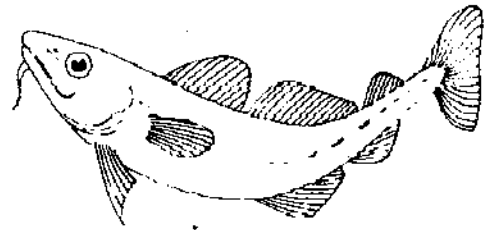


AQUATIC ENVIRONMENT MONITORING REPORT

Number 43



**Marine Pollution Monitoring
Management Group**

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



Directorate of Fisheries Research
Lowestoft, 1994

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

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Sea Disposal Monitoring**

LOWESTOFT
1994

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FOREWORD

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

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

In order to create consistent, co-ordinated monitoring, the Group laid down a set of Environmental Quality Objectives (EQOs) and then went on to develop Environmental Quality Standards (EQSs) by which fulfilment of the objectives could be judged. Numerical values have gradually been assigned to these Standards and this report includes details of those proposed for Organic contaminants in sediments.

In 1991, the Group's remit was extended to cover other Sea Disposal operations, particularly dredged material disposal. Section 3 includes details of the monitoring strategies proposed by the various GCSDM Task Teams for dredged material disposal sites.

In 1992, the group was asked by the Department of the Environment to produce guidelines on the Comprehensive Studies required for 'Less Sensitive Areas' identified under the Urban Waste Water Treatment Directive (DIR 91/927/EEC). The Group established a specialist Task Team to carry out this work and a summary of their final report is also included in Section 3.

The Group has now successfully achieved most of its original aims in the area of sewage-sludge monitoring, and the activities of the original Specialist Task Teams are drawing to a close. The disposal of sewage sludge to sea is due to be phased out by the end of 1998 and will be accompanied by a reduction in periodicity and scale of site monitoring. This will therefore be the last GCSDM report in the present format. The changing priorities of the Group have created the need for new Task Teams and areas of work and it is proposed that the next progress report will cover activities undertaken in 1994 and 1995. It should be published in the first half of 1996.

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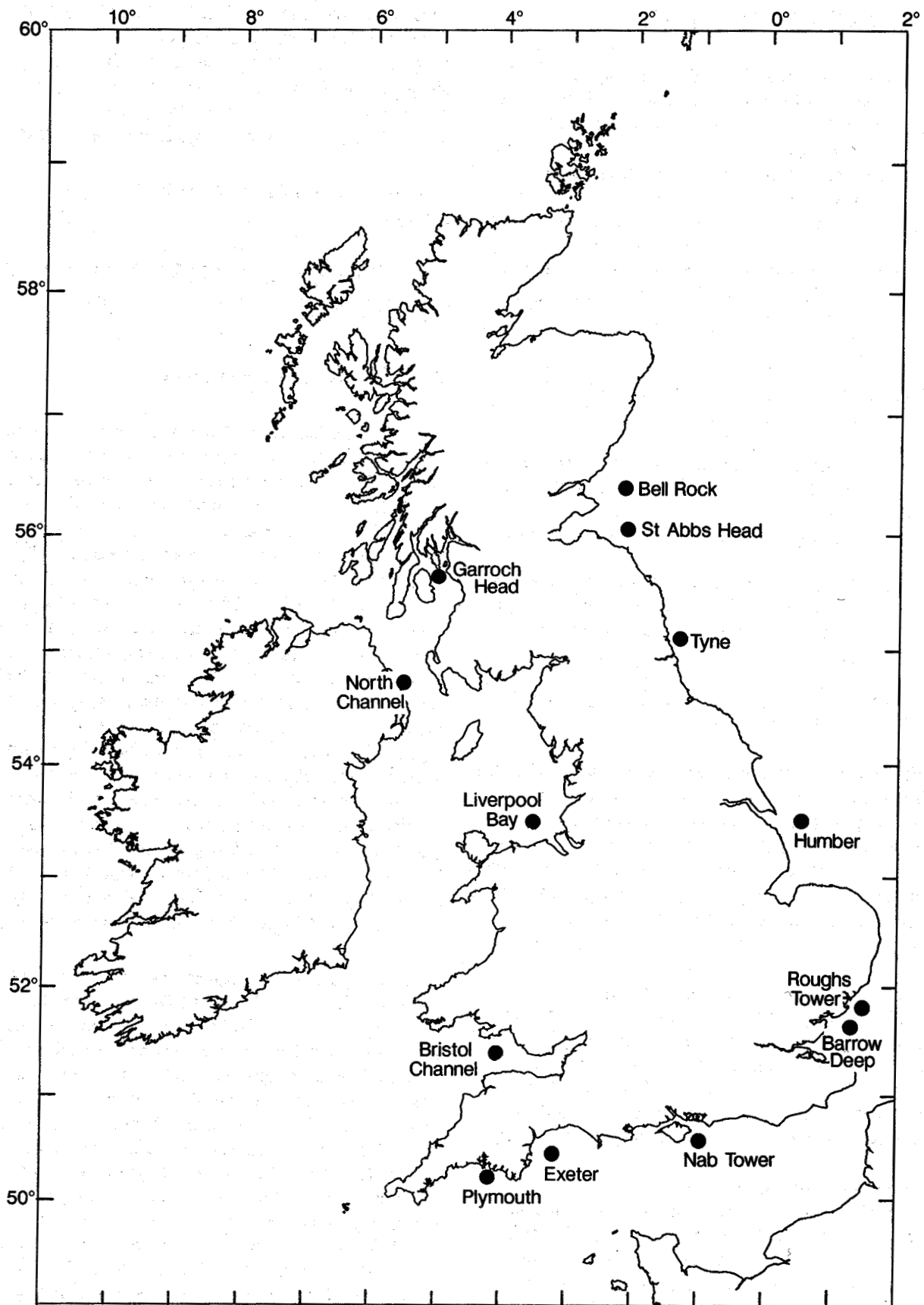


Figure 1. Locations of UK sewage-sludge disposal sites

1. INTRODUCTION

Following a review in 1985 of monitoring at the various sewage-sludge disposal sites around the UK (Figure 1), the Marine Pollution Monitoring Management Group (MPMMG) concluded that proper goals for the monitoring needed to be specified and that standards were required against which it would be possible to assess whether or not detectable effects occurred and whether they were acceptable. In order to achieve this task and to co-ordinate monitoring as far as practicable, it was agreed that a Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites (CGMSD) should be established.

From its terms of reference (MAFF, 1989) the Group set itself the following aims:

- (i) to define environmental quality objectives (EQOs) to be met at sewage-sludge disposal sites and to develop standards by which the meeting of those objectives could be verified;
- (ii) to develop detailed guidelines for monitoring using microbiological determinands, biological effects techniques, sediments, biota and water; and
- (iii) to produce a report on monitoring conducted in 1987 and 1988.

With the aid of specialist Task Teams established by the Group, most of these aims were successfully accomplished over the next four years. A set of common environmental quality objectives were laid down and environmental quality standards were defined to which numerical values have gradually been assigned (Annex 1). Detailed guidelines were also laid down on the methods to be used in monitoring compliance with these standards.

In 1989, the Group produced its first report (MAFF, 1989) detailing its activities and outlining the current monitoring work carried out at sewage-sludge disposal sites. Reports have since been produced on an annual basis (MAFF, 1991(a), 1991(b), 1992 and 1993(a)) and have included a review of monitoring work conducted at sewage-sludge disposal sites in the preceding year.

The Group's success in the area of sewage sludge disposal, and its numerous similarities with dredged material disposal led to an extension of the Group's remit in 1992, to cover dredged material and other disposal operations. The Group was duly renamed the Group Co-ordinating Sea Disposal Monitoring (GCSDM).

Environmental quality objectives and environmental quality standards for dredged material sites were proposed, based on those defined for sewage-sludge disposal (Annex 1).

This is the sixth report produced by the GCSDM and follows the format of previous reports. It details the progress made in 1993 in the areas of both sewage sludge and dredged material disposal. It reviews the monitoring work carried out at sewage-sludge disposal sites in 1992 and outlines surveys carried out in 1993.

A list of members of the GCSDM in 1993 is given in Annex 2.

2. TASKS UNDERTAKEN BY THE GCSDM IN 1993

2.1 Mode of operation

From the start, the GCSDM was intended to be a group which advises MPMMG on particular monitoring requirements and demonstrates through its reports the extent to which its advice is implemented, both by the licensees and by the regulatory agencies (for England and Wales, Ministry of Agriculture, Fisheries and Food (MAFF); for Scotland, Scottish Office Agriculture and Fisheries Department (SOAFD); and for Northern Ireland, Department of the Environment (Northern Ireland) (DoE(NI)). That being so, the main group has a restricted membership and meets only two or three times a year. Much of the detailed work is therefore undertaken by specialist Task Teams. This allows input by a wide range of organisations with relevant expertise, including several not directly associated with monitoring of disposal sites. By this means every effort is taken to ensure the work undertaken is kept outward looking. The following Task Teams were active during 1993: a Metals Task Team (Sub-Section 3.1); an Organics Task Team (Sub-Section 3.2); a Biology Task Team (Sub-Section 3.3); and a Sediment Bioassay Task Team (Sub-Section 3.4).

In 1992 in response to a request from the Department of the Environment (DoE), the GCSDM was asked to produce guidelines on the Comprehensive Studies that should be undertaken, in order to demonstrate that an area qualified to be regarded as a 'less sensitive' area under the terms of the Urban Waste Water Treatment Directive 91/271/EEC (European Communities, 1991). The GCSDM duly established a special Comprehensive Studies Task Team (Sub-Section 3.5) in June 1992 to undertake this task; the final report (a summary of which is given in Sub-Section 3.5) was submitted to DoE in August 1993 and after minor amendments was published in February 1994 (FRPB, 1994). The recommendations in the report have since been adopted by DoE and are being followed up by the Water Industry.

In the course of 1993, the GCSDM met on two occasions to review the progress of the Task Teams, finalise its fifth report and to further discussions on assessing the impacts of dredged material disposal sites.

2.2 Analytical Quality Control

During 1992 and 1993, a number of the Task Teams incurred poor support with their analytical intercomparison exercises. This was due in large part to both lack of funds and pressure of time for otherwise willing participants. In view of this the GCSDM proposed that all future analytical quality control (AQC) work should be carried out under the MPMMG's National Marine Analytical Quality Control Scheme (NMAQC), created to support the National Monitoring Plan. Since a number of organisations were already subscribing to this scheme it would also reduce any unnecessary duplication of AQC work. The proposal was accepted by the MPMMG and an alteration to the Metal AQC programme was effected to include the intercomparison of hydrofluoric acid (HF) digestion, which is of particular relevance to GCSDM work.

Biological and biologically related determinands were not covered by the scheme but it was agreed by the MPMMG that the GCSDM and subsequently through them, the Biology Task Team should progress this matter. The team subsequently established a National Biological Co-ordinating Committee which will report directly to the MPMMG.

From 1994, all future GCSDM AQC programmes will be carried out under the NMAQC Scheme.

3. PROGRESS BY THE TASK TEAMS

A list of the various Task Teams (and their membership) operating in 1993 is given in Annex 3.

3.1 The Metals Task Team

The final stages of the intercomparison exercise to test all aspects of sediment treatment in the laboratory prior to chemical analysis, were completed in 1993 and discussions continued on monitoring techniques at dredged material disposal sites.

3.1.1 Intercomparison exercise

The final report on this exercise was not completed as anticipated, by the end of 1993; it is now expected in 1994.

Due to anticipated difficulties with the provision of funds for further intercalibration exercises, the Task Team agreed to the proposal by the GCSDM that future intercomparison work should be carried out under the National Marine AQC Scheme.

3.1.2 Monitoring at dredged material disposal sites

The monitoring of reference sites, against which the impacts at dredged material disposal sites can be assessed, is seen as an important factor by the Task Team. Suitable reference sites will be sought based on the following criteria: the reference site should be as similar as possible to the disposal site; it should be near to the disposal site but no nearer to the source of the dredgings than the disposal site.

The level of monitoring required at each site will vary depending on the nature of the particular operation. A simple cut off value based on the amount of material deposited was considered to be inappropriate. A more complex cut off has been proposed taking into account the results of the pre-disposal assessment carried out as part of the licensing process (this may include physical and chemical determinands and tests of biological responses (biotest)); monitoring will automatically be required for any site receiving more than 15 000 tonnes of waste per annum. A site receiving less than 15 000 tonnes of waste per annum but which has a positive biotest response for the waste will also require monitoring (both biotest and chemical). A site receiving less than 15 000 tonnes of waste per annum with no positive biotest response for the waste will not require monitoring.

A standard list of metals for routine determination in all surveys was agreed by the Task Team and includes cadmium, copper, chromium, nickel, lead and zinc. In order to quantify anthropogenic components of metals it will be necessary, depending on site-specific characteristics, to determine one or more normalisers such as aluminium, lithium and scandium. Grain size and mineralogical content can affect the natural metal content of a sediment and can confound attempts to compare concentrations of metals throughout a given area. This is due to the fact that clay minerals have a relatively high natural metal content compared to sand and also a greater active surface area which adsorbs metals. The use of a non-contaminant element associated with clay minerals such as aluminium, lithium or scandium, can account for the grain size and mineralogical variations thus allowing comparison between sediments (ICES, 1989(a)).

The use of water column studies as a monitoring tool was considered by the Task Team. Experimental data have shown that significant quantities of mercury are released to the water column immediately after the disposal of dredged material at Site 'Z' in Liverpool Bay; but that it is re-adsorbed within 10-100 seconds depending on environmental conditions. Such short term release to the water column is only likely to affect a very small quantity of plankton and the practicalities of monitoring such effects at disposal sites is question-

able and none are proposed. Laboratory testing of wastes under controlled conditions will be considered as an alternative option by the Task Team.

3.2 The Organics Task Team

The Organics Task Team completed the fourth round analytical intercomparison exercises to assess the accuracy of organic contaminant analyses, and also proposed environmental quality standards for sediments.

3.2.1 Intercomparison exercises

After a poor response to the initial deadlines for returns, 18 out of 21 laboratories did eventually submit results. The exercise involved the analysis of 4 samples including 2 standards. The results obtained were variable and a number of problems were noted, the main being inadequate calibration and clean-up procedures.

The variability of the results in this exercise indicated a clear need for further exercises to be carried out to achieve adequate quality control, however, for a number of reasons the Task Team agreed that future exercises should be carried out under the UK National Marine AQC Scheme. To ensure participation in the scheme it was proposed that the required AQC be included as part of the conditions of marine disposal licenses: a formal recommendation to this effect by the GCSMD has been accepted by MAFF and will be implemented as soon as the exact requirements of the NMAQC are known. SOAFD already have such a requirement and GCSMD was disappointed to learn via its Task Team that MAFF have yet to implement this recommendation.

Problems associated with the variance of sampling have also brought into question the validity of analytical data. The Task Team have affirmed the importance of multiple sampling at each site if statistically valid data are to be produced and have recommended further research to determine the effects/extent of sampling variance.

3.2.2 Sediment quality criteria

The Equilibrium Partitioning Approach involves the setting of a quality standard for a contaminant in a sediment at a concentration which, in equilibrium with the surrounding water, does not lead to a breach of the relevant water quality criterion for that contaminant.

