NORWEGIAN
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Scenario document for the calculation of environmental exposure from antifouling active substances from nets used in fish farms

1. Introduction, aim and limitations

This scenario document focuses on parameters that are essential for the calculation of PEC values for water and sediment in a fish farm area. Starting points for the development of this scenario document have been the e-consultation from 2012 launched by SE based on the copper pyrithione CAR (TMII2012-Env item3i-FishNetEconsultation_results _31May2012.pdf), as well as information gathered on fish farming conditions in Norway and in other countries through an e-consultation launched by the Norwegian Environment Agency in December 2014. The document concentrates on the following issues:

- The parameters needed to calculate emissions (E_{local} values) and PEC values in the area in which the aquaculture facility is situated.
- The release of antifoulants from the service life of fish nets. The washing of the fish nets before re-treatment at designated locations undoubtedly causes emissions of antifoulants. However, this release often happens at other locations than the fish farms where the nets are deployed. Furthermore, this issue is in some countries dealt with through other national legislation.
- Marine fish farms. At present, sufficient information on freshwater fish farming is not available.

The development of this scenario document is referred to in the Manual of Technical Agreements (MoTA) v. 6, point 1.12 in the separate PT 21 document referred to in section 5.2.12. The scenario is mainly meant as a first tier approach for use during the product authorisation stage, but it can also be used for future active substance evaluations where use on fish nets is applied for. Regarding parameters, it is obvious that some of the values will vary greatly between the countries. Union authorisation is not foreseen for product type 21, and as agreed during the e-consultation round in December 2014, standard parameter values could be used for a first tier exposure assessment of products if there is a lack of better suited regional values and for a first tier active substance evaluation. If there is knowledge within a specific country that the standard values do not represent the local conditions, the values could be adapted (in accordance with Article 37 of the BPR).

MAMPEC version 3 is the suggested preferred model for PEC calculations. It has previously been decided to use MAMPEC v. 2.5 for BPD Annex I assessments of antifoulants. However, several years have passed since this decision. Furthermore, it is expected that the scenario will mainly be used for product assessments. MAMPEC 3.0.1 was launched in August 2014, and is a better and more developed model than its predecessor. Documentation on this version of MAMPEC and a description of the differences between MAMPEC v. 3.0.1 and the previous version can be found on the web site of Deltares (MAMPEC - Deltares). The handbook with technical documentation of MAMPEC v. 3.0 (van Hattum et al., 19. August 2014) gives a thorough description of the model, and the release notes for MAMPEC v. 3.0.1 gives an overview of the differences between this version and the previous one. MAMPEC 3.0.1 has been used for all example PEC calculations presented in this scenario document.

2. Parameters for emission (E_{local}) calculations

Default values for the calculation of a daily emission load from a reasonably worst case fish farm are given in the table below. Instead of presenting values for a worst case (large farm with many large nets) and a typical case (smaller farm with fewer and smaller nets) fish farm, the values have been chosen to represent a fish farm which could be situated both in open and somewhat more sheltered areas. The reasoning is that a large farm would need a more open location with a high water exchange rate in order to be operative and well-functioning (i.e. a combination of a worst case E_{local} and a better case location), and a smaller farm would often be situated in a more sheltered area with a lower water exchange rate (i.e. a combination of a better case E_{local} and a worst case location). It is difficult to say which of these situations would represent a refinement over each other. Therefore, the table lists a set of default values for the E_{local} calculation representative of a fish farm which could be found in several types of locations. Refinement options regarding fish farm locations are discussed in chapter 3. However, in cases where it is known or expected that the default values for the E_{local} calculation are not representative for a country e.g. at product authorisation, they could be replaced by more appropriate values in accordance with Article 37 of the BPR.

A discussion of each parameter follows below the table.

