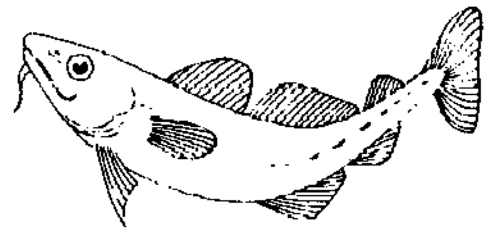
ISSN 0142-2499

AQUATIC ENVIRONMENT MONITORING REPORT
Number 39



Marine Pollution Monitoring Management Group

Fifth Report of the Group Co-ordinating Sea Disposal Monitoring

MAFF

Directorate of Fisheries Research
Lowestoft, 1993

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

AQUATIC ENVIRONMENT MONITORING REPORT
Number 39

Marine Pollution Monitoring Management Group

Fifth Report of the Group Co-ordinating Sea Disposal Monitoring

LOWESTOFT
1993

This report was written and compiled by J. Jones, S. M. Rowlatt, BSc PhD, H. L. Rees, MSc PhD and the Chairman of the GCSDM, J. E. Portmann, BSc PhD of the MAFF Fisheries Laboratory, Burnham-on-Crouch, Essex CMO 8HA, from whom further copies may be obtained.

Aquat. Environ. Monit. Rep., MAFF Direct. Fish. Res., Lowestoft, (39): 42pp

CONTENTS **Page**

/ continued

FOREWORD

This is the fifth report of the Group Co-ordinating Sea Disposal Monitoring (GCSDM), a sub-group of the Marine Pollution Monitoring Management Group (MPMMG).

The Group was established in 1987 to co-ordinate UK effort and resources applied to monitoring the impact of sewage-sludge disposal at sea.

It directly addressed the problems of inconsistent and unco-ordinated monitoring by laying down a set of environmental quality objectives (EQOs) together with a set of descriptive environmental quality standards (EQSs) by which fulfilment of these objectives could be judged. Detailed guidelines and procedures for certain types of monitoring were also provided. Work continued with the EQOs and EQSs being further developed and numerical values set which take into account the different characteristics of disposal sites.

The Group has produced reports on an annual basis, detailing its progress and that of its Specialised Task Teams. Each report also contains a review of monitoring carried out in the previous year and assesses the extent to which the methods used complied with the GCSDM guidelines. It also assesses the extent to which the results show that the defined EQOs and EQSs are being met.

In 1991, the MPMMG extended the remit of the Group to cover other sea disposal operations such as dredged material disposal. The Group has found that the similarities between dredged material disposal and sewage sludge disposal mean that, with some amendments, the objectives previously identified for sewage sludge should be equally applicable to dredged material. EQOs and EQSs for dredged material disposal have been proposed on this basis.

P. W. Greig-Smith
Deputy Director
(Aquatic Environment Protection)
Directorate of Fisheries Research
Ministry of Agriculture, Fisheries and Food

EXECUTIVE SUMMARY

In this fifth report, the Group Co-ordinating Sea Disposal Monitoring (GCSDM) details the activities of its Task Teams, continues its evaluation of the monitoring of sewage-sludge disposal sites by the assessment of the results from programmes undertaken in 1991 and summarises monitoring activities carried out during 1992.

In June 1992, the GCSDM established a new Task Team to aid the Department of the Environment (DoE) in the implementation of the Urban Waste Water Treatment Directive. The Team was charged with defining comprehensive studies to predict ‘no adverse effects’ in support of proposals for less sensitive areas under the new Directive. Preliminary studies have been proposed for Coastal Waters.

In view of the similarities between the disposal of dredged material and the disposal of sewage sludge, the Group has proposed EQOs and EQSs for dredged material based on those previously defined for sewage sludge. The GCSDM will continue to develop the standards with a view to the inclusion of relevant parameters and recommending appropriate numerical limits.

Work was completed in 1992 on the development of a biotic index which could be applied to marine situations. Proposed by the GCSDM, the work was undertaken jointly with financial support from the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) and the National Rivers Authority (NRA). The results clearly show that there is scope for classifying areas of seabed in terms of the pollution status of the benthic communities, based on the Infaunal Trophic Index (ITI) values. It is recommended that the ITI is applied alongside existing measures of pollution stress to allow further development of the index.

Work has continued on the setting of EQSs for organic components at sewage-sludge disposal sites. Participation in analytical inter-comparison exercises is essential in order to demonstrate adequate quality control by which suitable EQSs can be set. Continued reluctance of licensees to participate in these exercises is of increasing concern and steps must be taken to rectify this situation.

At sewage-sludge disposal sites, no evidence of significant accumulation of sludge contaminants was found at any of the dispersive sites sampled. At Garroch Head, the only accumulating site in the UK, effects of organic enrichment were again confirmed.

GCSDM considers that large detrital material of sewage origin should not be found to occur in the area of disposal. The occurrence of litter should therefore, be assessed at all sites using appropriately selected gear.

Fish disease and population studies should be conducted according to International Council for the Exploration of the Sea (ICES)/GCSDM recommendations, using adequate sized fish samples. The use of fish as a means of indicating faecal contamination of a disposal site is not effective and in future studies, the GCSDM recommends that sediments should be used in preference to fish gut contents.

More attention should be given to the recording and reporting of physical indicators of sewage contamination, especially tomato pips, within sediments.

For compliance testing against proposed EQSs for benthos, sampling procedures are not always adequate, and modifications (notably increased replication at ‘representative’ stations) will be required at certain sites in order to facilitate comparisons between stations or station groups near to and distant from contaminant sources.

Long time-series of contaminant data provide a firm basis for assessing year-on-year fluctuations in context and every effort should be made to continue to collect time-series data.

A multiple method approach to assessing the impact of sewage sludge disposal is desirable as this gives a clearer picture of the extent of contamination.

The technique of normalisation of metals in sediments shows considerable promise but the question of sensitivity needs to be addressed.

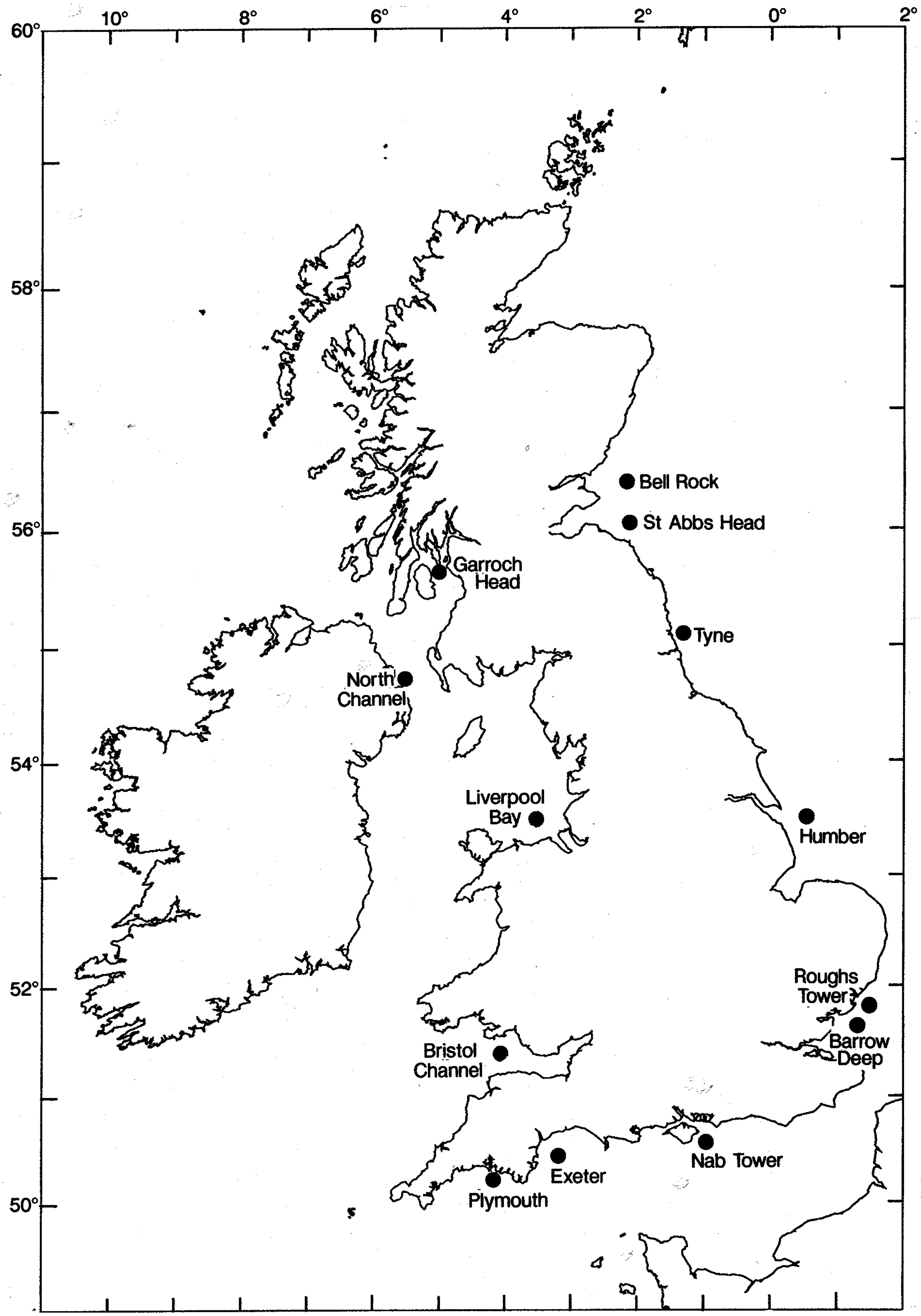


Figure 1. Locations of UK sewage-sludge disposal sites

1. INTRODUCTION

Following a review in 1985 of monitoring as it was then conducted at the various sewage-sludge disposal sites around the UK (Figure 1), the Marine Pollution Monitoring Management Group (MPMMG) concluded that proper goals for the monitoring needed to be specified and that standards were required against which it would be possible to assess whether or not detectable effects occurred and whether they were acceptable. In order to achieve this task and to co-ordinate monitoring as far as practicable, it was agreed that a Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites (CGMSD) should be established. (In 1992, following a change in its remit to cover other disposal activities in the marine environment, the Group was renamed and its new title is the Group Co-ordinating Sea Disposal Monitoring (GCSDM)). Following discussions with the then Water Authorities Association and others, the GCSDM met for the first time on 3 September 1987 with the following terms of reference:

(i) to continue to evaluate sewage-sludge monitor ing programmes, and advise on their develop ment and co-ordination, to make best use of available resources, expertise and techniques — where appropriate, recommendations should be made for the termination of ineffective programmes;

(ii) to identify and report upon those areas where research is necessary in support of monitoring;

(iii) to verify methods, develop standard protocols and intercalibrate analyses used in monitoring programmes;

(iv) to formulate environmental quality standards (EQSs) against which monitoring programmes could be designed and results assessed;

(v) to advise on responses to technical issues arising at the Oslo and London Conventions on disposal of wastes at sea (Great Britain - Parliament, 1972(a)(b));

(vi) to encourage the production of regular reports on the progress and results of monitoring by those responsible for the conduct of the programmes; and

(vii) to produce an annual review of monitoring carried out at all sites, which would be made widely available.

Arising from these terms of reference the GCSDM set itself the following aims:

(i) to define environmental quality objectives (EQOs) to be met at sewage-sludge disposal sites and the development of standards by which the meeting of those objectives could be verified;

(ii) to develop detailed guidelines for monitoring using microbiological determinands, biological effects techniques, sediments, biota and water; and

(iii) to produce a report on monitoring conducted in 1987 and 1988.

The GCSDM has since published four reports – in the autumn of 1989 (MAFF, 1989), the spring of 1991 (MAFF, 1991(a)), the spring of 1992 (MAFF, 1991(b)), and the autumn of 1992, (MAFF, 1992(a)).

The first report laid down a set of common environmental quality objectives (EQOs) and described a set of environmental quality standards (EQSs) by which the fulfilment of the objectives could be judged (Annex 1). Detailed guidelines were laid down for certain types of monitoring, particularly for those parameters for which the method used determines the results such as Eh and organic carbon. Guidance was also provided on the procedures to be followed for certain types of biological monitoring (benthos and prevalence of fish disease) and for metals in sediments. A brief outline was also provided of the monitoring being carried out at sewage-sludge disposal sites in 1988.

The second and third reports described the progress being made with the actual definition of EQSs and gave further detailed guidance on the methods to be used in monitoring compliance with these standards. The reports also contained a detailed review of the monitoring conducted in the preceding year, 1989 – being the first full year for which the GCSDM recommendations on methods and objectives were available. A brief outline was also provided of the monitoring conducted at sewage-sludge disposal sites in the reporting year.

The fourth report detailed the progress achieved in the development of standards for assessing change in the benthos, and the significance of levels of metals and organics in the environment — particularly in the sediments at sewage-sludge disposal sites. As with the two previous reports, a review of the results of work conducted in 1990 was included together with an outline of the monitoring conducted in 1991.

Throughout 1992, the GCSDM continued to pursue the goals originally assigned to it and also to establish new goals in the areas of dredged material disposal sites and Urban Waste Water Management. This, the fifth report, details the progress on all three of these fronts and, following the format of previous reports, reviews the results of monitoring work at sewage-sludge disposal sites during 1991 and outlines the monitoring work carried out in 1992.

A list of the members of the GCSDM in 1992 is given at Annex 2.

2. TASKS UNDERTAKEN BY THE GCSDM IN 1992

2.1 Mode of operation

From the start, the GCSDM was intended to be a group which advises MPMMG on policy and demonstrates through its reports the extent to which its advice is implemented, both by the licensees and by the regulatory agencies (for England and Wales, Ministry of Agriculture, Fisheries and Food (MAFF); for Scotland, Scottish Office Agriculture and Fisheries Department (SOAFD); and for Northern Ireland, Department of the Environment (Northern Ireland) (DoE(NI)). That being so, the main group has a restricted membership and meets only two or three times a year. Much of the detailed work is therefore undertaken by specialist Task Teams. This allows input by a wide range of organisations with relevant expertise, including several not directly associated with monitoring of disposal sites. By this means every effort is taken to ensure the work undertaken is kept outward looking. The three Task Teams established in previous years remained active during 1992: a Metals Task Team (Sub-Section 3.1); an Organics Task Team (Sub-Section 3.2); and a Biology Task Team (Sub-Section 3.3).

Two new Task Teams were established in 1992, one as a result of direct authorisation by the GCSDM's parent group MPMMG and the second as a result of recommendations by the Metals Task Team.

In the course of 1992, the GCSDM met on three occasions to review the progress of the Task Teams, finalise its fourth report and to discuss the applicability of its existing objectives to assessing the impacts of dredged material disposal sites.

2.2 The need for new Task Teams

In June of 1992, the GCSDM was authorised by its parent group the MPMMG to establish a new Task Team to assist The Department of the Environment (DoE) in the implementation of Directive 91/271 EEC (European Communities, 1991), concerning Urban Waste Water Treatment. The objective of the Directive is to prevent the environment from being adversely affected by the disposal of insufficiently treated urban waste water. It requires that discharges of waste water and disposal of sludge from relevant waste water treatment plants are subject to general regulations including the possibility of tertiary treatment, by the year 2005 at the latest. Receiving waters are to be classified into one of three groups: sensitive, 'normal' or less sensitive areas. Member States are required to identify both sensitive and less sensitive areas by 31 December 1993. Areas designated as sensitive must include freshwaters, estuaries and coastal waters which are found to be, or are likely to become, eutrophic. Discharges to these areas will be subject to a requirement to remove appropriate nutrients.

A marine water body or area can be identified as a less sensitive area if the discharge of waste water does not adversely affect the environment as a result of morphology, hydrology or specific hydraulic conditions which exist in the area. This will include open bays, estuarine and other coastal waters with good water exchange and which are not subject to eutrophication or oxygen depletion. Discharges in less sensitive areas may be subject to less stringent treatment provided the discharge receives at least primary treatment and that comprehensive studies indicate that the discharge will not adversely affect the environment.

It is therefore necessary to establish the nature of the comprehensive studies required to demonstrate that coastal (and estuarine) areas qualify for consideration as less sensitive areas. It was for this reason that GCSDM was authorised to convene a Task Team on Comprehensive Studies which was duly established in June 1992 and met on two occasions during 1992.

As a result of its discussions throughout the year on dredged material disposal sites, the Metals Task Team recommended to the GCSDM that a Task Team on biotesting of sediments at dredged material disposal sites be formed to carry out a study of methods, particularly taking into account those currently used in prelicence tests. The GCSDM duly accepted the recommendation and a Sediment Bioassay Task Team was established. There was some delay in completing the Team and it was therefore unable to meet during 1992.

2.3 Co-ordination of monitoring of other sea disposal operations

In discussions on the extension of its remit to cover other disposal activities, the Group recognised that the disposal of dredged material bears a number of similarities to the disposal of sewage sludge. It was agreed that the Group review the objectives previously identified for sewage sludge (Annex 1) and consider their applicability to dredged material disposal.

The physical nature and quality of dredged material means some impact on the immediate zone of deposition is unavoidable. The scale of effect will depend upon the size of the dredging operation and the timescale over which disposal takes place. The objectives defined need to allow for, but seek to minimise, the physical impact within the disposal zone and avoid adverse effects outwith the area. Their overall aim should be to preserve conditions that as closely match natural conditions as is practicable, given the uses in the area and to avoid significant effects upon species of economic and conservation interest.

With some minor amendments and additions, the sewage sludge objectives fulfilled these requirements and formed the basis of the following proposed EQOs.

