SCOTTISH ENVIRONMENT PROTECTION AGENCY

POLICY NO 28

Initial Dilution and Mixing Zones for Discharges from Coastal and Estuarine Outfalls

This policy was agreed by SEPA's Corporate Management Team on 24 August 1998 following external consultation with the following organisations:

East of Scotland Water Authority
North of Scotland Water Authority
West of Scotland Water Authority
Malt Distillers Association
Convention of Scottish Local Authorities
Friends of the Earth Scotland
Keep Scotland Beautiful
Scottish Office (Water Services Unit & Environment Protection Unit)
Chemical Industries Association
Confederation of British Industry (Scotland)
Environment Agency
Northern Ireland Environment & Heritage Service
Scottish Wildlife & Countryside Link

This policy is intended to inform the decisions taken by SEPA when consenting discharges to marine waters. The policy will also provide dischargers and other interested parties with the expectations and context within which SEPA will arrive at its decisions. The policy attempts to maintain an appropriate balance between sufficient prescription to provide a useful regulatory framework and sufficient flexibility to remain applicable to the potentially wide range of situations encountered. SEPA accepts that a degree of interpretation of the policy may be required to safeguard appropriate environmental standards.

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Scottish water authorities and private industry depend heavily on the use of the marine environment for the disposal of effluents. Most coastal towns and many large commercial plants discharge their wastewater directly to the sea through a sea outfall. As the effluent discharges, it usually forms a buoyant plume which rises to the surface. Sea water becomes entrained and mixing occurs, diluting the plume as it rises to form a surface "boil". The degree to which this occurs varies considerably as the tidal cycle alters both the depth of the outfall below the surface and the ambient velocity of the water past the end of the outfall. The dilution which the plume receives as it rises from the point of discharge is known as the **initial dilution**.

Subsequent, or secondary, mixing with the receiving water occurs away from the boil and is generally slower, the rate depending on hydrographic conditions. If the initial effluent is buoyant then this secondary mixing will normally be restricted to the upper layers of the sea until the relative densities are such that mixing can take place throughout the water column.

SEPA may identify an area of sea surface surrounding a surface boil and define it as a **mixing zone.** This zone comprises an early part of the secondary mixing process and is prescribed to ensure that no environmental damage will be encountered outwith its boundaries. An individual mixing zone is only defined with respect to an established environmental quality standard (EQS) for a particular polluting substance. The mixing zone is the area of sea surface within which the EQS will be exceeded.

This policy lays down a common set of SEPA criteria for quantifying these dilution processes, while recognising that there may be different degrees of complexity and site specificity involved, depending on the nature and composition of the discharge, and the dynamics and sensitivity of the receiving water. This policy does not apply to marine fish farm installations.

The objective of defining mixing zones is to allow a rational and sound scientific basis for the derivation of marine discharge consent conditions which can be related to readily enforceable end of pipe effluent concentrations and design criteria.

Initial Dilution

SEPA will expect new or modified sewage discharges with greater than 100 population equivalent to be designed and constructed to provide:

- minimum initial dilution of 100 times (95 percentile) for primary treated effluents
- minimum initial dilution of 50 times (95 percentile) for secondary treated effluent, including septic tank effluent.

These criteria are based on the estimated requirements to reduce to acceptable levels both the visibility of density slicks and the occurrence of smell nuisance.

- minimum initial dilution of 50 times (95 percentile) is also expected for significant new or modified industrial discharges, although these will be judged on a case by case basis.

A mean rate of flow of effluent will be used when deriving the estimates of initial dilution.

These expectations will be applied uniformly in coastal waters, but SEPA accepts that discharges made at certain estuarine locations may not be able to achieve these minimum criteria. Exceptions may also be considered where the discharger can demonstrate to SEPA's satisfaction that the costs associated with complying with these standards are excessive in relation to the environmental benefit.

Careful design of the type and position of the outfall diffuser can maximise the initial dilution that is achieved and hence minimise the environmental impact of the discharge. In order to do this, some form of numerical modelling is required. In addition, modelling can assist in determining the shape and dilution potential of the mixing zone. All modelling work must conform to SEPA's generic modelling requirements listed in Appendix 1.

Dischargers will be expected to use one of the models listed in Appendix 2 to ensure compatibility with SEPA's ability to audit the calculations. This list will be updated as necessary and dischargers may use other models if agreed in advance with SEPA.

Particular checks should be made that the effluent plume reaches the sea surface after initial dilution for all possible combinations of effluent density and receiving water stratification. If it is found that the effluent cannot always be guaranteed to reach the surface then this extra complication with all its implications for water quality must be considered. In these cases, appropriate standards may have to be met at the point that the plume is stopped by a density barrier after only limited initial dilution.

SEPA accepts that, in specific cases, a phased approach may be appropriate for the implementation of outfall design requirements. Any phasing arrangement will be included in the consent conditions.

