduce exposure arising from application activities may not be appropriate to also reduce exposure arising from removal activities. In addition the level of reduction achieved by the risk mitigation measures differs between application and removal activities (based on the information provided in the CESA and CEPE surveys, 2011).

Pleasure craft scenario

With regard to the professional pleasure craft and amateur pleasure craft activities, the only situations that result in significant direct exposure of surface water according to the ESD are following removal of paints based on the realistic worst case scenario defaults (where F_{water} = 1 to conservatively cover the situation at a boatyard with minimal control measures. See Tables 0.20 and 0.22 of the PT21 ESD). This simplifies the selection of scenarios for consideration of multiple simultaneous exposure, since both the professional pleasure craft and amateur pleasure craft use categories can be covered by realistic worst case removal activities, added to the in-service losses following the same basic principle as shown above for commercial shipping application activities. For the professional situation, removal is assumed to take place almost continuously for 6 months, whilst amateur removal activities occur almost continuously for 3 months. Such a long duration of activity supports the inclusion of these emission routes in the multiple simultaneous exposure assessment.

For all other activities in these sectors (e.g. application activities based on realistic worst case or typical case defaults and removal activities based on typical case defaults) all assume loss to waste water or soil only for professionals and amateurs. The need to consider multiple simultaneous exposure from losses direct to surface water and via an STP emitting into surface water was agreed during the development of this guidance. To address the additional inputs via an STP the professional pleasure craft removal scenario highlighted above should be combined with the professional maintenance and repair application scenario, with losses from the STP conservatively assumed to be added direct to the same marina. This is intended as a very simple approach for the purposes of a first tier assessment. However this would be representative of a situation where an STP outflow directly emits into a marina. For the professional maintenance and repair application situation, the ESD assumes activities to take place almost continuously for 6 months, with emissions via an STP that are broadly comparable (in terms of E_{local} values) to the emissions via the realistic worst case professional removal activities (see worked example below). Such a long duration of activities combined with the comparable size of emissions adds weight to the inclusion of this additional STP emission route in the multiple simultaneous exposure assessment. Note that the professional maintenance and repair application situation has been selected in preference to the professional new build pleasure craft application situation for the purposes of the multiple simultaneous assessment because of the longer duration of activities and greater likelihood of proximity of the STP to the marina (note that new build activities are proposed to take place in boat yards or mass production facilities that are not necessarily situated near water).

The inclusion of the additional route of exposure via the STP is only recommended for the professional removal and application activities based on the realistic worst case defaults. Emissions from the typical case defaults are significantly smaller, and multiple simultaneous assessments of such small emissions is not considered warranted based on these small emissions. Similarly the inclusion of the STP route for the amateur scenario is not considered warranted, again because this emission route is significantly smaller than the direct loss to water already assessed (e.g. Fstp = 0.025 compared to Fwater = 1 for the realistic worst case amateur scenarios).

An example calculation is included below. This is based on removal of paint by a professional with emissions directly entering water; application of paint by a professional during M& R activities with emissions entering via an STP, all combined with the standard in-service losses. The professional use scenario has been chosen as an example since this includes the additional route via an STP. However where both professional and amateur uses are proposed, both scenarios described above should be included in a full assessment of multiple simultaneous exposure. In the example below the number of boats treated during the painting period has been reduced to 28. In the original PT21 ESD it was assumed that 10% of the 500 boats in the pleasure craft marina would be professionally treated (hence the original N_{boat} = 50). However the original pleasure craft marina has been amended to contain only 276 boats to reflect the likely occupancy of a marina with the OECD ESD defined dimensions. For consistency the N_{boat} parameter here has been reduced in line with the amended marina. Note that the original painting period has been retained as 183 d. This is because on the basis of the PT21 ESD, the painting period reflects the continuous activity during the 6 months of the winter period and is not considered to be linked to the number of boats treated. Because it is assumed that the N_{boat} and T_{paint} parameters are independent in this example, only the N_{boat} parameter has been amended. This results in the assessments based on the amended parameter being less conservative than the original PT21 ESD defaults. However this is consistent with the affect that the reduced boat occupancy has on the OECD marina scenario for in-service losses, which is also less conservative than the PT21 ESD default. If the T_{paint} parameter were to be reduced in line with the reduced N_{boat} parameter, there would be no impact on the overall risk assessment.

Example calculation no. 2: application and removal of paint from pleasure craft by a professional (M&R activities) **plus** in-service losses.

To demonstrate the possible multiple simultaneous exposure arising from the professional pleasure craft M&R scenario, assuming the worst case scenario defaults the emission load is calculated as shown in the separate tables below. The same dummy substance properties are used as per commercial shipping in example no. 1 above.

(a) Application – professional M&R [see Table 0.14 of the PT21 ESD]				
Variable/parameter	**Unit**	**Symbol**	**Value for realistic worst case**	**S/D/O/P**
Input:				
The painting period	**[d]**	T_{paint}	183	D
Number of days to paint one boat	**[d]**	N_{days}	--	-
Number of boats treated per painting period	**[-]**	N_{boat}	28	D
The concentration of a.s. in the paint	**[g l^{-1}]**	$C_{a.s.}$	75	S
The theoretical amount of paint applied per boat	**[l]**	V_{paint}	4.5	O
Fraction to surface water	**[-]**	F_{water}	0	D
Fraction to STP	**[-]**	F_{STP}	Max. 0.06	D
Fraction to soil	**[-]**	F_{soil}	Max. 0.06	D
Output:				
Total emission to STP	**[g d^{-1}]**	$Elocal_{STP}$	**3.10**	O
Total emission to soil		$Elocal_{soil}$	**3.10**	O
End calculations:				
$Elocal_{STP}$ = (Vpaint * Nboat * F_{STP} * Ca.i. / Tpaint $Elocal_{SOIL}$ = (Vpaint * Nboat * F_{SOIL} * Ca.i. / Tpaint				

