Harmonisation of Environmental Emission Scenarios:
An Emission Scenario Document for Antifouling Products in OECD countries

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This document will be sent to the full OECD Task Force on Biocides (TFB) and the OECD Task Force on Environmental Exposure Assessment (TFEEA) for their review, followed by distribution to the Joint Meeting Heads of Delegation for declassification under written procedure.

0 EXECUTIVE SUMMARY

0.1 Background to this document

According to national legislations within the Organisation for Economic Co-operation and Development (OECD) the evaluation of environmental exposure to biocides, including antifouling products, is an integral part of the risk assessment of a biocidal product or of an active ingredient for regulatory purposes. Preferably, representative data from well-designed field studies should form the basis for environmental exposure assessment. Although for some existing active ingredients monitoring data may be available, for many information on actual environmental concentrations is limited or non-existing. As for other chemicals, exposure models offer an alternative solution for estimation of the environmental emissions and concentrations.

In the context of the OECD Biocides Programme initiated in 1998 the development of guidance for exposure assessment of biocides was given high priority in view of the wide variety of exposure scenarios associated with the use of these chemicals. Wood preservatives were the first product type selected. This resulted in the "Emission Scenario Document (ESD) for Wood Preservatives" published in 2003 (OECD (2003)).

In view of the number of existing scenarios already available and ongoing international activities involving antifouling products, the OECD Biocides Steering Group chose antifouling products as the second biocidal product type for which an ESD had to be produced. Subsequently, a project was started - financed by the European Commission - with the aim to produce an ESD for antifouling products that is harmonised and applicable in all EU Member States and non-EU OECD Member countries. The actual work of producing the ESD was done by a consultant overseen by a Steering Group. The Steering Group was composed of regulators from different OECD countries, the European Commission and industry representatives.

The report is based on:

- Emission scenarios developed in different OECD countries and;
- Discussions in the OECD Steering Group on Anti-Fouling Products for the project “Development of environmental emission scenario document for active substances used in anti-fouling products” (European Commission Service Contract No. B4-3040/2002/348010/MAR/C3).

The primary aim of the harmonised ESD is for use in risk assessments in notification and authorisation procedures in regulatory frameworks used in all OECD countries. The ESD is intented to be used for general risk assessment and is explicitly not for site specific risk assessments. Furthermore it’s important to note that the recommended scenarios for service life of the antifouling products in the ESD are limited to the calculation of the initial local concentrations in the primary receiving environmental compartments. The recommended scenarios for the application and removal are limited to the calculation of the emission load. The scope of this document is intended to develop a methodology for determining the emission load or initial concentrations from the use of antifoulants. The determination of any Predicted Environmental Concentration (PEC) in the receiving environmental compartment as well as in secondary environ-ments taking removal processes into account and therefore any assessment of the environmental impact of antifoulants should be carried out according to the regional practices in the Member States of the OECD. Thus, for example, in the European Union

(EU) the use of Technical Guidance Documents or Technical Notes on Guidance under the Biocidal Products Directive (BPD) should be employed to determine PEC values.

0.2 Introduction

Fouling is an unwanted growth of biological material, such as algae, on a surface immersed in water. Fouling occurs in both salt and fresh water, but the fouling process is more rapid in salt water and there are more fouling organisms in salt water. To prevent fouling of immersed surfaces antifouling products (or antifoulants) are used.

The following areas of use for antifouling products are known (Van Dokkum et al., 1998; OECD, 2001):

- Ship hulls;
- Nets in fish farms;
- Mariculture equipment other than fish nets (such as lobster pots);
- Buoys and other small objects;
- Sluice doors;
- Harbour constructions;
- Inlet pipes of e.g. cooling systems;
- Marine sensors;
- Offshore constructions.

The most important area of use for antifouling products is the use on ship hulls for pleasure crafts and commercial ships. Wordldwide the demand for this use is approximately 95% of the total demand (Brennan Research Group, 2000). So, for this use area an environmental emission scenario needs to be available.

The question is for which other use areas an environmental emission scenario also needs to be available. Based on use volume, the use on offshore structures such as drilling platforms, is after the use on ship hulls the most important. World wide the demand for this use is approximately 2.5% of the total demand (pers. com. R. Fenn). It was decided that an environmental emission scenario needs to be available for this use. This is however not developed in the present document, but reference is made to work carried out within the framework of the OSPAR Convention on the model CHARM (Chemical Hazard Assessment and Risk Management) (Thatcher et al., 2001). This model provides the amount of drilling platforms in a defined area and the dimensions and characteristics of the receiving environment (seawater). The amount of antifoulant applied on a platform and the leaching rate of the active ingredient has to be included.

Arguments other than use volume can be used to decide on the necessity of the availability of an environmental emission scenario. From the other use areas it was decided that the use in aquaculture (on nets used in fish farms, lobster pots and crab pots) is the only relevant one. Although the market share of this use is minor compared to the use on ship hulls and offshore constructions, the emission from this use was considered important as fish from fish farms is meant for human consumption and therefore there is the potential risk of secondary poisoning. Existing emission scenarios for the use of antifouling products in aquaculture are not available. For nets used in fish farming a “service life” scenario was under development in the United Kingdom. However, further work has not been undertaken due to changes in personnel and work priorities. Although some information was available with respect to the potential emission routes of antifouling products used on aquaculture equipment, insufficient data were available to be able to develop new scenarios within this project.

Three parts of the life cycle for antifouling products used on ship and boat hulls are considered:
- Application;
- Servicee life;
- Removal.

For service life emission scenarios were already developed in different OECD countries for different environments (e.g. a harbour or a shipping lane). These existing scenarios were evaluated and compared with the aim of producing one harmonised environmental emission scenario for each of the relevant environments.

For application and removal no existing scenarios were available. The processes of application and removal of antifouling paint used on ship hulls were considered relevant as considerable contamination of water and soil is possible. Therefore new scenarios with respect to application and removal were developed within this project. These scenarios are mainly based on data from a report of Safinah consultants (Safinah 2004), drafted under assignment of the European Council of the Paint, Printing Ink and Artists' Coulours Industry (CEPE).

As described before, the primary aim of the harmonised and newly developed scenarios is for use in risk assessments in notification and authorisation procedures in regulatory frameworks used in all OECD countries. Therefore it is important that the harmonised scenarios are typical OECD emission scenarios. Important to note is that the scenarios are to a large extent based on information from the European countries. This was caused by the fact that there was simply not enough information available on other countries. More work to obtain these data is therefore recommended. Where possible data from countries outside the EU are incorporated in the scenarios. Considering the above comments, it should be emphasized that these emission scenarios may not be as relevant to North American waters, and particularly to U. S. waters, as they are to those for the European countries.

0.3 Existing and newly developed scenarios

Table 0.1 presents a summary of the existing scenarios for service life and newly developed scenarios for the removal and application of antifouling paint used on ship hulls.

Table 0.1 Summary of existing and newly developed emission scenarios for ship hulls

Application	Service life	Removal
Newly developed scenarios for: • New building commercial ships; • New building pleasure craft (professional); • Maintenance and repair: commercial ships; • Maintenance and repair: pleasure craft (professional and non-professional).	Existing scenarios: Open sea (1 scenario): • *Open sea scenario MAM-PEC (Van Hattum et al., 2002).* Shipping lane (3 scenarios): • *Shipping lane scenario MAM-PEC (Van Hattum et al., 2002);* • *Finnish shipping lane using MAM-PEC (Koivisto, 2003);* • *Danish shipping lane (Madsen et al., 1999).* Commercial harbour (3 scenarios): • *Commercial harbour MAM-PEC (Van Hattum et al., 2002);* • *Finnish harbour using MAM-PEC (Koivisto, 2003);* • *Estuary with small harbour scenario MAM-PEC (Van Hattum et al., 2002).* Estuarine and coastal marinas (5 scenarios): • *Marina scenario MAM-PEC (Van Hattum et al., 2002);* • *Marina scenarios REMA (Comber et al., 2001) ;* • *Yacht basin scenario (Johnson and Luttik, 1994);* • *Finnish marina using MAM-PEC (Koivisto, 2003);* • *Danish marina Madsen et al., 1999).* Marinas in lakes (1 scenario): • *Swiss marina, (modified from MAM-PEC, BUWAL, 2000).*	Newly developed scenarios for: • Maintenance and repair: commercial ships; • Maintenance and repair: pleasure craft (professional and non-professional).

The existing emission scenarios for the life cycle stage service life for antifouling products used on ship hulls were evaluated and compared to produce harmonised emission scenarios.

0.4 Recommended scenarios for service life of antifouling products on ship hulls

Based on the evaluation and comparison of the existing "service life" scenarios the following was recommended:

It is recommended to perform risk assessments for antifoulants on ship hulls during service life with the following harmonised scenarios:

- Shipping lane scenario: **"modified MAM-PEC shipping lane scenario"**;
- Commercial harbour scenario: **"modified MAM-PEC estuarine harbour scenario"**;
- Marina scenario: **"Marina during high season"** (the worst case shipping characteristics and harbour dimensions of the REMA estuarine marina scenario in combination with the hydrodynamic calculation method of the MAM-PEC estuarine marina scenario).

The model MAM-PEC can be obtained from the web-site of CEPE: www.cepe.org under “Publications” and “Antifouling products” (report and model). The recommended scenarios for service life as described in this section will be incorporated in the MAM-PEC model obtainable from the CEPE web-site.

In addition to this it has to be mentioned that the existing “marina in lake scenario” was considered very country specific and therefore not suitable to be used in risk assessment for all OECD countries. Data available were insufficient to develop a realistic worst case “marina in lake scenario” for the OECD. However, authorities may consider to use the relative simple Swiss marina scenario (modified from MAM-PEC by BUWAL (2000)) with parameters adapted to their specific local situations.

For a correct use of the three recommended scenarios a few general notes are described below.

Within the OECD Antifouling Steering Group it was discussed which value will be the PEC to be compared with the PNEC. E.g. for a marina: is the PEC the value calculated in the marina or the value in water just outside the marina? The different models take sometimes a different approach with respect to this issue: e.g. REMA calculates a concentration in the marinas as well as in the estuarine area outside the marinas. This issue also relates to the protection goals set by the competent authority: e.g. in the Netherlands the concentration in the marina calculated with USES 2.0 is used as the PEC, as marinas are considered to be essential as a brood place for some marine organisms. So, the outcome of the environmental emission scenarios presented for commercial harbours and marinas in this document can be used as the 'final' PEC but also other models or dilution factors can be used to calculate the 'final' PEC using models like REMA, EUSES or dilution factors. The outcome of the service life scenarios was therefore defined as the dissolved initial local concentration. For the calculation of the concentration in secondary environments (taking removal processes into account) and the calculation of the total concentration (including suspended matter) reference can be made to documents like the EU-TGD (ECB, 2003). Therefore, also the recommendations on use of MAM-PEC scenario modelling given here, do not refer to its modelling of secondary environments and related processes.

A recommended general value of 95% for the application factor is introduced. For boosters this may lead to an overestimation of the market share as this is for all boosters at the moment much lower than 95%. But according to representatives of industry a market share of 90% for a (future) booster would be possible. To anticipate on future developments a maximum default value of 90% (0.90) is recommended. However, actual market data can be provided by the notifier, leading to an adaptation of the value of 90%. If available, real data on the market share should be used.

In risk assessment in general measured values are preferred over calculated values. If these data are representative and relevant, they should be used instead of estimated concentrations. In the EU-TGD more guidance is presented on the assessment, interpretation and use of measured data.

There are reasons to deviate from the environmental emission scenarios - local situation (e.g. low tide) or seasonal influences - leading to other parameter settings. Especially concerning the marina scenario, OECD regions exist with lower and higher tide than the recommended 1.5 m. When performing a risk assessment it may be important for countries in those regions to pay attention to the tidal heights in the specific country and if necessary adapt the default value of 1.5 m and other hydrology settings.

For inorganic active ingredients special modules or models can be used to calculate the dissolved and total concentrations for different species. Such a model is included in the MAM-PEC model. These models however are not discussed in the present document.

The tables 0.2 to 0.7 contain the necessary input parameters and model calculations of the initial local environmental concentrations for the recommended scenarios for service life of antifouling paints used on ship hulls.

Source of Parameters:

S	Data Set	parameter must be present in the input data set for the calculation to be executed (there has been no method implemented in the system to estimate this parameter; no default value is set, data either to be supplied by the notifier or available in the literature);
D	Default	parameter has a standard value (most defaults can be changed by the user);
O	Output	parameter is the output from another calculation (most output parameters can be overwritten by the user with alternative data);
P	Pick list	parameter values to be chosen from a pick list with values.

0.4.1 Shipping lane scenario

The (modified) MAM-PEC shipping lane scenario is considered a realistic worst case scenario for risk assessment within OECD countries.

In the tables 0.2 and 0.3 the input parameters and model calculations for the “shipping lane scenario” are described. To calculate the emission load (table 0.2) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 0.2 Shipping lane: Emission scenario for calculating the emission load from biocides used in antifouling products for ship hulls (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping characteristics				
Length categories of ships: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[m]	Cat 1-6 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5 Cat 6	 50-100 100-150 150-200 200-250 250-300 300-350	D
Number of ships moving at any time of the day for cat 1-6: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[-]	$N_{ships,moving}$	 3.9 1.7 1.6 0.4 0.5 0.1	D
Average surface area per ship for cat 1-6[1)]: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[m^2]	$AREA_{ship}$	 1,163 3,231 6,333 10,469 15,640 21,844	D
Application factor and leaching rate				
General application factor of the antifouling product	[-]	Fappl	0.95[2)]	D
Application factor of a booster biocide	[-]	Fappl	0.90[2)]	D
Leaching rate for ships moving [3)]	[$g.m^{-2}.d^{-1}$]	Kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}6\ moving}\ (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1);
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant.

In table 0.3 the default values necessary for the calculation of the dissolved initial concentration are presented.

Table 0.3 Shipping lane: Emission scenario for calculating the concentration of antifouling biocides in seawater (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (area shipping lane)				
Length	[m]	LENGTHsl	20,000	D
Width	[m]	WIDTHsl	10,000	D
Depth	[m]	DEPTHsl	20	D
Water quality				
Silt concentration	[g.m^{-3}]	Csilt	5	D
Temperature	^{O}C	TEMP	15[1)]	D
Salinity	^{O}/oo	SALINITY	34	D
Particular organic carbon	[g.m^{-3}]	POC	0.3	D
Dissolved organic carbon	[g.m^{-3}]	DOC	0.2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	0	D
Tidal current	[m.s^{-1}]	CURRENTtid	1	D
Output:				
The average dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[g.m^{-3}]	$Clocal\_initial_{water,diss}$		O
Calculation:				
Calculations with the MAM-PEC model[2)]				

1) According to the EU-TGD the default average marine temperature to be used in the EU countries is 9 ^{o}C (ECB, 2003);

2) Due to the complexity of the model this calculation is not described.

0.4.2 Commercial harbour scenario

Commercial harbour scenario: It is recommended to use the (modified) MAM-PEC estuarine harbour. For product registration in regions where tide is insignificant specific scenarios may have to be developed. This may be realised by using other parameter settings for the recommended harbour scenario (e.g. use the hydrology settings of the Finnish scenario and correct further the water exchange volume under low tide conditions (see also section 4.3.3: Finnish commercial harbour scenario using MAM-PEC)).

In the tables 0.4 and 0.5 the input parameters and model calculations for the "commercial harbour scenario" are described. To calculate the emission load (table 0.4) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 0.4 Commercial harbour: Emission scenario for calculating the emission load from biocides used in antifouling products for ship hulls (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of ships: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m]	Cat 1-6 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5	 50-100 100-150 150-200 200-250 250-300	D
Number of ships at berth at any time of the day for cat 1-5: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,berth}$	 11 5 5 1 2	D
Number of ships moving at any time of the day for cat 1-5: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,moving}$	 1.8 0.4 0.4 0.1 0.1	D
Average surface area per ship for cat 1-5[3]: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m^2]	$AREA_{ship}$	 1,163 3,231 6,333 10,469 15,640	D
Application factor and leaching rate				
General application factor of the antifouling product	[-]	Fappl	0.95[2]	D
Application factor of a booster biocide	[-]	Fappl	0.90[2]	D
Leaching rate for ships moving and at berth[1]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}6\ at\ berth}$ ($AREA_{ship}$ * $N_{ships,berth}$ * Fappl * kleach) + $Sum_{cat\ 1\text{-}6\ moving}$ ($AREA_{ship}$ * $N_{ships,moving}$ * Fappl * kleach)				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1).

In table 0.5 the default values necessary for the calculation of the dissolved initial concentration are presented.

Table 0.5 Commercial harbour: Emission scenario for calculating the concentration of antifouling biocides in seawater (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Distance from mouth	[m]	LENGHTm-h	1,000	D
Length	[m]	LENGTHch	5,000	D
Width	[m]	WIDTHch	1,000	D
Depth of harbour	[m]	DEPTHch	15	D
Harbour entrance width	[m]	WIDTHent	2,500	D
Harbour entrance depth	[m]	DEPTHent	10	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	35	D
Temperature	^{O}C	TEMP	15[1)]	D
Salinity	^{O}/oo	SALINITY	34	D
Particular organic carbon	[$g.m^{-3}$]	POC	1	D
Dissolved organic carbon	[$g.m^{-3}$]	DOC	2	D
pH	-	pH	7.5	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	1.5	D
River flow velocity	[$m.s^{-1}$]	CURRENTriver	1.0	D
Depth of river	[m]	DEPTHriver	10	D
Density difference	[$kg.m^{-3}$]	RHOdiff	0.4	D
Flush in harbour	[$m^3.s^{-1}$]	FLOWriver	0	D
Density difference of flush	[$kg.m^{-3}$]	RHOdiff,flush	0	D
Output:				
The average dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water, diss}$		O
Calculation:				
Calculations with the MAM-PEC model[2)]				

1) According to the EU-TGD the default average marine temperature to be used in the EU countries is 9 ^{o}C (ECB, 2003);
2) Due to the complexity of the model the calculations are not described in this document.

0.4.3 Marina scenario

It is recommended to use a harmonised scenario that combines the worst case shipping characteristics and harbour dimensions of the REMA-model with the calculation methods (hydrology) of MAM-PEC. Within the OECD, regions with lower and higher tide than 1.5 m exist. When performing a risk assessment it may be important for countries in these regions to pay attention to the tidal heights in the specific country and if necessary adapt the default value of 1.5 meter, and under low tide conditions also the water exchange volume (see also section 4.3.3: Finnish commercial harbour scenario using MAM-PEC).

In the tables 0.6 and 0.7 the input parameters and model calculations for the “marina scenario” are described. To calculate the emission load (table 0.6) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 0.6 Marina: Emission scenario for calculating the emission load from biocides used in antifouling products for boat hulls (modified from REMA and MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length category of pleasure crafts	[m]	Cat 0	1-50	D
Number of ships at berth at any time of the day	[-]	$N_{ships,berth}$	500	D
Average surface area per craft	[m^2]	$AREA_{ship}$	30.7	D
Application factor and leaching rate				
General application factor of the antifouling product	[-]	Fappl	0.95 [2)]	D
Application factor of a booster biocide	[-]	Fappl	0.90 [2)]	D
Leaching rate for ships at berth [1)]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 0\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;

2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant.

In table 0.7 the default values necessary for the calculation of the dissolved initial concentration are described.

Table 0.7 Marina: Emission scenario for calculating the concentration of antifouling biocides in seawater (modified from REMA and MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Length	[m]	LENGTHm	141.5	D
Width	[m]	WIDTHm	141.5	D
Depth of harbour	[m]	DEPTHm	4	D
Harbour entrance width	[m]	WIDTHent	100	D
Harbour entrance depth	[m]	DEPTHent	4	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	35	D
Temperature	^{O}C	TEMP	20[1)]	D
Salinity	$^{O}/oo$	SALINITY	34	D
Particular organic carbon	[$g.m^{-3}$]	POC	1	D
Dissolved organic carbon	[$g.m^{-3}$]	DOC	2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	1.5	D
Tidal current	[$m.s^{-1}$]	CURRENTtid	1	D
Density difference	[$kg.m^{-3}$]	RHOdiff	0.1	D
Flush in harbour	[$m^3.s^{-1}$]	FLOWharbour	0	D
Density difference of flush	[$kg.m^{-3}$]	RHOdiff,flush	0	D
Output:				
The average dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water,diss}$		O
Calculation:				
Calculations with the MAM-PEC model[2)]				

1) According to the EU-TGD the default average marine temperature to be used in the EU countries is 9 ^{o}C (ECB, 2003);

2) Due to the complexity of the model the calculations are not described in this document.

0.5 Recommended scenarios for the application and removal of antifouling products on ship hulls

For the application and removal of paint on ship hulls new scenarios were developed within this project. For a correct use of these scenarios a few general notes are described below.

There is a lot of difference between shipyards or boatyards with respect to measures undertaken to prevent antifouling paint entering the environment. Several shipyards in OECD countries will work in closed systems, while other yards work in highly exposed environments. To prevent certain biocides being prohibited by only using a worst-case scenario for OECD countries, for every scenario, a “typical case” and a “realistic worst case" was defined.

The default values used in the scenarios were mainly derived from the Safinah report (Safinah, 2004, see also section 3.1). Where necessary more information was provided by industry (CEPE) and the National Institute for Public Health and the Environment (RIVM) in the Netherlands. The status of the default data varies from information based on:

- Statistics (Safinah, 2004);
- Expert judgement (Safinah, 2004; and additional information by industry and RIVM);
- “Best estimates” by the OECD Steering Group on Anti-Fouling Products.

Due to the lack of specific data the effects of control measures taken by new building and maintenance and repair facilities are for the greater part not taken into account for the development of the scenarios for application and removal. However this doesn't apply to all scenarios. For several developed scenarios some control measurements are considered (e.g. the use of paint cells and painting in docks instead of exposed slipways).

Considering the text above it is important to note that the default values are not firm values, but the best available estimates made by the OECD Steering Group on Anti-Fouling Products. If more realistic values are available from practice or statistics, these values can be replaced when performing risk assessment. It is up to the applicant to propose adequate protection measures for the antifouling coating to be used, for example in a shipyard, in order to evaluate that antifouling coating under the “typical case” assumptions (or even a better case). Examples of these measures are the collection and disposal of the removed paint as waste or the use of closed circuit blasting systems.

The outcome of the scenarios for application and removal is an emission load. For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to to the regional practices in the Member States of the OECD. Thus, for example, in the European Union the use of Technical Guidance Documents or Technical Notes on Guidance under the Biocidal Products Directive should be employed to determine PEC values. However, a few considerations with respect to the further calculation of the concentrations in water, soil or sewage treatment plant (STP) are described below.

For the yearly average environmental concentrations the user should sum up the initial concentrations resulting from the application and removal scenarios when they occur in the same compartment (water, STP or soil). For the daily concentrations during the emission period it may be assumed that application and removal do not occur on the same day.

Particulate emissions of antifoulants from application and removal life-stages will have different fate and behaviour properties compared to molecular emissions from the service-life stage, e.g. lower bioavailability and longer persistence.

According to the EU-TGD, in the absence of more detailed data concerning adsorption/ bioavailability/persistence, the substance content in small particles can be handled as if it was distributed in molecular form (EU-TGD: ECB, 2003). However, according to expert information form CEPE, it is believed that because of the application techniques used, any release to the environment during application also results in an emission being in particle form. The information according to CEPE is described below:

- Paint droplets from overspray are relatively large and dense, and therefore primarily confined to the spraying area. Additionally, due to the high volatility of the solvents used in typical antifouling paint formulations the droplets undergo significant drying before they reach the surrounding water surface. Thus if released to the surrounding water environment, they consist of relatively large particles which are not readily dispersed into the environment;
- Some co-biocides have considerable substantivity to particles of the primary antifouling agent, cuprous oxide;
- Other biocides are incorporated into polymers and are only released due to the action of physical erosion or slow hydrolysis.

Furthermore it is important to note that not all potential emissions during application will enter the aquatic environment directly. For example for the application of paint on new commercial ships a distinction is made between application of the final paint coat in a dock and application on an exposed slipway. The potential emission factor to surface water (without control measures, e.g. shrouding) for the slipway is 0.35. For painting in the dock the potential emission factor is only 0.075 (less overspray due to a more confined area). The greatest part of the emissions occurring at the exposed slipway will enter the environment directly. But potential emissions occurring in the dock will enter the environment partly in the form of dried paint onto the dock walls (leaching) and partly via the air directly to the surface water. Because of the relative short immersion period of the dock into the water (compared to ship hulls during service life of the antifoulant) the emission to the surface water will be small. But because there is no data available on the amount of antifoulant directly emitted in the water the emission factor for painting in the dock is maintained at 0.075.

The potential emissions during paint removal will occur in the form of dry paint flakes or paint dust that either goes to waste, a STP or directly to water. Even when the paint is going directly to surface water it should be considered that the dissolved concentration in practice will be lower than the calculated concentration.

Next to these general notes explanations of several input parameters used in the scenario descriptions for application and removal are described.

Painting and removal period (Tpaint and Tremoval): In the scenarios a painting period or a removal period is used to express a time period during which application or removal takes place more or less continuously in one ship or boat yard. For commercial ships this will be a relative short period. During one painting period of, for example 2 days, one ship is painted. For example, for non-professional application on pleasure boats the period will be much longer. During a period of several months 350 pleasure boats will be painted. Because of the amount of boats that have to be painted it is assumed that painting takes place almost continuously during this period.

Painting and removal interval (Tint): Painting and removal intervals are used to indicate when emissions take place. A painting or removal interval is used in case of application and removal of paint during maintenance and repair of pleasure boats and mass production of pleasure crafts (300 boats per year). The interval indicates an unbroken period per year when no emissions due to the corresponding activity occur. For example the non-professional application of paint on pleasure craft is assumed to take place continuously during 3 months (winter and early spring). During the remaining 9 months no non-professional application takes place (boats are either in the water or in storage). So in this case the painting interval is 9 months.

Painting and removal frequency (Tint and Tfreq): Painting and removal frequencies are used to express the amount of relative short painting or removal periods during one year. A painting or removal frequency is used for new-building and maintenance and repair (M&R) for commercial ships and during new building of pleasure craft in a small boatyard (building at maximum 30 boats per year). If the painting of one commercial ship takes 2 days (the painting period) and the painting frequency is 3, this means that 3 ships per year are painted.

The theoretical coverage of the paint (COVERAGE): The theoretical coverage of the paint is the volume of paint that is theoretically needed to paint a certain area of the ship hull.

The theoretical coverage of the paint does not take into account:
- The losses emitted to the environment;
- Excess paint applied on the hull (paint overlap during the application process, the subsequent coating of join up seams and butts after the coating and assemblage of the separate hull blocks, etc. (see also section 4.2.1);
- And waste (paint residues in cans, etc.).

Thus, in addition to the theoretical coverage of the paint the user of an antifouling product should count for a certain percentage extra paint for losses that are emitted elsewhere during application.

Theoretical amount of paint applied per ship (Vpaint): The average hull surface of an average (OECD) ship multiplied with the theoretical coverage of the paint forms the theoretical amount of paint applied per ship, which is the amount of paint that is theoretically needed to paint the entire ship hull. The emission factors used in the developed scenarios for the application of paint are based on this theoretical amount of paint applied per ship.

The fraction excess paint applied (Fexcess): The theoretical coverage of the paint is the volume of paint that is theoretically needed to paint a certain area of the ship hull. As described earlier the theoretical coverage of the paint does not take into account excess paint applied on the hull. The theoretical paint demand and excess paint applied (expressed in a “fraction excess paint applied”) together form the total amount of paint applied per ship. The total amount of paint applied per ship is important to know for the removal scenarios. By using the total amount of paint it is possible to determine what amount will be removed during maintenance and repair. In this document the excess paint applied is not relevant for the application scenarios. The emission fractions used are based on the theoretical amount of paint applied per ship.

The fraction of the paint that is to be removed from the ships hull (Fwashing, Fabrasion): This fraction depends on the removal method. A distinction is made between paint removed by high pressure water washing (HPW) and paint removed by abrasion. When abrasion is used an additional distinction can be made between reblasting (abrasion of the entire ship hull area) and spot blasting (abrasion of small parts of the ship hull that are in bad condition).

Fraction of active ingredient (a.i.) remained in exhausted or old paint ($Fa.i._{exhpaint}$ or $Fa.i._{old\ paint}$): 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.

A distinction can be made between old paint and exhausted paint. High pressure washing will remove only the leached layer (exhausted paint). 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 a.i. Abrasion will remove 30% of the paint film. This 30% consists of the leached layer and an additional layer of old paint which contains a fraction of 0.30 (expert judgement CEPE) of the original concentration of a.i. (see also section 4.4.2).

0.5.1 Application

For application a distinction was made between new building and maintenance and repair (M&R). The following scenarios were developed:

New building
- Commercial ships → professional;
- Pleasure craft → professional.

Maintenance and repair
- Commercial ships → professional;
- Pleasure craft → professional;
  → non-professional.

In the tables 0.8 to 0.17 the recommended scenarios for the application of paint on ship hulls are described.

New building commercial ships

The following scenarios were developed:

Realistic worst case: Two commercial ships are painted per year. Per ship two anti-fouling coats are applied. The first coat is applied on block in painting cells or open air. Significant emissions may occur from painting on block in the open air. But because painting on block is done in a longer time period and normally on another location compared to where the final coat is applied, the emissions due to painting on block stage are not included in this scenario. The application of the final coat is carried out in one day on an exposed slipway (in the open air on a hard standing area near or above the water). The paint is applied using airless spray.

Typical case: Two commercial ships are painted per year. Per ship two antifouling coats are applied. The first coat is applied on block in painting cells. Significant emissions of antifoulant are not expected from painting in painting cells. Therefore the emissions due to the application of the first coat are not included in this scenario. The application of the final coat is carried out in one day in the dock (less exposed compared to a slipway). As for the realistic worst case scenario the paint is applied using airless spray.

According to the Safinah report for both scenarios the potential emissions are assumed to end up in the surface water. Therefore the fraction to soil in the scenarios as described in table 0.8 is zero.

Table 0.8 New building ships in an average OECD shipyard: 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	1[1)]	1[1)]	D
Number of ships treated in an EU/US shipyard per painting period	[-]	Nship	1	1	D
The average hull surface of a ship	[m^2]	$AREA_{ship}$	EU/US: 2500 Asia: 8600[2)]	EU/US: 2,500 Asia: 8,600[2)]	D
Theoretical coverage of the paint	[$m^2.l^{-1}$]	COVERAGE			S
Number of coats applied on the hull	[-]	Ncoats	1 (only the final coat)	1 (only the final coat)	D
The concentration of a.i. in the paint	[$g.l^{-1}$]	Ca.i.			S
Fraction to surface water	[-]	F_{water}	0.35[3)]	0.075	D
Fraction to soil	[-]	F_{soil}	0	0	D
Output :					
The theoretical amount of paint applied per ship[4)]	[l]	Vpaint			O
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$			O
Intermediate calculations:					
$Vpaint = Ncoats * (AREA_{ship} / COVERAGE)$					
End calculations:					
$Elocal_{water} = (Vpaint * Nship * F_{water} * Ca.i.) / Tpaint$					

1) Expert judgement: 1 day is needed for the application of the final coat (expert judgement CEPE). The application of the first coat is not included in this scenario;
2) Note that all other values are based on the European/US situation;
3) Note that this fraction seems fairly high. It would mean that a third of the antifouling paint ends up in the water. This fraction is derived from Safinah (2004): potential emission based on overspray during application of the paint on a slipway. The fraction of 0.35 is also described as the realistic worst case loss factor for airless spray in the RIVM comments. According to Finnish data the total losses are typically 30% of the total amount of paint used which would result in 0.43 as a sum of all these emission fractions (water, soil, STP, waste);
4) The theoretical paint demand is the amount of paint that is theoretically needed to paint the entire ship hull. The theoretical paint demand does not contain the excess paint applied on the hull due to overlap during the application process, the subsequent coating of join up seams and butts, etc. The theoretical paint demand and the excess paint together form the total amount of paint that is applied on the ships hull (see also the explanation in section 4.2).

The emission load finally ends up in a river or harbour. For the calculation of concentrations in a river reference is made to general environmental exposure assessment guidelines such as the EU-TGD (ECB, 2003). Individual countries have to decide on the river dimensions and waterflow. For the emission to a harbour the dimensions of the recommended commercial harbour for service life of antifouling paints are used (Table 0.9).

Table 0.9 Calculation of the environmental concentrations for new building ships in an average EU/US shipyard for both realistic worst case and typical case (point source in harbour)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting frequency per year[1)]	[-]	Tfreq	2	D
Length of the harbour	[m]	LENGTHch	5,000	D
Width of the harbour	[m]	WIDTHch	1,000	D
Depth of the harbour	[m]	DEPTHch	15	D
Total emission to water	$[g.d^{-1}]$	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in surface water	$[g.m^{-3}]$	$PEClocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) The amount of painting periods per year.

New building pleasure craft

The following scenarios were developed:

Realistic worst case: Thirty pleasure boats (<7.5 m) are painted per year in a small boat yard. Per boat 3 litres of paint are applied. The application of the paint is carried out in two days in the open air on compact earth or a hard standing area with some temporary shrouding. Depending on the quality of the control measurements for the soil (e.g. hard standing area of compacted earth) the emission either goes to soil or a STP or a combination of these two options. This possibility is included in the scenario. It is assumed that the new building facility is not situated near the water. The paint is applied either using brush and roller or using a mixture of airless spray and brush and roller (expert judgement CEPE). In the scenario a choice can be made between these two application methods. According to Safinah (2004) brush and roller is more common for a small boat yard.

Typical case: Three hundred pleasure boats (<7.5 m) are painted per year in a mass production facility. This means that painting takes place practically every day (a painting frequency can no longer be determined, painting takes place continuously all year). Per boat 3 litres of paint are applied using airless spray. Because all the painting takes place indoors on a hard standing area significant emissions directly to the environment are not expected. Emissions that may occur are emissions to a STP. But the amounts of antifoulant that possibly remain after waste water treatment are not considered important for the environment.

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to water in the scenario as described in table 4.5 is zero.

Table 0.10 New building pleasure craft in an average OECD boatyard: 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	2	365	D
Number of boats treated in a boatyard per painting period	[-]	Nboat	1	300	D
The concentration of active ingredient in the paint	[$g.l^{-1}$]	Ca.i.			S
The theoretical amount of paint applied per boat[1)]	[l]	Vpaint	3	3	D
Fraction to surface water	[-]	F_{water}	0	0	D
Fraction to STP[2)]	[-]	F_{STP}	Application by mixture of airless spray / brush and roller: Max. 0.06 Application by brush and roller only: Max. 0.025	0	D
Fraction to soil[2)]	[-]	F_{soil}	Application by mixture of airless spray / brush and roller: Max. 0.06 Application by brush and roller only: Max. 0.025	0	D
Output :					
Total emission to soil	[$g.d^{-1}$]	$Elocal_{soil}$			O
Total emission to STP	[$g.d^{-1}$]	$Elocal_{STP}$			O
End calculations:					
$Elocal_{soil}$ = (Vpaint * Nboat * F_{soil} * Ca.i.) / Tpaint $Elocal_{STP}$ = (Vpaint * Nboat * F_{STP} * Ca.i.) / Tpaint					

1) The system of paint volume demand is very different to ships. Most of the paint companies assume that the coating will be applied by the boat owner/yard and so supply a paint calculator. Using this calculator the required paint amount can be estimated. However, this is not what happens in practice. In reality the typical owner applies one touch up coat to the existing antifouling coating and one full coat of antifouling. On the basis of discussions with paint companies, boat builders and marina operators etc. Safinah has determined default values for the theoretical amount of paint applied per boat;
2) Depending on the control measurements of the boat yard the emission up to a maximum of 6% (potential emission weighted for brush/roller and spray) or 2.5% (for brush and roller only) either goes to soil or a STP or a mixture between these two options.

The emission load finally ends up onto the soil or in a STP. In table 0.11 the calculation method of the initial concentration in soil is presented.

Table 0.11 Calculation of the environmental concentrations for new building pleasurecraft in an average OECD boatyard for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting frequency per year	[-]	Tfreq	Realistic wost case: 30 Typical case: n/a	D
Length of the receiving soil compartment[1)]	[m]	LENGTH	9.5	D
Width of the receiving soil compartment	[m]	WIDTH	4.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[2)]	D
Soil density (dry weight)	$[kg.m^{-3}]$	$RHOsoil_{dw}$	1,504[3)]	
Total emission to soil	$[g.d^{-1}]$	$Elocal_{soil}$		O
Output :				
Predicted environmental concentration in soil	$[g.kg^{-1}]$	$PECClocal_{soil}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) A boat of 7.5 m length and 2.5 m width is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 metre wide;
2) In line with the environmental emission scenario of the OECD for Wood Preservatives;
3) Based on EU-TGD (ECB, 20034) (wet weight is 1700 $kg.m^{-3}$).

M&R commercial ships

The following scenarios were developed:

Realistic worst case: Twenty (expert judgement CEPE) commercial ships are painted per year. Per ship two antifouling coats are applied. The coats are applied in two days in an exposed floating dock or marine lift (in the open air, on a hard standing area, unshrouded). The paint is applied using airless spray.

Typical case: Twenty commercial ships are painted per year. Per ship two antifouling coats are applied. The coats are applied in two days in a graving dock (in the open air, on a hard standing area, shrouded). The paint is applied using airless spray.

According to the Safinah report for both scenarios the potential emissions are assumed to end up in the surface water. Therefore the fraction to soil in the scenarios as described in table 0.12 is zero.

Table 0.12 M&R of commercial ships in an average OECD shipyard: 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	2[1)]	2[1)]	D
Number of ships treated per painting period	[-]	Nboat	1	1	D
The average hull surface of a typical OECD ship	[m^2]	$AREA_{ship}$	EU/US: 2500 Asia: 7963[2)]	EU/US: 2,500 Asia: 7,963[2)]	D
Theoretical coverage of the paint	[$m^2.l^{-1}$]	COVERAGE			S
Number of coats applied on the hull	[-]	Ncoats	2	2	D
The concentration of a.i. in the paint	[$g.l^{-1}$]	Ca.i.			S
Fraction to surface water	[-]	F_{water}	0.35	0.075[3)]	D
Fraction to soil	[-]	F_{soil}	0	0	D
Output :					
The theoretical amount of paint applied per ship	[l]	Vpaint			O
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$			O
Intermediate calculations:					
Vpaint = Ncoats * ($AREA_{ship}$ / COVERAGE)					
End calculations:					
$Elocal_{water}$ = (Vpaint * Nboat * F_{water} * Ca.i.) / Tpaint					

1) Expert judgement CEPE: one day for each coat;
2) Note that all other values are based on the European/US situation. Note also that the value for Asia is lower than for the new building scenario (Table 0.8) as also smaller ships are maintained and repaired.;
3) See also application of paint during new building commercial ships.

The emission load finally ends up in a river or harbour. For the calculation of concentrations in a river, reference is made to general environmental exposure assessment guidelines such as the EU-TGD (ECB, 2003). Individual countries have to decide on the river dimensions and waterflow. For the emission to a harbour, the dimensions of the recommended commercial harbour for service life of antifouling paints are used.

Table 0.13 Calculation of the environmental concentrations for application of paint during M&R of commercial ships in an average OECD shipyard (point source in harbour or river, see also scenario new building for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting frequency per year[1)]	[-]	Tfreq	20[2)]	D
Length of the harbour	[m]	LENGTHch	5,000	D
Width of the harbour	[m]	WIDTHch	1,000	D
Depth of the harbour	[m]	DEPTHch	15	D
Total emission to water	$[g.d^{-1}]$	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in surface water	$[g.m^{-3}]$	$Clocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) The amount of painting periods per year;
2) Expert judgement CEPE.

Professional M&R pleasure craft,

The following scenarios were developed:

Realistic worst case: Fifty pleasure boats (>7.5 meter) are painted per year in a repair shop at a boat yard (hard standing area or compacted earth). According to Safinah boats < 7.5 meter are mainly repaired by non-professionals. Therefore it is assumed that professional M&R is mainly carried out on boats with a length above 7.5 meter. Per boat 4.5 litres of paint are applied using a mixture of airless spray and brush and roller. The application of the paint takes place almost continuously during 6 months (in winter time) in the open air on compact earth with some shrouding.