Use	Objective	Notes
1. Coastal zone maintenance	As a consequence of the dredged material disposal, the coastline should not be more or less subject to coastal erosion than previously	This assumes that under most circumstances the existing coastline is to be maintained. Occasions may arise where coastal nourishment is regarded favourably (in which case disposal would be regarded as "beneficial use")
2. Basic amenity use	Dredged material disposal should not result in changes to the nature of a nearby bathing beach, nor should recreational diving, other water contact sports, nature conservation or sites of historical interest in nearby areas be affected by increased turbidity or siltation. Extraneous material e.g. wires, cables, scrap iron etc. should not be allowed to litter the seabed	
3. Navigational use	The dredged material should not be deposited near to or in areas where navigational use would be prejudiced	Observance of this requirement will need to take account of marginal restoration and overall benefit
4. Fishing	There should be minimal interference with normal fishing activity, and the quality of the product in terms of safety for human consumption should not be adversely affected	This implies no major physical change in the nature of the seabed and no diminuation of the suitability of the product for human consumption
5. Protection of commercial species	Preservation of the general well-being of commercially exploited species	Probably little different in practice to Use 6
6. General ecosystem conservation	Outwith the immediate deposition zone aquatic life should not be adversely affected and the ecosystem should be typical of coastal water of similar physical characteristics and latitude	This includes avoidance of import of pest species and disease and excludes change if it is regarded as beneficial
7. Preservation of the natural environment	Outwith the immediate deposition zone the quality of the environment should be indistinguishable from that of the adjacent estuarine or marine environment	This requirement stems from North Sea Conference agreements. In practice it will be little different to Use 6

The means of demonstrating whether the above uses are maintained in an area is by comparison with standards. It is not possible at this stage to assign numerical standards in all cases. Accordingly, the GCSDM has listed the criteria and the basis on which the standards are expected to be judged.

The standards are essentially based on those previously defined for sewage sludge, with appropriate amendments and, as for sewage sludge, apply to the area outwith the mixing zone. GCSDM will continue to develop these standards with the inclusion of relevant parameters.

EQO	Criteria	Basis of Standard
1. Coastal zone maintenance	Position Mean High Water Spring Tide (MHWST) and nature of shoreline	No significant change without perceived benefit
2. Amenity use	Turbidity	No significant increase
	Siltation	No siltation cover of seabed artefacts/wrecks
	Litter	No material extraneous to seabed material to be deposited
3. Navigational use	Depth	Depth of water in navigable /navigated areas to be within defined limits
4. Fishing	Seabed	Trawl grounds not to be physically altered/obstructed
	Microbiological contamination	Measured levels in the product to be below those prescribed by public health authorities/MAFF and EC legislation
	Chemical contamination	Measured levels in the product to be below prescribed limits
5. Protection of commercial species	Water column and benthic habitat	No significant siltation of habitat and no toxic effects from dredged material
	Fish disease	No significant increase in prevalence compared to normal
6. Ecosystem maintenance AND	Benthic diversity	Deviation from control site(s) to be within normal limits
7. Protection of the environment	Water quality	Dissolved oxygen levels not to be significantly suppressed and toxic substances not to be released into water column at harmful concentrations
	Sediment texture and quality	No significant change in grain size distribution. No toxic effects on benthic species. No persistent increase in concentration of contaminants.
	Benthic fauna	No deviation from control sites

2.4 Development of a biotic index

In its fourth report the GCSDM included details on the progress of work undertaken to develop a biotic index for the assessment of the pollution status of marine benthic communities. The work was undertaken and funded, jointly by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) and the National Rivers Authority (NRA).

The objective of the project was to develop an index from existing data, either by the adoption of an existing index or the development of a new index.

By the end of 1991, a data base had been compiled consisting of 8 suitable data sets from around the UK. A review of existing indices had also been completed and had identified the Infaunal Trophic Index (ITI) (Word, 1979) as having the most promise. As a result of this, significant effort was applied to adapting it for use in UK waters.

The index was applied to each of the eight data sets and its performance assessed in relation to other methods of determining pollution status in marine benthic communities. The effects of pooling to higher taxonomic levels on the performance of the index was also assessed.

The ITI successfully reflected known pollution gradients for each of the pollution types in the database (i.e. sewage sludge, oil drilling by-products and, sewage and industrial effluents). It was consistently among the best methods of discriminating between sites and, in comparison between sites, the ITI was amongst the most statistically powerful measurements. Potential was also shown for classifying areas of seabed as normal, changed and degraded, based on the ITI values.

The identification of all taxa to the level of family prevented the allocation of some key families to trophic groups. The elimination of these families from the calculation of the index resulted in different index values, but there is scope for reducing the taxonomic effort once sufficient information is known at the species level in the form of a standard taxonomic list.

Clearly, there is scope for classifying areas of seabed in terms of the pollution status of the benthic communities, based on the ITI values. However, further information on its response in a wider range of conditions is required. Applying the ITI alongside existing measures of pollution stress, to marine data sets, will provide the necessary information to allow further development of the index.

3. PROGRESS BY THE TASK TEAMS

A list of the various Task Teams (and their membership) operating in 1992 is given in Annex 3.

3.1 The Metals Task Team

During 1991, the Metals Task Team developed numerical values (proposed action limits) for EQSs for Metals (MAFF, 1992(a)). The Team has been reviewing their application in 1992.

The second phase of the analytical intercomparison exercise was also undertaken in 1992 and consideration was given to monitoring techniques for dredged material disposal sites.

3.1.1 Intercomparison exercise

The second phase of this exercise involved the analysis of a sediment sample. Early difficulties in obtaining uniform sized sub-samples were finally resolved and samples were distributed to all participating laboratories by the end of June. The results so far are very promising. For each of the first three stages, sieving, digestion and analysis, the coefficients of variation were generally less than 20% indicating that the sediment splitting technique worked well. The final stage, which tests all aspects of sediment treatment, is not yet complete. A full report is expected in early 1993.

3.1.2 Monitoring at dredged material disposal sites

With the intercomparison exercise drawing to a close the Task Team turned its attention to this new area of study.

There are ‘Oslo guidelines for the management of dredged material’, which are used to harmonise dredged material assessment throughout the Oslo Convention area. The Task Team concluded that advice should be in broad agreement with these guidelines and that the criteria used to test the suitability of a waste for disposal (whether physical, chemical or biological) should also be used as part of the environmental assessment of the disposal site. In view of this the Team recommended that the GCSDM convene a task team to carry out a detailed study on biotesting methods. The range of disposal operations varies from regular deposit of maintenance material to one-off capital operations. The Team suggests that details of monitoring will need to be decided on both a site-specific and disposal operation-specific basis and that pre-disposal monitoring should be carried out wherever possible at both treatment and reference sites.

3.2 The Organics Task Team

The Organics Task Team has continued to assess the analytical intercomparison exercises and to make further progress with the development of environmental quality standards.

3.2.1 Intercomparison exercises

The Task Team had intended to begin the fourth round of the intercomparison exercise in spring 1992, but in view of the poor response in the previous exercise it was decided to delay it until questionnaires were returned, which would enable the Team to assess the commitment to future exercises. With the encouraging response of 21 laboratories agreeing to participate in the next round, samples of sediment were duly distributed in the new year. However, to date only 9 of the 21 laboratories have made returns. This is yet again a disappointing and regrettable result.

Participation in these exercises is essential in order to demonstrate adequate quality control by which suitable environmental quality standards can be set. If the situation does not improve early in 1993 it will be necessary for the GCSDM to consider the means by which compliance can be ensured.

3.2.2 Development of EQSs

The Task Team has continued to pursue the equilibrium partitioning model approach for setting provisional EQSs for organic components. Some values have been proposed based on data from the USA but some revision is required to allow for the water quality measures in operation in European waters. The effect of differential toxicities of PCB congeners on standards is also under consideration and it is suggested that, using the worst case approach, the partitioning coefficients for the most toxic congeners are used to derive standards. The Team is currently reviewing the available data, including comparison of the proposed standards with existing levels of contaminants found in the sludge disposal areas. Provisional standards should be available early in 1993. This will make it doubly important that the licensees are capable of determining CB congeners accurately.

3.3 The Biology Task Team

The Biology Task Team has addressed the question of dredged material disposal sites and has made significant headway in identifying the factors to be considered in deciding upon biological monitoring approaches and sampling for EQS compliance.

3.3.1 Biological monitoring approaches

There are a number of possible effects of dredgings disposal operations ranging from simple blanketing (physical effects) to organic enrichment and chemical toxicity, or combinations thereof. Both the nature of the deposited material and that of the receiving area will determine the type of biological response to be expected together with its severity and will also influence the techniques and monitoring methods to be used at any one site.

The monitoring strategy supported by the Task Team favours the development of ‘impact hypotheses’ (as described in the Oslo Commission’s guidelines), together with the construction of generic models for the responses of the benthos to different categories of dredged material. However, for these to be effective, they will need to be versatile in order to account for the variability in the nature of the receiving environment, the dredged material and the disposal practices. The Task Team is currently working on this matter.

Guidelines for the design of sampling programmes and for sampling methods should largely be met by those devised for sewage-sludge disposal sites, although special importance will be attached to the physico-chemical assessments of sediments in the receiving environment and of transport pathways. The frequency of sampling will be determined on a site-specific basis but should rarely exceed once per year.

3.3.2 Environmental Quality Standards

The GCSDM’s draft specifications for environmental quality standards recognise the likelihood of adverse consequences at the seabed, within the disposal site itself, arising from the immediate settling of sediments following bulk discharge. Therefore, the main objective will be to minimise the intensity and spatial scale of effects beyond the ‘mixing zone’. The Team’s approach to sampling for EQS compliance will be similar in principle to that developed for sewage-sludge disposal sites, involving comparison between ‘treatment’ and ‘reference’ sites. Regular reappraisals of sampling design will be necessary to ensure the continued effectiveness of monitoring for EQS compliance; a critical factor in this respect will be any temporal variability in the nature and quantity of the material disposed of.

3.4 The Comprehensive Studies Task Team

When established in June 1992, the Task Team was charged with defining comprehensive studies to predict ‘no adverse effects’ in support of proposals for less sensitive areas for the Urban Waste Water Directive. In approaching the task, the Team has concentrated on establishing suitable predictive modelling and assessment techniques.

In view of the nature of the discharges concerned, the Team regards the relevant parameters for consideration in any proposed studies to be oxygen demand, nitrogen and particulate organic carbon and that the main considerations regarding the potential effects of discharges to an area are:

(a) Overall loading to the sea area and its effects. The area may be as large as the North Sea or as small as for example the Thames estuary;

(b) Far-field but 'local' effects such as enhanced phytoplankton growth and solids deposition remote from the outfall;

(c) Local effects in the vicinity of the outlet, e.g. deposition of particulate organic matter.

The discharges in question already exist, generally discharging without primary or secondary treatment. The effects of overall loading to the sea area can therefore be dealt with by considering current water quality and basing predictions on load reduction. In proposed less sensitive areas where discharges already receive primary treatment, a relatively simple environmental assessment should establish whether or not 'no adverse effects' occur. In all other cases the comprehensive study will need to be predictive and then verified by post operational monitoring. Predictions based on the overall loading of an area means that the consideration of any single discharge will require an assessment of the cumulative effects of all relevant discharges into the water body. However, the status of water can be altered by the length of outfalls. For instance, a primary effluent can have a significant effect in shallow water, if the initial dilution is not high enough. The Task Team is therefore proposing that a minimum initial dilution of 50 is imposed on all primary discharges to coastal waters.

The Team has agreed that each comprehensive study needs to be site specific as the hydrography and substrate type which determine the studies are likely to vary widely. Bearing this in mind the Team has made the following preliminary proposals to the GCSDM. These proposals are being worked on and a final report to DoE is due by late Summer 1993.

Comprehensive studies in estuaries

Estuaries have not yet been considered in detail. Estuarine assessment is simple for the marginal load differences between primary and secondary treatment. Because the difference in nutrient loads is considered only marginal, the only effects anticipated relevant to the Directive would be on dissolved oxygen and sediment enrichment. Predictive models exist or can be adapted to deal with this.

Where estuaries as defined include coastal waters or large drying areas then the problem becomes more complex.

Comprehensive studies in coastal waters

In multiple discharge locations, particularly in confined waters, there is no alternative to full scale hydrodynamic modelling incorporating transport, deposition and decay sub-models. Such a model will allow prediction of effect and tests of significance.

On open coastlines and/or single discharge locations simpler methods could apply:

(i) Far-field conservative parameter effects: Only applicable to nitrogen in this case. Using a simple model based on tidal excursion and phytoplankton growth rates an area of effect can be predicted. The model will also provide information on transfer of pollutants to adjacent areas.

(ii) Effects of nitrogen in the defined area: To assess whether the area has potential for undesirable trophic effects, use can be made of a simple model converting nitrogen to phytoplankton chlorophyll.

(iii) Far-field sedimentation: This can be predicted from a simple dynamic model giving critical depositional stresses over a tidal cycle. This gives a second area of effect which may differ from that in (i).

(iv) Environmental Quality Standards: These may apply throughout an area or refer to specific zones. Compliance can be easily predicted from simple dilution and transport models. No EQS can be exceeded.

(v) Local effects on benthos: The methodology developed for Southern California Coastal Water Research Project (SCCWRP) can predict worst case local deposition and effects based largely upon mass emission rates (Mearns and Word, 1982). The significance of this can be assessed through comparison with reference sites and, it is hoped, use of the Infaunal Trophic Index currently being developed.

The suite of studies described will allow assessment of probable change once measures of significance are developed. They will also generate the hypotheses necessary for investigative field work and for the continuing monitoring essential for fulfilment of Article 6.

4. REVIEW OF MONITORING AT SEWAGE-SLUDGE DISPOSAL SITES DURING 1991

4.1 Introduction

This section follows the format of earlier reports in this series and assesses whether various monitoring programmes meet the goals described in the first report (MAFF, 1989). It considers examples of monitoring undertaken in 1991 although, where appropriate, reference is made to other work. Nearly all the surveys followed the GCSDM guidelines for analytical methodology (MAFF, 1989). In some cases, where consistency with earlier work was judged more important than comparability with other sites, long-established procedures were retained. Notable examples of this were at the St Abbs Head and Bell Rock sites. It is encouraging to note that some studies, while complying with the monitoring guidelines, also attempted to achieve comparability with earlier work by carrying out special studies (e.g. the Forth River Purification Board (FRPB)/Lothian Regional Council (LRC) survey of St Abbs Head).

Table 1 lists the sewage-sludge disposal sites surveyed in 1991 (see Figure 1 for locations) and the techniques used. Further details of this work can be found in the fourth report of GCSDM (MAFF, 1992(a)). Some areas are surveyed only every second or third year and therefore no samples were taken in 1991. This report aims to show examples of monitoring and therefore not all work is described. Time-series studies, where relatively few samples are collected in any particular year, are not reported after each sampling occasion.

The following discussion is arranged according to the various EQOs set by GCSDM (see Annex 1) and any relevant EQSs are given at the start of each section.

4.2 EQO: Prevention of aesthetic problems and interference with other uses of the sea

In its first report the GCSDM noted that this objective related to the possible presence of a surface slick, an increase in the turbidity of the water column, contamination of the seabed with plastic and other persistent materials, and the fouling of fishing apparatus. In practice surface slicks and an increase in turbidity do not occur outwith the immediate mixing zone.

Table 1. Summary of techniques used in surveys at sewage-sludge disposal sites in 1991

Area/Authority	Sediment			Benthos epibenthos	Fish sampling	Litter assessment
	Metals	Pesticides/ PCBs	Microbiology			
Tyne						
MAFF	+		+	+		
Northumbrian Water	+		+	+		+
Humber						
MAFF				+		
Roughs Tower						
Anglian Water	+		+			
Barrow (Thames)						
MAFF	+			+		
Nab						
Southern Water	+	+	+			
Exeter						
South West Water	+		+	+		
Liverpool Bay						
MAFF	+					
North West Water	+			+		
Garroch Head						
SMBA/SRC	+			+	+	
Bell Rock						
FRPB/LRC	+		+	+	+	
SOAFD						
St Abbs Head						
FRPB/LRC	+			+	+	
SOAFD						

The GCSDM considers that the only acceptable standard for large detrital material of sewage origin is that they should not be found to occur in the area of disposal, either in surface trawls or in bottom trawls, dredge or grab samples. If they do occur, measures (e.g. screening) should be taken to clean the waste. Because it is recognised that not all of the sewage-derived solids found in a disposal site may be of sludge origin, the GCSDM has recommended that subsequent compliance with the standard should be checked by monitoring sludge quality at the point of loading to show no retention of solids on a 5 mm sieve.

MAFF surveyed the Tyne sewage disposal site and the region to the south in May, 1991 using 2 m beam trawls (Figure 2). Table 2 shows a list of the litter found at the seabed and demonstrates that, as in previous years, sanitary products were still present at the disposal site. While this is considered unacceptable, it should be noted that screens were introduced at the Northumbrian Water Sewage Treatment Works (STWs) in 1990 and that observations in 1991 of the recently-deposited material at the sea surface revealed very little litter. Observations at the seabed will be continued to assess the rate at which sewage debris is dispersed or decomposed.