Table 1: List of parameters for the calculation of E_{local} from a fish farm

Parameter description	**Suggested default value**	**Parameter source**
Concentration of a.i. in product, $C_{a.i.}$	*To be inserted for each product, in g/L*	S
Number of nets per fish farm area, N_{net}	10	D / S
Coverage of product (amount of product used per kg net), COVERAGE	1 L/kg	D / S
Weight per m^2 of net, W_{net}	0.36 kg/m^2	D / S
Area of each net, $AREA_{net}$	5103 m^2	D / S
Time impregnated net is deployed in the water, $T_{deployment}$	180 d	D / S
Fraction of released a.i. per deployment time of nets, $F_{a.i.}$	0.8	D / S

D = default, S = product specific / product or region specific

The daily emission from the fish nets on the fish farm, E_{local}, can be calculated by using the following equation:

$$E_{local}\ (g/d) = (N_{net} \cdot AREA_{net} \cdot W_{net} \cdot COVERAGE \cdot C_{a.i.} \cdot F_{a.i.}) / T_{deployment}$$

Discussion of emission parameters

Concentration of a.i. in product, $C_{a.i.}$

Must be inserted for each individual product.

Number of nets per fish farm area, N_{net}

The large majority of fish farms contain up to 10 nets, even though some contain more. It is considered that a fish farm with 10 nets of the size proposed in the table above represent a reasonable worst case fish farm.

Coverage of product (amount of product used per kg net), COVERAGE

According to information from the Norwegian fish net industry, Sunde et al. (2008) and product information found online, 1 L product per kg fish net is a representative amount for most products and could be used as a standard parameter in the absence of product-specific input.

Weight per m² of net, W_{net}

There are different kinds of nets and their weight depends on many factors. Most commonly, nets are made of nylon (polyamide), but as different net manufacturers use different weaving techniques, mesh sizes etc., there is some variability in the weight of 1 m^2 net. According to representatives from the fish net industry, this can vary by several hundred grams per m^2, but a representative value would be 360 g/m^2. This covers both nets for smolts and adult fish.

Area of each net, $AREA_{net}$

There are four main types of nets in Norway, as shown in the following figure. Nets with a square shape are used in well-protected locations. Round nets are however more frequently used, since they are better suited for locations exposed to rougher weather conditions.

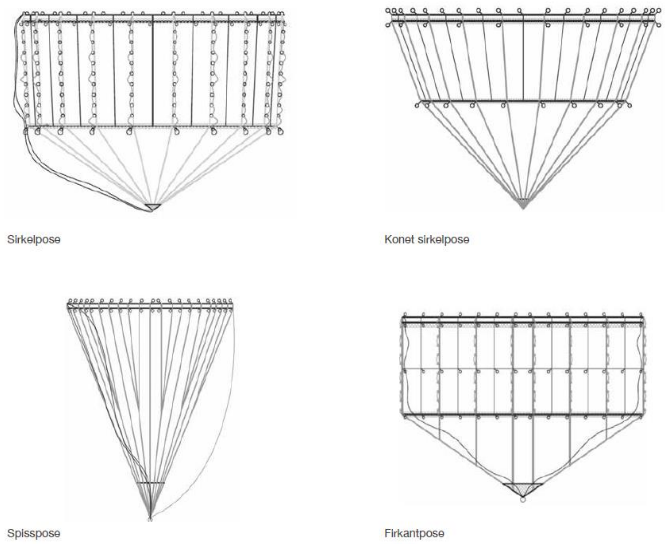

Figure 1: Typical fish nets currently used in the Norwegian fish farming industry. Top left: circular net. Top right: conical circular net. Bottom left: pointed net. Bottom right: squared net

Dimensions representative of a circular cylindrical net have been used for the purpose of this scenario, as circular nets are the most common and as cylindrical nets would have the largest area of the circular nets (i.e. for reasons of conservativeness). Circular cylindrical nets have also been used as representative examples in a report by the Norwegian Food Safety Authority and the Directorate of Fisheries (2010), which is further referred to below.

For circular nets, the development over the past years has been in the direction of larger nets. There are several reports published which confirm this. According to a report on Best Available Techniques (BAT) for fish farming in the Nordic countries (Heldbo et al., 2013), the trend is an increasing fish net size. A survey conducted by the Norwegian Food Safety Authority and the Directorate of Fisheries (2010) shows that between 2005 and 2009, the number of small fish nets has decreased by approx. 60 %, the number of medium-sized fish nets has remained stable, whereas the number of large and very large fish nets has increased considerably, by approx. 530 % and 517 %, respectively. The following table gives the definitions of net sizes used in this survey.

