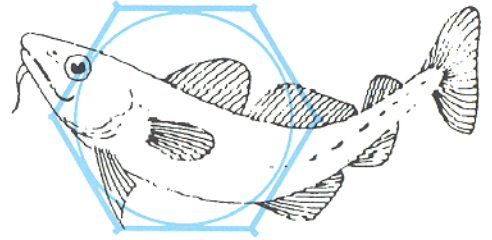


AQUATIC ENVIRONMENT MONITORING REPORT

Number 31



**Marine Pollution Monitoring
Management Group**

**Fourth Report of the Group
Co-ordinating Sea Disposal Monitoring**



Directorate of Fisheries Research
Lowestoft, 1992

**MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH**

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FOREWORD

This is the fourth report of a Marine Pollution Monitoring Management Group (MPMMG) Sub-Group which was originally called the Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites (CGMSD). As the work of this Group proceeded it became apparent that much of it was relevant to the monitoring of other sites used for the disposal of material such as that dredged from harbours and navigation channels. Accordingly, in mid-1991, the MPMMG agreed to extend the remit of the original group, which led to a change in its name to the Group Co-ordinating Sea Disposal Monitoring (GCSDM) late in 1991. This report describes the progress made by the Group during 1991.

The Group was established in 1987 when, following a review of existing monitoring, it had become apparent to the MPMMG that UK effort and resources applied to scientific investigations and monitoring of the impact of disposal of sewage sludge was uncoordinated and contained many inconsistencies.

The Group's first report addressed these problems directly and contained a set of environmental quality objectives (EQOs) with associated descriptive environmental quality standards (EQSs), which were intended to have common applicability and represent good technical and environmental practice. That first report also provided details of procedures to be followed when conducting monitoring for fish diseases, certain microbiological components, benthic community structure, metals in sediments and a number of method-determined sampling and analytical procedures.

The second report continued with this theme of guidance and included details of procedures for studies on biological effects, that can be used to provide evidence of deterioration in environmental quality as a consequence of the disposal of sewage sludge. The second report also gave details of the start made in 1989 in setting numerical limits for some of the EQOs which are more difficult to quantify.

This work continued through 1990 and 1991 and, as the details in this report show, approaches have now been selected that will allow numerical EQSs to be set for disposal sites which take appropriate account of the different characteristics of different disposal grounds.

The report also includes an assessment of the monitoring conducted in 1990, and the extent to which: (i) the methods used complied with the CGMSD guidance; and (ii) the results demonstrate that the defined EQOs and EQSs for sewage-sludge disposal sites are being met. Details are also given of the monitoring of sewage-sludge disposal sites, carried out during 1991 by the various licensees operating throughout the UK and by the licensing authorities (SOAFD/ DOE(NI)/MAFF).



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EXECUTIVE SUMMARY

In this fourth report, the Group Co-ordinating Sea Disposal Monitoring (GCSDM), formerly the Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites (CGMSD), details the activities of its Task Teams, continues its evaluation of monitoring, by assessment of programmes undertaken in 1990, and summarises research activities carried out during 1991.

Work is nearing completion on defining the environmental quality objectives (EQOs) and the environmental quality standards (EQSs) which establish whether the EQOs are being met, outlined by the CGMSD in its first report (MAFF, 1989). This report includes details of the action limits proposed for metal levels in sediments and for the extent of change in the benthos. In both cases, the limits are to be regarded as action levels rather than absolute standards, as some change is likely in the light of experience with their use.

The CGMSD has discussed the extent to which monitoring needs to be continued after disposal of sewage sludge ceases. It recommends that some monitoring should be carried out at all sites in the year after disposal ceases, and that further monitoring would be desirable thereafter for up to 10 years, at least at sites used for disposal of major amounts of sewage sludge. The reasons for this are spelt out in this report.

For sewage-sludge disposal sites, it is apparent that monitoring at most of them is now being conducted according to the guidelines recommended by the CGMSD. Where other methods are still in use, in most cases, there is either an over-riding need to maintain continuity with a long time series of earlier data or the work is being specially undertaken by a licensee as a means of checking the overall status of an area rather than demonstrating compliance with an EQS. It has, however, become apparent that some licensees are using methods of analysis that are inadequate for the purpose of demonstrating compliance with standards for organics and steps will have to be taken to rectify this situation.

Only minor effects of sewage-sludge disposal were detected, except at the non-dispersive Clyde disposal site, where the expected and previously noted effect of organic enrichment was confirmed.

Fish and shellfish quality at all sites was acceptable in relation to human health protection standards.

Fish disease studies should only be conducted in accordance with CGMSD guidelines, in relation to the numbers of fish required, etc. Surveys using small numbers of fish, whether for fish disease or population status studies, should be discontinued. The use of fish as a means of indicating faecal contamination of a disposal site is not effective, is potentially misleading and should also be discontinued.

Monitoring should be carried out at all sites to establish whether sewage-sludge disposal gives rise to litter problems.

An experimental study, undertaken at the Thames disposal site using the Microtox test, produced some interesting results. The test should be utilised on a wider scale in order to establish the significance of these preliminary results and their possible relationship to potential biological effects.

In relation to future monitoring, the Group proposes that more attention should be paid in future to assessing temporal trends (i.e. the use of post-survey results on a time sequence basis). In the light of the preliminary proposals for compliance standards for acceptable change in benthos and concentrations of metals in sediments, there is a need to review current sampling practice and sampling design. Closely spaced transect sampling appears to offer good opportunities for detecting whether or not sewage-sludge disposal has any environmental impact.

The CGMSD has discussed an extension of its remit to address the need for monitoring at disposal sites in general, particularly those used for dredged material, and around pipelines. Its membership and its remit have been extended by the MPMMG as a result and its new title (the Group Co-ordinating Sea Disposal Monitoring (GCSDM)) embraces these aspects.

1. INTRODUCTION

Following a review in 1985 of monitoring, as it was then conducted at the various sewage-sludge disposal sites around the UK, 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. Following discussions with the then Water Authorities Association and others, the CGMSD met for the first time on 3 September 1987 with the following terms of reference:

- (i) to continue to evaluate sewage-sludge monitoring programmes, and advise on their development 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 CGMSD 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 micro-biological determinands, biological effects techniques, sediments, biota and water; and

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

The CGMSD has since published three reports — in the autumn of 1989 (MAFF, 1989), the spring of 1991 (MAFF, 1991) and spring of 1992 (MAFF, 1992).

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. These are reproduced at 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 report 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 report also contained a detailed review of the monitoring actually conducted in 1988 and, in particular, commented on the extent to which it met the needs identified by the CGMSD. A brief outline was also provided of the monitoring being conducted at sewage-sludge disposal sites in 1989.

The third report continued the pattern set by the second report with an outline of the work undertaken by the CGMSD itself and by its Task Teams, particularly in terms of developing quantitative definitions of standards. The third report contained a detailed review of monitoring conducted in 1989 - the first full year for which the CGMSD recommendations on methods and objectives were available. A brief outline was also provided of the monitoring being conducted at sewage-sludge disposal sites in 1990.

Throughout 1991, the CGMSD continued to pursue the goals originally assigned to it. The report which follows, details 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, important chapters of this fourth report of the CGMSD are an outline of the monitoring conducted in 1991 and a review of the results of work conducted in 1990 and the extent to which they met the CGMSD objectives.

A list of the members of the CGMSD in 1991 is given at Annex 2.

2. TASKS UNDERTAKEN BY THE CGMSD IN 1991

2.1 Mode of operation

From the start, the CGMSD 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, the Ministry of Agriculture, Fisheries and Food (MAFF); for Scotland, the Scottish Office Agriculture and Fisheries Department (SOAFD); and for Northern Ireland, the 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 that the work undertaken is kept outward looking. Three Task Teams were active during 1991: a Metals Task Team (sub-section 3.1); an Organic Task Team (sub-section 3.2); and a Biology Task Team (sub-section 3.3).

In the course of 1991, the CGMSD met on two occasions to review the progress by the three Task Teams and to finalise its third report. It also discussed its own future activities in the light of the suggestion by its parent group the MPMMG that it should consider:

- the implications of the decision to cease disposal of sewage sludge to sea by the end of 1998 on the need for further monitoring after the disposal operations cease; and
- a possible extension of its role to include co-ordination of the monitoring of other sea disposal activities.

2.2 The need for monitoring in the future

The Group confirmed its view, expressed in its third report (MAFF, 1992), that it would be necessary to continue monitoring all of the sewage-sludge disposal sites at least until disposal operations cease. It concluded that the scale of monitoring thereafter would depend upon the nature of the site, the effects previously observed, or lack of them, and the scale of the disposal operation. Based on these considerations the Group recommends that:

- (i) monitoring be carried out, at least by the licensing authorities and preferably also by the licensee, at all sites in the year after disposal ceases;

- (ii) monitoring, albeit at a reduced level, be carried out by the licensing authority every two years thereafter at the Forth, Clyde, North Channel, Liverpool Bay, Thames and Tyne sites, either until it is clear that no change is apparent or for a further 10 years whichever is the least;
- (iii) at other sites, surveys should be conducted by the licensing authority 6 years after disposal ceases; and
- (iv) subsequent monitoring would depend upon the results obtained at the 6th and 11th year points.

These recommendations take account of the need to demonstrate that the disposal areas are in good shape after disposal ceases and the fact that, although a few adverse effects or changes have been observed in the past, in most cases the disposal operation was underway many years before monitoring began. It will therefore be necessary to establish the true baseline state after disposal ceases. If changes do arise, it will also be highly desirable to ensure that they are accurately documented to assist future predictions of effect in other, similar situations. Since no two disposal sites are identical, it would not be appropriate to monitor fewer sites than those suggested but it should be recognised that the recommendations for future studies do assume a reduced scale of monitoring both in terms of stations sampled and in determinands and frequency of measurement. 'Follow-up' monitoring will not necessarily cover all sites and determinands previously studied.

2.3 Co-ordination of monitoring of other sea disposal operations

Discussion of the extension of its remit to cover other sea disposal operations, led the Group to conclude that it did indeed seem likely that its guidelines on methods for both chemical analyses and biological effects studies would be applicable to other disposal activities in the marine environment. It also considered that at least the approaches which it had adopted for setting EQOs and EQSs might be applicable to other activities. In relation to the monitoring of the effects of pipeline discharges, it was recognised that co-ordination of such activities is essentially a matter for the National Rivers Authority (NRA) in England and Wales, the DOE(NI) and the river purification authorities in Scotland. Since the DOE(NI) and the river purification authorities are already represented on the Group, it was decided to invite a representative from the NRA to serve on the Group as a full member; the NRA duly appointed such a representative.

The Group recognised that the disposal of dredged material bears a number of similarities to the disposal of sewage sludge and that it was increasingly becoming

ing the focus of attention by organisations such as the Oslo Commission and the London Convention countries. Initial consideration of the possible impact of disposal of dredged material at sea led the Group to conclude that some of its objectives, as well as the approaches which it had recommended, both for assessing the impact of the disposed material and the standards against which that impact might be judged, might well be applicable to dredged material. Accordingly, late in 1991 it was agreed that additional members be invited to represent dredging interests. These invitations were duly accepted.

In view of these changes both to its remit and in membership, the Group concluded that its original title was no longer appropriate. Accordingly, and with the agreement of the MPMMG it was decided the Group should be re-named the Group Co-ordinating Sea Disposal Monitoring (GCSDM).

2.4 Development of a biotic index for marine benthic communities

In its third report, the CGMSD referred to a proposal made by its Biology Task Team that work be undertaken to develop a biotic index for the assessment of the pollution status of marine benthic communities. This suggestion was strongly endorsed by the CGMSD and was taken up and funded jointly by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) and the NRA. The work was undertaken during the 1991/92 financial year. The GCSDM is closely monitoring progress with this project and has a nominee on the steering group.

The objectives of the project were, broadly, to develop an index from existing data either by the adaption of an existing index or the development of a new index. The stages of the work were as follows:

- (i) the compilation of suitable datasets and establishment of a computerised database;
- (ii) the review of existing indices used in both fresh and marine waters;
- (iii) the derivation of the marine biotic index; and
- (iv) the testing and validation of the marine biotic index.

Eight suitable datasets were identified from around the UK and compiled on a computer database. The literature review revealed a large number of existing indices. Of those developed for use in the marine environment, the index that had been used most extensively was the Infaunal Trophic Index (ITI) (Word, 1979).

This index was developed over a period of ten years and has been applied successfully to the southern Californian shelf and in Puget Sound. The index works by classifying benthic species into four groups according to their feeding strategy and combining the total abundance of all taxa in each of the four groups, using a formula. The theory underlying the formulation is the changing dominance, in terms of abundance, of the feeding groups along organic pollution gradients. As such, the ITI has been shown to be particularly useful in relation to organic pollution (Word, 1990).

As a consequence of the promise offered by this index, a significant effort is being applied to adapt it for use in UK waters. A list of taxa was generated from the eight UK datasets to be classified into the four trophic groups according to the criteria set out in Word (1990). The index is now being applied to each of the eight datasets 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 and of confounding natural environmental influences on the performance of the index are being assessed. The adaptation of the ITI for use in UK waters seems likely to provide an alternative approach to the assessment of pollution status in marine benthic communities. If this proves to be correct, the investigation will have been justified.

3. PROGRESS BY THE TASK TEAMS

A list of the various Task Teams (and their membership) operating in 1991 is given at Annex 3.

3.1 The Metals Task Team

The Metals Task Team undertook an analytical intercomparison exercise during 1990 and also considered how to set numerical values to the EQOs of no change in metal levels and no unacceptable adverse effects of sediment metal concentrations on biota.

3.1.1 Intercomparison exercise

The analytical intercomparison exercise was planned as a two-phase study. The first step was simply to involve the analysis of standard solutions containing unknown concentrations of metals. The second phase would involve the analysis of a real sediment sample. Progress with the first of these was delayed by difficulties with the distribution of the samples and, subsequently, by very slow returns of results by some of the participating laboratories. However, the exercise was completed by the end of 1991 and although it revealed some minor operational difficulties in some laboratories these were rectified during the course of the study

and all laboratories eventually achieved excellent results. By the end of the year, work was also well in hand with the preparation of the sandy-mud sediment sample but distribution was delayed by difficulties encountered in producing uniform sized sub-samples. These problems are expected to be resolved and the intercomparison study will proceed as one of the major functions of the Task Team during 1992.