The potential dilution, shape and orientation of any mixing zone under various hydrographic conditions cannot be usefully defined without some technical monitoring of the specific receiving water. Field studies may have to include some temperature and salinity measurements to assess the likelihood of stratification. The identification of a suitable outfall location and derivation of appropriate consent conditions, based on design requirements, will require an assessment of the total dilution, subject to the conditions 1-10 listed below.

The mixing zone should meet all of the following criteria that are relevant:

1. It is expected that the mixing zone around the effluent surface boil would normally be set at a maximum distance of 100m in any direction (that the plume may travel) from the centre of the boil, or from the nearest individual diffuser boil where there is a multiport arrangement. The dilution this allows must be calculated for each site.

2. The concentration of dispersing effluent must be such that no established relevant UK or SEPA chemical Environmental Quality Standard is breached outwith the mixing zone. This must take account of the individual standards which may be expressed as annual mean values, or percentile exceedence values, or maximum allowable concentrations.

3. Where an effluent requires control through toxicity-based criteria then the concentration of dispersing effluent must be such that there is no residual toxicity outwith the defined mixing zone ie. the residual concentration of the toxic substance shall comply with the Predicted No Effect Concentration (PNEC) lethal or sub-lethal, acute or chronic, determined from an appropriate SEPA approved toxicity test (see Definitions).

4. After initial dilution there should no point within the mixing zone where the residual concentration of effluent exceeds the 3 hour acute No Observed Effects Concentration (NOEC) for any SEPA approved lethal or sub-lethal test. Twenty-four hour acute tests may be substituted where such test data cannot be obtained.

5. Two or more mixing zones from different neighbouring outfalls must not merge or take up all the diluting capacity of any receiving water body. It is recommended that the edges of the mixing zones be at least 100m apart. If, for any reason, this criterion cannot be met, then the toxicity of the mixed effluents must be considered.

6. Normally no mixing zone would be expected to impinge on the MLWS shoreline, although SEPA recognises that this may be varied in narrow estuarine locations.

7. A mixing zone should generally not plug an estuary, sea loch or small bay. It is expected that a mixing zone in such a situation should take up no more than a half of the narrowest dimension.

8. SEPA has a statutory obligation, under the Conservation (Natural Habitats etc.) Regulations 1994, not to issue a consent for any discharge which has been shown, by an appropriate assessment, to be likely to have an adverse effect on the designated conservation interests of a Special Area of Conservation (SAC, under the European Habitats Directive) or a Special Protection Area (SPA, under the European

Wild Birds Directive). Where a mixing zone may impinge on any SAC or SPA, SEPA has a duty to ensure, before issuing a consent, that the integrity of the site will not be adversely affected. The integrity of a site is defined (Scottish Office Circular 6/1995) as the coherence of its ecological structure and function, across its whole area, that enables it to sustain the habitat, complex of habitats and/or levels of populations of the species for which it was classified. SEPA will ensure that no mixing zone will jeopardise the integrity of any designated sites, and will apply the same approach to other sites with statutory conservation designation (eg SSSIs). Consideration will also be given to other areas which have a recognised, but non-statutory, conservation interest (eg Marine Consultation Areas).

9. The mixing zone should not give rise to any significant visible slicks or other aesthetic problems.

10. Where solids are present in the effluent, and where these solids are expected to accumulate on the sea bed, a similar approach to that used for the liquid dispersal will be utilised. In this case the 100m mixing zone is retained but the toxicity criteria must recognise the extended exposure times possible for the resident benthic organisms.

    The sea bed sediment must meet standstill clauses for appropriate EC dangerous substances outside the mixing zone. Build up of other potentially toxic substances must also be avoided but no formally accepted quantitative standards currently exist.

    SEPA will expect that no solids will be permitted to accumulate on the sea bed within the identified mixing zone in quantities which would give rise to acute toxicity. However, the science of sediment toxicity is in a developmental stage with no widely agreed protocols for toxicity testing. SEPA will discuss individual cases with each discharger.

    Where adverse benthic effects can be demonstrated to arise only from non-persistent organic sources then the levels of acceptable change will be as described in 3.3.3 pp9-10 of the Comprehensive Studies Task Team Report, second edition (1997)[1]. The predictive BenOss model UKWIR(1996)[2] may be used where the organic load is expected to be significant.

It is recognised that calculating the dilution and potential effects resulting from defining a mixing zone in this way requires a degree of accompanying survey work and technical data that may not be available or reasonably obtainable. The decision on whether to relax any of these guidelines has to be site-specific and based on a sound assessment of risk. Previous SEPA experience has shown that some effluents exhibit either greater or lesser toxicity than an existing knowledge of their chemical constituents would suggest. A preliminary toxicity screening of any significant complex effluent should be undertaken before assuming toxicity does not need to be considered.