Table 2: Characterisation of fish net sizes

Net size	Net volume	Examples of corresponding net dimensions[1]	Examples of corresponding net areas[2]
Small	< 9000 m^3	C = 60 m, D = 20-30 m	1487-2087 m^2
Medium	9000–19500 m^3	C = 90 m, D = 20-30 m	2445-3345 m^2
Large	19500–39000m^3	C = 120-157 m, D = 20 m	3546-5103 m^2
Very large	> 39000 m^3	C = 157 m, D = 30-40 m	6673-8243 m^2

1) *C = circumference, D = depth*
2) *Corresponding to the given examples of net dimensions*

The total number of fish nets in the different size categories are given in the following figure from the same survey report:

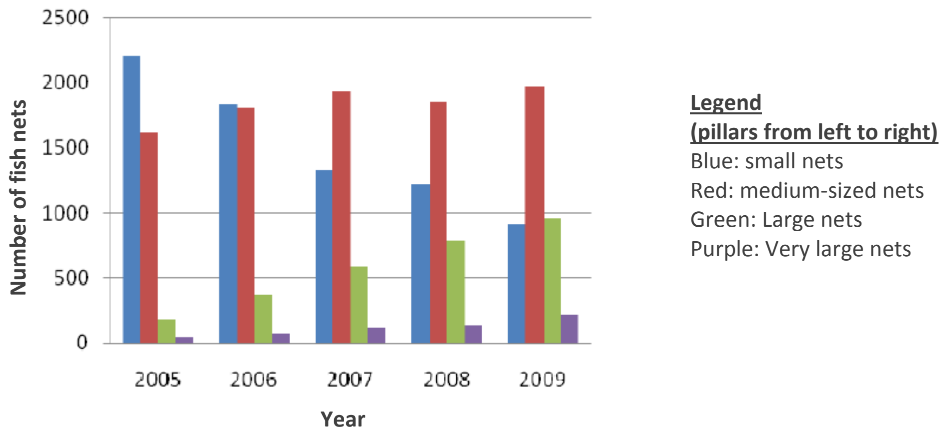

Figure 2: Fish net sizes in the salmon and rainbow trout farming industry from 2005 to 2009.

Based on these numbers, a size corresponding to a large net has been chosen as a default in this scenario. According to a report from SINTEF (Sunde et al., 2008), nets with a circumference of 157 m are becoming increasingly common. Net depth varies depending on sea depth, currents, distance to the coast etc. According to The Norwegian Food Safety Authority and the Directorate of Fisheries (2010), net depths of 20 m are common. In their report, they use a net with a circumference of 157 m (i.e. a radius of 25 m) and a depth of 20 m as an example of a large net. These dimensions are therefore proposed as a default net size, in case nothing else is known of net sizes in the particular country in which a product is sought authorised.

The total area of the default net:

Cylinder area + bottom area = $(157 \text{ m} \cdot 20 \text{ m}) + (\pi \cdot (25 \text{ m})^2) = 3140 \text{ m}^2 + 1963 \text{ m}^2 = 5103 \text{ m}^2$

Time impregnated net is deployed in the water, $T_{deployment}$

Most impregnated nets are deployed somewhere between 5 and 12 months before they are taken up and re-impregnated. The expected lifetime of an impregnated net varies with local conditions such as temperature and currents. As a simplification, we suggest to use 180 days as a default value unless other information is available.

Fraction of released a.i. per deployment time of nets, $F_{a.i.}$

For ships, according to the PT 21 ESD and the CEPE leach rate calculation method, 90 % of the original applied a.i. is assumed to leach out during service life. According to representatives from the Norwegian aquaculture industry, about 20-30 % of the amount of applied antifoulant is left in the net when the net is taken up onto land for re-impregnation. The antifoulants used for fish nets are incorporated into the fibers of the nets, and this is not necessarily comparable to ship antifoulants which are applied on a smooth surface and are meant to have a self-polishing action.