3.1.2 Development of EQSs

The Task Team made considerable progress with the development of numerical values for EQSs for metals. Trials with data for six sewage-sludge disposal sites showed that an approach similar to an analytical quality control chart would allow year-by-year changes to be identified with reasonable certainty. Because considerable variation can occur for natural reasons on a year-by-year basis, it is important that the chart be established using data for several years. The Task Team has recommended that a minimum of 4 years data be used but, as an interim measure, data for 1, 2 or 3 years can be used. Such charts are used extensively for analytical chemistry quality-control purposes and are extremely useful in revealing gradual drift off target of both accuracy and precision. Since analytical chemistry data are usually normally distributed, there is some doubt as to whether field chemistry data, which are not always normally distributed, need to be logarithmically transformed. Further trials will be conducted and statistical advice is being sought during 1992. Subject to the conclusions of these investigations, minor changes to the protocol may be necessary but it is clear that the proposed procedure meets the desired purpose. The charts will be used to set "benchmark concentrations" for each disposal site and clearly the levels set will differ from site to site depending on local circumstances.

The Task Team has also made tentative proposals for biologically based criteria. The approach adopted for their derivation was based on the equilibrium partitioning approach and defines as the standard that concentration in the sediment which, when in equilibrium with the surrounding water does not give rise to a concentration in that water which would exceed the water quality criteria for that metal. This is based on sound chemical principles and has been shown to work well for hydrophobic organic contaminants. It is recognised that there may be difficulties in applying the approach to metals directly since metal solubility is influenced by factors such as the organic carbon and sulphide content of sediments. It is therefore proposed that, rather than regard the derived concentration values as absolute standards, they should be regarded as action levels. As such, the concentrations should be regarded purely as levels which, if exceeded, indicate that studies should be initiated to investigate chemically or biologically the availability of the metals in

question to organisms. It is expected that, in the light of experience in applying these action limits, the numerical values may be modified. However, their initial application to areas such as Liverpool Bay indicates the general validity of the approach.

The proposed action levels, which it is stressed are tentative in nature and are not absolute limits, are as follows:

Metal	Action level (mg kg ⁻¹)	Metal	Action level (mg kg ⁻¹)
Copper	40	Arsenic	8
Zinc	200	Nickel	100
Mercury	0.4	Chromium	100
Lead	40	Cadmium	2

They refer to the <63 µm fraction of the sediment (i.e. that used in monitoring of disposal sites), rather than whole sediment and assume the presence of 1% organic carbon in the sediment. For example, the action level for copper in a sediment containing 2% of organic carbon would be 80 mg kg⁻¹.

3.2 The Organics Task Team

This Task Team has a similar role to that of the Metals Task Team and is making steady progress with the development of ecological quality standards and the conduct of analytical intercomparison exercises.

3.2.1 Intercomparison exercises

By the end of 1991, the Task Team had completed three intercomparison exercises for chlorinated biphenyls. The first and second exercises had served to identify a number of analytical procedural problems, in the participants' laboratories. These problems were duly resolved and, in the third exercise, good results were achieved by the five laboratories that actually returned results. Unfortunately, however, this was a very poor response, as 14 laboratories initially participated in the sampling procedure. It was particularly noticeable that some of the licensees responsible for disposal of the largest quantities of sewage sludge did not take part in the study. Disposal at sea licences include a requirement for the licensee to monitor the PCB content of their sludge, concentration and load limits and some field monitoring for PCB. The ability to perform accurate analyses of organic contaminants in both sewage sludge and sediments in the disposal site is therefore important if they are to ensure that they meet their licence conditions. This lack of participation is therefore particularly regrettable.

3.2.2 Development of EQSs

Better progress is being made on the assignment of numerical values to the EQSs of no detectable increase in concentration and no undesirable biological effect. The equilibrium partitioning approach and a background concentration approach are being followed and it is expected that tentative proposals will be put before the GCSDM early in 1992.

3.3 The Biology Task Team

The Biology Task Team has addressed the question of intercomparability of data and the need to demonstrate reliably that there has been no statistically significant change in the benthos at a particular site or, if a change has occurred, that the change is acceptably small. In the course of this work, a number of related problems have been identified and agreement has been reached on solutions to them.

3.3.1 Intercomparison of nomenclature and identification procedures

In the course of two intercomparison exercises, the second of which is still in progress, it became apparent that participants were using different nomenclatures for some animals and that with unfamiliar taxa they were experiencing varying degrees of difficulty in identification to the species level. The Task Team has therefore agreed that a common taxonomic code should be adopted by all involved in studies of benthos at sewage-sludge disposal sites. This is based on the nomenclature in the Species Directory published by the Marine Conservation Society (Howson, 1987) and, for archival purposes, codes are being sought from the American National Oceanographic Data Centre. The system of coding used by this centre is internationally recognised and is both hierarchical and flexible.

The Task Team also recognised that identification of animals to the family level is both easier and less time consuming (up to 50% less with unfamiliar species). Several data sets were examined to establish whether loss of sensitivity to change is experienced if identification is restricted to the family level. The conclusion reached was that the loss in sensitivity is not so large as to matter for the purpose of identifying whether an appreciable change is taking place, but some uncertainties remain about the consequences for identifying subtle effects. The Task Team therefore recommends that identification to the family level should be used for descriptive (grid-type) surveys, designed to check on the continued suitability of sites sampled for EQS compliance-testing. However, for the latter purpose, it strongly recommends that the initial surveys should be

conducted with identification to species level, to allow for further statistical evaluation of the consequences of pooling on variability in selected measures of community structure.

3.3.2 Development of EQSs

Two objectives relate to the assessment of change in the benthos, namely ecosystem maintenance and preservation of the environment. The Task Team interpreted these as meaning, respectively, no unacceptable change and preservation of the *status quo*. They concluded that, for sewage sludge generally, the main cause of a radical shift in species composition is organic enrichment and that the best indicators for this are based on total abundance (A), total number of taxa (T) and total biomass (B) measured as ash-free dry weight. The ratios A/T and B/A also have value in interpreting the data. Following extensive trials with data from real surveys of a range of sewage-sludge disposal sites, the Task Team concluded that guideline values could be set for EQSs for both the *status quo* and acceptability of change.

The Task Team identified the importance of pairwise comparisons at environmentally similar sites, so as to allow for the possibility of synchronous natural changes with time. This involves calculation of percentage of difference in the selected measure at one location (x) relative to another (y), and takes the general form:

$$\left[\left(\frac{\text{Value of measure at x}}{\text{Value of measure at y}} \right) - 1 \right] \times 100$$

Their recommendations for monitoring compliance with the *status quo* requirement are that the following limits should be set:

Primary variables

A baseline value % \pm 50

T baseline value % \pm 20

B baseline value % \pm 20

Derived values

A/T baseline value % \pm 50

B/A baseline value % \pm 50

The baseline value represents the percentage of difference (averaged over at least 3 years) between strategically-placed sites peripheral to the known sphere of waste influence.

The following limits are recommended for monitoring compliance with the acceptability of change requirement:

Primary variables

A + 200% of reference value

T + 50% of reference value

B + 50% of reference value

Derived variables

A/T + 100% of reference value

B/A - 50% of reference value

In this case, the comparison is between a site within the known sphere of waste influence, relative to the outside area (using the above formula) and hence the percentage of change at the former is permissible up to the specified limits. It is important to note that these limits allow for an initial phase of positive change (\equiv 'early enrichment') in the primary variables. A good knowledge of the present status of the enrichment process (if any) within the sphere of waste influence is therefore essential to effective application.

Limits for compliance with the *status quo* of course apply, as the EQO states, outwith the immediate zone of effect. For limits of acceptability, it must also be recognised that these were derived on the basis of data from quiescent rather than highly dispersive sites. For compliance with the *status quo*, the Task Team also emphasises that the limits should not be regarded as pass/fail levels (since changes would not normally be expected to approach limits of acceptability) but rather as Action Points which would indicate the need for further, more detailed, examination as to the cause of the problem. For both EQOs, if the breach of the Action Point is only minor, the Task Team points out that this may be due to natural causes and, unless it persists for more than three years, is probably not significant. However, this would need to be checked by careful assessment of the data to confirm that there is no conclusive evidence of adverse effects attributable to the discharge. The Task Team is presently developing guidelines for 'follow-up' action to meet the various circumstances that may arise. It is also apparent that the Action Points will differ from site to site and that they should not be regarded as immutable and may have to be modified in the light of experience in their use to take account of local scales of variability. In this respect, further evaluation of statistical methods for compliance testing, and of the related issue of effective sampling design, will be essential.

4. REVIEW OF MONITORING AT SEWAGE-SLUDGE DISPOSAL SITES DURING 1990

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 of the CGMSD (MAFF, 1989). It considers examples of monitoring undertaken in 1990 although, where appropriate, reference is made to other work. Nearly all of the surveys followed the CGMSD guidelines for analytical methodology (MAFF, 1989). In some cases, where consistency with earlier work was judged to be more important than comparability with other sites, long-established procedures were retained. Notable examples of this were at the Liverpool Bay 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 Thames Water/Water Research Centre study of the Barrow Deep and the Fourth River Purification Board/Lothian Regional Council survey of St Abbs Head).

Table 1 lists the sewage-sludge disposal sites surveyed in 1990 and details the techniques used. Some areas are surveyed only every second or third year and therefore no samples were taken in 1990. 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 the CGMSD (MAFF, 1989) 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 CGMSD 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 sea bed, 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 1990

Area/Authority	Sediment				Benthos, epibenthos	Water quality	Fish sampling	Litter assessment
	Metals	Pesticides/ PCBs	Toxicity	Microbiology				
Tyne MAFF Northumbrian Water	*			*	*			*
Humber MAFF Yorkshire Water	*	*		*	*			
Barrow (Thames) MAFF Thames Water	*		*	*	*			
Nab Southern Water	*	*		*				
Plymouth South West Water	*			*	*			
Bristol Channel Wessex/Welsh Water	*			*	*			*
Liverpool Bay MAFF North West Water	*	*						
North Channel DOE (NI)	*			*	*			
Garroch Head SMBA/SRC	*				*	*	*	
Bell Rock FRPB/LRC	*			*	*		*	
St Abbs Head FRPB/LRC	*				*		*	

The CGMSD considers that the only acceptable standard for large detrital material of sewage origin is that it should not be found to occur in the area of disposal, either in surface trawls or in bottom trawls, dredge or grab samples. If it does 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 CGMSD 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-sludge disposal site and the region to the south of it in May, 1990 using 2 m beam trawls (see Figure 3). Table 2 shows a list of the litter found and demonstrates that, as in previous years, sanitary products were still present at the

disposal site. While this is considered to be unacceptable, it should be noted that screens have since been introduced at the Northumbrian Water Sewage Treatment Works and that observations in 1991 of the recently-deposited material revealed very little litter.

Sampling of the Garroch Head disposal site with an otter trawl revealed only small (<5 mm) objects and materials obviously attributable to the disposal operations. The amounts of such material taken were similar to the quantities collected in 1989. Sewage-derived and non-sewage-derived debris was found in otter trawls at the Bell Rock and St Abbs Head sites during the Forth River Purification Board/Lothian Regional Council surveys. The Wallace Evans survey of the Bristol Channel sewage-sludge disposal site found two items of sewage-derived litter while trawling for fish samples and no litter in the benthic dredge samples. While this suggests little sewage

Table 2. Litter in Tyne beam trawls, May 1990

Type of litter	Station numbers (see Figure 3 for station positions)							
	44	43	42	41	40	39	38	36
Plastic fragment	*	*	*			*		
Nylon fishing line						*		
Cellophane	*	*		*	*			
Adhesive tape	*						*	
Rubber washer							*	
Foam rubber			*					
Plaster			*					
Condom packet		*						
Foil fragment	*		*					
Cloth fragment	*		*					
Sanitary towel	14	14	13	3				
Tampon	6	6	12	3				
Cigarette filter	38	31	31	5				
Hair	*		*					
Chewing gum	*							
String		*	*					
Paper		*						
Cardboard fragment	*							
Matchstick	2	1	2					
Wood fragment	*	*	*					
Vegetable matter (inc. peel)	*	*	*					
Leaf litter	*	*	*	*	*			
Clinker		*	*			*		
Coal	*					*	*	
Approx. volume of litter (l)	1.8	1.8	1.6	0.4	<<0.1	<<0.1	<<0.1	0
Approx. total sample volume (l)	6	6	8	7	6	10	80+	5

+ Mostly stones/coal

contamination at these three sites, it should be noted that large trawls and dredges are not efficient devices for sampling litter.

As in previous CGMSD reports, it is recommended that fine-meshed beam trawls should 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-meshed sampling devices is subject to legal restrictions and should be used only with permission (e.g. by the Fisheries Departments).

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

In its first report, the CGMSD pointed out that the appropriate authorities are the public health authorities

and MAFF and that there are advisory limits for contaminants in foodstuffs. The only standard that has ever been in danger of being breached is that set for mercury.

In 1990, no data specifically relating to sewage-sludge disposal sites were reported, although the National Monitoring Programme operated by the Fisheries Departments deals with the quality of fish all round the coast of UK and includes fish from the disposal site areas. These data (Table 3) continue to indicate compliance with the European Commission and Paris Commission EQS for mercury of 0.3 mg kg⁻¹ (European Communities, 1982, 1984) which relates to the mean mercury content of a mixed basket of fish. The levels of other contaminants are not such that they give concern in relation to human health. Full details of this survey work are published periodically by the Fisheries Departments.

Table 3. Concentrations of mercury in fish muscle - 1990 results

Area	Species	Number of fish analysed	Mean length of fish (cm)	Mean mercury concentration in fish muscle (mg kg ⁻¹ wet wt)	Range of concentrations (mg kg ⁻¹ wet wt)	Standard deviation of data sets
Liverpool Bay	Cod	25	31.2	0.11	0.06-0.35	0.06
	Whiting	25	29.8	0.30	0.10-0.54	0.11
	Plaice	25	29.2	0.20	0.10-0.40	0.08
	Sole	25	27.4	0.14	0.07-0.25	0.04
	Flounder	25	33.1	0.23	0.07-0.44	0.10
	Dab	25	24.3	0.18	0.07-0.32	0.06
	All fish	150		*0.17		
Morecambe Bay	Whiting	25	30.3	0.28	0.19-0.51	0.07
	Plaice	25	30.9	0.11	0.02-0.29	0.05
	Sole	25	28.4	0.16	0.11-0.26	0.04
	Flounder	25	31.3	0.25	0.09-0.43	0.09
	Dab	25	26.2	0.19	0.10-0.29	0.05
	All fish	125		*0.21		

* Weighted mean based on the relative contribution of each species to the 1990 commercial landings from the area

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

In its first report, the CGMSD indicated that this objective would be met provided there was 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.