Typical case: Fifty pleasure boats (>7.5 m) are painted per year in a repair shop at a boat yard (hard standing area). According to Safinah boats < 7.5 are mainly repaired by non-professionals. Therefore it is assumed that professional M&R is mainly carried out on boats with a length above 7.5 m. Per boat 4.5 litres of paint are applied using brush and roller. The application of the paint takes place almost continuously during 6 months (in winter time).

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 0.14 is zero.

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 0.15 Calculation of the environmental concentrations for professional application of paint during M&R of pleasure craft in an average OECD boat yard/marina for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting interval[1)]	[month]	Tint	6	D
Length of the receiving soil compartment[2)]	[m]	LENGTH	12.5	D
Width of the receiving soil compartment	[m]	WIDTH	5.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[3)]	D
Soil density (dry weight)	$[kg.m^{-3}]$	$RHOsoil_{dw}$	1,504[4)]	
Total emission to soil	$[g.d^{-1}]$	$Elocal_{soil}$		O
Output :				
Predicted environmental concentration in soil	$[g.kg^{-1}]$	$Clocal_{soil}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) Period in which painting does not occur;
2) A boat of 7.5 m length and 2.5 m width is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 meter wide;
3) In line with the environmental emission scenario of the OECD for Wood Preservatives;
4) Based on EU-TGD (ECB, 2003) (wet weight is 1700 $kg.m^{-3}$).

Non-professional M&R pleasure craft

For the application of paint pleasure craft during non-professional M&R in OECD marinas only one scenario was determined. It is assumed that non-professionals do not (or not often) paint their boats in semi-closed or closed environments. The following scenario was determined:

Three hundred and fifty pleasure boats (<7.5 m) are painted per year in an open system on compacted earth. It is possible that non-professional application takes place on a hard standing area. The potential emission than goes (partially) to waste water. This possibility is included in the scenario. Per boat 2.5 litres of paint are applied using brush and roller. The application of the paint takes place almost continuously during 3 months (late winter and early spring). In contrast with professional application this does not necessarily happen at the same area. For example boats can be taken home for application or painted in storage areas. Therefore it is assumed that only 5 boats are painted on the same spot per painting period.

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 0.16 is zero.

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 0.17 Calculation of the environmental concentrations for non-professional application of paint during M&R of pleasure craft in an average OECD marina for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting interval 1)	[month]	Tint	9	D
Length of the receiving soil compartment 2)	[m]	LENGTH	9.5	D
Width of the receiving soil compartment	[m]	WIDTH	4.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1 3)	D
Soil density (dry weight)	[kg.m^{-3}]	$RHOsoil_{dw}$	1,504 4)	
Total emission to soil	[g.d^{-1}]	$Elocal_{soil}$		O
Output :				
Predicted environmental concentration in soil	[g.kg^{-1}]	$Clocal_{soil}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) Period in which painting does not occur;
2) A boat of 7.5 m length and 2.5 m width is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 metre wide;
3) In line with the environmental emission scenario of the OECD for Wood Preservatives;
4) Based on EU-TGD (ECB, 2003) (wet weight is 1700 kg.m^{-3}).

0.5.2 Removal

For application a distinction was made between new building and M&R. Removal of the old paint layer on a ship hull takes place only during M&R of ship hulls. The following scenarios were developed:

Maintenance and repair
- Commercial ships → professional;
- Pleasure craft → professional;
  → non-professional.

In the tables 0.18 to 0.23 the recommended scenarios for the removal of paint on ship hulls are described.

M&R commercial ships

The following scenarios were developed:

Realistic worst case: Twenty (expert judgement CEPE) commercial ships are treated per year. The paint is removed in one day in an exposed floating dock or marine lift (in the open air, on a hard standing area). After the hull is washed the paint is removed by reblasting. A ship is normally treated by spot blasting after which new paint is applied on top of the old paint. But after a certain time period the entire ship hull needs to be reblasted because of the layers of paint that accumulate on the hull during spot blasting and repainting the hull). Depending on the control measurements of the yard the potential emission then either goes to surface water or is disposed of as waste or a combination of these two options (wash water can be treated/filtered on the yard before discharge or disposal). This possibility is included in the scenario. For the realistic worst case concentration during the emission period reblasting should be considered. But for the calculation of the yearly average concentration the ratio of spot blasting/reblasting is important. According to expert judgement of CEPE spot blasting and reblasting occurs in a ratio 10:1.

Typical case: Twenty commercial ships are treated per year. The paint is removed in one day in a graving dock (in the open air, on a hard standing area). The paint is removed by high pressure water washing. As for the realistic worst case scenario the potential emission either goes to surface water or is disposed of as waste or a combination of these two options. This possibility is included in the scenario. The calculation of the yearly average will be equal for both realistic worst case and typical case, because both spotblasting and reblasting may occur in the same shipyard.

According to the Safinah report for both scenarios the potential emissions end up in the surface water (as for application). Therefore the fraction to soil in the scenario as described in table 0.18 is zero.

Table 0.18 Removal of the paint layer in an average OECD shipyard

Variable/parameter	Unit	Symbol	Value for realistic worst case	Value for typical case	S/D/O/P
Input:					
The removal period	[d]	Tremoval	1 [1)]	1 [1)]	D
Number of boats treated per removal period	[-]	Nboat	1 (as for application)	1 (as for application)	D
The average hull surface of a typical OECD ship	[m^2]	$AREA_{ship}$	EU/US: 2500 Asia 7963 [2)]	EU/US: 2,500 Asia 7,963 [2)]	D
Theoretical coverage of the paint	[$m^2.l^{-1}$]	COVERAGE			S
Number of coats applied on the hull	[-]	Ncoats	2	2	D
Fraction excess paint applied [3)]	[-]	Fexcess	0.20 [4)]	0.20	D
Fraction of the paint that is to be removed from the ships hull by HPW (exhausted paint)	[-]	Fwashing	0.20	0.20	D
Fraction of the paint that is to be removed from the ships hull by abrasion	[-]	Fabrasion	Reblasting [5)]: 0.10	Spot blasting [5)]: 0.005	D
Ratio reblasting/spot blasting [7)]	[-]	$RATIO_{blasting}$	1/10	1/10	
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 HPW	[-]	$Fa.i._{exhpaint}$	0.05 [1)]	0.05 [1)]	D
Fraction of a.i. remained in old paint removed by abrasion	[-]	$Fa.i._{old\ paint}$	0.30 [1)]	0.30 [1)]	D
Fraction to surface water [8)]	[-]	F_{water}	Max. 1	Max. 1	D
Fraction to soil	[-]	F_{soil}	0	0	D
Output :					
The total amount of paint applied per ship [9)]	[l]	$Vpaint_{total}$			O
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$			O
Intermediate calculation:					
$Vpaint_{total}$ = Ncoats * ($AREA_{ship}$ / COVERAGE) * (1+Fexcess)					
End calculations:					
$Elocal_{water}$ = ($Vpaint_{total}$ * Nboat * Ca.i. * (Fwashing * $Fa.i._{exh\ paint}$ + Fabrasion * $Fa.i._{old\ paint}$) * F_{water}) / Tremoval Emission load for the calculation of the yearly average: $Elocal_{water}$ = ($Vpaint_{total}$ * Nboat * Ca.i. * F_{water} * (Fwashing * $Fa.i._{exh\ paint}$ + Fabrasion_reblasting * $RATIO_{blasting}$ * $Fa.i._{old\ paint}$ + Fabrasion_spot blasting * $Fa.i._{old\ paint}$ * (1- $RATIO_{blasting}$))) / Tremoval					

1) Expert judgement CEPE;
2) Note that all other values are based on the European/US situation. Note also that the value for Asia is lower than for the new building scenario (Table 0.8) as also smaller ships are treated;
3) The theoretical paint demand is the amount of paint that is theoretically needed to paint the entire ship hull. The theoretical paint demand does not contain the excess paint applied on the hull due to overlap during the application process, the subsequent coating of join up seams and butts, etc. The theoretical paint demand and

the excess paint together form the total amount of paint that is applied on the ships hull. This is important for the calculation of the amount of a.i. remained on the ships hull;

4) A fraction of 0.20 is the worst case value for the application of excess paint during M&R;
5) At reblasting the top layer of the old paint is removed from the entire ship hull, at spot blasting paint is removed only from parts of the hull;
6) Used for the calculation of the concentration during the emission period;
7) Expert judgement CEPE. Because spot blasting as well as reblasting occurs at the same shipyards, for the calculation of the yearly average concentration both spot blasting and reblasting has to be taken into account. Spot blasting removes paint from 5% of the hull area whereas reblasting removes paint from the total hull area (5% of 0.10 = 0.005);
8) Depending on the control measurements of the ship yard the emission up to a maximum of 100% either goes to surface water or to waste or a combination of these two;
9) Theoretical amount of paint + excess paint.

The emission load finally ends up in a river or a harbour. For the calculation of concentrations in a river reference is made to general environmental exposure assessment guidelines such as the EU-TGD (ECB, 2003). Individual countries have to decide on the river dimensions and waterflow. For the emission to a harbour the dimensions of the recommended commercial harbour for service life of antifouling paints are used.

Table 0.19 Calculation of the environmental concentrations for removal of the paint layer during M&R of commercial ships in an average OECD shipyard (point source in harbour or river) for both realistic worst and typical case

Variable/parameter	**Unit**	**Symbol**	**Value**	**S/D/O/P**
Input:				
The removal frequency per year[1]	[-]	Tfreq	20[2]	D
Length of the harbour	[m]	LENGTHch	5,000	D
Width of the harbour	[m]	WIDTHch	1,000	D
Depth of the harbour	[m]	DEPTHch	15	D
Total emission to water	[$g.d^{-1}$]	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in surface water	[$g.m^{-3}$]	$Clocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) The amount of removal periods per year;
2) Expert judgement CEPE.

Professional M&R pleasure craft,

The following scenarios were developed:

Realistic worst case (US): As for application during M&R fifty pleasure boats (>7.5 meter) are treated per year in a repair shop at a boat yard (hard standing area or compacted earth). According to Safinah boats < 7.5 meter are mainly repaired by non-professionals. Therefore it is assumed that professional M&R is mainly carried out on boats with a length above 7.5 meter. The removal of the paint layer is done by HPW followed by abrasion and takes place almost continuously during 6 months.

Typical case (EU): As for application during M&R fifty pleasure boats (>7.5 m) are treated per year in a repair shop at a boat yard (hard standing area). The removal of the paint layer is done by HPW only and takes place almost continuously during 6 months.

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 0.20 is zero.

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;

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 (see also section 4.4.2);
4) Depending on the control measurements of the boatyard the emission goes to soil, surface water, or a STP or a mixture between these 3 options.

Table 0.21 Calculation of the local intial environmental concentrations in soil and surface water for professional removal of the paint layer during M&R of pleasure craft in an average OECD boatyard for both realistic worst and typical case

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
Soil				
The removal interval[1)]	[month]	Tint	6	D
Length of the receiving soil compartment[2)]	[m]	LENGTH	12.5	D
Width of the receiving soil compartment	[m]	WIDTH	5.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[3)]	D
Soil density (dry weight)	[$kg.m^{-3}$]	$RHOsoil_{dw}$	1,504[4)]	
Total emission to soil	[$g.d^{-1}$]	$Elocal_{soil}$		O
Surface water				
Length	[m]	LENGTHm	141.5	D
Width	[m]	WIDTHm	141.5	D
Depth of harbour	[m]	DEPTHm	4	D
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in soil	[$g.kg^{-1}$]	$PEClocal_{soil}$		O
Predicted environmental concentration in surface water	[$g.m^{-3}$]	$PEClocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) Time period in which removal of paint does not occur;
2) The weighted average boat length of boats > 7.5 m is 10.36 m. A boat of 10.5 m length and 3.5 m width is assumed. For the determination of the surface of the receiving environmental compartment (compacted earth for the realistic worst case scenario) a “walking path” around the boat (width: 1 m) for the applier of the paint is assumed;
3) In line with the environmental emission scenario of the OECD for Wood Preservatives;
4) Based on EU-TGD (ECB, 2003) (wet weight is 1700 $kg.m^{-3}$).

Non-professional M&R pleasure craft

It is assumed that non-professionals do not (or not often) work in semi-closed or closed environments. For the removal of paint from pleasure craft during non-professional M&R in OECD marinas the following scenarios were determined:

Realistic worst case:
Three hundred and fifty pleasure boats (<7.5 m) are treated per year on lifting from the marina in the open air on compacted earth (washing area). It is also possible that non-professional removal takes place on a hard standing area. The potential emission then goes (partially) to waste water. This possibility is included in the scenario. The removal of the paint takes place by HPW only and occurs almost continuously during 3 months.

Typical case: In Europe hulls are most commonly washed only and then repainted. In the USA there is a higher proportion of abrading carried out. After the boat is washed down it is moved to an other area for the removal of paint by abrasion (and finally the application of new paint). Therefore in this scenario only the abrasion of the boat hull is considered. As for non-professional application the abrasion of the 350 boats does not necessarily happen at the same area. For example boats can be taken home for application or painted in storage area. Therefore it is assumed that only 5 boats are abraded on the same spot per painting period.

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 0.22 is zero.

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;

4) Depending on the control measurements of the boatyard the emission goes to soil, surface water or a STP or a mixture between these 3 options;
5) 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 treat 5 boats. The remaining 9 months of the year removal does not occur.

Table 0.23 Calculation of the environmental concentrations in soil and surface water for non-professional removal of the paint layer in an average OECD boatyard/marina (see M&R) for both realistic worst and typical case

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
Soil				
The removal interval[1)]	[$month^{-1}$]	Tint	9	D
The removal frequency	[-]	Tfreq	5	D
Length of the receiving soil compartment[2)]	[m]	LENGTH	9.5	D
Width of the receiving soil compartment	[m]	WIDTH	4.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[3)]	D
Soil density (dry weight)	[$kg.m^{-3}$]	$RHOsoil_{dw}$	1,504[4)]	
Total emission to soil	[$g.d^{-1}$]	$Elocal_{soil}$		O
Surface water				
Length	[m]	LENGTHm	141.5	D
Width	[m]	WIDTHm	141.5	D
Depth of harbour	[m]	DEPTHm	4	D
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in soil	[$g.kg^{-1}$]	$PEClocal_{soil}$		O
Predicted environmental concentration in surface water	[$g.kg^{-1}$]	$PEClocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) Time period in which removal of paint does not occur.
2) A boat of 7.5 m length and 2.5 m width is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 metre wide.
3) In line with the environmental emission scenario of the OECD for Wood Preservatives.
4) Based on EU-TGD (ECB, 2003) (wet weight is 1700 $kg.m^{-3}$).

READERS GUIDE TO THIS DOCUMENT

A description of industry and use areas with respect to antifouling products is given in chapter 1.

Chapter 2 provides more extensive information on the topics leaching rate and anti-fouled underwater area for ship hulls. These parameters are considered most important for estimating the emission of antifouling biocides from ship hulls.

Chapter 3 describes the potential points of release of antifouling chemicals during the processes that can be distinguished for the different life cycle phases (application, service life and removal) of antifouling products used on ship hulls and in aquaculture use.

The scenarios for antifoulants used on respectively ship hulls and on aquaculture equipment that were already developed in different OECD countries (existing scenarios) are described in chapter 4 and 5. Within chapter 4 the newly developed scenarios for the application and removal of paint on ship hulls are presented.

The existing scenarios described in chapter 4 are evaluated and compared in chapter 6 to develop harmonised scenarios.

Chapter 7 presents a summary of all the recommended environmental emission scenarios (both harmonised and new scenarios) which can be used in risk assessments in notification and authorisation procedures in regulatory frameworks used in all OECD countries.

The harmonised scenarios as recommended in chapter 7 are tested in chapter 8. The purpose of this exercise is to see if the scenarios work and if they result in the desired output for different types of anti-fouling products (e.g. organics and inorganics). It is not a validation exercise.

Finally in chapter 9 some concluding remarks are made.

ROYAL HASKONING

CONTENTS

ANNEXES:

Annex I	Description of existing calculation models for estimating the emission from service life from the use of antifouling biocides on ship hulls;
Annex II	Provision of biocide Leaching rate data for Anti-Fouling Products. A Discussion Document from the Anti-Fouling Working Group of CEPE. April 2003;
Annex III	Members of the OECD Steering Group on Anti-Fouling Products.

1 INTRODUCTION

1.1 Background

According to national legislations within the Organisation for Economic Co-operation and Development (OECD) the evaluation of environmental exposure to biocides, including antifouling products, is an integral part of the risk assessment of a biodal product or of an active ingredient for regulatory purposes. Preferably, representative data from well-designed field studies should form the basis for exposure assessment. Although for some existing active ingredients monitoring data may be available for many information on actual environmental concentrations is limited or non-existing. As for other chemicals, exposure models offer an alternative solution for estimation of the environmental emissions and concentrations.

In the context of the OECD Biocides Programme initiated in 1998 the developemnt of guidance for exposure assessment of biocides was given high priority in view of the wide variety of exposure scenarios associated with the use of these chemicals. Wood preservatives were the first product type selected. This resulted in the "Emission Scenario Document for Wood Preservatives" published in 2003 (OECD, 2003).

The European Parliament and the Council adopted in 1998 the Directive 98/8/EC on the placing of biocidal products on the market (Biocidal Products Directive). As an implication an environmental risk assessment is to be carried out. For this purpose a uniform method to predict the potential environmental emissions needs to be available. Therefore it was decided that emission scenario documents need to be developed for the various biocidal product types. This resulted in the so-called EUBEES I and II projects of which the results were published in 2002 and 2004 (ref).

In view of the number of already existing scenarios and ongoing international activities involving anti-foulants, the OECD Biocides Steering Group chose antifouling products as the second biocidal product type for which an Emission Scenario Document (ESD) has to be produced. Subsequently, a project was started - financed by the European Commission - with the aim to produce an ESD for antifouling products that is harmonised and applicable in all EU Member States and non-EU OECD Member countries. The actual work of producing the ESD was done by a consortium of two consultants overseen by a Steering Group. The Steering Group was composed of regulators from different OECD countries, the European Commission and industry representatives. The members of the Steering Group are presented in Annex III.

In this document the emission scenarios available for several applications of antifouling products are evaluated and compared with the aim of producing one harmonised environmental emission scenario for each of the relevant applications. If there are no existing environmental emission scenarios for a certain use category (for either/or application, in-service use or during removal) the processes involved, potential emission pathways and factors affecting emissions are described. For several use categories without existing scenarios which were considered relevant (e.g. application and removal of antifouling paint on ship hulls) new scenarios were developed.

The primary aim of the harmonised emission scenarios is for use in risk assessments in notification and authorisation procedures in regulatory frameworks used in all OECD countries. Therefore it is important that the harmonised scenarios are typical OECD emission scenarios. It's important to note that the harmonised scenarios that are developed within this project are intented to be used for general risk assessment and explicitly not for site specific risk assessments. Furthermore it's important to note that the recommended scenarios for service life of the antifouling products in the ESD are limited to the calculation of the initial local concentrations in the primary receiving environmental compartments. The recommended scenarios for the application and removal are limited to the calculation of the emission load. The scope of this document is intended to determine a methodology for determining the emission load or initial concentrations from the use of antifoulants. The determination of any Predicted Environmental Concentration in the receiving environmental compartment as well as in secondary environments taking removal processes into account and therefore any assessment of the environmental impact of antifoulants should be carried out according to the regional practices in the Member States of the OECD. Thus, for example, in the European Union the use of Technical Guidance Documents or Technical Notes on Guidance under the Biocidal Products Directive system should be employed to determine PEC values. In chapter 9 guidance will be given on how to use the harmonised emission scenarios with respect to determining the local PEC.

According to the OECD definition antifoulants are underwater paints/treatments, antifoulants, e.g. for use on/in:

- Boats;
- Bilge water;
- Lobster pots;
- Marine structures;
- Fishing nets;
- Intake pipes.

Definitions of the EU, IMO and some OECD member states are given below:

- EU Biocidal Products Directive 98/8/EC: Antifouling Products are used to control growth and settlement of fouling organisms (microbes and higher forms of plant and animal species) on vessels, aquaculture equipment or other structures used in water (Product Type 21);
- IMO AFS Convention: antifouling systems: "A coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms.";
- US: Antifouling agents are agents that kill or repel organisms that attach to underwater surfaces, such as boat bottoms;
- Switzerland: antifoulings are underwater paints, which reduce the attachment of animal and plant organisms to structures such as ships, buoys and jetties (appendix 4.13 of Swiss Ordinance relating to Environmental Hazardous Substances);
- Canada: the Pest Management Regulatory Agency (PMRA) in Canada regulates biocide releasing antifouling products. The definition is as follows:
  "An antifoulant is any coating or treatment to eliminate or repel fouling organisms, the use of which results in the release of a biocide to the aquatic environment".

Some of the definitions also include antifouling systems in which no biocides are used. The present document will not deal with these type of systems.
The report is based on:

- Emission scenarios developed in different OECD countries and;
- Discussions in the OECD Antifouling Steering Group for the project "Development of environmental emission scenario document for active substances used in anti-

fouling products" (European Commission Service Contract No. B4-3040/2002/348010/ MAR/C3).

1.2 Description of industry and use area

Fouling is an unwanted growth of biological material, such as algae, on a surface immersed in water. Fouling occurs in both salt and fresh water, but the fouling process is more rapid in salt water and there are more fouling organisms in salt water. To prevent fouling of immersed surfaces anti-fouling products are used.

The following areas of use for anti-fouling products are known:
- Ship hulls;
- Nets in fish farms;
- Mariculture equipment other than fish nets (such as lobster pots);
- Buoys and other small objects;
- Sluice doors;
- Harbour constructions;
- Inlet pipes of e.g. cooling systems;
- Marine sensors;
- Offshore constructions.

(Van Dokkum et al., 1998; OECD, 2001)

The most important area of use for antifouling products is the use on ship hulls for pleasure crafts and commercial ships. Worldwide the demand for this use is approximately 95% of the total demand (Brennan Research Group (2000)). So, for this use area an environmental emission scenario needs to be available. The question is for which other use areas an environmental emission scenario also needs to be available. Based on use volume, the use on offshore structures such as drilling platforms is after the use on ship hulls the most important. World wide the demand for this use is approximately 2.5% of the total demand (pers. com. R. Fenn). It was decided that an environmental emission scenario needs to be available for this use. This is however not developed in the present document, but reference is made to work carried out within the framework of the OSPAR Convention on the model CHARM (Chemical Hazard Assessment and Risk Management) (Thatcher et al., 2001). This model provides the amount of drilling platforms in a defined area and the dimensions and characteristics of the receiving environment. Using the amount of antifoulant applied on a platform and the leaching rate of the active ingredient the environmental release can be estimated.

Other arguments than use volume can be used to decide on the necessity of the availability of an environmental emission scenario. From the other use areas it was decided that the use in aquaculture - i.e. on nets used in fish farms - is the only relevant one. Although the market share of this use is minor compared to the use on ship hulls and offshore constructions the emission from this use was considered important as fish from fish farms is meant for human consumption and therefore there is the potential risk of secondary poisoning.

The use of antifouling products is one of the issues in PARCOM Recommendation 94/6 on Best Environmental Practice (BEP) for reduction of inputs of potentially toxic chemicals from aquaculture use. No parties have drawn up specific national BEPs yet, but a few have implemented specific action programmes (OSPAR, 2003). E.g. in Norway the aquaculture organisation (FHL) and the organisation for the deliverance of supply to the aquaculture industry including the netwashing industry (NLTH) have on a voluntary basis developed an action plan for the reduction of copper use in aquaculture. In line with PARCOM recommendations HELCOM recommendation 20/1 states that "Washing and drying of net cages should be used instead of application of toxic antifouling compounds".

This document concerns the development of environmental emission scenarios to estimate the emission of the biocide used in an antifouling product. This product can either be a paint (for ship hulls) or a oil or water based formulation (for aquaculture). Many terms are used for the biocide used in the product. In the present document the term antifouling product is used for the paint or the formulation and antifouling biocide is used for the active ingredient added to the product to prevent fouling.

In summary this document will examine the use of antifoulants on:

- Ship hulls and;
- Aquaculture equipment (fish nets, lobster and crab pots).

The document will look at three parts of the life cycle for each of these. The life cycle parts considered are:

- Application;
- Service life;
- Removal.

For ship hulls and aquaculture use the processes of application, service life and removal are described in sections 1.2.1 and 1.2.2.

1.2.1 Ship hulls

Fouling of the underwater surface of ships with algae, other micro-organisms and small invertebrates have a serious impact on the operational costs of shipping. Fouling of a ships hull causes the water resistance of a ship to increase strongly, causing an almost exponential increase in fuel demand with increasing thickness of the fouling layer. Further, it may lead to the introduction of non-endemic species in sensitive environments. Therefore antifouling products are applied on ship hulls (Van Hattum et al., 2002; Van Dokkum et al., 1998).

Biocide-based antifouling paints are widely used to prevent fouling. Since the mid 1960s TBT has been applied in most antifouling paint systems. Due to serious effects observed in oyster cultures, coastal mollusc populations, and in some deep water snail species, many countries have banned the application of TBT-based paints on recreational boats and small vessels (< 25 m), or posed limits to acceptable leaching rates. Since that period various new products, usually based on copper in combination with an organic biocide, have been applied in the pleasure boating sector. Non-biocidal coatings are being used on a limited scale or are still in the testing phase. In some countries pilot experiments with small scale mechanical removal systems for small pleasure boats have been conducted. In Finland mechanical removal of fouling organisms and the application of new paint is done in summer for passenger and cargo ships sailing in ice conditions in winter, because the ice cover partially removes the antifouling paint and fouling organisms from sailing ships.

In October 2001 the International Maritime Organization approved the "International Convention on the Control of Harmful Anti-Fouling Systems on Ships" (IMO, 2001). This Convention contains two main aims with different timescales. The first aim (which has already been achieved) was for the global prohibition of the application of organotin compounds which act as biocides in anti-fouling systems on ships by 1 January 2003. The second aim is for a complete prohibition of the presence of organotin compounds which act as biocides in anti-fouling systems on ships by 1 January 2008. When the second part of the convention comes into force ship hulls must be surveyed and carry an international antifouling certificate proving their compliance with the Convention.

The EU is putting the IMO controls in place via an amendment (2002/62/EC) to the Marketing and Use Directive (76/769/EEC). Additionally, in the EU legislation has recently been adopted to ban organotin compounds for all ships flying the flag of a member state from 1 July 2003 and for all ships - irrespective of their flag - entering an European port by 1 January 2008 (EU, 2003).

The following paragraphs give short descriptions of the processes with respect to the use of anti-fouling products on ship hulls.

Application

Anti-fouling products are applied as paint, which forms a protective top layer on the ship hull. For the application of anti-fouling paints there are two possibilities. The paint is applied by:

- Brush and roller,
- Or spraying.

Paint application methods vary according to the area of the ship that is being painted, for example (Environment Agency UK, 2002):

- Paint may be mixed manually or automatically;
- Coating may take place either indoors or outdoors;
- Shrouding fences may be used to prevent release of overspray from the painting area to the environment.

Air-assisted spraying systems (pneumatic spraying) may be used for painting ship hulls, but spraying is usually undertaken using airless sprayers, which have a higher transfer efficiency (Environment Agency UK, 2002; Van Dokkum et al.; 1998).

Service life

During service life the antifouling biocide leaches into the water, preventing organisms to attach to the ship hull. Anti-fouled ships may sail in fresh water (inland waterways and lakes) or in salt water (open sea). Ships may be moored in harbours and marinas.

A difference can be made between the leaching rate of the antifouling biocide during mooring and the rate during sailing. The difference in leaching rates between the two situations depends not only on the type of antifouling biocide, but also on the characteristics of the paint matrix that is used. Leaching rates are also influenced by the water quality and the age of the paint matrix although the influence of these factors cannot be quantified at the moment (see section 2.2) for more information with respect to leaching rates).

Removal of old coatings

Methods for the removal of old antifouling paint layers are:

- Hydroblasting;
- Abrasive blasting;
- Scraping and sanding.

Hydroblasting for coating removal will remove the entire coating and any corrosion. Antifouling biocidal emissions may consist of fouling organisms (accumulation of antifouling biocides) and pieces of coating. It may be performed at:

- Slipways;
- Dry docks;
- Small docks for fishery and recreational ships;
- Yachting wharves;
- Winter storage areas for yachts;
- Marinas.

At abrasive blasting hard pieces of grit or other abrasives are blown to the paint surface, and remove the paint layer. Copper slag, coal slag, steel grit, steel shot and glass may be used. The technique can be applied to roughen or to remove the entire paint layer. Abrasive blasting is performed at (Van Dokkum et al., 1998):

- Larger wharves (with dry docks/slipways for seagoing ships);
- Slipways/smaller docks for fishery and recreational ships;
- Specialised companies (conservation plants).

There are three basic types of abrasive blasting used in shipyards (Environment Agency UK, 2002; Handboek Milieuvergunningen, 2003):

- Centrifugal blasting (dry), which has the advantage of easy recovery of abrasive materials for reuse and recycling;
- Air nozzle or pneumatic blasting (dry), which is often performed in open systems;
- Wet abrasive blasting, this has the advantage of a decreased dust emission when blasting in the open air. Water is usually injected into the airborne stream of abrasive although in slurry blasting the abrasive and water are premixed before being propelled. This method is used for the removal of chipping paint, marine growth (including organisms), mud, and salt water from the ship’s hull.

High pressure water washing will normally not remove the full coating. But fouling, rust and paint not so firmly attached can be removed. The difference with hydroblasting are the pressures used. Van Dokkum et al. (1998) assumes that in case of self-polishing paints (see section 1.3.1) high pressure water washing is sufficient to prepare the ship for the application of a new coating. But in practice also abrasive blasting or hydro-blasting of self-polishing paints may occur, because commercial owners will sometimes require full removal and this will only be guaranteed by either abrasive blasting or hydroblasting).

Scraping and sanding is used in some member states where sometimes the scrapings are collected. Special paint removers and more gentle abrasives such as sponge jetting may be used for pleasure craft.

1.2.2 Aquaculture use

This section describes the processes with respect to the use of anti-fouling products in aquaculture. Because nets in fish farms and lobster and crab pots are continuously immersed in the water, the nets can be protected against unwanted growth of organisms by antifouling products. The total market share of antifoulants on fish nets and lobster/ crab pots is much smaller than the share of antifoulants used on ship hulls. The emission of antifouling products used on aquaculture equipment is nevertheless considered to be important, because of the fact that in aquaculture a great amount of nets is immersed in a relative small amount of water. Primary or secondary poisoning may be of relevance. Next to the environmental interest it is important to consider that lobsters, crabs and fish from fish farms are meant for human consumption. But exposure scenarios for organisms at the top of the food-chain (secondary poisoning) or for human beings are not included in the present document. Guidance on human exposure to biocidal products is to be found in the TGD (ECB, 2003). Information is only available for antifouling products used on fish nets. Therefore proces descriptions with respect to the use of antifouling products on lobster and crab pots are not included in the following sections.

<u>Application</u>
The application of antifouling products on fishnets takes place by dipping the nets into the product. Impregnated nets are hung out to dry. The drying time depends on the weather conditions and whether the nets are hung out inside or outside. In the case of water based formulations, impregnated nets must be totally dry before they are put into water (nets treated with oil based antifoulants are not completely dry). Net dipping takes place all year round. Typically the application of antifouling products is repeated once a year (ECB, 2003). Some fish farms - e.g. in France - do no treat their nets with antifoulants, but use for example high pressure water blasting for the removal of fouling organisms.

<u>Service life</u>
During service life the antifouling biocide leaches into the water, preventing organisms to attach to the fish nets. As for antifoulants used on ship hulls the leaching rate is an important parameter and depends also on the type of antifoulant biocide, water quality and the age of the antifoulant.

<u>Removal</u>
Fish nets are cleaned by pressure washer and large scale washing machines (ECB, 2003).

1.3 Types of antifouling products

Different types of antifouling systems (paints or formulations) exist. This section describes the existing types of antifouling products and the areas where these types are normally used. It does not cover the specific antifouling biocides (the active ingredients as e.g. copper), but rather the ready to use antifoulant product types. It is important to distinguish between these types, because the life cycle and the leaching process vary between antifouling systems. This may result in different data requirements not only for different kinds of antifouling biocides but also for different antifouling systems (e.g. leaching rate).

1.3.1 Ship hulls

The major application of antifouling biocides is on ship hulls. Antifouling biocides are applied as paint, which forms a protective top layer on the ship hull. From this paint the antifouling biocides are released. Biocidal antifouling products often contain more than one biocide, e.g. copper compounds can be combined with organic biocides, to give good protection during mooring as well as during sailing. In table 1.1 the different types of existing antifouling systems for ship hulls, their characteristics and the areas where they are used are described.

Table 1.1 Types of antifouling systems for ship hulls ((Van Dokkum et al., 1998 and CEPE, 1999)

Antifouling system	Characteristics	Field of use
Soluble matrix type	• The biocides are not bound in the matrix and diffuse through the paint layer to the water; • Exponentially decrease release rate of the biocide (high initial release rate, after some time release rate too slow to prevent fouling) ; • The binding compound of the matrix dissolves slowly in water; • Time after which the paint layer has to be renewed depends on the biocide used; • Often needs not to be removed before next application on pleasure boats.	• Marine water; • Fresh water (with copper as the most important active ingredient); • Used on pleasure boats.
Insoluble matrix type	• Same characteristics as the soluble matrix type, except that the binding compound of the matrix does not dissolve in water; • Needs to be removed before next application.	• Marine water; • Fresh water (with copper as the most important a.i.); • Used on pleasure boats.
Ablative or polishing tin free paints	• Has the same leaching characteristics as the soluble and insoluble matrix types, except that this paint erodes by hydrolysis. This increases emission due to diffusion, because of the shorter diffusion path; • Usually needs not to be removed before next application on pleasure boats.	• Marine water; • Fresh water (with copper as the most important active ingredient); • Used on fast motor boats and racing sailing boats.
TBT self polishing co-polymer antifoulings (self polishing organotin paints)	• Containing tributyltinmetacrylate co-polymer; • The biocide is bound to a matrix; • When exposed to water the matrix hydrolyses and the biocide is released; • Constant release rate when the ship is moving; • To guarantee prevention of fouling when the ship is not moving (free), copper is usually added to the paint.	• Marine water; • The application of organotin on ships is prohibited globally by 1 January 2003. The presence of organotin compounds acting as biocides will be completely prohibited by 1 January 2008.
TBT-free self polishing antifoulings (self polishing tin free paints)	• Is supposed to have the same characteristics as TBT self polishing co-polymer antifoulings, but is not necessarily bound to a matrix; • Usually needs not to be removed before next application on pleasure boats.	• All kind of boats.

Table 1.2 Other methods of fouling control ((Van Dokkum et al., 1998 and CEPE, 1999)

Method	Characteristics	Field of use
Other methods of fouling control (not considered further in this report, because no biocides are used)	Examples of other techniques to prevent fouling without using biocides are: • Non-stick coatings: the top layer of this coating is formed by a layer with low surface tension, which give fouling organisms no opportunities to attach firmly; • Ultrasound; • Electricity.	-

1.3.2 Aquaculture use

Nets on fish farms are impregnated with an antifouling formulation. When the nets are immersed in the water the antifouling biocides are released.

Three types of antifouling products exist:
- Water-based net impregnation formulations;
- Oil-based net impregnation formulations;
- Wax emulsion based net impregnation formulations.

The most important antifouling biocide in aquaculture use is copper (OSPAR, 2003; Scottish Association for Marine Science and Napier University, 2002). E.g. in the UK and Finland cuprous oxide is the only approved antifouling biocide for use in aquaculture. In Spain chromium oxide is used (OSPAR, 2003).

2 LEACHING RATE AND THE ANTIFOULED UNDERWATER AREA

2.1 Introduction

In this chapter more extensive information is given on the topics leaching rate and antifouled underwater area for ship hulls. These are considered to be the most important parameters for estimating the emission of antifouling biocides from ship hulls.

2.2 Leaching rate

The emission of biocides in antifouling products from ship hulls is normally determined by using the leaching rate and the total antifouled underwater area. The antifouling leaching rate is therefore a critical parameter in an environmental risk assessment. As already mentioned in section 1.2.1, the leaching rate depends on the type of compound, characteristics and age of the paint matrix and velocity of the ship as well as water characteristics.

Release rates of antifouling biocides from antifouling paints are required by a number of regulatory authorities to review and regulate the release of these biocides into the aquatic environment. An accurate biocide release rate value is essential. There has been much debate over experimentally derived release rate data. Some methods are generally considered overly conservative and are not believed to assess the actual environmental loading of the biocide into the environment. In a report of the CEPE Anti-Fouling Working Group (CEPE, 2003) the available methods to determine leaching rates are described.

The present methods are:
- Laboratory methods (only developed for salt water);
- Field tests;
- Mass balance method.

Laboratory methods are standardised ASTM- and ISO-methods measuring the release rates during a given time of immersion under specified conditions. The limitations of the first versions of these methods are that they were primarily developed for organotin copolymer containing and first generation TBT-free copper-containing antifouling paints in fully saline water only. Further, the short testing period may lead to release data that are too high. For example, in practice copper leaching rate for soluble matrix type paints decays exponentially with time so testing at two time windows during the coating's service life would give a more realistic picture. Finally, test results from different laboratories show significant levels of variation. It should be noted that these methods may serve only as a guide for the actual release rate, since they may overestimate the release rates for some paint types and the testing time is often only 45 days, which may be too short to detect the actual steady state release rate from antifouling paints in service. ISO and ASTM are working on methods for several alternative antifouling biocides to TBT (e.g. Irgarol 1051®). It is expected that the resulting methods will be laboratory methods based on the existing methods for organotin and copper. It should be noted that it is possible to use these methods over several weeks to obtain long-term leaching rates.

The Space and Naval Warfare Systems Center, San Diego has developed a field method for measuring in-situ organotin release rates using a dome placed on an immersed painted ship hull. The release rates measured by this device are significantly lower than those obtained by laboratory methods.

CEPE has developed a calculation method for the determination of leaching rates based on the assumption that the total release of biocide can never exceed the amount incorporated into the coating (see Annex II). This method has been accepted as an interim solution by Norway and the Netherlands as the method used for submission of release rate data with a product. The model assumes that the biocide release rate falls linearly for the first 14 days following immersion. The biocide rate is thereafter constant from day 14 until the last day of the coating specified life-time. The ratio of the cumulative amount of biocide released during the first 14 days following immersion to the average release rate during the remainder of the coating's specified life-time is 30. Finally, 30% of the biocide is retained in the paint film at the end of its specified lifetime.

While results from current laboratory methods are likely to over-estimate the leaching rate of the antifouling paint in-service, they can be used in a precautionary approach to environmental risk assessment in the absence of more refined and/or longer term leaching data, and/or an appropriate calculation method can be used. In a mass-balance calculation the approach with a default 30 % retention of the active substance at the end of the service life as proposed by CEPE may not be a realistic worst-case approach because the leaching gradient and the assumption that 30 % of the active substance is retained on the painted surface may not be applicable to all antifouling paints of all coating types and/or active substances based on their physicochemical properties. For example, a new coating type exists on the market that displays a low initial release rate which is slowly increasing until a possible steady state release rate is reached. This has implications on the suitability of the above referred calculation methods since the initial 14 days high release is absent in these coatings. Therefore, the calculation method should not be used unless the release behaviour of the paint is known.

The discussion on how to determine a leaching rate from all data available and on test methodology is outside the scope of this document. However, in figure 2.1 guidance is presented on a procedure which can be followed.

No information is available on the leaching rate of antifouling biocides from fishnets.