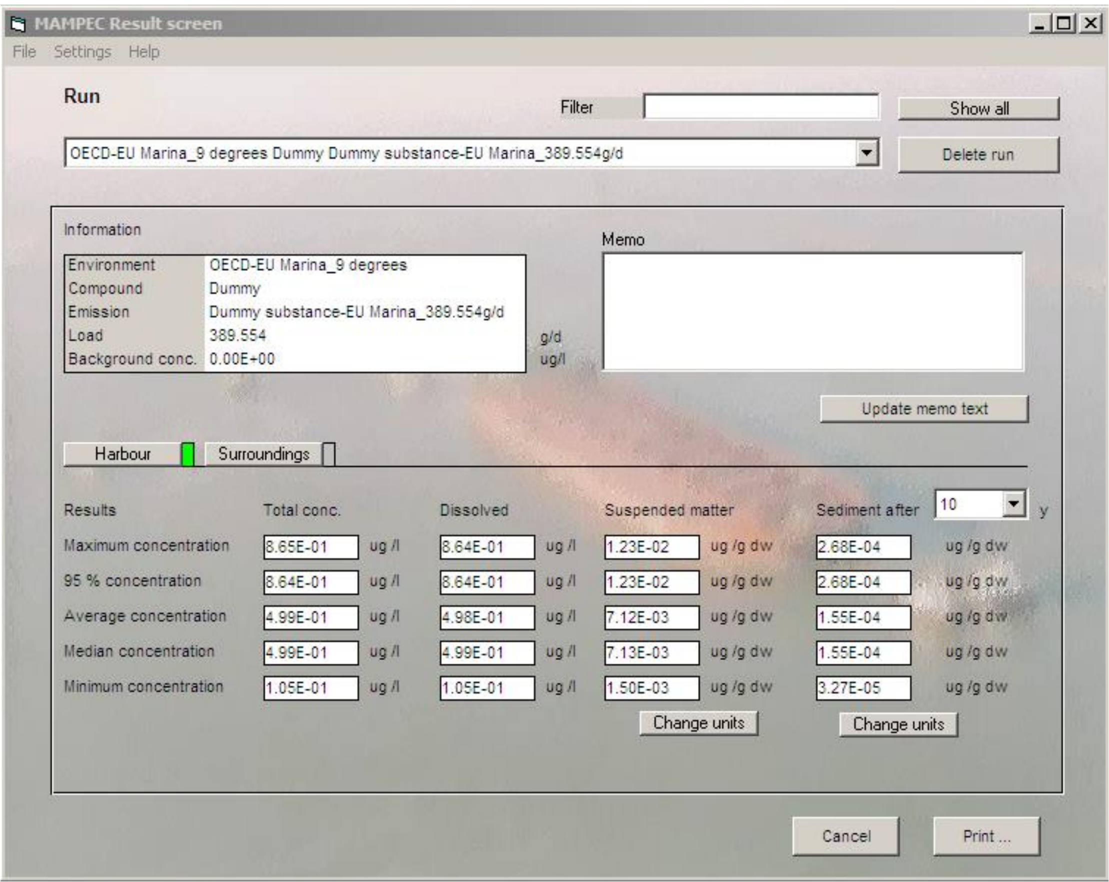
(a) Removal - professional M&R [see Table 0.20 of the PT21 ESD]				
Variable/parameter	**Unit**	**Symbol**	**Value for realistic worst case**	**S/D/O/P**
Input:				
The removal period	**[d]**	$T_{removal}$	183	D
Number of days for the treatment of one boat	**[d]**	N_{days}	n/a	D
Number of boats treated per removal period	**[-]**	N_{boat}	28	D
The amount of paint applied per boat	**[l]**	V_{paint}	4.5 (as application)	D
Fraction of the paint that is to be removed from the boat hull by HPW	**[-]**	$F_{washing}$	0.2	D
Fraction of the paint that is to be removed from the boat hull by abrasion	**[-]**	$F_{abrasion}$	0.1	D
The concentration of a.s. in the original paint	**[g l^{-1}]**	$C_{a.s.}$	75	S
Fraction of a.s. remained in exhausted paint removed by washing	**[-]**	$F_{a.s.exh\ paint}$	0.05	D
Fraction of a.s. remained in old paint removed by abrasion	**[-]**	$F_{a.s.old\ paint}$	0.9[a]	D
Fraction to surface water	**[-]**	F_{water}	Max. 1.00	D
Fraction to STP	**[-]**	F_{STP}	Max. 1.00	D
Fraction to soil	**[-]**	F_{soil}	Max. 1.00	D
Output:				
Total emission to surface water	**g d^{-1}**	$Elocal_{water}$	**5.16**	
End calculations:				
$Elocal_{water}$ = (Vpaint * Nboat * Ca.i. * (Fwashing * Fa.i. exh paint + Fabrasion * Fa.i. old paint) * Fwater) / Tremoval				

[a]increased to reflect discussions at TMIV2011 on the need to increase the $F_{a.s.old}$ paint to ensure maintenance of mass balance

For the in-service losses which were simulated assuming a dummy leach rate of 5 µg cm^{-2} d^{-1} for all boats (n=276), this resulted in a daily emission load of **381.294 g/d** to the marina. Running this in a standard MAMPEC simulation gave an average total concentration within the marina of **0.488 µg/l**.

For the purposes of this worked example only it has been assumed that the substance passes through the STP with no biodegradation, sorption to sludge or loss to air. Hence the $Fstp_{water}$ is conservatively assumed to be 1. In a full assessment the fraction could be set to a more realistic value using the substance properties and the SIMPLETREAT model. In addition, to simplify the calculation no consideration of the effluent discharge rate has been included. This is appropriate for a simple first tier assessment, particularly as the standard effluent discharge rate of 2 million litres per day is relatively small compared to the total exchange volume of the OECD ESD marina (246.2 million litres). Hence additional dilution caused by the STP load being released in a volume of effluent would be minimal in this case.

Using the MAMPEC model, the $Elocal_{water}$ values from the professional application activity and the professional removal activity can be added to the daily emission load from the in-service losses to give a total of 3.10 + 5.16 + 381.294 = 389.554 g/d. This value can be used as an input parameter in the Emission input screen of MAMPEC. This can be combined with the OECD marina scenario and dummy substance compound parameters to generate a PECsw:-.



As can be seen above, using the MAMPEC model for a combined daily emission load of **389.554 g d^{-1}** to the OECD marina results in an average total PECsw of **0.498 µg l^{-1}** within the OECD Marina. Note that in a full assessment it would be appropriate to present the results from both within the harbour and in the area adjacent to the marina..

Since the simulation of in-service loss resulted in a PECsw of 0.488 µg/l, the effective PECsw arising from the removal losses alone can be calculated by simple subtraction i.e. 0.498 – 0.488 = **0.01 µg/l**.