Fish samples were taken at both the Bell Rock and St Abbs Head areas for population analysis. At Bell Rock, the number of fish species taken at the disposal site was similar to that at the control site although abundance was greater at the latter (Table 4). At St Abbs Head the species richness as well as abundance, were greater at the control site than at the disposal site (Table 5). These differences were not considered by the Fourth River Purification Board to be significant.

Common dab were retained for microbiological analysis from both control and disposal sites at Bell Rock and St Abbs Head (10 fish from each site). Fish from the St Abbs Head control site contained low concentrations of presumptive coliforms: 5-349 g⁻¹ of

gut content. Two fish contained 2 faecal coliforms g⁻¹ of gut content. Fish at the disposal site contained rather higher numbers of bacteria: 8 fish contained >2,400 presumptive coliforms g⁻¹ of gut content and 8 contained 2 - >2,400 faecal coliforms g⁻¹ of gut content. Fish from Bell Rock displayed similar variations

Table 4. Fish samples collected at the Bell Rock disposal and reference sites in 1990

Fish species	Numbers of fish caught	
	Station 13	Control
Cod	9	12
Haddock	101	74
Whiting	222	981
Common dragonet	1	9
Butterfish	-	1
Grey gurnard	5	13
Pogge	2	18
Plaice	9	34
Common dab	49	313
Long rough dab	5	26
Lemon sole	4	-
Norwegian topknot	-	4
Cuckoo ray	3	8
Fatherlasher	1	-
Sprat	-	5

Table 5. Fish samples collected at the St Abbs Head disposal and reference sites in 1990

Fish species	Numbers of fish caught	
	Station 13	Control
Cod	19	579
Haddock	1	7
Whiting	108	556
Herring	-	6
Common dragonet	10	5
Sand goby	17	-
Monkfish	1	1
Sandeel	3	9
Plaice	2	-
Pogge	1	1
Dab	44	27
Long rough dab	406	18
Lemon sole	1	42
Norway topknot	1	1
Thornback	-	1
Four-bearded rockling	16	-
Snake blenny	1	-
Sprat	2	14
Wolf fish	-	2
Scad	-	2
Fatherlasher	-	3
Grey gurnard	-	3
Poor cod	-	36

in bacterial content, those from the centre of the disposal site containing higher concentrations of presumptive coliforms than those from the control site. At both Bell Rock and St Abbs Head, the results for 1990 were similar to those from earlier years. These observations indicate that fish do feed in the disposal site but it is not considered that the bacterial contamination which they acquire as a consequence (which is confined to the gut) poses a risk to human consumers. Since examination of sediments for bacteria is more readily conducted and the results are more easily interpreted, it is suggested that this approach should be adopted in future.

At Garroch Head, only small numbers of fish were collected at control and reference sites (Table 6). The Institute of Aquaculture, University of Stirling concluded that the fish from the control and disposal sites did not differ significantly in either internal or external pathology. The strength of this conclusion must be tempered by the small sample size.

Table 6. Fish and shellfish samples collected at the Garroch Head disposal and reference sites in 1990

Haul no. and area	Fish species taken		Fish length (cm)	Invertebrata taken	
	No.	Scientific name Common name		No.	Scientific name Common name
Disposal site (P7) Haul 1	8	<i>Trisopterus esmarkii</i> Norway pout	12.0-14.7	1	<i>Buccinum undatum</i> Whelk
	1	<i>Trisopterus minutus</i> Poor cod	23.1	1	<i>Pandalus</i> sp. Prawn
	1	<i>Melanogrammus aeglefinus</i> Haddock	25.5		
	2	<i>Merlangius merlangus</i> Whiting	20.7-21.1		
	34	<i>Gadus morhua</i> Cod	15.7-24.8		
	26	<i>Pollachius virens</i> Saithe	18.5-36.9		
	4	<i>Pleuronectes platessa</i> Plaice	15.7-22.7		
	9	<i>Hippoglossoides platessoides</i> Long rough dab	13.8-20.6		
Disposal site (P7) Haul 2	1	<i>Trisopterus esmarkii</i> Norway pout	12.5	1	<i>Macropipus</i> sp. Velvet crab
	3	<i>Gadus morhua</i> Cod	13.8-21.4		
	2	<i>Pleuronectes platessa</i> Plaice	18.7-28.8		
Disposal site (P7) Haul 3	45	<i>Trisopterus esmarkii</i> Norway pout	11.6-16.7		
	11	<i>Trisopterus minutus</i> Poor cod	12.9-15.5		
	1	<i>Merlangius merlangus</i> Whiting	16.2		
	31	<i>Gadus morhua</i> Cod	15.2-23.6		
	6	<i>Hippoglossoides platessoides</i> Long rough dab	15.7-17.0		
	2	<i>Platichthys flesus</i> Flounder	31.9-33.2		
	1	<i>Pleuronectes platessa</i> Plaice	20.4		
	1	<i>Limanda limanda</i> Common dab	17.6		
	1	<i>Clupea c. harengus</i> Herring	31.3		
Reference station (G1) Haul 1	2	<i>Trisopterus esmarkii</i> Norway pout	11.6-23.6	1	<i>Liocarcinus depurator</i> Swimming crab
	1	<i>Trisopterus luscus</i> Bib	24.0		
	3	<i>Trisopterus minutus</i> Poor cod	14.9-16.4		
	2	<i>Merlangius merlangus</i> Whiting	16.9-20.3		
	1	<i>Gadus morhua</i> Cod	32.6		
	2	<i>Merluccius merluccius</i> Hake	17.7-23.6		
Reference station (G1) Haul 2	1	<i>Hippoglossoides platessoides</i> Long rough dab	16.4		
	2	<i>Trisopterus esmarkii</i> Norway pout	18.1-18.3	1	<i>Buccinum undatum</i> Whelk
	2	<i>Merlangius merlangus</i> Whiting	20.2-23.1	1	<i>Crangon allmani</i> Brown prawn
	2	<i>Hippoglossoides platessoides</i> Long rough dab	13.4-15.9	13	<i>Nephrops norvegicus</i> Norway lobster
	1	<i>Platichthys flesus</i> Flounder	27.7		
Reference station (G1) Haul 3	1	<i>Glyptocephalus cynoglossus</i> Witch	12.4		
	3	<i>Trisopterus esmarkii</i> Norway pout	16.5-18.6	3	<i>Octopus octopus</i> Octopus
	2	<i>Trisopterus minutus</i> Poor cod	15.1-15.5	2	<i>Crangon allmani</i> Brown prawn
	6	<i>Merlangius merlangus</i> Whiting	18.3-20.4	1	<i>Hyas araneus</i> Spider crab
	1	<i>Merluccius merluccius</i> Hake	19.0	12	<i>Nephrops norvegicus</i> Norway lobster
	1	<i>Pleuronectes platessa</i> Plaice	24.8	1	<i>Munida banfica</i> Squat lobster
Intermediate station (J7) Haul 1	1	<i>Trisopterus esmarkii</i> Norway pout	11.6-16.7	42	<i>Pandalus</i> sp. Prawns
	8	<i>Trisopterus minutus</i> Poor cod	12.9-15.5	1	<i>Crangon allmani</i> Brown prawn
	8	<i>Merlangius merlangus</i> Whiting	16.2	1	<i>Macropipus</i> sp. Velvet crab
	1	<i>Gadus morhua</i> Cod	15.2-23.6	34	<i>Asterias rubens</i> Starfish
	4	<i>Merluccius merluccius</i> Hake	19.0		
	12	<i>Hippoglossoides platessoides</i> Long rough dab	15.7-17.0		
	4	<i>Pleuronectes platessa</i> Plaice	20.4		

Table 7. Disease data for dab from waste disposal and reference sites on the north-east coast of England in May 1990

Station number	ICES rect-angle	Total number in sample	Number sampled in each group									Diseases														
			Gp I			Gp II			Gp III			Gp I				Gp II				Gp III		All epidermal diseases for all groups (%)				
			M	F		M	F		M	F		L	H	U	Epi-dermal diseases (%)	L	H	U	Epi-dermal diseases (%)	L	H		U	Epi-dermal diseases (%)	L/N	Liver nodules (%)
58-61	39 F3	245	51	49		24	76		3	42		3	5	0	8.0	9	2	10	21.0	1	0	4	24.4	6	13.3	13.9
67-70	38 F1	249	55	45		35	65		0	49		1	0	10	11.0	2	0	6	8.0	1	1	5	28.5	7	14.2	10.4
78-81	39 E8	N/S	-	-		-	-		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90-94	38 E8	148	44	23		11	52		0	18		7	2	1	14.9	11	1	7	30.2	0	2	1	22.3	1	5.6	21.6

Key: M = male
 F = female
 L = Lymphocystis
 H = Epidermal hyperplasia
 U = Epidermal ulcer
 L/N = Liver nodule >2mm in diameter
 N/S = Not sampled

MAFF conducted a survey of diseases in dab off the north-east coast of England in 1990 (Table 7). The numbers of fish caught were 245, 249 and 148 from the 3 sampling areas (ICES rectangles 39F3, 38F1, and 38E8). This sampling programme met the CGMSD approved guidelines. Two factors explain the contrast in meeting guidelines shown by the Garroch Head and north-east England surveys. Firstly, the towing times were considerably longer off the north-east coast of England than those used at Garroch Head (1 hour compared to 10 minutes). Secondly, dab are not common off the west coast of Scotland. The effects of these factors may be counteracted by survey design (i.e. sampling a locally abundant species using longer tows). However, it is clear that there is little point in conducting fish disease work which is not carried out in accordance with the CGMSD recommendations. These are based on the internationally agreed procedures proposed by ICES and yield data that are statistically reliable. Work that does not meet the specification should be either discontinued or upgraded.

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

In its first report, the CGMSD suggested that suitable indicators of alterations in environmental quality are 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 1990 is reviewed below.

4.5.1 The Firth of Forth: St Abbs Head and Bell Rock

Changes in the benthos were generally within the boundaries of previous surveys and no persistent trends could be discerned. Quantitative results demonstrated the influence on the outcome of data analyses of one or two numerical or biomass dominants, whose fluctuations from year to year can probably be accounted for by natural events (e.g. variation in recruitment success). Furthermore, one or two stations appeared to stand out from a general uniformity in substrate type, again due to natural variability. To the extent that certain of these species (or stations) could be considered to have a 'masking' effect on the identification of anthropogenically-related trends, then the effects of their (arbitrary) exclusion on the outcome of future analyses may be of interest.

Separation of stations into 'impacted' and 'non-impacted' groups, based on the outcome of analysis for coprostanol in sediments in 1987, again provided no evidence of significant differences between selected measures of community structure. However, as in 1989, values of diversity and evenness were marginally lower, and abundance and abundance/taxa ratios marginally higher in the 'impacted' group at St Abbs Head. This site was also characterised by the presence, in moderate numbers, of a capitellid polychaete at the disposal site centre. This species is normally regarded as being an indicator of organic enrichment. Accordingly, this observation, linked with indications of overall benthic change, can be taken to indicate continued localised evidence of mild organic enrichment.

Survey emphasis at these two sites is primarily spatial. However, methodological differences apart, the potential for extracting relevant parts of the data-base for a more thorough analysis of temporal trends remains, and would be worthwhile. This could be particularly helpful in assessing the suitability of the present sampling regime for the possible future demands of compliance-testing against guideline values for permissible change arising from Task Team proposals.

4.5.2 The Humber

The gravelly substrates found in this area are not amenable to quantitative sampling of the benthos by grab; an earlier qualitative appraisal was provided by Murray *et al.* (1980(a)). For some years, MAFF has sampled populations of the horse-mussel (*Modiolus modiolus*), which is widely distributed in the area, for examination of biological 'condition' and trace metal concentrations/burdens in flesh. An example of trends in the concentrations of cadmium at the disposal site, compared with a reference site off the Norfolk coast, is shown in Figure 1. On each occasion, and at each site, the results from analyses of 8 individuals in the length range 7-9 cm were selected. Results are expressed as arithmetic means, together with 95% 'Least Significant Intervals'. Means whose intervals do not overlap may be assumed to be significantly different.

Although there is appreciable year-to-year variability, a downward trend in cadmium content is evident in sediment at the disposal site (Figure 2). This corresponds with a reduction in cadmium load in sewage sludge, although the wider influence of reduction in loads to the Humber estuary itself (for which there is also some evidence) cannot be dismissed. It should be noted that there is no history of commercial exploitation for human consumption of these east coast *Modiolus* populations (see Rees and Nicholson, 1989).

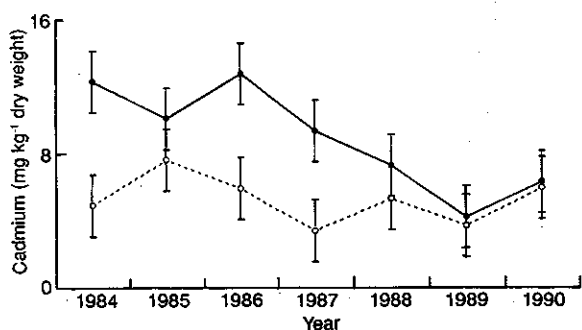


Figure 1. Trends in concentrations of cadmium in horse-mussel flesh from the Humber disposal site (continuous line) and off the Norfolk coast (broken line)

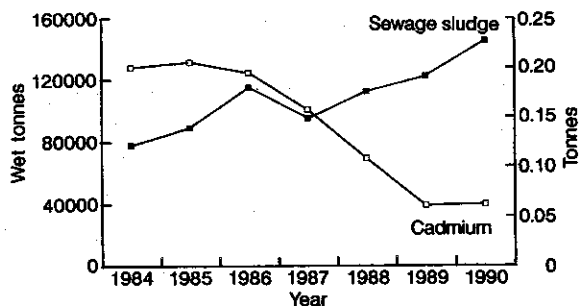


Figure 2. Trends in total loads of sewage sludge, and of cadmium, deposited at the Humber disposal site

4.5.3 The Thames Estuary: Barrow Deep

The disposal site is located in a dispersive area, characterised by the presence of linear sand-banks inshore. Sediments range from gravel to silty sands but, for the most part, are amenable to quantitative sampling by grab. A wide-scale grid survey was conducted in 1990, and trends evident from the benthos data (retained on 1 mm and 0.5 mm mesh sizes) were examined in relation to environmental variables. Although similar relationships were apparent whichever mesh size was used, there was an indication that greater sensitivity was achieved using the finer (0.5mm) mesh size.