Definitions

For the purposes of interpreting this policy the following terms are defined:

Acute toxicity:
Toxicity arising from exposure of an organism for a period which is short relative to the life

span of that organism. This would be in the order of minutes for bacteria and usually up to 4 days for fish. The duration of an acute toxicity test is generally 4 days or less and mortality is the response most often measured.

Chronic toxicity:
Toxicity arising from exposure of an organism for a period which is a significant proportion of the life span of that organism, such as 10% or more. A chronic toxicity test is used to study the effects of continuous long-term exposure to a chemical or other potentially toxic material.

No Observed Effect Concentration (NOEC):
The highest concentration of a material in a toxicity test that has no statistically significant adverse effect on the exposed population of test organisms as compared with the controls.

Predicted No Effect Concentration (PNEC):
The environmental concentration of a chemical or substance which is regarded as a level below which the balance of probability is such that an unacceptable effect will not occur.

References

1. Comprehensive Studies for the purpose of Article 6 & 8.5 of Dir 91/ 271 EEC. The Urban Waste Water Treatment directive. Comprehensive Studies task Team, Marine Pollution Monitoring Management Group - Second Edition 1997.

2. Forecasting the Deposition and Biological Effects of Excess Carbon from Sewage Discharges. UK Water Industry Research Limited 1996.

APPENDIX 1

SEPA Standards for models

These guidelines form the basis of a common core of generic standards required by mathematical modelling presented to SEPA. It is important that all work presented to SEPA is based upon sound science using the best available information and that the models used

are shown to be "fit for purpose". The sophistication and cost of any project will be expected to reflect the complexity and scope of the scenario to be modelled.

The following eleven points list the key areas which any modelling studies for any media should cover. The points are equally applicable to a simple study of the environmental impact of a septic tank discharge or to the design and location of a large power station smoke stack, except that the scope and depth of the study will vary.

1. Statement of objective - to explain clearly the situation being modelled and the objectives of the modelling study, including details of the output required from the model.

2. Justification of the model - to demonstrate that the model used is suitable for this study, this should include examples of previous applications in similar circumstances.

3. Technical description of model - history of the model, development history, published articles, details of the conversion of the model into a software package. Details of the experience and training of the model users.

4. Data - any model is only as good as the source data, the data required for the model must be clearly defined.

5. Data collection - the data collection and measurement techniques should be quoted, including expected errors and relevant quality assurance. The raw data should be available to SEPA if required, as should details of the instrumentation and their calibrations.

6. Calibration - it is important that the model is calibrated against a full data set which is representative of the range of conditions to be modelled. The model coefficients to be calibrated and the procedures used to optimise the calibration must be stated clearly.

7. Validation - data sets independent of those used for calibration must be employed for validation tests. Every effort should be made to validate the model across the range of conditions for which it will be run. Validation tests and analysis of model errors must be undertaken for the key variables required from the modelling study.

8. Sensitivity analysis - this analysis must be presented to demonstrate the effect on the key output parameters resulting from variation of input data and controlling assumptions.

9. Quality assurance - to demonstrate that the model has been subject to an evaluation procedure establishing its suitability for the relevant tasks.

10. Auditability - to ensure that there is a clear account of the modelling exercise for inspection by SEPA.

11. Reporting - clear description of the model including the underlying principles and implicit or explicit assumptions. Also a clear summary of the numerical output, the likely errors, bias, sensitivity and their implications for the objectives of the study and the conclusions.

APPENDIX 2

Approved Initial Dilution Models

- **ELSID**

The ELSID software is freely available from the Environment Agency of England and Wales. The program can calculate dilutions for discharges into still waters, calculate dilutions for

discharges into tidal waters and perform Monte-Carlo simulations of initial dilution to calculate 95 percentile compliance. Particularly for small discharges, it is recommended that the Cederwall equation is used and this is provided as part of ELSID.

- **PLUMES**

PLUMES is a model from the United States Environment Protection Agency which includes two initial dilution models and a model interface manager for preparing common input and running the model. PLUMES models are intended for use with plumes discharged to marine and fresh water.

- **CORMIX**

CORMIX is a length scale model intended for the analysis and prediction of wastefield characteristics and dilutions of submerged multiport discharges. It attempts to cover cases of positively or negatively buoyant discharges issuing into stratified or non-stratified flowing water. If sufficient hydrographic data are available CORMIX can also be used to calculate potential dilution within a defined mixing zone.

Which model is chosen for a particular outfall will be dependent on the situation and should be discussed with the appropriate SEPA staff. In general terms ELSID should be chosen where the water is not too shallow and the rising plumes from multiport diffusers do not merge. In more complex situations CORMIX or PLUMES should be used. All of these models are available free, subject to certain use conditions. Use of the above models does not exclude any discharger, or their consultants, using other calculations in addition to these for their own purposes.