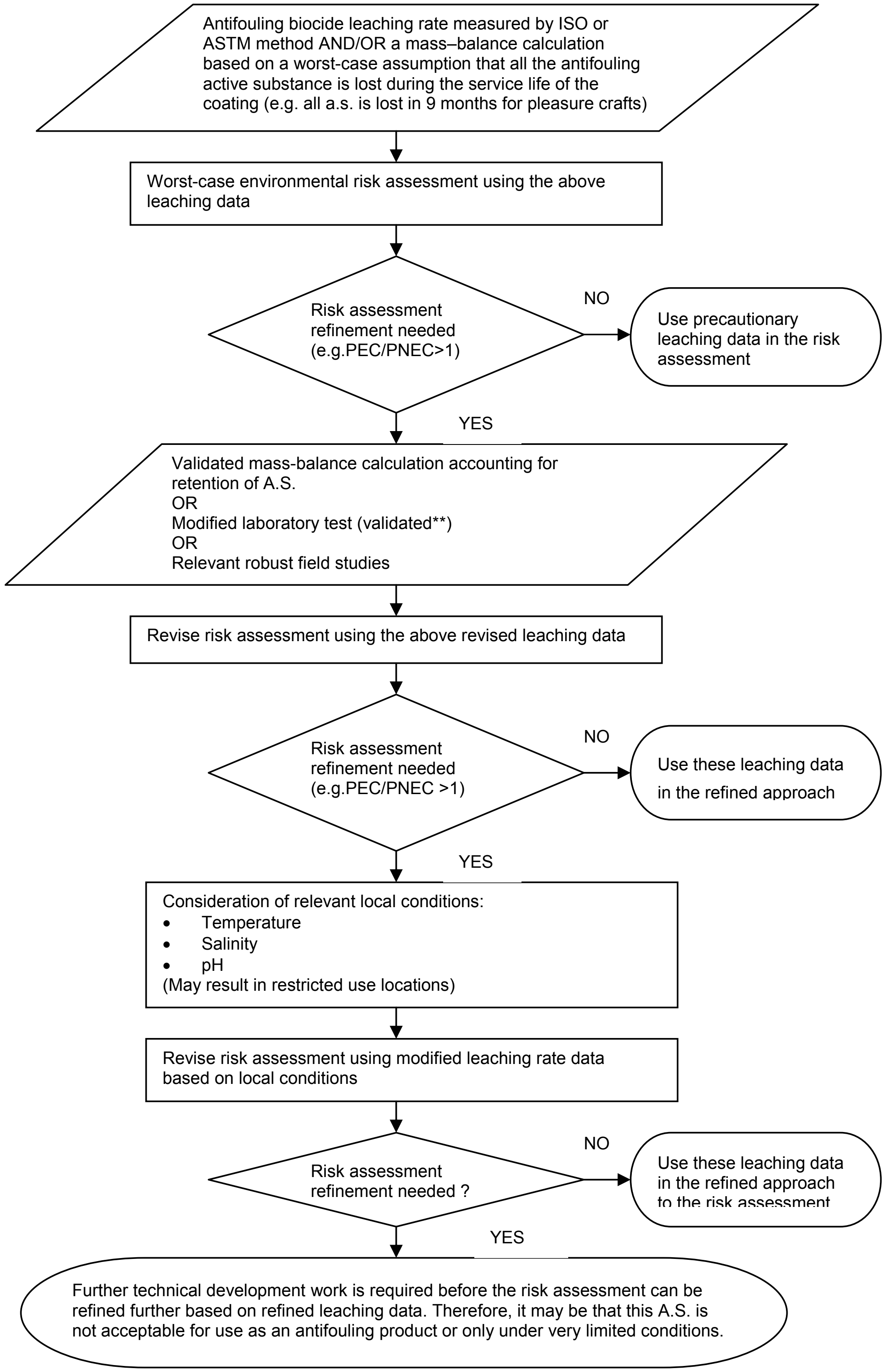

Figure 2.1 Procedure on the derivation of a leaching rate of antifouling biocides to be used in risk assessment

General notes to the decision making flow chart are:

1) Calculation methods cannot be provided in isolation without supporting laboratory data or validation data. However they can be used – provided they are validated – in the assessment;
2) It should be noted that risk assessment refinement may be achieved by modifying parameters other than leaching rate which may affect the predicted environmental concentration. However, leaching rate is one of the most significant parameters, and this has been considered in isolation within this section.

2.3 Antifouled underwater area for ship hulls

The other factor beside the leaching rate in estimating the emission of antifouling biocides from ship hulls during service life, is the underwater area of the ship treated with the antifouling product or total antifouled underwater area. This area depends on shipping intensities, dimensions of the various categories of ships, residence time of ships (often called “shipping characteristics”) but also cargo load and weather or sailing conditions. A distinction is often made between commercial ships in harbours and pleasure crafts in marinas, where the latter category has a length of less than 25 m.

There are a lot of data on shipping patterns. Van Hattum et al. (2002) conclude based on their search for data on commercial harbours, open sea and shipping lanes, that there are a number of sources but a structured and aggregated reporting system for the European waters is lacking. One of the problems for example is that port statistics are not kept on a standardised basis. Shipping dimensions may be based on length, depth or four different ways of expressing ship weight. Also, some ports only keep statistics with respect to the cargo of the ships, which can also be expressed in different ways.

However, several calculation methods are developed to calculate the antifouled under-water area of ship hulls. These methods are used in calculation models that are used to predict the concentration of antifoulants in the surface water (see also chapter 4). The methods used in these models are described in the following sections. A distinction is made between commercial ships (section 2.3.1) and pleasure craft (section 2.3.2).

2.3.1 Commercial ships

This section describes the calculation methods for the antifouled underwater area of commercial ships. Methods to calculate the antifouled surface area of commercial ship hulls were available in Van Hattum et al. (2002) (the MAM-PEC model) and Koivisto, S. (2003) (Finnish model based on MAM-PEC).

<u>Van Hattum et al. (2002)</u>
The antifouled underwater areas for the MAM-PEC scenario were calculated based on the method in a US modelling study predicting Sea-Nine concentrations with the EXAMS model (Willingham and Jacobsen, 1996). In this study the estimation of the antifouled underwater area for ships in the New York Harbor was based on average dimensions of nine ship types (219 m length and 33 m width). Based on a simple geometrical model the following formula was derived:

Antifouled underwater area (m^2) = length (m) * width (m) * 1.3
The length classes are based on ships in the Rotterdam Harbour. According to the MAM-PEC model the width and depth of the ships is assumed to be respectively 15% * length and 0.05 * lengh. This is roughly matching with sluices and port facilities in Dutch harbours and with ship dimensions in the New York Harbour.

For the development of MAM-PEC, the wetted hull areas were also calculated with a box model assuming that 50% of the box (i.e. the ship) is under water. Both methods yielded reasonably matching surface area estimates. But for reasons of comparability the calculation proposed by Willingham and Jacobsen (1996) was adopted for the MAM-PEC model.

Van Hattum et al. (2002) state that the antifouled underwater estimation has a large uncertainty, because there is a lot of variation in the proportions of commercial ships. The calculation of Willingham and Jacobsen (1996) was adopted, because it has no use to develop a more detailed equation when suitable boat dimensions are not available. It is recommended that in further studies a more refined approach is followed. Combined with detailed port or shipping statistics this should provide a basis for a more reliable estimation of the antifouled underwater area. A fixed module to calculate the surface area with the calculation of Willingham and Jacobsen (1996) is not included in the model. The average surface areas calculated with this calculation are included as default values in the default emission scenarios of MAM-PEC. These values are considered suitable for comparative purposes. Next to this the user has the option to modify the length categories and the average surface areas per ship, if such data are known from other studies.

<u>Earlier Finnish model (Komsi equation)</u>
In first instance the lengths and wet surface areas of vessels for the Finnish model were calculated from the database provided by the Finnish Maritime Administration. The data (length, breadth and depth) were collected from the Portnet system and consisted of 1459 vessels that visited Finnish harbours in 2001. Long ships are rare at Finnish harbours, as only 4% of ships were longer than 200 metres. The size of ships operating in the Baltic Sea is restricted by the Danish straits that restrict the maximum size of ships entering the Baltic Sea. Length, width and depth of vessels were used for the calculation of the antifouled underwater area according to a formula suggested by Juha Komsi from the Port of Helsinki:

Antifouled underwater area = 0.95 * length * (0.8 * (depth + depth) + width)

In the final version of the Finnish scenario the choice was made to replace the calculation of Juha Komsi by the Holtrop equation which is described below.

<u>Finnish model (Holtrop equation)</u>
The Ship Laboratory of the Helsinki University of Technology suggests the use of the Holtrop equation (Holtrop, 1977) for the calculation of the submersed wet surface area of ships. This calculation is given below.

$$S = L(2T + B)\sqrt{C_M}\left[0.5303368 + 0.6321359C_B - 0.360327(C_M - 0.5) - 0.0013553\frac{L}{T}\right]$$

S: Submersed ship area;
L: Length of ship;
T: Depth;
B: Width;
C_M: Factor on how full-bodied the main arch of the ship is (=0,975);
C_B: Factor on how full-bodied the underwater volume of the ship is (= 0,8).

The factors C_M and C_B are calculated according to the formulas:

$$C_M = \frac{A_M}{B \cdot T}$$

$$C_B = \frac{\nabla}{L \cdot B \cdot T}$$

A_M: The area of the main arc of the ship. It is the area of the biggest cross-section of the ship which is in general in the middle of the ship;
∇: The underwater volume of the ship (displacement).

The Holtrop equation is originally used as a calculationmethod for the resistance of a moving ship, the propulsion properties and the scale effects between models and full size ships. The calculation of the wet surface area of the ship is part of this calculation method. For the calculation of the hull surface it is assumed that the ship is fully loaded (100% of the intended underwater area of the ship hull is under water). C_M and C_B vary depending on the ship type. Faster ships have a smaller value and slower ships (e.g. tankers) a higher value. The default values for C_M and C_B are chosen on the basis of empirical data based on knowledge on their normal variation interval. The middle value from this normal variation interval was chosen as the default. Typically C_M varies from 0,95 up to 0,98. For the Finnish scenarios a value of 0,975 has been chosen. C_B varies from 0,75 up to 0,85 and a value of 0,8 has been chosen for the Finnish scenarios.

The other default parameters of the equation are based on statistical analysis of a large data set that was available for when the study was made. According to the Ship Laboratory the equation is not very sensitive for the changes in its factors. Changes in the default parameter values will cause max. 5% change in the wet area results obtained with this equation under its normal use conditions.

Note that all the equations calculate wet surface areas without the additional equipment found in the bottom of ships such as the propeller and the helm. The area of these should be added to get the total wet surface area if further refinement of the ship area calculation is desired.

<u>Comparison</u>
In table 2.1 the differences in surfaces areas calculated with the equations of respectively Komsi, Holtrop and Willingham and Jacobsen (MAM-PEC) are displayed.

Table 2.1 Comparison of wet surface areas of ships calculated by three different equations

Length (m)	Area (m^2) Komsi	Area (m2) Holtrop	Area (m2) MAM-PEC	% Holtrop/ Komsi	% MAM-PEC/ Komsi	% MAM-PEC/ Holtrop
<50	426	412	348	97	82	84
50-100	1,725	1,646	1,483	95	86	90
100-150	3,493	3,316	2,997	95	86	90
150-200	6,763	6,431	5,906	95	88	92
200-250	11,259	10,743	9,710	95	86	90
>250	16,895	16,092	14,832	95	88	92
Total area	*40,561*	*38,640*	*35,276*	*95*	*87*	*91*

Van Hattum et al. (2002) indicate that their calculation has a large uncertainty and that more research, preferably by shipbuilders, is necessary. The surface values calculated with the Holtrop equation do not differ much from the values calculated with the Komsi equation. The Holtrop equation seems to be the best choice, because it considers the typical shapes of a ships hull and is better founded compared with the other two equations. Therefore it is proposed to use the Holtrop equation in the commercial ship scenario's. The surface areas in the Finnish "commercial ship scenarios" were already calculated with the Holtrop equation. The original antifouled surface areas per ship for the MAM-PEC scenarios as described in chapter 4 are replaced by the surface areas calculated with the Holtrop equation.

2.3.2 Pleasure craft

The data on shipping patterns for pleasure crafts are more scarce compared to the data for commercial ships and are based on regional surveys. E.g. in the UK a survey was carried out by the Environment Agency reported in 1998 (Comber et al., 2001) while for Switzerland data are reported by Becker-van Slooten (1995) and for Finland by Koivisto at the Finnish Environment Institute (2003). In marinas the density of pleasure crafts present is highly season-dependent being higher in spring and summer.

This section describes the calculation methods for the antifouled underwater area of pleasure craft. Methods to calculate the antifouled surface area of pleasure craft were available in Van Hattum et al. (2002), Koivisto, S. (2003) and Linders and Jager (1998) (USES). In Comber, S. et al. (2001) (the REMA-model) and Madsen T. et al. (1999) (the Danish model) a different approach was taken. An average surface area of pleasure craft was determined based on surveys and experience.

<u>Van Hattum et al. (2002)</u>
Van Hattum et al. (2002) present the following formulas - based on recommendations in commercial brochures by some paint suppliers - for motor boats and sailing boats:

Antifouled under water area motor-launch (low draught) = length at water line * (width + depth)

Antifouled under water area sailing yacht (intermediate draught) = 0.75 * length at water line * (width + depth)

Antifouled under water area sailing yacht (deep keel) = 0.5 * length at water line * (width + depth)

As can be seen from these formulas motor boats require a greater volume of antifouling paint than sailing yachts.

Despite of these formulas, the MAM-PEC model uses the approach of Bauer and Jacobsen (1997) where the antifouled surface area is set as 50% * deck area. Based on values from Bauer and Jacobsen (1997) the average antifouled surface area of pleasure craft was set on 22.5 m^2.

Koivisto, S. (2003)
The wet surface areas of pleasure craft in the Finnish model are calculated by the equations provided by CEPE:

Antifouled under water area motor-boat = length at water line * (width + depth) * 0.85

Antifouled under water area sailing boat = length at water line * (width + depth) * 0.5

The length at the waterline of pleasure craft is considered 0.9 times the total length, because (according to this model) for many boats the length at the waterline is 10-15% less than the overall length.

The average boat length in the Finnish marina model is 7.7 m. The average surface area is 19.8 m^2.

Linders and Jager (1998)
In this model the antifouled surface area is calculated using the required cover of antifouling paint [$m^2.m^{-3}$] and the volume of paint [m^3] needed per yacht.

Antifouled surface area = cover of antifouling paint * volume of paint per yacht

When using the default values for the cover of antifouling paint and the volume of paint per yacht, this model assumes an antifouled surface area of 5 m^2.

A submersed area of 5 m^2 is very low compared to the data for the other marina scenarios.

Comber, S. et al. (2001)
The approach taken for REMA with respect to the antifouled surface area for an average pleasure craft was based on the mean-boat length in UK marinas (9.2 m). Data were obtained from the Environment Agency antifoulant survey (Boxall at al. 1998). The estimated surface area below the water line for an average boat kept in a UK marina was 30.7 m^2. Due to their larger surface area motorboats required a larger volume of antifouling paint than sailing boats (47% were motorboats and 53% were sailing boats).

Madsen T. et al. (1999)
In this model the surface area for pleasure craft is assumed to be 18 m^2. This value is based on an estimate made by the Danish Sailing Association.

Comparison
The data on shipping characteristics can be relatively old for the different environmental emission scenarios (e.g. Linders and Jager). Some of the scenarios are very country specific (Comber, Madsen and Koivisto).

There is a lot of variation in pleasure crafts and suitable boat characteristics. Information is only available on average boat lengths in several countries and not in marinas. There may be marinas with many large boats (e.g. 9 m) even when the average boat length in the corresponding country is for example only 7 m.

In the Safinah report (Safinah,2004) data were gathered covering 18 of the 30 OECD countries and covering most of the major pleasure craft markets. The data that were gathered consist of boat lengths. The results are described in table 2.2.

Table 2.2 Pleasure craft on the OECD market

Boat lengths	Percentage of the OECD market
2.5-7.5 m	77%
7.5-12 m	21%
12-18 m	1.3%
>18 m	0.7%

Since boat characteristics (e.g. the distribution of motor boats and sailing boats and the length and corresponding width and depth of boats) and the distribution of the boat lengths within the ranges as described in table 2.2 are not available, detailed calculations with e.g. the calculations of CEPE cannot be done.

Further information on boat characteristics (and boat places) was derived from the “Blue Flag” Campain in Germany for the year 2004 (data that were available on 30 March 2004 are used). The Blue Flag is an eco-label awarded to almost 2900 beaches and marinas in 24 countries across Europe and South Africa in 2003. The Blue Flag Campaign is owned and run by the independent non-profit organisation Foundation for Environmental Education (FEE). The Blue Flag works towards sustainable development at beaches/marinas through strict criteria dealing with water quality, environmental education and information, environmental management, and safety and other services. The award of a Blue Flag marina is based on compliance with 22 criteria covering amongst other things the aspects water quality and environmental management. The small individual Blue Flag can be awarded to interested boat owners/users wanting to contribute to the Blue Flag Campaign. The boat owner signs an environmental code of conduct declaring that he/she will act according the issues outlined in the code of conduct.

For the approximately 200 individual boats participating the Blue Flag, boat characteristics (length, width and depth) are available. The boat lengths are described in table 2.3.

Table 2.3 Pleasure craft participating the Blue Flag

Boat lengths	Percentage
2.5-7.5 m	26%
7.5-12 m	69.2%
12-18 m	5.1%
>18 m	0%

As for the data from Safinah 2004 the distribution of motor boats and sailing boats is not available. Furthermore it must be noted that the values as described in table 2.3 are not necessarily representative for the average boat lengths in Germany as the boat lengths are derived from boats participating the Blue Flag.

It is recommended that more research will be done with respect to boat characteristics in marinas in the OECD countries. Until then, it is recommended to use a fixed average value for the antifouled surface area per boat. The surface area estimated by Comber et al. (2001) is considered a realistic worst case value as the average boat length of Comber et al. (2001) is larger compared to the boat lengths of the other calculation methods, and the average surface area is larger compared to boats with the same boat length in Finland (a higher ratio surface area/boat dimensions).

3 POTENTIAL EMISSION ROUTES

3.1 Introduction

This chapter describes potential emission scenarios together with the potential points of release of antifouling chemicals during the processes that can be distinguished for the different life cycle phases (application, service life and removal) of antifouling products used on ship hulls and in aquaculture use.

Recent data with respect to the processes of application and removal can be found in Safinah (2004). This report was drafted under contract of CEPE as it was concluded after the start of the project that almost no - certainly recent - data were available for these processes. The aim of this report was to provide an assessment of potential environmental emissions due to the application and removal of antifouling paints on ship hulls and fish nets.

The Safinah report formed the basis for the scenarios developed in the next chapter.

3.2 Ship hulls

This section indicates the potential emission scenarios with the potential points of release for the application, service life and removal of antifouling products on ship hulls. The information is mainly derived from Safinah (2004). Flow-charts with description are given for the phases of application, service life and removal. More extensive descriptions on the processes of application, service life and removal are given in section 1.2.1.

3.2.1 Application

During the application of antifouling paint on ship and boat hulls emissions to air, soil and surface water may occur. A part of the antifouling biocide may be disposed of as chemical waste. The potential emission scenarios together with the potential points of release for the antifouling product are given in figures 3.1 and 3.2. A distinction is made between application of paint on:

- commercial ships;
- and pleasure boats.

Application on commercial ships will only be carried out by professionals, whereas the painting of pleasure boats may be carried out by both professionals and non-professionals. Professionals may use both spraying techniques and brush and roller. Non-professionals mainly use brush and roller.

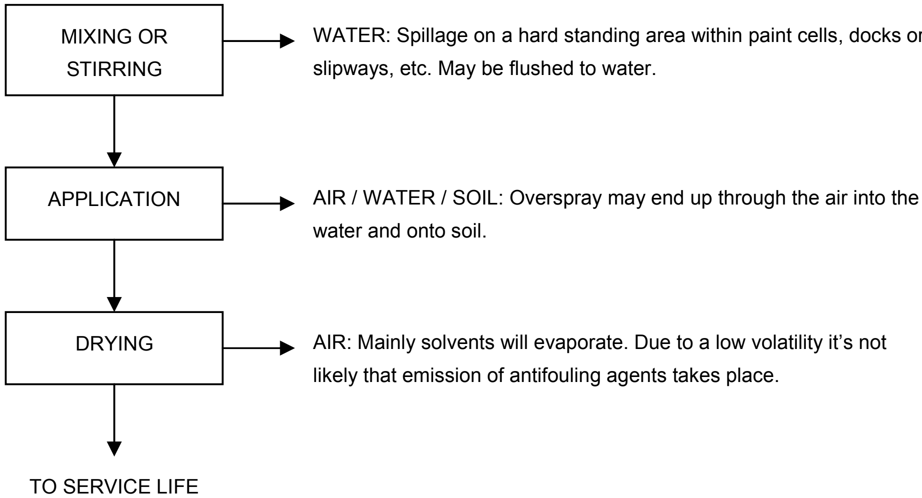

Figure 3.1 Application of antifouling paint on commercial ships (professional)

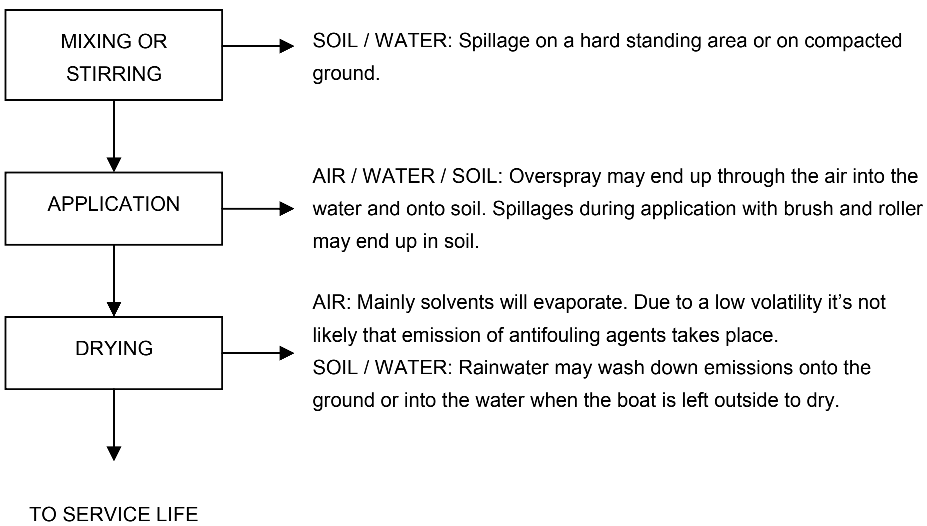

Figure 3.2 Application of antifouling paint on pleasure boats (both professional and non-professional)

The emitted amount of the antifouling biocide from the antifouling product is dependent on:

- The characteristics of the facility including the working practice and control measures to prevent emissions;
- The characteristics of the active ingredient of the antifouling product and the matrix;
- The application method (brush/roller or spraying);
- The average hull surface of a ship that is to be painted;
- The amount of ships that is painted in a certain time period.

Safinah (2004) gives information on the characteristics of OECD facilities and the used application methods, working practices and the amount of potential emissions to the environment.

3.2.2 Service life

The release of the antifouling biocide can occur during sailing or mooring of the ship.

With respect to sailing the following environments can be distinguished:

- Open sea;
- Sea shipping lanes. The number of ships sailing on these lanes can be high, for example in the English Channel;
- Lakes and rivers. These can vary from small to large rivers. On small rivers the number of pleasure crafts sailing can be very high, especially in the summer. On large rivers and canals pleasure crafts but also commercial ships are sailing. On some large rivers the number of ships can be very high, especially near commercial harbours, for example several rivers near Rotterdam. Mainly pleasure crafts and passenger ships are sailing on lakes. Shipping takes place mainly in large and medium sized lakes.

With respect to mooring the following environments can be distinguished:

- Harbours. These can vary from large commercial harbours like Rotterdam or smaller estuarine harbours. Harbours in freshwater environments - near large rivers or lakes - can also be important but will contain in general less ships than commercial and estuarine harbours;
- Marinas. These can be situated in - small - estuaries or in an enclosed area directly at the coast. Freshwater marinas can be situated at lakes and rivers;
- Ships can also be attached to buoys, which can for example occur near the coast where ships are anchored along the coast line or in lakes;
- Natural sized harbours: These are important in some OECD countries with archipelagos and coastlines with shallow areas and islands (e.g. Sweden and Finland). Natural harbours are often small bays or spaces between small islands and are often very shallow. They are very popular during the boating season.

It should be noted that often a combination of commercial port inclusive shipyards, fishing port, ferry port and sport boat port occurs.

The entry route for antifouling biocides into the aquatic environment during service life is by leaching from painted hulls (see figure 3.3). Direct emissions to other environmental compartments are not considered because of the fact that most of the antifouled area of the ship hull is under water.

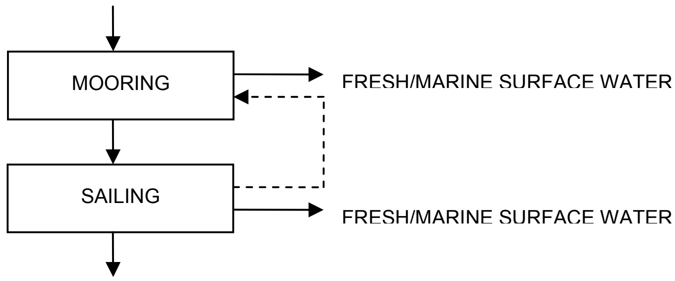

Figure 3.3 Service life

Legend:

= route of the ship

= route of the antifoulant

The emission of an antifouling biocide into the water is influenced by many factors. Therefore emissions of antifouling biocides cannot be easily estimated. The leaching rate of the antifouling biocide and the antifouled underwater area for ship hulls are very important. The leaching rate depends on several factors (water characteristics, type of antifouling product, characteristics and age of paint matrix and velocity of the ship). The total antifouled underwater surface depends on shipping intensities, dimensions on the various categories of ships, and many factors such as cargo load and residence time of the various ships (Van Hattum et al., 2002). The leaching rate and the antifouled under water area are described more extensively in sections 2.2 and 2.3.

After emission, hydrodynamic transport and mixing processes of water have a major effect on the distribution of the antifouling biocides. Other factors that influence the end concentration in the water, such as:

- Biological degradation;
- Hydrolysis;
- Adsorption to organic matter;
- Bioaccumulation;
- Volatilization;
- And UV-degradation;

are dependent on the characteristics of the antifouling biocide and the total abiotic environment (including the aquatic environment and weather conditions etc).

A ship may be found in marine as well as in fresh waters and may be sailing in open sea or moored in a harbour. In chapter 4 environmental emission scenarios are described on the basis of different environments and the ships that are present there. These emission scenarios are derived from the existing calculation models that are developed to predict the concentration of antifoulants leached into the surface water.

3.2.3 Removal

During the removal of antifouling paint on ship and boat hulls emissions to air, soil and surface water may occur. A part of the antifouling biocide may be disposed of as chemical waste. The potential emission scenarios together with the potential points of release for the antifouling product are given in figures 3.4 and 3.5. As for application (see section 3.2.1) a distinction is made between removal of the old paint layer from:

- Commercial ships and;
- Pleasure boats.

Removal of the paint layer from commercial ships will only be carried out by professionals, whereas the removal of paint from pleasure boats may be carried out by both professionals and non-professionals.

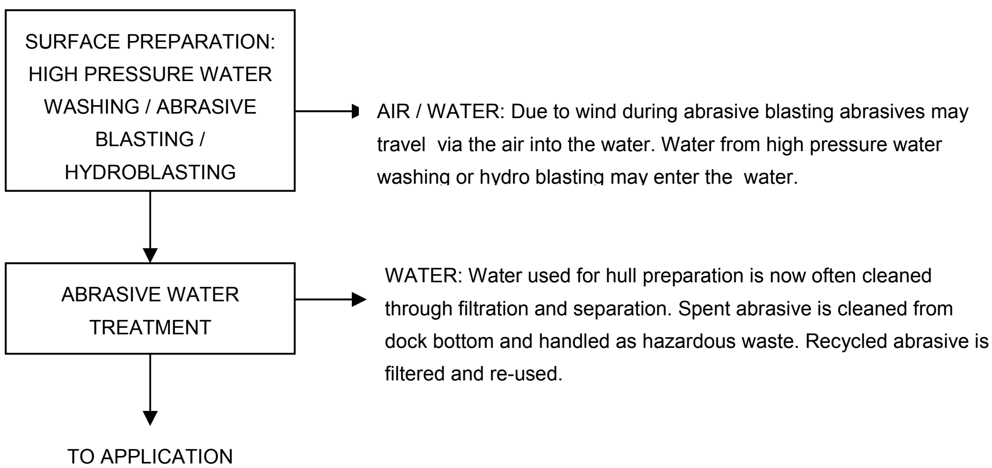

Figure 3.4 Removal of antifouling paint from commercial ships (professional)

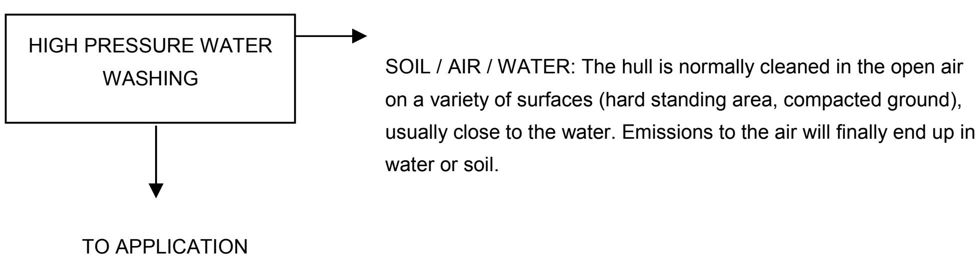

Figure 3.5. Removal of antifouling paint from pleasure boats (both professional and non-professional)

The emitted amount of antifouling product and biocide is dependent on:

- The characteristics of the facility including the working practice and control measures to prevent emissions;
- Regulations in force;
- The age and type of the antifouling coating;
- The removal method (hydro blasting or abrasive blasting);
- The average hull surface of a ship that is to be treated;
- The amount of ships that is treated in a certain time period.

Safinah (2004) gives information on the characteristics of OECD facilities and the used removal methods, working practices and the amount of potential emissions to the environment.

3.3 Aquaculture use

Aquaculture equipment covers nets used on fish farms, lobster and crab pots. But as described in section 1.2.2 information on the processes with respect to the use of antifoulants on lobster and crab pots is not available. Therefore this section describes the possible scenarios and emission routes for the application, service life and removal of antifouling products on nets used in fish farms. More extensive descriptions on the processes of application, service life and removal are given in section 1.2.2.

3.3.1 Application

For the application phase of antifouling products on nets used in fish farms the following scenarios are considered relevant:
- Professional application to nets for fish farms by manufacturers of nets: dipping (seasonal);
- Professional application to nets, retreatment by service companies and by fish farmers: dipping (seasonal).

The application of antifouling products on fish nets will only occur by professionals.

During the application of an antifouling product on nets for fish farms emissions to air (evaporation) and soil may occur (see figure 3.6). Remnants of the antifouling product may be disposed of as chemical waste (e.g. on gloves etc.). Remnants of antifoulants on gloves etc. are not considered in this report as the life cycle stage of waste treatment is outside the scope of this document. During the drying of the nets evaporation of the solvent may continue.

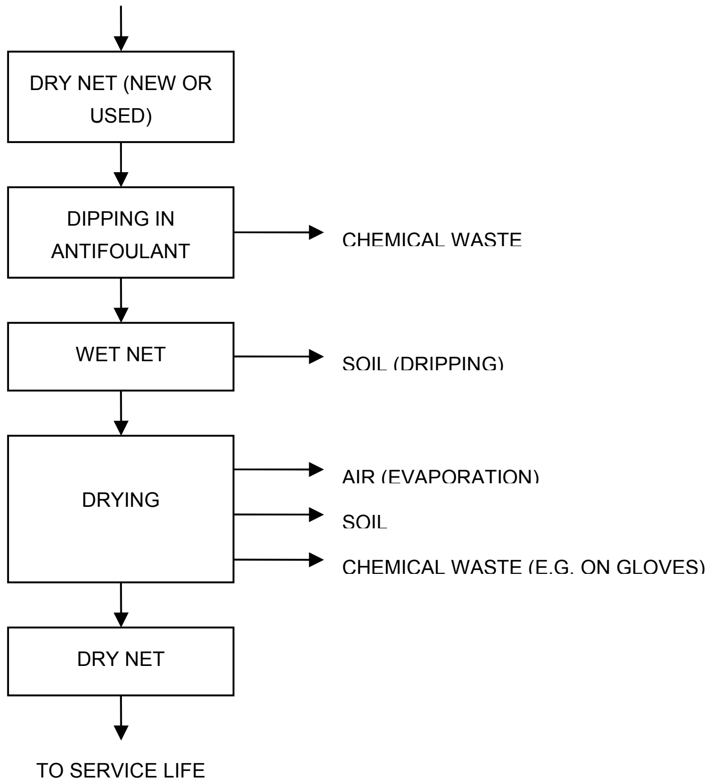

Figure 3.6 Application (professional)

The emitted amount of antifouling biocide is dependent on:

- The characteristics of the facility including the working practice and control measures to prevent emissions;
- The characteristics of the antifouling product and biocide;
- The amount of nets that are treated in a certain time period.

The measures that have been taken to prevent soil pollution determine the quantity of emissions of the soil at the dipping area. For example, drying of nets can take place over the dipping tank or over a separate collecting tank to prevent antifouling biocide leaching into the soil. For example, in Finland the application of antifouling paint and the removal of old paint are usually performed by the fish farmers. The application is done by dipping the net in to a container and the net is kept above the container as far as paint is dripping from the net. Thereafter the net is dried. The whole procedure can be done in a covered place, but in some places the net is treated and dried outdoors.

The UK-HSE has commissioned a project on the pattern of use of antifouling products in fish farming (Wade, 2003). Questionnaires were sent to and returned by the four major net treatment companies in the UK. In total 1477 nets were treated with water-based antifouling product per year using approximately 328,000 litres. This is equal to 200 - 350 litres product per net. In total 305 nets were treated with oil-based antifouling product per year using approximately 132,000 litres. This is equal to 300 - 400 litres product per net. Nets are treated in purpose built buildings or outside. Nets are immersed or pulled through a bath. Product lost from the process- e.g. from drainage racks - is collected and sent to special waste sites for disposal.

3.3.2 Service life

For the service life of antifoulant products in aquaculture use there is one scenario possible: fish nets in fishfarm scenario (in coastal areas).

Emissions of antifoulant biocides during service life occur due to leaching from the fishnets (see figure 3.7). The primary receiving environmental compartment is the aquatic environment. Direct emissions to other environmental compartments during service life are not relevant because of the fact that the greatest part of the nets is under water.

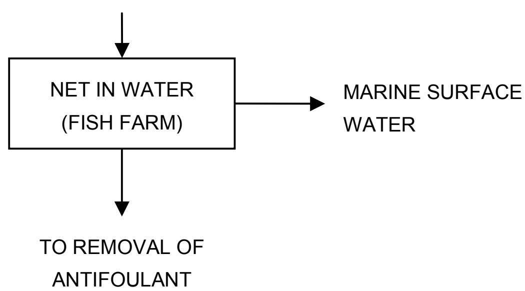

Figure 3.7 Service life antifoulants on fish nets

As in the case of antifouling product on ship hulls the concentration of antifouling biocide in the water coming from fish nets is influenced by many factors. The emissions cannot be easily estimated. The leaching rate, the net density and the amount of antifouling product on the surface of the fish net and absorbed in the net is important. An additional factor may be the activity of the fish. After emission:

- Hydrodynamic transport;
- Mixing processes of water;
- Boilogical degradation;
- Hydrolysis;
- Adsorption to organic matter;
- Bioaccumulation;
- Volatilization;
- And UV-degradation;

influence the end concentration in the water. Therefore the characteristics of the antifouling biocide and the aquatic environment have to be known.

3.3.3 Removal

A possible scenario for the removal of antifouling products (and probably marine growth) from fish nets would be the washing of the nets by professional service companies or the fish farmers.

In Finland the old antifoulant coating and attached organisms are removed from fish nets by washing in a washing machine. Washing machines can be situated outdoors and the waste water can be led directly to soil or surface water. The purpose is not to remove the coating but to remove fouling, but some of the antifoulant will be removed during washing.

In the UK washing takes place in purpose built washing plants with washing machines or washed onshore (Wade, 2003, personal communication). Waste from the washing process is treated on- or off-site: washing water is often recycled and shells and seaweed, sludge, etc. are often disposed at special waste sites. Cleaning can also be done by high pressure spraying (e.g. in Canada).

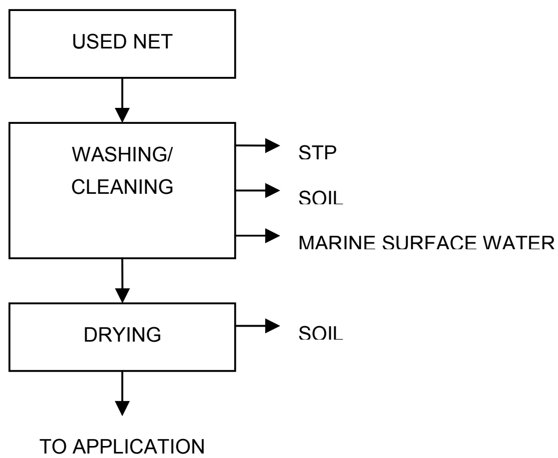

Figure 3.8 Removal (professional)

4 DESCRIPTION OF EMISSION SCENARIOS FOR SHIP HULLS

4.1 Introduction

In this chapter emission scenarios to estimate environmental concentrations of antifouling biocides used on ship hulls are described. Emission scenarios are described - if available or developed within this project - for application, service life and removal. The chapter ends with an overview of these emission scenarios.

In this report the emission scenarios are presented in text and tables. In the tables the input and output data and calculations are specified. The input and output data are divided into four groups:

S	data Set	parameter must be present in the input data set for the calculation to be executed (there has been no method implemented in the system to estimate this parameter; no default value is set, data either to be supplied by the notifier or available in the literature);
D	Default	parameter has a standard value (most defaults can be changed by the user);
O	Output	parameter is the output from another calculation (most output parameters can be overwritten by the user with alternative data);
P	Pick list	parameter values to be chosen from a pick list with values.

4.2 Application

The application of the antifouling product on a ship or boat hull may take place by professionals as well as non-professionals. No existing emission scenarios are available. However, the proces of application of antifouling paint is considered important, because significant emissions of antifouling paint may occur at exposed painting areas. Therefore new environmental emission scenarios with respect to the application of antifouling paint on ship and boat hulls were developed within this project.

For the development of the scenarios the following was taken into acount:

- Characteristics of a “typical” and a “realistic worst case OECD facility” (e.g. a shipyard): the methods of application, the sources of potential emissions (e.g. over spray), potential receiving environmental compartments and control measures;
- The dimensions of the primary receiving compartments (surface water, soil, air);
- The fraction of paint potentially emitted to each environmental compartment;
- The hull surface of an average OECD ship or boat;
- The amount of ships treated in the facility per period;
- The average amount of paint used per ship.

It's important to note that due to the lack of specific data the effects of control measures taken by new building and maintenance and repair facilities are for the greater part not taken into account for the development of these scenarios. However this doesn't apply to all scenarios. For example for new building commercial ships some control measurements used in the typical case scenario are considered, e.g. the facts that paint cells are used and that a dock is more confined compared to a slipway. These measurements result in a much smaller emission factor to surface water for the typical case scenario compared to the realistic worst case scenario.

A distinction was made between application of paint on new ships and the application during maintenance and repair (M&R). Scenarios are built for:

New building
- Commercial ships → professional;
- Pleasure craft → professional.

Maintenance and repair
- Commercial ships → professional;
- Pleasure craft → professional;
  → non-professional.

The new environmental emission scenarios with respect to the application of antifouling paint on ship hulls are presented in sections 4.2.1 and 4.2.2. To explain the developed emission scenarios several general notes to the scenarios are included in this section. More specific notes and explanations are added to the corresponding scenarios.

Most of the data used to describe each of the scenarios are based on data from the Safinah report. If otherwise, it is indicated whether the data represents expert judgement from industry or is a best estimate from the OECD Working Group.

"Typical case" and "realistic worst case": There is a lot of difference between shipyards or boatyards with respect to the prevention of antifouling paint entering the environment. Several shipyards in OECD countries will work in closed systems, while other yards work in highly exposed environments. To prevent certain biocides being prohibited by only using a worst case scenario for OECD countries, for most scenarios a "typical case" and a "realistic worst case" was defined.