As was to be expected, substrate type accounted for a major component of the variability. However, there was some evidence of enhancement in populations at localities known to be influenced by dispersed particulates from sludge disposal. Such enhancement is characteristic of an early phase in the process of organic enrichment (e.g. Pearson and Rosenberg, 1978). Overall, the composition and distribution of communities were similar to those found in previous years.

4.5.4 Plymouth

Sampling design comprised a wide grid of stations over the disposal ground and sampling methods allowed comparison with an earlier survey conducted by MAFF (Eagle *et al.*, 1979). The outcome of a thorough analysis and interpretation of the data provided no evidence of effects which could be attributed to sludge disposal. Faunal associations across the grid varied in accordance with natural environmental factors, especially substrate type, and the overall composition of the fauna was little different from that sampled by Eagle *et al.* (1979) in 1975.

4.5.5 The Bristol Channel

This is a highly dispersive area, characterised by mixed substrates ranging from mobile sands to rocky ground. A detailed description of environmental conditions at the locality is given in Murray *et al.*, (1980(b)) Effects of sewage-sludge disposal at the sea bed, if present, would be expected to be relatively subtle in nature. However, the chance of detecting such effects must be set against the likelihood of high natural variability in benthic populations, and the additional complication of sampling difficulties on variable substrates. Assessment at this site has involved sampling by anchor dredge along transects through the disposal site, which provides at best a 'semi-quantitative' snapshot of the benthos, but at least ensures that adequate quantities of material are retained for analysis. The outcome of multivariate analyses of the data demonstrates the strong links between faunal associations and substrate type.

There was no evidence of gradients in the data which could be related to sludge disposal; neither was there any evidence of tracers such as tomato pips, which commonly occur at sites of accumulation. Sampling limitations notwithstanding, the absence of any evidence of detrimental effect would accord with expectation. This outcome has the benefit of providing 'reassurance' about the disposal operation and, as such, justifies continuance of the sampling programme.

4.5.6. Garroch Head

Sampling design was the same as those of previous years, and took the form of a transect of stations running through the disposal site. These were sampled by a Van Veen grab. The work was again successful in identifying well-defined if highly localised zones of biological effect, consistent with the settling in quantity of sewage-sludge particulates in this quiescent area. Overall, biomass was higher than in 1989, and there was some evidence of a further slight extension of zones of highly and moderately enriched conditions beyond those previously identified. It is suggested that this is due to the more effective use of the whole disposal site rather than, as in previous years, use of only one small area. However, the magnitude of changes in the benthos at individual stations remained well within the range of those observed over the preceding 11 years.

4.6 EQO: Maintenance of the receiving environment without distinguishable change

In its first report, the CGMSD 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 Transect study of sediment chemistry at the Tyne disposal site

In order to assess the impact of sludge disposal on sediment chemistry, samples were collected by MAFF in May 1990 along a line extending from the mouth of the River Tyne, through the sewage-sludge disposal site to about 17 km offshore (Figure 3).

Faecal bacteria (*E. coli* and faecal streptococci) were determined in surface scrapes of sediment to detect any influence of sewage sludge. Concentrations of carbon and nitrogen were measured in the <63 µm fraction of the sediment by CHN analyser, after pre-treatment with SO₂ solution to remove carbonates. Metals (Al, Cd, Cu, Cr, Hg, Ni, Pb and Zn) were measured in *aqua regia* digests of the <63 µm fractions. Concentrations of trace metals in sediment extracts were determined by atomic absorption spectrophotometry (AAS).

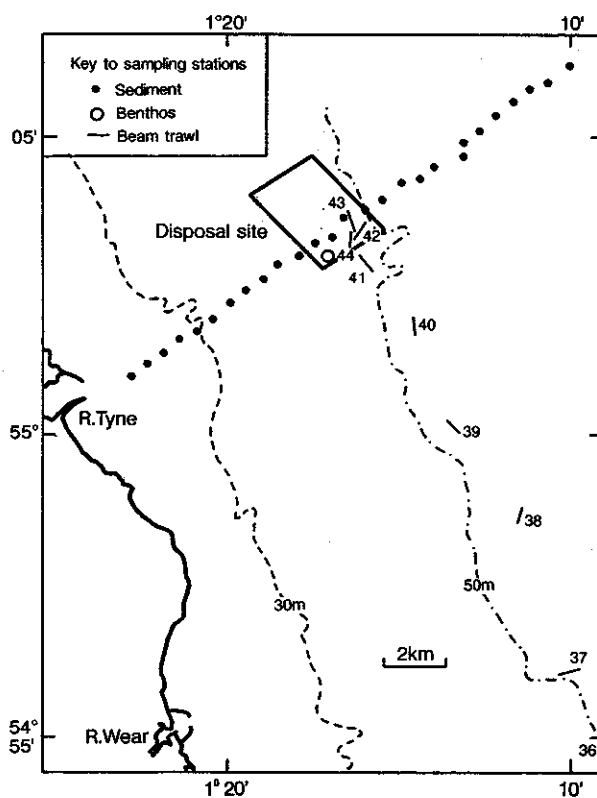


Figure 3. Sediment sampling stations off the River Tyne, May 1990

Figure 4 shows the distribution of concentrations of metal in the fine (< 63 µm) sediment fraction along the transect using copper as an example, together with the numbers of *E. coli* in the sediment. There is no evidence of elevated concentrations of copper (or other metals) in the region of the disposal site where the bacteria indicate that sludge settles. Thus, it may be concluded that there is no detectable accumulation of trace metals from sewage sludge at the sea bed.

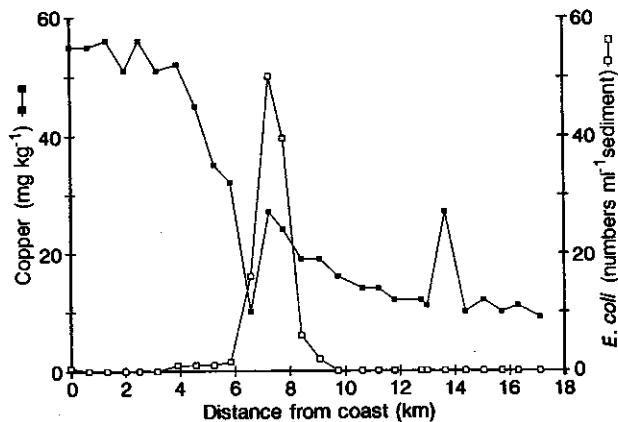


Figure 4. Concentration of copper (mg kg⁻¹) in the <63 μm fraction of sediment and numbers of E.coli in surface sediment along a transect off the River Tyne, May 1990

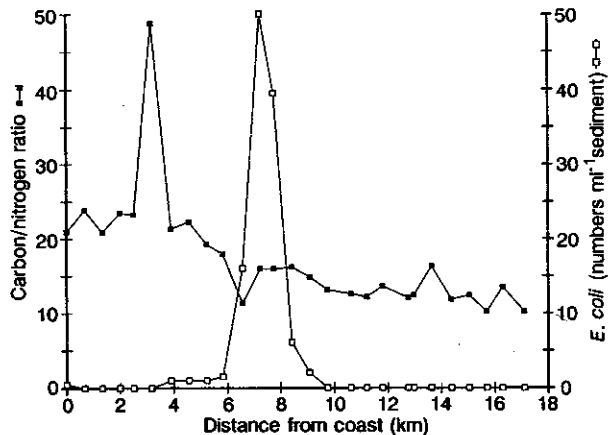


Figure 6. C/N ratio in the <63 μm fraction of sediment and numbers of E.coli in surface sediment along a transect off the River Tyne, May 1990

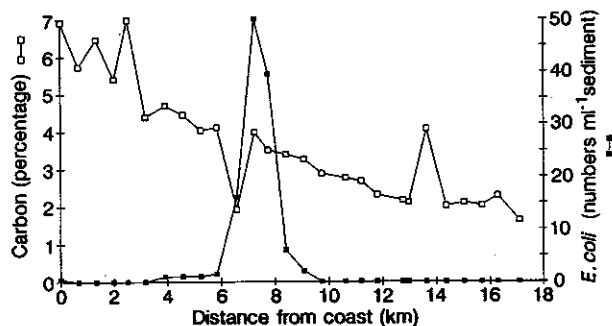


Figure 5. Concentration of carbon (%) in the <63 μm fraction of sediment and numbers of E.coli in surface sediment along a transect off the River Tyne, May 1990

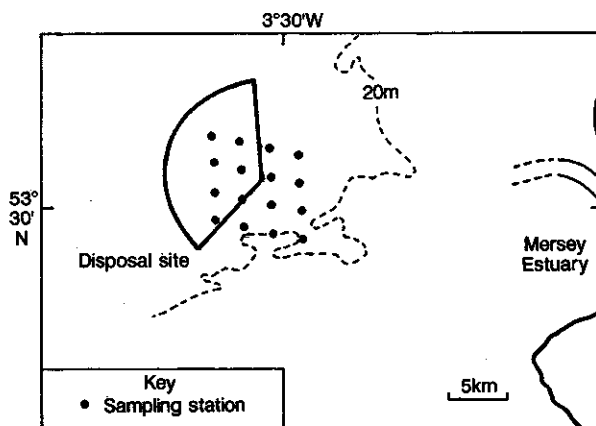


Figure 7. The sewage-sludge disposal site and sediment sampling grid in Liverpool Bay

A similar approach can be applied to the interpretation of the data on concentrations of carbon in the sediment and, as Figure 5 shows, there is no evidence of any accumulation of organic carbon at the disposal site. It must be borne in mind when considering organic carbon data, that coal is generally present in these sediments due largely to erosion of outcrops of coal on the sea bed and past industrial practices and that these may mask any minor influence of sewage sludge on carbon content. One possible method to overcome this problem is to consider the C/N ratio; this may give a more sensitive indication of the presence of sludge which has a high concentration of nitrogen relative to carbon. Figure 6 shows the C/N ratio and the *E. coli* counts. They are clearly unrelated and no evidence exists that sewage-sludge dispersion has an impact on the natural gradient offshore of the C/N ratio.

The value of this study is that, by using closely-spaced sampling stations, it has been possible to demonstrate the independence of the metal and bacterial concentrations and allow the conclusion to be drawn that sewage-sludge disposal off the Tyne has had no significant effect on the metal (copper) content of sediment chemical quality.

4.6.2 Liverpool Bay time-series

Each year, about 1.5 million wet tonnes of sewage sludge are deposited at a designated site in Liverpool Bay (Figure 7) by North West Water Ltd. MAFF has studied the area since the 1970s to assess effects on water, sediment and fish quality.

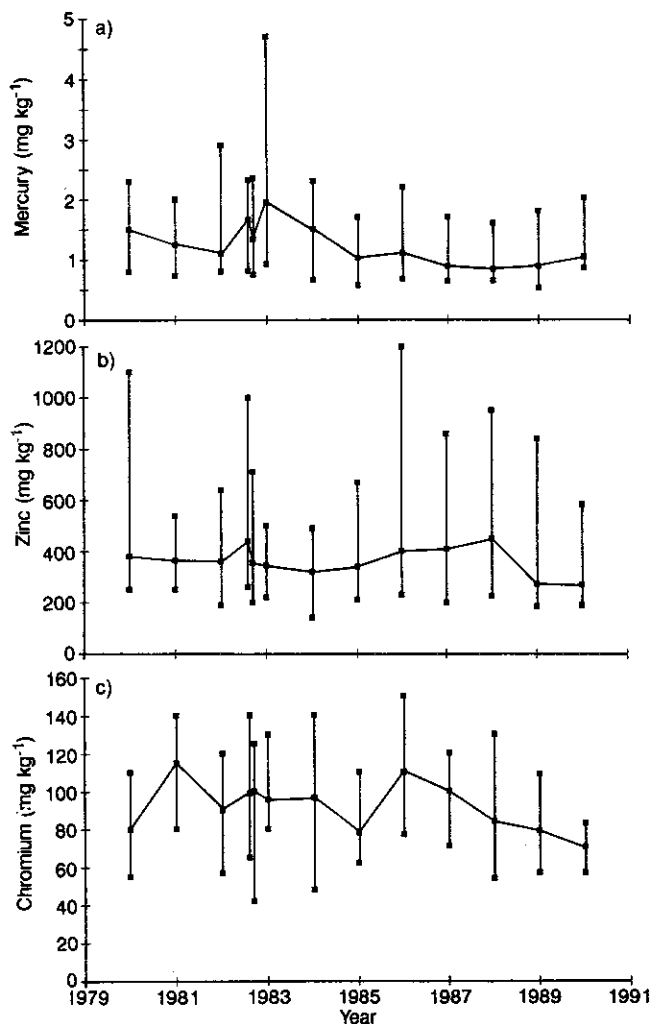


Figure 8. Time-series of concentrations of metals in the $<90 \mu\text{m}$ fraction of sediment collected near the Liverpool Bay sewage-sludge disposal site: (a) mercury; (b) zinc; and (c) chromium

This work has included the analysis of sediment samples collected near the disposal site (see, for example, Figure 27), where effects on sediment chemistry have previously been observed (e.g. Norton *et al.*, 1984). Sediment samples were collected in 1990 and analysed using the methods described by the CGMSD (MAFF, 1989) except that, for reasons of consistency with earlier work, the $<90 \mu\text{m}$ sediment fraction was used rather than the $<63 \mu\text{m}$ fraction.

Concentrations of trace metals in the sediments exhibit highly skewed distributions and are therefore described using non-parametric measures. Figure 8(a-c) shows the median and range of concentrations of mercury, zinc and chromium from 1980 to 1990. The most notable feature of the time-series is the absence of any marked trend over the decade of study.

