Summary

This paper presents guidance for setting consent limits on in-feed therapeutants where the predicted fate of the contaminants may not be determined by the routine method (DEPOMOD modelling) due to bulk export of a significant proportion of the applied load from the model domain. The guidance is therefore precautionary, taking account of the need to assess the risk in different situations.

In topographically constrained areas it is recommended that the mass of chemical exported from the far field allowable zone of effect is limited to that required to disperse over half of the 'up-loch' low water area to the far-field Environmental Quality Standard concentration.

In topographically unconstrained areas it is recommended that the mass of chemical exported from the far field allowable zone of effect is limited to that required to disperse over 10 km^2 to the far-field Environmental Quality Standard concentration.

Contents

Glossary of acronyms

AZE	Allowable zone of effect	MAC	Maximum allowable concentration
EQS	Environmental quality standard	MATC	Maximum allowable toxicant concentration
EmBZ	Emamectin benzoate	NOEC	No observable effect concentration
FF-	Far-field	TFBZ	Teflubenzuron

1 Introduction

Predictions of the fate of in-feed anti-parasitic chemicals, as used at marine caged fish farms, are routinely made using the DEPOMOD particle-tracking modelling software. The simulated area is limited to a 1 km^2 model domain surrounding the discharge source by virtue of the use of a single point current data record to drive the model. In hydrographically dynamic areas, typically where the near-bottom current speeds exceed the resuspension threshold for extended, or multiple, periods of the 15-day data record, the fate of a significant proportion of the discharged chemical may lie beyond the model domain, either in the open sea or in an accretion zone. An alternative assessment of the potential for breaches of the far-field EQS is required where the routine modelling strategy is inadequate.

It can be predicted, by use of a hypothetical model as presented in section 5, that the export of teflubenzuron from the far-field AZE has the potential to result in some breach of the far-field EQS if an appropriate constraint is not imposed by appropriate consent conditions.

The method outlined in this document to assess the release of in-feed chemicals at dispersive sites is the approach adopted by SEPA and should be used by applicants unless it is proposed to provide some other robust methodology for making this assessment. SEPA are happy to accept other methodologies, supported by the scientific literature, to solve the problem of setting limits at dispersive sites. Such approaches will be assessed on a case by case basis. If in doubt about a methodology or to confirm the robustness of a proposed approach, please contact FFModelling for discussion before submitting the application.

One example of another potential way of assessing the export would be to assume that the amount of sea lice treatment chemical that is predicted by Autodepomod to be left within the near field area remains within this area; and the amount of chemical that is predicted to be exported to the far field area is limited to the 10km^2 area (discussed in section 4) at the far field EQS standard. The two values may then be added together to form a consent recommendation.

2 Environmental Quality Standards

2.1 Far-field EQS

Ecotoxicological studies have been undertaken to determine 'no observable effect concentrations' (NOEC) and 'maximum acceptable toxicant concentrations' (MATC) for species identified as representative of the most sensitive fauna that may potentially be impacted by the discharge of these anti-parasitic therapeutants. Environmental quality standards (EQS) have been derived from the resulting concentrations by applying a safety factor. Hereafter, the far-field Environmental Quality Standard is referred to by 'FF-EQS'.

2.1.1 Teflubenzuron

The current FF-EQS for teflubenzuron (TFBZ) is 0.002 mg/kg of dry sediment. This has been derived from a NOEC with a x10 safety factor. For modelling purposes this is determined using a standard sediment density of 1216 kg/m^3 and a standard mixing depth – due to bioturbation – of 5 cm.

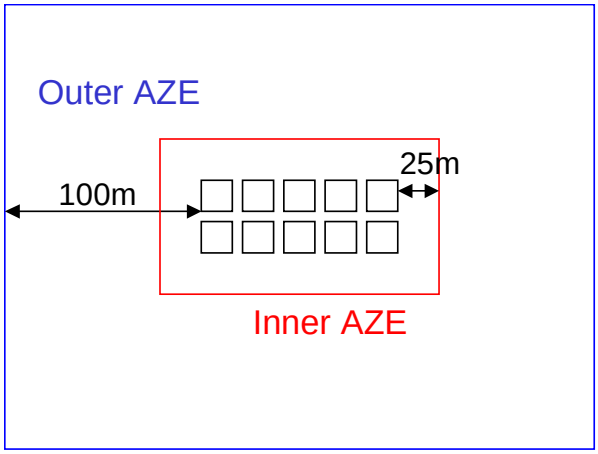
2.1.2 Emamectin benzoate

The current far-field sediment EQS for emamectin benzoate (EmBZ) is 0.763 µg/kg of wet sediment. This has been derived from a MATC with a x100 safety factor. For modelling purposes this is determined using a standard sediment density of 2416 kg/m^3 and a standard mixing depth – as a result of bioturbation – of 5cm.