Furthermore, enforcement activities in the past show a substantial release of antifoulants from fish net washing. It has therefore been considered reasonable to assume that 80 % of the originally applied a.i. is released during service life ($F_{a.i.}$ = 0.8), as a reasonable worst case. Currently, many operators rinse/wash the nets while they are deployed because it is not required to change nets while it is fish there and to prevent fouling. The work can be done e.g. by use of ROV (remotely operated vehicle), robots or high pressure water washing. This can happen as frequently as every 10 days and theoretically then the leaching of antifoulants from the nets can increase. As a simplification, however, this scenario focuses on the overall fraction released per lifetime of a deployed net instead of taking into account many smaller intervals / peaks of release during washing of deployed nets. Furthermore, it is assumed as a simplification that the deployment period of all nets on the fish farm is the same, i.e. all nets on the fish farm are deployed for a "season" of 180 days at a time.

During the e-consultation around the preparation of this scenario in December 2014, it was reported that a lower $F_{a.i.}$ is assumed for fish farms in Denmark. This was supported by monitoring data from two Danish fish farming sites. When such information is available at product authorisation, lowering the $F_{a.i.}$ could be an example of an appropriate national refinement option.

3. Scenario for PEC calculations

During the e-consultation round in December 2014, it was agreed that MAMPEC should be the preferred model for the PEC calculations in this scenario. Several options regarding which MAMPEC environmental scenario to choose as representative for a fish farm location were discussed. The OECD EU commercial harbour does not seem to be fitting for a fish farm area as it is assumed that a river runs past the harbour, and that the current (flow velocity, F) relates to the river, not the water movement within the harbour itself. Such a closed-in area with the current running in front of it would not be representative for the layout of fish farm areas. Two other scenarios were considered instead: the open harbour (which is new to MAMPEC v. 3) and the shipping lane.

Open harbour: According to the handbook with technical documentation for MAMPEC v. 3 (van Hattum et al., 2014), the hydrodynamic exchange in this scenario is driven by current alone, similarly to the shipping lane scenario (see figure 3 below). It is recommended to use this scenario if the jetties are absent or floating, i.e. when the area is not as closed in as in a commercial harbour environment. No river is foreseen in this scenario, the current is rather flowing directly through the area. It is considered that the open harbour most closely represents a reasonable worst case location for a fish farm and for this reason, the open harbour has been chosen as a starting point for the purpose of this scenario.

Shipping lane: There is clearly a difference between a fish farm location and a shipping lane. However, if this scenario is to be used as a starting point, the settings would need to be modified in order to create a smaller water volume and reduced currents compared to the original scenario. A modified shipping lane scenario could be used as a refinement option in case such an environment is seen as more representative in an individual country at product assessment, or in an EU wide active substance assessment together with requirements of use in fish net antifoulants only in areas with sufficiently open water exchange conditions.

For more information on the technical details of these two scenarios, please see the MAMPEC handbook with technical documentation (van Hattum et al., 2014).

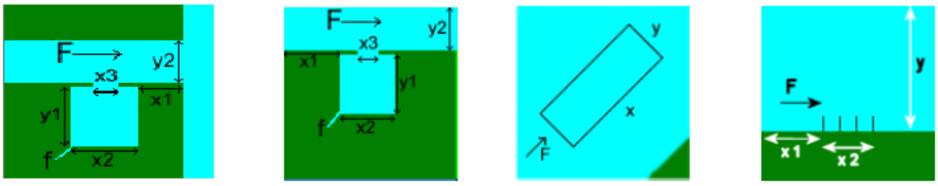

Figure 3: Layouts of (from left to right) a commercial/estuarine harbour, a marina, an open sea / shipping lane and an open harbour in MAMPEC v. 3. For the two scenarios to the left, the flow velocity (F) is defined outside of the area and the hydrodynamic exchange is driven by many factors, whereas for the two scenarios to the right, the flow velocity is defined within the area itself and is the main hydrodynamic exchange driving force.

A calculation example representing reasonable worst case PEC values (i.e. calculated using the open harbour scenario as a starting point) is included in Appendix 1. Regarding the input parameters used in the open harbour scenario, please see the section directly below.

Adjustment of parameters

In line with the discussion of E_{local} parameters, we propose that the input parameters used in MAMPEC for the PEC calculations could be used as default values, but that they can be adapted at product authorisation if there are values available which more appropriately reflect the national conditions.