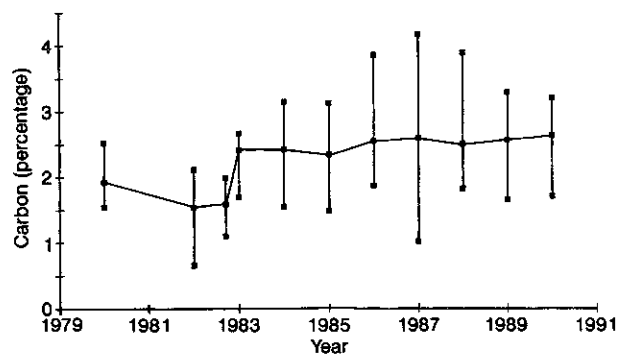


Figure 9. Time-series of concentrations of carbon in the $<90 \mu\text{m}$ fraction of sediment collected near the Liverpool Bay sewage-sludge disposal site

Figure 9 shows carbon data presented in the same manner as those of metals. This shows a consistent median value during the period 1983 to 1990, although it appears that the concentrations may have been slightly lower in the early years of the decade. The concentration ranges show considerable overlap between all years, suggesting that this small difference is of little significance.

When considering data from this sandy area, it must be recognised that the $<90 \mu\text{m}$ fraction in general represents less than 5% of the total sediment and that, when considered on a whole sediment basis, the concentrations of metals are very low.

It is known that sediments in the vicinity of the disposal site contain higher concentrations of several metals (e.g. copper, mercury, zinc and lead) than sediments further away (Norton *et al.*, 1984) and it seems reasonable to conclude that there has been some accumulation of metal contaminants in the area as a direct consequence of the sewage-sludge disposal operation. However, the fact that there has been no increase over the past 10 years indicates that the system is in equilibrium and has been so for at least the last decade. It should be noted that there appears to have been a slight decrease in the concentrations of mercury and chromium during the past five years (Figures 8(a) and (c)) but that the variability of the data make this difficult to confirm.

Long time-series studies are particularly valuable, because they put into context annual variations due to short-term effects (such as storms) and form a firm basis on which to base sediment standards of 'no change' (see sub-section 3.1).

4.6.3 Spatial survey of the Thames Estuary: Barrow Deep

The Water Research centre (WRC) surveyed the Barrow Deep disposal site (Figure 10) for Thames Water using a spatial survey for the measurement of the metals zinc, lead, mercury and cadmium which were measured in both the <63 μm (presently recommended) and the <90 μm (previously used) fractions

of sediment. Satisfactory relationships between the <63 μm and <90 μm fractions were obtained for zinc, lead and mercury (Figure 11) but not for cadmium. (Such dual analyses, if carried out for a period of years' should allow a continuous time-series to be built up). There appears to be a general decrease in the concentrations of these metals in the <90 μm size fraction over the period 1985-1990. Figure 12 (a-d) shows the distribution of zinc over this period.

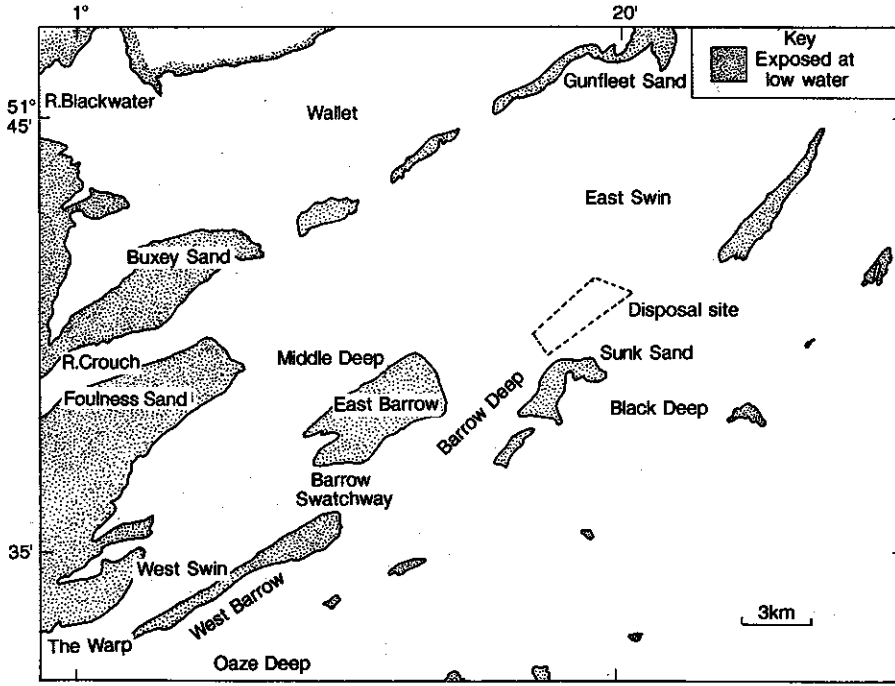


Figure 10. The Barrow Deep, Outer Thames Estuary

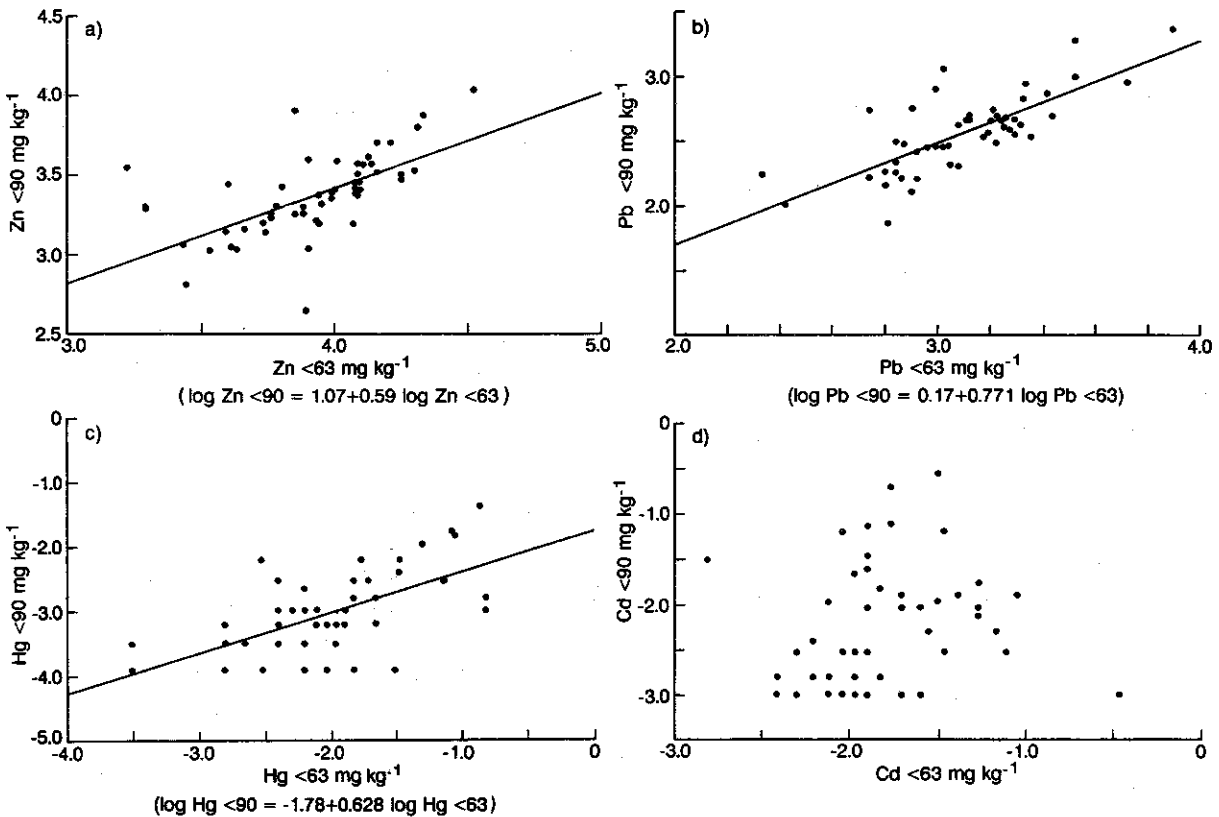


Figure 11. The relationships between metal concentrations (mg kg^{-1}) in the <63 μm and the <90 μm fractions of sediment from the Barrow Deep area of the Outer Thames Estuary: (a) zinc; (b) lead; (c) mercury; and (d) cadmium

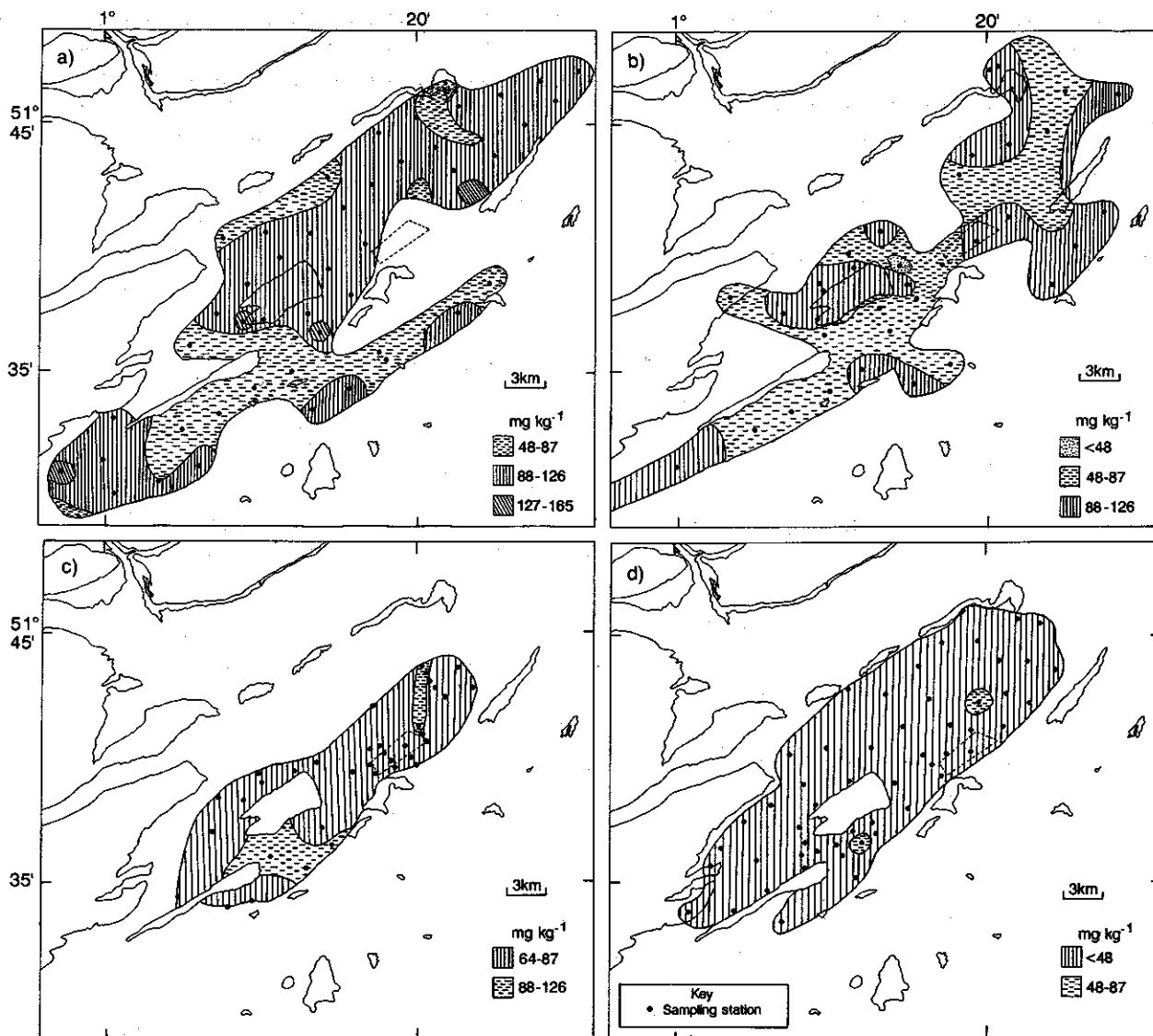


Figure 12. The distribution of zinc concentrations (mg kg^{-1}) in the $<90 \mu\text{m}$ fraction of sediment in the Barrow Deep area of the Outer Thames Estuary: (a) 1985; (b) 1986; (c) 1988; and (d) 1990

Areas with relatively high concentrations of metals in the $<90 \mu\text{m}$ fraction are largely confined to single sites, with the exception of cadmium where an area in the Barrow Swatchway is indicated. More extensive elevated areas are apparent in the $<63 \mu\text{m}$ data (Figure 13 (a-d)). Areas of relatively high concentration of cadmium and mercury occur at the disposal site and to the south of the East Barrow Sand. Elevated zinc and lead concentrations occur at these sites and also in the Middle Deep, along the northern margin of the West Barrow Sand and in the East Swin. The areas in the Barrow Deep also show elevated concentrations of total organic carbon and faecal bacteria, suggesting that sludge may accumulate in these areas and give rise to the elevations in metal concentrations (Figures 14 and 15). These data suggest that, of the two sediment fractions, analysis of the $<63 \mu\text{m}$ part is the more sensitive indicator of accumulation and supports the CGMSD advice that it should be used whenever possible.

4.6.4 Spatial survey of the Humber

A spatial survey of metal concentrations in sediments at the Humber disposal site was carried out by Yorkshire Water (Figure 16). The data show a decreasing trend in lead and mercury offshore but no notable elevations in metal or carbon associated with the sewage-sludge disposal site.

4.7 Microtox test

In their Thames study, WRc used the Microtox test on an experimental basis in order to establish its suitability as an indicator of the presence of sewage sludge and as a possible means of assessing the impact of sediment contamination on aquatic life. The test assesses the toxicity of organic extracts of whole sediment by measuring reductions in the light output of species of a luminescent bacterium.