Emissions to air: Emissions to air are not integrated in the new scenarios as these are considered not relevant for environmental risk assessment. Biocides used in antifouling paints are not very volatile. In case of the emission of paint particles due to overspray deposition of the particles will occur. Emissions to air will only be important for scenarios with respect to human exposure.

Source of the default values: The default values used in the scenarios were mainly derived from the Safinah report (Safinah 2004, see also section 3.1). Where necessary more information was provided by industry and the RIVM. The status of the default data varies from information based on:
- Statistics (Safinah 2004);
- Expert judgement (Safinah 2004 and additional information by industry and RIVM);
- To best estimates by the OECD Working Group.

Considering the text above it is important to note that the default values are not firm values, but the best available estimates made by the OECD Working Group. If more realistic values are available from practice or statistics, these values can be replaced when performing risk assessment. It is up to the applicant to propose adequate protection measures for the antifouling coating to be used, for example in a shipyard, in order to get that antifouling coating to be evaluated under the “typical case” assumptions (or even a better case). Examples of these measures are the collection and disposal of the removed paint as waste or the use of closed circuit blasting systems at the application of paint.

Outcome of scenarios:
The outcome of the scenarios for application and removal is an emission load. For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to to the regional practices in the Member States of the OECD. Thus, for example, in the European Union the use of Technical Guidance Documents or Technical Notes on Guidance under the Biocidal Products Directive system should be employed to determine PEC values. However, a few considerations with respect to the further calculation of the concentrations in water, soil or STP are described below.

For the yearly average environmental concentrations the user should sum up the initial concentrations resulting from the application and removal scenarios when they occur in the same compartment (water, STP or soil). For the daily concentrations during the emission period it may be assumed that application and removal do not occur on the same day.

Particulate emissions of antifoulants from application and removal life-stages will have different fate and behaviour properties compared to molecular emissions from the service-life stage, e.g. lower bioavailability and longer persistence.

According to the EU TGD, in the absence of more detailed data concerning adsorption/ bioavailability/ persistence, the substance content in small particles can be handled as if it was distributed in molecular form (TGD 2003). However, according to expert information form CEPE, it is believed that because of the application techniques used, any release to the environment during application also results in an emission being in particle form. The information according to CEPE is described below:

- Paint droplets from overspray are relatively large and dense, and therefore primarily confined to the spraying area. Additionally, due to the high volatility of the solvents used in typical antifouling paint formulations the droplets undergo significant drying before they reach the surrounding water surface. Thus if released to the surrounding water environment, they consist of relatively large particles which are not readily dispersed into the environment;
- Some co-biocides have considerable substantivity to particles of the primary antifouling agent, cuprous oxide;
- Other biocides are incorporated into polymers and are only released due to the action of physical erosion or slow hydrolysis.

Furthermore it is important to note that not all potential emissions during application will enter the aquatic environment directly. For example for the application of paint on new commercial ships a distinction is made between application of the final paint coat in a dock and application on an exposed slipway. The potential emission factor to surface water (without control measures, e.g. shrouding) for the slipway is 0.35. For painting in the dock the potential emission factor is only 0.075 (less overspray due to a more confined area). The greatest part of the emissions occurring at the exposed slipway will enter the environment directly. But potential emissions occurring in the dock will enter the environment partly in the form of dried paint onto the dock walls (leaching) and partly via the air directly to the surface water. Because of the relative short immersion period of the dock into the water (compared to ship hulls during service life of the antifoulant) the emission to the surface water will be small. But because there is no data available on the amount of antifoulant directly emitted in the water the emission factor for painting in the dock is maintained at 0.075.

The potential emissions during paint removal will occur in the form of dry paint flakes or paint dust that either goes to waste, a Sewage water Treatment Plant (STP) or directly to water. Even when the paint is going directly to the surface water it should be considered that the dissolved concentration in practice will be lower than the calculated concentration.

Emissions to the environment: For the amount of antifouling product emitted to the environment (expressed in emission factors) in general only the potential emission (without taking control measures into account) is known from Safinah 2004. In absence of other data these potential emission factors are used as (worst case) default values. This means that the emission factors may be lower if control measures are used.

Input parameters: In this paragraph several input parameters of the developed scenarios are explained.

In the scenarios a painting period or a removal period is used to express a time period during which application or removal takes place more or less continuously in one ship or boat yard. For commercial ships this will be a relative short period. During one painting period of, for example 2 days, one ship is painted. For example for non-professional application on pleasure boats the period will be much longer. During a period of several months 350 pleasure boats will be painted. Because of the amount of boats that have to be painted it is assumed that painting takes place almost continuously during this period.

Painting and removal intervals or frequencies are used to indicate when emissions take place. A painting or removal interval is used in case of application and removal of paint during maintenance and repair of pleasure boats and mass production of pleasure craft (300 boats per year). The interval indicates an unbroken period per year when no emissions due to the corresponding activity occur. For example the non-professional application of paint on pleasure craft is assumed to take place continuously during 3 months (winter and early spring). During the remaining 9 months no non-professional application takes place (boats are either in the water or in storage). So in this case the painting interval is 9 months. A painting or removal frequency is used to express the amount of relative short painting or removal periods during new-building and M&R for commercial ships and during new building of pleasure craft in a small boatyard (building max. 30 boats a year). If the painting of one commercial ship takes 2 days (the painting period) and the painting interval is 3, this means that 3 ships per year are painted.

The theoretical coverage of the paint is the volume of paint that is theoretically needed to paint a certain area of the ship hull.

The theoretical coverage of the paint does not take into account:
- The losses emitted to the environment;
- Excess paint applied on the hull (paint overlap during the application process, the subsequent coating of join up seams and butts after the coating and assemblage of the separate hull blocks, etc. (see also section 4.2.1);
- And waste (paint residues in cans, etc.).

Thus, in addition to the theoretical coverage of the paint the user of an antifouling product should count for a certain percentage extra paint for losses that are emitted elsewhere during application.

The average hull surface of an average (OECD) ship multiplied with the theoretical coverage of the paint forms the theoretical paint demand, which is the amount of paint that is theoretically needed to paint the entire ship hull. The emission factors used in the developed scenarios for the application of paint are based on this theoretical paint demand.

The theoretical paint demand and excess paint applied (expressed in a “fraction excess paint applied”) together form the total amount of paint that is applied on the ships hull. The total amount of paint is used in case of the removal of paint. It is then important to know what amount of paint is applied on the hull to be able to determine what amount will be removed during maintenance and repair.

Output: In the calculations it is assumed that the output is the initial dissolved concentration in water. However, in reality the active ingredient will be emitted to water as paint particles.

The output of the scenarios is the initial local concentration of a.i. in the primary receiving compartments (not considering losses due to degradation or transport) and not the PEC to be compared with the PNEC. The competent authorities that use these scenarios can use methods like the ones described in the EU-TGD to calculate the PEC in the secondary environments (for example adjoining waters or the sediment) and to calculate the total concentration in surface water or the concentration in sediment (ECB 2003).

To perform risk assessments for emissions to soil or sediment average concentrations over a certain time period are normally used, therefore yearly averages are calculated as well.

4.2.1 New building

Commercial ships

The building of new commercial ships consists of the following stages of construction:
- Hull block construction (block stage): Hull-blocks are structural units normally composed of several panels or sub-units and being erected as a whole. Hull block construction exists of the manufacturing and assembly of these units and the outfit of various ship systems onto the hull blocks prior to the erection of the ship. The reasons for shipyards to built on block-stage are the better accessibility of a hull block compared to an entire ship and the fact that a hull block can be moved for down-hand work if necessary. This is easier and less expensive than overhead

work. Hull block outfit, which typically is done nearby material storage buffers and shops, allows work to be performed with material and tools that are more readily available;
- Erection of the ship. The hull blocks are assembled to build the entire ship;
- On-board work: When the hull blocks are erected, on-board work is required to complete the building process.

Coating activities may take place at block stage prior to the erection of the ship or after the ship is erected.

At a shipyard, coating activities for antifouling coatings can take place in a number of locations. In general however the following are the typical locations and activities for the application of antifouling paints:

Figure 4.1 The typical locations and activities for the application of antifouling paints

Location	Typical work scope
Paint cell	Application of at least one coat of antifouling to the vertical sides and the full scheme to the flat bottom. The amount of work depends on the erection speed of the yard.
At block stage	In the open air, if no paint cells are available. Then at least one coat of antifouling is applied and often the full scheme to the Flat bottom. Unit join ups are surface prepared and coated also.
In a temporary shelter	Similar activities as per Paint cell.
On the slipway or in the dock, pre-launch	All final antifouling application are made unless there is a pre-delivery dry-dock, in which case one coat may be held in reserve.
Pre-delivery dry-dock	Used by yards that have a very long delivery time and now no longer common in the more advanced yards (most OECD countries). Final coat and wash down after the outfitting period and before the vessel goes to sea trials.

Source: Safinah (2004)

The application method in OECD countries is predominantly by airless spray. There are some minor applications by brush and roller but these are considered too minor to take into consideration. The majority of the worlds' ships are built in Japan and Korea (approximately 80%) and they predominantly paint on block in paint cells as far as possible.

For the application of paint on new ships in an typical OECD shipyard a realistic worst case and a typical case scenario had to be determined. An obstacle to do this was the fact that the number of ships built per year in a "typical OECD shipyard" could not be determined. The majority of the worlds ships are built in Japan and Korea (approximately 80% according to Safinah 2004). There is quite a difference between Asian countries on one hand and the European countries and the US on the other hand. An average Asian shipyard builds several dozens of ships per year whereas shipyards in the EU and US typically build one or two ships per year. Data on the exact numbers of ships built in Asian countries are not available and further the new building facilities and control measurements in Asian countries are normally much better (they predominantly paint on block in painting cells as far as possible) compared to those in the EU and US. Therefore for this scenarios the European/US situation was taken into account. Next to the default value for the average hull surface for a typical EU/US ship a default value for a typical Asian ship is nevertheless included in the scenario description. Asian countries may adapt the other default values where necessary when using this scenario.

Considering the text above the two following scenarios were determined:

- *Realistic worst case*: Two commercial ships are painted per year. Per ship two antifouling coats are applied. The first coat is applied on block in painting cells or open air. Significant emissions may occur from painting on block in the open air. But because painting on block is done in a longer time period and normally on another location compared to where the final coat is applied, the emissions due to painting on block stage are not included in this scenario. The application of the final coat is carried out in one day on an exposed slipway (in the open air on a hard standing area near or above the water). The paint is applied using airless spray. Safinah (2004) considers painting on a slipway as a realistic worst case;
- *Typical case*: Two commercial ships are painted per year. Per ship two antifouling coats are applied. The first coat is applied on block in painting cells. Significant emissions of antifoulant are not expected from painting in painting cells. Therefore the emissions due to the application of the first coat are not included in this scenario. The application of the final coat is carried out in one day in the dock (less exposed compared to a slipway). As for the realistic worst case scenario the paint is applied using airless spray.

According to the Safinah report for both scenarios the potential emissions are assumed to end up in the surface water. Therefore the fraction to soil in the scenarios as described in table 4.2 is zero. As described in section 4.2 the default values for the realistic worst case and the typical case are not firm values, but they are the best available to the OECD Working Group.

Table 4.2 New building ships in an average OECD shipyard: 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	1 [1)]	1 [1)]	D
Number of ships treated in an EU/US shipyard per painting period	[-]	Nship	1	1	D
The average hull surface of a ship	[m^2]	$AREA_{ship}$	EU/US: 2,500 Asia: 8,600 [2)]	EU/US: 2,500 Asia: 8,600 [2)]	D
Theoretical coverage of the paint	[$m^2.l^{-1}$]	COVERAGE			S
Number of coats applied on the hull	[-]	Ncoats	1 (only the final coat)	1 (only the final coat)	D
The concentration of a.i. in the paint	[$g.l^{-1}$]	Ca.i.			S
Fraction to surface water	[-]	F_{water}	0.35 [3)]	0.075	D
Fraction to soil	[-]	F_{soil}	0	0	D
Output :					
The theoretical amount of paint applied per ship [4)]	[l]	Vpaint			O
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$			O
Intermediate calculations:					
Vpaint = Ncoats * ($AREA_{ship}$ / COVERAGE)					
End calculations:					
$Elocal_{water}$ = (Vpaint * Nship * F_{water} * Ca.i.) / Tpaint					

1) Expert judgement: 1 day is needed for the application of the final coat (expert judgement CEPE). The application of the first coat is not included in this scenario;
2) Note that all other values are based on the European/US situation;
3) Note that this fraction seems fairly high. It would mean that a third of the antifouling paint ends up in the water. This fraction is derived from Safinah (2004): potential emission based on overspray during application of the paint on a slipway. The fraction of 0.35 is also described as the realistic worst case loss factor for airless spray in the RIVM comments. [Note: according to Finnish data the total losses are typically 30% of total amount of paint used which would result in 0.43 as a sum of all these emission fractions (water, soil, STP, waste)];
4) The theoretical paint demand is the amount of paint that is theoretically needed to paint the entire ship hull. The theoretical paint demand does not contain the excess paint applied on the hull due to overlap during the application process, the subsequent coating of join up seams and butts, etc. The theoretical paint demand and the excess paint together form the total amount of paint that is applied on the ships hull (see also the explanation in section 4.2).

The emission load finally ends up in a river or harbour. For the calculation of concentrations in a river reference is made to general environmental exposure assessment guidelines such as the EU-TGD (ECB, 2003). Individual countries have to decide on the river dimensions and waterflow. For the emission to a harbour the dimensions of the recommended commercial harbour for service life of antifouling paints are used.

Table 4.3 Calculation of the environmental concentrations for new building ships in an average EU/US shipyard for both realistic worst case and typical case (point source in harbour)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting frequency per year[1)]	[-]	Tfreq	2	D
Length of the harbour	[m]	LENGTHch	5,000	D
Width of the harbour	[m]	WIDTHch	1,000	D
Depth of the harbour	[m]	DEPTHch	15	D
Total emission to water	[g.d^{-1}]	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in surface water	[g.m^{-3}]	$PEClocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) The amount of painting periods per year

Pleasure craft

At a boat yard the antifouling coats are applied to the completed hull after erection. On-block coating (as for new building commercial ships) does not take place.

Broadly boat yards can fall into 3 types:

- Super yacht facilities – building 2-3 boats per year;
- Original Equipment Manufacture (OEM) boat yards (original Equipment Manufacturer – mass produced boats/hulls) – building 2-300 boats per year;
- Small boat yards building largely one-off vessels building up to 20-30 boats per year.

The coating activities for antifouling can take place in a variety of environments, largely dependent on the type of boat yard. The conditions vary, but broadly speaking, both super yacht facilities and OEM facilities carry all the work out indoors. While for the smaller boat yards, the work can be a mix of indoors and outdoors.

The super yacht builders and OEM builders generally work on hard standing facilities, while the substrate in boat yards for coating activities can vary from hard standing to compacted earth, although sometimes with temporary shrouding.

Thus the following locations and scope can be defined.

Table 4.4

Location	Typical work scope
In work shop	For OEM manufacturers who are producing standard design hulls, then the coating activity takes place at the end of the production line, generally undercover in a well-controlled environment, commensurate with mass production techniques. Some hulls will only be taken to show room specification (one coat of antifouling), rather than have the full scheme applied.
In fabrication shed	For the large yachts and super yachts the work is carried out in a multi purpose shed, where the degree of containment is not as good as an OEM facility but still offers complete protection from outside elements.
Outside	Outside work, in an open environment, is usually undertaken by the custom builders. One off construction of vessels varying in size and type, from small skiffs to mega yachts or specialist racing yachts. The Application of antifouling can take place in a variety of facilities, from enclosed to open. The ground can be hard standing to compacted earth and for applications in the open, shrouding may or may not be used to contain over spray.

Source: Safinah (2004)

Safinah (2004) makes a difference between boats with a length below 7.5 meters and above 7.5 meters. The majority of boats are boats below 7.5 metres. It is assumed that OEM (mass-production) boat yards and small boat yards are building preliminary small boats and that the boats with a length of above 7.5 meter are built by the super yacht facilities.

In contrast to commercial ships the surface area of the boats, the theoretical coverage of the paint etc. are not included in the scenarios for pleasure boats. The amount of paint is not calculated using the surface area of the ships hull, but with help of a so called “paint calculator” which only requests the boat length for the determination of the amount of paint that has to be applied. However, this is not what often happens in practice. In reality the owner applies one touch up coat to the existing antifouling coating and one full coat of antifouling.

The use of airless or air assisted spray techniques dominates the mega yacht and OEM markets, while roller and brush are more common in the one off custom-built market because of the relatively low through put.

Considering the the text above the two following scenarios were determined for the application of paint on new built pleasure craft in an average OECD boatyard:

Realistic worst case: Thirty pleasure boats (<7.5 m) are painted per year in a small boat yard. Per boat 3 litres of paint are applied. The application of the paint is carried out in two days in the open air on compact earth or a hard standing area with some temporary shrouding. Depending on the quality of the control measurements for the soil (e.g. hard standing area of compacted earth) the emission either goes to soil or a STP or a combination of these two options. This possibility is included in the scenario. It is assumed that the new building facility is not situated near the water. The paint is applied either using brush and roller or using a mixture of airless spray and brush and roller (expert judgement CEPE). In the scenario a choice can be made between these two application methods. According to Safinah 2004 brush and roller is more common for a small boat yard.

Typical case: Three hundred pleasure boats (<7.5 m) are painted per year in an mass production facility. This means that painting takes place practically every day (a painting frequency can no longer be determined, painting takes place continuously all year). Per boat 3 litres of paint are applied using airless spray. Because all the painting takes place indoors on a hard standing area significant emissions directly into the environment are not expected. Emissions that possibly may occur are emissions to a sewage water treatment plant (STP). But the amounts of antifoulant that possibly remain after waste water treatment are not considered important for the environment.

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to water in the scenario as described in table 4.5 is 0.

Table 4.5 New building pleasure craft in an average OECD boatyard: 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	2	365	D
Number of boats treated in a boatyard per painting period	[-]	Nboat	1	300	D
The concentration of active ingredient in the paint	[g.l^{-1}]	Ca.i.			S
The theoretical amount of paint applied per boat[1)]	[l]	Vpaint	3	3	D
Fraction to surface water	[-]	F_{water}	0	0	D
Fraction to STP[2)]	[-]	F_{STP}	Application by mixture of air-less spray / brush and roller: Max. 0.06 Application by brush and roller only: Max. 0.025	0	D
Fraction to soil[2)]	[-]	F_{soil}	Application by mixture of airless spray / brush and roller: Max. 0.06 Application by brush and roller only: Max. 0.025	0	D
Output :					
Total emission to soil	[g.d^{-1}]	$Elocal_{soil}$			O
Total emission to STP	[g.d^{-1}]	$Elocal_{STP}$			O
End calculations:					
$Elocal_{soil}$ = (Vpaint * Nboat * F_{soil} * Ca.i.) / Tpaint $Elocal_{STP}$ = (Vpaint * Nboat * F_{STP} * Ca.i.) / Tpaint					

1) The system of paint volume demand is very different to ships. Most of the paint companies assume that the coating will be applied by the boat owner/yard and so supply a paint calculator. Using this calculator the required paint amount can be estimated. However, this is not what happens in practice. In reality the typical owner applies one touch up coat to the existing antifouling coating and one full coat of antifouling. On the basis of discussions with paint companies, boat builders and marina operators etc. Safinah has determined default values for the theoretical amount of paint applied per boat;
2) Depending on the control measurements of the boat yard the emission up to a maximum of 6% (potential emission weighted for brush/roller and spray) or 2.5% (for brush and roller only) either goes to soil or a STP or a mixture between these two options.

The emission load finally ends up onto the soil or in a STP. In table 4.6 the calculation method of the initial concentration in soil is presented.

Table 4.6 Calculation of the environmental concentrations for new building pleasurecraft in an average OECD boatyard for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting frequency per year	[-]	Tfreq	Realistic wost case: 30 Typical case: n/a	D
Length of the receiving soil compartment[1)]	[m]	LENGTH	9.5	D
Width of the receiving soil compartment	[m]	WIDTH	4.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[2)]	D
Soil density (dry weight)	[kg.m^{-3}]	$RHOsoil_{dw}$	1,504[3)]	
Total emission to soil	[g.d^{-1}]	$Elocal_{soil}$		O
Output :				
Predicted environmental concentration in soil	[g.kg^{-1}]	$PECClocal_{soil}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB 2003).				

1) A boat of 7.5 m length and 2.5 m width is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 meter wide;
2) In line with the environmental emission scenario of the OECD for Wood Preservatives;
3) Based on EU-TGD (ECB, 2003) (wet weight is 1700 kg.m^{-3});
4) The yearly average for the typical case scenario is equal to the emission during the painting period.

4.2.2 Maintenance and repair

<u>Commercial ships</u>

Unlike new building activities the majority of ship maintenance and repair take place in non-OECD countries. Hard statistics are difficult to obtain but broadly approximately 40-60% of repair work is carried out in Singapore/China and an additional 10-15% is carried out in the Middle East. Thus, the OECD share is not likely to be more than 30-35%.

Ship repair yard procedures are more consistent than those for new building. Broadly the process of antifouling application is as follows.

The vessel is repaired using one of the following facilities:

- Graving dock;
- Floating dock;
- Marine railway;
- Marine lift.

After cleaning the ships hull (see removal) a new layer of antifouling paint is applied. The application is typically by airless spray, with limited use of brush and roller (more common on smaller vessels). In some countries 100% shrouding is effected, in others no shrouding is applied. Some facilities (warship ones in particular) can be totally enclosed, while others are very exposed.

Considering the the text above the two following scenarios were determined for the application of paint during M&R of ships in an average OECD shipyard the two following scenarios were determined:

Realistic worst case: Twenty (expert judgement CEPE) commercial ships are painted per year. Per ship two antifouling coats are applied. The coats are applied in two days in an exposed floating dock or marine lift (in the open air, on a hard standing area, unshrouded). The paint is applied using airless spray.

Typical case: Twenty commercial ships are painted per year. Per ship two antifouling coats are applied. The coats are applied in two days in an graving dock (in the open air, on a hard standing area, shrouded). The paint is applied using airless spray.

According to the Safinah report for both scenarios the potential emissions are assumed to end up in the surface water. Therefore the fraction to soil in the scenarios as described in table 4.7 is zero.

Table 4.7 M&R of commercial ships in an average OECD shipyard: 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	2[1)]	2[1)]	D
Number of ships treated per painting period	[-]	Nboat	1	1	D
The average hull surface of a typical OECD ship	[m^2]	$AREA_{ship}$	EU/US: 2,500 Asia: 7,963[2)]	EU/US: 2,500 Asia: 7,963[2)]	D
Theoretical coverage of the paint	[$m^2.l^{-1}$]	COVERAGE			S
Number of coats applied on the hull	[-]	Ncoats	2	2	D
The concentration of a.i. in the paint	[$g.l^{-1}$]	Ca.i.			S
Fraction to surface water	[-]	F_{water}	0.35	0.075[3)]	D
Fraction to soil	[-]	F_{soil}	0	0	D
Output :					
The theoretical amount of paint applied per ship	[l]	Vpaint			O
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$			O
Intermediate calculations:					
$Vpaint = Ncoats * (AREA_{ship} / COVERAGE)$					
End calculations:					
$Elocal_{water} = (Vpaint * Nboat * F_{water} * Ca.i.) / Tpaint$					

1) Expert judgement CEPE: one day for each coat;
2) Note that all other values are based on the European/US situation;
3) See also application of paint during new building commercial ships.

The emission load finally ends up in a river or a harbour. For the calculation of concentrations in a river reference is made to general environmental exposure assessment guidelines such as the EU-TGD (ECB, 2003). Individual countries have to decide on the river dimensions and waterflow. For the emission to a harbour the dimensions of the recommended commercial harbour for service life of antifouling paints are used.

Table 4.8 Calculation of the environmental concentrations for application of paint during M&R of commercial ships in an average OECD shipyard (point source in harbour or river, see also scenario new building for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting frequency per year[1)]	[-]	Tfreq	20[2)]	D
Length of the harbour	[m]	LENGTHch	5,000	D
Width of the harbour	[m]	WIDTHch	1,000	D
Depth of the harbour	[m]	DEPTHch	15	D
Total emission to water	$[g.d^{-1}]$	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in surface water	$[g.m^{-3}]$	$Clocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) The amount of painting periods per year;
2) Expert judgement CEPE.

Pleasure crafts

Most pleasure craft are repaired in the country of the owner and most are handled locally by marinas or the original boat yard. There is no information about how many boats are repaired professionally and how many are repaired in the Do It Yourself (DIY) market but the best estimates are 90-95% DIY work is carried out (many small boats). Even owners of larger boats will tend to carry out routine repairs themselves, only reverting to a boat yard for larger overhaul work.

Once the hull is cleaned (see removal) the boat is moved to its storage or repair area. The application of the paint can be carried out in a variety of environments, indoor, outdoor, hard standing, compacted ground and in some cases earth.

It is not uncommon for many marinas to use car parks for winter storage and M&R sites for boats. The owner does much of the work on a DIY basis, although larger projects can be contracted out to specialists' applicators or boat yards.

As with larger ships, there is often a reservoir of material left on the boat, which the relatively low-pressure wash does not remove, although it is unlikely that the owner will take that into account when applying the new scheme.

The owners may put up some temporary shrouding, and carry out the work over a period of time in sections depending on the weather (winter time is when most maintenance is carried out).

Thus the following locations and scope can be defined:

Table 4.9

Location	Typical scope of work
On storage or repair area in marina	Here the hull is prepared for coating. In the USA abrading of the hull takes place, before additional coats are applied. Can take place outside, with some shrouding to afford temporary protection from over spray. The ground can vary from hard standing to compacted earth.
In repair shop at boat yard	If the vessel is to be repaired professionally, is normally taken under cover for the work to be carried out, although coating application may still take place in the open air with some shrouding. The ground surface can vary from hard standing to compacted earth.
Open air	Some boat owners will take the vessels to a private storage area (their house) and undertake the work there. Here there will be a mix of open-air work, may be some shrouding and the ground may be hard standing or compacted earth.

Source: Safinah (2004)

The application method is dependent on where the work is carried out and who carries it out. Professional workers will use air or, airless spray equipment (boat yards or specialist contractors), while most DIY owners will use a brush or roller. According to Safinah 2004 discussions with paint companies, boatyards and boat owners indicate very low use of air/air assisted spraying in general.

Emission scenarios are determined for the application of paint during professional and non-professional M&R.

Professional

For the application of paint pleasure craft during professional M&R in OECD boat-yards the two following scenarios were determined:

Realistic worst case: Fifty pleasure boats (>7.5 meters) are painted per year in a repair shop at a boat yard (hard standing area or compacted earth). According to Safinah boats < 7.5 meters are mainly repaired by non-professionals. Therefore it is assumed that professional M&R is mainly carried out on boats with a length above 7.5 meters. Per boat 4.5 litres of paint are applied using a mixture of airless spray and brush and roller. The application of the paint takes place almost continuously during 6 months (in winter time) in the open air on compact earth with some shrouding.

Typical case: Fifty pleasure boats (>7.5 meters) are painted per year in a repair shop at a boat yard (hard standing area). According to Safinah boats < 7.5 meters are mainly repaired by non-professionals. Therefore it is assumed that professional M&R is mainly carried out on boats with a length above 7.5 meters. Per boat 4.5 litres of paint are applied using brush and roller. The application of the paint takes place almost continuously during 6 months (in winter time).

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 4.10 is zero.

Table 4.10 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 for 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 4.11 Calculation of the environmental concentrations for professional application of paint during M&R of pleasure craft in an average OECD boat yard/marina for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting interval[1)]	[month]	Tint	6	D
Length of the receiving soil compartment[2)]	[m]	LENGTH	12.5	D
Width of the receiving soil compartment	[m]	WIDTH	5.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[3)]	D
Soil density (dry weight)	$[kg.m^{-3}]$	$RHOsoil_{dw}$	1,504[4)]	
Total emission to soil	$[g.d^{-1}]$	$Elocal_{soil}$		O
Output :				
Predicted environmental concentration in soil	$[g.kg^{-1}]$	$Clocal_{soil}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) Period in which painting does not occur;
2) A boat of 7.5 m length and 2.5m breadth is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 metre wide;
3) In line with the environmental emission scenario of the OECD for Wood Preservatives;
4) Based on EU-TGD (ECB, 2003) (wet weight is 1700 $kg.m^{-3}$).

Non-professional

For the application of paint pleasure craft during non-professional M&R in OECD marinas only one scenario was determined. It is assumed that non-professionals do not (or not often) paint their boats in semi-closed or closed environments. The following scenario was determined:

Three hundred and fifty pleasure boats (<7.5 meter) are painted per year in an open system on compacted earth. It is possible that non-professional application takes place on a hard standing area. The potential emission then goes (partially) to waste water. This is possibility is included in the scenario. Per boat 2.5 litres of paint are applied using brush and roller. The application of the paint takes place almost continuously during 3 months (late winter and early spring). In contrast with professional application this does not necessarily happen at the same area. For example 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 1-5 boats are treated non-professionally at the same area).

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 4.12 is zero.

Table 4.12 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 (see also the description in front of the table).

Table 4.13 Calculation of the environmental concentrations for non-professional application of paint during M&R of pleasure craft in an average OECD marina for both realistic worst case and typical case scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The painting interval[1)]	[month]	Tint	9	D
Length of the receiving soil compartment[2)]	[m]	LENGTH	9.5	D
Width of the receiving soil compartment	[m]	WIDTH	4.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[3)]	D
Soil density (dry weight)	[kg.m^{-3}]	$RHOsoil_{dw}$	1,504[4)]	
Total emission to soil	[g.d^{-1}]	$Elocal_{soil}$		O
Output :				
Predicted environmental concentration in soil	[g.kg^{-1}]	$Clocal_{soil}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) Period in which painting does not occur;
2) A boat of 7.5 m length and 2.5 m width is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 meter wide;
3) In line with the environmental emission scenario of the OECD for Wood Preservatives;
4) Based on EU-TGD (ECB, 2003) (wet weight is 1700 kg.m^{-3}).

4.3 Service life

A lot of work has been done on estimating the release during service life of antifouling biocides from the use of antifouling products on ship hulls, especially the last 5 years. Calculation models have been developed specifically for antifouling biocides, the first one by Johnson and Luttik (1994). Recently the models REMA and MAM-PEC were developed. These models contain calculation methods for several of the processes described in paragraph 3.2.2. In Annex I these models are described. Section 4.3.6 provides a short description of the advantages and limitations of these models.

Table 4.14 describes which environmental emissions have scenarios available for each of the processes during the in-service life of an antifouling product on ships hulls. Sometimes reference is made to the models mentioned above.

Table 4.14 Existing environmental emission scenarios for identified scenarios

Identified process		Existing environmental emission scenario[1)]
Sailing	Open sea	• Open sea scenario MAM-PEC based on Northern section of the Dutch Continental Sector (Van Hattum et al., 2002).
	Shipping lane	• Shipping lane scenario MAM-PEC based on the eastern section of the main shipping lane along the Dutch coast (Van Hattum et al., 2002); • Finnish shipping lane based on the Gulf of Finland using MAM-PEC (Koivisto, 2003); • Danish shipping lane based on the narrows of Kronprins Frederiks Bro near Frederikssund (Madsen et al., 1999).
	Rivers, canals, streams, lakes	• No existing environmental emission scenario available.
Mooring	Commercial harbours	• Commercial harbour scenario MAM-PEC based on the Rotterdam harbour (Van Hattum et al., 2002); • Finnish harbour using MAM-PEC (Koivisto, 2003); • Estuary with small harbour scenario MAM-PEC (Van Hattum et al., 2002).
	Marinas in estuaries or directly situated in an enclosed area at the coast	• Marina scenario MAM-PEC based on a French Mediterranean marina in the Golfe Juan (Van Hattum et al., 2002); • Marina scenarios REMA (Comber et al., 2001); • Yacht basin scenario (Johnson and Luttik, 1994); • Finnish marina using MAM-PEC (Koivisto, 2003); • Danish marina based on the pleasure craft harbour of Jyllinge (Madsen et al., 1999).
	Marinas in lakes	• Swiss marina using MAM-PEC (BUWAL, 2000).
	Ships attached to buoys in lakes	• No existing environmental emission scenario available.
	Ships attached to buoys near the coast line	• No existing environmental emission scenario available.
	Natural harbours (e.g. small bays with shallow water in Scandinavia)	• No existing environmental emission scenario available.

1) Some of the existing scenarios have been subjected to validation exercises and some have not. These validation exercises will not be dicussed in this report, but reference is made to the validation exercises carried out for the MAM-PEC scenarios (see Chapter 6 of Van Hattum, B., A. Baart and J. Boon (2002)) and for the REMA scenario (see Section 6.2 of Comber, S. et al. (2001).

In sections 4.3.1 up to 4.3.5 the original existing emission scenarios are described. Only one modification has been made to the original descriptions. The original antifouled surface areas of commercial ships in the MAM-PEC scenarios are replaced by the areas calculated with the Holtrop equation (as described in section 2.3.1).

The surface areas in the Finnish “commercial ship scenarios” were already calculated using the Holtrop equation. Despite the fact that for both the Finnish and the MAM-PEC scenarios the antifouled area per length class is now calculated with the Holtrop equation one difference has still to be mentioned. The Finnish scenarios use the average surface area per length class of 1459 real existing ships, whereas the MAM-

PEC scenarios use the average length per length class (e.g. for a length class 50-100 m the average length is 75 m) and calculate the surface area.

Furthermore, in this report only the emission up to the primary receiving compartments is considered. Calculations of emissions to secondary environmental compartments (e.g. sediment) are not discussed, as this is outside the scope of the project. Therefore the sediment characteristics (e.g. fraction organic carbon in sediment) of the original scenarios are left out from the scenario descriptions.

4.3.1 Open sea

This section gives a short description of the default scenario “open sea” of the MAM-PEC-model, the only scenario available for open sea. In Annex I a more extensive description of the MAM-PEC model is given.

The “open sea” scenario of MAM-PEC is based on one of the Northern sections of the Dutch Continental sector with an average ship density of 1 ship per 1000 m^2. The Dutch section has one of the highest shipping densities of the world. Detailed statistics were available for the Dutch section of the North Sea and, additionally, the hydrology of the area is well known. Similar information for other European waters could not be retrieved. Therefore it was decided to use this area as the prototype environment for the development of the MAM-PEC model for the “open sea”.

In the tables 4.15 and 4.16 the default values and model calculations for the “open sea scenario” are described. To calculate the emission load (table 4.15) the model takes into account shipping characteristics, leaching rate and the application factor. The application factor represents the usage percentage for a particular antifouling product.

Table 4.15 Emission scenario for calculating the releases from biocides used in antifouling products with the open sea scenario of MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping characteristics				
Length categories of ships:	[m]	Cat 1-6		D
- Cat 1		Cat 1	50-100	
- Cat 2		Cat 2	100-150	
- Cat 3		Cat 3	150-200	
- Cat 4		Cat 4	200-250	
- Cat 5		Cat 5	250-300	
- Cat 6		Cat 6	300-350	
Number of ships moving at any time of the day for cat 1-6:	[-]	$N_{ships,moving}$		D
- Cat 1			0.095	
- Cat 2			0.04	
- Cat 3			0.04	
- Cat 4			0.01	
- Cat 5			0.01	
- Cat 6			0.002	
Average surface area per ship for cat 1-6[1)]:	[m^2]	$AREA_{ship}$		
- Cat 1			1,163	D
- Cat 2			3,231	
- Cat 3			6,333	
- Cat 4			10,469	
- Cat 5			15,640	
- Cat 6			21,844	
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	1[2)]	D
Leaching rate for ships moving [3)]	[$g.m^{-2}.d^{-1}$]	kleach		P
- Copper			500	D
- TBT			40	D
- Other biocides			25	D
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation: $Elocal_{water} = Sum_{cat\ 1\text{-}6\ moving}\ (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1);
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) According to the EU Biocides Directive, leaching rate data are required from the data-set supplied by the applicant.

Based on a brief selection of literature data and expertise available in the CEPE Antifouling Working Group, it was decided that the values as described in table 4.15 would be used as default leaching rates in the MAM-PEC model. However, the leaching rate can also edited by the user.

In table 4.16 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.16 Open sea scenario of MAM-PEC for calculating the concentration of antifouling biocides in sea water

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (area open sea)				
Length	[m]	LENGTHos	20,000	D
Width	[m]	WIDTHos	10,000	D
Depth	[m]	DEPTHos	20	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	5	D
Temperature	^{O}C	TEMP	15	D
Salinity	$^{O}/oo$	SALINITY	34	D
Particular organic carbon	[$g.m^{-3}$]	POC	0.3	D
Dissolved organic carbon	[$g.m^{-3}$]	DOC	0.2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	0	D
Tidal current	[$m.s^{-1}$]	CURRENTtid	1	D
Output:				
The average, median, minimum, 95-percentile, and maximum concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water,diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[$g.m^{-3}$]	$Clocal\_initial_{water,tot}$		O
The concentration on particulate matter	[$g.kg^{-1}$]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, the calculations are not described in this document. The MAM-PEC model uses the calculation models DELWAQ and SILTHER. A description of the basic set of formulas used in DELWAQ is presented in sections 5.4.1 to 5.4.3 of Van Hattum et al. (2002). In Appendix 3 of Van Hattum et al. (2002) an overview is given on how the exchange processes estimated with SILTHAR have been implemented in the MAM-PEC model.

The concentration in water is calculated by using the chemical equilibrium model DELWAQ, with steady state calculation option, to calculate the transport and chemical fate of the emitted compound in water and sediment, and by using the hydrodynamic model SILTHAR. In contrast with many other chemical equilibrium models the model DELWAQ is capable of a more comprehensive treatment of the subtle physicochemical and biological processes and interactions. The model can provide a spatial resolution (2D) and can easily be linked with hydrodynamic models such as SILTHAR. On the basis of information of the compound, the mass balance for the compound in the water column and sediment using the equations of a 2-dimensional steady state version of DELWAQ is calculated. The sediment dynamics and water exchange processes are calculated using the SILTHAR model. Hydrology in the open sea is dominated by tidal current.

Due to the complexity of the DELWAQ and SILTHAR model calculations, these are not described in this document. A description of the basic set of formulas used in DELWAQ is presented in sections 5.4.1 to 5.4.3 of Van Hattum et al. (2002). In Appendix 3 of Van Hattum et al. (2002) an overview is given on how the exchange processes estimated with SILTHAR have been implemented in the MAM-PEC model.

For each of the chosen scenarios the model creates a number of grid cells and a flow field. The flow field determines the exchange rates between the grid cells, and for each cell separate hydrological and chemical fate calculations are executed. After finishing all the input screens the calculations are started. For each of the grid cells the expected steady state concentrations are being calculated. This results in a distribution of concentrations in the specific environment. Average, median, minimum, 95-percentile, and maximum concentrations are being calculated for the dissolved concentration (μg/l including both the freely dissolved and the DOC-bound fraction), the total aqueous concentration (kg/l including fraction bound to particulate matter), the concentration on particulate matter, and sediment (μg/l organic carbon dry wt basis). As sediment processes are slow and attaining steady state may take years to decades, the model calculates sediment concentrations for different time periods (1, 2, 5 and 10 year). It is the responsibility of the user to determine which statistics need to be used. Maximum values, for example, only occur directly below the emissions, which are situated e.g. at the rear end of a harbour.

There is a broad distinction between organic and inorganic compounds both in the mechanisms and relative importance of the processes. For instance for copper, processes such as sorption, speciation- and redox reactions have a prominent role in the fraction of freely bioavailable and potentially toxic Cu^{2+}. As copper is an ingredient in many antifouling products, a specific module has been introduced in the MAM-PEC model which calculates Cu-speciation and predicts expected ranges of free Cu^{2+} ion concentrations.

4.3.2 Shipping lane

Shipping lane scenario MAM-PEC

This section gives a short description of the default scenario "shipping lane" of the MAM-PEC-model. In Annex I a more extensive description of the MAM-PEC model is given.