The open harbour scenario of MAMPEC is used as a starting point for a first tier reasonable worst case fish farm scenario. There is no standard open harbour scenario in MAMPEC, the input fields must be filled in by the user. As the open harbour would more closely resemble the shipping lane than the commercial harbour scenario with regards to water characteristics, general and sediment parameters, it is suggested to use these values also for the open harbour-based fish farm scenario. The temperature should be adjusted to 9 °C, in accordance with the MoTA. Furthermore, the layout and flow velocity are suggested adjusted compared to the shipping lane scenario (see below). Figure 4 further below shows an open harbour scenario with filled in values as outlined above.

Current strength / flow velocity

Sufficient water exchange, i.e. current strengths, are important criteria when assessing and approving new localities for fish farming. This is of importance for the environment, but also (and not the least) for fish health, something that drives the industry towards choosing locations with sufficient flow-through. In the OECD EU shipping lane scenario, the flow velocity is set to 1 m/s (100 cm/s). This would represent a very strong current compared to what can be expected in fish farms. Table 3 shows an example of the categorisation of current strengths at fish farming locations.

Table 3: Examples of current strength categorisation

Reference	Categorisation of current strength in cm/s and impact on sedimentation	
Iversen (2002)	< 3	area very vulnerable, 80 % of readily sinking particles deposited under the net
	4-6	area moderately vulnerable, higher degree of spreading of particles
	7-10	area has a low degree of vulnerability
	>10–25	area not vulnerable to emissions, less than 20 % of particles deposited under the net, and bottom currents might spread these particles further

Several references to recommendations for current strengths in fish farms are given in a report by the Norwegian Institute for Water Research (Golmen et al., 2005). The lowest recommended current is 2 cm/s (article from 1983, for a fish density of 8-10 kg/m^3 which is low compared to today's situation). In a sited article from 1996, a minimum current of 3 cm/s is recommended. According to personal communication from the Scottish Environmental Protection Agency (SEPA), the mean flow velocity in Scottish marine fish farms is 6.74 cm/s.

According to both Golmen et al. (2005) and information from the Norwegian Institute of Marine Research, there is an increase in the number of fish farms in more exposed locations. Also according to Heldbo et al. (2013), there is an increase in the number of fish farms with large nets in the Nordic countries in general. Larger nets with higher fish densities would in many cases need stronger currents both to provide the fish with enough oxygen and to comply with environmental criteria for the establishment of fish farms. Based on these reports and numbers, the following overall flow velocity (F) is suggested as a default value for the reasonable worst case scenario:

F = 3 cm/s

Refinement options: In case of refinements, a flow velocity of 7 cm/s is suggested as a starting point. Based on more knowledge on national conditions or for products which are meant or restricted for use only on nets deployed at more exposed locations, higher flow velocities could be justified on a case by case basis.

Dimensions of the fish farm area

A fish farm containing 10 nets with a diameter of 50 m each (cf. discussion on N_{net} and $AREA_{net}$ above) and some space between/around the nets, would cover an area of approximately 150 · 300 m. Furthermore, there are some requirements for the zone around the installations, which could be taken into account when defining the fish farm area relevant for PEC modelling. For example, there is a Regulation in Norway defining a zone of up to 100 m from the fish farm where no fishing activities are allowed. Furthermore, Standards Norway, an organisation responsible for standards connected to many areas of activity within the Norwegian industry, has published a standard with requirements for environmental sampling and surveillance of the seafloor on and around fish farms (NS 9410:2007). This standard is used by local authorities responsible for aquaculture in Norway when approving and following up sites for aquaculture. Three zones of influence are described; a near zone directly underneath the fish nets where larger particles sediment and which is highly influenced by the fish farm, a transition zone where smaller particles sediment and which is partly influenced by the fish farm, and a remote zone which could be influenced by the fish farm, but where other sources may contribute equally much to any pollution. The near and transition zones are seen as a fish farm's main recipient area, and therefore both these zones should be considered when defining an area for the fish farm. The zones are however not clearly defined, possibly as they are considered dependent on local conditions such as currents and seafloor topography. The consulting company Aquakompetanse (Sandnes, 2010) operates with a near zone up to 15 m from the farm and a transition zone up to 150 m from the farm. In connection with an ongoing revision of standard NS 9410:2007, the Norwegian Marine Research Institute has proposed that the transition zone should be more clearly defined, and has preliminarily suggested that it could cover an area of 300 m from the installations. On this background and in order to take into account that the reasonable worst case scenario should reflect a somewhat sheltered area, it is suggested to add 150 m to the length and width of the fish farm installations (which cover an area of approx. 150 · 300 m), to give an area of 300 · 450 m. Regarding the depth, the suggested reasonable worst case net depth is 20 m (cf. discussion of $AREA_{net}$ above). According to Iversen (2002), there should be at least 10 m between the net and the seafloor. Therefore, a reasonable worst case depth of 30 m is suggested. In conclusion, the following default dimensions could be used as a first tier approach:

	Reasonable worst case scenario
Area (length · width of fish farm):	300 m · 450 m
Depth:	30 m
Total volume:	4 050 000 m^3

Figure 4 shows an open harbour scenario which has been filled in with the values outlined above.

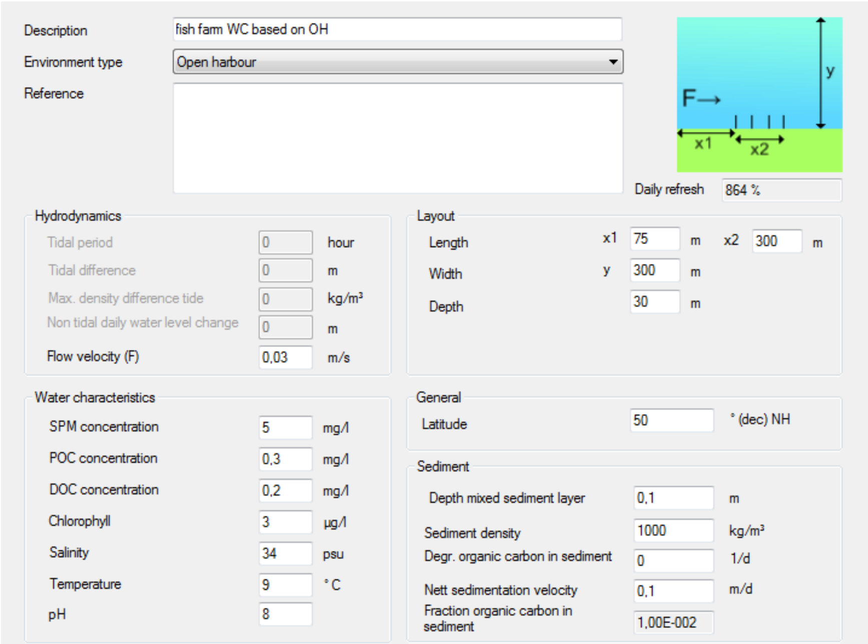

Figure 4: Example of an open harbour scenario where input values have been filled in as described in the text above. The water characteristics (with the exception of the temperature) and general parameters are identical to those used for the standard OECD EU shipping lane scenario. The flow velocity is set to 3 cm/s as described in the text. Regarding the layout, the area is defined as x1 + x2 + x1 · y. The length of the emission source (the fish nets), represented by x2, is 300 m. In order to get a total length of x of 450 m, x1 is set to 75 m. The width of the fish nets is represented by y, and is set to 300 m as described in the text.

Refinement options: If it can be argued, or set as a requirement, that a product is to be used on more open and/or deep fish farm locations than the area described in the reasonable worst case scenario, for example not close to shore, the area and depth of the fish farm area could be modified on a case by case basis.

A calculation example for a fictitious product, using the calculation of E_{local} as described above as well as the reasonable worst case scenario for PEC modelling, is included in Appendix 1.