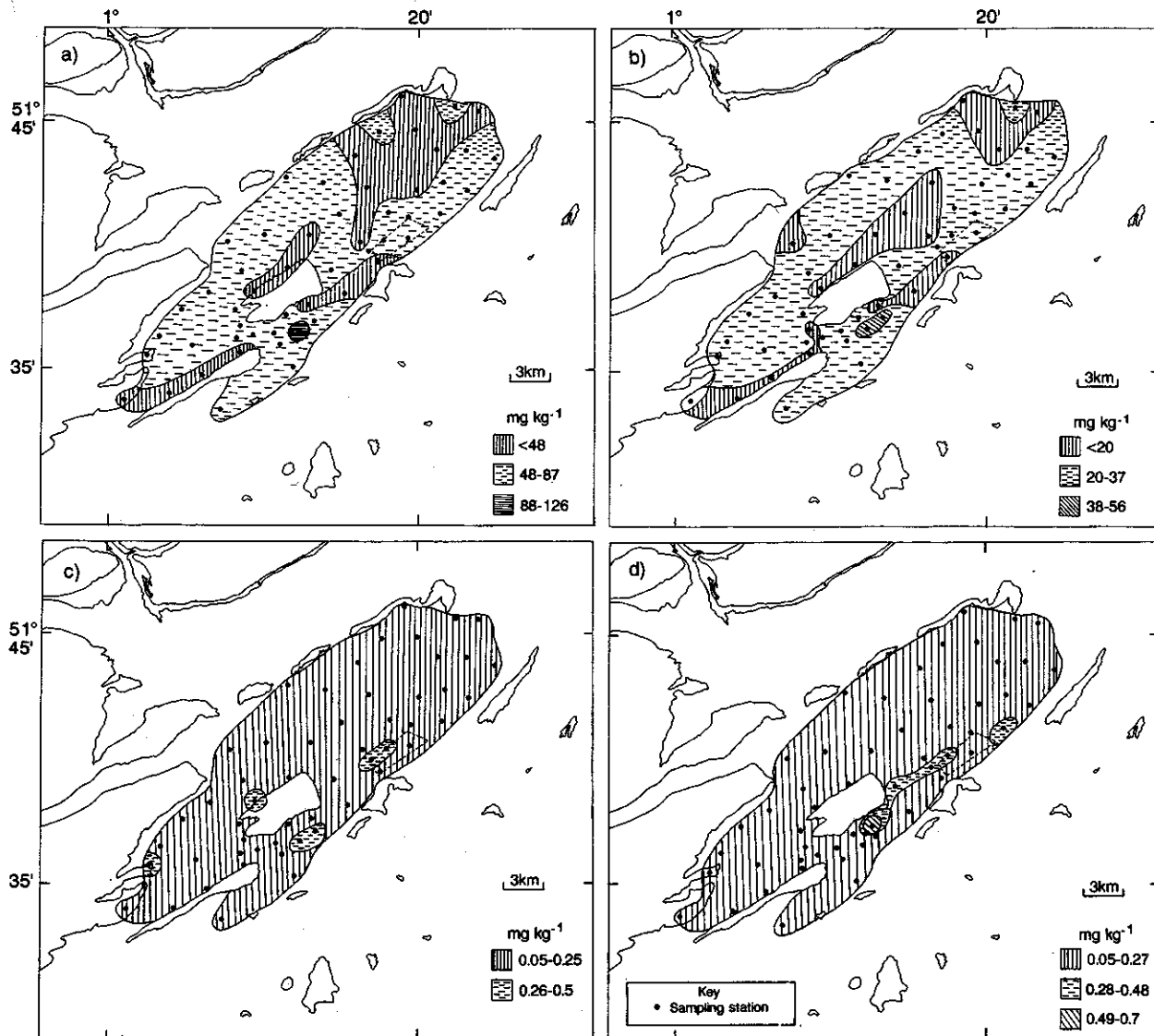


Figure 13. The distribution of metal concentrations (mg kg⁻¹) in the <63 μm fraction of sediment in the Barrow Deep area of the Outer Thames Estuary: (a) zinc; (b) lead; (c) mercury; and (d) cadmium

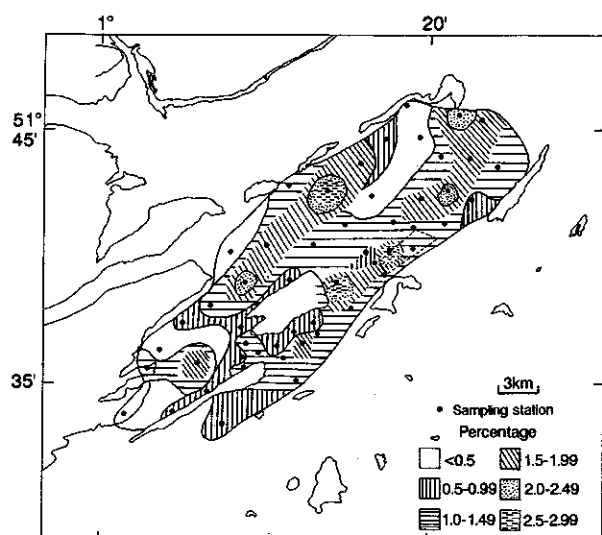


Figure 14. The distribution of total organic carbon concentrations (%) in the <63 μm fraction of sediment in the Barrow Deep area of the Outer Thames Estuary

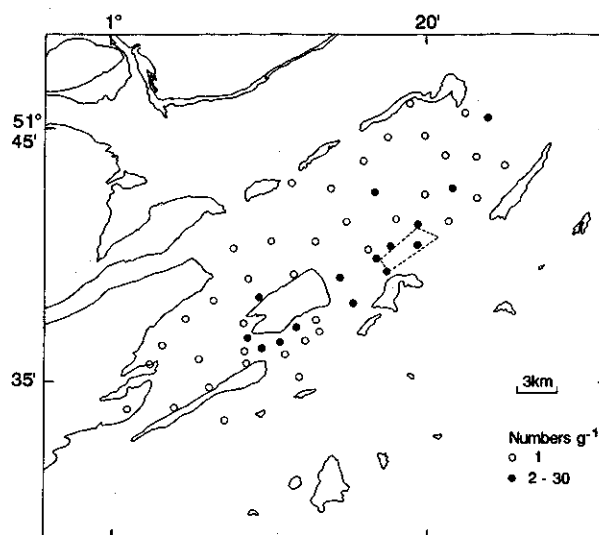


Figure 15. The distribution of total faecal streptococci counts (numbers g⁻¹) in the <63 μm fraction of sediment in the Barrow Deep area of the Outer Thames Estuary

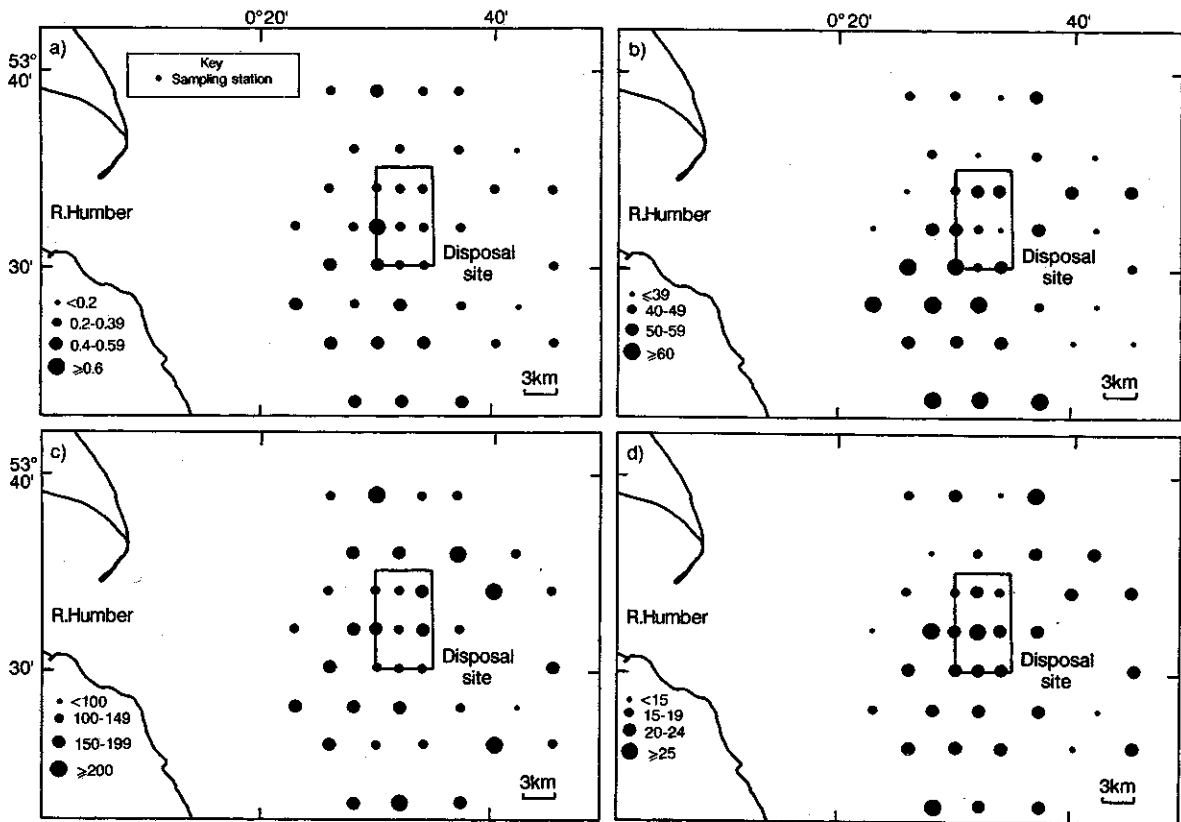


Figure 16. The distribution of metals (mg kg^{-1}) and carbon (%), around the Humber sewage-sludge disposal site in 1990: (a) mercury; (b) lead; (c) zinc; and (d) carbon

The values for the estimated EC_{50} are generated from a regression equation between an expression of light output and concentration of sediment extract. This relationship is determined for each set of samples and, consequently, the EC_{50} values can only be described as toxic relative to one another. As there were no chemical analyses of the extracts it is difficult to relate a toxic response from the Microtox test to contamination of the sediment. However, an indication of the degree of contamination can be obtained from comparative studies using the same extraction method.

Schiewe *et al.* (1985) carried out such a study in which the EC_{50} values of up to $2.5 \mu\text{l ml}^{-1}$ related to the more highly contaminated sediments from Puget Sound. EC_{50} values between 2.5 and $10 \mu\text{l ml}^{-1}$ were found for the majority of the remaining sediments taken from Puget Sound. The contaminants identified were principally organic compounds (aromatic hydrocarbons, chlorinated hydrocarbons and naphthalenes) and metals were found to be of negligible significance. These authors were reluctant to attribute toxicity solely to the organic components and concluded that Microtox toxicity was a reflection of general contamination.

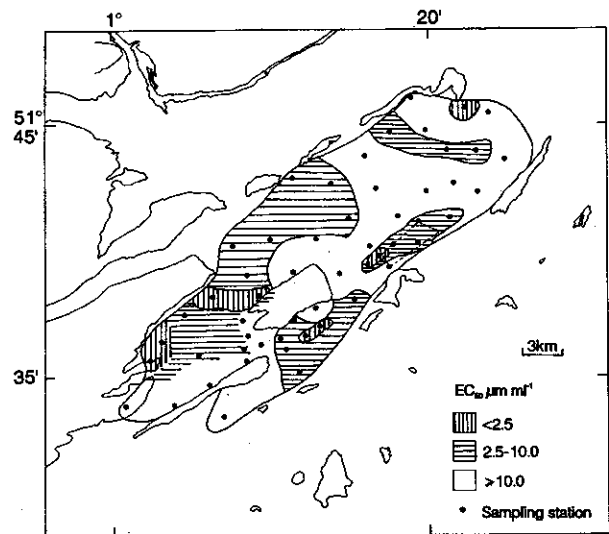


Figure 17. The distribution of Microtox mean EC_{50} values in sediment in the Barrow Deep area of the Outer Thames Estuary

Using the Puget Sound data, WRc conclude that 30 of the 53 Thames samples tested are contaminated to some degree (Figure 17). It must be emphasised that

this study does not explain the cause of the toxicity nor does it positively link it to the sewage sludge. However, the WRC report suggests that the inter-relationships observed indicate greater contamination and toxicity to the Microtox bacterium in areas with greater total organic carbon. WRC also suggest that the location of those areas in the Barrow Deep and the Swatchway implicates sewage-sludge disposal.

The results of this survey must clearly be regarded with considerable caution. Nevertheless, they are interesting in that they move from the determination of chemical concentration to assessment of biological effect. Such movement is desirable for the understanding of the significance of anthropogenic activities, but whether or not a bacterium is a suitable model is not clear. Further studies using Microtox and other biological tests should be pursued in order to establish the significance of these results.

4.8 Overall conclusions from the review of monitoring in 1990

- At some regularly-sampled locations, more attention should be given to comparison with the results of previous surveys, and hence on the identification of temporal trends, as data accumulate.
- There is a need to review current sampling practices, and sampling design, in the light of possible future requirements for compliance-testing against agreed guidelines for permissible change.
- Adequately-sized fish samples should be used for population studies or the studies should be discontinued.
- Closely-spaced transect sampling may provide good evidence for environmental impact or the lack of it at sewage-sludge disposal sites.
- Long time-series of contaminant data provide a firm basis for assessing year-on-year fluctuations in context and should always be collected.
- The Microtox test appears to be a useful technique and should be further evaluated.

5. MONITORING ACTIVITIES AT SEWAGE-SLUDGE DISPOSAL SITES IN 1991

5.1 Introduction

During 1991, surveys were carried out at the following disposal sites: Tyne, Humber, Nab, Thames (Barrow Deep), Roughs Tower, Exeter, Liverpool Bay, Garroch Head, Bell Rock and St. Abbs Head.

Short summaries of all of 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 CGMSD. 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.

A summary of the techniques used at each disposal site in 1991 is given in Table 8.

5.2 MAFF survey of the Tyne sewage-sludge disposal site, May 1991

- (a) Sediment samples were collected from the stations shown in Figure 18.
- (b) Metals (Cd, Cu, Cr, Hg, Ni, Pb and Zn) will be determined on 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 along a north-south transect through the disposal site, at the stations shown in Figure 19.
- (d) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) will be determined in the <63 μm fraction of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples for both the whole and the <63 μm fractions.
- (e) Benthic macrofauna and meiofauna will be identified and enumerated in sediment samples collected from the stations shown in Figure 19.