The "shipping lane" scenario of MAM-PEC is based on the Eastern section of the main shipping lane along the Dutch coast with an average density of 41 ships per 1000 km^2. The choice for this area (the Dutch section of the North Sea) as prototype environment for the development of the scenario for a "shipping lane" is based on the same reasons as for the MAM-PEC "open sea" scenario (one of the highest shipping densities of the world, availability of detailed statistics and knowledge of the hydrology of the area).

In the tables 4.17 and 4.18 the default values and model calculations for the "shipping lane scenario" are described. To calculate the emission load (table 4.17) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.17 Emission scenario for calculating the releases from biocides used in antifouling products with the shipping lane scenario of MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping characteristics				
Length categories of ships: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[m]	Cat 1-6 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5 Cat 6	 50-100 100-150 150-200 200-250 250-300 300-350	D
Number of ships moving at any time of the day for cat 1-6: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[-]	$N_{ships,moving}$	 3.9 1.7 1.6 0.4 0.5 0.1	D
Average surface area per ship for cat 1-6[1)]: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[m^2]	$AREA_{ship}$	 1,163 3,231 6,333 10,469 15,640 21,844	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	1[2)]	D
Leaching rate for ships moving [3)]	[g.m^{-2}.d^{-1}]	kleach		S
Output:				
Total emission	[g.d^{-1}]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}6\ moving} (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1);
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant.

In table 4.18 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.18 Shipping lane scenario of MAM-PEC for calculating the concentration of antifouling biocides in seawater

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (area shipping lane)				
Length	[m]	LENGTHsl	20,000	D
Width	[m]	WIDTHsl	10,000	D
Depth	[m]	DEPTHsl	20	D
Water quality				
Silt concentration	[g.m^{-3}]	Csilt	5	D
Temperature	^{O}C	TEMP	15	D
Salinity	^{O}/oo	SALINITY	34	D
Particular organic carbon	[g.m^{-3}]	POC	0.3	D
Dissolved organic carbon	[g.m^{-3}]	DOC	0.2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	0	D
Tidal current	[m.s^{-1}]	CURRENTtid	1	D
Output:				
The average, median, minimum, 95-percentile, and maximum concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[g.m^{-3}]	$Clocal\_initial_{water,diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[g.m^{-3}]	$Clocal\_initial_{water,tot}$		O
The concentration on particulate matter	[g.kg^{-1}]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, this calculation is not described in this document. For information on the specific copper module of see open sea scenario MAM-PEC.

The concentration in water is calculated by using the models DELWAQ and SILTHAR as described for the open sea scenario of MAM-PEC. The hydrology in the shipping lane is dominated by tidal current.

Finnish shipping lane scenario using MAM-PEC

This section gives a short description of the Finnish default scenario "shipping lane" using the MAM-PEC-model.

The Finnish "shipping lane" scenario is based on the Gulf of Finland and is assumed to have cargo traffic to and from Finnish harbours. Passenger ferries are not taken into account, because they are not treated with antifoulants in Finland. The length classification and wet surface area of ships have been changed in the Finnish shipping lane compared to the MAM-PEC default shipping lane. Smaller ships are assumed to operate in the Finnish shipping lane. The Finnish shipping lane has the same dimensions as the MAM-PEC default shipping lane. However, default values for water quality, etc. are changed.

In the tables 4.19 and 4.20 the default values and model calculations for the "shipping lane scenario" are described. To calculate the emission load (table 4.19) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.19 Emission scenario for calculating the releases from biocides used in antifouling products with the Finnish shipping lane scenario using MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of ships: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m]	Cat 0-5 Cat 0 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5	 0-50 50-100 100-150 150-200 200-250 250-300	D
Number of ships moving at any time of the day for cat 0-5: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,moving}$	 0.03 0.26 0.18 0.08 0.02 0.01	D
Average surface area per ship for cat 0-5[3)]: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m^2]	$AREA_{ship}$	 412 1,646 3,316 6,431 10,743 16,092	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	max. 0.2 [2)]	D
Leaching rate for ships moving[1)]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}6\ moving}\ (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant.
2) The user may edit this on the basis of the market share of the antifoulant.
3) The average surface areas were calculated from data provided by the Finnish Maritime Administration using the Holtrop equation.

Based on estimates of the Finnish Maritime administration and main Finnish shipping companies that 80% of cargo ships visiting Finland are not treated with antifouling products the application factor can be set to 0.20 at maximum.

In table 4.20 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.20 Finnish shipping lane scenario using MAM-PEC for calculating the concentration of antifouling biocides in sea water, sediment and particulate matter

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (area shipping lane)				
Length	[m]	LENGTHsl	20,000	D
Width	[m]	WIDTHsl	10,000	D
Depth	[m]	DEPTHsl	20	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	1	D
Temperature	^{O}C	TEMP	5	D
Salinity	$^{O}/oo$	SALINITY	4.6	D
Particular organic carbon	[$g.m^{-3}$]	POC	0.2	D
pH	-	pH	7.6	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	0	D
Tidal current	[$m.s^{-1}$]	CURRENTtid	0.05	D
Output:				
The average concentrations for: [2)]				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water,diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[$g.m^{-3}$]	$Clocal\_initial_{water,tot}$		O
The concentration on particulate matter	[$g.kg^{-1}$]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, the calculations are not described in this document;
2) Only the average concentration is calculated. The reason is not to get over conservative values when the input parameters have already been selected to present a relative worst scenario.

The tidal current of the scenario is set to 0.05 m/s. This is based on the long term average flow velocity on the sea surface of the Gulf of Finland (0.01-0.05 m/s). There is no tide in Finland. Other changes of water level due to wind etc. are irregular and not occurring daily so they are not taken into account.

The concentration in water for the Finnish “shipping lane” scenario is calculated by the same methods (DELWAQ and SILTHAR) as for the default “shipping lane” scenario of MAM-PEC.

Danish shipping lane scenario

This section gives a short description of the Danish shipping lane scenario based on the report of Madsen et al. (1999) where it is called the "Busy navigation route" scenario in Appendix 1. The scenario is based on the narrows of Kronprins Frederiks Bro near Frederikssund, Denmark.

In the tables 4.21 and 4.22 the default and model calculations for the "shipping lane scenario" are described. To calculate the emission load per day (table 4.21) the scenario takes into account shipping characteristics, leaching rate and the application factor.

Table 4.21 Emission scenario for calculating the releases from biocides used in antifouling products with the Danish shipping lane scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Number of ships at any time of the day	[-]	N_{ships}	70	D
Average surface area per ship	[m^2]	$AREA_{ship}$	18	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	0.7	D
Leaching rate for ships moving[1)]	[$g.m^{-2}.d^{-1}$]	$kleach_{moving}$		S
Average time that the centre of gravity of the boats stays in the default area of the shipping lane	[d]	$T_{b/w}$	$7.5.10^{-6}$	D
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = N_{ships} * AREA_{ship} * Fappl * kleach_{moving} * T_{b/w}$				

1) It is assumed that the leaching rate while sailing is twice the rate at berth.

The parameter $T_{b/w}$ is a shipping characteristic that is based on a sea speed of 5.5 - 7.4 km/h. A worst case approach was chosen. Therefore the lowest speed of 5.5 km/h was used to calculate the average time that the centre of gravity of the boats stays in the area of the shipping lane.

Table 4.22 Danish shipping lane scenario for calculating the concentration of antifouling biocides in seawater

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (area shipping lane)				
Length	[m]	LENGTHsl	1	D
Width	[m]	WIDTHsl	width of the boat	D
Depth	[m]	DEPTHsl	4.2 (3.5 - 5.4)	D
Water quality				
Temperature	^{O}C	TEMP	12.5	D
Salinity	$^{O}/oo$	SALINITY	14.5	D
Particular organic carbon	[$g.m^{-3}$]	POC	1.44	D
pH	[-]	pH	7	D
Hydrology				
Water exchange	[$m^3.m^{-2}.d^{-1}$]	RATEwater	0.6	
Output:				
Initial concentration in sea water	[$g.m^{-3}$]	$Clocal\_initial_{water}$		O
Calculation:				
Mass balance calculations.				

In the report from Madsen et al. (1999) the processes taken into account for the calculations are described like (bio)degradation, sorption to suspended matter, resuspension and sedimentation. The calculations themselves are however not described in the report.

4.3.3 Commercial harbour

Commercial harbour scenario MAM-PEC

In this section a short description of the default scenario “commercial harbour” of the MAM-PEC-model is given. Annex I contains a more extensive description of the MAM-PEC model.

The “commercial harbour” scenario of MAM-PEC is based on the Rotterdam harbour in the Netherlands. The default scenario “commercial harbour” is situated along a large estuarine river at a distance of 2 kilometres from the mouth of the river. The harbour may have additional flushing from a small river or urban drainage system discharging at the rear end of the harbour.

In the tables 4.23 and 4.24 the default values and model calculations for the “commercial harbour scenario” are described. To calculate the emission load (table 4.23) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.23 Emission scenario for calculating the releases from biocides used in antifouling products with the commercial harbour scenario of MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of ships: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[m]	Cat 1-6 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5 Cat 6	 50-100 100-150 150-200 200-250 250-300 300-350	D
Number of ships at berth at any time of the day for cat 1-6: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[-]	$N_{ships,berth}$	 57 25.5 24.5 5.5 7.5 1.5	D
Number of ships moving at any time of the day for cat 1-6: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[-]	$N_{ships,moving}$	 8.75 2.15 2.05 0.5 0.6 0.1	D
Average surface area per ship for cat 1-6[3]: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6	[m^2]	$AREA_{ship}$	 1,163 3,231 6,333 10,469 15,640 21,844	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	1[2]	D
Leaching rate for ships moving and at berth[1]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}6\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach) + Sum_{cat\ 1\text{-}6\ moving}\ (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1)

The number of ships at berth and moving at any time of the day were derived of the total cumulative annual port statistics of the Rotterdam harbour. An average residence time of 3 days was used for ships at berth, and a harbour manoeuvring time for arrival and depart was taken as 3 hours. The total number of ship movements includes not only arrival and departs of ships visiting the harbour, but also transits of ships sailing to upstream locations. The length category of these ships is not known, but is attributed to the smallest length category. With help of these residence and manoeuvring times and the total number of port visits and movements per year, the number of ships at berth and moving per length category were calculated.

In table 4.24 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.24 Commercial harbour scenario of MAM-PEC for calculating the concentration of antifouling biocides in seawater

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Distance from mouth	[m]	LENGHTm-h	2,000	D
Length	[m]	LENGTHch	10,000	D
Width	[m]	WIDTHch	2,000	D
Depth of harbour	[m]	DEPTHch	20	D
Harbour entrance width	[m]	WIDTHent	5,000	D
Harbour entrance depth	[m]	DEPTHent	20	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	$[g.m^{-3}]$	Csilt	35	D
Temperature	^{O}C	TEMP	15	D
Salinity	$^{O}/oo$	SALINITY	30	D
Particular organic carbon	$[g.m^{-3}]$	POC	1	D
Dissolved organic carbon	$[g.m^{-3}]$	DOC	2	D
pH	-	pH	7.5	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	1.5	D
River flow velocity	$[m.s^{-1}]$	CURRENTriver	1.5	D
Depth of river	[m]	DEPTHriver	10	D
Density difference	$[kg.m^{-3}]$	RHOdiff	0.8	D
Flush in harbour	$[m^{3}.s^{-1}]$	FLOWharbour	0	D
Density difference of flush	$[kg.m^{-3}]$	RHOdiff,flush	0	D
Output:				
The average, median, minimum, 95-percentile, and maximum concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	$[g.m^{-3}]$	$Clocal\_initial_{water, diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	$[g.m^{-3}]$	$Clocal\_initial_{water, tot}$		O
The concentration on particulate matter	$[g.kg^{-1}]$	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, these calculations are not described in this document. For information on the specific copper module of see the MAM-PEC open sea scenario.

The concentration in water is calculated by using the models DELWAQ and SILTHAR as described for the open sea scenario of MAM-PEC. With respect for a harbour, the SILTHAR model includes tidal exchange, horizontal flows in the harbour entrance and vertical circulation currents in the harbour.

Finnish commercial harbour scenario using MAM-PEC

In this section a short description of the scenario “Finnish harbour” using the MAM-PEC-model is given.

Commercial harbours in Finland, and the ships visiting these harbours, are considerably smaller than harbours and visiting ships in Rotterdam in the Netherlands. Therefore the “Finnish harbour” is significantly smaller compared to the default commercial harbour of MAM-PEC. The “Finnish harbour” is assumed to be located in Helsinki and receives cargo traffic. In this scenario passenger ferries are not taken into account, because they are not treated with antifoulants in Finland.

In the tables 4.25 and 4.26 the default values and model calculations for the “commercial harbour scenario” are described. To calculate the emission load (table 4.25) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.25 Emission scenario for calculating the releases from biocides used in antifouling products with the Finnish harbour scenario using MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of ships: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m]	Cat 0-5 Cat 0 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5	 0-50 50-100 100-150 150-200 200-250 250-300	P
Number of ships at berth at any time of the day for cat 1-3: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,berth}$	 0.15 1.18 0.82 0.36 0.08 0.03	D
Average surface area per ship for cat 1-3[3]: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m^2]	$AREA_{ship}$	 412 1,646 3,316 6,431 10,743 16,092	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	max. 0.2[2]	S
Leaching rate for ships moving[1]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}3\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this on the basis of the market share of the antifoulant;
3) The average surface areas were calculated from data provided by the Finnish Maritime Administration using the Holtrop equation.

The length classification and wet surface area of ships have been changed in the Finnish harbour scenario. Only ships having length less than 300 metres are assumed to be present. An average residence time of 12 hours was assumed on the basis of typical duration of cargo vessels visit, which is 12 up to 24 hours. No distinction is made between ships at berth and ships moving.

Based on estimates of the Finnish Maritime administration and main Finnish shipping companies that 80% of cargo ships visiting Finland are not treated with antifouling products the application factor can be set to 0.20 at maximum. For cargo ships sailing in ice conditions in winter, the ice cover removes the fouling organisms and would (partially) remove the antifouling paint.

In table 4.26 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.26 Finnish harbour scenario using MAM-PEC for calculating the concentration of antifouling biocides in sea water, sediment and particulate matter

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Distance from mouth	[m]	LENGHTm-h	444	D
Length	[m]	LENGTHch	444	D
Width	[m]	WIDTHch	1,000	D
Depth of harbour	[m]	DEPTHch	10	D
Harbour entrance width	[m]	WIDTHent	1,000	D
Harbour entrance depth	[m]	DEPTHent	10	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[g.m^{-3}]	Csilt	10	D
Temperature	^{O}C	TEMP	5	D
Salinity	^{O}/oo	SALINITY	4.6	D
Particular organic carbon	[g.m^{-3}]	POC	0.2	D
pH	-	pH	7.6	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	0	D
River flow velocity	[m.s^{-1}]	CURRENTriver	0.1	D
Depth of river	[m]	DEPTHriver	10	D
Density difference	[kg.m^{-3}]	RHOdiff	0	D
Flush in harbour	[m.s^{-1}]	FLOWharbour	0	D
Density difference of flush	[kg.m^{-3}]	RHOdiff,flush	0	D
Output:				
The average concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[g.m^{-3}]	$Clocal\_initial_{water,diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[g.m^{-3}]	$Clocal\_initial_{water, ot}$		O
The concentration on particulate matter	[g.kg^{-1}]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, the calculations are not described in this document.

The river flow velocity of this scenario is set to 0.1 m/s. This is a higher value than in the shipping lane as the moving ships are assumed to cause water turbulence in the harbour. Harbour flush situations are not typical for Finland as there is no tide.

In the MAM-PEC scenarios the processes of horizontal flow, tide and/or density differences determine the exchange. Under conditions of low tide, low flow and no density differences, other processes (e.g. changes of water level due to wind) become important according to a study performed by the Dutch Waterloopkundig Laboratorium and Delft Hydraulics (Baart, A. C. (2003)). The current version (1.4) of MAM-PEC does not yet include these processes and so when necessary they have to be adjusted manually. Baart, A. C. (2003) describes recommendations for (manual) adjustment of the water exchange (in m3/tidal period) due to non-tidal water exchanges.

The Finnish Environment Institute (FEI) considered the principles laid down in the study (Baart, A. C. (2003) an acceptable approach, but considers this not representative for Finnish conditions. At this moment FEI has corrected the water exchange rate due to other factors than tide for Finnish conditions. The corrections would increase the water exchange volume in the Finnish scenario by a factor of about 7. These corrections are included as notes in the Finnish scenario descriptions.

The concentration in water for the Finnish “harbour” scenario is calculated by the same methods as for the default “harbour” scenario of MAM-PEC.

Estuarine harbour scenario MAM-PEC
In this section a short description of the default scenario “estuarine harbour” of the MAM-PEC-model is given, the only scenario available for estuarine harbour. Annex I contains a more extensive description of the MAM-PEC model.

The “estuarine harbour” scenario of MAM-PEC is essentially the same as the “commercial harbour” scenario of MAM-PEC but differs in dimensions and the size of the harbour. This scenario was added in MAM-PEC to be able to calculate antifouling biocide concentrations for smaller harbours, because harbours with a size close to that of Rotterdam harbour are not found in other European countries.

The default scenario “estuarine” is situated along a large estuarine river at a distance of 1 kilometre from the mouth of the river. The estuarine harbour may also have additional flushing from a small river or urban drainage system discharging at the rear end of the harbour.

In the tables 4.27 and 4.28 the default values and model calculations for the “estuarine harbour scenario” are described. To calculate the emission load (table 4.27) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.27 Emission scenario for calculating the releases from biocides used in antifouling products with the estuarine harbour scenario of MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of ships: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m]	Cat 1-5 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5	 50-100 100-150 150-200 200-250 250-300	D
Number of ships at berth at any time of the day for cat 1-5: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,berth}$	 11 5 5 1 2	D
Number of ships moving at any time of the day for cat 1-5: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,moving}$	 1.8 0.4 0.4 0.1 0.1	D
Average surface area per ship for cat 1-5[3]: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m^2]	$AREA_{ship}$	 1,163 3,231 6,333 10,469 15,640	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	1[2]	D
Leaching rate for ships moving and at berth[1]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}5\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach) + Sum_{cat\ 1\text{-}5\ moving}\ (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1)

In table 4.28 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.28 Estuarine harbour scenario of MAM-PEC for calculating the concentration of antifouling biocides in seawater

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Distance from mouth	[m]	LENGHTm-h	1000	D
Length	[m]	LENGTHch	5000	D
Width	[m]	WIDTHch	1000	D
Depth of harbour	[m]	DEPTHch	15	D
Harbour entrance width	[m]	WIDTHent	2500	D
Harbour entrance depth	[m]	DEPTHent	10	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	35	D
Temperature	^{O}C	TEMP	15	D
Salinity	$^{O}/oo$	SALINITY	34	D
Particular organic carbon	[$g.m^{-3}$]	POC	1	D
Dissolved organic carbon	[$g.m^{-3}$]	DOC	2	D
pH	-	pH	7.5	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	1.5	D
River flow velocity	[$m.s^{-1}$]	CURRENTriver	1	D
Depth of river	[m]	DEPTHriver	10	D
Density difference	[$kg.m^{-3}$]	RHOdiff	0.4	D
Flush in harbour	[$m^3.s^{-1}$]	FLOWharbour	0	D
Density difference of flush	[$kg.m^{-3}$]	RHOdiff,flush	0	D
Output:				
The average, median, minimum, 95-percentile, and maximum concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water, diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[$g.m^{-3}$]	$Clocal\_initial_{water, tot}$		O
The concentration on particulate matter	[$g.kg^{-1}$]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, this calculation is not described in this document. For information on the specific copper module of the MAM-PEC open sea scenario.

The concentration in water is calculated by using the models DELWAQ and SILTHAR as described for the open sea scenario of MAM-PEC. With respect to an estuarine harbour the SILTHAR model includes tidal exchange, horizontal flows in the harbour entrance and vertical circulation currents in the harbour.

4.3.4 Estuarine marinas

Marina scenario MAM-PEC

In this section a short description of the default scenario “marina” of the MAM-PEC-model is given. Annex I contains a more extensive description of the MAM-PEC model.

The “marina” scenario of MAM-PEC is based on a French Mediterranean marina in the Golfe Juan. The marina is an enclosed area situated directly at the coast. The marina may have additional flushing from a small river or urban drainage system discharging at the rear end of the harbour.

In the tables 4.29 and 4.30 the default values and model calculations for the “marina scenario” are described. To calculate the emission load (table 4.29) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.29 Emission scenario for calculating the releases from biocides used in antifouling products with the marina scenario of MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length category of pleasure crafts	[m]	Cat 0	1-50	D
Number of ships at berth at any time of the day	[-]	$N_{ships,berth}$	299	D
Average surface area per craft[3)]	[m^2]	$AREA_{ship}$	22.5	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	1[2)]	D
Leaching rate for ships at berth[1)]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 0\ at\ berth} (AREA_{ship} * N_{ships,berth} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The average surface area was calculated according Bauer and Jakobson (1997) set at 50% of boat deck area.

The number of pleasure crafts at berth at any time of the day is given as the yearly average number of pleasure crafts present in the harbour. However, in marinas for pleasure crafts the density of ships present is highly season-dependant. The number of ships moving has not been indicated, as manoeuvring time in marinas is expected to be negligible to the time at berth.

In table 4.30 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.30 Marina scenario of MAM-PEC for calculating the concentration of antifouling biocides in seawater

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Length	[m]	LENGTHm	400	D
Width	[m]	WIDTHm	400	D
Depth of harbour	[m]	DEPTHm	3.5	D
Harbour entrance width	[m]	WIDTHent	100	D
Harbour entrance depth	[m]	DEPTHent	3.5	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	35	D
Temperature	^{O}C	TEMP	20	D
Salinity	$^{O}/oo$	SALINITY	34	D
Particular organic carbon	[$g.m^{-3}$]	POC	1	D
Dissolved organic carbon	[$g.m^{-3}$]	DOC	2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	1.5	D
Tidal current	[$m.s^{-1}$]	CURRENTtid	1	D
Density difference	[$kg.m^{-3}$]	RHOdiff	0.1	D
Flush in harbour	[$m^3.s^{-1}$]	FLOWharbour	0	D
Density difference of flush	[$kg.m^{-3}$]	RHOdiff,flush	0	D
Output:				
The average, median, minimum, 95-percentile, and maximum concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water,diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[$g.m^{-3}$]	$Clocal\_initial_{water,tot}$		O
The concentration on particulate matter	[$g.kg^{-1}$]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, the calculations are not described in this document. For information on the specific copper module of see MAM-PEC open sea scenario.

The concentration in water is calculated by using the models DELWAQ and SILTHAR. With respect to a marina the SILTHAR model includes tidal exchange, horizontal flows in the marina entrance and vertical circulation currents in the marina.

Finnish marina scenario using MAM-PEC

In this section a short description of the "Finnish marina" scenario using the MAM-PEC-model is given. This scenario is based on Finnish marinas in the Baltic Sea. The Finnish scenario is assumed to be located in a small, shallow and closed bay. The Finnish scenario assumes an early summer situation.

In the tables 4.31 and 4.32 the default values and model calculations for the "marina scenario" are described. To calculate the emission load (table 4.31) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.31 Emission scenario for calculating the releases from biocides used in antifouling products with the Finnish marina scenario using MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of pleasure boats: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6 - Cat 7 - Cat 8 - Cat 9	[m]	 Cat 0 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5 Cat 6 Cat 7 Cat 8 Cat 9	 0-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12 12-13 >13	D
Number of ships at berth at any time of the day for cat 0-9: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6 - Cat 7 - Cat 8 - Cat 9	[-]	$N_{ships,berth}$	 23 25 27 45 43 27 20 9 2 5	D
Average surface area per ship for cat 0-9[3]: - Cat 0 - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5 - Cat 6 - Cat 7 - Cat 8 - Cat 9	[m^2]	$AREA_{ship}$	 7 11 16 19 23 26 29 30 30 32	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	max. 0.9[2]	S
Leaching rate for ships moving[1]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 0\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant.
2) The user may edit this value on the basis of the market share of the antifoulant.
3) The average surface areas were calculated from data provided by the boat registers of Suomen Veneilyliito and Suomen Purjehtijaliitto with the calculation method provided by CEPE.

The application factor can be set to 0.9 at maximum because it is assumed that at least 10% of the boats in the marina are not treated with antifouling products. For each antifouling biocide the application factor will be adjusted on the basis of it's market share and can thus be considerably lower than 0.9.

The number of pleasure crafts at berth at any time of the day is given for an early summer situation. The number of ships moving has not been indicated, as manoeuvring time in marinas is expected to be negligible to the time at berth.
Compared with the default scenario of MAM-PEC changes are introduced in the length classes and the wet surface areas of the ships.

In table 4.33 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 4.33 Finnish marina scenario using MAM-PEC for calculating the concentration of antifouling biocides in seawater

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Length	[m]	LENGTHm	420	D
Width	[m]	WIDTHm	140	D
Depth of harbour	[m]	DEPTHm	2.2	D
Harbour entrance width	[m]	WIDTHent	140	D
Harbour entrance depth	[m]	DEPTHent	2.2	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	10	D
Temperature	^{O}C	TEMP	10	D
Salinity	$^{O}/oo$	SALINITY	4.6	D
Particular organic carbon	[$g.m^{-3}$]	POC	0.2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	0	D
Tidal current	[$m.s^{-1}$]	CURRENTtid	0.01	D
Density difference	[$kg.m^{-3}$]	RHOdiff	0	D
Flush in harbour	[$m^3.s^{-1}$]	FLOWharbour	0	D
Density difference of flush	[$kg.m^{-3}$]	RHOdiff,flush	0	D
Output:				
The average concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water, diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[$g.m^{-3}$]	$Clocal\_initial_{water, tot}$		O
The concentration on particulate matter	[$g.kg^{-1}$]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water, sediment and particulate matter, the calculations are not described in this document.

The tidal current of the scenario is set to 0.01 m/s. It is based on the long term average flow velocity on the sea surface of the Gulf of Finland (0.01-up to 0.05 m/s). This is a lower value than in the shipping lane as the marina is more closed. Marina flush situations are not typical for Finland as there is no tide. Other changes of water level (e.g. due to wind) may be important but are not included in the scenario (see also section 4.3.3: Finnish commercial harbour scenario).

The concentration in water for the Finnish marina scenario is calculated by the same methods (DELWAQ and SILTHAR) as for the default “shipping lane” scenario of MAM-PEC.

Marina scenario REMA

This section gives a short description of the default scenario “marina” of the REMA-model. In Annex I a more extensive description of the REMA model is given.

The REMA scenarios are based on UK marinas, harbours and estuaries. These cover a number of situations with estuaries of varying sizes and dynamics and marinas of different type (locked, open, pontooned). The following default estuaries were defined where each estuary consists of three segments each containing a marina:

- A small estuary that dries out;
- A well mixed estuary, with a narrow mouth;
- A well mixed estuary, with a wide mouth;
- A large complex estuary.

These four scenarios are based on data collected from existing hydrological models and from a 1998 survey on boat density and antifouling products usage data. Pleasure crafts afloat in UK waters varied from 73,000 to 150,000 with an average length of the pleasure crafts of 9.2 m (47% motor boats and 53% sailing yachts). The average number of vessels kept in a marina was 213 ranging from 30 to 500. In table 4.34, 4.35 and 4.36 the default values and model calculations for the marina scenario REMA are described. This description is given for all 4 estuaries, so sometimes ranges are given for default values for the marinas or the segments.

Next to the calculation of the concentration in the marinas the REMA-model also enables you to estimate the concentrations in the estuaries. This may enable the regulatory decisions to be based not just in light of data on open, semi-enclosed, or closed marinas where environmental effects would be expected, but also on the wider water course.

Table 4.34 Emission scenario for calculating the releases from biocides used in antifouling products with the marina scenario of REMA

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Number of pleasure boats at any time of the day in estuary segment 1-3: Segment 1 and 2 Segment 3	[-]	$N_{ships,s1}$ and $N_{ships,s2}$ $N_{ships,s3}$	50, 100, 125 or 600 0,10, 100 or 400	D
Number of pleasure crafts at any time of the day in marina 1-3: Marina 1 Marina 2 Marina 3	-]	$N_{ships,m1}$ $N_{ships,m2}$ $N_{ships,m3}$	0, 67 or 300 0, 140, 300 or 500 0 or 300	D
Number of ships at any time of the day in estuary segment 1-3: Segment 1 Segment 2 segment 3	[-]	$N_{ships,s1}$ $N_{ships,s2}$ $N_{ships,s3}$	0 or 10 0 or 10 0, 5 or 10	D
Average underwater area Leisure crafts Ships	[m^2]	AREA	30.7 1,000	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	1[2)]	D
Leaching rate for ships moving[1)]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission per segment	[$g.d^{-1}$]	$Elocal_{water,s1}$ $Elocal_{water,s2}$ $Elocal_{water,s3}$		O
Total emission per marina	[$g.d^{-1}$]	$Elocal_{water,m1}$ $Elocal_{water,m2}$ $Elocal_{water,m3}$		O
Calculations:				
Segment 1: $Elocal_{water,s1} = (AREA_{ship} * N_{ships,s1} * Fappl * kleach)$ Segment 2: $Elocal_{water,s2} = (AREA_{ship} * N_{ships,s2} * Fappl * kleach)$ Segment 3: $Elocal_{water,s3} = (AREA_{ship} * N_{ships,s3} * Fappl * kleach)$ Marina 1: $Elocal_{water,m1} = (AREA_{ship} * N_{ships,m1} * Fappl * kleach)$ Marina 2: $Elocal_{water,m2} = (AREA_{ship} * N_{ships,m2} * Fappl * kleach)$ Marina 3: $Elocal_{water,m3} = (AREA_{ship} * N_{ships,m3} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant.

In table 4.35 the default values necessary for the calculation of the antifouling biocide concentration in water and sediment are described for the marina. In table 4.36 the default values necessary for the calculation of the antifouling biocide concentration in water and sediment are described for the segments.

Table 4.36 Marina scenario of REMA for calculating the concentration of antifouling biocides in sea water: marina characteristics

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (marina lay-out)				
Marina size segment 1 and 2 segment 3	$[m^2]$	AREAm	20,000 50,000	D
Depth of marina (all segments)	[m]	DEPTHm	4	D
Water quality				
Temperature	^{O}C	TEMP	15	D
Fraction OC in suspended solids	-		0.1	D
Concentration of water column particles: Segment 1 Segment 2 and 3	$[mg.l^{-1}]$		13 25	D
Density of suspended solids	$[g.cm^{-3}]$		1.8	D
Hydrology				
Water flow half time (between segments and marinas)[1)] Segment 1 Segment 2 Segment 3	[h]	$T_{50}flow_{wat}$	12 - 24 12 12 - 48	D
Water depth segments	[m]		1.1 - 8.6	D
Output:				
Initial concentration in water in marina 1-3	$[mg.m^{-3}]$	$Clocal\_initial_{water,m1}$ $Clocal\_initial_{water,m2}$ $Clocal\_initial_{water,m3}$		O
Calculation:				
Calculations with QWASI.				

1) REMA describes water flow half times of 12 hours, 24 hours and 48 hours. The 48 h is considered to represent a closed marina. the 24 and 12 h semi-open and open respectively.

Table 4.37 Marina scenario of REMA for calculating the concentration of antifouling biocides in sea water: segment characteristics

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (segment lay-out)				
Water area Segment 1 segment 2 segment 3	[m^2]	AREAs	4.4 - 17.1 10^5 8.06 - 102 10^5 8.1 - 342 10^5	D
Water depth Segment 1 Segment 2 Segment 3	[m]	DEPTHs	1.1 - 3.76 2.27 - 8.6 3.39 - 6.1	D
Water quality				
Temperature	^{O}C	TEMP	15	D
Fraction OC in suspended solids	-		0.05	D
Concentration of water column particles: Segment 1 Segment 2 Segment 3	[mg.l^{-1}]		21 24 28	D
Density of suspended solids	[g.cm^{-3}]		1.8	D
Hydrology				
Water exchange rate Segment 1 Segment 2 Segment 3	[m^3.h^{-1}]		6,036 - 91,500 39,684 - 465,400 35,308 - 233,420	D
River water flow Segment 1 Segment 2 Segment 3	[m^3.h^{-1}]		920 - 47,500 0 - 23,400 0 - 20,200	D
Water depth segments	[m]		1.1 - 8.6	D
Output:				
Initial concentration in water in segment 1-3	[mg.m^{-3}]	$Clocal\_initial_{water,s1}$ $Clocal\_initial_{water,s2}$ $Clocal\_initial_{water,s3}$		O
Calculation:				
Calculations with QWASI.				

The REMA model is based on the QWASI (Quantitative Water-Air-Sediment Interaction) fugacity model developed by Mackay to calculate the transport and chemical fate of the emitted antifouling biocide.

Due to the complexity of the QWASI model calculations, these are not described in this document.

Yacht basin (marina) scenario USES

The model of USES is a one-dimensional box-model that describes a middle-size yacht basin where emission of antifouling products occurs by leaching from ships. The emission is calculated from leaching rate of the antifouling biocide expressed as (mass per area ship per time, and the total ship area. Assuming a certain water volume per ship and a residence time of water in the basin, the emission is converted to a concentration. This concentration is in fact the average total concentration during the water replacement time. The dissolved concentration is calculated applying equilibrium partitioning over the water phase and suspended matter using a solids-water partitioning coefficient.

The model was originally described by Luttik et al. (1993) and Luttik and Johnson (1996). In the Netherlands the model has been incorporated in the USES model as described by Linders and Jager (1998) for version USES 2.0 and Van Leeuwen (1999) for version USES 3.0.

For the fraction of ships in the water a distinction is made between summer, winter and the average fraction in a whole year. The whole year value is used as default. If necessary, several of the parameters can be altered by the user.

In table 4.38 and 4.39 the default and model calculations for the USES marina model are described.

Table 4.38 Emission scenario USES for calculating the releases from biocides used in antifouling products on pleasure crafts in a marina (Linders and Jagers 1998)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
Number of yachts in yacht-basin	[-]	N_{ship}	250	D
Cover of antifouling paint	[$m^2.m^{-3}$]	$AREAlitre_{anti}$	2,500	D
Fraction of ships in water	[-]	F_{ship}	0.5 (whole year) 1.0 (summer) 0.25 (winter)	D P P
Volume of paint per yacht	[m^3]	V_{anti}	0.002	D
Fraction ships in yacht-basin	[-]	$F_{s/ns}$	0.71	D
Leaching rate of compound	[$kg.m^{-2}.d^{-1}$]	kleach	5.10^{-5}	D
Intermediate result:				
Antifouling surface per yacht-basin	[m^2]	$AREA_{anti}$		O
Output:				
Total emission to water	[$g.d^{-1}$]	$Elocal_{water}$		O
Intermediate calculation:				
$AREA_{anti} = AREAlitre_{anti} * V_{anti} + N_{ship} * F_{ship} * F_{s-ns}$				
End calculation:				
$Elocal_{water} = AREA_{anti} * kleach$				

Table 4.39 USES-scenario for calculating the concentration of antifouling biocides in the water

Variable/parameter	Unit	Symbol	Value	D/O/P
Input:				
Mean ship deck area	$[m^2]$	$AREA_{deck}$	10	D
Water/ship ratio in yacht-basin	[-]	$F_{water/ship}$	3	D
Number of yachts in yacht-basin	[-]	N_{ship}	250	D
Depth of yacht-basin	[m]	$DEPTH_{basin}$	2.5	D
DT_{50} for advection in the yacht-basin	[d]	$DT_{50advec,\ basin}$	50	D
Concentration suspended matter in water	$[kg.m^{-3}]$	$C_{susp,water}$	0.015	D
First order rate constant for biodegradation in water	$[d^{-1}]$	kdegwater	$4.159.10^{-2}$	O
Suspended solids-water partitioning coefficient	$[m^3.kg^{-1}]$	Kp_{susp}	based on log Kow for organic substances	P
Intermediate results:				
Necessary harbour area per yacht	$[m^2]$	$AREA_{ship}$		O
Amount of water in yacht basin	$[m^3]$	V_{basin}		O
Rate constant for advection	$[d^{-1}]$	$k_{advec,basin}$		O
Overall rate constant for removal from basin	$[d^{-1}]$	k_{basin}		O
Output:				
Equilibrium dissolved concentration in yacht-basin	$[kg.m^{-3}]$	$Cwater_{,equi}$		
Peak concentration in water	$[kg.m^{-3}]$	$Cwater_{,0}$		
Average concentration in water over T days (4, 7, 21, 28 or 365; T = days)	$[kg.m^{-3}]$	$Cwater_{,T}$		
Intermediate calculation:				
$AREA_{ship} = (1 + F_{water/ship}) * AREA_{deck}$ $V_{basin} = N_{ship} * AREA_{ship} * DEPTH_{basin}$ $k_{advec,basin} = \ln 2 / DT_{50advec,\ basin}$ $k_{basin} = kdegwater / (1 + Kp_{susp} * C_{susp,water}) + k_{advec,basin}$				
End calculations:				
$Cwater_{,equi} = Elocal_{water} / (V_{basin} * k_{basin})$ $Cwater_{pest,T} = Cwater_{,equi} / (1 + Kp_{susp} * C_{susp,water})$ T ε {0,4,7,21,28,T_{bird},T_{mammal},365}				

Danish marina scenario

This section gives a short description of the Danish marina scenario based on the report of Madsen et al. (1999) where it is called the "Pleasure craft harbour" scenario (Appendix 1 of the report of Madsen et al.). The scenario is based on the pleasure craft harbour of Jyllinge, Denmark.

In the tables 4.40 and 4.41 the default and model calculations for the "Danish marina scenario" are described. To calculate the emission load per day (table 4.40) the scenario takes into account shipping characteristics, leaching rate and the application factor.

Table 4.40 Emission scenario for calculating the releases from biocides used in antifouling products with the Danish marina scenario

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Number of ships at any time of the day	[-]	N_{ships}	400	D
Average surface area per ship	[m^2]	$AREA_{ship}$	18	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	0.7	D
Leaching rate for ships at berth[1)]	[$g.m^{-2}.d^{-1}$]	$kleach_{berth}$		S
Time that the centre of gravity of the boats stays in the water of the marina	[d]	$T_{b/w}$	1 (always there)	D
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = N_{ships} * AREA_{ship} * Fappl * kleach_{berth} * T_{b/w}$				

1) It is assumed that the leaching rate while sailing is twice the rate when at berth.

The parameter $T_{b/w}$ is in fact a shipping characteristic. In the scenario it is assumed that the pleasure crafts are always in the marina. It is mentioned that this will overestimate the total leaching of antifouling biocides in the marina as - based on information from the Danish Sailing Association - the berths are occupied from mid-May until end-September. Also, from 1 July until 15 August the pleasure crafts are gone and there are almost no visitors in the marina.

Table 4.41 Danish marina scenario for calculating the concentration of antifouling biocides in seawater

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Area	[m]	AREAm	31,500	D
Depth of harbour	[m]	DEPTHch	2.3 (1.4 - 2.9)	D
Water quality				
Temperature	^{O}C	TEMP	12.5	D
Salinity	$^{O}/oo$	SALINITY	14.5	D
Particular organic carbon	[g.m^{-3}]	POC	1.44	D
pH	[-]	pH	7	D
Hydrology				
Tidal period	[h]	Ttidal	?	D
Tidal height	[m]	HEIGHTtidal	0.6	D
Water exchange	[m^{3}.m^{-2}.d^{-1}]	RATEwater	0.6	
Output:				
Initial concentration in sea water	[g.m^{-3}]	$Clocal\_initial_{water}$		O
Calculation:				
Mass balance calculations.				

In the report from Madsen et al. (1999) the processes taken into account for the calculations are described like (bio)degradation, sorption to suspended matter, resuspension and sedimentation. The calculations themselves are however not described in the report.

4.3.5 Freshwater marinas

In this section a short description of the “Swiss marina” scenario using the MAM-PEC-model is given. As no freshwater model was available, the Swiss Agency for Environment, Forests and Landscape adapted the MAM-PEC model to freshwater marinas to carry out risk assessments for the notification of new antifouling products. In future it might be useful to develop a more adapted freshwater model.