4. Other models

During the e-consultation in preparation of this scenario in December 2014, it was agreed that MAMPEC should be the preferred model for this scenario as according to the current knowledge no other models exist which would give a significant advantage over MAMPEC regarding fish farm PEC calculations. However, some other models were mentioned which could be consulted e.g. in case of refinements:

- DEPOMOD, developed by the Scottish Environment Protection Agency / the Scottish Marine Institute: http://www.sams.ac.uk/kenny-black/depomod, http://www.ecasatoolbox.org.uk/the-toolbox/eia-species/models)
- CoZMo-POP: http://www.utsc.utoronto.ca/labs/wania/downloads

5. Further development and refinement

- The consequences of in-situ washing of nets should be further evaluated and included in the scenario if this practice is becoming more common.
- The possible emission from washing on shore before re-treatment of nets should be included in the risk evaluation in countries where this is still allowed or common practice. An alternative is a general statements regarding need for RMM like what has been introduced for handling of possible releases from wood impregnation plants in all approvals for PT8 substances.
- Further data on the influence of different types of fibers might give possibilities to refinements in the input parameters.
- More real measured data on the F_{ai} might trigger a revision of the default value of 0.8, or real products specific values could be used at product authorisation stage.

References

Golmen et al., 2005: *Regionalt Utviklingsprogram (RUP) Hordaland – Forprosjekt "Havbruksanalyse", Bølgjer og strøm som lokaliseringskriterium*, Norsk institutt for vannforskning, Report No. 5063-2005

Heldbo (ed.) et al, 2013: BAT for fiskeopdræt i Norden – Bedste tilgængelige teknologier for akvakultur i Norden. TemaNord Report No. 2013:529, Nordic Council of Ministers

Iversen, 2002: *Resipientundersøkelse i forbindelse med etablering av oppdrett av matfisk av torsk (Gadhus morhua L.) og dyrking av blåskjell (Mytilus edulis L.) ved Landegode i Bodø kommune, Nordland*, Nordlandsforskning, Report No. 17/2002

Norwegian Food Safety Authority and Directorate of Fisheries, 2010: *For stor merd eller for mange fisk? Fiskeridirektoratets og Mattilsynets anbefalinger*, review with recommendations for the aquaculture industry in Norway

Sandnes, 2010: *Lokalitetskrav, overvåking og anbefalt oppfølging*, *Nasjonal vannmiljøkonferanse 10.-11. mars 2010*, Aquakompetanse, presentation

Sunde et al., 2008: *Tiltak for å begrense kobberbruk i havbruk – optimalisere metoder for å impregnere not*, SINTEF, Report No. SFH A084055

van Hattum et al, 2014: *MAMPEC 3.0 handbook, Technical Documentation*, IVM Institute for Environmental Studies, Report No. R-14/33

APPENDIX 1 – calculation example

Example product: copper-based antifoulant containing 20 % (wt/wt) copper, i.e. 200 g/L

Daily emission from the nets on the fish farm, E_{local}

E_{local} (g/d) = ($N_{net} \cdot AREA_{net} \cdot W_{net} \cdot COVERAGE \cdot C_{a.i.} \cdot F_{a.i.}$) / $T_{deployment}$
= (10 · 5103 m^2 · 0.36 kg/m^2 · 1 L/kg · 200 g/L · 0.8) / 180 d
= 16329.6 g/d

PEC calculations, MAMPEC v. 3.0.1

Reasonable worst case scenario – modified open harbour scenario, 450 · 300 · 30 m

Environment: settings from OECD EU shipping lane, with the following adjustments (cf. text and fig. 4 above):
length x1: 75 m, length x2: 300 m, width y: 300 m, depth: 30 m
F = 0.03 m/s
Temperature: 9 °C
Compound: copper (total)
Emission: E_{local} = 16329.6 g/d, entered manually

Average concentrations:

Water, total	1.53E−01 µg/L
Water, dissolved	1.33E−01 µg/L
Suspended matter	4.00 µg/g dw
Sediment after 1 y	7.29E−03 µg/g dw
Sediment after 10 y	7.23E−02 µg/g dw

Note on background concentrations

Please note that for these calculations, the background concentration of copper has been set to 0. In reality, it is likely that there is a background concentration of copper in the area, in particular where a fish farm already is established. This might influence the resulting PEC values considerably. Member States should consider this when evaluating products for use in their countries. Information from the evaluation of copper as a PT 21 active substance could also be used in this respect.