Numerical standards for chemical contaminants are derived from the following equation, which requires only three fundamental pieces of information.

$$C_{s/cr}^x = K_{oc} \times C_{w/cr}^x \times TOC$$

Where;

$C_{s/cr}^x$ is the sediment standard,

K_{oc} is the partition coefficient normalised to organic carbon; obtainable in the laboratory for non-ionic organics, from measurements of octanol/water partitioning,

$C_{w/cr}^x$ is the relevant water quality criterion,

TOC is the fractional organic carbon content of the sediment (i.e. 10% carbon in the sediment has $TOC = 0.1$).

Using available information, the Task Team have derived 'Sediment Action Limits' (levels which, if exceeded, indicate that studies should be initiated to investigate the availability of the contaminant to organisms). US chronic water quality criteria were applied, where available, as they had been thoroughly tested in the US. Some of the UK quality standards were deemed to be overly stringent and therefore less realistic, however, UK water quality standards were applied for those substances for which no US values were available. Limits were not derived for chlorinated solvents in view of the fact that such volatiles are likely to disappear during treatment prior to the disposal of sludge and are therefore unlikely to pose a threat to marine sediment quality (see MAFF, 1994).

'Sediment Action Limits' are given for a number of Red List and other priority hazardous substances (Tables 1 to 3). The list is, as yet, incomplete as only incomplete or conflicting data are available for some substances, these will require further investigations. The 'Sediment Action Levels' are presented in units of μg (g-organic carbon)⁻¹. Using the value derived for lindane ($0.04 \mu\text{g}$ (g-organic carbon)⁻¹) as an example, the 'Action Limit' for a sediment containing 10% organic carbon would be $4 \mu\text{g}$ lindane per kg of sediment (on a dry weight basis). A lower percentage of organic carbon i.e. 5% would result in the 'Action Limit' being reduced to $2 \mu\text{g}$ lindane per kg of sediment.

Whilst this approach appears to give realistic standards it is only a model and field studies are now required to assess its validity.

3.3 The Biology Task Team

During 1993, the main task was the production of a report on the monitoring and assessment of biological consequences of dredged material disposal: the final document is expected to be published during 1994.

Table 1. Provisional sediment safe levels for red listed and other priority hazardous organic substances

Substance	Water quality criterion ($\mu\text{g l}^{-1}$)	$\log K_{ow}$	K_{oc}	Sediment safe level ($\mu\text{g g-oc}^{-1}$)
Lindane	0.02*		1950	0.04
ppDDT	0.001		160000	0.16
ppDDE	0.01*	5.69	29673 ^(b)	0.297
HCBD	0.10*		2000	0.20
HCB	0.03*		37150	1.11
Aldrin	0.01*	5.0 ^(a)	12500 ^(b)	0.125
Endrin	0.0023	4.56	7205 ^(b)	0.0166
Total PCP as Arochlor	0.014		314000 ^(c)	4.40
Total PCB as ICES 7				2.312 ^(d)
PCB-28				0.279
PCB-31				0.192
PCB-52				0.300
PCB-101				0.285
PCB-118				0.334
PCB-153				0.474
PCB-105				0.117
PCB-138				0.292
PCB-156				0.045
PCB-180				0.348
Trifluralin	0.10*		13800	1.38
Dichlorvos	0.04*	1.4	137.6 ^(b)	0.0055
Atrazine and Simazine	2.0*		162 ^(e)	0.324
Azinphos methyl	0.01*	1.87	248 ^(b)	0.00248
Malathion	0.10		1778	0.178
Fluoranthene	8		45000	360

Table 2. Provisional sediment safe levels for red listed and other priority hazardous organic substances requiring review

Substance	Water quality criterion ($\mu\text{g l}^{-1}$)	$\log K_{ow}$	K_{oc}	Sediment safe level ($\mu\text{g g-oc}^{-1}$)
Dieldrin	0.002	5.48	22810 ^(b)	0.046
		4.56	7205 ^(b)	0.014
TCB (Total)	0.4*	3.8	2298 ^(f)	0.92
1, 3, 5-TCB	"	4.46	8275 ^(f)	3.31
1, 2, 4-TCB	"	4.23	5295 ^(f)	2.12
Pentachlorophenol (PCP)	7.9		24000	189.6
"	2.0*		24000	48
Tributyltin (TBT)	0.002*	3.2	717 ^(f)	0.0014
		3.84	2484 ^(f)	0.005
Triphenyltin (TPT)	0.008*	3.2	717 ^(f)	0.0057
		3.84	2484 ^(f)	0.0199

Table 3. Red listed and other priority candidate hazardous organic substances for which only partial data are available

Substance	Water quality criterion ($\mu\text{g l}^{-1}$)	$\log K_{ow}$	K_{oc}	Sediment safe level ($\mu\text{g g-oc}^{-1}$)
Isodrin	0.005*			
Endosulfan	0.0087			
Fenitrothion	0.01*			
Fenthion				
Azinphos ethyl				
Parathion			7762	
Parathion methyl			9772	
Heptachlor		5.44		
Heptachlor epoxide		5.40		
Anthracene			7400	
Benzo-a-anthracene			37000	
Benzo-b-fluoranthene			300000	
Benzo-k-fluoranthene			840000	
Benzo-g-perylene			1800000	
Benzo-a-pyrene			300000	
Chrysene			77000	
Phenanthrene			9300	

Notes (Tables 1-3):

* UK Water Quality Value used (US chronic value not available)

^(a) $\log K_{ow}$ value unrealistic, hexane:water coefficient used in preference

^(b) K_{oc} calculated from equation; $\log K_{oc} = 0.544 \log K_{ow} + 1.377$

^(c) Mean K_{oc} value for mixture of Arochlors 1242, 1254 and 1260 has been used these being the most common mixtures encountered in UK waters

^(d) Sum total for 7 ICES congeners (28, 52, 101, 118, 138, 153, 180). Values for individual congeners are calculated on a percentage basis in terms of their maximum concentration in any Arochlor mixture

^(e) Mean K_{oc} value for Atrazine + Simazine

^(f) K_{oc} calculated from equation; $\log K_{oc} = 0.843 \log K_{ow} + 0.158$

3.3.1 Infaunal Trophic Index

The Task Team were asked to consider whether wider application of the UK Infaunal Trophic Index (ITI-UK) (see MAFF, 1993(a)), could be recommended for assessing the biological effects of sewage sludge disposal and effluent discharges and for classifying the biological health of sediments as part of the National Rivers Authority (NRA) five year estuarine and coastal water quality survey.

Applications of the Index at some sewage-sludge disposal sites had already been undertaken with promising results, although further validation and development of the Index was still required. The Task Team recommended more general trial application of the Index in sewage-sludge disposal site monitoring, although not in isolation, but as a complement to other techniques. Use of the Index in an estuarine situation had proved unsatisfactory and restructuring of the Index will be necessary before its use in estuaries and intertidal areas can be considered.

Application of the ITI-UK around discharge points in the Firth of Forth had adequately described outfall effects, where present. However, the boundaries originally set for distinguishing the status of the benthos in relation to Californian sewage-sludge discharges on the basis of ITI values, did not appear to be realistic when applied to the Forth. Further work will therefore be required to establish locally suitable boundaries. For this reason the Index was not yet considered suitable for wider classification purposes. Further testing of the performance of the Index on individual discharges against the outcome of multivariate analysis of the same benthic data was strongly recommended.

3.3.2 Macrobenthos identification intercomparison exercise

This exercise was carried out in the Autumn of 1991 but the results only fully became available and assessed in late 1993. The exercise was the second carried out under the auspices of the Biology Task Team.

The main aims were as follows:-

- to compare methodology
- to assess the range and variability of staff time taken for each stage of the analysis
- to assess the range and variability in faunal determinands
- to provide information on the cost effectiveness of obtaining data at different levels of taxonomic resolution
- to compare the taxonomic literature used.

Replicate samples were provided to each of 19 participating laboratories. The sample material was collected

from a site 8 km east-northeast of the River Tyne in a silty sand area and secured using a 1 mm mesh. The sieve residues were fixed and preserved in buffered formo-saline solution but with no stain added. The laboratories were asked to use their usual methods but record all methodological information and to list taxa according to a standard species list. They were asked to list the taxonomic keys used, to record the processing time taken for each stage of the analysis and to record the level of expertise employed on the sample. They were to record the data at different taxonomic levels, at family level and at species level (or as near as practicable). They were to retain and return the sieve residue and the specimens. Above all, the confidentiality of the participating laboratories was to be respected.

The results of the exercise showed that identification to family level rather than achieving the best practicable separation of taxa represented a time saving of about 50%. The GCSDM accordingly recommends that wherever identification to family level can be used appropriately (i.e. where it can be shown not to significantly reduce the sensitivity of the data) it should be adopted in view of the time savings involved.

The exercise again highlighted many of the problems earlier identified by the GCSDM Biology Task Team, in particular the following:

- (i) There is a need for some form of system for communicating up-to-date taxonomic literature to laboratories involved in marine benthic monitoring.
- (ii) There is a need for a standard taxonomic list and a satisfactory coding system (which should be hierarchical). These should be readily available and there should be a system for updating both to accommodate taxonomic changes and addition of new records to the code.
- (iii) There is a need for training and maintenance of adequate taxonomic expertise in marine benthic biology. On the basis of the above results, adoption of a lower level of separation, e.g. to family level only, does not greatly improve inter-laboratory consistency. The Estuarine and Coastal Sciences Association (ECSA) workshops, Polychaete Colloquium and similar events should be encouraged. The introduction of the 'IDQ' qualification system may improve matters.
- (iv) Despite the fact that the Task Team had previously recommended biomass measurement as a standard technique many laboratories do not appear to undertake this routinely.
- (v) The need for intra-laboratory and inter-laboratory AQC procedures is clear. The inter-laboratory component will be addressed by the forthcoming National Marine AQC programme

of MPMMG. Within laboratories, it is worth noting again that water industry chemical laboratories are typically expected to spend 20% of their analytical effort on quality control. Biologists need to take this issue on board.

The last finding has been acted upon and a National Marine Benthos AQC programme has been established and is expected to be fully operational in the course of 1994 with over 25 contributors.

3.3.3 Monitoring and assessment of benthos at dredged material sites

The Task Team undertook an evaluation of the effects on the marine benthos of dredged material to UK waters with a view to assessing appropriate monitoring strategies for assessing compliance with Environmental Quality Objectives.

The review is to be published separately as a stand-alone document but the main conclusions are as follows:

- (i) Although published studies dealing with the effects on the benthos of dredgings disposal to sea are limited, especially in European waters, certain generalisations may be made regarding the nature of effects to be anticipated in response to different disposal regimes. These may be used to aid the formulation of site-specific 'impact hypotheses' for the effects of dredgings disposal, as advocated by the Oslo Commission and endorsed by the Task Team.
- (ii) The composition of dredged sediment disposed of to sea, along with disposal site practices, vary greatly around the United Kingdom coastline. Since environmental conditions at licensed disposal sites frequently differ from one location to another, it is not surprising that no single 'blueprint' for the conduct of benthic surveys at all locations can be provided. However, guidelines originally developed for monitoring at sewage-sludge disposal sites should largely cover the sampling requirement.
- (iii) For dredged material disposal sites, special importance is attached to physico-chemical assessments of sediments in the receiving environment, and of transport pathways, in order to establish effective biological sampling programmes. Pilot surveys employing remote sensing techniques such as side-scan sonar or towed photographic sledges are also to be recommended.

- (iv) The frequency of sampling will be determined on a site-specific basis, but should rarely exceed once per year.
- (v) A framework for deriving 'Environmental Quality Standards' for the benthos at dredgings disposal sites is provided by that previously developed for sewage-sludge disposal sites, i.e. involving comparisons between 'Treatment' and 'Reference' stations. However, local considerations will be even more important in survey design and in defining limits for permissible change. For example, for the regular disposal of dredged material consisting largely of organically-enriched fine sediments, the boundaries for permissible variability in these measures will be as for sewage-sludge disposal sites. However, alternative boundaries will have to be defined for locations in receipt of other types of dredged material or (with greater difficulty) those to which multiple inputs are made.
- (vi) Topics identified for future attention included further studies into the biological effects of UK dredgings disposal (including 'far-field' effects), an up-dated review of the chemical quality and physical nature of dredged material disposed of to UK waters, the development of laboratory systems for examining dose/response relationships, wider application of remote imaging methods (especially 'Sediment Profile Imaging'), and a consideration of the use of alternating disposal sites for major arisings in order to mitigate effects. Attention is also drawn to the need for further development of sampling protocols and quality assurance procedures for assessment of compliance against agreed 'Environmental Quality Standards'.

3.4 The Sediment Bioassay Task Team

After some initial delay in establishing the Team in 1992, the Task Team met for the first time in February 1993 and provisional selection criteria for suitable bioassay techniques were agreed.

At the present time chemical analysis of dredged material does not include all contaminants likely to be present and is therefore unlikely to give a comprehensive assessment of the potential environmental hazard associated with sea disposal. Bioassay techniques can complement chemical analyses by providing an estimate of the relative biological availability of the contaminants present and identifying samples which require more detailed analysis. To be of maximum use, bioassay sampling should therefore be linked to existing sampling procedures for chemical analysis.

A large number of dredged material samples may be assessed for disposal in the course of a year and from the licensing authorities' point of view any monitoring method must therefore offer a combination of low cost and rapid turn around. An assay that produces a consistent response and a scale of response proportional to some measurable index of community impact, will enable pass/fail criteria to be set more easily.

At the present time, whole sediment bioassays are the most practical and reliable, they require fewer assumptions to be made and are likely to introduce fewest alterations in partitioning and specification during testing. The Task Team is therefore concentrating on defining a whole sediment exposure system capable of use with a variety of species and expects to be able to set limits of acceptability for the identifiable responses.

3.5 The Comprehensive Studies Task Team

During 1993, the Task Team produced a final report (FRPB, 1994) for DoE, recommending the comprehensive studies required for 'less sensitive areas' identified under the Urban Waste Water Treatment Directive (DIR 91/271/EEC).

To comply with the Directive any comprehensive studies recommended must show that no adverse effects would be caused by allowing primary rather than secondary treated sewage to be discharged to Less Sensitive Areas. Since the Directive itself does not define adverse effects the following standards were proposed in respect of dissolved oxygen, nitrogen and particulate organic matter.

- (i) Dissolved Oxygen – when existing levels are above 7.0 mg l⁻¹, levels should not be reduced by more than 1 mg l⁻¹ in estuaries or by more than 0.5 mg l⁻¹ in coastal waters. If concentrations are predicted to fall below 7.0 mg l⁻¹ more study is required and individual areas must be considered on their merits.
- (ii) Nitrogen – as a consequence of installing primary rather than secondary treatment the input of nitrogen should not result in an increase (predicted) of greater than 1 mg m⁻³ chlorophyll arising through phytoplankton growth. (The report includes a proposed methodology for converting nitrogen to chlorophyll concentrations).
- (iii) Particulate organic matter – the effects of particulate organic matter on the benthos must not cause undue variation in relevant community variables, when measured against a reference site.