Overall it may be questioned whether based on this example an assessment of multiple simultaneous exposure is really necessary. This is because the loading from the in-service exposure is so much higher than from simultaneous application and removal activities i.e. 381.294 g/d from in-service compared with only 8.26 g/d from combined application and removal activities. Application and removal represents less than 4% of the total combined exposure resulting from professional activities. However it should be noted that these figures are based on a single example and in other situations the proportion of the removal emission load could be higher. For example, if the in-service scenarios were refined by the use of measured leaching rate data, it is possible that the proportion of the total multiple simultaneous exposure resulting from application and removal activities could be more significant. Overall it is recommended that as part of a tiered assessment consideration of this potential combined exposure is still necessary.

The first tier multiple simultaneous scenarios based on professional or amateur activities and in-service losses may need to be refined in order to achieve acceptable PEC:PNEC ratios (i.e. < 1.0). For professional activities it may be possible to refine the assessment by including appropriate forms of risk mitigation as per the professional commercial shipping activities. For amateur activities there has been no agreement on the appropriateness of risk mitigation. Therefore the amateur scenario would need to be refined without the use of risk mitigation e.g. by provision of additional data or information to refine the first tier scenario. However based on the observation above that the multiple simultaneous application and removal losses from professional activities represent less than 4% of the total loading, refinement of the multiple simultaneous exposure assessment is more likely to concentrate on refining the in-service losses.

3. Risk mitigation of application or removal losses

Where the worst case multiple simultaneous scenarios result in unacceptable PEC:PNEC ratios (i.e. >1), some consideration of the need for appropriate risk mitigation may be necessary. [Note that in addition to considering risk mitigation for the worst case scenarios, where mitigation is needed for the commercial shipping application scenario, additional consideration of a further commercial shipping scenario based on removal losses plus in-service losses should be performed. This is because the mitigation measures needed to achieve acceptable risks for the commercial shipping application scenario do not necessarily address the risks posed by removal activities.]

To assess the impact of risk mitigation on reducing environmental emissions from application or removal activities it is proposed that reference is made to the CESA (2011[3]) survey and CEPE (2011[4]) reports. Extensive information on the range of mitigation measures and the likely quantitative effect is available in these papers. Relevant tables from the CEPE (2011) report are reproduced below for completeness. Note that this report also includes quantification of risk mitigation for amateurs. However since no agreement at TM level has been reached on the appropriateness of risk mitigation for amateurs, these tables have not been included here and no further consideration of risk mitigation for non-professionals is recommended in this guidance. For further details please refer to the original CEPE report.

Table 2: Risk mitigation measures (RMM) for paint application during commercial ship building

ESD	CESA Index (Paint spraying)	Reduction effect of the RMM (fraction of potential emission)
No measures	20	1
Dock floor discipline	15	0.75
Dock floor discipline Use of containment (nets) Good spraying practices	8.5	0.425
Dock floor discipline Use of containment (nets) Good spraying practices Waste water treatment	7	0.35
Dock floor discipline Use of containment (nets) Good spraying practices Waste water treatment Low emission techniques	5.5	0.275

Note a similar table is included in CEPE (2011) with identical figures for mitigation of application during M&R activities on Commercial ships

Some further explanation is required to aid understanding of how these tables can be used quantitatively in the exposure assessment.

The results from the CESA survey are indexed so that they allow for the quantification of the reduction factor associated with each specific risk mitigation measure. The reference year 1985 from the CESA survey is associated with an index of 100. This is made up of an index of 20 for paint application, 10 for surface cleaning (high pressure washing) and 70 for paint removal. For potential emissions from paint application, this refers to an application by airless spray in an uncovered dry dock. This means that the

[3] CESA (2011).Characterisation of antifouling emission scenarios in European shipyards (TMII2011-ENV-item 5b).
[4] CEPE (2011). Risk mitigation measures applicable during application and removal of antifouling paints (TMII2011-ENV-item 5b).

CESA scenario with an emission index of 20 broadly corresponds to the PT21 ESD scenario described by the typical case defaults for application activities to commercial shipping. This index then allows quantification of the effects of risk mitigation. For example, an index of 15 for paint application means that emissions are reduced by 15/20 = 75% (or a 0.75 fraction) by taking an additional set of risk mitigation measures. In this case, an index of 15 is associated with the introduction of dock floor discipline. This fraction can then be applied to the potential emission calculated from the ESD.

The table scan also be used without reference to the CESA index. From Table 2 above it can be seen that with ‘No measures’ in place the fraction of potential emission is 1. This means that no mitigation is assumed and the default emissions are identical to those specified in the PT21 ESD. With the introduction of ‘Dock floor discipline’ as a form of mitigation, the emissions based on the ESD can be reduced to 0.75 compared to the no mitigation level. In this example, for application to commercial shipping, the reduction in emissions is only appropriate to the Typical case situation which assumes activities taking place in a dry dock (rather than the realistic worst case which assumes activities on an exposed slipway – where dock floor discipline has no effect on application emissions). It should also be noted that the quantitative effect of risk mitigation is cumulative. So the use of basic dock floor discipline measures reduces the typical case ESD defaults to a fraction of 0.75 of the ‘No measures’ or ESD default situation. The additional use of spray containment nets and implementation of good spraying practice in addition to dock floor discipline increases the level or mitigation to a fraction of 0.425 of the ‘No measures’ or ESD default situation.

Table 4: Risk mitigation measures for the new building of pleasure crafts

	Mixture of airless spray and brush/roller (WC)	Brush/roller (TC)	CESA index (Paint spraying blowing away)	Reduction effect of the RMM (fraction of potential emission)
No specific measures				
Emission to soil	1	1	18	1
Emission to STP	1	1	18	1
Implementation of dedicated area for paint application on hard standing with shrouding				
Emission to soil	0.36	0	6.5 (WC)	0.36 (WC)
Emission to STP	1	1	18	1
Waste water additional treatment (settling tank + oil separator)				
Emission to STP	0.15	0.15	2.7* (WC&TC)	0.15

*Assumed 85% reduction from index 18.