2.2 Far-field Allowable Zone of Effect

SEPA's current position is to apply an EQS as a maximum allowable concentration (MAC) beyond an area termed the 'far-field allowable zone of effect' (AZE). This AZE is defined as being equivalent to the area of the cages plus a 100 m margin. This is illustrated in Figure 2.1.

Figure 2.1 Illustration of AZE for group of ten square cages



2.3 Summary

SEPA currently limits the use of in-feed anti-parasitic chemicals by predicting the quantity that may be discharged from a fish farm site that does not result in a sediment concentration in excess of the EQS beyond the far-field AZE.

3 Precautionary 'best case' calculation

In terms of the assessment currently adopted, the best environmental outcome is that 'lost' chemical, for which the fate lays outwith the AZE, is deposited at concentrations lower than the far-field EQS.

In reality the actual distribution of material will be variable, dependent upon the vagaries of local currents and natural break-down processes, including duration in the photic zone; however, if the 'best case' of an even distribution is assumed, then the EQS may take the role of a cut-off concentration, determining the minimum area over which any specific quantity of chemical must be spread to maintain the EQS. Variable distribution however poses a theoretical risk that the FF-EQS may be breached.

As an **example**, 1 kg of teflubenzuron is distributed at the EQS concentration if it is evenly mixed with 1,000,000/0.002, or 500,000,000 kg of sediment.

At a sediment density of 1216 kg/m^3 the required volume of sediment is 500,000,000/1216, or 411,184.2 m^3.

By applying the bioturbation depth of 5 cm, the area of the required sediment is 411,184.2/0.05, or 8,223,684 m^2.

Thus, 1 kg of TFBZ must be evenly distributed over an area in excess of 8.2 km^2 for the EQS to be maintained.

In general:

$$\text{area} = \frac{\text{mass}}{\text{concentration} \times \text{density} \times \text{depth}}$$

and conversely:

$$\text{mass} = \text{area} \times \text{concentration} \times \text{density} \times \text{depth}$$

For each chemical, the EQS concentration, sediment density and bioturbation depth are constant. Therefore, a constant factor can be calculated by which mass and area may be inter-converted. The respective factors for both teflubenzuron and emamectin benzoate are presented in Table 3.1.

Table 3.1 Area-Mass conversion factors at EQS

teflubenzuron (TFBZ)	0.1216 m^2/mg
emamectin benzoate (EmBZ)	92.1704 m^2/µg

Similarly, the mass of chemical in the sediment, derived by the method above, can be related to a biomass treated at the dose rate specified by the respective manufacturers.

In general:

$$\text{biomass} = \frac{\text{sediment mass}}{\text{loss factor} \times \text{dose rate} \times \text{duration}}$$

and conversely:

$$\text{sediment mass} = \text{biomass} \times \text{dose rate} \times \text{duration} \times \text{loss factor}$$

where: biomass (kg)

'dose rate' is manufacturer's recommended daily treatment dose; 10mg/kg for TFBZ and 50 µg/kg for EmBZ.

'duration' is length of treatment; 7 days for both TFBZ and EmBZ

'loss factor' is the proportionality between the applied treatment mass and mass in sediment due to a combination of one or all of decay, excretion and retention in flesh; 90% for TFBZ and 74% for EmBZ.

For each chemical the loss factor, dose rate and treatment duration are constant. Thus constant factors may be derived to convert chemical sediment mass and treatable biomass. These are presented in Table 3.2.

Table 3.2 Mass-Biomass conversion factors at EQS

teflubenzuron (TFBZ)	0.0063 g/kg
emamectin benzoate (EmBZ)	0.0000259 g/kg

4 Constraints on receiving areas

The area available for dispersion determines the significance of the proportion of applied therapeutant exported from the model domain. Therefore, at a site within a sea-loch that is characterised by a residual current toward the head of the loch, the area 'up-loch', or 'headwards', of the site may be used to set a limit on the quantity of chemical that can be accommodated and hence that may be exported from the model domain.

When the exported chemical is transported toward open water, there is less restriction on the receiving area; however, the strong currents that result in bulk resuspensive transport may be localised – as in a strait – and dwindle to below the deposition threshold before reaching a receiving area of sufficient expanse to accommodate the chemical burden at concentrations less than the EQS.

There is currently insufficient information available for the majority of Scottish coastal waters to support rigorous assessment of the likely dispersion of material beyond the areas modelled; consequently, a precautionary approach to the setting of consent

quantities is recommended, accompanied by a requirement to carry out monitoring imposed by consent conditions.

As a guide, for sites in unconstrained areas, export is considered significant where greater than 1216 g of TFBZ or 922 g of EmBZ is exported from the model domain – these quantities would theoretically result in 10 km^2 of seabed reaching the respective FF-EQSs. At sites where the near-bed residual current is towards a topographically constrained area, the available receiving area should be determined and the quantity of chemical exported from the model domain compared with the value derived using the area-mass conversion factors.