Levels of acceptable change within the sphere of waste influence allow for an initial positive response of the benthos to organic enrichment, but should not exceed the following:

total abundance:	+ 200% of reference station value
total taxa:	+ 50% of reference station value
biomass:	+ 50% of reference station value

In the absence of pre-discharge monitoring data use can be made of the ITI-UK, predicted values of 60 would be acceptable.

The standards proposed must be regarded as guidelines, which will only be validated through experience. Although restrictive in nature they nevertheless permit sufficient margin for discharges at sites conforming with the requirements of the Directive which by definition must be less sensitive and of high naturally dispersive characteristics.

By way of the nature of the discharges concerned and the scope of factors involved, the studies proposed to show compliance with these standards, are in the first instance predictive. Many of the discharges concerned are at present untreated and any effects are likely to disappear with primary treatment, nevertheless this will need to be proven.

The studies recommended comprise a conceptual framework of field work to establish appropriate data support i.e. effluent loading, initial dilution and water movement; one or more predictive models, and post-discharge monitoring of predicted effects.

The Report recognised that in many cases there would be existing data and predictive models. Where such material is available it can be utilised in derivation of the information necessary to allow comparison with the guideline standards proposed.

In the absence of existing data or models the Report gives guidance on minimum field work and modelling requirements. In estuaries a modern 1-dimensional PC based model would be adequate. In coastal waters simple models, plume models for example, would be adequate for small discharge whilst requirements for larger discharges could be met by a continuity based model such as 'Flowsum' or by conventional 2-dimensional models using simplifying assumptions to reduce effort.

In respect of the deposition of organic solids and the effects of this, attempts at sophisticated modelling were not recommended. The guidelines proposed were based upon empirical relationships between mass emission rates of suspended solids and changes in the fauna. The predictions from this were thought to be overly pessimistic and the importance of monitoring test and reference sites to establish the criteria specific in the guideline standards was emphasised.

The Report emphasised the importance of monitoring dissolved oxygen, nutrient concentrations, phytoplankton growth and the condition of the benthic fauna. Guidelines on the frequency of monitoring and site selection were given, based upon routine programmes or targeted observations to test model predictions.

It is recognised that not all of the techniques proposed are fully validated and may be subject to development. The methodology used will need to be continuously reviewed.

Whilst the techniques are adequate to deal with larger discharges than those proposed in Article 6 of the Urban Waste Water Treatment Directive, great care will be necessary in any extension of their application. In particular, there is limited ability to predict effects on the benthic ecosystem and techniques require further development in this area if more certain predictions are to be achieved. The GCSDM has therefore endorsed a research proposal in this area. The work will produce a validated predictive model relating the emission and settlement of suspended solids (organic carbon) to changes in the sediment dwelling macrofauna communities.

4. REVIEW OF MONITORING AT SEWAGE-SLUDGE DISPOSAL SITES DURING 1992

4.1 Introduction

This section follows the format of earlier reports in this series and assesses whether the various monitoring programmes meet the goals described in the first report (MAFF, 1989). It considers examples of monitoring undertaken in 1992 although, where appropriate, reference is made to other work. Nearly all the surveys followed the GCSDM guidelines for analytical methodology (MAFF, 1989). In some cases, where consistency with earlier work was judged more important than comparability with other sites, long-established procedures were retained.

Table 4 lists the sewage-sludge disposal sites surveyed in 1992 (see Figure 1 for locations) and the techniques used. Further details of this work can be found in the

Table 4. Summary of techniques used in surveys at sewage-sludge disposal sites in 1992

Area/Authority	Sediment			Benthos epibenthos	Fish sampling	Litter assessment	Underwater video
	Metals	Pesticides/PCBs	Microbiology				
Tyne							
MAFF	+			+			
Northumbrian Water	+						+
Humber							
MAFF				+			
Yorkshire Water	+	+	+				
Barrow (Thames)							
MAFF	+			+		+	
Nab							
MAFF	+					+	
Southern Water	+	+	+				
Exeter							
MAFF	+					+	
Plymouth							
MAFF	+					+	
Liverpool Bay							
MAFF	+			+			
North West Water	+	+		+			
North Channel							
DoE (NI)	+		+	+			
Garroch Head							
SMBA/SRC	+	+	+	+	+		
SOAFD	+	+	+		+		
Bell Rock							
FRPB/LRC	+	+	+	+	+		
SOAFD					+		
St Abbs Head							
FRPB/LRC	+	+		+	+		
SOAFD					+		

fifth report of GCSDM (MAFF, 1993(a)). Some areas are surveyed only every second or third year and therefore no samples were taken in 1992. 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.

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

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

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

The outcome of a MAFF survey of litter at several disposal sites is shown in Table 5 (see also MAFF, 1994). This work was conducted in 1992 and the early part of 1993, by means of 5-10 minute tows using a 2 m beam trawl or, in the case of coarser grounds in the Bristol Channel, off the Humber and at Nab Tower, Newhaven scallop dredges. The amount of litter present varied markedly between sites due to a combination of local hydrographic conditions, the quantities of sludge disposed of, and the level of treatment prior to disposal. It is also important to note that not all artefacts are sewage-derived; for example, fragments of china, brick and glass at the Liverpool Bay site reflect an earlier history of sea disposal of domestic refuse, notably from the clearance of bomb-damaged buildings after the Second World War.

While an enhanced variety of sewage-derived debris at the Thames and Liverpool Bay sites may be accounted for by the relatively large quantities of sludge disposed of (about 4 and 2 million wet tonnes respectively, in 1991), data for the Tyne site, where both the greatest quantity and variety were encountered, indicate that this is not the only factor. About half a million tonnes of sludge were disposed of in 1991 but, unlike the bulk of material going to the Thames and Liverpool Bay sites,

the sewage effluent from which it is derived has only been subjected to primary treatment. Concern over the quantities of litter recovered here led to the recent installation by Northumbrian Water of finer-mesh screens in order to retain much of this material before sea disposal of sludge. As yet, there is no evidence to suggest a resultant improvement, although some allowance may need to be made for the persistence of certain artefacts whose presence at the seabed pre-dated the fitting of new screens.

Small quantities of sewage-derived litter were found at the centre of both sewage-sludge disposal grounds off the Forth (Bell Rock and St Abbs Head) but none was recorded at nearby reference sites. As in previous years, these observations relate to catches from Otter trawls, and are therefore not directly comparable with the above MAFF data. It is likely that the deployment of fine-mesh beam trawls at the Forth grounds would reveal a wider array of artefacts.

At the Garroch Head disposal site, sampling in 1992 (also with an Otter trawl) revealed the presence of sewage-derived material at the disposal site. Sanitary towels were recorded as 'abundant', condom foil wrappers and other noticeable plastic debris as 'common', and pieces of rope as 'frequent'. The amounts recorded were greater than in 1991.

More detailed investigations of the distribution of litter at these disposal sites, using fine-mesh beam trawls, would be desirable, not least so that the scale of any problem may be identified, and its significance assessed with reference to conditions at other sewage-sludge disposal sites.

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

In its first report, the GCSDM pointed out that the appropriate authorities are the public health authorities and MAFF and SOAFD, and that there are advisory limits for contaminants in foodstuffs.

In 1992, 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 the UK and includes fish from the disposal site areas. Full details of this survey work are published periodically by Fisheries Departments. One area of continuing interest is that of Liverpool Bay, where relatively high concentrations of mercury in fish flesh have been recorded in the past. Sampling in 1992 demonstrated that the EQS for mercury (0.3 mg kg^{-1} wet wt) adopted by the European and Paris Commissions

Table 5. Total quantity of litter found in trawl/dredge samples at sewage-sludge disposal sites

Litter description	Disposal site							
	Tyne	Humber	Thames	Nab	Exeter	Plymouth	Bristol Channel	Liverpool Bay
Wood	P		P	P				P
Leaf Litter	P		P	P	P	P		P
Straw			P					
Grass	P							
Coal						P		
Clinker				P				P
China								5
Brick				1				
Glass				P				5
Shoe				1		1		1
Industrial Rubber Glove				1				
Ring Pull				1				
Monofilament Nylon (Fishing Line)		P	P					
Nylon Twine	1		P		P	P	1	2
Natural Fibre String					P			
Bone				2				1
Skull (Small Mammal)			1					
Cereal Seed			1					
Onion Peel			1					
Tomato Stalk	1							
Potato Peel	3		3					
Pea Skin	1							
Pea Pod	1							
Broad Bean	1							
Piece of Carrot	1							
Cabbage Leaf	1							
Fruit Pip/Stone	2		9					
Nut Shell			2					
Orange Peel	1							
Tea Bag	1							
Chewing Gum	1							
Fragment of Sanitary Towel	36		10	6	1	1	1	2
Fragment of Tampon	6						4	2
Hormone patch	1				1			
Human Hair	P	P						P
Condom Packet		1						
Cigarette Filter	32	12						
Matchstick	3							
Plastic Bags								1
Plastic Unwrap Strip	3							
Amorphous Plastic Fragments	3		4			1	1	1
Plastic Solid	1			4				
Plastic Tie-Wrap								1
Plaster	3							
Plaster Tear Strip	1							
Make-up Sponge								1
Button								1
Adhesive Tape								
Elastic Band	2							1
Silver Foil	1		1					
Milk Bottle Top				1				
Identified Sweet/Drinks Wrapper	1			1				
Piece of 'J' Cloth								1
Rag			1					1
Piece of Net Curtain	1							
Strand of Wool	1		1					
Tissue Paper						1		
Rubber 'O' Ring								1
Piece of Rubber				1				
Puncture Repair Kit Patch	1							

Note: P = Present (not quantified)

was again met and that, more generally, the levels of contaminants in commercially exploited fish or shellfish gave no cause for concern relative to human health (see MAFF, 1994).

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

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

Standard International Council for the Exploration of the Sea (ICES) disease sampling programmes were completed by SOAFD at the St Abbs Head and Bell Rock disposal sites, and at adjacent and distant reference sites. No consistent significant differences were found in the levels of lymphocystis, skin ulcers or hyperplasia/papilloma of common dab at any of the sites although, for lymphocystis, differences were found between the sexes. Only a small number of dab were found with liver lesions, and no significance could be assigned to these. Relatively few haddock were found with vertebral anomalies, but the greatest proportion of these were from the Bell Rock disposal site area. Only one cod was found with a pseudobranch 'tumour'. No *Ichthyophonus* was found in fish from the disposal site areas. (Note: a contract report for DoE on fish diseases in Scottish waters, including work at the St Abbs Head ground, has recently been produced by SOAFD: see Begg and McVicar, 1993).

As in 1991, the ranges of fish and invertebrate species recorded by the Forth River Purification Board (FRPB) in Otter trawls from both the Bell Rock (see Table 6) and St Abbs Head disposal sites were comparable with those at nearby reference sites, and did not provide any evidence of adverse biological effects.

The results of a survey by SOAFD for P450-1A1 (EROD activity) in fish samples showed that levels were elevated in the vicinity of the Garroch Head disposal site and in the Irvine Bay area. (The latter area receives significant discharges of sewage and industrial wastes). Also, *Nephrops* samples were analysed for heavy metals, metallothionein and ATPase. Heavy metals and metallothionein levels did not appear to be related to a pollution gradient, but were apparently influenced by the occurrence of a parasitic infection of *Nephrops* (*Hematodinium perezii*). ATPase activity was highest in *Nephrops* collected distant from the disposal site.

Table 6. Bell Rock Otter trawl data 1992

	Station 13	Control
Fish species		
Cod	1	5
Codling		6
Haddock	70	33
Whiting	242	405
Sandeel		1
Common Dragonet	22	32
Grey Gurnard	17	2
Pogge	47	36
Plaice	3	10
Witch		1
Common Dab	134	47
Long Rough Dab	32	
Lemon Sole	39	24
Norwegian Topknot	1	
Cuckoo Ray	13	
Thornback Ray		1
Dogfish	1	
Sea slug	1	
Invertebrate species		
Anthozoa		
<i>Alcyonium digitatum</i>	+	+
<i>Urticina felina</i>	+	+
<i>Adamsia palliata</i>	+	
Crustacea		
<i>Pagurus prideauxi</i>	+	+
<i>Cancer pagurus</i>	+	
Mollusca		
<i>Eledone cirrhosa</i>	+	+
<i>Loligo forbesii</i>		+
<i>Pecten maximus</i>	+	+
Bryozoa		
<i>Flustra foliacea</i>	+	+
Echinodermata		
<i>Asterias rubens</i>	+	+
<i>Astropecten irregularis</i>	+	+
<i>Crossaster papposus</i>	+	+
<i>Ophiura ophiura</i>	+	+
<i>Ophiothrix fragilis</i>		+
<i>Echinus esculentus</i>	+	+
Anthropogenic debris		
Sanitary Towel		
Tin can	6	
Sweet wrapper	1	
Sticking plaster	+	
Elastic waistband	+	

Note: + = present (not quantified)

The results from 10 minute Otter trawl tows conducted by SEAS Ltd at the Garroch Head disposal site and at a nearby reference site are shown in Table 7. Although not truly quantitative, the data suggest fewer large epifaunal and demersal fish are found at the centre of the disposal site; similar observations have been made in previous years. Fish were also examined for internal and external disease symptoms: there was no evidence of abnormally high incidences of either, or of significant differences between samples from the disposal site and the reference site. (It was similarly concluded that there was no evidence of any adverse biological effects associated with the occurrence in some fish at the disposal site of human enteric bacteria). Previous GCSDM reports have emphasised the importance of