Note a similar table is included in CEPE (2011) with identical figures for mitigation of application during professional M&R activities on pleasure craft

Table 6: Risk mitigation measures for the paint removal of commercial ships

ESD	CESA Index (Paint spraying)	Effect of the RMM on potential emission reduction (fraction of potential emission)
No measures	80	1
Thorough cleaning of dock floor	35	0.4375
Thorough cleaning of dock floor Use of containment (nets)	25	0.3125
Thorough cleaning of dock floor Use of containment (nets) Waste water treatment	12.5	0.15625
Thorough cleaning of dock floor Use of containment (nets) Waste water treatment Low emission blast-cleaning techniques	7.5	0.09375

Table 9: Risk mitigation measures for paint removal pleasure crafts

	HPW+abrasion (WC)	HPW (TC)	CESA index
No risk mitigation measure			80
Emission to surface water	1 or 0	0	
Emission to soil	1	0	
Emission to STP	1	1	
Dedicated area with collection of water and wastes			20 (soil/water-WC) 60 (STP-WC)
Emission to surface water	0.25 or 0	0	
Emission to soil	0.25	0	
Emission to STP	0.75	1	
Dedicated area with collection of water and wastes Shrouding (fine meshed nets or other)			10 (soil/water-WC) 60 (STP-WC)
Emission to surface water	0.125 or 0	0	
Emission to soil	0.125	0	
Emission to STP	0.75	1	
Waste water treatment			10 (soil/water) 9* (STP-WC) 12** (STP-TC)
Emission to surface water	0.125 or 0	0	
Emission to soil	0.125	0	
Emission to STP	0.1125*	0.15**	

*0.15 of the 0.75 fraction directed to STP (85% elimination)
**0.15 of the 1 fraction directed to STP (85% elimination)

To demonstrate how this information could be used in the quantitative risk assessment a further example based on previous example no. 1 (see page 7) is presented. Example no. 1 was based on the scenario for application to a new build ship in a commercial shipyard **plus** in-service losses. To mitigate losses for this use pattern reference should be made to Table 2 from the CEPE (2011) report. In the original example no.1 only the typical case defaults have been assessed, but in any complete assessment the 'realistic worst case' defaults should also be included in the assessment of potential cumulative losses, to reflect the broad range of practices that may be in operation across EU boatyards. In line with the descriptions used in the OECD ESD, the realistic worst case is assumed to involve application of paint on an exposed slipway, in the open air on a hard standing area near or above water, compared with the typical case where application is carried out in a dock, which is less exposed than the slipway. According to Table 2 increasing levels of risk mitigation are possible over and above the emissions from the "no measures" situation, with increasing fractional reductions in emissions as increasing levels of mitigation are introduced (e.g. dock floor discipline, use of containment nets, good spraying practises etc). The "no measures" situation in each table from CEPE (2011) would be comparable to the respective OECD ESD default scenarios.

From example no. 1, using the MAMPEC model for a multiple simultaneous daily emission load of **7803 g d^{-1}** to the OECD commercial harbour resulted in an average total PECsw of **0.167 µg l^{-1}** within the Commercial harbour. Since the simulation of in-service loss only resulted in a PECsw of 0.105 µg/l, the effective PECsw arising from the application losses alone can be calculated by simple subtraction i.e. 0.167 – 0.105 = **0.062 µg/l**. This separate PECsw value may be used in determining the level of risk mitigation required.

For the purposes of this example, it has been assumed that the $PNEC_{water}$ is 0.14µg/l. So the multiple simultaneous scenario in example no. 1 results in a PEC:PNEC ratio of 0.167/0.14 = **1.19** and hence an unacceptable risk assessment.

As a simple refinement, risk mitigation measures equivalent to reducing the typical case default application emissions of the OECD ESD by 50 % could be introduced. Effectively this level of risk mitigation would reduce the potential emission by a fraction of 0.5 compared with the typical case OECD ESD defaults. Based on the information in Table 2 above, in order to achieve a 0.5 fraction reduction over and above the "No measures" scenario (which is equivalent to the OECD ESD typical case defaults in this example) it would be necessary to ensure application to commercial ships only took place in ship yards where dock floor discipline was in place, containment nets are used and good spraying practices adhered to. Note that good dock floor discipline alone would not achieve an adequate level of refinement (fractional reduction of only 0.75 according to Table 2 above). Including mitigation via use of containment nets and good spraying practice to dock floor discipline measures would lead to a proposed fraction reduction of 0.425 according to Table 2.

If this level of fractional reduction is applied to the application losses, the separate application PECsw would reduce to 0.062 * 0.425 = 0.0264µg/l and the reduced multiple simultaneous PECsw would be refined to 0.0264 + 0.105 µg/l = 0.131µg/l. With mitigation in place, the revised PEC:PNEC ratio becomes 0.131/0.14 = 0.94 and hence the risk is acceptable.

To implement this form of risk mitigation appropriate label phrases could be included such as:-

To protect the aquatic environment professional application activities on commercial ships must only take place in dry docks where dock floor discipline is practised and containment nets and good spraying practice are followed.

In addition, application activities on exposed slipways (which would be assessed via the realistic worst case scenario defaults) where suitable containment measures cannot be guaranteed should not be allowed where the PEC:PNEC ratio is unacceptable. Therefore a further phrase could be added thus:-

Do not apply this product on exposed slipways.

If the additional assessment of simultaneous removal and in-service losses also resulted in the need for risk mitigation, reference to Table 6 would allow the quantitative effect of risk mitigation to be used to refine removal losses. Additional label phrase may then also be appropriate.

The example above is presented to show how the information from the CEPE (2011) report could be used to quantitatively reduce application or removal losses via the introduction of risk mitigation measures. The information from the CEPE (2011) could be applied to the additional multiple simultaneous emission scenarios for professional and amateur activities on pleasure craft based on the various tables and scenarios outlined above.

4. Multiple simultaneous soil exposure assessment

Consideration of the potential for multiple simultaneous exposure of the soil environment is also required. The scenario focuses on the potential for direct exposure of the same area of soil i.e. to take account of multiple application and repair activities in the same location. According to the ESD activities on commercial ships do not result in direct exposure of soil and therefore these uses can be excluded from further consideration. The guidance has therefore concentrated on professional and amateur pleasure craft activities.

For the professional M&R of pleasure craft, for both application and removal and realistic worst case and typical case, the ESD default suggests that 50 boats are treated within a 6 month (183 d) period (see Table 0.14 and 0.20 of the PT21 ESD reproduced in Appendix 2 for completeness). The ESD assumes all these activities take place in the same area. For consistency with the amendments made earlier in the guidance (see Example 2) the Nboat parameter has been reduced to 28 for consistency with the revised pleasure craft marina.