In the tables 4.42 and 4.43 the default values and model calculations for the “marina scenario” are described. To calculate the emission load (table 4.42) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 4.42 Emission scenario for calculating the releases from antifouling biocides used in antifouling products with the Swiss scenario using MAM-PEC

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of pleasure boats: - Cat 1	[m]	Cat 1	0-10	D
Number of ships at berth at any time of the day: - Cat 1	[-]	$N_{ships,berth}$	75	D
Average surface area per ship for cat: - Cat 1	[m^2]	$AREA_{ship}$	10	D
Application factor and leaching rate				
Application factor of the antifouling product	[-]	Fappl	0.5[2)]	D
Leaching rate[1)]	[g.m^{-2}.d^{-1}]	kleach		S
Output:				
Total emission	[g.d^{-1}]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 0\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;

2) The application factor was determined for booster biocides.

Compared with the default scenario of MAM-PEC changes are introduced in the length classes and the wet surface areas of the ships.

In table 4.43 the default values necessary for the calculation of the dissolved biocide concentration, the total aqueous concentration and the concentration on particulate matter are described. The user may decide to use a dilution factor to predict the concentration in an adjacent river or great lake.

Table 4.43 Swiss marina scenario using MAM-PEC for calculating the concentration of antifouling biocides in fresh water

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Length	[m]	LENGTHm	50	D
Width	[m]	WIDTHm	100	D
Depth of harbour	[m]	DEPTHm	2	D
Harbour entrance width	[m]	WIDTHent	10	D
Harbour entrance depth	[m]	DEPTHent	2	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[$g.m^{-3}$]	Csilt	35	D
Temperature	^{O}C	TEMP	15	D
Salinity	$^{O}/oo$	SALINITY	0	D
Particular organic carbon	[$g.m^{-3}$]	POC	1.0	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.4	D
Tidal height	[m]	HEIGHTtidal	0.1	D
Tidal current	[$m.s^{-1}$]	CURRENTtid	0	D
Density difference	[$kg.m^{-3}$]	RHOdiff	0	D
Flow of river flushing into harbour	[$m^3.s^{-1}$]	FLOWharbour	0	D
Density difference of flush	[$kg.m^{-3}$]	RHOdiff,flush	0	D
Output:				
The average, median, minimum, 95-percentile, and maximum concentrations for:				
The dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[$g.m^{-3}$]	$Clocal\_initial_{water,diss}$		O
The total aqueous concentration (including fraction bound to particulate matter)	[$g.m^{-3}$]	$Clocal\_initial_{water,tot}$		O
The concentration on particulate matter	[$g.kg^{-1}$]	$Clocal\_initial_{part.}$		O
Calculation:				
Calculations with the MAM-PEC model[1)]				

1) Due to the complexity of the model calculation of the concentration in water and particulate matter, the calculations are not described in this document.

The concentration in water for the "Swiss marina" scenario is calculated by the same methods as for the default "marina" scenario of MAM-PEC.

4.3.6 Advantages and limitations for MAM-PEC, REMA and USES

In this section the advantages and limitations of the models REMA, MAM-PEC and USES are described. These models each include one or more of the existing emission scenarios for the emissions of antifoulants on ship hulls during service life as described in the sections above (section 4.3.1 up to 4.3.5).

USES

USES is virtually the same model as EUSES which is used in the risk characterisation of existing chemicals, new chemicals, pesticides and biocides in the Netherlands (by the Dutch authority and CTB).

<u>Advantages</u>

The model is highly generic, and can be easily adapted by changing the harbour dimensions, the advection time and the shipping characteristics.
Next to this the USES model is simple to use for inexperienced users. A manual is available.

<u>Limitations</u>

The disadvantage of USES is that the model is of limited realism because the receiving environmental compartment is represented by a 1-dimensional box. As the model is a highly simplified representation of reality the uncertainty of the calculation results is expected to be high. The only processes included in the model are the emission of the chemical from the boat hulls to water followed by an immediate distribution to water and suspended matter.

USES does not include the marine environment. The concentration of a chemical in the water is calculated for a general aquatic environment. The model is not able to take into account the complex hydrodynamic conditions and the water characteristics of a marine environment. The only parameter in USES that is used to describe hydrodynamics is the advection time.

The choice of the default values of the model parameters included in the USES model is not documented.

MAM-PEC (version 1.4)

<u>Advantages</u>

The MAM-PEC-model is developed for calculation of PECs of antifouling substances and includes emission, hydrology and chemical fate and behaviour. The hydrology is modelled in a separate hydrodynamic module (SILTHAR) that includes tidal exchange, horizontal flows in the harbour entrance and vertical circulation currents in the harbour. In this respect, it can be regarded as realistic. MAM-PEC is based on a concentration model, which makes it suitable for inorganic and organic substances.

The MAM-PEC model is a generic model. It includes scenarios for typical environments based on real situations. As the hydrology is modelled in an independent program, changing the characteristics of the receiving environment is possible because water exchange mechanisms will be adapted accordingly.

The sources of the default parameters for the typical scenarios included in the model are well described and documented, except for the estuarine harbour.

Next to this the model is easy to use and it’s possible for the user to create new scenarios. The user has access to all parameters used in the model. Documentation is provided with respect to user guidance.

Limitations
A sensitivity or uncertainty analysis has not been performed.

The multimedia part of the environmental modelling of MAM-PEC is not fully compatible with the EU-TGD risk assessment guidelines.

REMA
It is known that REMA slightly over estimates the concentrations in the surface water. This may be an advantage or a limitation.

Advantages
In the REMA model the distribution of the antifouling chemical in the receiving environmental compartments is calculated using generally accepted methods such as QWASI modelling. The REMA model provides the possibility to calculate concentrations not only in the marinas but also in the adjecant estuaries. The scenarios in the REMA-model are based on real situations. In this respect, it can be regarded as realistic.

Limitations
The fact that the REMA model is very specific (scenarios based on real situations) also has a disadvantage. The hydrology parameters are part of the scenarios and changing the scenarios with respect to dimensions of environmental compartments is therefore not recommended. The use of the REMA model is therefore restricted to the described typical estuary environments.

The origin of the default values used in the model is not fully documented. However, they are based on real data derived through measurement or research.

REMA is based on a fugacity model, which in principle makes it less suitable for inorganic substances.

A sensitivity analysis is not performed. However leaching rate, partition coefficients and estuarine water flows are identified as critical input parameters.
REMA is not as user friendly as MAM-PEC or USES. REMA stores the data in Access files but they are password protected and not reached by the user of the model. It’s neither possible to change all parameters that are used in the model. The program has a help-function. The source code can be made available to users who wish to develop the model further. However, amending the parameters will invalidate the model.

4.4 Removal

The removal of the antifouling product on a ship or boat hull may take place by professionals as well as non-professionals. Existing emission scenarios are not available for the removal of the paint layer from ship and boat hulls. Because, as for application, the process of removal of antifouling paint is considered important, new environmental emission scenarios with respect to removal of antifouling paint from ship and boat hulls were developed within this project.

For the development of the scenarios the same approach was followed as for the application of paint (see section 4.2) and the used default values in the scenarios were also mainly derived from the Safinah report (Safinah 2004). Scenarios are built for:

Maintenance and repair
- Commercial ships → professional;
- Pleasure craft → professional;
  → non-professional.

The newly developed environmental emission scenarios with respect to the application of antifouling paint on ship hulls are presented in sections 4.4.1 and 4.4.2.

To explain the developed emission scenarios for application several general notes to the scenarios were included in section 4.2. These notes also apply to the removal of the antifouling paint from the ship hull. Amongst others it was explained that the default values included in the scenarios are not firm values, but the best available to the OECD Working Group. If more realistic values are available from practice or statistics these values should be used when performing risk assessment.

Next to this it was described that for the amount of antifouling product emitted to the environment (expressed in emission factors) in general only the potential emission is known from Safinah 2004. “Potential” emission means that no (or at least not all) control measures were taken into account. In absence of other data these potential emission factors are used as (worst case) default values. The emission factors may thus be lower if control measures are used.

Finally several important input and output values (of which the explanations also apply to the scenarios for removal) for the developed emission scenarios were discussed. The default values for the scenarios for paint removal are mainly equal to those for application during maintenance and repair. For example the amount of ships treated is equal for both scenarios because the application and removal of paint from commercial during M&R occurs at the same shipyard. Compared to the scenario for application 3 additional fractions are added:
- The fraction excess paint applied;
- The fraction of the paint that is to be removed from the ships hull;
- The fraction of a.i. remained in the old paint.

The fraction excess paint applied: The theoretical coverage of the paint is the volume of paint that is theoretically needed to paint a certain area of the ship hull. The theoretical coverage of the paint does not take into account excess paint applied on the hull. The application of excess paint on the hull can be caused by paint overlap during the application process, the subsequent coating of join up seams and butts after the coating and assemblage of the separate hull blocks (see also section 4.2.1), etc. The theoretical paint demand and excess paint applied (expressed in a "fraction excess paint applied") together form the total amount of paint applied per ship. The total amount of paint applied per ship is important to know for the removal scenarios. By using the total amount of paint it is possible to determine what amount will be removed during maintenance and repair. In this document the excess paint applied is not relevant for the application scenarios. The emission fractions used are based on the theoretical amount of paint applied per ship.

The fraction of the paint that is to be removed from the ships hull: This fraction depends on the removal method. A distinction is made between paint removed by high pressure water washing (HPW) and paint removed by abrasion. When abrasion is used an additional distinction can be made between reblasting (abrasion of the entire ship hull area) and spot blasting (abrasion of small parts of the ship hull that are in bad condition).

Fraction of a.i. remained 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 layer that is to be removed from the hull.

More specific notes and explanations are added to the corresponding scenarios.

4.4.1 Commercial ships

After the ship is taken out off the water for maintenance and repair the underwater hull is cleaned of any fouling products, generally by a variety of possible methods:

- High pressure water washing (HPWW) 3,000 psi usually removing 30-50 microns of leached layer. This is usually an open system;
- Ultra high-pressure water blasting (UHP), which can be up to 36,000 psi. This generally removes the entire coating system, back to bare metal if required. This can be either an open or a closed system;
- Slurry blasting, a mix of water and abrasive media, which will also remove the complete scheme back to bare metal. This is generally an open system;
- Dry abrasive blasting using a variety of blast media. This is predominantly an open system, although closed systems are becoming more common.

The method of surface preparation adopted depends on the ship repair yard and the ship owners' needs as well the contractor used (some contractors have patented proprietary technologies).

HP washing will remove only the leached layer. Intact paint will remain on the hull. 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. in the paint.

When abrading takes place the exhausted paint layer (leached layer) is first removed by high pressure water washing. After that an additional layer of paint is removed using abrasion techniques. In total 30% of the old paint film is removed. This 30% consist of the leached layer that is removed by washing (20% with a fraction of 0.05 of the original concentration of a.i. in the paint) and an additional layer which is removed by abrasion that represents 10% of the paint film applied and contains 30% (expert judgement CEPE) of the original concentration of of a.i. the paint.

Considering the the text above the two following scenarios were determined for the removal of paint during M&R of ships in an average OECD shipyard:

- *Realistic worst case*: Twenty (expert judgement: considered as a realistic value by CEPE) commercial ships are treated per year. The paint is removed in one day in an exposed floating dock or marine lift (in the open air, on a hard standing area). After the hull is washed the paint is removed by reblasting (a ship is normally treated by spot blasting after which new paint is applied on top of the old paint. But after a certain time period the entire ship hull needs to be reblasted because of the layers of paint that accumulate on the hull during spot blasting and repainting the hull). Depending on the control measurements of the yard the potential emission then either goes to surface water or is disposed of as waste or a combination of these two options (wash water can be treated/filtered on the yard before discharge or disposal). This possibility is included in the scenario. For the realistic worst case concentration during the emission period reblasting should be considered. But for the calculation of the yearly average concentration the ratio of spot blasting/reblasting is important. According to expert judgement of CEPE spot blasting and reblasting occurs in a ratio 10:1;
- *Typical case*: Twenty commercial ships are treated per year. The paint is removed in one day in a graving dock (in the open air, on a hard standing area). The paint is removed by high pressure water washing (HPW). As for the realistic worst case scenario the potential emission either goes to surface water or is disposed of as waste or a combination of these two options. This possibility is included in the scenario. The calculation of the yearly average will be equal for both realistic worst case and typical case, because both spotblasting and reblasting may occur in the same shipyard.

According to the Safinah report for both scenarios the potential emissions end up in the surface water (as for application). Therefore the fraction to soil in the scenario as described in table 4.44 is zero.

Table 4.44 Removal of the paint layer in an average OECD shipyard

Variable/parameter	Unit	Symbol	Value for realistic worst case	Value for typical case	S/D/O/P
Input:					
The removal period	[d]	Tremoval	1[1)]	1[1)]	D
Number of boats treated per removal period	[-]	Nboat	1 (as for application)	1 (as for application)	D
The average hull surface of a typical OECD ship	[m^2]	$AREA_{ship}$	EU/US: 2,500 Asia 7,963[2)]	EU/US: 2,500 Asia 7,963[2)]	D
Theoretical coverage of the paint	[$m^2.l^{-1}$]	COVERAGE			S
Number of coats applied on the hull	[-]	Ncoats	2	2	D
Fraction excess paint applied[3)]	[-]	Fexcess	0.20[4)]	0.20	D
Fraction of the paint that is to be removed from the ships hull by HPW (exhausted paint)	[-]	Fwashing	0.20	0.20	D
Fraction of the paint that is to be removed from the ships hull by abrasion	[-]	Fabrasion	Reblasting[5)]: 0.10	Spot blasting[5)]: 0.005	D
Ratio reblasting/spot blasting[7)]	[-]	$RATIO_{blasting}$	1/10	1/10	
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 HPW	[-]	$Fa.i._{exhpaint}$	0.05[1)]	0.05[1)]	D
Fraction of a.i. remained in old paint removed by abrasion	[-]	$Fa.i._{old\ paint}$	0.30[1)]	0.30[1)]	D
Fraction to surface water[8)]	[-]	F_{water}	Max. 1	Max. 1	D
Fraction to soil	[-]	F_{soil}	0	0	D
Output :					
The total amount of paint applied per ship[9)]	[l]	$Vpaint_{total}$			O
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$			O
Intermediate calculation:					
Vpaint = Ncoats * ($AREA_{ship}$ / COVERAGE) * (1+Fexcess)					
End calculations:					
$Elocal_{water}$ = ($Vpaint_{total}$ * Nboat * Ca.i. * (Fwashing * $Fa.i._{exh\ paint}$ + Fabrasion * $Fa.i._{old\ paint}$) * F_{water}) / Tremoval Emission load for the calculation of the yearly average: $Elocal_{water}$ = ($Vpaint_{total}$ * Nboat * Ca.i. * F_{water} * (Fwashing * $Fa.i._{exh\ paint}$ + Fabrasion_reblasting * $RATIO_{blasting}$ * $Fa.i._{old\ paint}$ + Fabrasion_spot blasting * $Fa.i._{old\ paint}$ * (1-$RATIO_{blasting}$))) / Tremoval					

1) Expert judgement CEPE;
2) Note that all other values are based on the European/US situation;
3) The theoretical paint demand is the amount of paint that is theoretically needed to paint the entire ship hull. The theoretical paint demand does not contain the excess paint applied on the hull due to overlap during the application process, the subsequent coating of join up seams and butts, etc. The theoretical paint demand and the excess paint together form the total amount of paint that is applied on the ships hull. This is important for the calculation of the amount of a.i. remained on the ships hull;

4) A fraction of 0.20 is the worst case value for the application of excess paint during M&R;
5) At reblasting the top layer of the old paint is removed from the entire ship hull, at spot blasting paint is removed only from parts of the hull;
6) Used for the calculation of the concentration during the emission period;
7) Expert judgement CEPE. Because spot blasting as well as reblasting occurs at the same shipyards, for the calculation of the yearly average concentration both spot blasting and reblasting has to be taken into account. Spot blasting removes paint from 5% of the hull area whereas reblasting removes paint from the total hull area (5% of 0.10 = 0.005);
8) Depending on the control measurements of the ship yard the emission up to a maximum of 100% either goes to surface water or to waste or a combination of these two;
9) Theoretical amount of paint + excess paint.

The emission load finally ends up in a river or a harbour. For the calculation of concentrations in a river reference is made to general environmental exposure assessment guidelines such as the EU-TGD (ECB, 2003). Individual countries have to decide on the river dimensions and waterflow. For the emission to a harbour the dimensions of the recommended commercial harbour for service life of antifouling paints are used.

Table 4.45 Calculation of the environmental concentrations for removal of the paint layer during M&R of commercial ships in an average OECD shipyard (point source in harbour or river) for both realistic worst and typical case

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
The removal frequency per year[1)]	[-]	Tfreq	20[2)]	D
Length of the harbour	[m]	LENGTHch	5,000	D
Width of the harbour	[m]	WIDTHch	1,000	D
Depth of the harbour	[m]	DEPTHch	15	D
Total emission to water	[$g.d^{-1}$]	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in surface water	[$g.m^{-3}$]	$Clocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB 2003).				

1) The amount of removal periods per year;
2) Expert judgement CEPE.

4.4.2 Pleasure crafts

Repair procedures are fairly consistent and broadly involve the transfer of the boat from water to land using a variety of means:

- Boat lift;
- Railway;
- Crane.

Once ashore the underwater hull is then cleaned using a HP water wash (3,000psi), typically of the type used on private cars. At better marinas, this is done in a dedicated open-air area, with good drainage that contains the run off water and the solids removed into containment for subsequent disposal as hazardous waste.

Once the hull is washed down the boat is moved to its storage or repair area and the hull prepared for paint application. In the USA abrading of the hull is very popular, while in Europe, application of the new antifouling is done directly onto the existing antifouling. The work can be carried out in a variety of environments, indoor, outdoor, hard standing, compacted ground and in some cases earth.

Thus the following locations and scope can be defined:

Table 4.46

Location	Typical scope of work
On lifting from water	HP Water wash of hull to remove fouling and clean the surface. All facilities are in the open air, but some have contained drainage systems and filters as well as sumps to collect solid waste. For the worst case it can be assumed that all run off water and solids find their way back to the marina water.
On storage or repair area in marina	Here the hull is prepared for coating. In the USA abrading of the hull takes place, before additional coats are applied. Can take place outside, with some shrouding to afford temporary protection from over spray. The ground can vary from hard standing to compacted earth

Source: Safinah (2004)

The sources of emissions during M&R of pleasure craft are preliminary over-spray (application) and run off water from the washing down of the hull (removal).

HP washing will remove only the leached layer. Intact paint will remain on the hull. 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. in the paint.

When abrading takes place the exhausted paint layer (leached layer) is first removed by high pressure water washing. After that an additional layer of paint is removed using abrasion techniques. In total 30% of the old paint film is removed. This 30% consist of the leached layer that is removed by washing (20% with a fraction of 0.05 of the original concentration of a.i. in the paint) and an additional layer which is removed by abrasion that represents 10% of the paint film applied and contains 30% (expert judgement CEPE) of the original concentration of a.i. the paint.

Emission scenarios are determined for the removal of paint during professional and non-professional M&R.

Professional

For the removal of paint from pleasure craft during professional M&R in OECD boatyards the two following scenarios were determined:

Realistic worst case (US): As for application during M&R fifty pleasure boats (>7.5 meter) are treated per year in a repair shop at a boat yard (hard standing area or compacted earth). According to Safinah boats < 7.5 meter are mainly repaired by non-professionals. Therefore it is assumed that professional M&R is mainly carried out on boats with a length above 7.5 meter. The removal of the paint layer is done by HPW followed by abrasion and takes place almost continuously during 6 months.

Typical case (EU): As for application during M&R fifty pleasure boats (>7.5 meter) are treated per year in a repair shop at a boat yard (hard standing area). The removal of the paint layer is done by HPW only and takes place almost continuously during 6 months.

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 4.47 is zero.

Table 4.47 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;
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 (see also section 4.4.2);
4) Depending on the control measurements of the boatyard the emission goes to soil, surface water, or a STP or a mixture between these 3 options.

Table 4.48 Calculation of the local intial environmental concentrations in soil and surface water for professional removal of the paint layer during M&R of pleasure craft in an average OECD boatyard for both realistic worst and typical case

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
Soil				
The removal interval[1)]	[month]	Tint	6	D
Length of the receiving soil compartment[2)]	[m]	LENGTH	12.5	D
Width of the receiving soil compartment	[m]	WIDTH	5.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[3)]	D
Soil density (dry weight)	[$kg.m^{-3}$]	$RHOsoil_{dw}$	1,504[4)]	
Total emission to soil	[$g.d^{-1}$]	$Elocal_{soil}$		O
Surface water				
Length	[m]	LENGTHm	141.5	D
Width	[m]	WIDTHm	141.5	D
Depth of harbour	[m]	DEPTHm	4	D
Total emission to surface water	[$g.d^{-1}$]	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in soil	[$g.kg^{-1}$]	$PEClocal_{soil}$		O
Predicted environmental concentration in surface water	[$g.m^{-3}$]	$PEClocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

- Time period in which removal of paint does not occur;
- The weighted average boat length of boats > 7.5 m is 10.36 m. A boat of 10.5 m length and 3.5 m width is assumed. For the determination of the surface of the receiving environmental compartment (compacted earth for the realistic worst case scenario) a “walking path” around the boat (width: 1 m) for the applier of the paint is assumed;
- In line with the environmental emission scenario of the OECD for Wood preservatives;
- Based on EU-TGD (ECB, 2003) (wet weight is 1700 $kg.m^{-3}$).

<u>Non-professional</u>

It is assumed that non-professionals do not (or not often) work in semi-closed or closed environments. For the removal of paint from pleasure craft during non-professional M&R in OECD marinas the following scenarios were determined:

Realistic worst case:
Three hundred and fifty pleasure boats (<7.5 meter) are treated per year on lifting from the marina in the open air on compacted earth (washing area). It is also possible that non-professional removal takes place on a hard standing area. The potential emission then goes (partially) to waste water. This possibility is included in the scenario. The removal of the paint takes place by HPW only and occurs almost continuously during 3 months.

Typical case: In Europe hulls are most commonly washed only and then repainted. In the USA there is a higher proportion of abrading carried out. After the boat is washed down it is moved to an other area for the removal of paint by abrasion (and finally the application of new paint). Therefore in this scenario only the abrasion of the boat hull is considered. As for non-professional application the abrasion of the 350 boats does not necessarily happen at the same area. For example boats can be taken home for application or painted in storage area. Therefore it is assumed that only 5 boats are abraded on the same spot per painting period (based on Finnish data, in Finland typically 1-5 boats are treated non-professionally on the same area).

According to the Safinah report and when looking at the determined scenarios for both scenarios the potential emissions will end up in the soil or in waste water. Therefore the fraction to surface water in the scenario as described in table 4.49 is zero.

Table 4.49 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;

4) Depending on the control measurements of the boatyard the emission goes to soil, surface water or a STP or a mixture between these 3 options;
5) 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 treat 5 boats. The remaining 9 months of the year removal does not occur.

Table 4.50 Calculation of the environmental concentrations in soil and surface water for non-professional removal of the paint layer in an average OECD boatyard/marina (see M&R) for both realistic worst and typical case

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input:				
Soil				
The removal interval[1)]	[month^{-1}]	Tint	9	D
The removal frequency	[-]	Tfreq	5	D
Length of the receiving soil compartment[2)]	[m]	LENGTH	9.5	D
Width of the receiving soil compartment	[m]	WIDTH	4.5	D
Depth of the receiving soil compartment	[m]	DEPTH	0.1[3)]	D
Soil density (dry weight)	[kg.m^{-3}]	$RHOsoil_{dw}$	1,504[4)]	
Total emission to soil	[g.d^{-1}]	$Elocal_{soil}$		O
Surface water				
Length	[m]	LENGTHm	141.5	D
Width	[m]	WIDTHm	141.5	D
Depth of harbour	[m]	DEPTHm	4	D
Total emission to surface water	[g.d^{-1}]	$Elocal_{water}$		O
Output :				
Predicted environmental concentration in soil	[g.kg^{-1}]	$PEClocal_{soil}$		O
Predicted environmental concentration in surface water	[g.kg^{-1}]	$PEClocal_{water}$		O
End calculations:				
For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account as well as the calculation of the total concentration (including suspended matter) reference is made to documents such as the EU-TGD (ECB, 2003).				

1) Time period in which removal of paint does not occur;
2) A boat of 7.5 m length and 2.5 m width is assumed. For the determination of the surface of the receiving soil compartment a “walking path” around the boat for the applier of the paint is assumed. It was estimated that this path is 1 meter wide;
3) In line with the environmental emission scenario of the OECD for Wood Preservatives;
4) Based on EU-TGD (ECB, 2003) (wet weight is 1700 kg.m^{-3}).

4.5 Summary of the existing environmental emission scenarios

Table 4.51 presents a summary of the available scenarios for ship hulls.

Table 4.51 Summary of the available scenarios for ship hulls

Application	Service life	Removal
Newly developed scenarios for: • New building commercial ships; • New building pleasure craft (professional and non-professional); • M&R commercial ships; • M&R pleasure craft (professional and non-professional).	Existing scenarios: • Open sea: 1 scenario; • Shipping lane: 3 scenarios; • Rivers, canals, streams: Not available; • Commercial harbour: 3 scenarios; • Estuarine and coastal marinas: 5 scenarios; • Marinas in lakes: 1 scenario; • Ships attached to buoys in lakes: Not available; • Ships attached to buoys near coastline: Not available; • Natural harbours: Not available.	Newly developed scenarios for: • M&R commercial ships; • M&R pleasure craft (professional and non-professional).

5 EXISTING EMISSION SCENARIOS FOR AQUACULTURE USE

5.1 Introduction

In this chapter existing emission scenarios to estimate environmental concentrations of antifouling biocides used in aquaculture use are described. Emission scenarios are described - if available - for application, service life and removal. The chapter ends with an overview of existing emission scenarios.

5.2 Application

No existing environmental emission scenarios for the application of antifoulants on fishnets, crab and lobster pots are available.

5.3 Service life

Under contract of the UK-HSE work was undertaken to modify REMA for the use of antifouling products in fish farming (Penney, 2003). This version is called td-REMA: time-dependent REMA where the modelled environment is the one of REMA with four standard estuaries where the first three equal the dimensions of a sea loch. The marinas are set to a negligibly small size.
A total mass of antifouling biocide which is applied to a net and the number of nets per segment are input parameters for estimating the emission. The antifouling biocide is released either at a constant rate, a pulse or exponentially. The model calculates the concentration of the antifouling biocide in time for the water and sediment compartment. Example calculations were carried out for two Scottish sea lochs: a small and fast exchanging loch with little run off and a large and slowly exchanging loch with a large freshwater run off. This work highlighted that a sensitivity analysis still needed to be conducted and the model still needed to be refined to set up specific UK scenarios.
Two issues need more attention according to Penney (2003):

- The proportion of the antifouling biocide which is leached and becomes bound to farm waste. This influences the fate of the antifouling biocide as td-REMA assumes that the antifouling biocide is for 100% released to the water column;
- The influence of stratification in lochs on the sensitivity to vertical mixing.

Due to staff changes and changes in priorities, this work has not been continued.

No existing environmental emission scenarios for the service life of antifoulants on crab and lobster pots are available.

5.4 Removal

No existing environmental emission scenarios for the removal of antifoulants from fishnets, crab and lobster pots are available.

5.5 Summary of the existing environmental emission scenarios

Table 5.1 presents a summary of the available scenarios for aquaculture use.

Table 5.1 Summary of the available scenarios for aquaculture use

Application	Service life	Removal
Not available	For nets used in fish farming a scenario was under development (UK) but has not been continued.	Not available

6 COMPARISON AND SELECTION OF AVAILABLE ENVIRONMENTAL EMISSION SCENARIOS FOR SHIP HULLS

6.1 Introduction

In chapters 4 and 5.5 the available scenarios are described for application, service life and removal of antifoulants on ship hulls and aquaculture equipment. For aquaculture use no scenarios are available. Therefore aquaculture use is not included in this chapter.

The scenarios for application and removal of antifoulants from ship hulls are newly developed within this project. For service life the following scenarios with calculation models already existed:

- 1 scenario for open sea;
- 3 scenarios for shipping lane;
- 3 scenarios for commercial harbour;
- 5 scenarios for estuarine and coastal marinas;
- 1 scenario for marinas in lakes (fresh water).

In this chapter (sections 6.2, 6.3 and 6.4) the existing environmental emission scenarios for respectively a shipping lane, a commercial harbour and a marina are compared to obtain a harmonised emission scenario for each of these three environments. The comparison is done on a qualitative and quantitative basis where default values (like shipping characteristics and dimensions and hydrology of the harbour, shipping lane or marina) are compared.

In this report the emission up to the primary receiving compartments is considered. Calculations of emissions to secondary environmental compartments are not discussed, as this is outside the scope of the project. Therefore the comparison does not take into account the water and sediment characteristics (e.g. pH or salinity of the water or fraction organic carbon in suspended matter or sediment).

When a harbour scenario is available, the use of an open sea scenario and a shipping lane scenario may seem superfluous. The concentrations of an antifoulant leached in these environments will always be highest in the harbour, because of the high concentration of ships per m^3 water. But scenarios for open sea and shipping lane may be useful to protect certain ecosystems or species. For example, an authority may decide to set lower protection goals for commercial harbours compared to the shipping lanes and the open sea.

As the existing open sea scenario from MAM-PEC is not that useful from a regulatory point of view, only the shipping lane scenario will be recommended.

It is recommended to have a scenario for marinas in lakes (fresh water) next to the scenarios for ships and boats in salt water, because antifouling products used in fresh water can be different from antifoulants used on ships in salt water. But, as for the open sea, also for marinas in lakes only one existing emission scenario is available: the “Swiss marina” (this scenario is modified from MAM-PEC by the Swiss BUWAL (2000), see also section 4.3.5). However, this scenario is assumed to be the worst case scenario for Switzerland and is very country specific. Between different countries a lot of difference exists in the characteristics of freshwater marinas. Therefore an attempt was made to collect additional data on freshwater marinas from the US and Canada From the US no data became available within this project. In Canada a survey was sent out to 59 marinas based in Ontario. The survey was sent to marina operators in the St. Lawrence seaway area, Ottawa River, Lake Ontario and Lake Erie areas. Only about 5 responses came back with information. These 5 marinas are very differently situated.

Summarizing, these results are considered insufficient to develop a realistic worst case “marina in lake scenario” for the OECD. However, authorities may decide to use the relatively simple Swiss marina scenario with parameters adapted to their local specific situation. Compared to a scenario for a marine environment the Swiss marina scenario is less complicated due to lack of tide etc.

No scenarios were available for the use of antifoulants on:
- Boats on rivers, canals, streams;
- Boats attached to buoys in lakes;
- Boats attached to buoys near coastline;
- Boats in natural harbours.

It was decided not to develop new scenarios for these use areas because of the limited relevance with respect to environmental releases. Next to this these use areas are only important for a relative small number of countries within the OECD and the water concentrations in most of these locations will be lower than in marinas (due to lower ratio of antifouled underwater boat surface area to water volume).

For the use on offshore structures such as drilling platforms (see section 1.2) no emission scenarios were developed in the present document. Reference is made to work carried out within the framework of the OSPAR Convention on the model CHARM (Chemical Hazard Assessment and Risk Management) (Thatcher et al., 2001). This model provides the amount of drilling platforms in a defined area and the dimensions and characteristics of the receiving environment. With the amount of antifoulant applied on a platform and the leaching rate of the active ingredient the environmental release can be estimated.

6.2 Shipping lane

In this section the following existing default scenarios for the shipping lane scenario are compared:
- MAM-PEC scenario;
- Finnish scenario (using the MAM-PEC model);
- Danish scenario.

6.2.1 Qualitative comparison

The Danish scenario is based on the Narrows of Kronprins Frederiks Bro in Roskilde Fjord. The choice for this location is partly because of the relative heavy traffic in these narrows. In fact the Danish scenario is not a 'real' shipping lane where many different ships are sailing. It is based on a relative narrow waterway where pleasure crafts are sailing. Both MAM-PEC and Finnish scenario assume a shipping route for commercial ships in the open sea. Therefore it is decided to exclude the Danish scenario from the comparison in this section.

The calculation methods for both MAM-PEC and the Finnish scenario are similar but different default values are used. The “shipping lane” scenario of MAM-PEC is based on the Eastern section of the main shipping lane along the Dutch coast. The choice for this area is based on the fact that this area has one of the highest shipping densities of the world. The Finnish “shipping lane” scenario is based on the Gulf of Finland and smaller ships are assumed to operate in the Finnish shipping lane compared with the MAM-PEC scenario.

6.2.2 Quantitative comparison

In table 6.1 the default values of MAM-PEC and the Finnish scenario for the shipping characteristics, the application factor and the dimensions of the shipping lane are presented. The shipping characteristics are expressed as total antifouled underwater area.

Table 6.1 Shipping lane: Default values MAM-PEC scenario and Finnish scenario

Variable/parameter	Unit	MAM-PEC	Finnish scenario
Total antifouled underwater area [1)]	[m^2]	34,353	385.4
Application factor of the antifouling product	[-]	1	max. 0.2
Dimensions shipping lane			
Length	[m]	20,000	20000
Width	[m]	10,000	10000
Depth	[m]	20	20
Hydrology			
Tidal period	[h]	12.41	12.41
Tidal height	[m]	0	0
Tidal current	[m.s^{-1}]	1	0.05

1) The antifouled underwater area of the Finnish scenario is corrected for the maximum application factor (max. 0.2), which is based on estimates that 80% of ships visiting Finland are not treated with antifouling products. The actual antifouled underwater area is therefore only 20% of the total immersed ship hull surface (the total immersed ship hull surface is 1927 m^2: The antifouled underwater area = 1927 * 0.2 = 385.4 m^2).

The dimensions for the shipping lane area are similar for both scenarios. Different in the two scenarios are the number and size of ships present, the tidal current and the default values for the application factor.

The length classification and wet surface area of ships were changed in the Finnish shipping lane compared to MAM-PEC default shipping lane. The total antifouled surface area is considerably smaller for the Finnish scenario. This is mainly caused by the fact that fewer ships are assumed to operate in Finnish shipping lanes and that only 20% of these ships are assumed to be treated with antifoulant. Next to this the maximum size of ships entering the Baltic Sea is restricted by the Danish straits. It is assumed that 20 cargo ships pass through the shipping lane daily. The passage of ships through the 20 km shipping lane is assumed to last on average 42 min (average speed of vessels is assumed to be about 15 knots).

To express the influences of the difference in tidal current and the antifouled underwater area between the two scenarios calculations with the MAM-PEC model are performed for a dummy substance (see table 33). The concentration in the water of the shipping lane is calculated. Degradation of the dummy substance is not taken into account, because that would make the calculation results to complex to compare.

In the first calculation (1) the concentration of the dummy substance in the water is calculated for the default shipping lane scenario of MAM-PEC. In calculation 2 the parameters for all values were kept the same except for the value for the tidal current. This value was reduced from 1 $m.s^{-1}$ (the value for the default MAM-PEC scenario) to 0.05 $m.s^{-1}$ (the value for the Finnish scenario).

The decrease in antifouled underwater area will have a linear effect on the average concentration of antifoulant in the water. To view this effect the total antifouled underwater area for the Finnish scenario was included in calculation 3.

Table 6.2 Shipping lane: Comparison of the MAM-PEC and Finnish scenarios.

Total concentration of the dummy substance in the water	Unit	1 Default shipping lane scenario of MAM-PEC with a tidal current of 1 $m.s^{-1}$	2 Default shipping lane scenario of MAM-PEC with a tidal current of 0.05 $m.s^{-1}$	3 Finnish scenario (tidal current of 0.05 $m.s^{-1}$)	Difference between		
					2 / 1	2 / 3	1 / 3
Maximum concentration	[$ug.l^{-1}$]	$4.93.10^{-4}$	$7,14.10^{-3}$	$8.01.10^{-5}$	14.5	89.1	6.2
95 % concentration	[$ug.l^{-1}$]	$4.51.10^{-4}$	$6,13.10^{-3}$	$6.88.10^{-5}$	13.6	89.1	6.6
Average concentration	[$ug.l^{-1}$]	$7.82.10^{-5}$	$1.54.10^{-3}$	$1.73.10^{-5}$	19.7	89.1	4.5
Median concentration	[$ug.l^{-1}$]	$9.82.10^{-5}$	$2,40.10^{-3}$	$2,69.10^{-5}$	24.4	89.1	3.7
Minimum concentration	[$ug.l^{-1}$]	$7.24.10^{-7}$	$5,74.10^{-4}$	$6.44.10^{-6}$	793	89.1	0.1

The decrease in tidal current with a factor 20 (calculation 2 compared with calculation 1) causes an almost linear increase of the average concentration of the dummy substance. The minimum concentration increases with a factor 790. This is caused by the fact that due to a larger refreshment rate in the default scenario of MAM-PEC a greater difference is found between maximum, average and minimum concentrations.

Due to the relative low value for the antifouled underwater area per m^3 water the concentrations calculated with the Finnish scenario (calculation 3) show a linear decrease with a factor 89 compared with the results of calculation 2.

Except for the minimum concentration the increase of concentrations for the Finnish scenario due to a lower tidal current is completely undone by the decrease of concentrations due to a considerably smaller value for the total antifouled area (see the comparison between calculation 3 and 1). Thus, without taking degradation into account, the average concentration for the MAM-PEC scenario is a factor 4.5 higher compared with the average concentration of the Finnish scenario.

6.2.3 Conclusion

The Danish scenario does not comply with the characteristics of a shipping lane (a busy shipping route in the open sea).
In comparison with the Finnish scenario the value for the average concentration of a dummy substance in the water calculated with the default MAM-PEC scenario is a factor 4.5 higher. Further the MAM-PEC scenario represents a shipping lane that is important for more (and larger) ships of many different countries compared with the Finnish shipping lane, representing a realistic worst case situation for the OECD. The scenario would lead to a worst case estimation of the environmental release when using the 95% concentration or the maximum concentration, as these concentrations will be found only in the direct vicinity of the ships hulls. Therefore it is recommended to use the MAM-PEC scenario in combination with the average concentration as a realistic worst case scenario for risk assessment.

Although it is not recommended here, individual countries may still decide to use the maximum or 95% concentration. Chapter 9 will go more deeply into the question whether to use an average, maximum or 95% concentration.

The low tidal current of the Finnish scenario is important for regions where tidal current is insignificant (e.g. the Baltic countries). For product registration in these regions specific scenarios may have to be developed. This may be realised by using other parameter settings for the recommended shipping lane scenario (e.g. use the hydrology settings of the Finnish scenario).

6.3 Commercial harbours

In this section the following existing default scenarios for the shipping lane scenario are compared:

- MAM-PEC commercial harbour scenario;
- Finnish scenario (using the MAM-PEC model);
- MAM-PEC estuarine harbour scenario.

6.3.1 Qualitative comparison

The “commercial harbour” scenario of MAM-PEC is based on the Rotterdam harbour in the Netherlands. Commercial harbours in Finland, and the ships visiting these harbours, are considerably smaller than those in Rotterdam. Therefore the “Finnish harbour” is significantly smaller compared to the commercial harbour of MAM-PEC. The “Finnish harbour” is assumed to be located in Helsinki and receives cargo traffic. Only 20% of these cargo ships are treated with antifouling products in Finland. The “estuarine harbour” scenario of MAM-PEC was added in MAM-PEC to be able to calculate anti-fouling biocide concentrations for smaller harbours, because harbours with a size close to that of Rotterdam harbour are not found in many other European countries.
The calculation methods for all three scenarios are similar, but there are differences in the default values used. These differences will be discussed in the following section.

6.3.2 Quantitative comparison

In table 6.3 the default values of the MAM-PEC and the Finnish scenarios for the shipping characteristics, the application factor, the leaching rate and the dimensions of the receiving environmental compartment (the harbour) are presented. Next to this the antifouled underwater area per m^2 and per m^3 water is calculated.