Table 7. Details of Otter trawl hauls taken at Garroch Head, 1992

Haul No. and Area	Fish Species taken		Fish Lengths	Invertebrata taken	
Disposal Site (P7) Haul 1.	10 <i>Merlangius merlangus</i>	Whiting	177-221 mm	3	<i>Carcinus maenas</i> Common Shore Crab
	7 <i>Gadus morhua</i>	Cod	173-240 mm		
	9 <i>Pleuronectes platessa</i>	Plaice	147-180 mm		
	2 <i>Hippoglossoides platessoides</i>	Long Rough Dab	163-182 mm		
Disposal Site (P7) Haul 2.	3 <i>Merlangius merlangus</i>	Whiting	151-190 mm	4	<i>Liocarcinus depurator</i> Swimming Crab
	5 <i>Gadus morhua</i>	Cod	170-219 mm	1	<i>Echinus esculentus</i> Sea Urchin
	11 <i>Pleuronectes platessa</i>	Plaice	122-195 mm		
	2 <i>Hippoglossoides platessoides</i>	Long Rough Dab	138-161 mm		
Disposal Site (P7) Haul 3.	1 <i>Clupea harengus</i>	Herring	320 mm	1	<i>Liocarcinus depurator</i> Swimming Crab
	15 <i>Merlangius merlangus</i>	Whiting	150-222 mm		
	2 <i>Gadus morhua</i>	Cod	173-205 mm		
	4 <i>Pleuronectes platessa</i>	Plaice	129-180 mm		
	3 <i>Hippoglossoides platessoides</i>	Long Rough Dab	136-170 mm		
	1 <i>Limanda limanda</i>	Common Dab	169 mm		
Reference Station (G1) Haul 1.	2 <i>Pleuronectes platessa</i>	Plaice	235-248 mm	29	<i>Liocarcinus depurator</i> Swimming Crab
	2 <i>Hippoglossoides platessoides</i>	Long Rough Dab	167-187 mm	7	<i>Nephrops norvegicus</i> Norway Lobster
				3	<i>Pandalus borealis</i> Shrimp
				6	<i>Munida bamffica</i> Squat Lobster
				4	<i>Crangon allmanni</i> Prawn
				1	<i>Pagurus bernhardus</i> Hermit Crab
				7	<i>Aporhais pespelecani</i> Pelican's Foot Shell
				1	<i>Asterias rubens</i> Starfish
				1	<i>Sepia sp.</i> Squid
Reference Station (G1) Haul 2.	1 <i>Clupea harengus</i>	Herring	283 mm	54	<i>Liocarcinus depurator</i> Swimming Crab
	1 <i>Merlangius merlangus</i>	Whiting	237 mm	9	<i>Nephrops norvegicus</i> Norway Lobster
	1 <i>Trisopterus minutus</i>	Poor Cod	162 mm	1	<i>Munida bamffica</i> Squat Lobster
	2 <i>Merluccius merluccius</i>	Hake	239-317 mm	9	<i>Crangon allmanni</i> Prawn
	1 <i>Pleuronectes platessa</i>	Plaice	230 mm	2	<i>Aphrodita aculeata</i> Sea Mouse
	8 <i>Glyptocephalus cynoglossus</i>	Witch	133-213 mm	1	<i>Pagurus bernhardus</i> Hermit Crab
				1	<i>Brissopsis lyrifera</i> Heart Urchin
				6	<i>Asterias rubens</i> Starfish
				1	<i>Glossus humanus</i>
				1	<i>Sepia sp.</i> Squid
				4	<i>Aporhais pespelecani</i> Pelican's Foot Shell
	Reference Station (G1) Haul 3.	1 <i>Sprattus sprattus</i>	Sprat	135 mm	25
2 <i>Merlangius merlangus</i>		Whiting	200-214 mm	14	<i>Nephrops norvegicus</i> Norway Lobster
2 <i>Merluccius merluccius</i>		Hake	342 mm	2	<i>Pasiphaea sivado</i> Ghost Shrimp
2 <i>Pleuronectes platessa</i>		Plaice	159-185 mm	1	<i>Munida bamffica</i> Squat Lobster
2 <i>Hippoglossoides platessoides</i>		Long Rough Dab	186 mm	8	<i>Pandalus montagui</i>
8 <i>Glyptocephalus cynoglossus</i>		Witch	108-129 mm	1	<i>Asterias sp.</i> Starfish
				2	<i>Asterias rubens</i> Starfish
				1	<i>Brissopsis lyrifera</i> Heart urchin
				1	<i>Sepia sp.</i> Squid
				1	<i>Crangon allmanni</i> Prawn
				1	<i>Aphrodita aculeata</i> Sea Mouse
Reference Station (G1) Haul 4.		1 <i>Merlangius merlangus</i>	Whiting	130 mm	17
	2 <i>Pleuronectes platessa</i>	Plaice	220-270 mm	53	<i>Liocarcinus depurator</i> Swimming Crab
	2 <i>Hippoglossoides platessoides</i>	Long Rough Dab	108-205 mm	4	<i>Asterias rubens</i> Starfish
	3 <i>Merluccius merluccius</i>	Hake	352-387 mm	2	<i>Asterias sp.</i> Starfish
	1 <i>Glyptocephalus cynoglossus</i>	Witch	136 mm	1	<i>Sepia sp.</i> Squid
				14	<i>Aporhais pespelecani</i> Pelican's Foot shell
				2	<i>Aphrodita aculeata</i> Sea Mouse
				16	<i>Pandalus borealis</i> Shrimp
				7	<i>Munida bamffica</i> Squat Lobster
				14	<i>Crangon allmanni</i> Prawn
				1	<i>Pagurus bernhardus</i> Hermit Crab

adequate sample size in the statistical appraisal of fish disease incidence and, because of the relatively low numbers involved in this exercise, the findings must be treated with caution. It is re-emphasised that work which does not meet GCSMD recommendations (which in turn accord with internationally agreed procedures designed to ensure statistical reliability) should either be discontinued or up-graded.

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

In its first report, the GCSMD suggested that suitable indicators of alterations in environmental quality were the extent to which benthic diversity changes and the extent to which contaminant concentrations in sediments and water are maintained within appropriate set standards. The extent to which these criteria were met at the various disposal sites in 1992 is reviewed below.

4.5.1 Tyne

Data on the benthos at two locations in the vicinity of the Tyne sewage-sludge disposal site (Figure 2) were

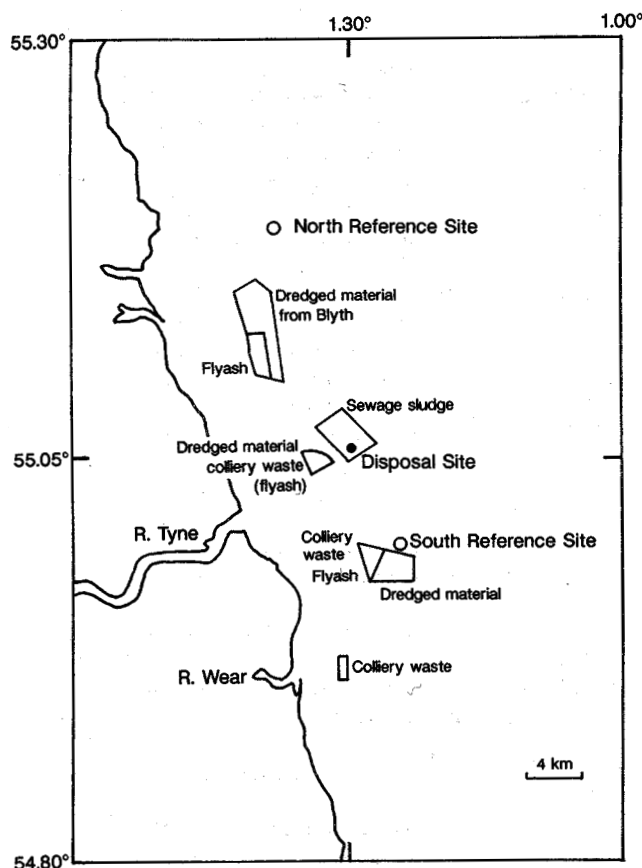


Figure 2. Tyne sewage sludge Disposal Site and the Reference Sites

tested against proposed 'Action Points' for permissible changes as proposed by the GCSMD Benthos Task Team (see MAFF, 1993(b)). Figure 3 shows the outcome up to 1991, which involves a comparison of annual values for the ratio of the chosen measure at a 'treatment' station (i.e. the disposal site) and at a 'reference' station (south of the disposal site). It can be seen that in no case is the 'Action Point' breached, although values for the ratios of abundance are generally significantly greater than zero. This may be taken as an indication of mild organic enrichment at the disposal site.

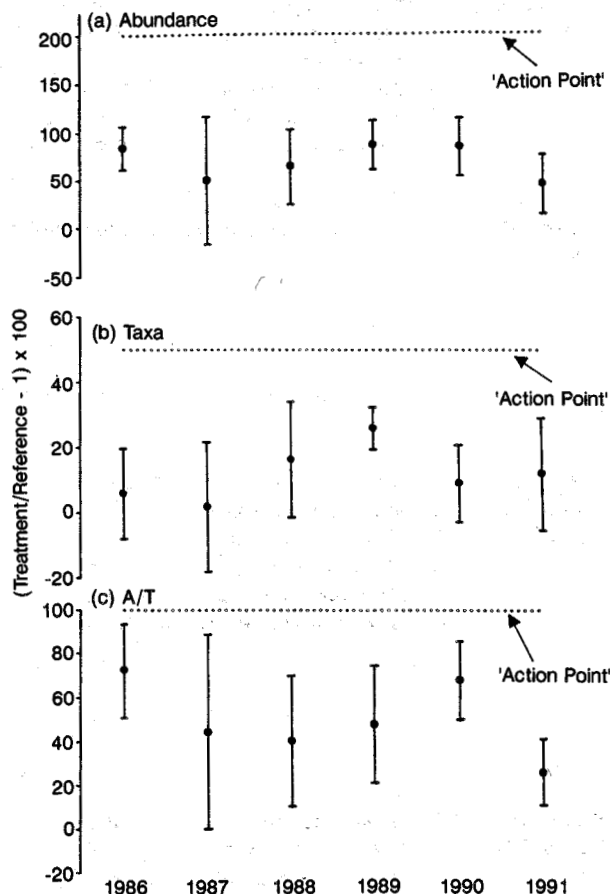


Figure 3. Means and 95% confidence intervals for pairwise comparisons of selected variables at the Tyne sewage-sludge disposal site. (Proposed 'Action Points' for acceptable change are superimposed)

Since 1989, an additional reference station has been sampled to the north of the disposal site (Figure 2). This northern station shares similar characteristics of depth and substrate type with the remaining two. The samples were worked up in 1993 (Boyd, 1994) in order to test for the possibility that the benthos at the southern reference station might itself be affected by nearby dredged material disposal, or be influenced by dispersing sewage sludge arising from a net southerly residual drift. Trends with time in diversity and evenness indices (Figures 4(a) and (b)) were very similar at the

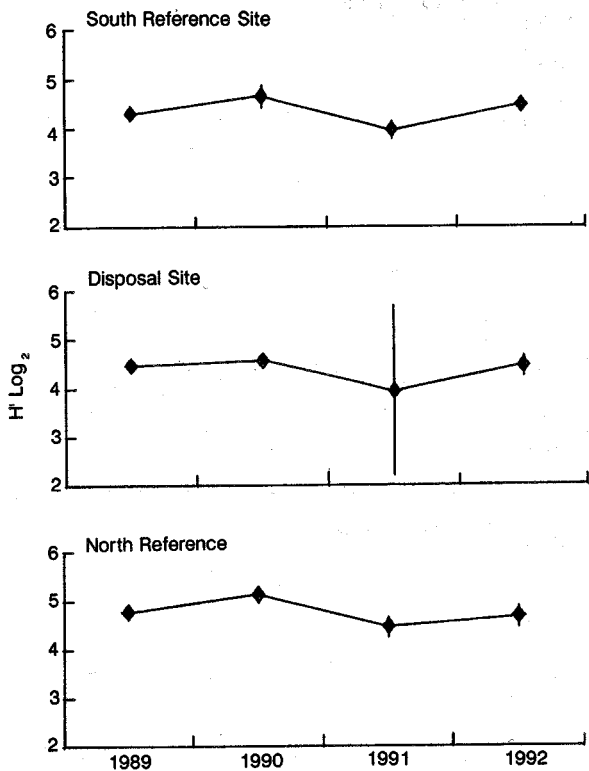


Figure 4(a). Temporal trends in Shannon-Wiener Diversity ($H' \log_2$) at the Tyne Disposal Site and the Reference Sites (mean and 95% confidence intervals)

three locations, although within any one year values tended to be highest at the northern station. Trends in numbers of taxa were also reasonably similar between years (Figure 5(a)) with the exception of 1989 at the disposal site; trends in densities were not so closely harmonised between stations (Figure 5(b)). Higher values of taxa tended to occur at the northern station compared with those at the southern reference station; numbers of individuals were comparable at both these stations, and lower than at the sludge disposal site. Both reference stations appear to be suitable targets for the future monitoring of trends, alongside those observed at the disposal site. Further examination of these trends in relation to 'Action Points' will be provided, as more annual data at the three regularly sampled stations become available.

4.5.2 St Abbs Head and Bell Rock

The benthic fauna at St Abbs Head was notable for the settlement of large numbers of the heart urchin *Echino-cardium cordatum*; a similar event occurred in 1987. This was a natural event, and was not accompanied by any reduction in the variety of taxa (some 339 in total at 11 stations) or their abundance, compared with previously. Application of an Infaunal Trophic Index gave values representative of a 'normal, healthy' community.

There was no equivalent settlement of *E. cordatum* at the Bell Rock site. Here, the total numbers of taxa (332

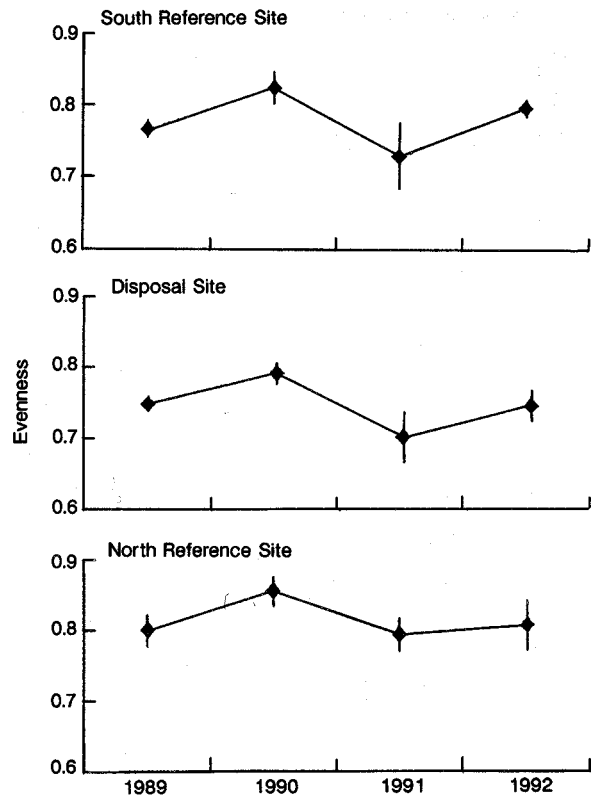


Figure 4(b). Temporal trends in Evenness at the Tyne Disposal Site and the Reference Sites (mean and 95% confidence intervals)

at 9 stations) and individuals were comparable with previous years. As at St Abbs Head, values of the Infaunal Trophic Index provided no evidence of sludge-related effects on the benthos.

As in previous years, stations at both disposal grounds were allocated to 'impacted' or 'unimpacted' groups according to the findings of a 1987 survey of coprostanol in sediments. Statistical testing of a range of univariate measures showed no significant differences between these groups.

Records for the presence of physical indicators of sludge disposal (notably tomato pips) in sediments showed a concentration of items in the central area of both disposal sites. Counts have tended to increase with time at St Abbs Head, with some 160 per grab being found in 1992. Numbers encountered at Bell Rock were generally lower, and there was no clearly discernible trend with time; some 50 pips per grab were found in 1992. These may be compared with counts of about 260 per grab recorded by MAFF at the Tyne sewage-sludge disposal site in 1992.

It may be concluded from work at the Bell Rock and St Abbs Head disposal sites that continued sewage-sludge disposal has had no discernible effect on the benthos, although a physical 'imprint' of sludge particulates is clearly evident.