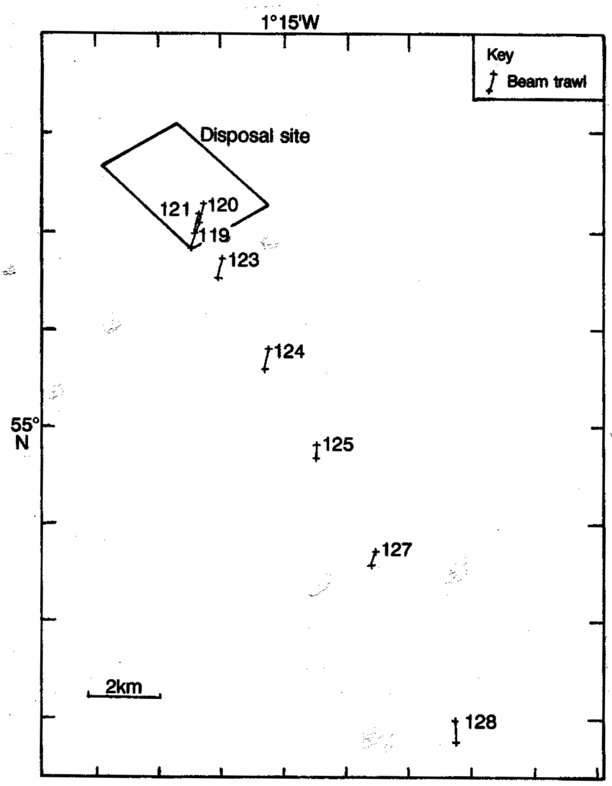


Figure 2. Positions of the beam trawls sampled for litter at the Tyne sewage-sludge disposal site, May 1991

Table 2. Litter in beam trawls from the Tyne, May 1991

Type of litter	Station numbers (see Figure 2 for locations)							
	119	120	121	123	124	125	127	128
Plastic fragment	*	*	*	*			*	
Cellophane	*	*	*	*	*			
Adhesive tape			*					
Elastic fragment			*					
Rubber washer					*			
Rubber "O"ring	*							
Foam rubber			*					
Corn plaster	*							
Condom packet			*					
Foil fragment	*	*	*					
Glass jar	*							
Glass fragment				*				
Cloth fragment		*	*	*				
Cotton bud		*						
Sanitary towel	3	4	8	4	2			
Tampon	2	4	7	6	2			
Cigarette filter	10	13	21	7				
Hair	*	*	*	*	*			
Paper	*		*					
Tissue	*		*					
Cardboard fragment			*					
Hardboard fragment						*		
Matchstick	2	6	7	1				
Wood fragment		*	*		*			
Vegetable matter (inc. peel)	*	*	*					
Peanut	*				*			
Plant fragment		*	*					
Leaf litter	*	*	*	*		*		
Clinker	*	*	*	*	*	*	*	*
Coal	*	*	*	*	*	*	*	
Approx. volume of litter (l)	3	1	1	1	0.15	<<0.1	<<0.1	0
Approx. total sample volume (l)	10	8	13	5	5	7	2	2

* *indicates presence*

Sampling of the Garroch Head disposal site with an otter trawl revealed only objects less than 5 cm and materials obviously attributable to the disposal operations. The amounts of such material taken were similar to the quantities collected in 1990. Sewage-derived debris was found in otter trawls at the Bell Rock and St Abbs Head sites during the FRPB/LRC surveys. This amounted to only a very small quantity of waste; 3 sanitary towels in each area and a sticking plaster at St Abbs Head. While this suggests little sewage contamination at these two sites, it should be noted that large mesh trawls of the type used in this survey are not efficient devices for sampling litter.

As in previous GCSDM reports, it is recommended that fine mesh beam trawls be used for litter assessment rather than coarse mesh fishing gear or sediment samplers, although it must be recognised that it is appropriate to note and report litter when observed in such devices. The use of fine mesh sampling devices is subject to legal restrictions and permission must be sought before their use from the appropriate Fisheries Department.

In this context, the MAFF laboratory has used fine mesh trawls to survey English sewage disposal sites for litter during 1992. In some cases, hard ground prevented the use of beam trawls and scallop dredges were employed. These data will be reported in the next report of the GCSDM.

4.3 EQO: Maintenance of commercial marine fish and shellfish at an acceptable quality for human consumption

In its first report, the GCSDM pointed out that the appropriate authorities are the public health authorities, MAFF and Scottish Office Agriculture and Fisheries Department (SOAFD), and that there are advisory limits for contaminants in foodstuffs.

Concentrations of organochlorine contaminants in the liver and muscle of cod sampled from the St Abbs Head disposal site were measured by SOAFD (Table 3). Concentrations were below accepted limits for the protection of human health, and were in the lower category described in the Joint Monitoring Group (JMG) guidelines for the assessment of marine pollution.

4.4 EQO: Preservation of the general well-being of commercially exploited species

In its first report the GCSDM indicated that this objective would be met provided there is no change in habitat as a consequence of the disposal operation. Additionally, all relevant water quality standards would have to be met and there should be no significant increase in diseased fish relative to comparable populations nearby.

Dab samples were taken by FRPB at both the Bell Rock and St Abbs Head areas in 1991 for determination, by Heriot-Watt University, of disease and contamination of the guts with faecal bacteria. At St Abbs Head, 2 fish were examined at the control site and 12 at the disposal site. Only a small number of fish were caught at the control site because the net ripped. At Bell Rock 10 fish were examined at both control and disposal site. Although no high level of disease or bacterial contamination were observed, it is impossible to draw any firm conclusions on the basis of such small samples (see MAFF, 1992(a)).

Examination of bacterial contamination is more readily conducted using sediments than with fish and the results are more easily interpreted. GCSDM therefore confirms its earlier suggestion that in future studies of bacterial contamination, sediments be used in preference to fish gut contents (MAFF, 1992(a)).

SOAFD examined liver samples from 60 individual female dabs from both reference and disposal sites at St Abbs Head. The sample included both fish affected and those unaffected by the viral disease lymphocystis. Samples were analysed for trace organochlorine contaminants. No statistically significant relationships were found between the levels of contaminants and the presence of lymphocystis.

At Garroch Head, fish were collected using 3 ten-minute tows at disposal and reference sites (Table 4). The numbers of fish caught were larger than in 1990.

The fish were subjected to external examination immediately after being brought on board and the following diseases noted: tumours, lymphocystis, lesions, skin hyperplasia/papilloma, skin ulcers,

Table 3. Concentration of organochlorine contaminants in cod collected from St Abbs Head (µg kg^{-1} wet wt.)

Tissue	n	CBs	4,4'-DDE	4,4'-DDT	4,4'-DDD	HCB	Dieldrin	Lipid %
Cod liver	15	522	110	21	26	37	26	29
Cod muscle	15	2.00	0.30	0.05	0.09	0.20	0.02	0.50

CBs = sum of CB28, 52, 101, 118, 138, 153, 180

Table 4. Otter trawls collected at the Garroch Head disposal and reference sites, 1991

Haul No. and Area		Fish Species taken		Fish Lengths (cm)		Invertebrata taken	
Disposal Site (Station P7) Haul 1	2	*Clupea harengus*	Herring	27.2-32.3	2	*Macropipus sp.*	Buccinum
	1	*Spratus sprattus*	Sprat Cod	8.5	1	*Munida bamffica*	Squat Lobster
	96	*Merlangius merlangus*	Whiting	14.9-22.6	1	*Asterias rubens*	Common Starfish
	13	*Pollachius virens*	Saithe	21.6-34.5	1	*Pandalus sp.*	Shrimp
	21	*Gadus morhua*	Cod	18.5-27.8			
	65	*Trisopterus minutus*	Poor Cod	11.2-16.5			
	19	*Trisopterus esmarkii*	Norway Pout	12.8-18.6			
	1	*Melanogrammus aeglefinus*	Haddock	18.4			
	11	*Pleuronectes platessa*	Plaice	12.9-23.9			
	1	*Hippoglossoides platessoides*	Long Rough Dab	15.9-20.6			
	2	*Limanda limanda*	Common Dab	19.6-21.5			
Disposal Site (Station P7) Haul 2	49	*Merlangius merlangus*	Whiting	15.0-21.4		*No invertebrates*	
	23	*Pollachius virens*	Saithe	21.4-38.1			
	23	*Gadus morhua*	Cod	17.3-27.8			
	20	*Trisopterus minutus*	Poor Cod	10.6-16.4			
	5	*Trisopterus esmarkii*	Norway Pout	14.4-16.2			
	1	*Melanogrammus aeglefinus*	Haddock	22.5			
	9	*Pleuronectes platessa*	Plaice	14.7-25.5			
	4	*Hippoglossoides platessoides*	Long Rough Dab	14.0-16.5			
	5	*Limanda limanda*	Common Dab	15.7-23.5			
Disposal Site (Station P7) Haul 3	74	*Merlangius merlangus*	Whiting	15.0-24.0	2	*Macropipus sp.*	Swimming Crab
	12	*Pollachius virens*	Saithe	21.8-35.3			
	6	*Gadus morhua*	Cod	16.4-25.7			
	40	*Trisopterus minutus*	Poor Cod	10.4-16.5			
	15	*Trisopterus esmarkii*	Norway Pout	14.9-19.2			
	2	*Merluccius merluccius*	Hake	17.8-21.6			
	1	*Pleuronectes platessa*	Plaice	25			
	4	*Hippoglossoides platessoides*	Long Rough Dab	14.2-17.3			
	2	*Limanda limanda*	Common Dab	20.0-20.5			
Reference Site Station (G1) Haul 1	18	*Merlangius merlangus*	Whiting	16.8-24.6	19	*Nephrops norvegicus*	Norway Lobster
	2	*Trisopterus minutus*	Poor Cod	14.7-15.4	1	*Pagurus bernhardus*	Hermit Crab
	6	*Merluccius merluccius*	Hake	18.0-35.4	12	*Pandalus sp.*	Shrimps
	1	*Rhinonemus cimbrius*	Bearded Rockling	15.6	3	*Asterias rubens*	Starfish
	1	*Hippoglossoides platessoides*	Long Rough Dab	15.2	3	*Macropipus sp.*	Swimming Crab
					1	*Aphrodita aculeata*	Sea Mouse
Reference Site Station (G1) Haul 2	1	*Clupea harengus*	Herring	29.8	3	*Aphrodita aculeata*	Sea Mouse
	1	*Sprattus sprattus*	Sprat	8.9	7	*Macropipus sp.*	Velvet Crab
	28	*Merlangius merlangus*	Whiting	15.7-23.6	2	*Munida bamficca*	Squat Lobster
	5	*Trisopterus minutus*	Poor Cod	14.0-20.8	7	*Pandalus sp.*	Prawns
	2	*Trisopterus esmarkii*	Norway Pout	14.5-20.1	12	*Aporrhais pes-pelecani*	Pelicans' Foot Shell
	6	*Merluccius merluccius*	Hake	17.8-22.0	1	*Pecten septemradiata*	Scallop
	1	*Rhinonemus cimbrus*	Bearded Rockling	15.7	7	*Crangon allmani*	Prawn
	1	*Pleuronectes platessa*	Plaice	20	1	*Octopus octopus*	Octopus
	1	*Glyptocephalus cynoglossus*	Witch	21.5			
Reference Site Station (G1) Haul 3	13	*Merlangius merlangus*	Whiting	17.1-22.3	6	*Macropipus sp.*	Swimming Crab
	8	*Trisopterus minutus*	Poor Cod	12.6-21.3	15	*Crangon allmani*	Brown prawn
	2	*Trisopterus esmarkii*	Norway Pout	16.6-19.7	14	*Pandalus sp.*	Shrimp
	10	*Merluccius merluccius*	Hake	15.1-22.3	6	*Aporrhais pes-pelecani*	Pelicans' Foot Shell
	5	*Glyptocephalus cynoglossus*	Witch	13.7-23.5	4	*Munida bamficca*	Squat Lobster
					1	*Pagurus bernhardus*	Hermit Crab
					1	*Pecten septemradiata*	Seven-rayed Scallop
					2	*Asterias rubens*	Common Starfish
					3	*Aphrodita aculeata*	Sea Mouse
					1	*Nereis sp.*	Rag-worm

skeletal deformities and skeletal damage to fin rays. Details of species examined, size range and gross pathological observations are given in Tables 5 and 6.

Internal examination of sub-samples from both trawl sites was carried out to discover any large internal tumours. Any clearly defined nodules greater than 2 mm on the livers were recorded. Bacterial concentration was measured in the gut contents and in local sediments.

The Institute of Aquaculture, University of Stirling, concluded that there was no evidence that the disposal site was having an adverse effect on the health of the fish or that the presence of faecal bacteria in the guts of the fish was having any deleterious effect on the health of the fish.

Fish were also sampled at the Forth disposal sites. At Bell Rock, the number and abundances of fish species were similar at both the disposal and control sites (Table 7). At St Abbs Head, unlike previous years, the

Table 7. Otter trawls collected at the Bell Rock disposal and reference sites, 1991

Fish species	Station 13	Control
Cod	11	100
Poor cod	1	14
Haddock	132	61
Whiting	564	686
Scad	1	-
Common Dragonet	4	9
Butterfish	-	1
Sand-eel	6	-
Grey Gurnard	4	7
Pogge	15	14
Plaice	3	9
Common Dab	169	39
Long Rough Dab	18	
Lemon Sole	8	40
Norwegian Topknot	2	-
Cuckoo Ray	6	7
Thornback Ray	-	1
Dogfish	1	-
Spurdog	1	1
Fatherlasher	1	3
Monkfish	-	1

Table 5. Fish catch and pathology at the Garroch Head sewage-sludge disposal site (Station G1), 1991

Fish Species	Number	Size Range (cm)	Gross Pathology
Whiting	59	15.7-24.6	Exothalmia - 1 fish Other NAD
Hake	22	15.1-35.4	NAD
Poor Cod	15	12.6-21.3	Exothalmia - 2 fish Others NAD
Witch	6	13.7-23.5	NAD
Norway Pout	4	14.5-20.1	NAD
Rockling	2	15.6-15.7	Small Head Lesion - 1 fish Other NAD
Log Rough Dab	1	15.2	NAD
Plaice	1	20.00	NAD
Herring	1	29.8	NAD
Sprat	1	8.9	NAD

NAD - no abnormality detected

Table 6. Fish catch and pathology at the Garroch Head sewage-sludge reference site (Station P7), 1991

Fish Species	Number	Size Range (cm)	Gross Pathology
Whiting	223	14.9-24.0	NAD
Poor Cod	125	10.4-16.5	Traumatic Head Lesions- 3 fish Others NAD
Saithe	48	21.4-38.1	NAD
Norway Pout	39	12.8-19.2	NAD
Plaice	21	12.9-25.5	NAD
Common Dab	9	15.7-23.5	NAD
Long Rough Dab	9	14.0-17.3	NAD
Haddock	2	18.4-22.5	NAD
Hake	2	17.8-21.6	NAD
Herring	2	27.2-32.3	NAD
Sprat	1	8.5	NAD

NAD - no abnormality detected

number of species was greater at the disposal site (Table 8). This was attributed to the net being ripped at the control site. Nonetheless, the fish populations at disposal and control sites appeared similar.

Table 8. Otter trawls collected at the St Abbs Head disposal and reference sites, 1991

Fish species	Station 13	Control
Cod	12	11
Haddock	6	4
Whiting	1005	39
Herring	54	4
Common Dragonet	77	2
Sand Goby	37	-
Sand-eel	1	-
Plaice	3	-
Pogge	3	-
Dab	71	1
Long Rough Dab	1089	17
Lemon sole	5	8
Norwegian Topknot	4	-
Thornback	4	-
5 Bearded Rockling	3	-
Snakeblenny	14	-
Coley	23	-
Grey Gurnard	10	4
Poor Cod	1	1

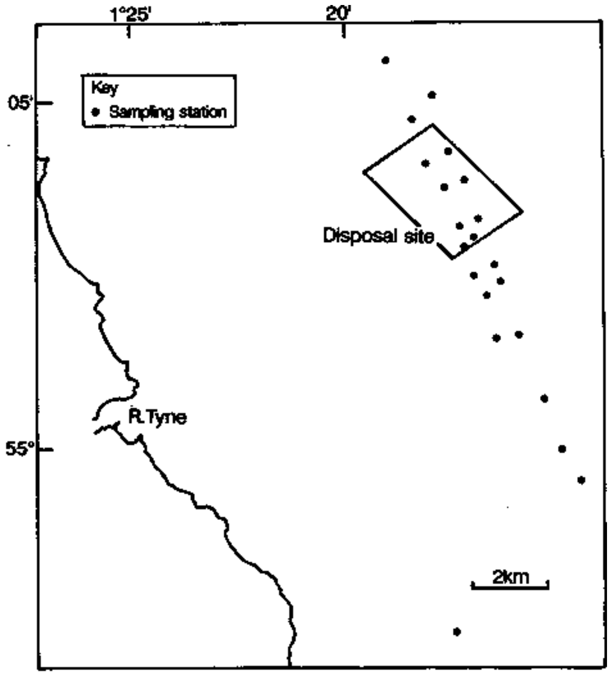


Figure 3. Benthic sampling positions at the Tyne sewage-sludge disposal site, May 1991

4.5 EQO: Protection of the ecosystem to ensure that it is typical for the type of area concerned

In its first report, the GCSDM suggested that suitable indicators of alterations in environmental quality were the extent to which benthic diversity changes and the extent to which contaminant concentrations in sediments and water are maintained within appropriate set standards. The extent to which these criteria were met at the various disposal sites in 1991 is reviewed below.

4.5.1 Transect studies at the Tyne

In May 1991, sampling was conducted along two parallel transects of stations running through the Tyne sewage-sludge disposal site (Figure 3). The benthic macrofauna (animals retained on a 0.5 mm mesh sieve), along with sediment samples for determinations of trace metal, organic content, and particle size, were taken by Day grab. The meiofauna (animals passing through 0.5 mm mesh sieves) were sampled by Craib core, as part of a collaborative project between MAFF and the Plymouth Marine Laboratory (PML), funded by the Chief Scientist's Group, to assess the utility of this component of the benthos in pollution monitoring. Prior to processing, Eh determinations of intact cores were made at 1 and 6 cm depths, using a 5 mm diameter combination redox electrode. (Eh provides an indication of the reduction-oxidation status of sediments, which may be influenced by organic matter inputs).

The transects took account of previous findings (e.g. Rees *et al*., 1992) which identified mild enrichment in the immediate vicinity of the disposal site. In the following account, data from adjacent stations across the transects were combined.