Table 6.3 Commercial harbour: Default values MAM-PEC scenarios and Finnish scenario

Variable/parameter	Unit	MAM-PEC commercial	MAM-PEC estuarine	Finnish scenario
Total antifouled underwater area 1)	[m^2]	511486 at berth 46908 moving	102362 at berth 8530 moving	1713 at berth
Application factor of the antifouling product	[-]	1	1	max. 0.2
Dimensions harbour				
Distance from mouth	[m]	2,000	1,000	444
Length	[m]	1,0000	5,000	444
Width	[m]	2,000	1,000	1,000
Depth of harbour	[m]	20	15	10
Harbour entrance width	[m]	5,000	2,500	1,000
Harbour entrance depth	[m]	20	10	10
Height dam harbour entr.	[m]	0	0	0
Width dam harbour entr.	[m]	0	0	0
Calculation surface area per m^2 and per m^3 water				
Antifouled underwater area per m^2 water	[m^2/m^2]	$2.56.10^{-2}$ at berth $2.35.10^{-3}$ moving $2.80.10^{-2}$ total	$2.05.10^{-2}$ at berth $1.71.10^{-3}$ moving $2.22.10^{-2}$ total	$3.86.10^{-3}$ at berth $3.86.10^{-3}$ total
Antifouled underwater area per m^3 water	[m^2/m^3]	$1.28.10^{-3}$ at berth $1.17.10^{-4}$ moving $1.40.10^{-3}$ total	$1.36.10^{-3}$ at berth $1.14.10^{-4}$ moving $1.47.10^{-3}$ total	$3.86.10^{-4}$ at berth $3.86.10^{-4}$ total
Hydrology				
Tidal period	[h]	12.41	12.41	12.41
Tidal height	[m]	1.5	1.5	0
River flow velocity	[$m.s^{-1}$]	1.5	1	0.1
Depth of river	[m]	10	10	10
Density difference	[$kg.m^{-3}$]	0.8	0.4	0
Flush in harbour	[$m.s^{-1}$]	0	0	0
Density difference of flush	[$kg.m^{-3}$]	0	0	0
Water exchange rate 2)	[$\%.tid^{-1}$]	64.77	80.35	2.84 3)

1) As for the shipping lane scenario the antifouled underwater area of the Finnish commercial harbour scenario is corrected for the maximum application factor (max. 0.2), which is based on estimates that 80% of ships visiting Finland are not treated with antifouling products. The actual antifouled underwater area is therefore only 20% of the total immersed ship hull surface (the total immersed ship hull surface is 8565 m^2: The antifouled underwater area = 8565 * 0.2 = 1713 m^2);
2) The percentage of the total volume of the harbour that is refreshed in a tidal period of 12.41 hours;
3) Not corrected for low tide conditions. The correction would increase the water exchange volume in the Finnish scenario by a factor of about 7 (see also section 4.3.3: Finnish commercial harbour scenario using MAM-PEC).

There is a large difference between the water exchange rate of the MAM-PEC scenarios on the one hand and the Finnish scenarios on the other hand.

In the exchange module of MAM-PEC the total water exchange volume is the sum of:
- The tidal prism (filling and emptying by the tide);
- The exchange volumes due to horizontal eddy generated in the harbour entrance by the passing main flow;
- The exchange volumes due to the vertical currents generated by density differences between the water inside and outside the harbour;
- And the extra water exchange due to a water discharge through the harbour to the sea (e.g. river flushing).

Harbour flush situations are not typical for Finland as there is (almost) no tide. As already described in section 4.3.3 " Finnish commercial harbour scenario using MAM-PEC ", according to a study performed by the Dutch Waterloopkundig Laboratorium and Delft Hydraulics (Baart, A. C. (2003)) under conditions of low tide, low flow and no density differences other (non-tidal) processes (e.g. changes of water level due to wind) become important. According to Baart, A. C. (2003) the value for the water exchange rate of the Finnish scenario has to be increased due to non-tidal water exchanges. The current version (1.4) of MAM-PEC does not yet include the described non-tidal processes. At this moment the Finnish Environment Institute (FEI) has corrected the water exchange rate due to other factors than tide for Finnish conditions. The corrections would increase the water exchange volume in the Finnish scenario by a factor of about 7. These corrections are included as notes in the Finnish scenario descriptions.

The total antifouled areas in the MAM-PEC estuarine harbour and the Finnish harbour respectively amount to 20% and 0.3% of the antifouled area in the MAM-PEC commercial harbour. The most important reasons for the difference in antifouled area between these harbours is that fewer ships are present in the estuarine and the Finnish harbours at any time of the day, and that smaller ships are present compared to the MAM-PEC commercial harbour. Furthermore, in the Finnish scenario it is assumed that only 20% of the ships present in the harbour are assumed to be treated with antifoulant. But because the dimensions of the estuarine and the Finnish harbours are smaller compared to the MAM-PEC commercial harbour, the differences in antifouled under-water area per m^2 and m^3 water are not that large, although the antifouled underwater area per m^2 and m^3 water is still considerably smaller for the Finnish scenario.

Another difference between both MAM-PEC scenarios and the Finnish scenario is the calculation of the number of ships in the harbour at any time of the day. For all three scenarios the number of ships present in the harbour at berth or moving at any time of the day is calculated with the following calculations:

$N_{ships.berth} = N_{visits} * T_{berth} / 365$

T_{berth}	:	average residence time for ships at berth;
$N_{ships.berth}$	:	number of ships present in the harbour at berth;
N_{visits}	:	total number of harbour visits per year per length category.

$N_{ships,moving} = N_{mov} * T_{manouvr} / 365$

$T_{manouvr}$	:	harbour manoeuvring time for arrival and depart;

$N_{ships,moving}$: number of ships moving in the harbour;
N_{mov} : total number of ship movements per year per length category in the harbour.

For MAM-PEC T_{berth} and $T_{manouvr}$ is respectively 3 days and 3 hours. The Finnish scenario uses only a T_{berth} which is set equal to 12 hours. This T_{berth} is actually a total time including $T_{manouvr}$, because the harbour is very small. Not much manoeuvring is necessary. The total amount of ships visiting the Finnish harbour may be relatively (per m^2) large compared to the MAM-PEC commercial harbour, but because of a much shorter residence time the total amount of ships in the harbour at any time of the day stays small.

To express the influence of the differences in hydrology, shipping characteristics and harbour dimensions between the three scenarios, calculations with the MAM-PEC model are performed for a dummy substance (see table 6.4). As for the comparison of the shipping lane scenarios the concentration in the water of the shipping lane is calculated and degradation of the dummy substance is not taken into account.

In calculation 1 the concentration of the dummy substance in the water is calculated for the default commercial harbour scenario of MAM-PEC. To be able to view the influence of a smaller water exchange (due to low tide etc.) in calculation 2 the values for all parameters were kept the same except for the hydrology data (e.g. tidal height). The default values for the hydrological parameters of the MAM-PEC commercial harbour were replaced by the default values of the Finnish hydrological situation.

To be able to compare the calculation results of the three scenarios in calculation 3 and 4 the total concentration of the dummy substance in the water was calculated for respectively the Finnish harbour and the MAM-PEC estuarine harbour.

Table 6.4 Commercial harbour: Comparison of the parameters used in MAM-PEC and the Finnish scenario.

Total concentration of the dummy substance in the water	1 Default commercial harbour scenario of MAM-PEC [μg.l^{-1}]	2 Default commercial harbour of MAM-PEC with hydrology of the Fin harbour [μg.l^{-1}]	3 Default Finnish harbour [μg.l^{-1}] 1)	4 Default estuarine harbour scenario of MAM-PEC [μg.l^{-1}]	Difference between			
					2 / 1	1 / 3	2 / 3	1 / 4
Maximum concentration	8.50.10^{-1}	2.49	9.54.10^{-2}	2.47.10^{-1}	2.93	8.91	26.1	3.44
95 % concentration	8.46.10^{-1}	2.29	9.52.10^{-2}	2.44.10^{-1}	2.71	8.89	24.1	3.47
Average concentration	2.71.10^{-1}	1.40	6.02.10^{-2}	8.53.10^{-2}	5.17	4.50	23.3	3.18
Median concentration	2.64.10^{-2}	1.46	5.74.10^{-2}	2.11.10^{-2}	55	0.46	25.5	1.25
Minimum concentration	3.83.10^{-3}	2.01.10^{-1}	1.46.10^{-2}	2.89.10^{-3}	52	0.26	13.8	1.33

1) Corrected for the maximum application factor (see also table 34).

Due to the changes in the hydrology of the harbour (calculation 2 compared with calculation 1) the average concentration of the dummy substance increases approximately with a factor 5. Due to the small water exchange rate in calculation 2 the differences in maximum and minimum concentrations are smaller compared to the concentrations in the default commercial harbour of MAM-PEC.

The effects of the changes in hydrology (calculation 2) are completely compensated by the decrease in antifouled underwater area in the default Finnish scenario (calculation 3). The decrease in antifouled underwater area is caused by the fact that fewer and smaller ships are present in the Finnish harbour at any time of the day. Next to this only 20% of these ships is assumed to be treated with an antifoulant (maximum application factor of 0.2). The value for the average concentration of the Finnish scenario is a factor 4.5 lower compared to the default commercial harbour of MAM-PEC. Even when the application factor of 0.2 is not included, the maximum and 95% concentrations of the Finnish scenario will be lower compared with these concentrations of the MAM-PEC commercial harbour. The average concentration will than be almost equal and the median and minimum concentrations will be higher.

The average concentration of the default estuarine harbour of MAM-PEC is approximately a factor 3 lower compared to the default commercial harbour of MAM-PEC.

6.3.3 Conclusion

The MAM-PEC commercial harbour scenario clearly represents a worst-case situation, which is mainly caused by the high amount of relatively large ships per m^3 water in the harbour. The MAM-PEC commercial harbour is based on one of the largest harbours in the world (Rotterdam harbour), whereas the MAM-PEC estuarine harbour is developed to represent smaller harbours in Europe. The MAM-PEC commercial harbour is probably not representative for all OECD countries. Harbours of the size of that of Rotterdam are not common in all countries. Because of a very low water exchange this also applies for the Finnish harbour.

The estuarine scenario is not representing the worst case situation. However, it's dimensions and number of ships present and moving is based on the Rotterdam harbour leading to a somewhat lower antifouled underwater area. Subsequently, average concentrations and 95% concentrations are only slightly lower.

Based on the information in the previous paragraph it is recommended to use the estuarine harbour in combination with the average concentration as a default PEC for risk assessment for the same reasons as the shipping lane. Also, it is recommended to gain more data on shipping characteristics and dimensions of commercial harbours in the OECD.

Despite of the fact that the estuarine harbour is recommended as the default scenario for risk assessment, it is important to notice that the low water exchange (due to low tide etc.) of the Finnish scenario is important for regions where tide is insignificant (e.g. the Baltic countries). For product registration in these regions specific scenarios may have to be developed (see also section 6.2.3). This may be realised by using other parameter settings for the recommended harbour scenario (e.g. use the hydrology settings of the Finnish scenario).

The purpose of the recommended harbour scenario is to perform a risk assessment for a harbour environment. However, individual countries may decide not to protect the harbour itself but only the adjacent waters. Reference is made to the EU-TGD for these kind of approaches.

6.4 Estuarine marinas

In this section the following existing default scenarios for the scenario “estuarine marina” are compared:

- MAM-PEC scenario;
- Finnish scenario (using the MAM-PEC model);
- the REMA scenarios;
- Danish scenario;
- USES scenario.

6.4.1 Qualitative comparison

Except for USES each of the marina scenarios is based on existing marinas:

- The scenario of MAM-PEC is based on a French Mediterranean marina in the Golfe Juan. The marina is an enclosed area situated directly at the coast. The marina may have additional flushing from a small river or urban drainage system discharging at the rear end of the harbour;
- The Finnish scenario is based on Finnish marinas in the Baltic Sea. The Finnish scenario is assumed to be located in a small, shallow and closed bay;
- The REMA scenarios are based on various existing UK marinas, harbours and estuaries. These cover a number of situations with estuaries of varying sizes and dynamics and marinas of different type (locked, open, pontooned);
- The Danish scenario is based on the pleasure craft harbour of Jyllinge, Denmark. This harbour was selected as a realistic worst case as the harbour has a large number of boats compared to the water volume of the harbour and a low water exchange;
- USES assumes a middle sized yacht basin and does not include the marine environment, but uses a general aquatic environment.

The REMA estuary is divided in different segments and it is assumed that each segment contains several pleasure crafts and larger ships. In the comparison these segments are not considered. Only the marinas are compared with the default marinas of the other four scenarios.

6.4.2 Quantitative comparison

In table 6.5 the default values of the various “marina” scenarios are presented. Next to this the antifouled underwater area per m^3 water is calculated.

Table 6.5 Default values "marina" scenarios

Variable/parameter	Unit	MAM-PEC	Finnish scenario	REMA [1]	USES	Danish scenario
Number of pleasure crafts at any time of the day	[-]	299	226 [2]	M1: 0, 67 or 300 [3] M2: 0, 140, 300 or 500 M3: 0 or 300	125 (yearly average) 250 (summer) 62.5 (winter)	400
Average ship lenghts	[m]	1-50	0-5 (7 m^2) 5-6 (11 m^2) 6-7 (16 m^2) 7-8 (19 m^2) 8-9 (23 m^2) 9-10 (26 m^2) 10-11 (29 m^2) 11-12 (30 m^2) 12-13 (30 m^2) >13 (32 m^2)	9.2	not available	not available
Average antifouled underwater area per ship	[m^2]	22.5[4]	19.8[5]	30.7[6]	5[7]	18[8]
Application factor of the antifouling product	[-]	1	max. 0.9	1	1	0.7
Total antifouled underwater area[9]	[m^2]	6,728 (yearly average)	4,036 (corresponds with an early summer situation)	M1: 0, 2057 or 9210 M2: 0, 4298, 9210 or 15,350 M3: 0 or 9210 (based on results of a survey carried out between April and July)	625 (yearly average) 1,250 (summer) 313 (winter)	5040 (yearly average)
Dimensions marina						
Length	[m]	400	420		-	-
Width	[m]	400	140		-	-
Surface marina	[m^2]	16,000 0	58800	M1 and M2: 20000 M3: 50,000	10,000	31,500
Depth of marina	[m]	3.5	2.2	4	2.5	2.3
Harbour entrance width	[m]	100	140	-	-	-
Harbour entrance depth	[m]	3.5	2.2	-	-	-
Height dam harbour entr.	[m]	0	0	-	-	-
Width dam harbour entr.	[m]	0	0	-	-	-

Variable/parameter	Unit	MAM-PEC	Finnish scenario	REMA [1)]	USES	Danish scenario
Calculation of the antifouled underwater area per m^3 water						
Antifouled underwater area per m^3 water	100 * [m^2/m^3]	1.2	3.1	M1: 0, 2.6 or 12 M2: 0, 5.4, 12 or 19 M3: 0 or 4.6	2.5 (yearly average)) 5.0 (summer) 1.3 (winter)	7.0
Hydrology						
Tidal period	[h]	12.41	12.41			
Tidal height	[m]	1.5	0			0.6
Tidal current	[$m.s^{-1}$]	1	0.01			
Density difference	[$kg.m^{-3}$]	0.1	0			
Flush in harbour	[$m.s^{-1}$]	0	0			
Density difference of flush	[$kg.m^{-3}$]	0	0			
Water flow half time (between segments and marinas)	[h]			Segment 1: 12-24 Segment 2: 12 Segment 3: 12-48		
Water exchange rate	[%.d^{-1}][10)]	84.1	3.9[11)]	Segment 1: 50-100 Segment 2: 100 Segment 3: 25-100	<1	26.1

1) Characteristics of the segments in the estuaries are not included;
2) Divided in different length categories. The percentage share of leisure boats was provided by the boat registers of the Finnish Boating Association and the Finnish Sailing Association with the calculation of CEPE;
3) M1, M2 and M3 = Marina 1, 2 or 3 within one of the four default estuaries of REMA;
4) Based on Bauer and Jakobson (1997) (50% of boat deck area) and data from the Golf Juan marina;
5) Calculation of the average surface areas are based on data provided by the boat registers of the Finnish Boating Association and the Finnish Sailing Association;
6) Based on a 1998 survey in the UK;
7) Based on the cover of antifouling paint (m^2 per m^3) and the average volume of paint used per yacht;
8) Based on the estimation of the Danish Sailing Association;
9) As for the shipping lane and commercial harbour scenarios the antifouled underwater areas of the Finnish and Danish marinas are corrected for the maximum application factor, based on estimates of a certain percentage of the boats not treated with antifouling products. The actual antifouled underwater area is therefore the total immersed ship hull surface multiplied with the application factor;
10) The percentage of the total volume of the marina that is refreshed in one day;
11) Not corrected for low tide conditions. The correction would increase the water exchange volume in the Finnish scenario by a factor of about 7 (see also section 4.3.3: Finnish commercial harbour scenario using MAM-PEC).

None of the scenarios takes the emission of antifouling biocides from pleasure crafts moving into account, as manoeuvring time in marinas is expected to be negligible to the time at berth.

The Danish and the Finnish scenarios assume a default application factor less than 1. For the Danish scenario an estimation is made by Hempel (1999) that 30-70% of pleasure boats is painted with an organic active substance. To establish a worst case situation, the choice was made for an application factor of 70%. In the Finnish scenario, it is considered that in early summer 90% of the boat places are occupied and that 90% of these boats have been treated with antifoulants. USES is the only scenario that takes different seasons into account. The assumption that pleasure craft are always in the marina will overestimate the total leaching of antifouling biocides is mentioned in the Danish scenario description.

The REMA marina has the highest antifouled underwater area / water ratio (0.19 $m^2.m^{-3}$) and can be regarded as the realistic worst case scenario. To investigate if this marina is representative for the OECD more data on marinas were searched for.

There is some information on 11 marinas located in Helsinki, Turku and Raiso in Finland (Koivisto, 2003). Four of these marinas have similar ratios boat places/water volume compared to this REMA marina. One marina (marina of Kaisaniemi) has even a higher ratio. However the antifouled underwater area of a Finnish boat is only 65% of the area of a typical UK boat. Therefore only the marina of Kaisaniemi is equal to the REMA marina.

More information on boat places in marinas was derived from the “Blue Flag” Campain in Germany for the year 2004 (see also section 2.3.2). The results are described in table 6.6.

Table 6.6 Number of boat places in marinas participating the Blue Flag.

Number of boat places	Percentage
<50	37.4%
51-100	37%
101-500	34%
500-1,000	3.3%
>1,000	1.6%

But because the water volumes for the corresponding marinas are not known the number of boat places as described in table 6.6 cannot be compared to the marinas of Kaisaniemi and REMA.

Because, as described earlier, more information is needed on “average” marinas in OECD countries and because the REMA-marina and the marina of Kaisaniemi are real existing marinas the choice for the characteristics of the REMA-marina is maintained.

It can be concluded that marinas with an antifouled underwater area / water ratio of 0.19 [$m^2.m^{-3}$] do occur and can be considered a realistic worst-case scenario. On the other hand it should be noted that more data are needed on aspects like the number of pleasure crafts present, the average antifouled underwater area per pleasure craft and the dimensions of the marina, because it is not clear whether the existing environmental emission scenarios are representative for “average” marinas in OECD countries. It is recommended to use a realistic worst case scenario: the REMA marina with an antifouled underwater area / water ratio of 0.19 [$m^2.m^{-3}$].

The calculation of the concentration in the water by the REMA model is very country specific. The MAM-PEC model has the advantage that it includes more detailed hydro-dynamic calculations by using the hydrodynamic model SILTHAR. Therefore it is proposed to use the hydrodynamic calculation method of MAM-PEC with the worst case shipping characteristics and marina dimensions of REMA. To be able to see what the influence is of changes in hydrology and harbour entrance width, several calculations are performed for a dummy substance (see table 6.7). Degradation of the dummy substance is again not taken into account (see also sections 6.2.2 and 6.3.2)

Table 6.7 Marinas: The influence of changes in hydrology and harbour entrance width.

Total concentration of the dummy substance in the water	**Unit**	**1** **REMA ship characteristics and marina dimensions calculated with the hydrology of MAM-PEC (harbour entrance width: 100 m)**	**2** **REMA ship characteristics and marina dimensions calculated with the hydrology of MAM-PEC (harbour entrance width: 50 m)**	**3** **REMA ship characteristics and marina dimensions calculated with the hydrology of MAM-PEC (harbour entrance width: 10 m)**	**4** **REMA ship characteristics and marina dimensions calculated with the hydrology of the Finnish marina (har-bour entrance width: 100 m)**
Maximum concentration	[ug.l^{-1}]	3.52.10^{-1}	3.62.10^{-1}	3.77.10^{-1}	2.14
95 % concentration	[ug.l^{-1}]	3.52.10^{-1}	3.62.10^{-1}	3.77.10^{-1}	2.14
Average concentration	[ug.l^{-1}]	1.66.10^{-1}	1.82.10^{-1}	2.05.10^{-1}	2.47.10^{-1}
Median concentration	[ug.l^{-1}]	1.34.10^{-1}	1,51.10^{-1}	1,72.10^{-1}	8.99.10^{-5}
Minimum concentration	[ug.l^{-1}]	2.74.10^{-2}	3,56.10^{-2}	6.00.10^{-2}	2.82.10^{-8}

In case of a smaller harbour entrance depth all concentrations approximately equally increase in value (calculations 1 to 3), but stay in the same order of magnitude. When using the default values for the hydrology of the Finnish marina (low water exchange) the difference between maximum and minimum concentrations increases.

6.4.3 Conclusion

It is recommended to use the hydrodynamic calculation method of MAM-PEC - as this includes the most detailed hydrodynamic modelling - with the worst case shipping characteristics and harbour dimensions of REMA.

All average concentrations in table 6.6 are in the same order of magnitude. Despite of the fact that both the MAM-PEC and the Finnish scenario use the hydronamic model SILTHAR, the default values for the hydrology of the MAM-PEC scenario are less country specific compared with the Finnish scenario (no tide). Therefore it is recommended to use the default hydrology values of the MAM-PEC marina.

In contrast to the REMA scenario in the MAM-PEC scenario a value for the "harbour entrance width" is included. To be able to calculate the concentrations in the water of a marina with dimensions derived from REMA, a value for this "harbour entrance width" has to be established. Because calculated concentrations in the water stay in the same order of magnitude when the values for harbour entrance width are varied (see table 6.6), and no information is available with respect to the average depth in OECD countries, it is proposed to use the original default value (100 m) of the MAM-PEC marina.

In the existing marina scenarios various (maximum) application factors were used. It was decided to include neither of these application factors in the recommended marina scenario, but to use a default application factor based on the estimate from the Safinah report (Safinah 2004) that 5% of the boats in OECD countries is not treated with an antifoulant. For boosters this may lead to an overestimation of the market share as this is for all boosters at the moment much lower than 95%. But according to representatives of industry a market share of 90% for a booster would be possible. To anticipate on future developments a maximum default value of 90% (0.90) is recommended. However, actual market data can be provided by the notifier leading to an adaptation of the value of 90%. If available real data on the market share should be used.

As described in section 6.4.2 the scenario that is recommended in this conclusion represents a worst case situation. The values for the surface area of the boat hull and the amount of ships per m^3 water from REMA are the highest of all existing marina scenarios. Furthermore, the amount of boats is based on a study carried out from April to July (high season) when the boats are launched after the winter season. As for commercial ships the maximum concentration calculated by this scenario will be found only in the direct vicinity of the boat places. Therefore it is recommended to use the average concentration instead of the maximum or 95% concentration as a default initial local PEC for risk assessment.

Summarizing, the default values for the recommended scenario (marina during high season) are:

- Number of pleasure crafts present at any time of the day: 500;
- Average antifouled underwater area: 30.7 m^2 (this was also concluded in section 2.3);
- General application factor: 0.95 (this value may be adapted on the basis of the market share)
- Application factor for booster biocides: 0.90 (this value may be adapted on the basis of the market share)

- Dimensions of marina: surface: 20,000 m^2 and depth: 4 m;
- Harbour entrance width: 100 m;
- Harbour entrance depth: 4m;
- Tidal period: 12.41 h;
- Tidal height: 1.5 m;
- Tidal current: 1 $m.s^{-1}$;
- Density difference: 0.1 $kg.m^{-3}$;
- Use of the average concentration as the initial concentration in risk assessments.

The purpose of the recommended marina scenario in this report is to perform a risk assessment for a marina environment. However, individual countries may decide not to protect the marina itself but only the adjacent waters. Therefore reference is made to REMA (calculates the concentrations of the antifoulant in the adjecant estuary) or the EU-TGD.

Within the OECD regions with lower and higher tide than 1.5 m exist. Variations in tidal heights have more effect on the antifoulant concentrations in a marina compared to the concentrations in a relative large commercial harbour. When performing a risk assessment it is important for countries in these regions to pay attention to the tidal heights in the specific country and if necessary adapt the default value of 1.5 m and other hydrology settings. It is recommended to assess the tidal variations within the OECD countries.

7 RECOMMENDED SCENARIOS FOR RISK ASSESSMENT

In the previous chapter environmental emission scenarios for the use of antifoulants were compared, harmonised and selected. This chapter consists of a summary of the recommended scenarios for antifoulants used on ship hulls. The input parameters and model calculations for the harmonised “service life scenarios” are described in tables. With respect to the newly developed scenarios for application and removal reference is made to the tables in chapter 4 which include the input parameters and calculation methods for these scenarios.

The purpose of the recommended scenarios is to serve as emission scenarios for use in risk assessments in notification and authorisation procedures in regulatory frameworks used in all OECD countries. However, individual countries may decide to modify the scenarios to local conditions (see remarks in chapter 9).

7.1 Application of paint on ship hulls

For the application of paint on ship hulls scenarios were developed within this project. A distinction was made between new building and maintenance and repair (M&R). It is recommended to use the following scenarios:

Table 7.1 Recommended scenarios for application of paint on ship and boat hulls

Scenarios	Section	Tables
New building	4.2.1	
Commercial ships		4.2 and 4.3
Pleasure craft, professional		4.5 and 4.6
Maintenance and repair (M&R)	4.2.2	
Commercial ships		4.7 and 4.8
Pleasure craft, professional		4.10 and 4.11
Pleasure craft, non-professional		4.12 and 4.13

For each scenario described in Table 7.1 a typical case and a realistic worst case is defined. This provides the possibility that certain antifoulants only may be approved for use in well equiped ship or boat yards that provide good protection against releases of antifoulants to the environment.

7.2 Service life of paint used on ship hulls

It is recommended to perform risk assessments for antifoulants on ship hulls during service life with the following harmonised scenarios:

- Shipping lane scenario: **"modified MAM-PEC shipping lane scenario"**;
- Commercial harbour scenario: **"modified MAM-PEC estuarine harbour scenario"**;
- Marina scenario: **"Marina during high season"** (the worst case shipping characteristics and harbour dimensions of the REMA estuarine marina scenario in combination with the hydrodynamic calculation method of the MAM-PEC estuarine marina scenario.

The model MAM-PEC can be obtained from the web-site of CEPE: www.cepe.org under “Publications” and “Antifouling products” (report and model). The recommended scenarios for service life as described in this section will be incorporated in the MAM-PEC model obtainable from the CEPE web-site.

The tables 7.2 to 7.7 contain the necessary input parameters and model calculations for these recommended scenarios.

7.2.1 Shipping lane scenario

In the tables 7.2 and 7.3 the input parameters and model calculations for the “shipping lane scenario” are described. To calculate the emission load (table 7.2) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 7.2 Shipping lane: Emission scenario for calculating the emission load from biocides used in antifouling products for ship hulls (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping characteristics				
Length categories of ships:	[m]	Cat 1-6		D
- Cat 1		Cat 1	50-100	
- Cat 2		Cat 2	100-150	
- Cat 3		Cat 3	150-200	
- Cat 4		Cat 4	200-250	
- Cat 5		Cat 5	250-300	
- Cat 6		Cat 6	300-350	
Number of ships moving at any time of the day for cat 1-6:	[-]	$N_{ships,moving}$		D
- Cat 1			3.9	
- Cat 2			1.7	
- Cat 3			1.6	
- Cat 4			0.4	
- Cat 5			0.5	
- Cat 6			0.1	
Average surface area per ship for cat 1-6[1)]:	[m^2]	$AREA_{ship}$		
- Cat 1			1,163	D
- Cat 2			3,231	
- Cat 3			6,333	
- Cat 4			10,469	
- Cat 5			15,640	
- Cat 6			21,844	
Application factor and leaching rate				
General application factor of the antifouling product	[-]	Fappl	0.95[2)]	D
Application factor of booster biocides	[-]	Fappl	0.90[2)]	D
Leaching rate for ships moving [3)]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}6\ moving}\ (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1);
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant.

In table 7.3 the default values necessary for the calculation of the initial local dissolved biocide concentration are described.

Table 7.3 Shipping lane: Emission scenario for calculating the initial local concentration of antifouling biocides in seawater (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (area shipping lane)				
Length	[m]	LENGTHsl	20,000	D
Width	[m]	WIDTHsl	10,000	D
Depth	[m]	DEPTHsl	20	D
Water quality				
Silt concentration	[g.m^{-3}]	Csilt	5	D
Temperature	^{O}C	TEMP	15[1)]	D
Salinity	^{O}/oo	SALINITY	34	D
Particular organic carbon	[g.m^{-3}]	POC	0.3	D
Dissolved organic carbon	[g.m^{-3}]	DOC	0.2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	0	D
Tidal current	[m.s^{-1}]	CURRENTtid	1	D
Output:				
The average initial local dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[g.m^{-3}]	$Clocal\_initial_{water,diss}$		O
Calculation:				
Calculations with the MAM-PEC model[2)]				

1) According to the EU TGD the default average marine temperature to be used in the EU countries is 9 ^{o}C (ECB, 2003);
2) Due to the complexity of the model this calculation is not described.

7.2.2 Commercial harbour scenario

In the tables 7.4 and 7.5 the input parameters and model calculations for the “commercial harbour scenario” are described. To calculate the emission load (table 7.4) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 7.4 Commercial harbour: Emission scenario for calculating the emission load from biocides used in antifouling products for ship hulls (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length categories of ships: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m]	Cat 1-6 Cat 1 Cat 2 Cat 3 Cat 4 Cat 5	 50-100 100-150 150-200 200-250 250-300	D
Number of ships at berth at any time of the day for cat 1-5: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,berth}$	 11 5 5 1 2	D
Number of ships moving at any time of the day for cat 1-5: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[-]	$N_{ships,moving}$	 1.8 0.4 0.4 0.1 0.1	D
Average surface area per ship for cat 1-5[3)]: - Cat 1 - Cat 2 - Cat 3 - Cat 4 - Cat 5	[m^2]	$AREA_{ship}$	 1,163 3,231 6,333 10,469 15,640	D
Application factor and leaching rate				
General application factor of the antifouling product	[-]	Fappl	0.95[2)]	D
Application factor of a booster biocide	[-]	Fappl	0.90[2)]	D
Leaching rate for ships moving and at berth[1)]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 1\text{-}6\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach) + Sum_{cat\ 1\text{-}6\ moving}\ (AREA_{ship} * N_{ships,moving} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant;
3) The average surface areas were calculated according the method described by Holtrop (1977) (see section 2.3.1).

In table 7.5 the default values necessary for the calculation of the initial local dissolved aqueous biocide concentration are described.

Table 7.5 Commercial harbour: Emission scenario for calculating the initial local concentration of antifouling biocides in seawater (modified from MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Distance from mouth	[m]	LENGHTm-h	1,000	D
Length	[m]	LENGTHch	5,000	D
Width	[m]	WIDTHch	1,000	D
Depth of harbour	[m]	DEPTHch	15	D
Harbour entrance width	[m]	WIDTHent	2,500	D
Harbour entrance depth	[m]	DEPTHent	10	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[g.m^{-3}]	Csilt	35	D
Temperature	^{O}C	TEMP	15[1)]	D
Salinity	^{O}/oo	SALINITY	34	D
Particular organic carbon	[g.m^{-3}]	POC	1	D
Dissolved organic carbon	[g.m^{-3}]	DOC	2	D
pH	-	pH	7.5	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	1.5	D
River flow velocity	[m.s^{-1}]	CURRENTriver	1.0	D
Depth of river	[m]	DEPTHriver	10	D
Density difference	[kg.m^{-3}]	RHOdiff	0.4	D
Flush in harbour	[m.s^{-1}]	FLOWharbour	0	D
Density difference of flush	[kg.m^{-3}]	RHOdiff,flush	0	D
Output:				
The average local initial dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[g.m^{-3}]	$Clocal\_initial_{water,diss}$		O
Calculation:				
Calculations with the MAM-PEC model[2)]				

1) According to the EU TGD the default average marine temperature to be used in the EU countries is 9 ^{o}C (ECB, 2003);

2) Due to the complexity of the model this calculation is not described. For information on the specific copper speciation module of see the MAM-PEC open sea scenario.

7.2.3 Marina scenario

In the tables 7.6 and 7.7 the input parameters and model calculations for the “marina scenario” are described. To calculate the emission load (table 7.6) the model takes into account shipping characteristics, leaching rate and the application factor.

Table 7.6 Marina: Emission scenario for calculating the emission load from biocides used in antifouling products for boat hulls (modified from REMA and MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Shipping related settings				
Length category of pleasure crafts	[m]	Cat 0	1-50	D
Number of ships at berth at any time of the day	[-]	$N_{ships,berth}$	500	D
Average surface area per craft	[m^2]	$AREA_{ship}$	30.7	D
Application factor and leaching rate				
General application factor of the antifouling product	[-]	Fappl	0.95[2)]	D
Application factor of booster biocides	[-]	Fappl	0.90[2)]	D
Leaching rate for ships at berth[1)]	[$g.m^{-2}.d^{-1}$]	kleach		S
Output:				
Total emission	[$g.d^{-1}$]	$Elocal_{water}$		O
Calculation:				
$Elocal_{water} = Sum_{cat\ 0\ at\ berth}\ (AREA_{ship} * N_{ships,berth} * Fappl * kleach)$				

1) The leaching rate from antifouling products will be obtained from the dossier provided by the applicant;
2) The user may edit this value for user defined emission scenarios on the basis of the market share of the antifoulant.

In table 7.7 the default values necessary for the calculation of the initial local dissolved aqueous biocide concentration, the total aqueous concentration, the concentration on particulate matter and the sediment are described.

Table 7.7 Marina: Emission scenario for calculating the concentration of antifouling biocides in seawater (modified from REMA and MAM-PEC)

Variable/parameter	Unit	Symbol	Value	S/D/O/P
Input				
Dimensions of the environmental compartment (harbour lay-out)				
Length	[m]	LENGTHch	141.5	D
Width	[m]	WIDTHch	141.5	D
Depth of harbour	[m]	DEPTHch	4	D
Harbour entrance width	[m]	WIDTHent	100	D
Harbour entrance depth	[m]	DEPTHent	4	D
Height dam harbour entr.	[m]	HEIGHTdam	0	D
Width dam harbour entr.	[m]	WIDTHdam	0	D
Water quality				
Silt concentration	[g.m^{-3}]	Csilt	35	D
Temperature	^{O}C	TEMP	20[1)]	D
Salinity	^{O}/oo	SALINITY	34	D
Particular organic carbon	[g.m^{-3}]	POC	1	D
Dissolved organic carbon	[g.m^{-3}]	DOC	2	D
pH	-	pH	8	D
Hydrology				
Tidal period	[h]	Ttidal	12.41	D
Tidal height	[m]	HEIGHTtidal	1.5	D
Tidal current	[m.s^{-1}]	CURRENTtid	1	D
Density difference	[kg.m^{-3}]	RHOdiff	0.1	D
Flush in harbour	[m.s^{-1}]	FLOWharbour	0	D
Density difference of flush	[kg.m^{-3}]	RHOdiff,flush	0	D
Output:				
The average total initial dissolved concentration in water (including both the freely dissolved and the DOC-bound fraction)	[g.m^{-3}]	$Clocal\_initial_{water,diss}$		O
Calculation:				
Calculations with the MAM-PEC model[2)]				

1) According to the EU TGD the default average marine temperature to be used in the EU countries is 9 ^{o}C (ECB, 2003);

2) Due to the complexity of the model this calculation is not described. For information on the specific copper speciation module see MAM-PEC open sea scenario.

7.3 Removal of paint from ship hulls

As for application for the removal of paint from ship hulls scenarios were developed within this project. For application a distinction was made between new building and M&R. Removal of the old paint layer on a ships hull takes place only during M&R of ship and boat hulls. It is recommended to use the scenarios as described in table 7.8.

Table 7.8 Recommended scenarios for application of paint on ship and boat hulls

Scenarios	Section	Tables
M&R commercial ships	4.4.1	4.44 and 4.45
M&R pleasure craft, professional	4.4.2	4.47 and 4.48
M&R pleasure craft, non-professional	4.4.2	4.49 and 4.50

For each scenario described in Table 7.8 a typical case and a realistic worst case is defined. This provides the possibility that certain antifoulants only may be approved for use in well equiped ship or boat yards that provide good protection against releases of antifoulants to the environment.

8 TESTING OF THE ENVIRONMENTAL EMISSION SCENARIOS FOR SHIP HULLS

8.1 Testing scenarios for service life

The scenarios for a shipping lane, a commercial harbour and a marina as recommended in section 7.2 are tested in this section. The testing of the scenarios is not a validation exercise. The aim is more to see if the scenarios work and if they result in the desired output for different types of anti-fouling products (e.g. organics and inorganics). For each recommended scenario calculations have been performed using 3 dummy substances:

- Dummy 1: a fast degrading organic antifoulant;
- Dummy 2: a slow degrading organic antifoulant;
- Dummy 3: an inorganic antifoulant (a metal).

Test data (e.g. leaching rate, solubility, degradation rates of the dummy substances) which were used as input values for the calculations were provided by industry. For each dummy substance the test data are listed in table 8.1 below.

It has to be noted that the concentrations in water presented are the dissolved initital concentrations. A copper speciation model was not used.

Table 8.1 Test data

Parameter	**Unit**	**Dummy 1**	**Dummy 2**	**Dummy 3**
Leaching rate	[µg.cm-^{2}.day^{-1}]	2.5	4.0	50
Molecular mass	[g.mol^{-1}]	333.2	290.04	63.5
Vapour pressure at 20 °C	[Pa]	2.1.10^{-5}	8.5.10^{-5}	0
Solubility at 20 °C	[g.m^{3}]	1.3	1.9	1.0.10^{-3}
Degradation rates in water at 20 °C:				
- Abiotic	[d^{-1}]	13.86	0	n/a
- Photolytic	[d^{-1}]	0	0	n/a
- Biological	[d^{-1}]	5.54	4.1.10^{-2}	n/a
Degradation rates in sediment at 20 °C:				
- Abiotic	[d^{-1}]	0	0	n/a
- Photolytic	[d^{-1}]	0	0	n/a
- Biological	[d^{-1}]	0.69	1.4.10^{-3}	n/a
Kd (only for metals)	[m^{3}.kg^{-1}]	n/a	n/a	30.0
Kow (only for organic compounds)	[-]	3.7	3.8	n/a
Koc (only for organic compounds)	[-]	3.13	4.6	n/a
Henry's constant (only for organic compounds)	[Pa.m^{3}.mol^{-1}]	5.5.10^{-3}	2.0.10^{-2}	n/a

The MAM-PEC calculation model consists basicly of three input screens:

- A screen with the characteristics of the relevant environment (e.g. a commercial harbour);
- A screen with the characteristics of the active ingredient of an antifouling paint (e.g. copper);
- A screen with shipping characteristics where the amount of ships and the surface area of the ships is described.

For the testing of the recommended scenarios the the original default environments and shipping characteristics of the MAM-PEC model were adapted by simply overwriting the relevant default values and saving them with an other name (e.g. “Dummy marina”). For the testing the (adapted) hydrology as well as the degradation of the a.i. in the water according to the MAM-PEC model is considered.

In table 8.2 the calculation results for the recommended shipping lane scenario are included.

Table 8.2 Recommended shipping lane scenario

Dissolved concentration of the dummy substance in the water	Unit	Dummy 1 (fast degrading, organic)	Dummy 2 (slow degrading, organic)	Dummy 3 (inorganic).
Maximum concentration	[ug.l^{-1}]	1.46.10^{-4}	6.55.10^{-4}	9.77.10^{-3}
95 % concentration	[ug.l^{-1}]	1.42.10^{-4}	5.99.10^{-4}	8.94.10^{-3}
Average concentration	[ug.l^{-1}]	4.08.10^{-5}	1.30.10^{-4}	1.94.10^{-3}
Median concentration	[ug.l^{-1}]	6.84.10^{-5}	1.31.10^{-4}	1.95.10^{-3}
Minimum concentration	[ug.l^{-1}]	9.09.10^{-8}	9.60.10^{-7}	1.43.10^{-5}

In table 8.3 the calculation results for the recommended commercial harbour scenario are included.