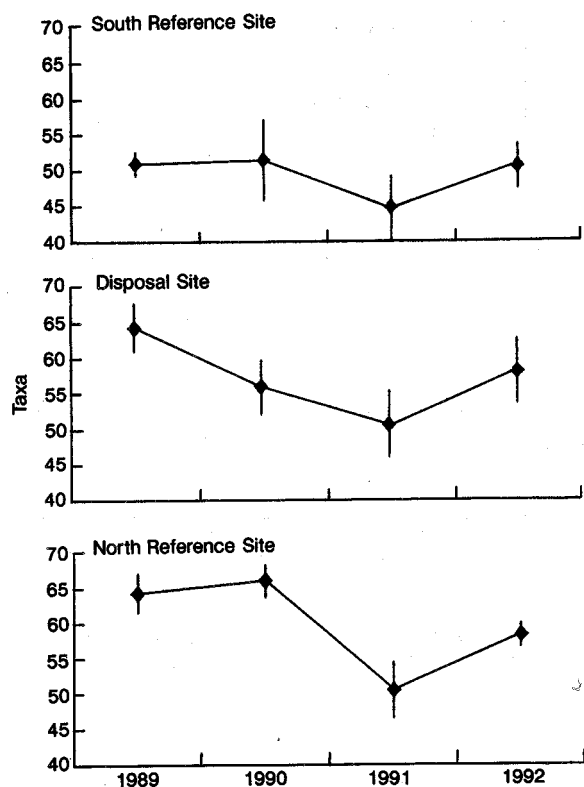


Figure 5(a). Temporal trends in numbers of Taxa at the Tyne Disposal Site and the Reference Sites (mean and 95% confidence intervals)

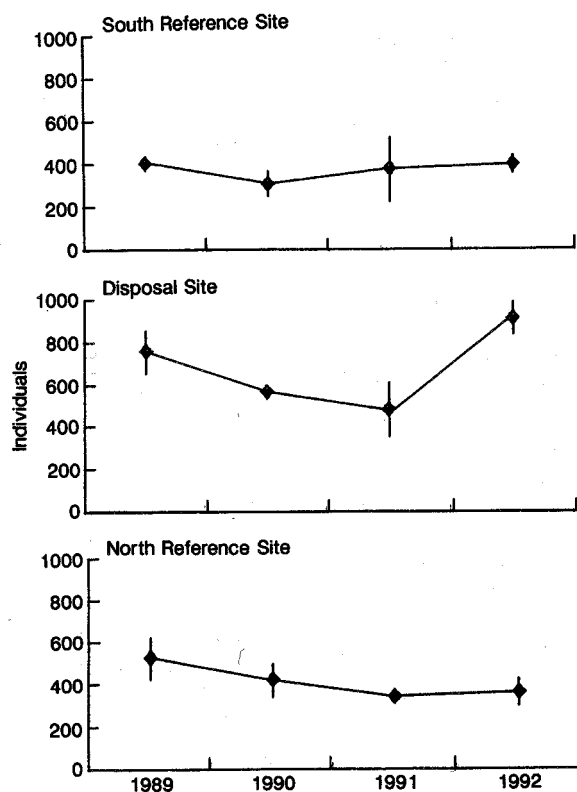


Figure 5(b). Temporal trends in counts of Individuals at the Tyne Disposal Site and at the Reference Sites (mean and 95% confidence intervals)

4.5.3 Garroch Head

Sampling of the benthos along intersecting transects across the Garroch Head disposal site revealed marked gradients of change associated with the deposition of sewage sludge at this relatively quiescent deep-water area. Such trends are broadly consistent with observations made in previous years. As the centre of the disposal site is approached, the trend is towards dominance by small-sized opportunistic species such as the polychaete worm *Capitella* and the oligochaete worm *Tubificoides*, generally at the expense of larger-sized (and longer-lived) species which are more typically associated with oxic sediments that are not subject to excessive inputs of organic carbon.

A trend towards increased biomass and numbers of opportunistic polychaetes at stations to the south and west of the centre suggested a shift in the areas of maximal sludge deposition in these directions. These and other changes fell within the ranges of variation which have been established for each station over the last 14 years and are considered acceptable despite the fact they breach the following EQO.

4.6 EQO: Maintenance of the receiving environment without distinguishable change

In its first report GCSDM explained that compliance with this objective would be judged by the extent to which contaminant concentrations and the benthic fauna at and around the disposal site, had remained unchanged.

4.6.1 Nab Tower

Each year approximately 250 000 tonnes of sewage sludge, and between 600 000 and 1 500 000 tonnes of dredged material are deposited at the Nab Tower disposal site. Surveys were carried out in 1992 by both MAFF and Southern Water.

MAFF survey

Surveys were carried out by MAFF in 1989, 1991 and 1992 to monitor changes in sediment quality over time. They were based on a random stratified design centred on the area of likely impact. Samples were sieved at 63 μm and the fine fraction digested using *aqua regia*, and analysed by flame atomic absorption spectrophotometry.

Table 8. Concentrations of metals (mg kg⁻¹) in the <63 µm fraction of sediment from the area of the Nab sewage sludge disposal site in 1989, 1991 and 1992

Year		N	Cr	Cu	Hg	Ni	Pb	Zn
1989	mean	23	42.3	27.2	0.41	38.9	62.6	106.7
	SD		10.2	22.6	0.39	31.0	98.8	46.8
1991	mean	21	55.9	60.9	0.29	27.1	72.6	163.0
	SD		11.4	48.3	0.28	8.4	55.0	117.0
1992	mean	23	63.8	33.9	0.15	27.5	55.0	98.3
	SD		12.5	11.0	0.07	7.0	45.5	17.5

Table 8 shows the mean values and standard deviations for the concentrations of metal in the <63 µm fraction in the three years. While some elements appear to show consistent changes, for example increasing chromium and decreasing mercury, it is not possible to draw firm conclusions without many more years' data such as were presented for Liverpool Bay and the Thames in previous reports in this series.

Southern Water survey

Forty-four sites were sampled for sediment in the first week of June 1992 (Figure 6). Due to the hard nature of the seabed, a Shipek grab had to be used. The grab and buckets were made from stainless steel to minimise any contamination of the samples with metals from the sampler.

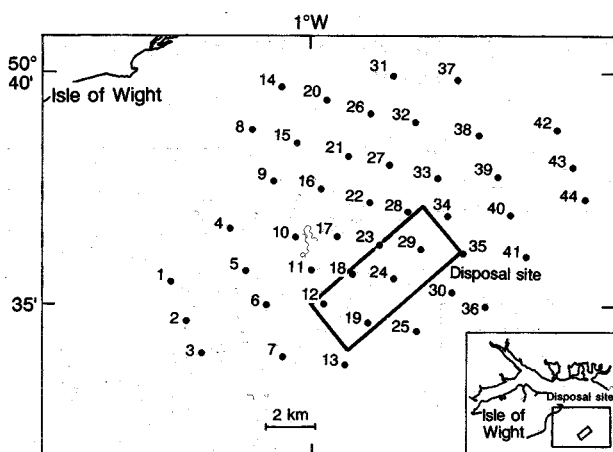


Figure 6. Nab Tower 1992 - sampling sites

Particle size analysis of the sediments showed them to be mostly sandy gravels and gravelly sands with no distinct pattern to their distribution, although there was some indication of the sandier sediments being located around the periphery of the survey area. This sediment type accords with the rather high energy tidal currents in the area. The highest concentration of fine material (45%) was recorded at Station 23, located at the northern edge of the disposal area (Figure 7). It should be noted that MAFF surveys have, in the past, recorded occurrences of fine dredged material in this area.

The abundances of faecal coliforms, faecal streptococci and *Clostridium* sp. were measured at most sites (Figures 8 and 9).

Generally, the <63 µm fraction of the sediment was analysed for mercury, cadmium, chromium, copper, nickel, lead and zinc using an *aqua regia* digestion technique. A few sediments contained insufficient <63 µm material for analysis, and in these cases the <125 µm fraction was used. Thus, nearly all metal analyses were carried out precisely in accord with GCSDM guidelines. Figures 10-14 show the distribution of sediment metals throughout the survey area.

Various organochlorine compounds, including CBs and pesticide residues, were measured at 19 sites through the survey area. The distributions of organochlorines are shown in Figure 15.

Concentrations of organic carbon were generally higher than in previous surveys, but were similar to those found at other UK sewage-sludge disposal sites (Figure 16). Close to the disposal site itself, however, concentrations of carbon are lower. Southern Water take this as an indication that the elevated concentrations are unlikely to be due to sewage-sludge disposal.

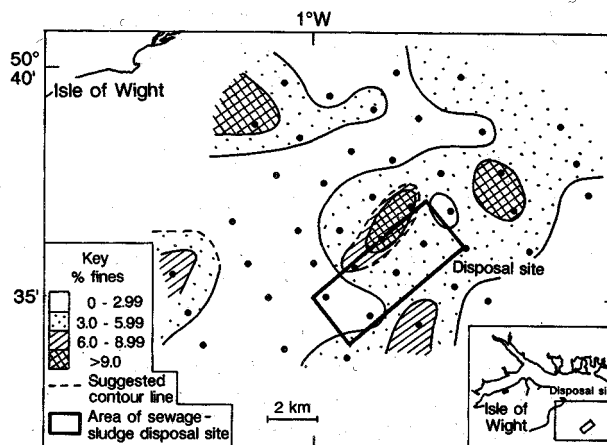


Figure 7. Nab Tower 1992 - distribution of the fine sediment fraction (<63 µm)

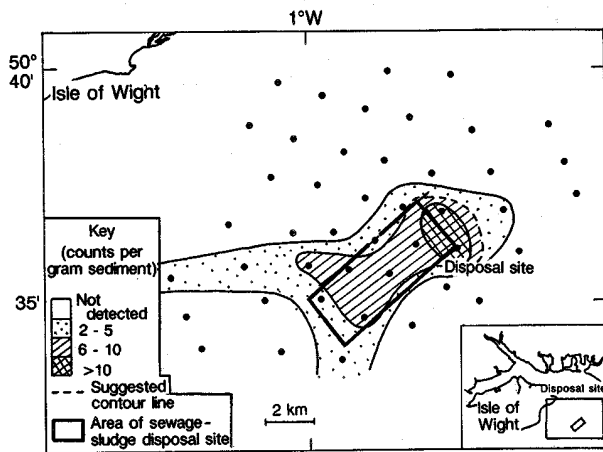


Figure 8. Nab Tower 1992 – distribution of faecal streptococci

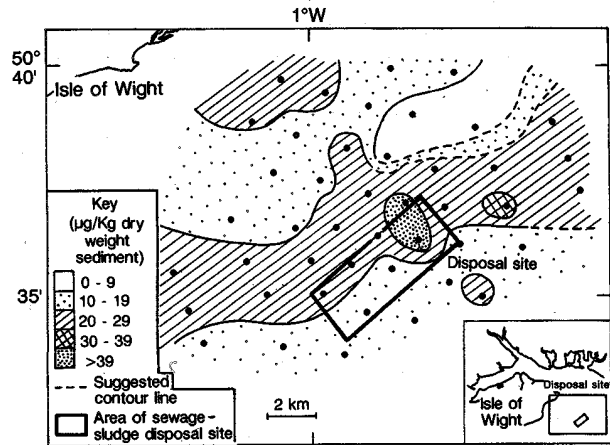


Figure 11. Nab Tower 1992 – distribution of copper

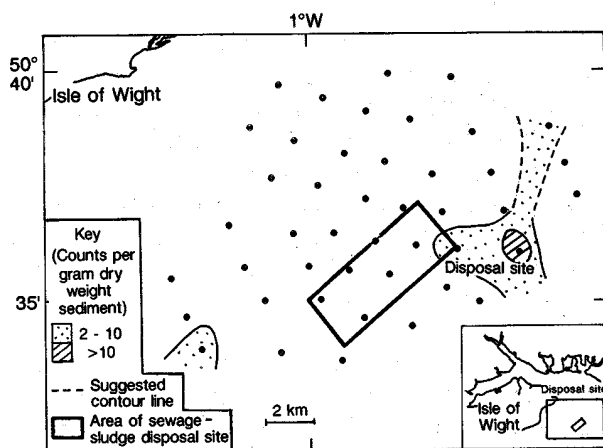


Figure 9. Nab Tower 1992 – distribution of Clostridium spp.

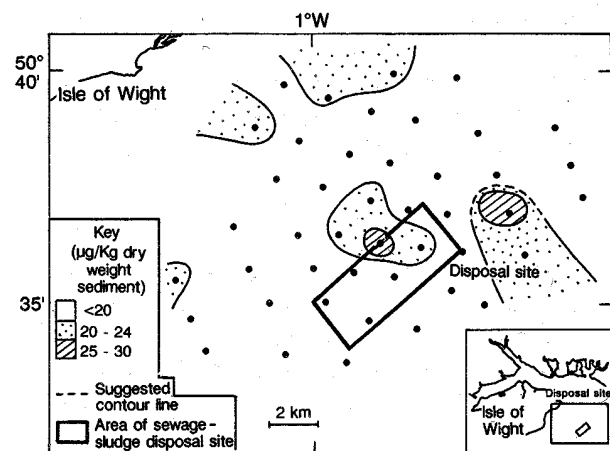


Figure 12. Nab Tower 1992 – distribution of nickel

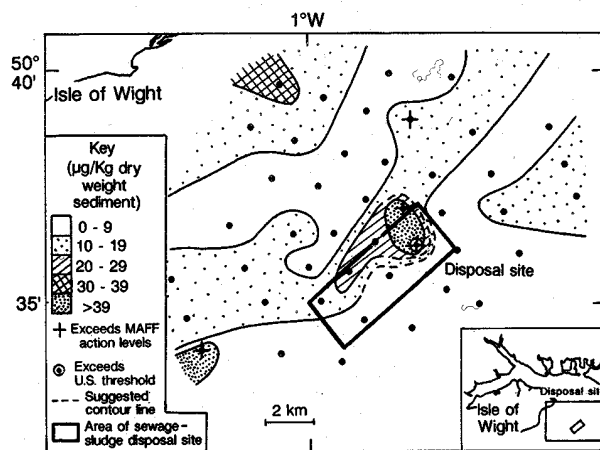


Figure 10. Nab Tower 1992 – distribution of mercury

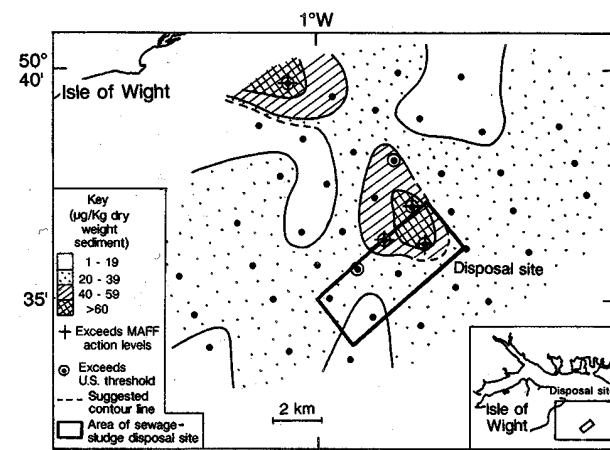


Figure 13. Nab Tower 1992 – distribution of lead

Correlation analysis (Table 9) revealed positive relationships between fine material, copper, nickel, lead and zinc. This suggests a similar source for these materials, possibly dredged material. The high concentrations of fines at the northern boundary of the disposal site also suggest the influence of dredged material disposal.