Eh values from Craib cores at 1 and 6 cm depths are shown in Figure 4. At 1 cm depth, all values were positive, providing no indication of significant deterioration in sediment quality. Ranges astride each mean indicate appreciable between-core variability at most stations; however, noticeably lower mean values occur in surface sediments at and just beyond the southern part of the disposal site. This trend is not apparent at 6 cm, again indicating that the physico-chemical condition of sediments in the general area has not been significantly impaired by sludge disposal. However, the two lowest values were encountered at approximately 1 km either side of the disposal site centre.

Tomato pips are a commonly-used indicator of contamination by sewage particulates, as they generally survive passage through the human digestive system and sewage treatment works. Trends in counts (Figure 5) provide clear evidence of localised accretion. Peaks in counts at the northern and southern edges of the disposal site can probably be accounted for by the tendency of the disposal vessel to alternate between these locations during discharge. While there is slight attenuation of the curve to the south, indicating some lateral transport, it is clear that — at least for this component of the particulate matter — contamination is largely confined to within and immediately beyond the disposal site.

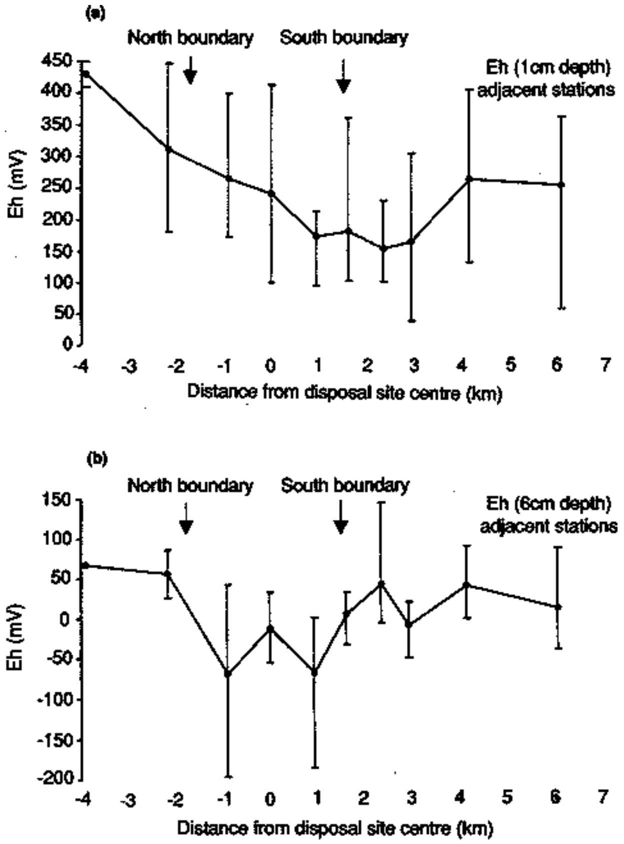


Figure 4. ***Trends in Eh values along transects through the Tyne sewage-sludge disposal site (mean and range): (a) 1 cm depth; and (b) 6 cm depth***

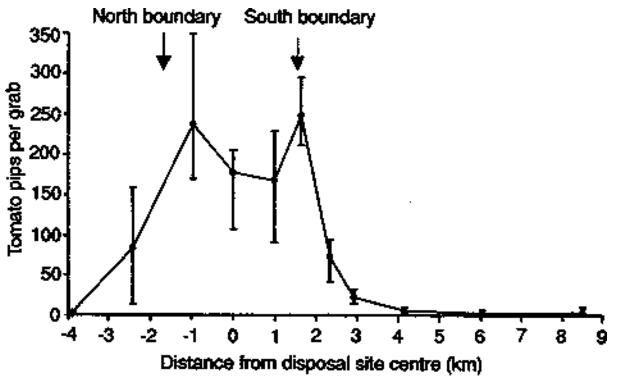


Figure 5. ***Trends in tomato pips along transects through the Tyne sewage-sludge disposal site (mean and range)***

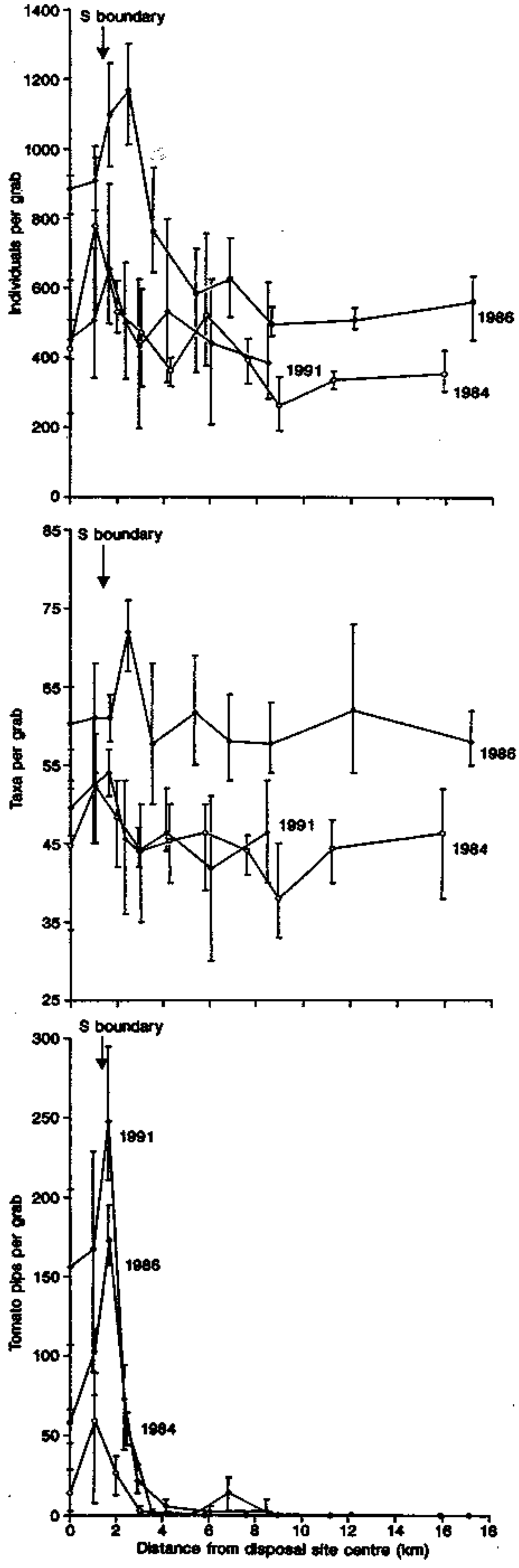


Figure 6. ***Trends in individuals, taxa and tomato pips along transects through the Tyne sewage-sludge disposal site (mean and range)***

In Figure 6, trends in total numbers of macrofauna individuals, taxa, and tomato pips, are compared with earlier data along a transect running south from the disposal site. (Sampling was conducted in February, 1984 and June, 1986). Peaks in tomato pips correspond with those in abundance and taxa, and add weight to earlier conclusions concerning a localised response of the benthos to mild organic enrichment. A comparison of counts of tomato pips between years suggests that there may be an accumulation of less degradable material at the disposal site. However, there is no indication of a worsening trend in the fauna — indeed patterns in the 1991 data are very similar to those of 1984 and, for numbers of individuals, are not markedly elevated compared with trends in 1986. A similar pattern of localised response has been observed in the meiofauna (P. Somerfield, PML, pers. comm.). A full account of macrofauna changes along the length of the transects of Figure 3 awaits completion of sample analyses.

Between-sample variability in macrofauna counts was relatively high in 1991, which may be partly accounted for by adverse weather conditions at the time of sampling. Nevertheless, results were consistent with earlier findings, which indicated mild organic enrichment close to the disposal site. Such changes remain within proposed 'Environmental Quality Standards' for the benthos at this location (MAFF, 1992(a), Rees and Pearson, 1992). Annual sampling at representative stations, as reported in MAFF (1992(b)), is continuing, and will be the subject of future reporting.

4.5.2 Garroch Head

Sampling in 1991 again succeeded in identifying a marked gradient of change in the benthic macrofauna, of limited spatial extent, which could be ascribed to organic enrichment of sediments at this relatively quiescent deep-water location. Changes in the physico-chemical data generally matched those of the benthic fauna. Effects were characterised by high numbers of smaller-sized 'opportunistic' organisms and a much reduced complement of taxa in the immediate vicinity of the disposal site. Away from this, lower abundances of a wide range of taxa, including larger-sized species, were encountered.

As in 1990, there was evidence of a slight increase in the area of grossly enriched sediments to the south and west of the disposal site centre. However, reduced enrichment at stations beyond 2 km from the centre was also evident, suggesting a more concentrated targetting of disposal activity. As in previous years, gross effects were therefore confined to the immediate vicinity of the disposal site and, overall, variability at regularly sampled stations was within the range observed over the 13 years of monitoring at this location.

4.5.3 St Abbs Head and Bell Rock

Monitoring at these disposal sites was conducted in May and October, 1991, respectively, on circular grids of stations encompassing the disposal sites. Sampling design and procedures followed those of previous years. Both sites are relatively homogeneous in nature, though somewhat coarser sediments are encountered at Bell Rock.

Tomato pips and other sewage-derived artefacts were recorded in sediments at both sites, with highest numbers occurring at or near to the disposal-site centres. In recent years, there has been a gradual increase in the mean count of tomato pips at St Abbs Head, suggesting a tendency towards local accumulation at least of larger-sized particles arising from the disposal activity.

Gradients in the benthic fauna could largely be explained by subtle variability in substrate type, which was considered to be unrelated to sewage-sludge disposal. A comparison of faunal indices with previous years suggested a return to the higher values of diversity and evenness encountered in the early 1980s. This may be partly explained by the continued decline in the dominance of the polychaete *Myriochele*, which again does not appear to be related to the effects of sludge disposal.

As in previous reports, the benthos were analysed in groups of stations defined as 'impacted' or 'unimpacted' on the basis of an earlier survey of coprostanol levels in sediments. A range of univariate measures of community structure was employed, but no statistically significant differences were found between the two groups at either site. However, as in 1990, marginally lower mean values for diversity, and higher mean values for abundance and the abundance:taxa ratio, suggested slight enrichment at the 'impacted' group of stations at St Abbs Head. Support for this judgement is provided by observations on the occurrence of the polychaete *Capitella*, a commonly cited indicator of organic enrichment, which was found in highest densities at the centre of the disposal site. However, counts of substantially less than 100 per grab (with the use of a 0.5 mm mesh sieve) may be contrasted with counts of more than 2000 per grab (with the use of a 1 mm mesh sieve) at the Garroch Head sewage-sludge disposal site, where more quiescent conditions prevail.

4.5.4 Exeter

A grid of 22 stations encompassing the main area of disposal was conducted in September, 1991. A 'benchmark' survey conducted by MAFF in the mid-1970s (Eagle *et al*., 1978) provided a useful means for evaluating any long-term changes in the status of the benthic fauna which might be attributable to sludge disposal.

Water depths in the survey area ranged from 30-50 m. Stations were typically muddy in nature, and supported a diverse fauna, indicating relatively stable conditions at the seabed. There was some evidence of a reduction in numbers of individuals and taxa at the northern edge of the disposal site. This would be consistent with tidally-induced dispersion of particulates approximately along an east-west axis, and corresponds with local elevations in organic carbon. Comparable findings were reported by Eagle *et al.* (1978). However, these effects were relatively subtle in nature, and the general picture revealed from multivariate analysis was of a homogeneous community structure across the sampling area.

In contrast to Garroch Head, there was no evidence for the presence of anoxic sediments at depth, or for the proliferation of 'opportunistic' species at the expense of others, near to the disposal site. A perspective on the magnitude of benthic changes occurring at the two locations is provided by the ranges of taxa and individuals encountered per grab. These were, respectively, 27-52 and 81-273 at Exeter, compared with 7-56 and 124-9907 at Garroch Head. Ranges of % organic carbon at the two locations were, respectively, 1.04-2.40 and 1.05-13.78.

4.5.5 Overall conclusions

On the basis of the benthic work reported in this section the following recommendations may be made:

1. More attention should be given to the recording and reporting of physical indicators of sewage contamination within sediments, especially tomato pips.

2. For compliance-testing against proposed 'Environmental Quality Standards' for the benthos, some modifications to sampling practices (notably increased replication at 'representative' stations) will be required at certain disposal areas, notably Bell Rock, St Abbs Head, Barrow Deep and Liverpool Bay, in order to facilitate comparisons between stations or station groups near to and distant from contaminant sources.

4.6 EQO: Maintenance of the receiving environment without distinguishable change

In its first report, the GCSDM explained that compliance with this objective would be judged by the extent to which background concentrations and the nature of the benthic fauna remained unchanged.

4.6.1 Tyne

Each year approximately 500 000 tonnes of sewage sludge are deposited at a disposal site 10 kilometres off the mouth of the River Tyne. By determining faecal bacteria in seabed sediments, Rowlatt *et al.* (1991) showed that the zone of initial sludge settlement is situated at the southern edge of the disposal site. They also demonstrated that, with the possible exception of chromium, there was no evidence of any accumulation of metals at the settlement area in 1988.

In order to assess whether settlement results in a long-term build-up of sludge-derived metals at the seabed, sediments have been collected annually in May, when weather conditions permitted. They were taken at positions located randomly in a sampling zone centred on the settlement area. The surface 1 cm of sediment was sampled and sieved at 63 µm according to the GCSDM guidelines (MAFF, 1989). The fraction passing through the sieve was digested with *aqua regia* and analysed using atomic absorption spectro-photometry.

Figure 7 shows the mean concentrations of sediment metals with error bars of 1 standard error of the mean. This figure shows no increasing trend in concentrations of metals and in some cases (e.g. chromium and lead) suggests a decrease. From these data it may be concluded that the sewage-sludge disposal operation at the Tyne site is not causing a year-on-year deterioration in sediment quality. Taking these observations with the earlier work of Rowlatt *et al*. (1991), it may be concluded that the sludge disposal operation at the Tyne is not, as far as metals are concerned, having a detrimental effect on environmental quality either in the short- or long-term

4.6.2 Nab Tower

Each year approximately 250 000 tonnes of sewage sludge, and between 600 000 and 1 500 000 tonnes of dredged material are deposited at the Nab Tower disposal site.

Surveys carried out in 1989 (23 samples), and 1991 (21 samples) were based on a random stratified design and centred on the area of likely impact. This type of survey design is used to monitor changes in sediment quality over time. Samples were sieved at 63 µm.

Table 9 shows the mean values and standard deviations for the concentrations of metals in the <63 µm sediment fraction in 1989 and 1991. Few firm conclusions can be drawn until further data are collected, although it should be noted that the values are within the ranges found at other UK sewage-sludge disposal sites.

Table 9. Concentrations of metals in the 63µm fraction of sediments at the Nab Tower sewage-sludge disposal site in 1989 and 1991

Year		Concentration (mg kg^{-1})					
		Hg	Pb	Cu	Zn	Cr	Ni
1989	Mean	0.41	62.6	27.8	106.7	42.3	38.9
	S.D.	0.39	98.8	22.6	46.8	10.2	31
1991	Mean	0.29	72.6	69.9	163	55.9	27.1
	S.D.	0.28	55	48.3	117	11.4	8.4

Note: All cadmium analyses were below the detection limit of the method used (0.2 mg kg^{-1})

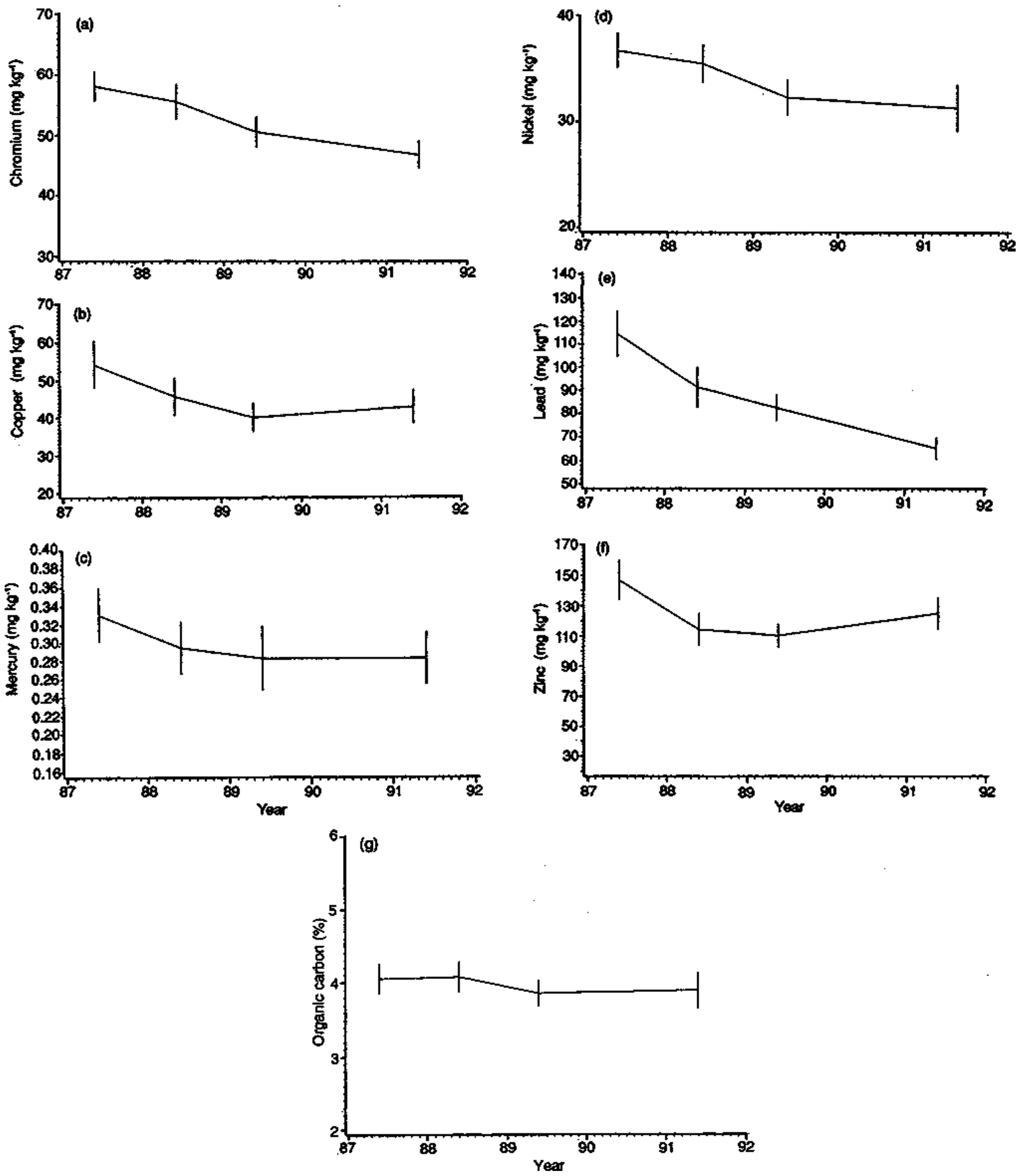


Figure 7. ***Concentrations of various metals and organic carbon in the <63 µm fraction of sediments collected in the zone of initial settlement at the southern edge of the Tyne sewage-sludge disposal site: (a) chromium; (b) copper; (c) mercury; (d) nickel; (e) lead; (f) zinc and (g) organic carbon***

These data, together with those for the Tyne disposal site presented above and those for Liverpool Bay (MAFF, 1992(a)) indicate the importance of carrying out a long series of measurements before drawing conclusions from a time-series.