For amateur M&R of pleasure craft the ESD recognises that not all activities take place in the same area, with boats taken home for maintenance or painted in storage areas for example. Both these situations are addressed in the scenarios recommended in this guidance. For application and removal activities, the ESD default suggests that 5 boats are treated on the same spot per 3 month (91 d) treatment period (see Table 0.16 and 0.22 of the ESD reproduced in Appendix 2 for completeness).

For all these scenarios the PT21 ESD proposes the calculation of an $Elocal_{soil}$ value which is an average daily emission rate calculated over the entire treatment period (based on either T_{paint} or $T_{removal}$). The use of such an average value could lead to the risk to soil dwelling organisms being underestimated, since exposure levels immediately after an application or removal event will be higher than the average value. It is not considered logical that applying paint to 28 boats in the same location would give you a lower level of exposure than painting a single boat. The use of average values may also make it more difficult to consider potential combined exposure levels from simultaneous maintenance cycles.

To address this the guidance considers following solution to derive potential multiple simultaneous exposure levels in soil. The professional and amateur treatment periods are the same for both application and removal activities. Therefore it is possible to estimate emissions from complete maintenance cycles (i.e. removal followed by application on successive days) and to assume these are evenly spaced throughout the respective treatment periods to calculate potential accumulation occurring between maintenance cycles.

For example, for the professional activities, 28 boats are treated within 183 d. Assuming 1 d of removal and 1 d of application per boat maintenance cycle, there would be 56 d of activity and 127 d of intervals between maintenance cycles. With 27 interval periods in-between the maintenance cycles on 28 boats, the average interval would be 4.7 d. For repeated exposure events of this nature, residues will accumulate if at the end of the interval there are levels remaining from the previous exposure event. Provided that the concentration arising from a single maintenance period can be calculated, a multiple application factor (MAF) can be used to account for accumulation of residues throughout the entire treatment period. Assuming single first order kinetics:-

MAF[5] = $(1-e^{-nki})/(1-e^{-ki})$

MAF: Multiple application factor – the exposure level after n applications compared to a single application
k: first order rate constant ($\ln2/DT_{50,soil}$) (d^{-1})
n: number of applications
i: interval between application (d)

The MAF approach builds on the first tier assumption that the active substance is fully available for degradation processes (of any kind: biological or abiotic). This may not be true for active substances inside paint particles emitted to the environment, where the release rate (*k* in “1/h”) from the particle may be rate limiting. Although thre MAF approach does not explicitly try to address release from intact paint particles, overall discussions at TMII21013 concluded that the approach was suitably conservative for the purposes of a first tier exposure assessment. The conservatism of this approach may need to be reconsidered in the future, if release from paint particles is ever incorporated into fuure PT21 exposure assessments.

To calculate the concentration arising from a single maintenance event, the information from Table 0.14 and 0.20 from the PT21 ESD can be combined to derive an amended $Elocal_{soil}$ value (essentially the Nboat and Tpaint or Tremoval parameters are removed):-

$Elocal_{soil}$ for single maintenance period = ($Vpaint_{application}$ * $Fsoil_{application}$ * Ca.i.) + ($Vpaint_{removal}$ * Ca.i. * ($F_{washing}$ * $F_{a.i.exh.\ paint}$ + $F_{abrasion}$ * $F_{a.i.\ old\ paint}$) * $Fsoil_{removal}$)

The Elocalsoil value can then be used to calculate an initial PECsoil following a single maintenance cycle assuming even mixing in the standard soil volume for this professional scenario described in the ESD (12.5m long x 5.5m wide by 0.1m deep[6]) and no degradation between removal and application as a simple worst case. This can be combined with the MAF to estimate cumulative loading over the entire maintenance period.

[5] the equation for the MAF has been taken from the SANCO guidance document on risk assessment for birds and mammals (SANCO/4145/2000), however it is still mathematically correct to use it here.

[6] some consideration could be given to harmonising the depth parameter with that of the PT8 ESD (i.e. 0.5m). However since the ESD states the receiving soil environment is ‘compacted earth’ and some emissions of intact paint particles will occur, assuming greater mixing over a deeper soil layer may be somewhat unrealistic in this case.

As an example, using the same dummy substance as used in the aquatic exposure section above, the following calculations are possible:-

$Elocal_{soil}$ for single maintenance period[7] = (4.5 * 0.06 * 75) + (4.5 * 75 * (0.20 * 0.05 + 0.10 * 0.30) * 1) = 20.25 + 13.5 = 33.75 g per maintenance cycle

PECsoil for a single maintenance cycle (g kg^{-1}) = 33.75 / (12.5 * 5.5 * 0.1 * 1504) = 3.26×10^{-3} g kg^{-1} = 3.26 mg kg^{-1}

For the purposes of the worked example, a soil DT_{50} of 10 d will be assumed. On this basis:-

$MAF = (1 - e^{(-28 * 0.0693 * 4.7)} / (1 - e^{(-0.0693 * 4.7)}) = 3.60$

Total PEC_{soil} for entire treatment period = 3.26 * 3.60 = 11.7 mg kg^{-1}

For the amateur activities, 5 boats are treated within 91 d. Assuming 1 d of removal and 1 d of application per boat maintenance cycle, there would be 10 d of activity and 81 d of intervals between maintenance cycles. With 4 intervals, the average interval would be 20.25 d.

To calculate the concentration arising from a single maintenance event, the information from Table 0.16 and 0.22 can be combined to derive an amended $Elocal_{soil}$ value:-

$Elocal_{soil}$ for single maintenance period = ($Vpaint_{application}$ * $Fsoil_{application}$ * Ca.i.) + ($Vpaint_{removal}$ * Ca.i. * ($F_{abrasion}$ * $F_{a.i.\ old\ paint}$[8]) * $Fsoil_{removal}$)

The Elocalsoil value can then be used to calculate an initial PECsoil following a single maintenance cycle assuming even mixing in the standard soil volume for the amateur scenario described in the ESD (9.5m long x 4.5m wide by 0.1m deep). This can be combined with the MAF to estimate cumulative loading over the entire maintenance period.

A further worked example is included below.