Several of the samples exceeded the MAFF 'Action Levels' for mercury and lead. These observations highlight the problem that, when surveying sites where dredgings and sewage sludge are co-disposed, it may be difficult to separate the effects of these two operations. The question is whether GCSDM action levels for

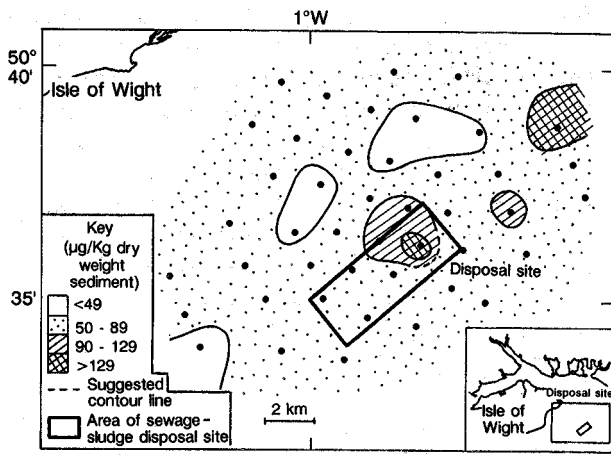


Figure 14. Nab Tower 1992 – distribution of zinc

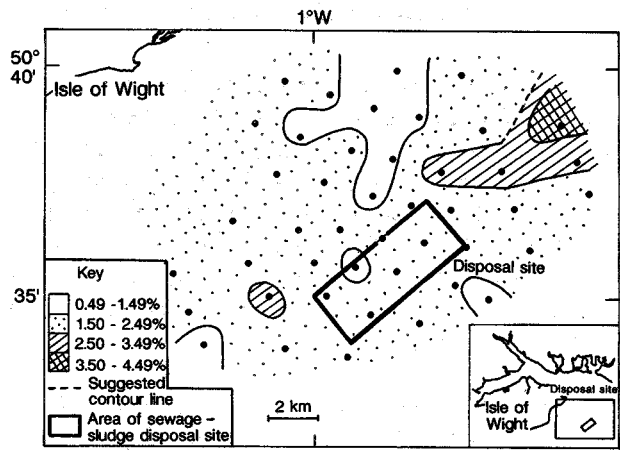


Figure 16. Nab Tower 1992 – distribution of organic carbon

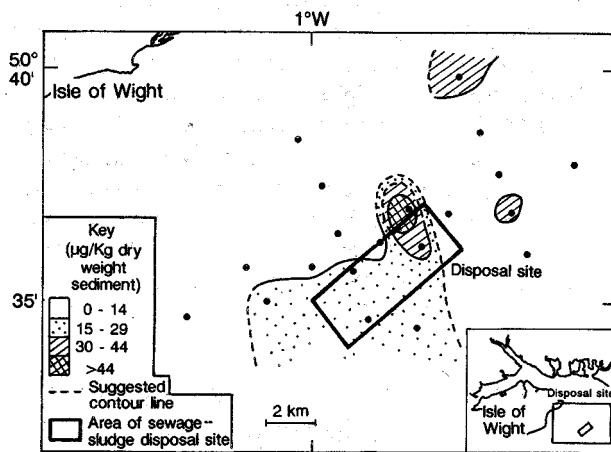


Figure 15. Nab Tower 1992 – distribution of organochlorine pesticides

metals, designed for sewage-sludge disposal sites, can be applied to areas where both materials are deposited. It would appear from first principles that they should be, but this cannot be confirmed without further survey work at dredged material disposal sites.

The highest concentrations of PCBs and total organochlorine pesticides (Figure 15) were detected at sites within the disposal area. The concentrations of DDT at site 37 exceed US threshold values. However, this site is 4 km from the disposal area and it is unlikely that these relatively high concentrations are the result of sewage-sludge disposal. Further work is required on both PCB and pesticide residues within this survey area. Particular attention should be paid to the notoriously difficult analyses of these compounds, and participation in the MPMMG's proposed AQC scheme is to be recommended.

Table 9. Correlation coefficients (*r*) between selected variables at the Nab Tower disposal site

Variables	<63	Hg	Ni	Cr	Zn	Pb	Cu	% C	C/N	PCBs	OCPs
<63	1.000	N/S	0.4563	N/S	0.3392	0.3260	0.3046	N/S	N/S	N/S	N/S
Hg		1.000	N/S	N/S	N/S	N/S	N/S	-0.3294	N/S	N/S	N/S
Ni			1.000	0.5945	0.5694	0.3720	0.5098	N/S	N/S	N/S	N/S
Cr				1.000	N/S	N/S	N/S	N/S	N/S	N/S	N/S
Zn					1.000	0.6587	0.8118	0.3426	N/S	N/S	0.6097
Pb						1.000	0.6211	N/S	0.3125	N/S	0.7950
Cu							1.000	N/S	N/S	N/S	0.5704
% C								1.000	-0.4962	N/S	N/S
C/N									1.000	N/S	0.6595
PCBs										1.000	N/S
OCPs											1.000

N/S = No significance

Note: All correlation values are for $v - 2 = 40$. $r = 0.3044$ at $p = 0.05$, $r = 0.3932$ at $p = 0.01$, $r = 0.4896$ at $p = 0.001$

4.6.2 Thames transect survey

Between 1887 and 1967, sewage sludge and dredged material were disposed of at two sites in the outer Thames Estuary, one in the Black Deep and one in the Barrow Deep. The Black Deep site received sewage sludge between 1915 and 1967 and dredged material between 1887 and 1920. The Barrow Deep site has been used exclusively for sewage sludge disposal since 1967, with approximately 4.5 million wet tonnes being disposed there each year.

A monitoring survey was undertaken in May 1992. Sediment samples were collected with a 0.1 m² Day grab from 49 sites in the outer Thames Estuary. Transects were sampled in the Middle, Barrow, Black and Knock Deeps. The Barrow Deep transect was extended offshore as far as the Outer Gabbard, and inshore as far as the Oaze Deep to include 'background samples'. The samples were wet sieved at 63 µm and the fines analysed using *aqua regia* digestion and atomic absorption spectrophotometry (Harper *et al.*, 1989). Concentrations of metals in the sediments are shown in Figures 17-20.

In general, concentrations of metals do not vary greatly over the survey area, with few areas exhibiting elevated concentrations for all metals. The highest concentrations of metals were generally found along the Barrow,

Black and Oaze Deeps. Figure 21 shows the range, and mean concentrations of lead present in the Middle, Barrow, Black, Knock and Oaze Deeps. Although the ranges overlap, the mean values for the Barrow, Black and Oaze Deeps are higher than for the Middle and Knock Deeps. The southern-most sites in both the Knock and Middle Deeps also show relatively high concentrations. With the exception of mercury, concentrations of metals at sites in the eastern part of the survey area, furthest from the influence of anthropogenic inputs, do not differ greatly from many of the sites further inshore.

Concentrations of metals at the Barrow Deep disposal site are not high compared to those at other sites away from the immediate area of disposal.

Sediment transport studies carried out previously (Talbot *et al.*, 1982) suggest that the elevated concentrations of metals along the Barrow Deep, and at the southern-most site in the Middle Deep, may be attributable to sewage-sludge disposal operations at the Barrow Deep disposal site. Higher concentrations of metals in the Black Deep, particularly at the southern end, might be associated with the dredged material and sewage-sludge disposal operations carried out at the Black Deep disposal site prior to 1967. Elevated concentrations of metals in the Oaze Deep may be a result of their closer proximity, relative to the rest of the survey, to the industrialised River Thames.

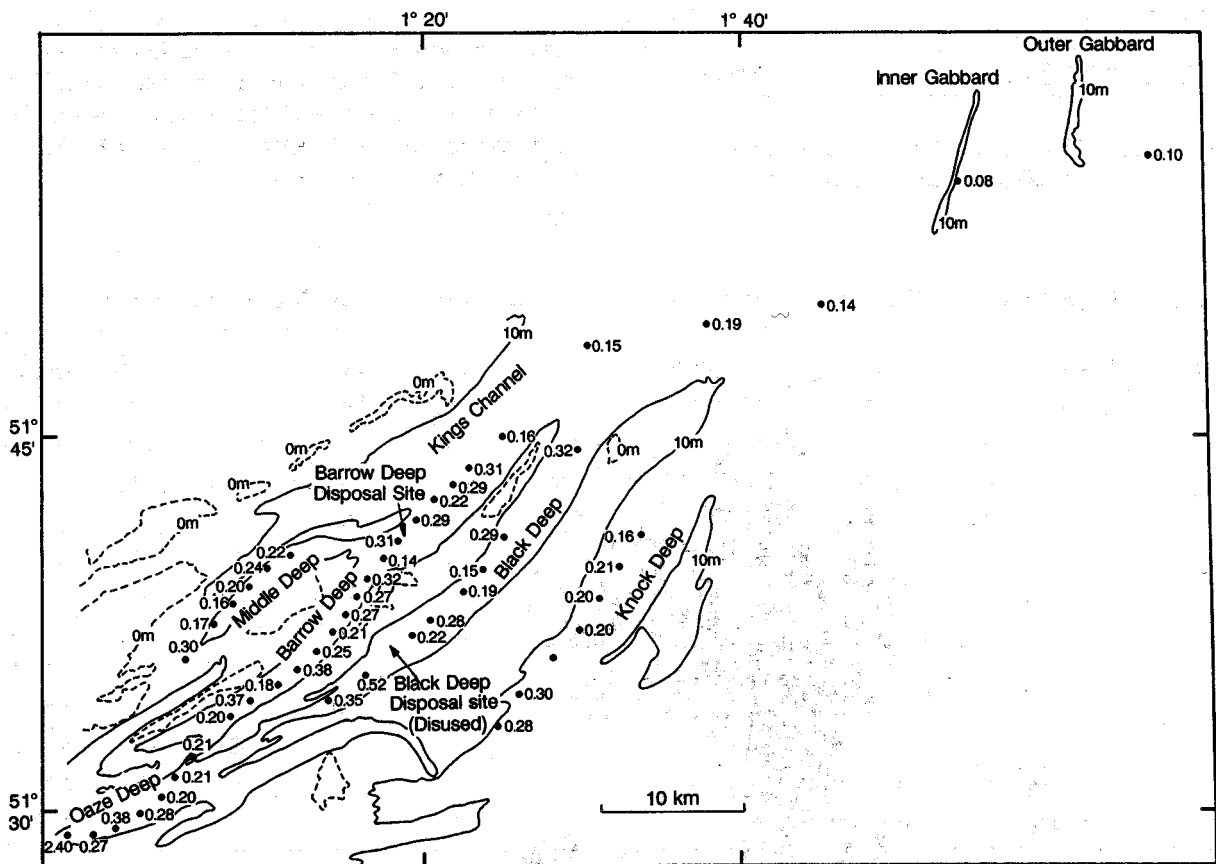


Figure 17. Distribution of the concentrations of mercury (mg kg⁻¹) in the fine (<63 µm) fraction of sediment samples collected from the outer Thames Estuary

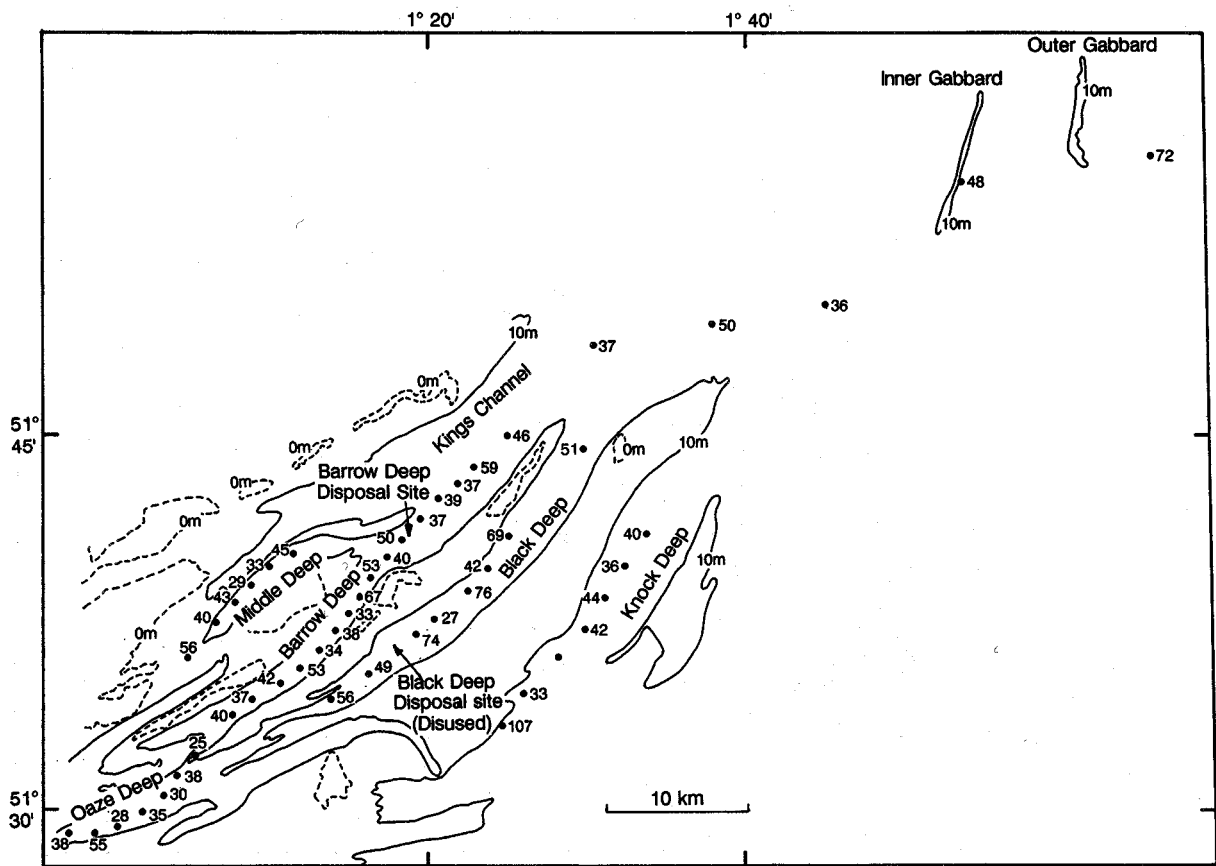


Figure 18. Distribution of the concentrations of copper (mg kg^{-1}) in the fine ($<63 \mu\text{m}$) fraction of sediment samples collected from the outer Thames Estuary