4.6.3 Exeter

South West Water carried out a survey of the Exeter disposal site in 1991. There was little evidence of contamination at the disposal site other than a slight elevation of organic carbon at the northern edge (Figure 8). This occurred in the region where sewage sludge is deposited. Faecal bacteria in the sediment indicate where the sewage sludge reaches the seabed (Figure 9).

Lead and zinc values did not show any clear pattern associated with sewage sludge disposal.

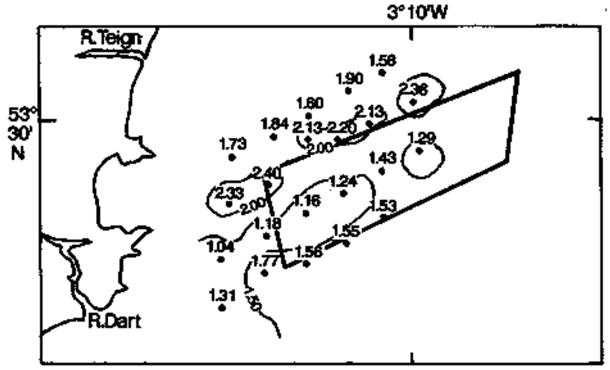


Figure 8. Concentrations of organic carbon (%) in the <63 µm fraction of sediments around the Exeter sewage-sludge disposal site

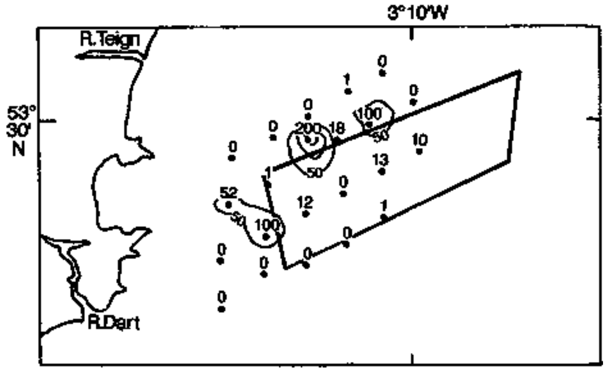


Figure 9. Concentrations of faecal streptococci (numbers g^{-1}) in sediments around the Exeter sewage-sludge disposal site

4.6.4 Roughs Tower

Sediment samples collected by Anglian Water on an extensive grid did not show any evidence of elevated concentrations of metals associated with sewage disposal at this site compared with surrounding areas (Figure 10).

4.6.5 St Abbs Head

Lothian Regional Council and the Forth River Purification Board analysed carbon and various metals in sediments around the disposal sites in the Forth.

At St Abbs, both the <2 mm and the <63 µm fractions of the sediment were analysed. Figure 11 shows the mean concentrations of carbon in the <2 mm fraction plotted for the period 1978-1991. While the values have fluctuated during this period they have shown no consistent trend. This indicates that dispersion and/or degradation effectively prevents any accumulation at the site.

Summary data for organic carbon and nitrogen in the <63 µm fraction of the sediment are shown in Table 10. The 1991 mean values for carbon and nitrogen were 2.14% and 1967 mg kg^{-1} respectively. These values are similar to those for 1989 and 1990, but higher than in previous years. It is unclear why there was an increase in concentration between 1988 and 1989. No such change was apparent in the <2 mm fraction, although it should be noted that the use of the coarser size fraction may mask variations in the fine fraction which represents a small proportion of the whole sediment.

Taking the <63 µm data as a more sensitive tool for indicating accumulation of organic matter resulting from disposal, a statistical comparison was made of the carbon and nitrogen concentrations in the inner and outer zones of the disposal site. Using a ‘t’ test with groups of 17 and 8 stations, no significant difference in carbon or nitrogen concentrations was found.

The distribution of carbon, presented as maps, is shown in Figure 12. The plots show that, for the <2 mm fraction, the highest values of carbon tend to be associated with a centre-north-west arc at the disposal site. The variation in organic carbon in the <63 µm fraction is less pronounced, and would indicate a more central distribution.

Figure 13 shows the mean concentrations of metals in the <2 mm fraction since surveys began together with $\pm$ 2 standard deviation ‘warning limits’. These indicate no increasing trend over the period for any of the metals. Copper, lead, nickel and zinc show peak concentrations around 1981-2 followed by a marked decline, since when values have remained more stable.

Metal concentrations in the <63 µm fraction between 1986 and 1991 (Table 11) suggest some accumulation of copper, lead and nickel over the last 3 years. Using a ‘t’ test (as in the case of carbon above), no significant differences were found between the inner and outer zones of the survey area for these metals.

All the metal concentrations at St Abbs Head were well below the effects range-low (ER-L) toxicity values defined by the National Oceanic and Atmospheric Administration (NOAA) (Table 12).

The FRPB/LRC report used several different techniques to assess the impact of sludge disposal; time-series studies of both <2 mm and <63 µm sediment fractions, statistical comparisons of the inner and outer areas, ‘warning’ and ER-L values and mapping techniques. GCSDM approves of this multiple-method approach and believes it gives a clear picture of the extent of contamination.

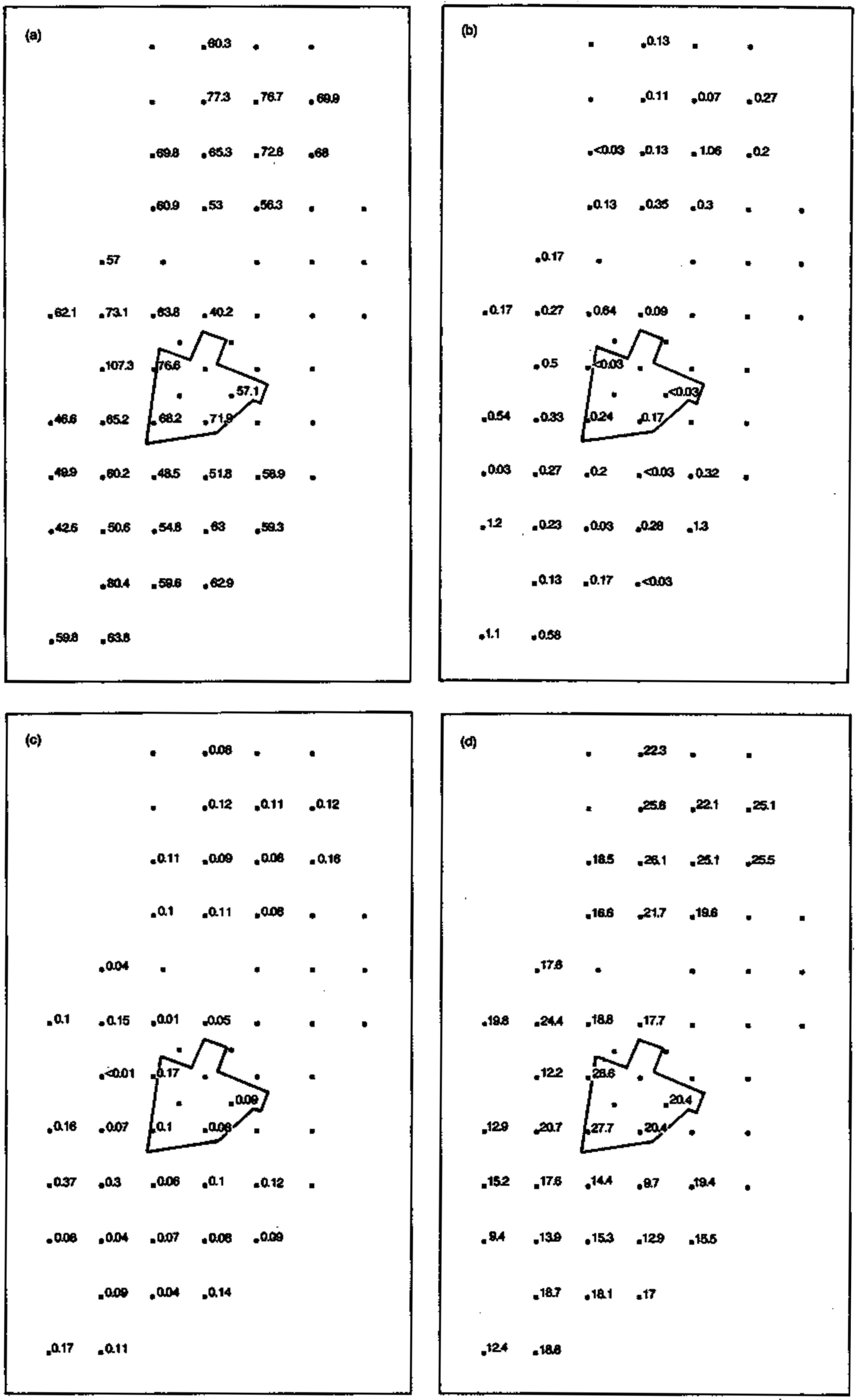


Figure 10. Concentrations of metals (mg kg^{-1}) in the <63 µm fraction of sediments around the Roughs Tower sewage-sludge disposal site: (a) zinc; (b) cadmium; (c) mercury and (d) lead

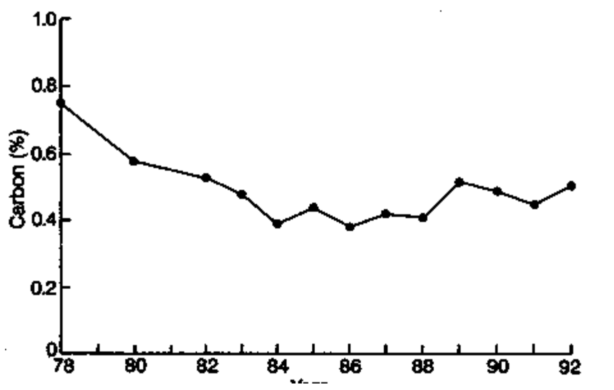


Figure 11. Time series of carbon concentrations in the <2 mm fraction of sediments at the St Abbs Head sewage sludge disposal site

Table 10. Annual mean values of sediment organic carbon and nitrogen at St Abbs Head sewage-sludge disposal site

Year	<63 µm		<2 mm	
	% C	mgN kg^{-1}	% C	mgN kg^{-1}
1986	-	-	0.42	537
1987	1.56	1573	0.41	520
1988	1.63	1255	0.52	472
1989	2.18	2078	0.49	503
1990	2.12	2022	0.45	441
1991	2.14	1967	0.51	449

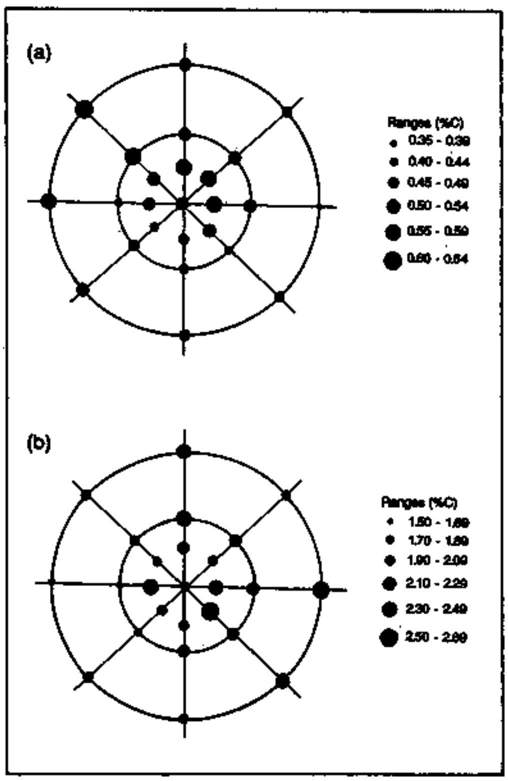


Figure 12. Distribution of concentrations of carbon in sediments at the St Abbs Head sewage-sludge disposal site: (a) <2 mm sediment fraction; and (b) <63 µm sediment fraction

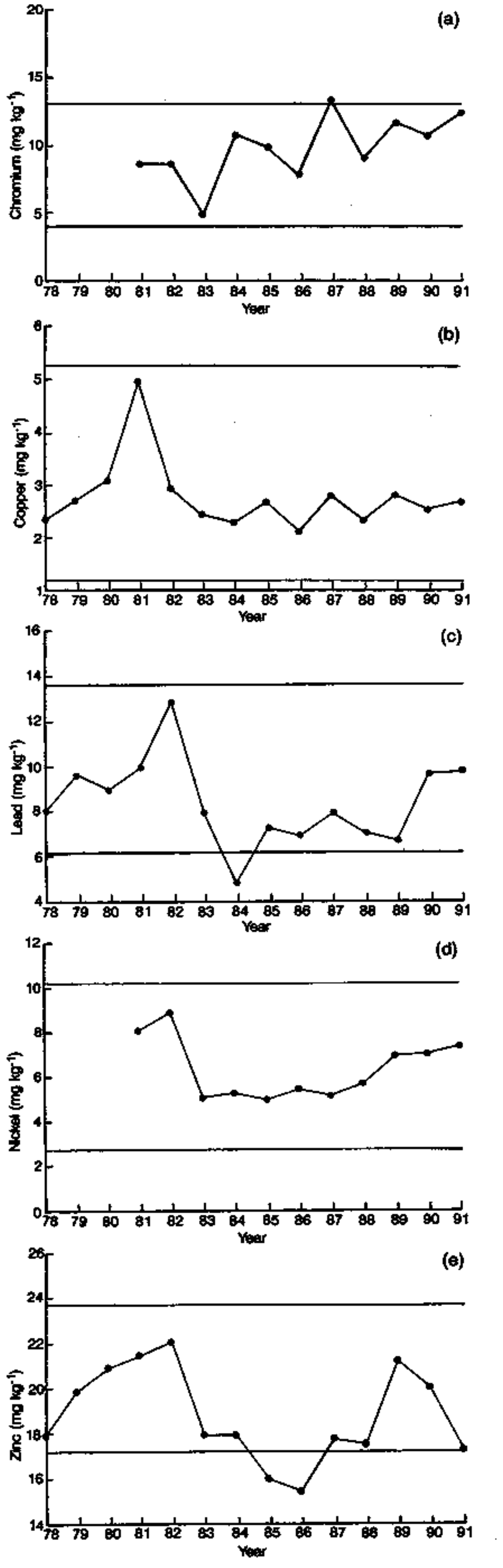


Figure 13. Time series of concentrations of metals in sediments (mg kg^{-1}) at the St Abbs Head sewage-sludge disposal site: (a) chromium; (b) copper; (c) lead; (d) nickel and (e) zinc

Table 11. ***Annual mean values (mg kg^{-1}) of trace metals in the <63 µm fraction at St Abbs Head sewage-sludge disposal site***

Year	Cu	Zn	Pb	Cr	Ni	Fe
1986	7.1	35.5	13.9	16.2	11.4	10757
1987	7.6	43.8	18.1	22.6	11.7	11280
1988	7.7	36.2	14.9	25.8	11.9	10248
1989	9.9	49.7	31.6	23.5	21.2	8830
1990	11.5	64.3	32.7	28.4	19.9	16583
1991	11.4	50.2	29.3	30.8	20.4	11771

Table 12. ***Effects Range Low and Median values for metals and organohalogens (mg kg^{-1}) defined by the National Oceanic and Atmospheric Administration (NOAA)***

Metal/ organohalogen	Effects Range - Low and - Median (mg kg^{-1}) ER-L	ER-M
Copper	70	390
Zinc	120	270
Lead	35	110
gamma HCH	-	-
pp DDD	0.002	0.020
pp DDE	0.002	0.015
pp DDT	0.001	0.007
PCB	0.05	0.40

4.6.6 Thames Estuary: Barrow Deep

Sewage sludge from London has been deposited at a designated site in the Barrow Deep since 1967 (Figure 14). Water movements transport the dispersing sludge around the East Barrow Sand and initial settlement of sludge solids occurs at several locations, as has been demonstrated using radiotracers (Figure 14).