$Elocal_{soil}$ for single maintenance period = (2.5 * 0.025 * 75) + (2.5 * 75 * (0.10 * 0.30) * 1) = 4.69 + 5.63 = 10.32 g per maintenance cycle

PECsoil for a single maintenance cycle (g kg^{-1}) = 10.32 / (9.5 * 4.5 * 0.1 * 1504) = 1.61×10^{-3} g kg^{-1} = 1.61 mg kg^{-1}

For the purposes of the worked example, a soil DT_{50} of 10 d will be assumed. On this basis:-

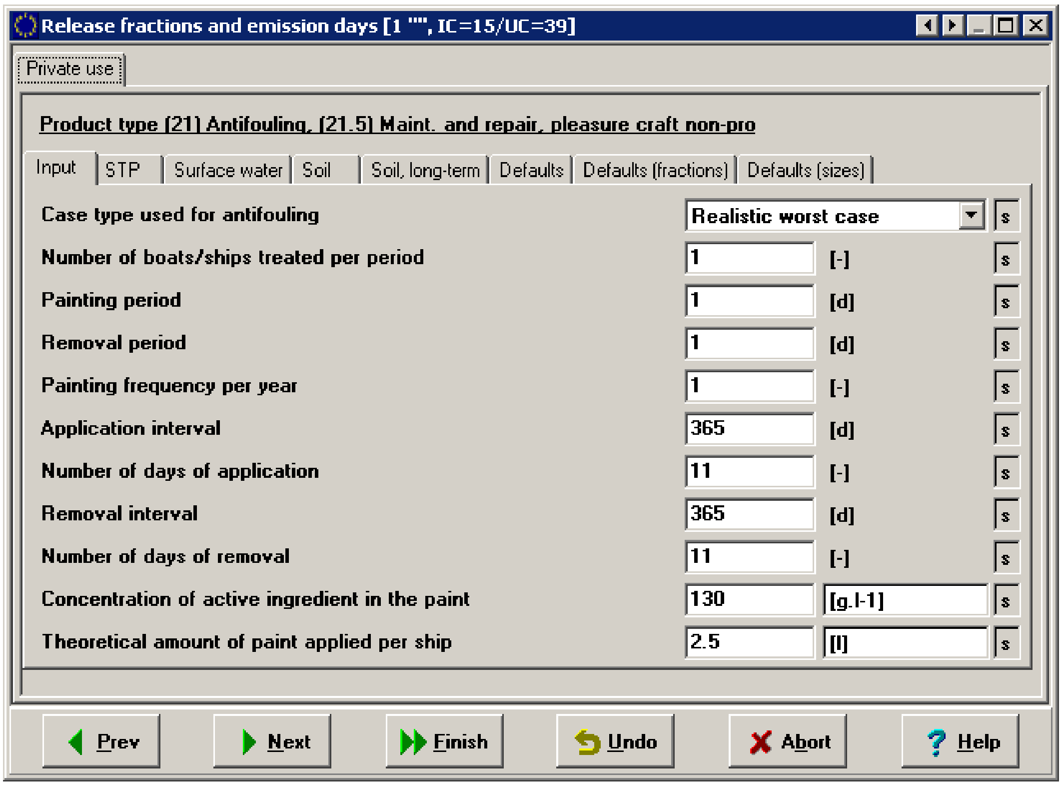
$MAF = (1 - e^{(-5 * 0.0693 * 20.25)} / (1 - e^{(-0.0693 * 20.25)}) = 1.32$

[7] using the default values for the realistic worst case scenario.
[8] using the default values for the typical removal case to make it compatible with the application scenario.

Total PEC_{soil} for entire treatment period = 1.61 * 1.32 = 2.13 mg kg^{-1}

This part of the guidance has been developed to address the issue identified in the original ESD which derives an average $Elocal_{soil}$ value that may underestimate exposure, and also to address the potential for cumulative exposure which is the principle aim of this paper. This approach has the advantage that it maintains much of the original ESD scenarios in terms of the typical professional and amateur maintenance cycles and only requires one extra parameter (MAF) to solve the two issues. However by deviating from the ESD in deriving the $Elocal_{soil}$ value in a different manner, it should be recognised that this approach will result in significant increases in soil exposure predictions that may go beyond the original level of protection afforded by the agreed OECD ESD. However this approach was agreed at TMIV2011.

At TMII2013 an additional adapted M&R soil scenario was agreed for amateur users. This scenario covers the situation when a single vessel is repeatedly treated at home by an amateur. The scenario assumes 10 successive years of treatment. This scenario should also be assessed if the DT_{90} in soil is > 1 year AND the single year PEC;PNEC is greater than 0.1. A screenshot from the EUSES model for this adapted scenario is shown in the figure below. The MAF approach can be used for this adapted scenario by setting the number of applications to 11 and the interval to 365 d.



Glossary

HPW: High pressure water washing: In the PT 21 ESD a distinction is made between paint removed by high pressure water washing (HPW) and paint removed by abrasion. The paint removed by high pressure water washing is determined by the parameter *Fwashing*. The fraction removed by abrasion is determined by the parameter *Fabrasion*.

MAF: Multiple application factor – the exposure level after n applications compared to a single application

M&R: Maintenance and repair

RMM: Risk mitigation measures – specific measures implemented to reduce emissions from PT21 application, maintenance and repair activities

TC: Typical case – this terminology is used in the PT21 OECD ESD to define a set of typical case default parameters and assumptions

WC: Worst case – this terminology is used in the PT21 OECD ESD to define a set of realistic worst case default parameters and assumptions. These are more conservative than the typical case defaults and together they are intended to represent some of the large variability on practises that can be expected in this area.

References

CESA (2011).Characterisation of antifouling emission scenarios in European shipyards (presented at TMII2011-ENV-item 5b).

CEPE (2011). Risk mitigation measures applicable during application and removal of antifouling paints (presented at TMII2011-ENV-item 5b).