Table 8. 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				+		
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						

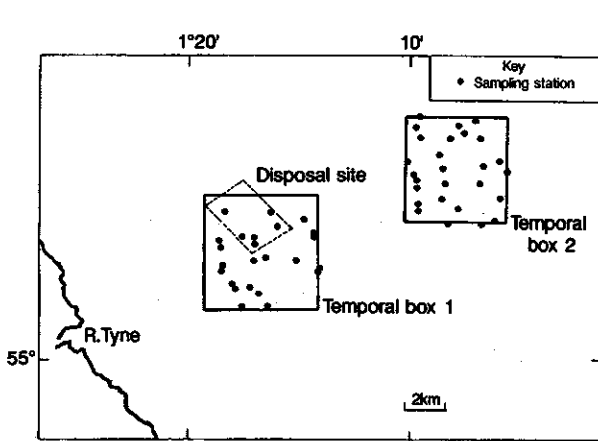


Figure 18. MAFF sediment survey of the Tyne sewage-sludge disposal site, May 1991

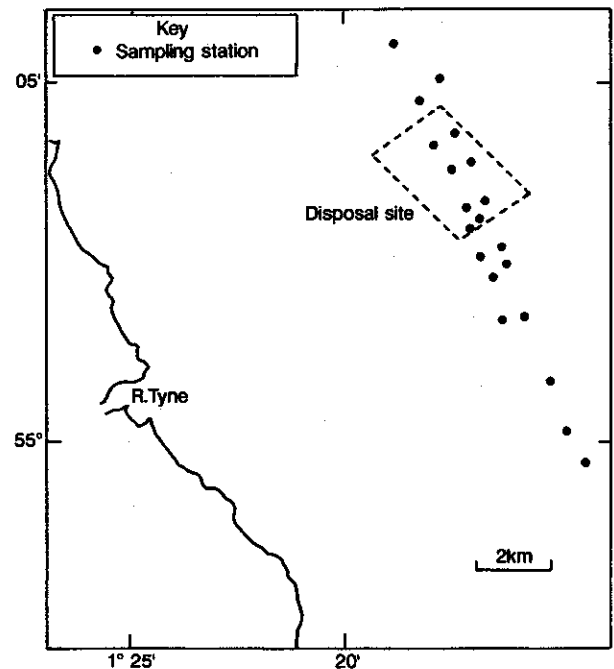
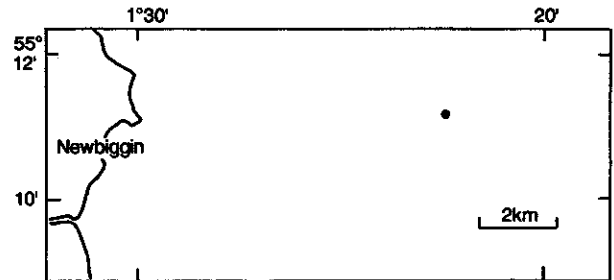


Figure 19. MAFF survey of benthos/bacteria at the Tyne sewage-sludge disposal site, May/August 1991

5.3 Northumbrian Water survey of the Tyne sewage-sludge disposal site, January/December 1991

- (a) Sediment samples were collected by Day grab from the stations shown in Figure 20.

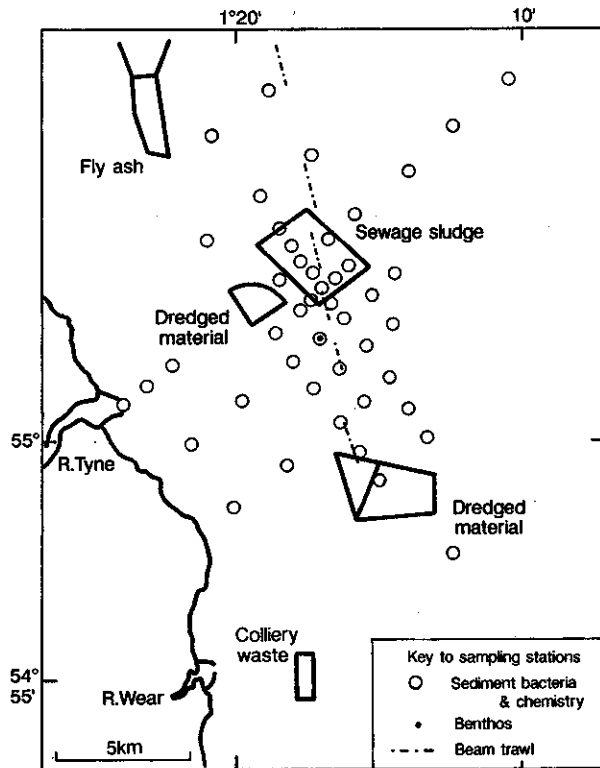


Figure 20. Northumbrian Water survey of the Tyne sewage-sludge disposal site, May/November 1991

- (b) *Escherichia coli* and group D faecal streptococci were enumerated in surface scrapes of the sediment.
- (c) Metals (Cu, Pb and Zn) were determined in the <63 μm fraction of the sediment.
- (d) Benthic infauna will be identified to species level and enumerated in samples collected from a station south of the disposal site (Figure 20). These will form part of the GCSDM Task Teams' Analytical Quality Control programme.
- (e) Two-metre beam trawl tows were carried out at the stations shown in Figure 20. Any litter collected was identified and enumerated. Epifauna will be identified to species level and enumerated.

5.4 MAFF survey of the Humber sewage-sludge disposal site, May 1991

- (a) Samples of horse-mussel (*Modiolus modiolus*) were collected at the stations shown in Figure 21. These will be analysed for Hg, Cd, Cu, Pb and Zn as part of a study of temporal trends in chemical quality of the mussel population.

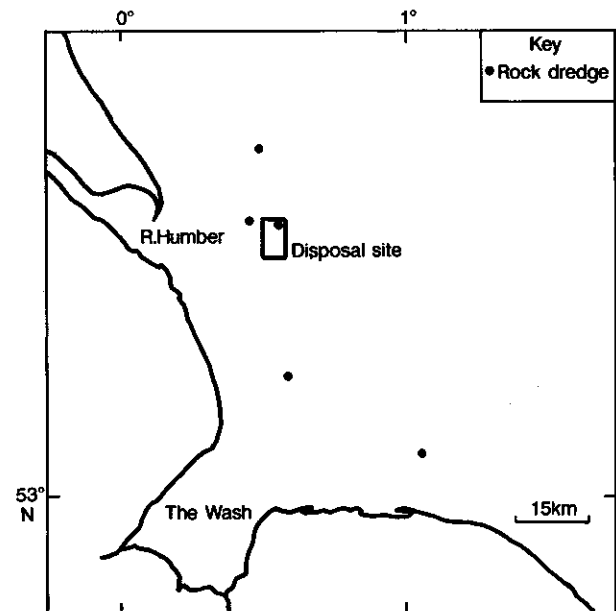


Figure 21. MAFF survey of *Modiolus modiolus* at the Humber sewage-sludge disposal site, May 1991

5.5 Anglian Water survey of the Roughts Tower sewage-sludge disposal site, October 1991

- (a) Sediment samples were collected from the stations shown in Figure 22.
- (b) *E. coli* and group D faecal streptococci were enumerated in surface scrapes of the sediment.
- (c) Metals (Cd, Hg, Pb and Zn) were determined in the <63 μm fraction of the sediment.

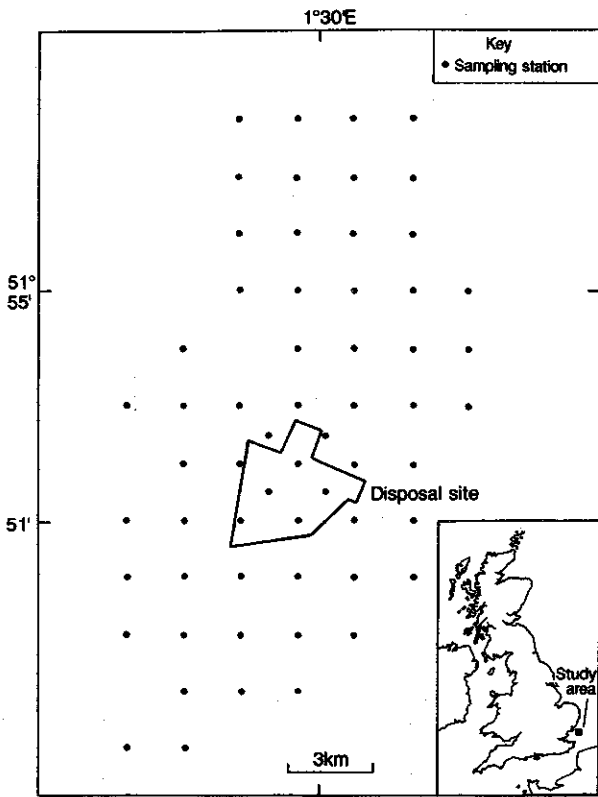


Figure 22. Anglian Water survey of the Roughs Tower sewage-sludge disposal site, October 1991

5.6 MAFF survey of the Barrow Deep (Thames Estuary) sewage-sludge disposal site, May 1991

- (a) Samples of sediment were collected from known areas of sludge settlement. Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn), carbon and nitrogen will be determined in both the whole and the <math><63 \mu\text{m}</math> fraction of the sediment (Figure 23).

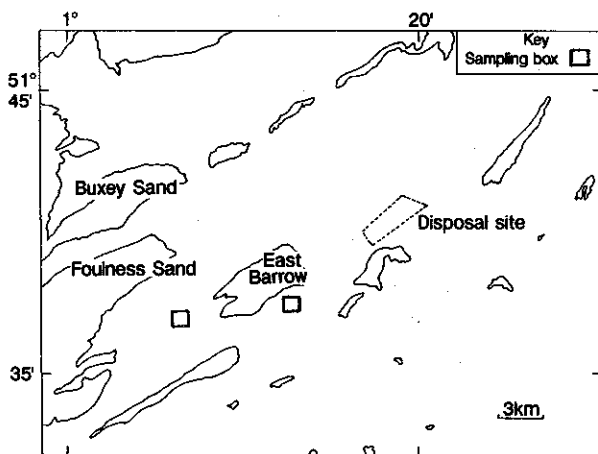


Figure 23. MAFF survey of the Barrow Deep sewage-sludge disposal site, May 1991

- (b) Samples were also collected for the identification and enumeration of benthic infauna.

These samples form part of a study on temporal trends.

5.7 MAFF survey of the Nab sewage-sludge disposal site, December 1991

- (a) Samples of sediment were collected from the stations shown in Figure 24.

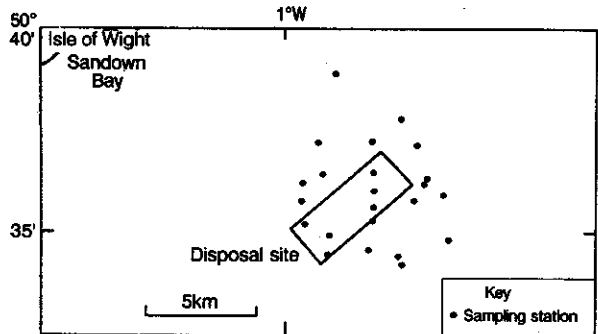


Figure 24. MAFF survey of the Nab sewage-sludge disposal site, December 1991

- (b) Metals (Cd, Cu, Hg, Ni, Pb and Zn), carbon and nitrogen were determined in the <math><63 \mu\text{m}</math> fraction of the sediment.

5.8 Southern Water survey of the Nab sewage-sludge disposal site, October 1991

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

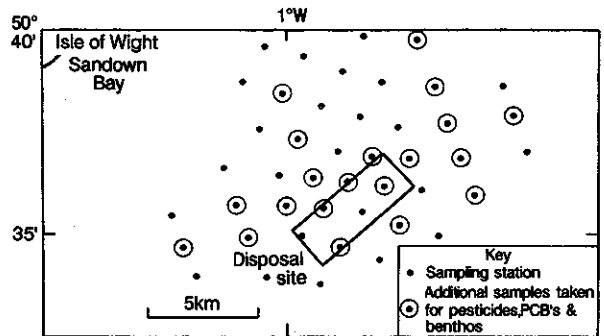


Figure 25. Southern Water survey of the Nab sewage-sludge disposal site, October 1991

- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) will be determined in the <math><63 \mu\text{m}</math> fraction of the sediment. Carbon and nitrogen will also be determined in these samples.
- (c) Faecal bacteria (*E. coli*, group D faecal streptococci and *Clostridium*) were enumerated in surface scrapes of the sediment.
- (d) Sediments from selected sites will be analysed for PCBs and pesticide residues (Figure 25).
- (e) Benthic infauna will be identified and enumerated in samples from these sites.

5.9 MAFF survey of the Exeter sewage-sludge disposal site, December 1991

- (a) A core sample was taken from the station shown in Figure 26.

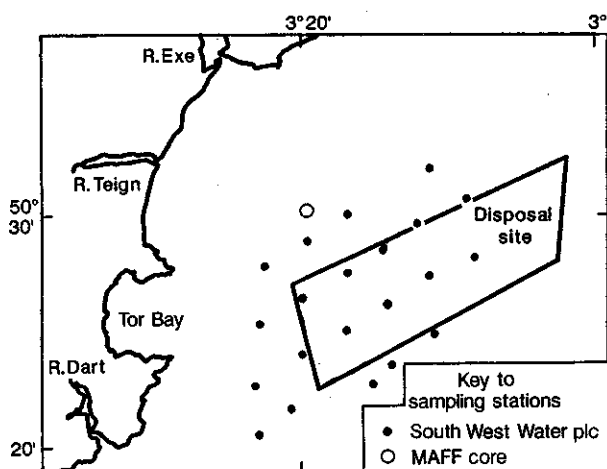


Figure 26. South West Water survey of the Exeter sewage-sludge disposal site, September/October 1991

- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn), carbon and nitrogen will be determined in four sections of the core: 0-2 cm; 10-12 cm; 20-22 cm; and 28-30 cm.

5.10 South West Water survey of the Exeter sewage-sludge disposal site, September/October 1991

- (a) Two sediment samples were taken, using a Day grab, from each of the stations shown in Figure 26.