During the period 1985-1991, samples of surface sediment were collected, at least annually, from five stations in both the Barrow and Middle Deeps. On each occasion new sets of stations were located randomly within set sampling zones (Figure 14).

Metals and carbon have been analysed in whole sediment, together with the fine fraction. While this does not follow the GCSDM guidelines, it is reported here as an example of the use of a normalisation technique.

Figure 15 shows the mean value of fines at the two sites and demonstrates a high degree of synchronisation between them, suggesting that at least a component of the variations are region-wide rather than simply local. During the period 1986-1990, the fines at the two sites exhibited not only synchronicity but also generally lower concentrations in autumn, the time of greatest storm frequency, and higher concentrations in summer, a time of relatively quiescent conditions. This indicates that the fine fraction of the surface sediments is mobile, particularly during autumn and winter storms, and confirms the dispersive nature of the outer Thames Estuary.

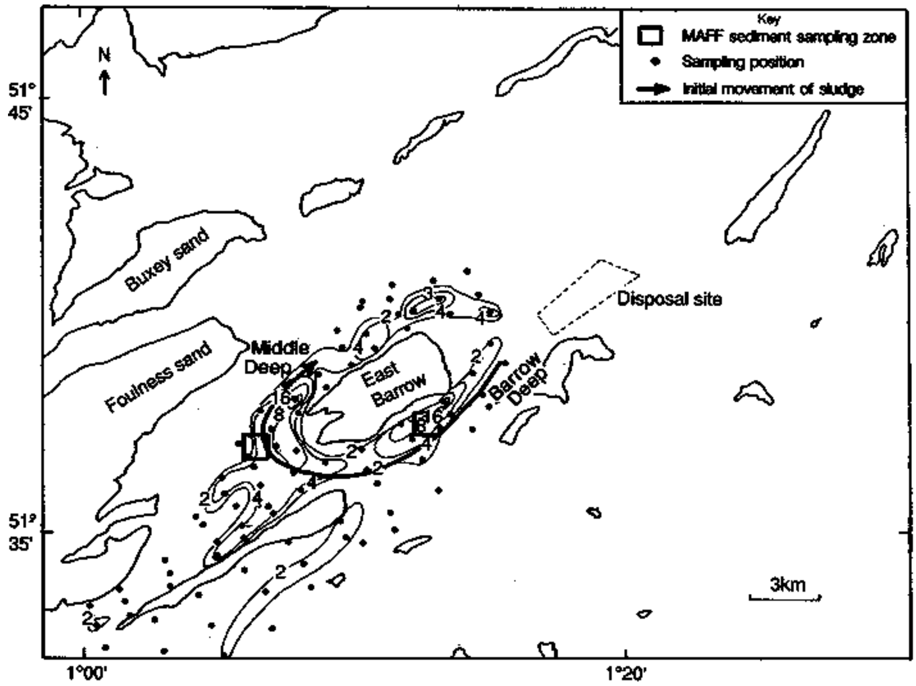


Figure 14. Location of the Barrow Deep disposal site in the outer Thames showing the MAFF sediment sampling zones, the direction of residual water movement and the main areas of initial settlement shown by radiolabelled sludge (Talbot et al. 1982)

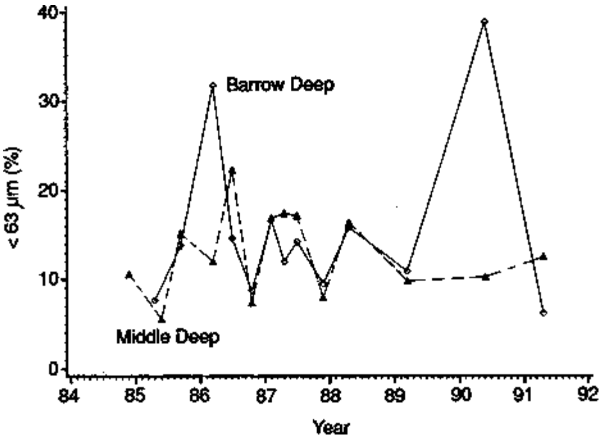


Figure 15. Fines (% <63 µm) content of sediment from the Barrow and Middle Deep sampling zones

The strong association of many metals with fines (see for example Figure 16) due to, among other things, adsorption on clay minerals, can cause a strong positive relationship between metal and fines when whole sediments are considered. In the present case, this applies to chromium, copper, mercury, nickel, lead and zinc. It is possible to counter the effects of variations in fines content on concentrations of metals in whole sediment by examining metal/fines ratios; i.e. to normalise the metal data.

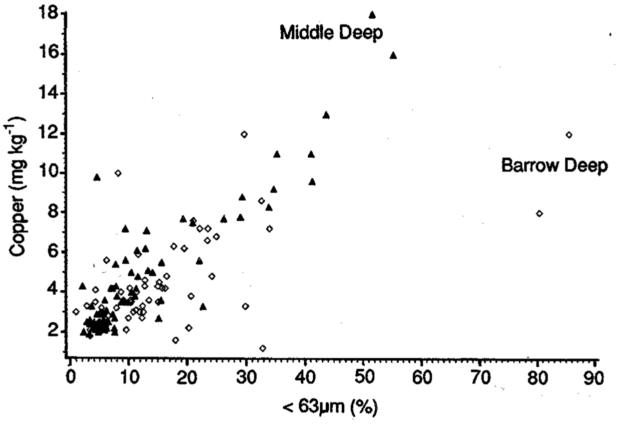


Figure 16. Relationship between copper (mg kg^{-1}) and fines (% <63 µm) in sediment from the Barrow and Middle Deep sampling zones

Figures 17 and 18 show the mean metal/fines ratios (i.e. normalised metal values) and ranges of mercury and lead (as examples of the trace metals analysed) in the Barrow Deep and Middle Deep zones. The most notable feature of these data sets is that while there have been some variations, there is no evidence of a trend, either worsening or improving, over the period studied.

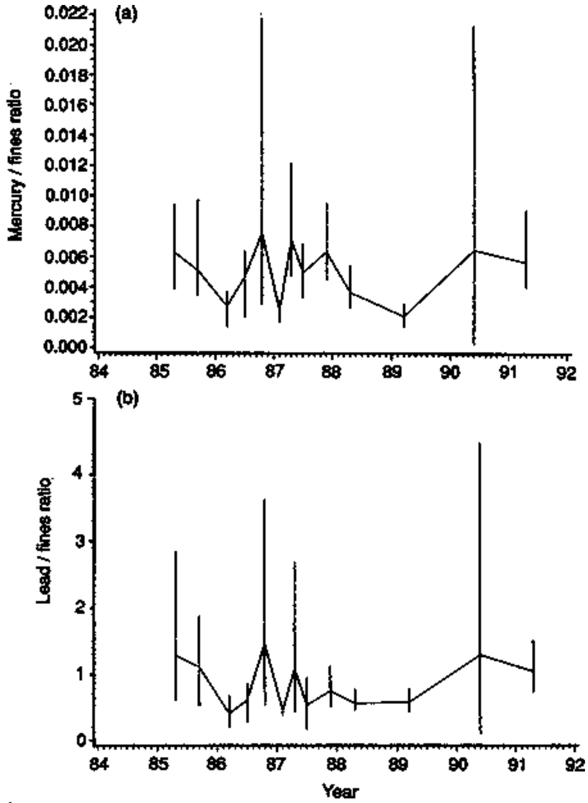


Figure 17. Time series of metal/fines ratios in sediments from the Barrow Deep sampling zone (mean and range): (a) mercury; and (b) lead

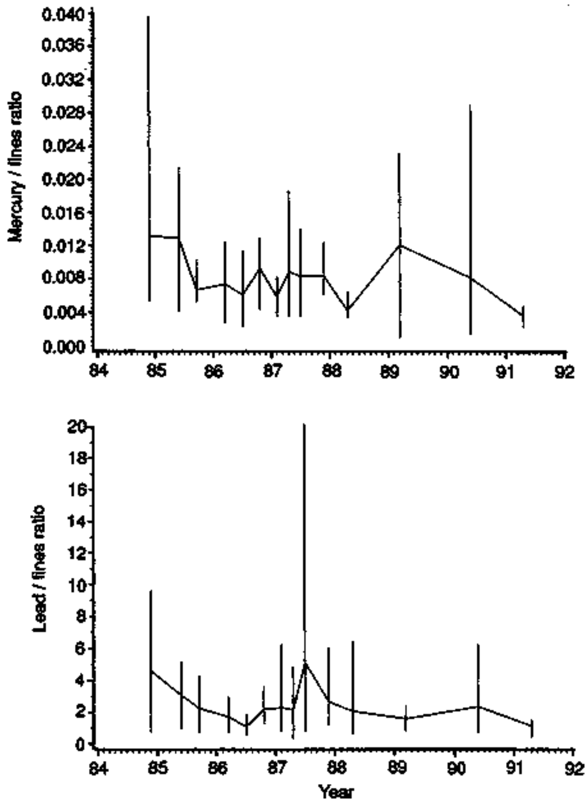


Figure 18. Time series of metal/fines ratios in sediments from the Middle Deep sampling zone (mean and range): (a) mercury; and (b) lead

The use of a normaliser has allowed whole sediment to be analysed, with considerable saving in laboratory time and has allowed a clear conclusion to be drawn. However, the sensitivity of such a technique must be questioned on the basis of the St Abbs Head results. Fine fraction data from samples collected in the Thames area in 1992 will be presented in the next report of the GCSDM.

4.7 Overall conclusions from the review of monitoring in 1991

- Long time-series of contaminant data provide a firm basis for assessing year-on-year fluctuations in context and every effort should be made to continue to collect time-series data.

- No evidence of significant accumulation of sludge contaminants was found at any of the dispersive disposal sites sampled. Garroch Head is the only accumulating site in UK and was selected as such.

- The occurrence of litter ought to be assessed at all sites using appropriate gear.

- Fish disease studies ought to be conducted according to ICES/GCSDM recommendations or not at all.

- Bacterial examination of gut contents of fish shows no effects of note and need not be continued.

- More attention should be given to the recording and reporting of physical indicators of sewage contamination within sediments, for example tomato pips.

- For compliance-testing against proposed ‘Environmental Quality Standards’ for the benthos, some modifications to sampling practices (notably increased replication at ‘representative’ stations) will be required at certain disposal sites, in order to facilitate comparisons between stations or station groups near to and distant from contaminant sources.

- A multiple method approach to assessing the impact of sewage-sludge disposal is desirable as this gives a clearer picture of the extent of contamination.

- The technique of normalisation shows considerable promise but the question of sensitivity needs to be addressed.

5. MONITORING ACTIVITIES AT SEWAGE-SLUDGE DISPOSAL SITES IN 1992

5.1 Introduction

During 1992, surveys were carried out at the following disposal sites (see Figure 1): Tyne, Humber, Thames (Barrow Deep), Nab, Exeter, Plymouth, Liverpool Bay, North Channel, Garroch Head, Bell Rock and St Abbs Head.

Short summaries of all the surveys are given in the following sub-sections. As far as possible, the surveys were carried out in accordance with the methods recommended by the GCSDM. Methods may differ from those recommended where environmental characteristics (e.g. substrate type or hydrography) render them inappropriate, or where comparability with previous surveys can only be ensured by retaining existing methods.

5.2 MAFF survey of the Tyne sewage-sludge disposal site, May 1992

(a) Sediment samples were collected from the sites shown in Figure 19.

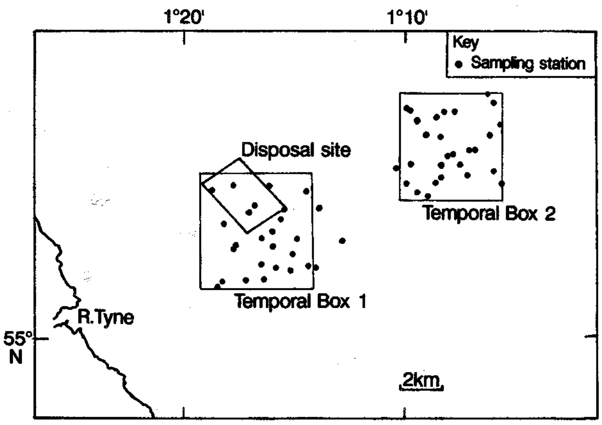


Figure 19. MAFF temporal trend survey of the Tyne sewage-sludge disposal site, May 1992

(b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn), carbon and nitrogen were determined in the <63 µm fraction of the surface 0-1 cm of the sediment. The samples form part of a study on temporal trends in sediment quality at the disposal site.

(c) Sediment samples were also collected, by Day grab, along a north-south transect through the disposal site at the stations shown in Figure 20.

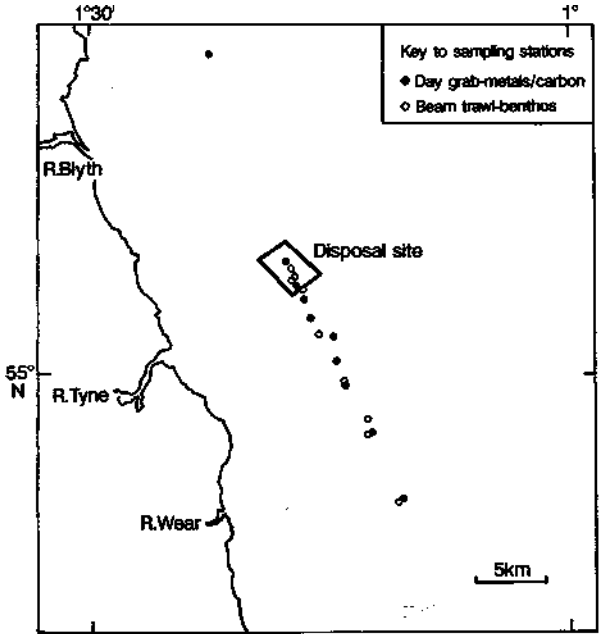


Figure 20. MAFF transect survey of the Tyne sewage-sludge disposal site, May 1992

(d) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <63 µm fraction of the top 0-1 cm of the sediment. Carbon and nitrogen were also determined in these samples.

(e) Benthic infauna were identified and enumerated in samples from a selected number of these stations.

(f) Beam trawl samples were taken at the stations shown in Figure 20. Benthic infauna will be identified and enumerated in these samples.

5.3 Northumbrian Water survey of the Tyne sewage-sludge disposal site, May/October 1992

(a) Sediment samples were collected by Day grab from the stations shown in Figure 21.

(b) Samples from these sites were analysed for metals (Cd, Cu, Cr, Hg, Mn, Ni, Pb and Zn) in the <63 µm fraction of the surface 0-1 cm.

(c) Benthic infauna were identified and enumerated in samples from the sites shown in Figure 21.

(d) Beam trawl hauls were made at five sites during May, September and October. Epifauna were identified to species level and enumerated.

(e) Underwater video surveys were carried out along a north-south transect through the disposal site.

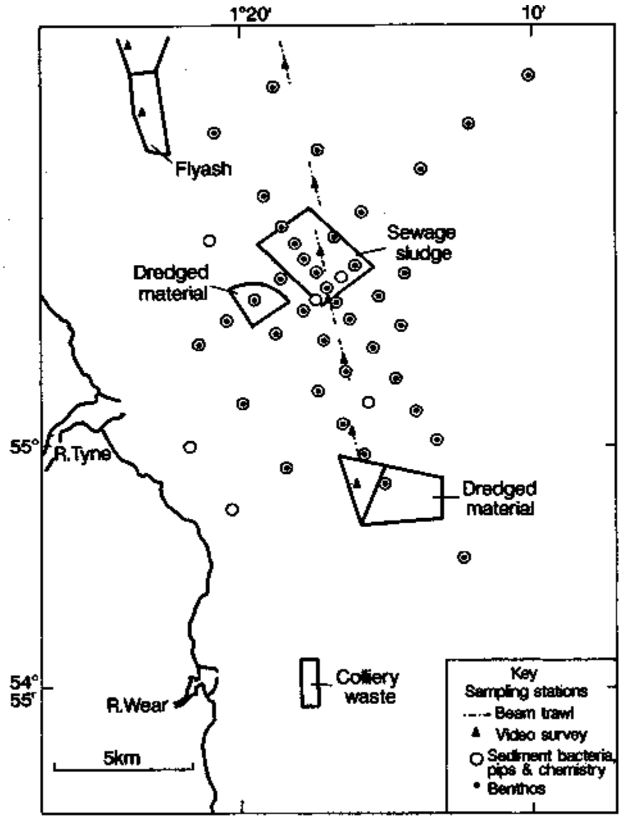


Figure 21. Northumbrian Water survey of the Tyne sewage-sludge disposal site, May/November 1992

5.4 MAFF survey of the Humber sewage-sludge disposal site, May 1992

(a) Samples of horse mussel (*Modiolus modiolus*) were collected at the stations shown in Figure 22. These will be analysed for metals (Hg, Cd, Cu, Pb and Zn) as part of a study on temporal trends in chemical quality of the mussel population.

5.5 Yorkshire Water survey of the Humber sewage-sludge disposal site, September 1992

(a) Sediment samples were collected at the stations shown in Figure 23.

(b) Faecal bacteria (*E. coli* and faecal streptococci) were enumerated in scrapes of the surface 0-1 cm of the sediment.

(c) PCB and pesticide residues were also determined in the surface 0-1 cm of the samples.

(d) Metals (Cd, Hg, Pb and Zn), carbon and nitrogen were determined in the <63 µm fraction of the remainder of the surface sample.