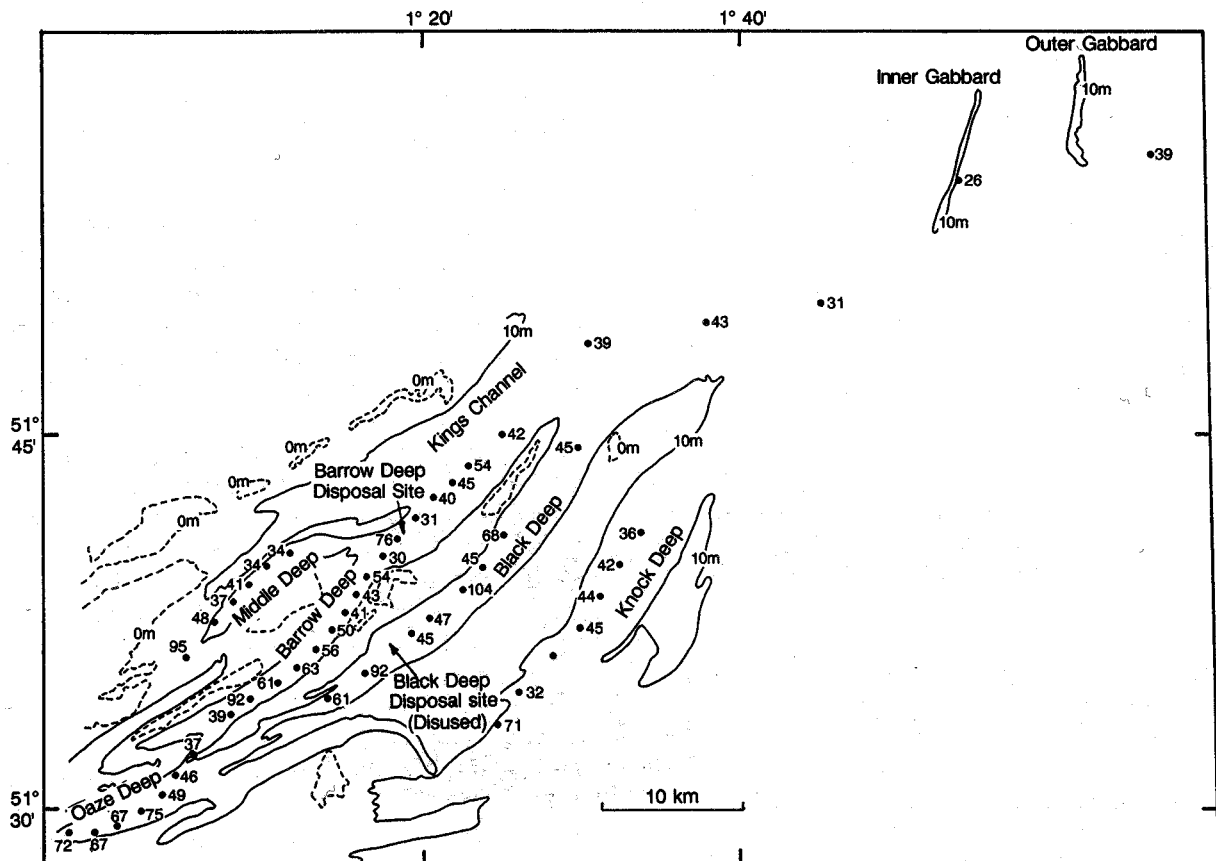


Figure 19. Distribution of the concentrations of lead (mg kg^{-1}) in the fine ($<63 \mu\text{m}$) fraction of sediment samples collected from the outer Thames Estuary

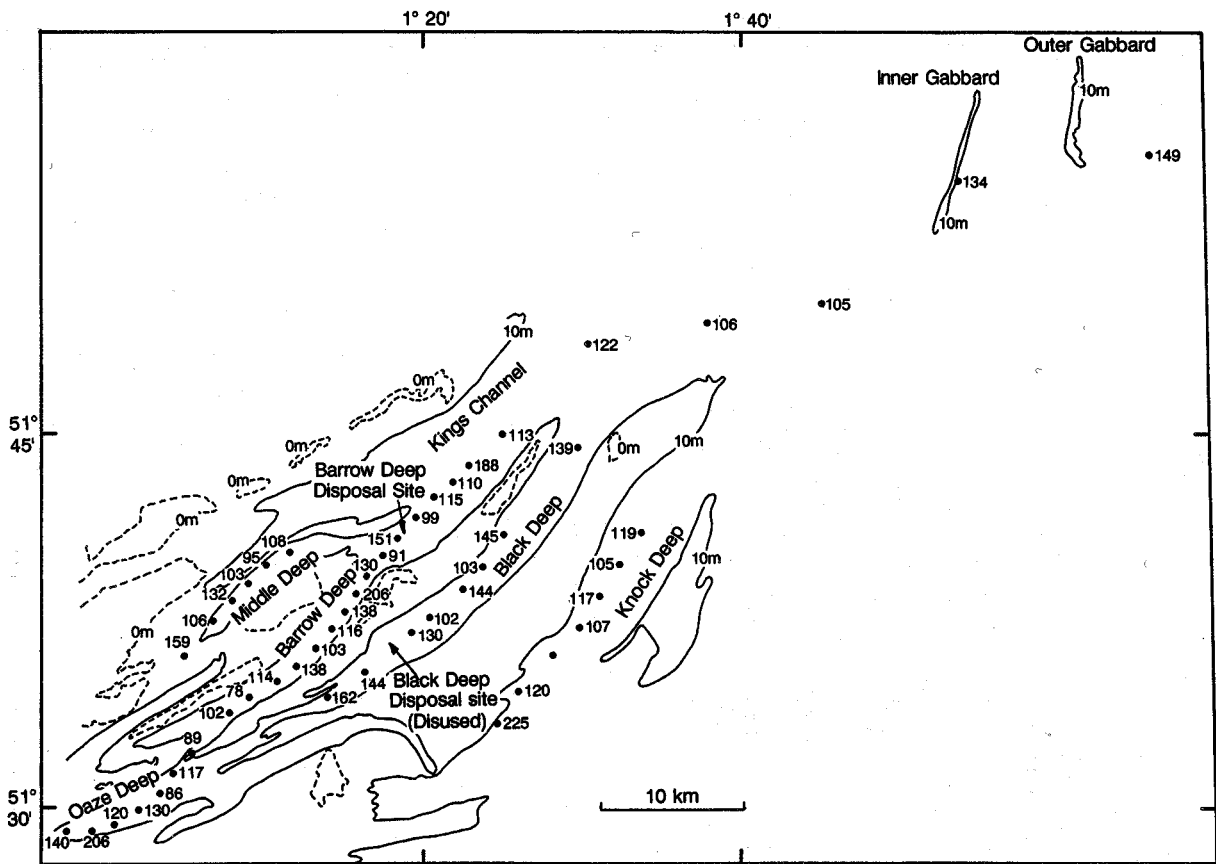


Figure 20. Distribution of the concentrations of zinc (mg kg^{-1}) in the fine ($<63 \mu\text{m}$) fraction of sediment samples collected from the outer Thames Estuary

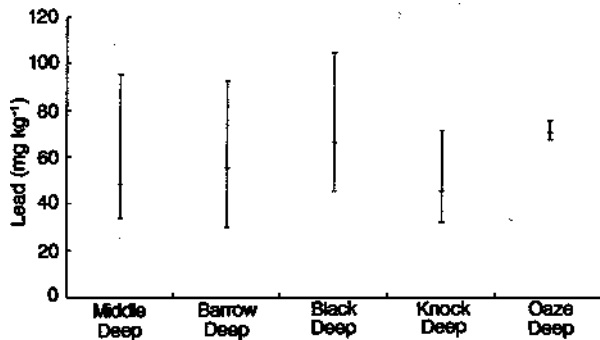


Figure 21. Concentrations of lead (mean and range) present in sediments from the Middle, Barrow, Black, Knock, and Oaze Deeps

The results of this survey suggest that heavy metals associated with sewage sludge are dispersed away from the immediate area of disposal to become part of the general sediment metal load for the Thames Estuary. The results also show that concentrations of metals in sediments in the inshore part of the survey closest to both land based and marine anthropogenic input do not vary greatly from those furthest offshore.

4.6.3 Plymouth

Each year approximately 60 000 wet tonnes of sewage sludge is deposited at the Plymouth disposal site. The impact of this disposal operation is assessed at regular intervals as part of the licensing authorities obligations under Part II of the Food and Environmental Protection Act (FEPA), 1985 (Great Britain – Parliament, 1985).

Surveys were carried out in 1986, 1988 and 1992 to monitor changes in sediment quality over time. As with the studies at Nab Tower they were based on a random stratified design centred on the area of likely impact. Samples were sieved at $63 \mu\text{m}$ and the fine fraction digested using *aqua regia*, and analysed by flame atomic absorption spectrophotometry.

Table 10 shows the mean values and standard deviations for the concentrations of metal in the $<63 \mu\text{m}$ fraction in the three years. While some elements appear to show consistent change, for others the pattern is one of little change. However, it must be noted that, as with the Nab Tower data (see earlier section), it is not possible to draw firm conclusions without many more years' data.

Table 10. Concentrations of metals (mg kg^{-1}) in the $<63 \mu\text{m}$ fraction of sediment from the area of the Plymouth sewage-sludge disposal site in 1986, 1988 and 1992

Year		N	Cr	Cu	Hg	Ni	Pb	Zn
1986	mean	15	38	32	0.23	22	79	100
	SD		3.9	10.7	0.07	2.2	45.3	9.5
1988	mean	15	41	33	0.26	27	52	111
	SD		2.8	7.7	0.05	1.1	7.1	7.8
1992	mean	26	54.7	39	0.24	25.2	53.6	132.6
	SD		5.3	9.2	0.04	1.6	9.6	23.2

4.6.4 Humber

Yorkshire Water survey

Forty-one sites were sampled for sediment in the period 14-18 September 1992 (Figure 22). Due to the hard nature of the seabed, a Shipek grab had to be used. The grab and buckets were made from stainless steel to minimise any contamination of the samples with metals from the sampler. On retrieval the sediments were photographed with a scale bar before sampling. This procedure is one which GCSDM endorses as of value for the clarification of questions which may arise after the survey.

At the majority of sites, a single grab did not provide sufficient material to allow for the collection of adequate sub-samples, and a number of grabs were therefore taken.

The abundances of faecal bacteria were measured at most sites. The $<63 \mu\text{m}$ fraction of the sediment was analysed for trace metals and organic carbon. Various organochlorine compounds, including individual CBs, were measured.

The results showed a general reduction in concentrations for the majority of determinands since 1990. However, improvements in the limits of detection in 1992, may account for some of these apparent reductions.

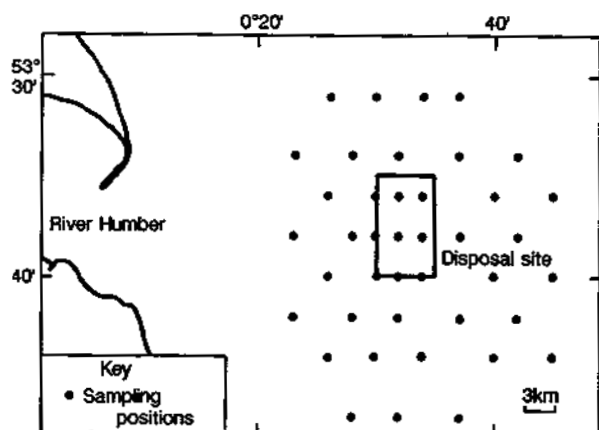


Figure 22. Yorkshire Water Survey of the Humber sewage-sludge disposal site, 1992

4.6.5 St Abbs Head and Bell Rock

Sediments collected at St Abbs Head in 1992 comprised muddy and fine sands, similar to 1991 with silt and clay concentrations in the range 2.9-34.9%. Sediments at Bell Rock comprised fine and medium sands, with silt and clay concentrations ranging from 2.3 to 8.2%, similar to 1991.

The distribution of waste water-derived material at both disposal sites continues to show highest accumulations towards the centre of each site. Mean densities of tomato pips at St Abbs Head show a gradual increase with time, while those at Bell Rock show an average similar to that seen in 1990 (see Section 4.5.2).

Organic carbon and nitrogen concentrations at both sites were similar to those previously recorded, with values in the St Abbs Head sediments (0.47% for carbon and 543 mg kg^{-1} for nitrogen) slightly higher than those for Bell Rock (0.24% carbon and $264 \text{ mg nitrogen kg}^{-1}$). A comparison of carbon and nitrogen concentrations between inner and outer stations revealed no significant differences at either site, indicating no serious accumulation of organic material.

An analysis of mean concentrations of trace metals at St Abbs Head and Bell Rock showed that the 1992 values were all generally within the long term ranges encountered at the sites (e.g. Figures 23-28). A comparison of mean concentrations between the inner and outer stations again failed to show any significant differences, suggesting little accumulation is taking place. Although for chromium (at both sites) and zinc at Bell Rock, the GCSDM guideline would appear to have been breached in 1988 and 1990, this may be partly attributable to difficulties during analysis. The overall concentrations of zinc and other trace metals are quite low at the Bell Rock site and these levels are all well below the ER-L toxicity limits identified by the US National Oceanographic and Atmospheric Administration (NOAA) and compare with levels found at other sewage-sludge disposal sites e.g. Plymouth. Trace metal concentrations at the control station were similar to previous years, and also in the same ranges observed at the

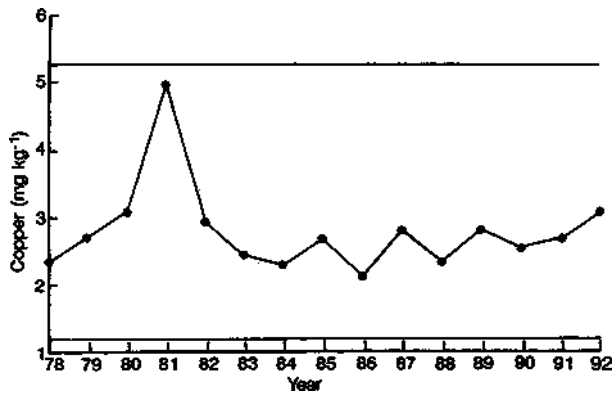


Figure 23. Sediment survey data for 1978-1992. *St Abbs Head: temporal trends in levels of copper in sediment. (Boundaries (= 'warning limits') represent ± 2 standard deviations from the mean concentration derived from the first five years of sampling)*

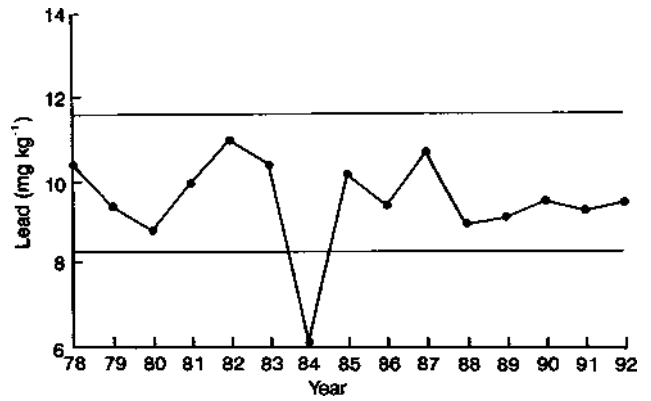


Figure 26. Sediment survey data for 1978-1992. *Bell Rock: temporal trends in levels of lead in sediment. (Boundaries (= 'warning limits') represent ± 2 standard deviations from the mean concentration derived from the first five years of sampling)*

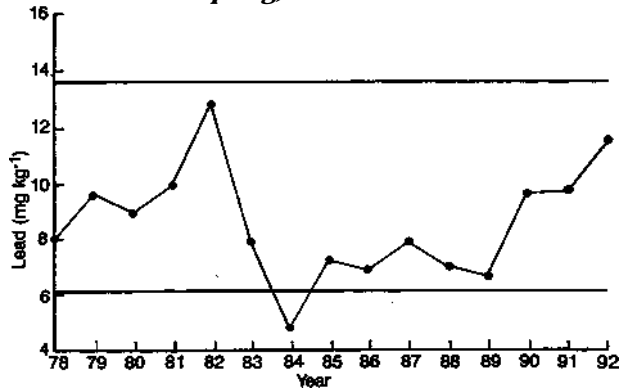


Figure 24. Sediment survey data for 1978-1992. *St Abbs Head: temporal trends in levels of lead in sediment. (Boundaries (= 'warning limits') represent ± 2 standard deviations from the mean concentration derived from the first five years of sampling)*