Harmonisation of Environmental Emission Scenarios: An Emission Scenario Document for Antifouling Products in OECD countries European Commission Directorate-General Environment 23 September 2004 Final Report 9M2892.01

Appendix 1: Worked example of application and removal scenarios to justify inclusion of application only in first tier worst case multiple simultaneous exposure assessment for Commercial shipping activities

(b) Application					
Variable/parameter	**Unit**	**Symbol**	**Value for realistic worst case**	**Value for typical case**	**S/D/ O/P**
Input:					
The painting period	**[d]**	T_{paint}	2	2	D
Number of boats treated per painting period	**[-]**	N_{boats}	1	1	D
The average hull surface of a typical OECD ship	**[m²]**	$AREA_{ship}$	2500	2500	D
Theoretical coverage of the paint	**[$m^2\ l^{-1}$]**	**COVERAGE**	5	5	S
Number of coats applied on the hull	**[-]**	N_{coats}	2	2	D
The concentration of a.s. in the paint	**[$g\ l^{-1}$]**	**C*a.s.***	75	75	S
Fraction to surface water	**[-]**	F_{water}	0.35	0.075	D
Fraction to soil	**[-]**	F_{soil}	0	0	D
Output:					
The theoretical amount of paint applied per ship	**[l]**	V_{paint}	1000	1000	O
Total emission to surface water	**[$g\ d^{-1}$]**	$Elocal_{water}$	**13125**	**2813**	O

(a) Removal					
Variable/parameter	**Unit**	**Symbol**	**Value for realistic worst case**	**Value for typical case**	**S/D/ O/P**
Input:					
The removal period	[d]	$T_{removal}$	1	1	D
Number of boats treated per removal period	[-]	N_{boat}	1	1	D
The average hull surface of a typical OECD ship	[m^2]	$AREA_{ship}$	2500	2500	S/D
Theoretical coverage of the paint	[$m^2\ l^{-1}$]	COVERAGE	5	5	S
Number of coats applied on the hull	[-]	N_{coats}	2	2	D
Fraction excess paint applied	[-]	F_{excess}	0.2	0.2	D
Fraction of the paint that is to be removed from the ships hull by HPW (exhausted paint)	[-]	$F_{washing}$	0.2	0.2	D
Fraction of the paint that is to be removed from the ships hull by abrasion	[-]	$F_{abrasion}$	Reblasting: 0.10	Spot blasting: 0.005	D
Ratio reblasting/spot blasting	[-]	$RATIO_{blasting}$	1/10		D
The concentration of a.s. in the original paint	[$g\ d^{-1}$]	Ca.s.	75	75	S
Fraction of a.s. remained in exhausted paint removed by HPW	[-]	$Fa.s._{exhpaint}$	0.05	0.05	D
Fraction of a.s. remained in old paint removed by abrasion [AMENDED FOLLOWING TMIV2011]	[-]	$Fa.s._{old\ paint}$	0.9	0.9	D
Fraction to surface water	[-]	F_{water}	1.00	1.00	S/D
Fraction to soil	[-]	F_{soil}	0	0	D
Output:					
The total amount of paint applied per ship	[l]	$Vpaint_{total}$	1200	1200	O
Total emission to surface water	[$g\ d^{-1}$]	$Elocal_{water}$	**9000**	**1305**	O
Total emission to surface water: yearly average calculation		$Elocal_{waterya}$	2075	2075	O

Since $Elocal_{water}$ is always higher for application activities (for comparable scenario defaults) the inclusion of application losses only in the first tier approach is justified. Removal losses should be assessed only if the higher application losses require mitigation or refinement.

Appendix 2: Summary tables from the PT21 OECD ESD used to derive the multiple simultaneous assessment in soil

Table 0.14 Professional M&R of pleasure craft in an average OECD boat yard/marina: application of paint

Variable/parameter	Unit	Symbol	Value for realistic worst case	Value for typical case	S/D/O/P
Input:					
The painting period	[d]	Tpaint	183[1] (6 months)	183[1] (6 months)	D
Number of boats treated per painting period	[-]	Nboat	50[2]	50[2]	D
The concentration of a.i. in the paint	$[g.l^{-1}]$	Ca.i.			S
The theoretical amount of paint applied per boat	[l]	Vpaint	4.5	4.5	D
Fraction to surface water	[-]	F_{water}	0	0	D
Fraction to STP[3]	[-]	F_{STP}	Max. 0.06	Max. 0.025	D
Fraction to soil[3]	[-]	F_{soil}	Max. 0.06[4]	Max. 0.025	D
Output :					
Total emission to STP	$[g.d^{-1}]$	$Elocal_{STP}$			O
Total emission to soil	$[g.d^{-1}]$	$Elocal_{soil}$			O
End calculations:					
$Elocal_{STP}$ = (Vpaint * Nboat * F_{STP} * Ca.i.) / Tpaint $Elocal_{soil}$ = (Vpaint * Nboat * F_{soil} * Ca.i.) / Tpaint					

1) Based on experience of representatives of industry in the OECD Steering Group on Anti-Fouling Products;
2) Based on 10% of the boats that are at berth in a realistic worst case marina (500). Approximately 10% of the boats are repaired professionally;
3) Depending on the control measurements of the boat yard the emission up to a maximum of 6% either goes to soil or a STP or a mixture between these two options;
4) Potential emission weighted for brush/roller and spray.

Table 0.16 Non-professional M&R of pleasure craft in an average OECD marina: application of paint

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting period	[d]	Tpaint	91[1] (3 months)	D
Number of days to paint one boat[2]	[-]	Ndays	1	D
Number of boats treated per painting period	[-]	Nboat	5[3]	D
The concentration of active ingredient in the paint	$[g.l^{-1}]$	Ca.i.		S
The theoretical amount of paint applied per boat	[l]	Vpaint	2.5[1]	O
Fraction to surface water	[-]	F_{water}	0	D
Fraction to STP[4]	[-]	F_{STP}	Max. 0.025	D
Fraction to soil[4]	[-]	F_{soil}	Max. 0.025	D
Output :				
Total emission to STP	$[g.d^{-1}]$	$Elocal_{STP}$		O
Total emission to soil	$[g.d^{-1}]$	$Elocal_{soil}$		O
End calculations:				
$Elocal_{STP}$ = (Vpaint * Ndays * Nboat * F_{STP} * Ca.i.) / Tpaint $Elocal_{soil}$ = (Vpaint * Ndays * Nboat * F_{soil} * Ca.i.) / Tpaint				

1) Expert judgement CEPE;
2) In this scenario an extra parameter (Ndays) is used to express the fact that during a time period of 3 months it takes 5 days to paint 5 boats. The remaining 9 months of the year painting does not occur;
3) 10% of the boats are repaired professionally (Safinah) and that 20% of the boats are not painted at all per year (expert judgement industry). Thus 350 (70%) of the boats that are at berth in a realistic worst case marina (500) are repaired non-professionally each year. During 3 months 350 boats are painted. This does not necessarily happen at the same spot of 9.5 m length and 4.5 m width (boats can be taken home for application or painted in storage area). Therefore it is assumed that only 5 boats are painted on the same spot per painting period (based on Finnish data: In Finland typically 1-5 boats are painted on the same spot);
4) Depending on the control measurements (hard standing area) the emission up to a maximum of 2.5% either goes to soil or a STP or a mixture between these two options. For non-professional application it is most likely that the emission goes to soil.