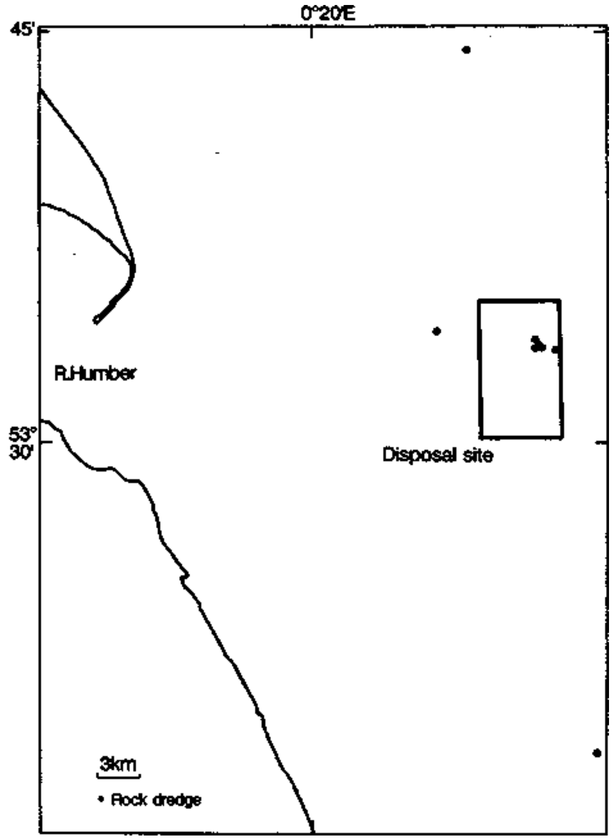


Figure 22. MAFF survey of the Humber sewage-sludge disposal site, May 1992

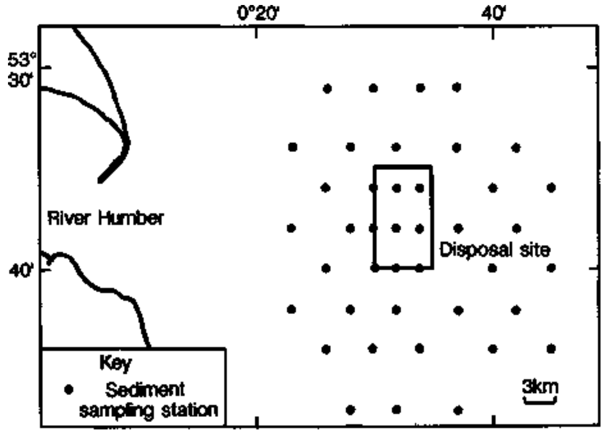


Figure 23. Yorkshire Water survey of the Humber sewage-sludge disposal site, September 1992

(b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn), carbon and nitrogen were determined in the <63 µm fraction of the surface 0-1 cm of the sediment. Benthic infauna were identified and enumerated in samples from a selected number of these sites.

(c) Beam trawls were deployed at 3 sites and the contents assessed for litter.

(d) Sediment samples were collected from known areas of sludge settlement. Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn), carbon and nitrogen were determined in the <2 mm fraction of the sediment.

5.6 MAFF survey of the Barrow Deep (Thames Estuary) sewage-sludge disposal site, May 1992

(a) Sediment samples were collected from the sites shown in Figure 24.

5.7 MAFF survey of the Nab sewage-sludge disposal site, December 1992

(a) Sediment samples were collected from the sites shown in Figure 25.

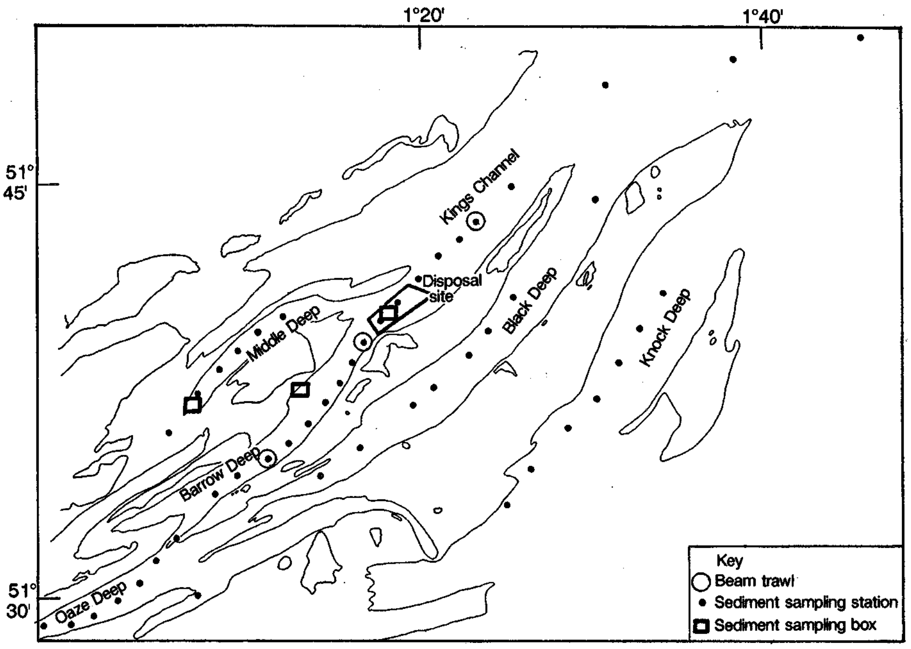


Figure 24. MAFF survey of the Barrow Deep sewage-sludge disposal site, May 1992

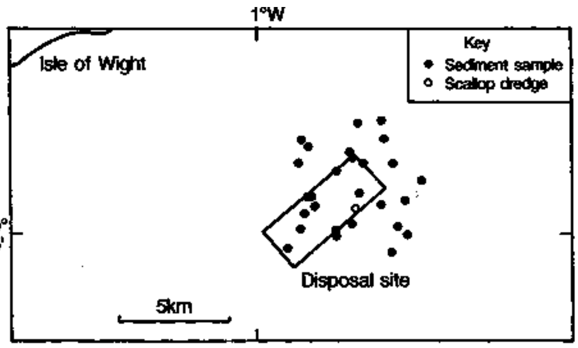


Figure 25. MAFF survey of the Nab sewage-sludge disposal site, December 1992

(b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <63 µm fraction of the top 0-1 cm of the sediment. Carbon and nitrogen were also determined in these samples. The samples form part of a study on temporal trends in sediment quality at the disposal site.

(c) A scallop dredge sample was taken at the site shown in Figure 25 for the assessment of litter.

5.8 Southern Water survey of the Nab sewage-sludge disposal site, June 1992

(a) Sediment samples were collected from the sites shown in Figure 26.

(b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <63 µm fraction of the top 0-1 cm of the sediment. Carbon and nitrogen were also determined in these samples.

(c) Faecal bacteria (*E. coli*, group D faecal streptococci and *Clostridium*) were enumerated in surface scrapes of the sediment.

(d) PCB and pesticide residues were determined in the top 5 cm of the sediment.

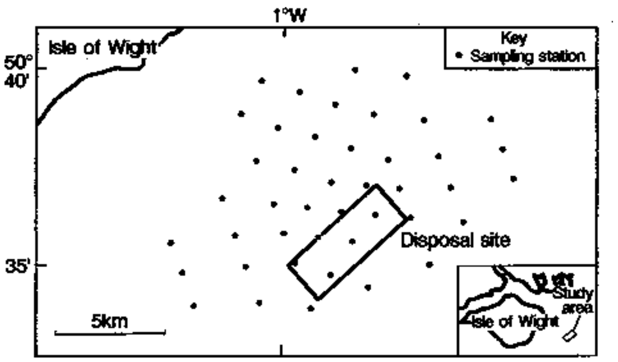


Figure 26. Southern Water survey of the Nab sewage-sludge disposal site, June 1992

5.9 MAFF survey of the Plymouth sewage-sludge disposal site, December 1992

(a) Sediment samples were collected from the sites shown in Figure 27. (Stations outside the disposal site are in the zone of effect.)

(b) Metals (Cd, Cu, Cr, Hg, Ni, Pb and Zn) will be determined in the <63 µm fraction of the top 0-1 cm of the sediment. Carbon and nitrogen were also determined in these samples.

(c) Beam trawl samples were taken at the 3 sites shown in Figure 27 and assessed for litter.

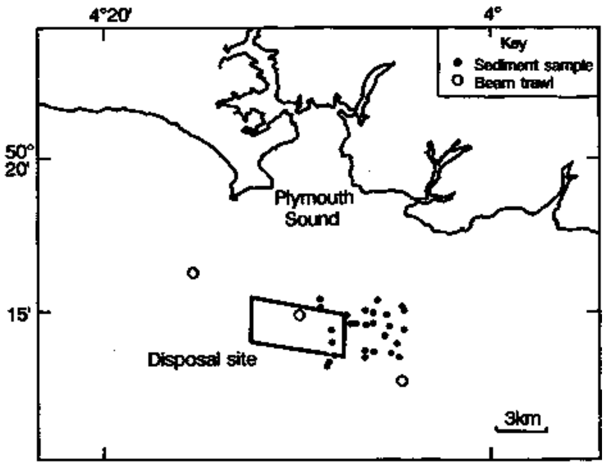


Figure 27. MAFF survey of the Plymouth sewage-sludge disposal site, December 1992

5.10 MAFF survey of the Exeter sewage-sludge disposal site, December 1992

(a) Sediment samples were collected from the sites shown in Figure 28. (Stations outside the disposal site are in the zone of effect.)

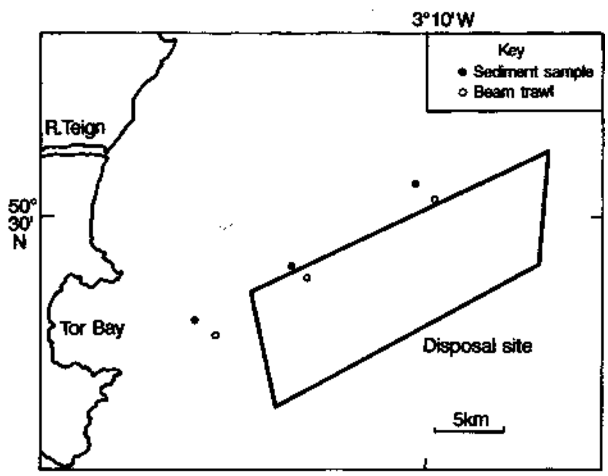


Figure 28. MAFF survey of the Exeter sewage-sludge disposal site, December 1992

(b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <63 µm fraction of the top 0-1 cm of the sediment. Carbon and nitrogen were also determined in these samples.

(c) Beam trawl samples were taken at the 3 sites shown in Figure 28, for the assessment of litter.

5.11 MAFF survey of the Liverpool Bay sewage-sludge disposal site, May 1992

(a) Sediment samples were collected at the stations shown in Figure 29.

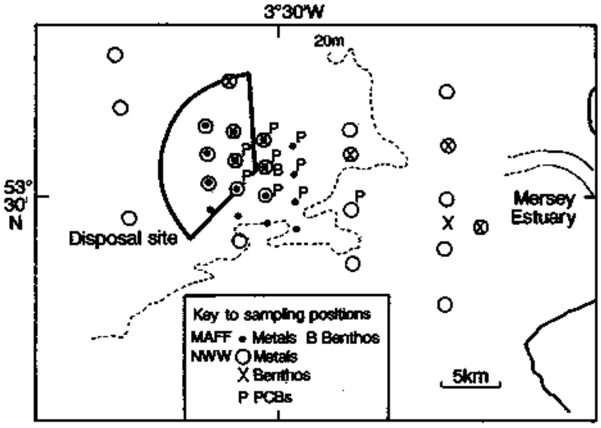


Figure 29. MAFF and North West Water surveys of the Liverpool Bay sewage-sludge disposal site, May and September 1992

(b) Metals (Cd, Cu, Cr, Hg, Ni, Pb and Zn) were determined in the <90 µm fraction of the top 0-1 cm of the sediment. Carbon and nitrogen were also determined in these samples.

(c) Benthic infauna were identified and enumerated in 3 samples taken from the station shown in Figure 29.

5.12 North West Water Ltd survey of the Liverpool Bay sewage-sludge disposal site, September 1992

(a) Sediment samples were collected from the sites shown in Figure 29.

(b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <63 µm fraction of the surface 0-1 cm.

(c) Benthic infauna were identified and enumerated in sediment samples taken from 9 sites (see Figure 29).

(d) PCBs (congeners 28, 52, 101, 118, 138, 153 and 180) were determined in sediment samples collected from the sites shown in Figure 29.

5.13 DoE (NI) survey of the North Channel sewage-sludge disposal site, 1992

(a) Sediment samples were collected from the sites shown in Figure 30.

(b) Faecal bacteria (*E. coli*, group D faecal streptococci and *Clostridium*) were enumerated in surface scrapes of the sediment.

(c) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <63 µm fraction of the surface 0-1 cm. Carbon and nitrogen were also determined in these samples.

(d) Additional samples were collected from the sites shown in Figure 30 for the identification and enumeration of benthic fauna and tomato pips.

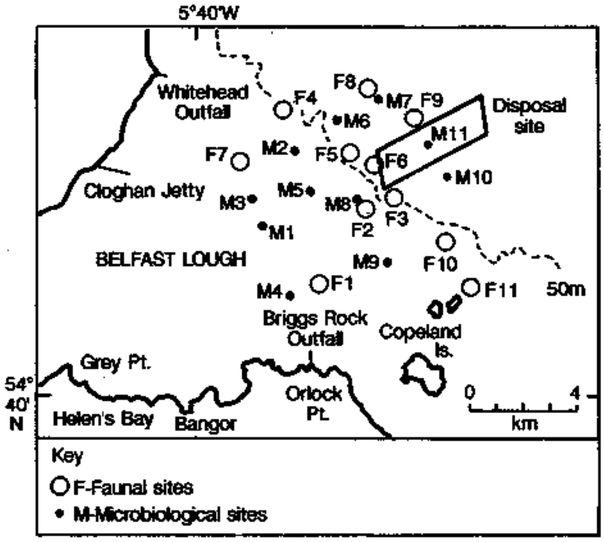


Figure 30. DoE(NI) survey of the North Channel sewage-sludge disposal site, April 1992

5.14 Scottish Marine Biological Association/Strathclyde Regional Council survey of the Garroch Head sewage-sludge disposal site, April 1992

(a) Sediment samples were collected at the stations shown in Figure 31.

(b) Dissolved oxygen content was determined in the water immediately above the sediment surface.

(c) Metals (As, Cd, Cr, Cu, Fe, Hg, Ni, Pb and Zn) were determined in whole samples of the surface 0-1 cm of the sediment. Carbon, nitrogen, PCB and pesticide residues were also determined in these samples.

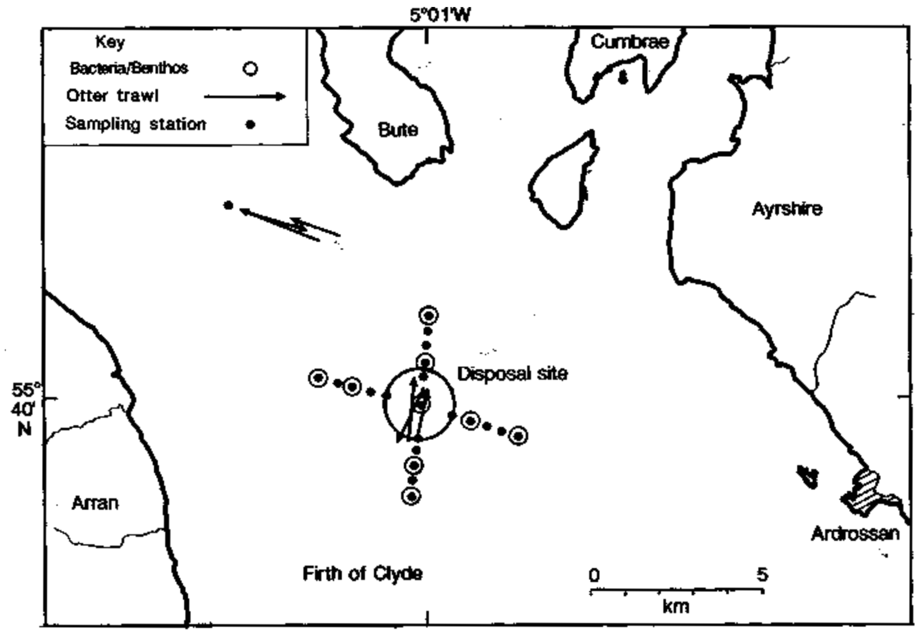


Figure 31. Scottish Marine Biological Association/Strathclyde Regional Council survey of Garroch Head sewage-sludge disposal site, April 1992

(d) Eh and pH measurements were made on core samples from selected stations (Figure 31), at 1cm intervals to a maximum depth of 10 cm.

(e) Two grab samples were collected from each of the stations shown in Figure 31 and sieved on a 1 mm mesh. Benthic infauna were identified and enumerated.

(f) Faecal bacteria (*E. coli*, faecal streptococci and *Clostridium*) were enumerated in surface scrapes of sediment from these sites.

(g) Otter trawls were deployed at the stations shown in Figure 31. Epifauna will be identified to species level and enumerated.

(h) Histopathological and microbiological investigations will be carried out on fish collected from the trawls.

5.15 SOAFD survey of the Garroch Head sewage-sludge disposal site, 1992

(a) A total of 114 sediment samples were collected from the Garroch Head area, including both the present disposal site and the site used prior to 1974. Sixty eight samples were collected for heavy metal analysis and 46 samples for enumeration of faecal coliforms, faecal streptococci and *Clostridium perfringens* spores.

(b) Water samples were collected from three discrete depths at 20 sampling stations, for suspended solids measurements and the enumeration of faecal coliforms and faecal streptococci. In addition, at each station vertical transmissometer profiles and echosounder surveys were undertaken, before and after a sewage-sludge disposal operation.

(c) Fish and shellfish samples were collected from the Garroch Head area. Samples of seven species were retained for heavy metal analysis, and samples of three species retained for trace organic analysis.