5 Environmental Risk

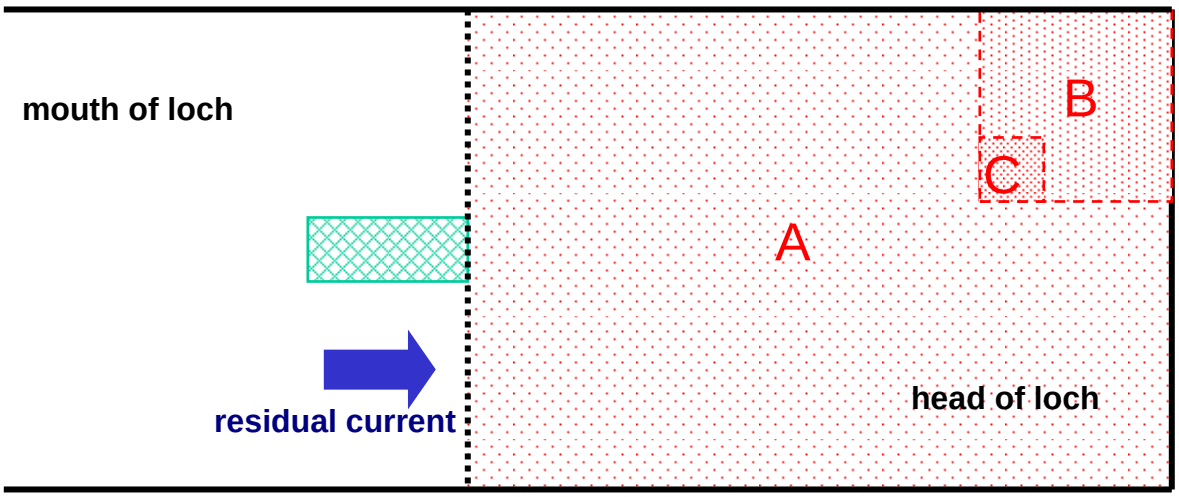
The potential problem can be illustrated by the following example of a treatment with Calicide at a site holding 500 tonnes of fish in a highly dispersive area, where *all* of the excreted TFBZ is exported from the far-field outer AZE. Calculations indicate that an area of 260 km^2 would be required to disperse the quantity discharged and still meet the EQS for TFBZ. As previously stated, this is a hypothetical situation, and the distribution of the impacted sediment will be variable, with areas where chemical concentration falls below the EQS value and 'hot-spots' where the EQS may be exceeded for a limited period of time.

Appropriate restrictions are required therefore to manage this risk. Where the high currents responsible for the bulk export of chemical from the far-field AZE are expected to prevail over a distance in excess of 3 km from the site, the exported material should be distributed over an area in excess of 10 km^2. Allowable export quantities may be derived by application of the conversion factors of described in section 3. While transient hotspots exceeding the EQS are possible these are not expected to present any significant environmental risk due to the safety factors built into the derivation of standards and the modelling approach.

Using a simplified 'topographically constrained' situation as an example and by reference to the areas defined in Figure 5.1, it is evident that if sufficient chemical leaves the AZE to cover area 'A' at the FF-EQS, then, should the dispersion be constrained to area 'B' – 10% of 'A' – concentration will theoretically be 10 times the FF-EQS. Similarly, dispersion constrained to area 'C' may result in concentrations of 100 times the FF_EQS.

In situations therefore where dispersion is not fully defined, concentrations of generally less than the FF-EQS and predominately less than 10 times the FF-EQS can be expected by limiting the quantity of chemical exported from the FF-AZE to 50% of that required to cover the 'up-loch' area to the FF-EQS. This approach affords an acceptable level of confidence that environmental conditions will not be impacted to an unacceptable degree.

Figure 5.1 Relative impact areas 'up-loch' of cage site.



Notes: A = low water area of loch above cage site

B = 10% A

C = 1% A

6 Recommended limits

6.1 Topographically constrained receiving area

Where receiving area is constrained, as in a loch or voe with a 'headward' residual, the quantity of chemical should be restricted to that sufficient to cover 50% of the available seabed at the EQS concentration. For this purpose 'available seabed' is defined as low water area 'headward' of the farm site.

6.2 Topographically unconstrained receiving area

Where the receiving area is unconstrained, and where the prevailing currents can reasonably be expected to prevent settlement for 3 km it is recommended that the quantity consented is limited to that required to contaminate 10 km^2 at the EQS concentration. This equates to sufficient EmBZ to undertake a treatment of 3558.7 tonnes biomass and a quantity of TFBZ sufficient to treat 19.3 tonnes.