Table 8.3 Recommended commercial harbour scenario

Dissolved concentration of the dummy substance in the water	Unit	Dummy 1 (fast degrading, organic)	Dummy 2 (slow degrading, organic)	Dummy 3 (inorganic).
Maximum concentration	[ug.l^{-1}]	5.00.10^{-3}	3.23.10^{-1}	2.04
95 % concentration	[ug.l^{-1}]	4.82.10^{-3}	3.17.10^{-1}	2.00
Average concentration	[ug.l^{-1}]	2.41.10^{-3}	1,13.10^{-1}	7.15.10^{-1}
Median concentration	[ug.l^{-1}]	2.09.10^{-3}	2.99.10^{-2}	1.90.10^{-1}
Minimum concentration	[ug.l^{-1}]	5.11.10^{-4}	4.36.10^{-3}	2.79.10^{-2}

In table 8.4 the calculation results for the recommended marina scenario are included.

Table 8.4 Recommended marina scenario

Dissolved concentration of the dummy substance in the water	Unit	Dummy 1 (fast degrading, organic)	Dummy 2 (slow degrading, organic)	Dummy 3 (inorganic).
Maximum concentration	[ug.l^{-1}]	3.08.10^{-1}	5.55.10^{-1}	5.69
95 % concentration	[ug.l^{-1}]	3.07.10^{-1}	5.54.10^{-1}	5.68
Average concentration	[ug.l^{-1}]	1,51.10^{-1}	3.23.10^{-1}	3.31
Median concentration	[ug.l^{-1}]	1.25.10^{-1}	3.02.10^{-1}	3.10
Minimum concentration	[ug.l^{-1}]	2.62.10^{-2}	6.96.10^{-2}	7.13.10^{-1}

As expected for every scenario all concentrations are lower for the fast degrading antifoulant (dummy 1) compared to the slow degrading organic antifoulant (dummy 2) and the inorganic antifoulant (dummy 3) respectively. Further, when looking at the non-degrading dummy 3, the difference between the different concentrations (minimum, maximum, 95%, etc.) is larger for the shipping lane compared to respectively the commercial harbour and the marina. This is caused by the fact that in the shipping lane and, to a lower extent, the commercial harbour a higher refreshment rate and/or less mixture of the water occurs. Finally for all scenarios the difference between the 95% and the average concentration is smaller for the fast degrading dummy 1 compared to both dummy 2 and 3.

It can be concluded that the recommended scenarios work and produce logical output for different types of anti-fouling products.

8.2 Testing scenarios for application and removal

The scenarios for application and removal as recommended in sections 7.1 and 7.3 are tested in this section. As for the testing of the scenarios for service life this will not be a validation exercise, but the aim is to see if the scenarios work and if they result in the desired output.

The composition of paints used on commercial ships is normally different of those used on pleasure craft. Therefore two kinds of antifouling paints (containing copper) are considered. Dummy 1 is used on commercial ships and dummy 2 is used on pleasure craft. Antifouling paints generally contain 2 biocides e.g. a copper compound and an organic booster. Therefore each scenario is tested for two biocides:

- Dummy 1: Antifouling paint used on commercial ships

  Copper compound: Ca.i. = 823 [$g.l^{-1}$]
  Organic booster: Ca.i. = 91 [$g.l^{-1}$]
  COVERAGE = 4.8 [$m^2.l^{-1}$]

- Dummy 2: Antifouling paint used on pleasure craft

  Copper compound: Ca.i. = 547 [$g.l^{-1}$]
  Organic booster: Ca.i. = 25 [$g.l^{-1}$]

For several scenarios the choice can be made whether the potential emission goes to the environment or (depending on the control measurements) to a STP or to waste. For the calculations performed in this section it is assumed that the total emission load goes to the environment (i.e. surface water for paint used on commercial ships and soil for paint used on pleasure craft).

<u>Application</u>

In table 8.5 the calculation results for the recommended scenario for the application of paint during new building of commercial ships are presented.

Table 8.5 Recommended scenario for the application of paint during new building of commercial ships (Dummy 1)

Emission load of a.i. to water	Unit	Realistic worst case: during painting period	Typical case: during painting period
Copper	[kg.d^{-1}]	150	32
Organic booster	[kg.d^{-1}]	17	3.5

In table 8.6 the calculation results for the recommended scenario for the application of paint during new building of pleasure craft are presented.

Table 8.6 Recommended scenario for the application of paint during new building of pleasure craft (Dummy 2)

Emission load of a.i. to soil	Unit	Realistic worst case: during painting period	Typical case: during painting period
Copper	[g.d^{-1}]	49	0
Organic booster	[g.d^{-1}]	2.3	0

In table 8.7 the calculation results for the recommended scenario for the application of paint during M&R of commercial ships are presented.

Table 8.7 Recommended scenario for the application of paint during M&R of commercial ships (Dummy 1)

Emission load of a.i. to water	Unit	Realistic worst case: during painting period	Typical case: during painting period
Copper	[kg.d^{-1}]	150	32
Organic booster	[kg.d^{-1}]	17	3.5

In table 8.8 the calculation results for the professional application of paint during M&R of pleasure craft are presented.

Table 8.8 Recommended scenario for the professional application of paint during M&R of pleasure craft (Dummy 2)

Emission load of a.i. to soil	Unit	Realistic worst case: during painting period	Typical case: during painting period
Copper	[g.d^{-1}]	40	17
Organic booster	[g.d^{-1}]	1.8	0.77

In table 8.9 the calculation results for the recommended scenario for the non-professional application of paint during M&R of pleasure craft are presented.

Table 8.9 Recommended scenario for the non-professional application of paint during M&R of pleasure craft (Dummy 2)

Emission load of a.i. to soil	Unit	Both realistic worst case and typical case: during painting period
Copper	[g.d^{-1}]	1.9
Organic booster	[g.d^{-1}]	0.086

Removal

In table 8.10 the calculation results for the recommended scenario for the removal of paint during M&R of commercial ships are presented.

Table 8.10 Recommended scenario for the removal of paint during M&R of commercial ships (Dummy 1)

Emission load of a.i. to water	Unit	Realistic worst case: during painting period	Typical case: during painting period
Copper	[kg.d^{-1}]	41	12
Organic booster	[kg.d^{-1}]	4.6	1.3

In table 8.11 the calculation results for the recommended scenario for the professional removal of paint during M&R of pleasure craft are presented.

Table 8.11 Recommended scenario for the professional removal of paint during M&R of pleasure craft (Dummy 2)

Emission load of a.i. to soil	Unit	Realistic worst case: during painting period	Typical case: during painting period
Copper	[g.d^{-1}]	27	6.7
Organic booster	[g.d^{-1}]	1.2	0.31

In table 8.12 the calculation results for the recommended scenario for the non-professional removal of paint during M&R of pleasure craft are presented.

Table 8.12 Recommended scenario for the non-professional removal of paint during M&R of pleasure craft (Dummy 2)

Emission load of a.i. to soil	Unit	Realistic worst case: during painting period	Typical case: during painting period
Copper	[g.d^{-1}]	53	2.3
Organic booster	[g.d^{-1}]	2.4	0.10

The emission loads should be converted to initial concentrations and PECs in the receiving compartments. As noted in chapter 1.1 the relevant guidelines like the the EU-TGD should be used to carry out these calculations.

9 DISCUSSION

Harmonised environmental emission scenarios for all OECD countries?: The primary aim of the harmonised and newly developed scenarios is for use in risk assessments in notification and authorisation procedures in regulatory frameworks used in all OECD countries. Therefore it is important that the harmonised scenarios are typical OECD emission scenarios. However it must be noted that the scenarios are to a large extent based on information from the European countries. This was caused by the fact that there was simply not enough information available on, for example, the situation in the US or Australia. More work to obtain these data is recommended. Where possible data from countries outside the EU are incorporated in the scenarios.

Predicted Environmental Concentration (PEC) and Predicted No Effect Concentration (PNEC): within the OECD Antifouling Steering Group it was discussed which value will be the PEC to be compared with the PNEC. E.g. for a marina: is the PEC the value calculated in the marina or the value in water just outside the marina? The different models take sometimes a different approach with respect to this issue: e.g. REMA calculates a concentration in the marinas as well as in the estuarine area outside the marinas. This issue also relates to the protection goals set by the competent authority: e.g. in the Netherlands the concentration in the marina calculated with USES 2.0 is used as the PEC, as marinas are considered to be essential as a brood place for some marine organisms. So, the outcome of the environmental emission scenarios presented for commercial harbours and marinas in this document can be used as the 'final' initial local PEC but also other models or dilution factors can be used to calculate the 'final' initial PEC using models like REMA, EUSES or dilution factors. For the calculation of the 'final' local PEC and concentrations in secondary environments taking removal processes into account and the calculation of the total concentration (including suspended matter) reference can be made to documents such as the EU-TGD (ECB, 2003).

Average, maximum or 95% PEC: the outcome of the MAM-PEC calculations is a maximum, 95% and average concentration. The question is whether which outcome to use as the local initial environmental concentration. It was decided that, as the aim is to use realistic worst case estimations of the input values for a typical OECD scenario (hydrology, shipping characteristics and dimensions of the receiving compartment) the average value would normally have to be recommended in the document.

Tiered approach: when considering the fact that 3 “service life” scenarios are available for antifoulants used on commercial ship hulls (commercial harbour, shipping lane and open sea) the question is whether this is necessary or not. When an antifoulant passes one scenario without environmental concern other scenarios may not be necessary. E.g. the calculated PEC in a harbour will always be higher compared to the PEC for shipping lane and open sea, because of the high concentration of ships per m^3 water. However, scenarios for e.g. a shipping lane may be useful when a competent authority decides to protect certain ecosystems or species. Authorities may decide not to protect commercial harbours, but only the areas in the open sea or shipping lane. In a similar manner, it may be considered that the environmental concentrations calculated for the default seawater marina will always be higher compared to natural marinas, ships attached to buoys and most marinas in lakes.

Validation status: validation is a crucial step in the development of environmental emissions scenarios and exposure modelling. Although validation is outside the scope of this document the status was indicated for models like MAM-PEC and REMA. Clearly, more validation exercises are needed - especially for the recommended scenarios.

Measured data: in risk assessment in general measured values are preferred over calculated values. If these data are representative and relevant they should be used instead of estimated concentrations. In the EU-TGD more guidance is presented on the assessment, interpretation and use of measured data.

Factors that influence estimated environmental concentrations: there are reasons to deviate from the recommended environmental emission scenarios -local situation (e.g. low tide) or seasonal influences - leading to other parameter settings.

Application factor: a recommended general value of 95% for the application factor is introduced. For boosters this may lead to an overestimation of the market share as this is for all boosters at the moment much lower than 95%. But according to representatives of industry a market share of 90% for a (future) booster would be possible. To anticipate on future developments a maximum default value of 90% (0.90) is recommended. However, actual market data can be provided by the notifier leading to an adaptation of the value of 90%. If available real data on the market share should be used.

Selection of the leaching rate value: It is very important for the correctness of the estimated environmetal concentrations to choose a leaching rate value that is representative for the scenario and risk assessment case in question.

Fate of the substance: The outcome of the scenarios for application and removal is an emission load. However, a few considerations with respect to the fate of the a.i. in particulate emissions of antifoulants from application and removal life-stages are described below.

For the yearly average environmental concentrations the user should sum up the initial concentrations resulting from the application and removal scenarios when they occur in the same compartment (water, STP or soil). For the daily concentrations during the emission period it may be assumed that application and removal do not occur on the same day.

Particulate emissions of antifoulants from application and removal life-stages will have different fate and behaviour properties compared to molecular emissions from the service-life stage, e.g. lower bioavailability and longer persistence.

According to the EU TGD, in the absence of more detailed data concerning adsorption/ bioavailability/ persistence, the substance content in small particles can be handled as if it was distributed in molecular form (TGD 2003). However, according to expert information form CEPE, it is believed that because of the application techniques used, any release to the environment during application also results in an emission being in particle form. The information according to CEPE is described below:

- Paint droplets from overspray are relatively large and dense, and therefore primarily confined to the spraying area. Additionally, due to the high volatility of the solvents used in typical antifouling paint formulations the droplets undergo significant drying before they reach the surrounding water surface. Thus if released to the surrounding

water environment, they consist of relatively large particles which are not readily dispersed into the environment;
- Some co-biocides have considerable substantivity to particles of the primary antifouling agent, cuprous oxide;
- Other biocides are incorporated into polymers and are only released due to the action of physical erosion or slow hydrolysis.

Furthermore it is important to note that not all potential emissions during application will enter the aquatic environment directly. For example for the application of paint on new commercial ships a distinction is made between application of the final paint coat in a dock and application on an exposed slipway. The potential emission factor to surface water (without control measures, e.g. shrouding) for the slipway is 0.35. For painting in the dock the potential emission factor is only 0.075 (less overspray due to a more confined area). The greatest part of the emissions occurring at the exposed slipway will enter the environment directly. But potential emissions occurring in the dock will enter the environment partly in the form of dried paint onto the dock walls (leaching) and partly via the air directly to the surface water. Because of the relative short immersion period of the dock into the water (compared to ship hulls during service life of the antifoulant) the emission to the surface water will be small. But because there is no data available on the amount of antifoulant directly emitted in the water the emission factor for painting in the dock is maintained at 0.075.

The potential emissions during paint removal will occur in the form of dry paint flakes or paint dust that either goes to waste, a Sewage water Treatment Plant (STP) or directly to water. Even when the paint is going directly to the surface water it should be considered that the dissolved concentration in practice will be lower than the calculated concentration.

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Annex I
Description of existing calculation models for estimating the emission from service life from the use of antifouling biocides on ship hulls

INTRODUCTION

In this annex an overview is given of 3 models which can be used to predict environmental concentrations of antifoulings used in coatings for ship hulls: USES, REMA and MAM-PEC. Both REMA and MAM-PEC have recently been developed specifically for antifoulings. Other fate models can be used for the same purpose. Examples are EXAMS, ECOS and DELWAQ. However, these models need to be adapted to accommodate the main features of the emission patterns that are deemed important for antifoulings (like shipping characteristics and leaching rates). Besides, many models need to be modified or linked to another tailor-made model to deal with complex hydraulic processes of typical marine environments. In both the REMA and MAM-PEC project it was decided after an evaluation of the available chemical fate models, to develop a new model for antifoulings. The models are not described in detail in this chapter. Described are the prototype environments modelled which is important for the selection of environmental emissions scenarios in the next chapter.

REMA

The REMA model provides predictions of antifoulant concentrations in marinas and estuaries based on the quantitative water-air sediment interaction (QWASI) model developed by Mackay et al. (1983). The model uses partition data obtained from laboratory experiments.

The model requires a large number of input variables describing discharges, physico-chemical properties and environmental parameters. Therefore the model, in its initial form, was considered unsuitable for routine use or for use by inexperienced operators. The model was set up for several UK marinas and estuaries. These cover a number of scenarios, with estuaries of varying sizes and dynamics and marinas of different types (e.g. locked, open, pontooned etc.). Using this approach, the only information a user needs to input would be the properties of the antifoulant and the number of vessels in each marina. The following range of estuary types was specified:

- a small estuary that dries out;
- a well mixed estuary, with a narrow mouth;
- a well mixed estuary, with a wide mouth;
- a large, complex estuary.

Each estuary type is divided into three estuary segments each containing a marina as shown in figure A1.1.

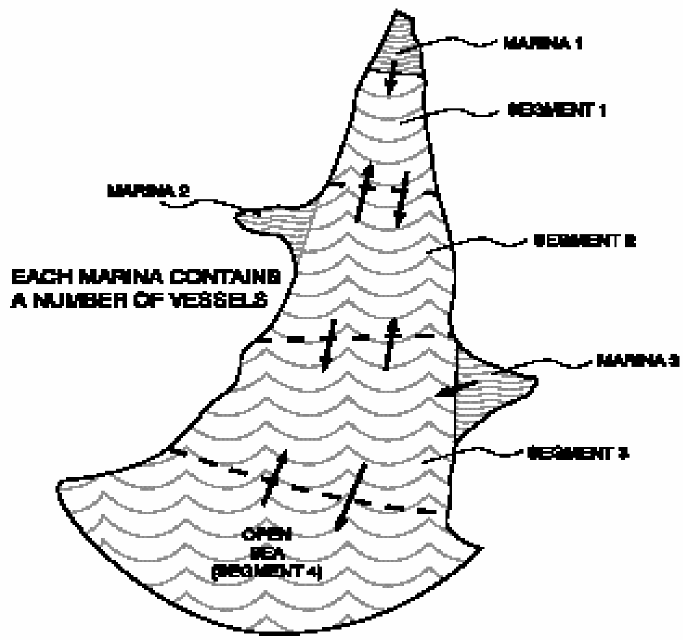

Figure A1.1 **Schematic drawing of the estuary in the REMA-model: estuary with three segments each containing a marina**

Each estuary segment has an inflow from a river, which itself may have a known concentration of the biocide. The open sea at the mouth of the marina may be seen as the fourth segment. A marina and an estuary type can be chosen from default lists. Most of the parameters can be changed by the user. However, the user should do this with caution, because e.g. the size of a default marina is based on real situations.

The output of the model is expressed as the steady state concentration in bulk water and sediment for both the marinas and the estuary segments. No calculations are made for changes in the open sea segment as this is assumed to stay constant.

The outputs of the REMA-model were validated against monitoring data. The model has been shown to produce predicted environmental concentrations for two UK estuaries, which are close to measured values for the selected antifoulants.
[Source: REMA-report]

MAM-PEC

This section gives a short description of the characteristics of the MAM-PEC-model. In chapter 5 the default scenarios within the MAM-PEC-model will be discussed and compared with possible scenarios in practice (see 3.2.2) and, when necessary, with comparable default scenarios from other calculation models.

The MAM-PEC model generates predicted environmental concentrations for fixed default marine environments. During the MAM-PEC project a choice was made between a generic model for a few standard environments (with flexibility for adaptation to mimic local conditions) or a region-specific model (based on e.g. existing models for North Sea, Baltic, Mediterranean). Because of (a.o.) the facts that in the case of a region specific model adaptation to other regions can only be done with large effort and standardisation is complex, the choice was made for the following five standard or prototype environments:

- Commercial harbour;
- Estuary with small harbour;
- Marina;
- Open sea;
- Shipping lane.

In figure A1.2 these prototype environments are depicted.

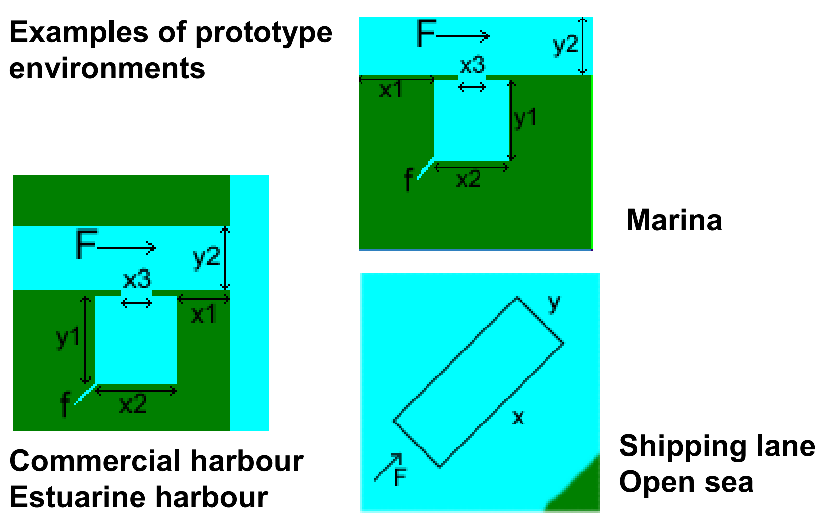

Figure A1.2 The prototype environments included in the MAM-PEC Model (from Van Hattum et al., 2002).

According to MAM-PEC these represent the most important existing marine scenarios. The commercial harbour is situated along a large estuarine river at a distance of 2 km from the mouth of the river. The estuarine harbour is similar and differs in dimensions and the size of the harbour. The marina is an enclosed area situated directly at the coast. An additional poorly flushed marina was added as a default scenario to mimic conditions with low tidal exchange (e.g. Baltic, Mediterranean). Both marina, commercial and estuarine harbour may have additional flushing from a small river or urban drainage system discharging at the rear end of the harbour.

As described earlier the defined standard environments can be adapted to local situations and added. The model takes into account emission factors (e.g. leaching rates, shipping intensities, residence times, ship hull underwater surface areas),

compound related properties and processes (e.g. Kd, Kow, Koc, volatilisation, speciation, hydrolysis, photolysis, bacterial degradation), and properties and processes related to the specific environment (e.g. currents, tides, salinity, suspended matter load). There is a broad distinction between organic and inorganic compounds both in the mechanisms and relative importance of the processes. For instance for copper, processes such as sorption, speciation- and redox reactions have a prominent role in the fraction of freely bioavailable and potentially toxic Cu^{2+}.
As copper is an ingredient in many antifouling products, a specific module has been introduced in the MAM-PEC model which calculates Cu-speciation and predicts expected ranges of free Cu^{2+} ion concentrations.

The outputs of the model consist of the average, median, minimum, 95-percentile and maximum concentrations for the different default environments for the dissolved concentration, the total aqueous concentration, the concentration on particulate matter and the sediment. As sediment processes are slow and attaining steady state may take years to decades, the model calculates sediment concentrations for different time periods (1, 2, 5 and 10 year). It is the responsibility of the user to determine which statistics need to be used. Maximum values, for example, only occur directly below the emissions, which are situated e.g. in the rear end of the harbour.

For a selected number of compounds model-predictions for specific environments were compared with measured concentrations in order to evaluate the validity of the model. The model predictions appeared to be reasonably in line with results from monitoring studies.
[Source: MAM-PEC-report]

USES

In this section the USES-model is described. This model consists of a single default scenario. In chapter 5 the characteristics of this scenarios will be discussed and compared with possible scenarios in practice (see 3.2.2) and, when necessary, with comparable default scenarios from other calculation models.

For calculating the emissions of antifoulants in the aquatic environment a middle size yacht-basin was modelled. This scenario that is incorporated in USES 3.0 (Uniform System for the Evaluation of Substances) is derived from the original scenario of Luttik et al. 1993. USES 3.0 has been developed by the RIVM in the Netherlands (Linders and Jager 1997).

The emission is calculated from the mean leaching rate of the antifoulant and the total ship area. The emission is converted to a concentration in the water with help of the water volume per ship and the residence time of water in the basin. The concentration is calculated applying equilibrium partitioning over the water phase and suspended matter using a solids-water partitioning coefficient.

In the USES-model, only the concentrations for the water phase (including suspended matter) in the yacht basin are calculated.

The results of model calculations were compared with monitoring data from three sample sites in Sweden and two sample sites in the Netherlands. This was done for tributyltin, copper, irgarol and diuron. Based on these measurements it was concluded

that in some cases the model calculates too high values in comparison with the measured values, but that they are not unrealistic high. However, applying the defaults regardless of the antifoulant and the environment to be assessed will result in data with very little relevance.
[Source: USES 3.0 and Council of Europe, 1996]

Annex II
Provision of biocide Leaching rate data for Anti-Fouling Products. A Discussion Document from the Anti-Fouling Working Group of CEPE. April 2003.

PROVISION OF BIOCIDE LEACHING RATE DATA FOR ANTI-FOULING PRODUCTS

A Discussion Document from the Anti-Fouling Working Group of CEPE

CEPE Anti-Fouling Working Group, April 2003

1. Introduction

For anti-fouling coatings, a significant route of exposure into the environment is entry of active substances into the aquatic environment as they are leached from the paint film. The ***biocide leaching rate*** is therefore a critical parameter in an environmental risk assessment. This issue has been the focus of discussion with several regulatory authorities and standards organisations (eg. ASTM, ISO). The following chapter describes the position of Anti-Fouling Coatings Manufacturers who are members of CEPE[1] to the issue.

1.1 Biocide leaching rate from anti-fouling coatings

Release rates of biocides from anti-fouling paints (AF) are required by a number of regulatory authorities to review/regulate the release of biocides into the aquatic environment. An accurate biocide release rate value is essential when conducting an environmental risk assessment. There has been much debate over experimentally derived release rate data, with some methods generally considered overly conservative and not believed to assess the actual environmental loading of the biocide into the environment. This document summarises the current situation.

1.2 Present Methods

1.2.1 Laboratory methods

The following recognised standard methods have been developed to measure the release rate of biocides from AF paints:

ASTM D5108-90	Organotin release rates from A/F coating systems in sea water
ASTM D6442-99	Copper release rates from A/F coating systems in seawater
ISO 15181-1	Determination of release rate of biocides from A/F paints – General method for extraction of biocides
ISO 15181-2	Determination of release rate of biocides from A/F paints - Determination of copper-ion concentration in the extract and calculation of the release rate

These methods are standardised laboratory methods using a rotating cylinder device measuring the release rates during a given time of immersion (45 days) under specified conditions (T: 25^{o}C +/- 1; salinity: 33 – 34 parts per thousand; pH: 7,9 - 8,1).

However the following limitations should be taken into consideration when using data generated following the above mentioned standardised laboratory methods:

[1] CEPE is the European Association of Paint Manufacturers

The Laboratory methods above (with the rotating cylinder device) were primarily developed and validated for organotin copolymer-containing and first generation TBT-free copper-containing A/F paints.

The results obtained from 'round robin' tests of the methods above show a significant level of variation between different experimental laboratories for organotin copolymer containing paints and a high level of variation for first generation tin-free copper containing formulations.

The ASTM and ISO methods specify that release rates are to be measured in fully saline water (33-34 parts per thousand) and at a seawater temperature of 25^0C +/-1. Release rates at lower salinity and/or at lower temperatures, such as those generally prevalent in Finnish waters (Gulf of Finland) and the Baltic Sea, are expected to be lower.

In some cases the short testing period in the standard methods above generates release rate data which is too high and does not necessarily represent the release rate of a biocide during the in-service lifetime of an anti-fouling coating. For example it is well known that the copper leaching rate for soluble-matrix type paints decays exponentially with time. In these cases, the ASTM/ISO 'pseudosteady state' release rates measured for days 21-45 is clearly an overestimate of the 'average' release rate over the paint's specified lifetime. In some cases leaching rate data derived from the methods above, if representative of product on ships hulls, would suggest that that there will be no biocide remaining in the paint after a few months in service. This is clearly not the case.

1.2.2 Field tests

The Space and Naval Warfare Systems Center, San Diego (SSCSD), has developed a field method for measuring in-situ organotin release rates using a dome placed on the painted surface of an immersed hull. A fixed volume of water sampled through this device was analysed and the organotin release rate results obtained by this method were found to be an order of magnitude lower than results obtained using the standardised laboratory methods described above.

SSCSD has recently used the dome method to measure in situ copper release rates from immersed panels and the published results demonstrate that the release rates measured in the field by this technique are also significantly lower than those measured using laboratory methods.

These results suggest that the laboratory methods above may overestimate organotin and copper release rates from anti-fouling paints and hence the environmental loading into the aquatic environment. Therefore interpretation and use of the derived release rates, as direct input into environmental risk assessments should only be done with caution.

It should be noted that it is stated in the published ASTM (D5108-90) method for determination of leaching rate for organotin, that the test method only serves as a guide for the organotin leach rate in service. It is further stated in the ASTM method for determination of copper release rates (D 6442-99) that '*the test method has not yet been validated to reflect in-situ copper release rates for anti-fouling paints and therefore should not, at present, be used in the process of generating environmental risk* *assessments*', and '*this test method serves only as a guide for characterisation of the early release pattern as well as estimating the steady state release of copper from anti-fouling coatings'.* Further it is stated in ISO method for copper (ISO 15181-1), that '*actual release rate of biocides from ship's hulls into the environment will depend on many factors such as ship operating schedules, length of service, berthing conditions, paint condition, as well as temperature, salinity, pH, pollutants and bacterial content'.*

1.2.3 Mass balance method - Calculation method (See Appendix 1)

The European Paint Industry (CEPE) has developed a calculation method for the determination of leaching rates based on the assumption that the total release of biocide can never exceed the amount incorporated into the coating. Data generated by this method has been accepted as an interim solution by some countries' authorities (Norway, and The Netherlands) as the method used for submission of release rate data with a product application.

Data calculated by this method for the release of copper from an organotin copolymer paint shows good agreement with copper release rates measured via the ISO method, although that agreement was less good for copper release from rosin-based paints, and there is no data currently available for other biocides. The calculation method has, on recommendation from CEPE been placed on the agenda in ISO/TC35/SC9/Working Group 27, for further discussion.

The method is a simplified generic model of biocide release, which is based on the assumption that the majority of biocide in the paint that is applied is released at a constant rate during the specified lifetime.

The calculated release rate derives from the volume of dry paint film applied, the loading of biocide in the paint, and the specified lifetime of the product.

The model assumes that:
- the biocide release rate falls linearly for the first 14 days following immersion;
- the biocide release rate is thereafter constant from day 14 until the last day of the coating's specified life-time;
- the ratio of the cumulative amount of biocide released during the first 14 days following immersion to the average release rate during the remainder of the coating's specified lifetime is 30;
- 30% of biocide is retained in the paint film at the end of its specified lifetime.

Based on these assumptions, and from knowledge of the biocide content of the paint, specified dry film thickness and its specified lifetime, it is possible to calculate

X: Amount of biocide released during first 14 days ($\mu g/cm^2$)
Y: Average leaching rate during the rest of the lifetime ($\mu g/cm^2$pr day)

(See Appendix 1: Figure A1.1)

In common with release rate data which is generated by the ASTM/ISO experimental methods described above, it is probable that the calculated average release rate will overestimate the release rate under static conditions, *i.e.* when the vessel is idle in a harbour (*static release rate*). This is the typical situation for many pleasure craft, which are only sailing for a small amount of time during a season, and for ocean-going vessels when they are in port. Conversely, both the calculated and measured average release rate will most probably underestimate the release rate when the ship is in operation (*dynamic release rate*), as would be the case when a vessel is at sea. Release rates higher than the calculated or experimentally measured average release rates will therefore mostly occur in deep-sea areas under conditions of high dilution, rather than in shallow in-shore or coastal waters.

1.3 Development of Leach Rate Test Methods within ASTM and ISO

ASTM is currently working on draft documents at sub committee level for three biocides: Sea-Nine 211, Irgarol, and Zinc Omadine.

ISO has just initiated work at Working Group (WG) level for three biocides: Zineb, Dichlofluanid (Preventol A4) and Pyridine-Triphenyl Borane.

It is likely that the resulting ISO/ASTM standard methods will be laboratory methods based on the existing release rate methods for organotin and copper.

In the long-term it is envisaged that more accurate and reproducible experimental methods to determine the release rate of biocides from anti-fouling paints will be established.

2. Conclusion

Internationally accredited standard methods exist for measuring the release rates of copper and tin biocides from anti-fouling paint films and additional methods are currently being developed for a number of organic biocides. However, the relationship between biocide release rates obtained by these laboratory test methods and the true environmental inputs of biocides from anti-fouling paints is uncertain and release rate data from these methods cannot be reliably used for environmental risk assessment. A calculation method has been used to estimate biocide release rates from anti-fouling coatings, based on the assumption that 70% of the biocide is released during the lifetime of the coating. Also, for this method there is no direct relationship between the environmental input at a certain moment in time and the calculated average release of biocide.

Given the present level of uncertainty with all approaches, until internationally agreed guidelines are developed, approved and validated, care must be taken when selecting a release rate value to use in an environmental risk assessment. However, as several regulatory authorities demand that an environmental risk assessment is performed, the best available release rate data, either experimental, calculated, or both, should be used taking due account of the limitations stated in this document. A proposed testing strategy for obtaining release rates for biocides from anti-fouling paints is given in Figure A.2.1 below.

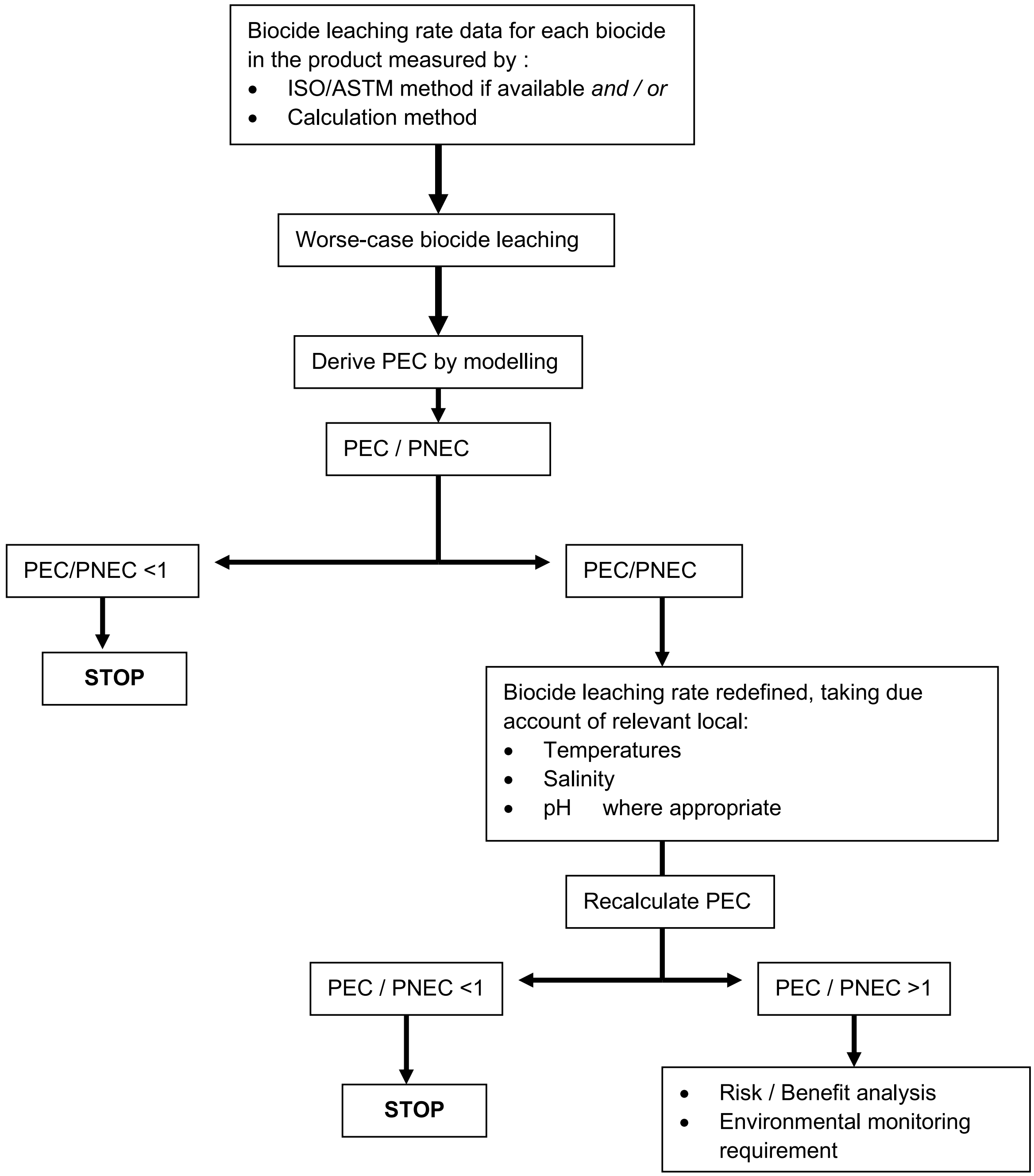

Figure A2.1 Proposed Testing Strategy for Release Rate of Biocides From Anti-Fouling Paints

APPENDIX 1
A METHOD FOR CALCULATING THE RELEASE RATE OF BIOCIDES FROM ANTI-FOULING PAINTS

<u>Definitions</u>
X = Amount of biocide released during first 14 days (μg/cm^2)
Y = Average leaching rate during the rest of the lifetime (μg/cm^{2}pr day)

<u>Assumptions:</u>
First 14 days linear drop in release rate
Rest of the lifetime: Constant leaching rate
X/Y = 30: Constant by experience from leaching rate measurement
30% of biocide is retained in the paint film at the end of its specified lifetime (i.e. 70% is released)
See figure 1 for further details

These assumptions are based on extensive experience within the paint industry of the measured release rates of copper and tin biocides from organotin copolymer and first generation TBT-free anti-fouling paints.

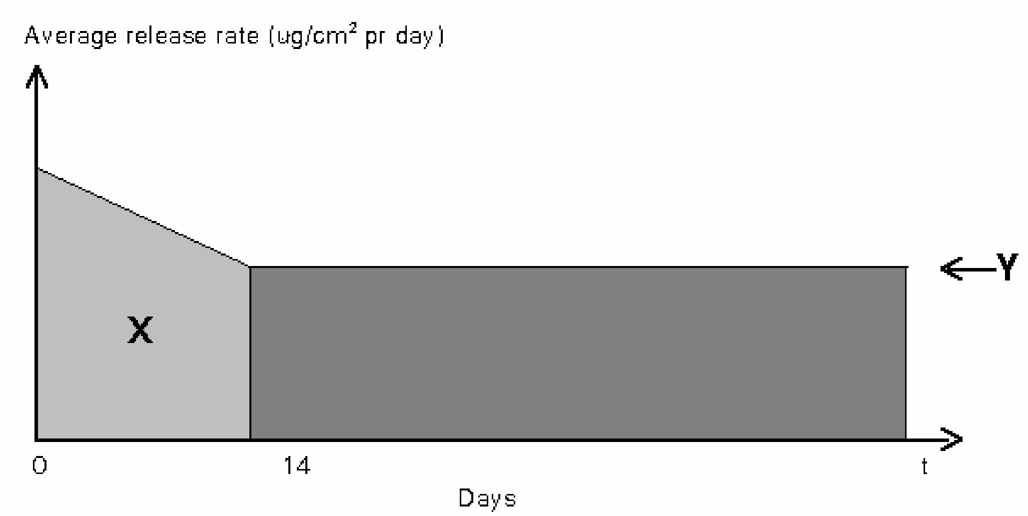

Figure A1.1

<u>Calculations:</u>
The calculation of total cumulative amount of biocide released during the lifetime t (μg/cm^2) is made according to the following equations:

1) **X** + (**t** -½) x **30** x **Y** = $\mathbf{L_a}$ x **a** x $\mathbf{W_a}$ x **100/SVR** x **SPG** x **DFT**

2) **X/Y** = **30**

where:
- **t** is the specified lifetime (months) of the paint for the dry film thickness DFT

- **30**: 1 month = 30 days
- **½**: half a month (14 days)
- **L_a** is the fraction of the active ingredient in the dry film released during the life time t, assumed to be 0.7. (From experience in practice L_a is estimated to be 0.7)
- **a** is the weight fraction of active ingredient in the biocide
- **W_a** is the concentration of biocide in the wet paint in weight %
- **100** is included to secure the units of measure in the equation
- **SVR** is the solid volume ratio (volume of dry paint versus volume of wet paint) in %
- **SPG** is the specific gravity of the wet paint (g/cm^3)
- **DFT** is the dry film thickness (in micron) specified for the lifetime t. The value to be applied depends on the type of paint

Total release of the biocide (μg/cm^2) during the lifetime t as derived from the geometrics of figure A1.1: X + (t-½) x 30 x Y

Total release of biocide (μg/cm^2) during the lifetime t, for the specified film thickness DFT, the concentration of biocide in the wet paint W_a and with the fraction of biocide L_a actually released during the lifetime t:

$$L_a \times a \times W_a \times 100/SVR \times SPG \times DFT$$

On the basis of equation 1 and 2 and on the basis of data on the individual anti-fouling paints and their specifications both the assumed total release during the first 14 days and the assumed average release rate of biocide during the rest of the lifetime of the product can be calculated.

ROYAL HASKONING

Annex III
MEMBERS OF THE OECD STEERING GROUP on Anti-Fouling Products

MEMBERS OF THE OECD STEERING GROUP on Anti-Fouling Products

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