(d) Samples of shellfish and sediment were collected from the immediate vicinity of the present Garroch Head disposal site, for determination of the spatial distributions of organic contaminant loads and for bioassay. A sample of plaice was collected as part of the annual, temporal trend monitoring programme.

(e) Samples of fish and shellfish were also collected for metallothionein, heavy metal, P450 and organic contaminant analysis.

5.16 Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1992

(a) Sediment samples were collected from the stations shown in Figure 32.

(b) Particle size analysis, metals (As, Cd, Cr, Cu, Fe, Hg, Pb, Zn and Ni), carbon and nitrogen were determined in these samples.

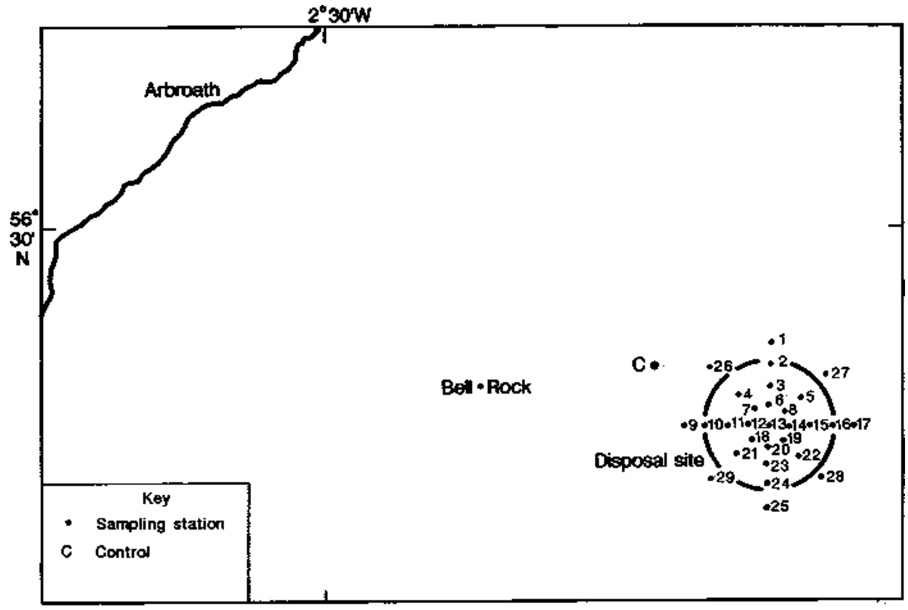


Figure 32. Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1992

(c) Two sediment samples were collected from each of the stations, C (control), 1, 3, 9, 11, 13, 15, 17, 23 and 25, for the enumeration of macrobenthos, fruit pips and faecal bacteria (group D faecal streptococci).

(d) Sediment samples from stations C, 1, 3, 9, 11, 13, 15, 23, 25, 27, and 29 were analysed for organochlorines (HCB, aldrin, α-HCH, γ-HCH, dieldrin, ppDDT, ppTDE, ppDDE and PCB).

(e) Aggasiz trawl samples were taken at stations C and 13, for the identification and enumeration of fish species. Adult fish were examined for lesions, histopathology and microbiology.

5.17 Forth River Purification Board/Lothian Regional Council survey of the St Abbs Head sewage-sludge disposal site, June 1992

(a) Sediment samples were collected from the stations shown in Figure 33.

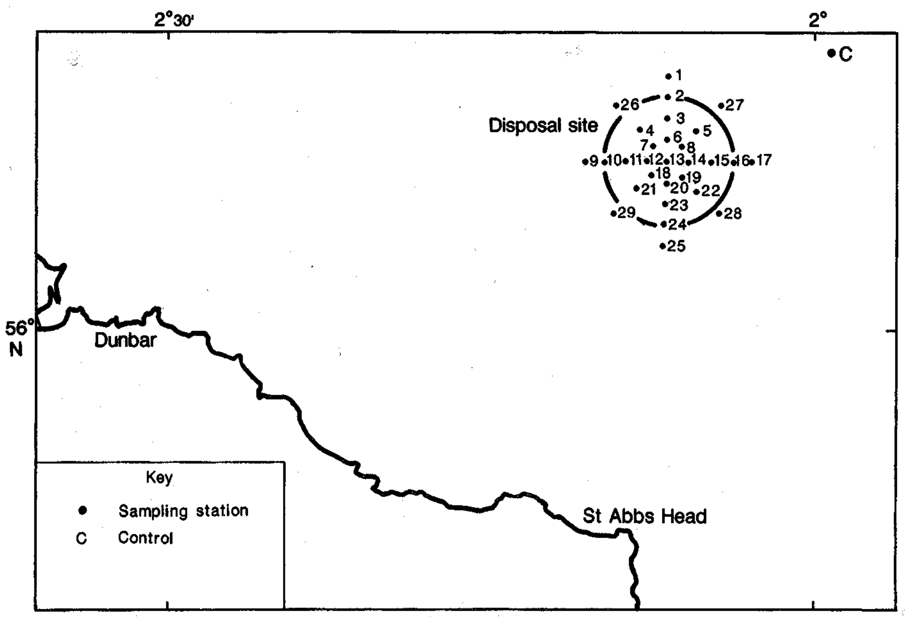


Figure 33. Forth River Purification Board/Lothian Regional Council survey of the St Abbs Head sewage-sludge disposal site, June 1992

(b) Particle size analysis, metals (As, Cd, Cr, Cu, Fe, Hg, Ni, Pb and Zn), carbon and nitrogen were determined in these samples.

(c) Samples from stations 1, 3, 9, 11, 15, 17, 23, 27, and 29 were also taken for the enumeration of benthic infauna and fruit pips.

(d) Samples from stations C, 1, 3, 9, 11, 13, 15, 17, 23, 25, 27 and 29 were analysed for organochlorines (HCB, aldrin, a-HCH, g-HCH, dieldrin, ppDDT, ppTDE, ppDDE and PCB).

(e) Otter trawl samples were taken at stations C and 13 for the assessment of fish diseases.

5.18 SOAFD surveys of the Bell Rock and St Abbs Head sewage-sludge disposal sites, 1992

(a) A sample of 5 624 common dab (*Limanda limanda*) was examined for disease by standardised ICES methods (ICES, 1989) and datasets for recommended fish length groups were prepared for both the St Abbs Head and the Bell Rock disposal sites and the relevant reference areas. All cod caught (256) were examined for pseudobranch lesions and all haddock >26 cm (766) were examined for the fungal disease Ichthyophonus. All whiting (544) were examined for the occurrence of gill and eye parasites.

(b) A DoE funded project studying the variation of fish disease levels at the St Abbs Head sewage-sludge disposal site and designated reference area, was terminated in 1992. Full statistical evaluation of the results is in progress.

6. REFERENCES

EAGLE, R.A., HARDIMAN, P.A., NORTON, M.G. AND NUNNY, R.S., 1978. The field assessment of effects of dumping wastes at sea : 3. A survey of the sewage sludge disposal area in Lyme Bay. Fish. Res. Tech. Rep., MAFF Direct. Fish. Res., Lowestoft, ***49***: 22pp.

EUROPEAN COMMUNITIES, 1991. Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment. Off. J. Eur. Commun., ***L135/42***, 1990: 40-45.

GREAT BRITAIN-PARLIAMENT, 1972(a). Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, Oslo, 15 February 1972. Her Majesty's Stationery Office, London, 12pp. (Cmnd 4984).

GREAT BRITAIN-PARLIAMENT, 1972(b). Final act of the Intergovernmental Conference on the Convention on the Dumping of wastes at Sea, London, 13 November 1972. Her Majesty's Stationery Office, London, 20pp. (Cmnd 5169).

ICES, 1989. Methodology of fish disease surveys. Coop. Res. Rep., Int. Coun. Explor. Sea, (***172***): 1-153.

MAFF, 1989. First report of the Marine Pollution Monitoring Management Group's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites. Aquat. Environ. Monit. Rep., MAFF Direct. Fish Res., Lowestoft, ***20***: 64pp.

MAFF, 1991(a). Second report of the Marine Pollution Monitoring Management Group's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites. Aquat. Environ. Monit. Rep., MAFF Direct. Fish Res., Lowestoft, ***25***: 39pp.

MAFF, 1991(b). Third report of the Marine Pollution Monitoring Management Group's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites. Aquat. Environ. Monit. Rep., MAFF Direct. Fish Res., Lowestoft, ***27***: 37pp.

MAFF, 1992(a). Fourth report of the Marine Pollution Monitoring Management Group's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites. Aquat. Environ. Monit. Rep., MAFF Direct. Fish Res., Lowestoft, ***31***: 38pp.

MAFF, 1992(b). Monitoring and surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea, 1990. Aquat. Environ. Monit. Rep., MAFF Direct. Fish Res., Lowestoft, ***30***: 1-66.

MEARNS, A.J. AND WORD, J.Q., 1982. Forecasting effects of sewage solids on marine benthic communities. pp 495-512. *In*: Mayer, G.F. (ed.) Ecological stress and the New York Bight: science and management. Columbia, S. Carolina: Estuarine Research Federation.

REES, H.L., ROWLATT, S.M., LAMBERT, M.A., LEES, R.G. AND LIMPENNY, D.S., 1992. Spatial and temporal trends in the benthos and sediments in relation to sewage sludge disposal off the north-east coast of England. ICES J.Mar.Sci., ***49***: 55-64.

REES, H.L. AND PEARSON, T.H., 1992. An approach to the setting of environmental quality standards at marine waste disposal sites. ICES CM 1992/E:33, 10pp (mimeo).

ROWLATT, S.M., REES, H.L., VIVIAN, C.M.G. AND PARKER, M.M., 1991. The monitoring of UK sewage-sludge disposal sites. Chemistry and Ecology, ***5***: 17-33.

TALBOT, J.W., HARVEY, B.R., EAGLE, R.A. AND ROLFE, M.S., 1982. The field assessment of effects of dumping wastes at sea: 9. Dispersal and effects on benthos of sewage sludge dumped in the Thames Estuary. Fish. Res. Tech. Rep., MAFF Direct Fish. Res., Lowestoft, ***63***: 42pp.

WORD, J.Q., 1979. The Infaunal Trophic Index. pp 19-39. *In*: Southern California Coastal Water Research Project Annual report for 1978. Southern California Coastal Water Research project, El Segundo, C.A.

ANNEX 1. DEFINITIONS OF EQOs AND EQSs

A1. Environmental quality objectives: definitions

The following EQOs are proposed by the GCSDM for sewage-sludge disposal sites. In order to maintain comparability with objectives used in fresh waters and estuaries the objectives are described in terms of 'use' of the areas.

	Use	Objective	Notes
A1.1	***Basic amenity use***	Maintenance of environmental quality so as to prevent public nuisance arising from aesthetic problems and interference with other legitimate uses of the sea	This refers to the presence of persistent surface slicks, aesthetic contamination of the seabed with plastics and other persistent materials, and fouling of fishing equipment
A1.2	***Commercial harvesting of fish and shellfish for public consumption***	Maintenance of environmental quality, such that commercial marine fish and shellfish quality shall be acceptable for human consumption, as determined by the appropriate competent authorities (e.g. MAFF)	This objective relates only to the suitability for human consumption; the general health of the fish and shellfish is protected under use (Sub-section A1.3)
A1.3	***Protection of commercial species***	Preservation of the general well-being of commercially exploited species	Probably little different in practice from use (Sub-section A1.4)
A1.4	***General ecosystem conservation***	Maintenance of environmental quality so as to protect aquatic life and dependent non-aquatic organisms, such that the ecosystem is typical of coastal water with those physical characteristics and latitude	Depending on the conditions in the area, it may be necessary to allow for a mixing zone within which the EQO would not apply, but for both the water column and the benthic environment this should be kept as small as practicable
A1.5	***Preservation of the natural environment***	Outwith the immediate disposal zone, the quality of the receiving environment will be indistinguishable from that of the adjacent estuarine or marine environment	This limitation on contamination is in line with the decisions taken at the second North Sea Conference*

A2. Environmental quality standards : definitions

The means of demonstrating whether the above uses are maintained in any area is by comparison with standards. In most cases, there are no internationally agreed standards by which compliance can be assessed. Indeed, there are few nationally set standards, except for certain of the heavy metals for which water and food standards have been set.

** Second International Conference on the Protection of the North Sea, London, 1987. Department of the Environment, London*

Accordingly, the GCSDM has listed the criteria by which maintenance of the defined use or EQO can be assessed, together with an indication of how the basis of the standards could be judged, as follows:

	EQO	Criteria	Basis of Standards
A2.1	***Aesthetic - no nuisance (Use - Sub-section A1.1)***	Turbidity	Increase in suspended solids
		Floatables	Occurrence in standardised surface trawls
		Persistent sewage debris	Occurrence in benthic trawls. Visual inspection
A2.2	***Fish and shellfish***	Bacterial contamination) Chemical contamination)	Measured levels to be below those prescribed by public health authorities/MAFF
A2.3	***Protection of commercial species (Use - Sub-section A1.3)***	Water column and benthic environment	No significant effect on habitat. Measured levels of potentially toxic materials to be below levels of effect and within any relevant EQS
		Fish disease	No significant increase in prevalence compared with normal limits in control populations
A2.4	***Ecosystem - maintenance (Use - Sub-section A1.4)***	Benthic diversity	Deviation from the control site(s) to be within normal limits
		Water quality	Dissolved oxygen to exceed, and toxic substances in the water column to be below, levels of effect, and within any EQS set by relevant legislation
		Sediment quality	Grain size, carbon/nitrogen and toxic substances to be below levels of effect, and within any EQS set by relevant legislation
A2.5	***Preservation of the environment (Use - Sub-section A1.5)***	Sediment quality	Minimal percentage change over background levels of metals and other contaminants. No continuing upward trends after ‘steady state’ is achieved
	Outwith the zone of immediate effect	Water quality	Must be within any EQS set by relevant legislation
		Benthic fauna	No deviation from control sites

ANNEX 2. MEMBERSHIP OF THE GCSDM IN 1992

Dr J E Portmann (Chairman)
Ministry of Agriculture, Fisheries and Food
Fisheries Laboratory
Remembrance Avenue
BURNHAM-ON-CROUCH
Essex CMO 8HA

Mr C Davies+
Thames Water Utilities
Operational Services
Maple Lodge Sewage Treatment Works
Denham Way
RICKMANSWORTH
Herts WD3 2SQ

Mr W Halcrow
Director
Forth River Purification Board
Heriot-Watt Research Park
Avenue North
Riccarton
EDINBURGH EH14 4AP

Dr J M Heap
Scientific Services Laboratories
Lothian Regional Council
Department of Water and Drainage
4 Marine Esplanade
EDINBURGH EH6 7LU

Dr J Riddell
Department of Civil Engineering
Strathclyde University
John Anderson Building
107 Rottenrow
GLASGOW G4 0NG

Mr J G MacAulay
Department of Regional Chemist
Strathclyde Regional Council
14 Everard Drive
GLASGOW G21 1XB

Dr R J Ramsay
Department of the Environment for Northern Ireland
Environment Service
Calvert House
23 Castle Place
BELFAST BT1 1FY

Mr D Saward
Scottish Office Agriculture and Fisheries Department
Marine Laboratory
Victoria Road
Torry
ABERDEEN AB9 8DB

Dr P C Head
North West Water Ltd
Dawson House
Great Sankey
WARRINGTON WA5 3LW

Mr R S Allen
Harwich Haven Authority
Harbour House
The Quay
HARWICH
Essex CO12 3HH

Mr J Seager*
NRA Head Office
Rivers House
Waterside Drive
Aztec West
Almondsbury
BRISTOL BS12 4UD

+ *Replaced by Ms V Birkett at the end of 1992*
* *Replaced by Dr M Everard in mid 1992*

ANNEX 3. TASK TEAMS AND THEIR MEMBERSHIP IN 1992

Metals

Dr S M Rowlatt (Chairman)
MAFF

Dr I Davies
SOAFD

Mr E Donaldson
Department of Economic Development (NI)

Dr D Harper
Forth River Purification Board

Dr P Head
North West Water Ltd

Mr J Webster
Lothian Regional Council

Dr J Towner
EAG Ltd

Mr B Miller
Clyde River Purification Board

Benthos

Dr H Rees (Chairman)
MAFF

Mr I Codling
WRc

Dr S Hull
Forth River Purification Board

Dr M Elliot
University of Hull

Mr D Moore
SOAFD

Mr J Pomfret
Analytical and Environmental Services Ltd

Dr T Pearson
Scottish Environmental Advisory Services

Mr I Rees
University College of North Wales

Dr M Service
DANI

Dr J Cotter
MAFF

Mr N Shillabeer
ICI (Brixham Laboratory)

Dr R Warwick
Plymouth Marine Laboratory

Organics

Dr I Ridgway (Chairman)
Forth River Purification Board

Mr C Allchin
MAFF

Dr B Crathorne
WRc

M Cunningham
Strathclyde Regional Council

Mr E Donaldson
Department of Economic Development (NI)

G Firth
NRA Yorkshire Region

Dr A Kelly
SOAFD

Mr R Law
MAFF

Mr H Rogers
WRc

Mr M Tombs
North West Water Ltd

Mr J Webster
Lothian Regional Council

Mr D Yeoman
Strathclyde Regional Council

Comprehensive Studies

Mr W Halcrow
Forth River Purification Board

Dr H Rees
MAFF

Mr P C Nicholas
Wallace Evans

Mr R A Milne
NRA Welsh Region

Dr S Malcolm
MAFF

Mrs I A Jack
Forth River Purification Board

Dr P Tett
University College of North Wales

Ministry of Agriculture, Fisheries and Food
Directorate of Fisheries Research
Fisheries Laboratory
Lowestoft
Suffolk
NR33 OHT
England

AQUATIC ENVIRONMENT MONITORING REPORT Number 39