Table 0.20 Professional removal of the paint layer in an average OECD boatyard

Variable/parameter	Unit	Symbol	Value for realistic worst case	Value for typical case	S/D/O/P
Input:					
The removal period	[d]	Tremoval	183[1] (6 months)	183[1] (6 months)	D
Number of boats treated per removal period	[-]	Nboat	50[2]	50[2]	D
The amount of paint applied per boat	[l]	Vpaint	4.5 (as for application)	4.5 (as for application)	D
Fraction of the paint that is to be removed from the boat hull by HPW[3]	[-]	Fwashing	0.20	0.20	D
Fraction of the paint that is to be removed from the boat hull by abrasion[3]	[-]	Fabrasion	0.10	n/a	D
The concentration of active ingredient in the original paint	$[g.l^{-1}]$	Ca.i.			S
Fraction of a.i. remained in exhausted paint removed by washing[3]	[-]	$Fa.i._{-exh\ paint}$	0.05	0.05	D
Fraction of a.i. remained in old paint removed by abrasion[3]	[-]	$Fa.i._{-old\ paint}$	0.30	n/a	D
Fraction to surface water[4]	[-]	F_{water}	Max. 1	Max. 1	D
Fraction to STP[4]	[-]	F_{STP}	Max. 1	Max. 1	D
Fraction to soil[4]	[-]	F_{soil}	Max. 1	Max. 1	D
Output :					
Total emission to soil	$[g.d^{-1}]$	$Elocal_{soil}$			O
Total emission to STP	$[g.d^{-1}]$	$Elocal_{STP}$			O
Total emission to water	$[g.d^{-1}]$	$Elocal_{water}$			O
End calculations:					

$Elocal_{soil}$ = (Vpaint * Nboat * Ca.i. * (Fwashing * $Fa.i._{-exh\ paint}$ + Fabrasion * $Fa.i._{-old\ paint}$) * F_{soil}) / Tremoval

$Elocal_{STP}$ = (Vpaint * Nboat * Ca.i. * (Fwashing * $Fa.i._{-exh\ paint}$ + Fabrasion * $Fa.i._{-old\ paint}$) * F_{STP}) / Tremoval

$Elocal_{water}$ = (Vpaint * Nboat * Ca.i. * (Fwashing * $Fa.i._{-exh\ paint}$ + Fabrasion * $Fa.i._{-old\ paint}$) * F_{water}) / Tremoval

1) Based on expert judgement CEPE;

2) Based on 10% of the boats that are at berth in a realistic worst case marina (500). Approximately 10% of the boats are repaired professionally;

Table 0.22 Non-professional removal of the paint layer in an average OECD boatyard/marina

Variable/parameter	Unit	Symbol	Value for realistic worst case	Value for typical case	S/D/O/P
Input:					
The removal period	[d]	Tremoval	91[1] (3 months)	91[1] (3 months)	D
The number of days for the treatment of one boat[5]	[-]	Ndays	n/a	1	
Number of boats treated per removal period	[-]	Nboat	350[2]	5	D
The amount of paint applied per boat	[l]	Vpaint	2.5	2.5	D
Fraction of the paint that is to be removed from the boat hull by HPW[3]	[-]	Fwashing	0.20	n/a	D
Fraction of the paint that is to be removed from the boat hull by abrasion[3]	[-]	Fabrasion	n/a	0.10	D
The concentration of active ingredient in the original paint	$[g.l^{-1}]$	Ca.i.			S
Fraction of a.i. remained in exhausted paint removed by washing[3]	[-]	$Fa.i._{exh\ paint}$	0.05	n/a	D
Fraction of a.i. remained in old paint removed by abrasion[3]	[-]	$Fa.i._{old\ paint}$	n/a	0.30	D
Fraction to surface water[4]	[-]	F_{water}	Max. 1	n/a	D
Fraction to STP[4]	[-]	F_{STP}	Max. 1	Max. 1	D
Fraction to soil[4]	[-]	F_{soil}	Max. 1	Max. 1	D
Output :					
Total emission to STP	$[g.d^{-1}]$	$Elocal_{STP}$			O
Total emission to soil	$[g.d^{-1}]$	$Elocal_{soil}$			O
Total emission to surface water	$[g.d^{-1}]$	$Elocal_{water}$			O
End calculations:					
$Elocal_{soil}$ = (Vpaint * Nboat * Ndays * Ca.i. * (Fwashing * $Fa.i._{exh\ paint}$ + Fabrasion * $Fa.i._{old\ paint}$) * F_{soil}) / Tremoval					
$Elocal_{STP}$ = (Vpaint * Nboat * Ndays * Ca.i. * (Fwashing * $Fa.i._{exh\ paint}$ + Fabrasion * $Fa.i._{old\ paint}$) * F_{STP}) / Tremoval					
$Elocal_{water}$ = (Vpaint * Nboat * Ndays * Ca.i. * (Fwashing * $Fa.i._{exh\ paint}$ + Fabrasion * $Fa.i._{old\ paint}$) * F_{water}) / Tremoval					

1) Based on expert judgement of CEPE;

2) Based on the fact that 10% of the boats are repaired professionally (Safinah 2004) and that 20% of the boats are not painted at all per year (expert judgement industry). Thus 70% of the boats that are at berth in a realistic worst case marina (500) are repaired non-professionally each year;

3) HP washing will remove only the leached layer. For pleasure boats the leached layer represents typically 20% of the paint film applied (Safinah, 2004) and contains a fraction of 0.05 (expert judgement CEPE) of the original concentration of of a.i. the paint. Abrasion will remove 30% of the old paint film. This 30% consists of the leached layer and an additional layer which contains a fraction of 0.30 (expert judgement CEPE) of the original concentration of of a.i. the paint;