- (b) *E. coli* and faecal streptococci were enumerated in surface scrapes of the sediment.
- (c) Metals (Cd, Hg, Pb and Zn), carbon and nitrogen were determined in the <math><63 \mu\text{m}</math> fraction of the sediment.
- (d) Particle size distributions were determined on the second sediment samples.
- (e) Benthic infauna, retained on 5 mm and 1 mm sieves, were identified to species level and enumerated.

5.11 MAFF survey of the Liverpool Bay sewage-sludge disposal site, October 1991

- (a) Sediment samples were collected from the stations shown in Figure 27.

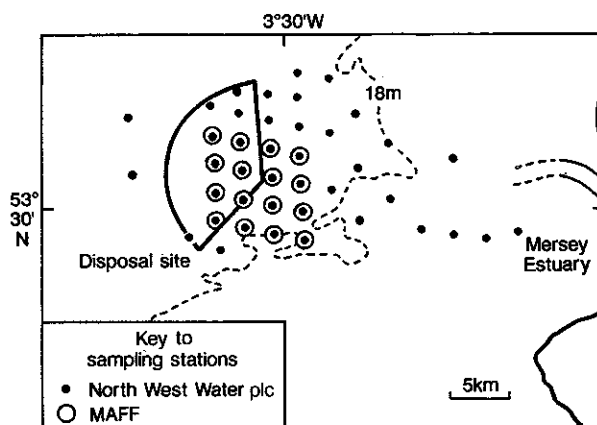


Figure 27. MAFF/North West Water surveys of the Liverpool Bay sewage-sludge disposal site, October 1991

- (b) Metals (Cd, Cr, Cu, Hg, Pb, Ni and Zn) will be determined in the <math><90 \mu\text{m}</math> fraction of the surface 0-1 cm of the sediment. Organic carbon and nitrogen will be determined in the remainder of the sample.

- (c) Sediments from selected sites will be analysed for benthic infauna (Figure 28).

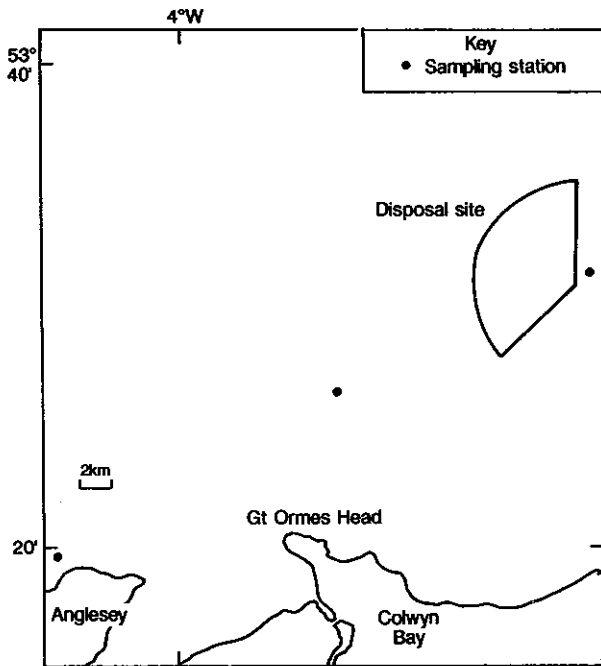


Figure 28. MAFF Benthic sampling stations in Liverpool Bay in 1991

5.12 North West Water survey of the Liverpool Bay sewage-sludge disposal site, October 1991

- (a) Sediment samples were collected from the stations shown in Figure 27.
- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) will be determined in the <90 µm fraction of the sediment.

- (c) Benthic infauna will be identified and enumerated in samples from the stations shown in Figure 27.

5.13 Scottish Marine Biological Association/Strathclyde Regional Council survey of the Garroch Head sewage-sludge disposal site, May 1991

- (a) Sediment samples were collected at the stations shown in Figure 29.
- (b) Metals (As, Cd, Cu, Cr, Hg, Ni, Pb, and Zn) will be determined in whole samples of the surface 0-1 cm of the sample.
- (c) Organochlorine compounds (dieldrin, γHCH, opDDD, ppDDD and PCBs) will also be determined in these samples.
- (d) Eh and pH measurements were made on the sediment samples.
- (e) Temperature, salinity and oxygen content were determined in the water immediately above the sediment sample.
- (f) Trawl samples were collected at the sites indicated in Figure 29. Benthic infauna and epifauna will be identified and enumerated in these samples.
- (g) Histopathological and microbiological investigations will be carried out on fish samples collected in the trawls.

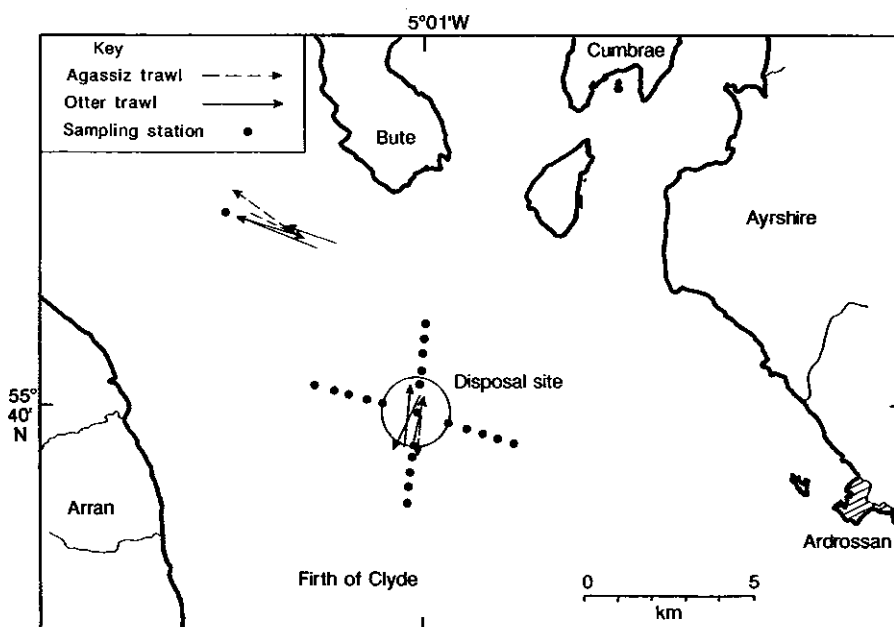


Figure 29. Scottish Marine Biological Association/Strathclyde Regional Council survey of the Garroch Head sewage-sludge disposal site, May 1991

5.14 Scottish Office Agriculture and Fisheries Department (SOAFD) surveys of the Bell Rock and St Abbs Head sewage-sludge disposal sites in 1991

- (a) Samples, composed of 4,615 common dab, (*Limanda limanda*), were examined for disease by standardised ICES methods (ICES, 1989) and a full data set for the recommended fish length groups were achieved for both the St Abbs Head and Bell Rock disposal sites and their adjacent reference areas. All cod caught (146) were examined for pseudobranch lesions and samples were taken for tissue nematode analyses. Haddock >26 cm (262) from each haul were examined for vertebral deformities.
- (b) Fish samples were also taken at monthly intervals, as part of a DOE-funded project, to assess the short-term spatial, biological and temporal variation in fish diseases.

- (c) At the St Abbs Head sewage-sludge disposal site, 91 sediment samples were collected from the stations shown in Figure 30, comprising 13 for organohalogen analysis, 29 for heavy metal analysis, 20 for particle size analysis, and 29 for faecal coliforms, faecal streptococci and *Clostridium perfringens* spore determinations. At the St Abbs Head reference site, four sediment samples were collected for the same analyses and determinations.
- (d) At the Bell Rock sewage-sludge disposal site, 71 sediment samples were collected from the stations shown in Figure 30, comprising 13 for organohalogen analysis, 29 for heavy metal analysis, and 29 for faecal coliforms, faecal streptococci and *Clostridium perfringens* spore determinations. At the Bell Rock reference site, three sediment samples were collected for the same analyses and determinations.
- (e) Fifteen cod samples (muscle and liver) were collected from the St Abbs Head disposal site for trace organic analysis.

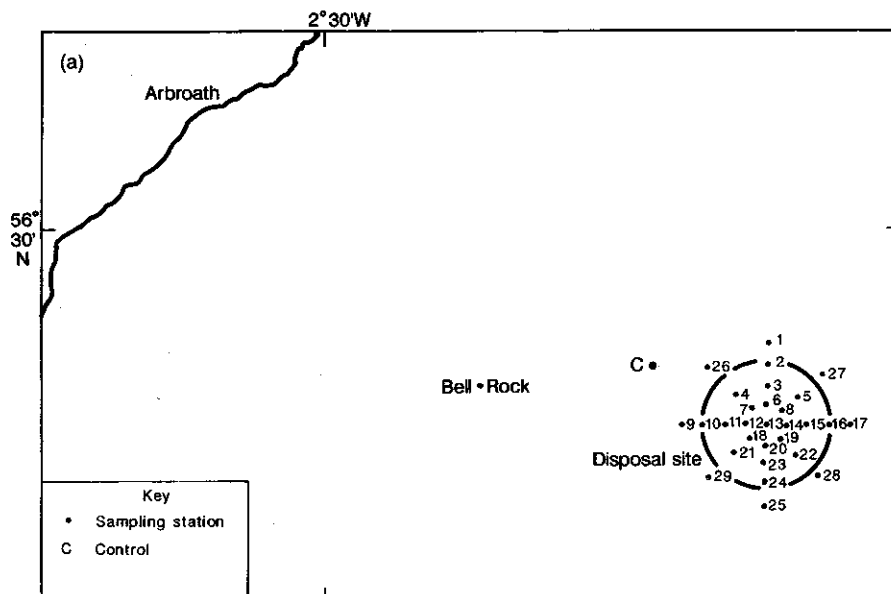


Figure 30(a). Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1991

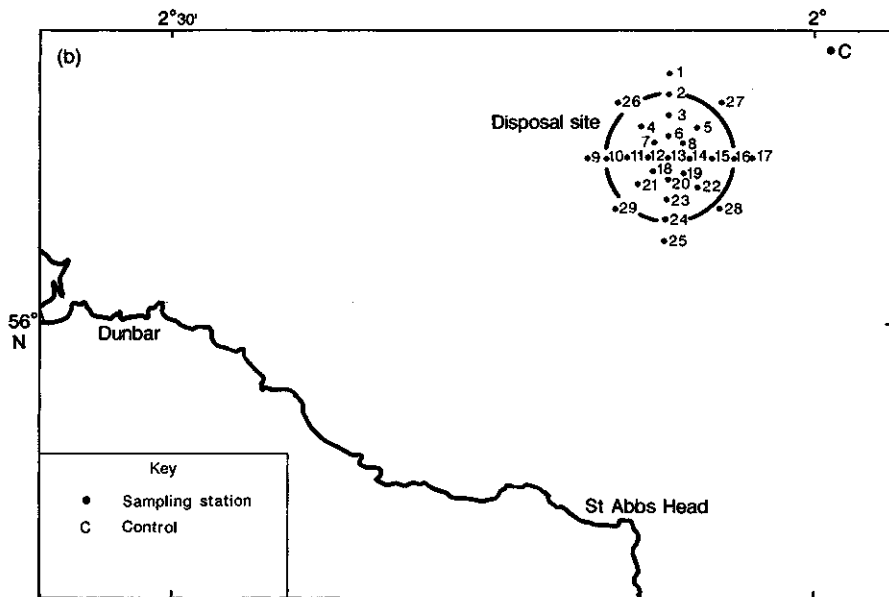


Figure 30(b). Forth River Purification Board/Lothian Regional Council survey of the St Abbs Head sewage-sludge disposal site, June 1991

5.15 Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1991

- (a) Sediment samples were collected from the stations shown in Figure 30.
- (b) Particle size analysis, metals (As, Cd, Cr, Cu, Fe, Hg, Pb, Zn and Ni), carbon and nitrogen were determined in these samples.
- (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, 17, 23, 25, 27 and 29 were analysed for organochlorines (HCB, aldrin, α HCH, γ HCH, dieldrin, ppDDT, ppTDE, ppDDE and PCBs).
- (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.

5.16 Scottish Office Agriculture and Fisheries Department (SOAFD) survey of the Garroch Head sewage-sludge disposal site in 1991

- (a) Samples of *Buccinum* were collected at monthly intervals for the assessment of parasitic infection.
- (b) Samples of sediment were collected in the vicinity of the sewage-sludge disposal area for analysis of organic contaminants and identification of concentration gradients.
- (c) Samples of fish were collected in the vicinity of the sewage-sludge disposal area for investigation of the spatial distribution, and temporal trends, in organic contaminants.
- (d) Samples of water were collected to measure the movement and dispersion of organic contaminants associated with sludge particulate material.

5.17 Forth River Purification Board/Lothian Regional Council survey of the St. Abbs Head sewage-sludge disposal site, June 1991

- (a) Sediment samples were collected from the stations shown in Figure 30.
- (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, α HCH, γ HCH, dieldrin, ppDDT, ppTDE, ppDDE and PCBs).
- (e) Otter trawl samples were taken at stations C and 13 for the assessment of fish diseases.

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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 <i>Basic amenity use</i>	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 sea bed with plastics and other persistent materials, and fouling of fishing equipment
A1.2 <i>Commercial harvesting of fish and shellfish for public consumption</i>	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 <i>Protection of commercial species</i>	Preservation of the general well-being of commercially-exploited species	Probably little different in practice from use (Sub-section A1.4)
A1.4 <i>General ecosystem conservation</i>	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 <i>Preservation of the natural environment</i>	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 <i>(Use — Sub-section A1.1)</i>	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 <i>(Use — Sub -section A1.3)</i>	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 occurrence compared with normal limits in control populations
A2.4 Ecosystem - maintenance <i>(Use— Sub-section A1.4)</i>	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 <i>(Use — Sub-section A1.5)</i>	Sediment quality	Minimal percentage change over background levels of metals and other contaminants. No continuing upward trends after 'steady state' is achieved
<i>Outwith the zone of immediate effect</i>	Water quality	Must be within any EQS set by relevant legislation
	Benthic fauna	No deviation from control sites

ANNEX 2. MEMBERSHIP OF THE CGMSD (GCSDM) IN 1991

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* Appointed late in 1991

ANNEX 3. TASK TEAMS AND THEIR MEMBERSHIP IN 1990

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Department of Economic Development (NI)

Dr D Harper
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Dr P Head
North West Water plc

Mr J Webster
Lothian Regional Council

Benthos

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