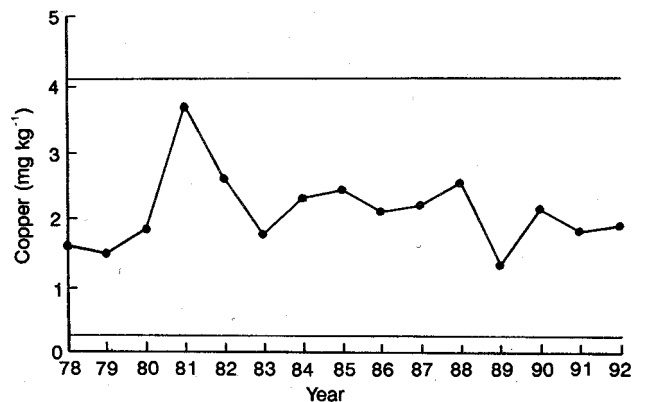


Figure 27. Sediment survey data for 1978-1992. *Bell Rock: temporal trends in levels of copper in sediment. (Boundaries (= 'warning limits') represent ± 2 standard deviations from the mean concentration derived from the first five years of sampling)*

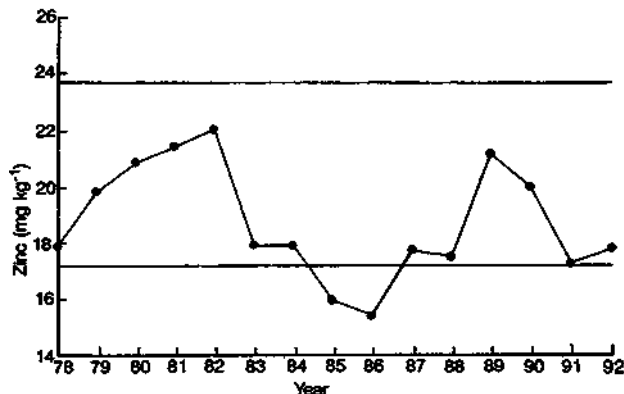


Figure 25. Sediment survey data for 1978-1992. *St Abbs Head: temporal trends in levels of zinc in sediment. (Boundaries (= 'warning limits') represent ± 2 standard deviations from the mean concentration derived from the first five years of sampling)*

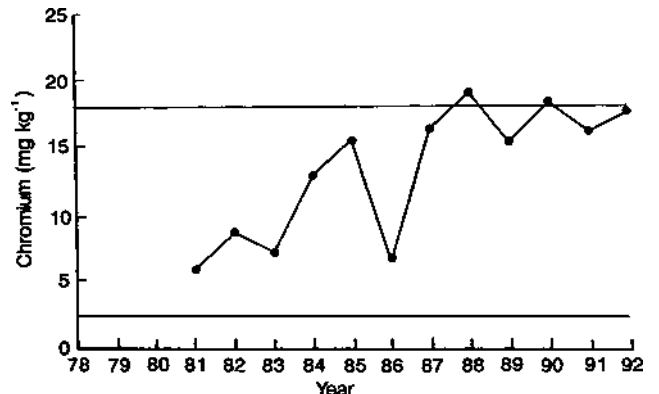


Figure 28. Sediment survey data for 1978-1992. *Bell Rock: temporal trends in levels of chromium in sediment. (Boundaries (= 'warning limits') represent ± 2 standard deviations from the mean concentration derived from the first five years of sampling)*

disposal site, indicating minimal effect of sewage sludge disposal on sediment contamination.

This survey again demonstrates the value of using standards, in this case the ER-L values of NOAA. These values and the GCSDM action levels for metals should be used at all sites.

4.7 Overall conclusions from the review of monitoring in 1992

1. There continue to be differences in detail as to what is monitored at each site but these are now mainly attributable to the genuinely different natures of the different areas. Where monitoring requirements are similar so too, in most cases, are the methods used.
2. Time-series of data extending over several years (and accompanied by continuity in sampling and analytical approaches) are again shown to be valuable in physico-chemical and biological assessments of the effects of sewage-sludge and other disposal operations.
3. No evidence of significant accumulations of sludge-derived chemical contaminants was found at any of the dispersive disposal sites sampled.
4. Physical indicators of sludge disposal were frequently encountered, although in variable quantities from one locality to another, depending on the nature of sewage treatment processes prior to sludge disposal, the quantities of sludge disposed of, and the dispersive properties of the receiving environment.
5. Samples should in general be photographed to provide a record of all samples collected in case questions arise after the survey.
6. Efforts should be made to improve and to develop new methods to distinguish the effects of dredged material and sewage sludge at sites where co-disposal occurs.
7. GCSDM and NOAA action levels for metals appear to be suitable for application at all sites.
8. All analytical laboratories contributing data on sewage sludge monitoring ought to be participants in the MPMG AQC scheme.
9. Closer attention should be given by those actually doing the monitoring to sampling design, and in particular to achieving an appropriate degree of replication at selected stations. The latter is especially important for the testing of compliance with agreed EQSs.

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

5. MONITORING ACTIVITIES AT SEWAGE-SLUDGE DISPOSAL SITES IN 1993

5.1 Introduction

During 1993, surveys were carried out at the following disposal sites (see Figure 1): Tyne, Humber, Roughs Tower, Barrow Deep, Nab Tower, Bristol Channel, Liverpool Bay, North Channel, Garroch Head, Bell Rock and St Abbs Head.

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

5.2 MAFF survey of the Tyne sewage-sludge disposal site, May 1993

- (a) Sediment samples were collected from the sites shown in Figure 29.
- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <63 μm fraction of the surface 0-1 cm of the sediment. The samples form part of a study on temporal trends in sediment quality at the disposal site.

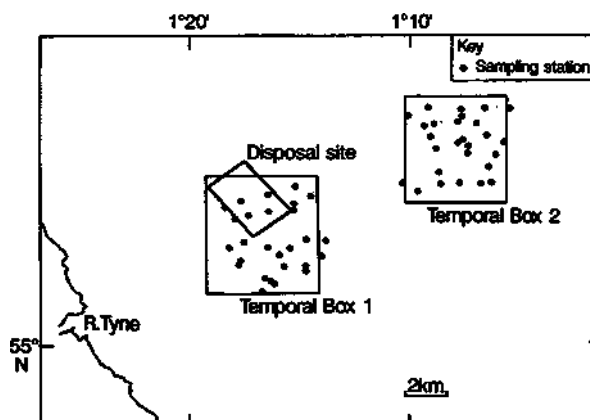


Figure 29. MAFF temporal trend survey of the Tyne sewage-sludge disposal site, May 1993

- (c) Sediment samples were also collected by Day grab from 3 stations along a north-south transect through the disposal site at the stations shown in Figure 30.
- (d) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <math><63 \mu\text{m}</math> fraction of the top 0-1 cm of the sediment.
- (e) Benthic infauna were identified and enumerated in samples from these stations.
- (f) Beam trawl samples were also taken at stations along the transect for the identification and enumeration of litter and benthic infauna.

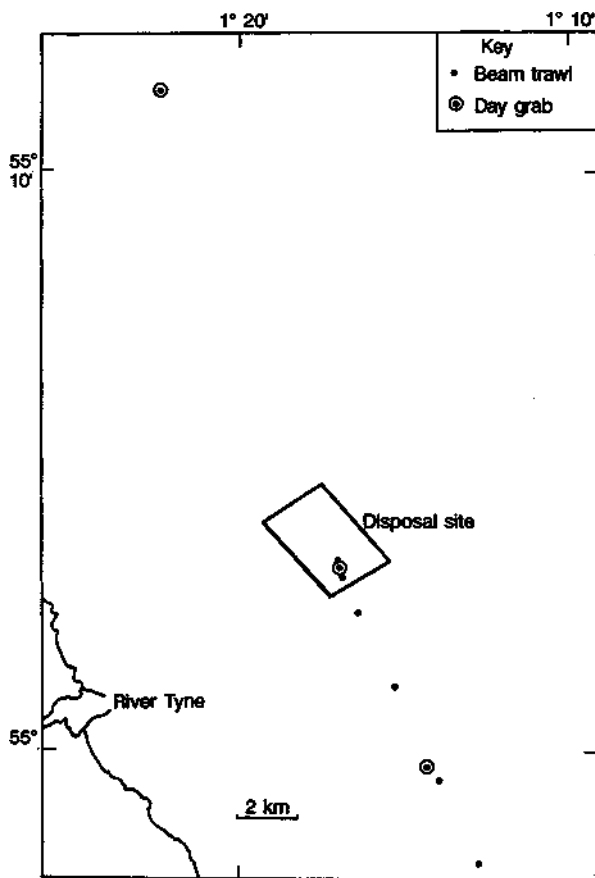


Figure 30. MAFF transect survey of the Tyne sewage-sludge disposal site, May 1993

5.3 Northumbrian Water survey of the Tyne sewage-sludge disposal site, June/October 1993

- (a) Sediments samples were collected by Day grab from the stations shown in Figure 31.
- (b) Metals (Cd, Cu, Cr, Hg, Mn, Ni, Pb and Zn) were determined in the <math><63 \mu\text{m}</math> fraction of the top 0-1 cm of the sediments.

- (c) Benthic infauna were identified and enumerated in samples from the sites shown.
- (d) Beam trawl hauls were carried out at six sites during June and August. Epifauna were identified to species level and enumerated.
- (e) Additional sediment samples were taken at six sites for organic analyses.
- (f) Pips were enumerated in samples from all sites for use as a sewage tracer.

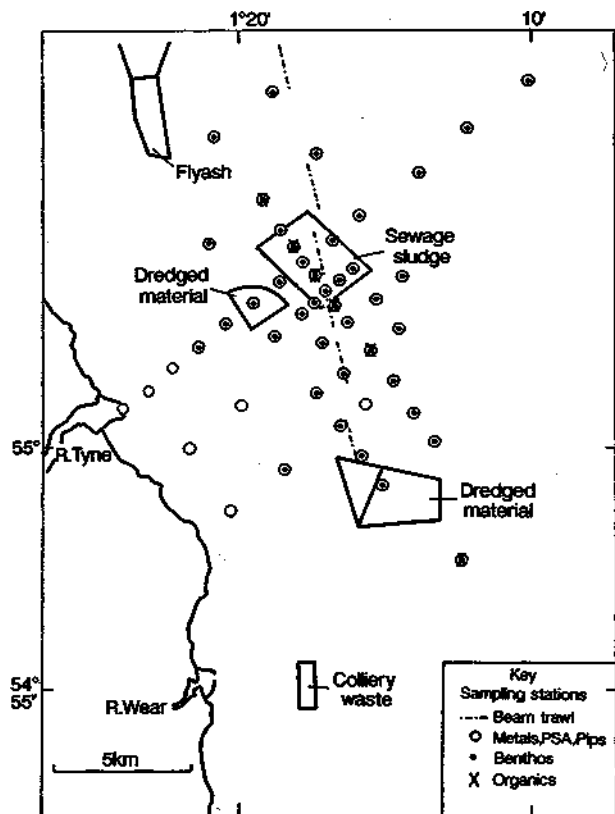


Figure 31. Northumbrian Water survey of the Tyne sewage-sludge disposal site, June/October 1993

5.4 MAFF survey of the Humber sewage-sludge disposal site, May 1993

- (a) Samples of horse mussel (*Modiolus modiolus*) were collected at the stations shown in Figure 32. These will be analysed for metals (Cd, Cu, Hg, Pb and Zn) as part of a study on temporal trends in chemical quality of the mussel population.

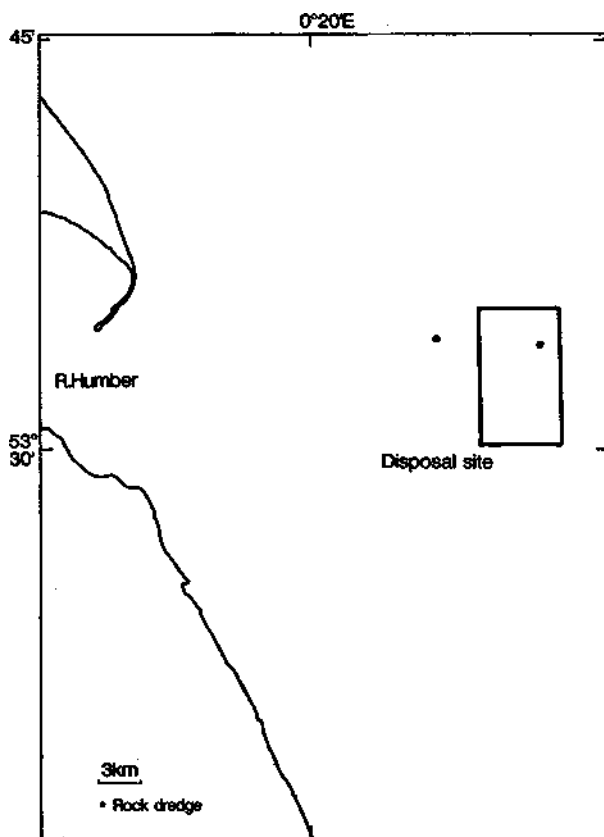


Figure 32. MAFF survey of the Humber sewage-sludge disposal site, May 1993

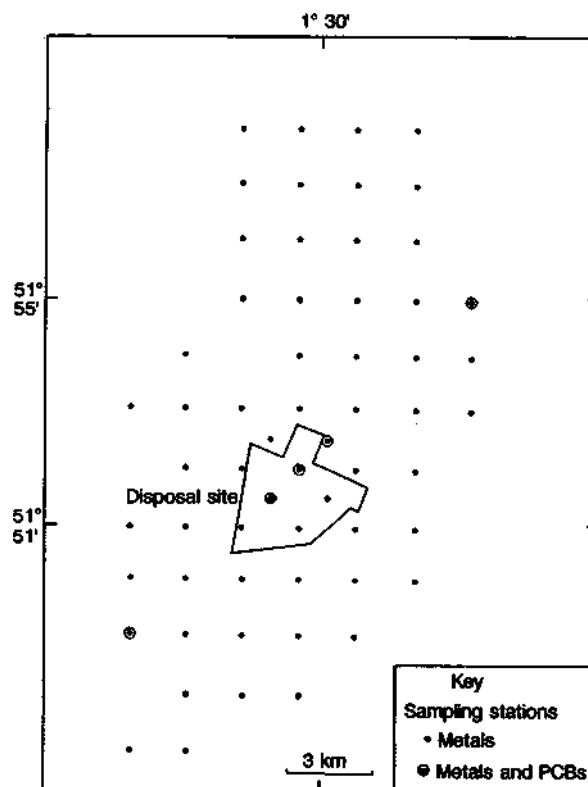


Figure 33. Anglian Water survey of the Roughs Tower sewage-sludge disposal site, September 1993

5.5 Anglian Water survey of the Roughs Tower sewage-sludge disposal site, September 1993

- Sediment samples were collected from the sites shown in Figure 33.
- Metals (Cd, Hg, Pb and Zn) were determined in the <math><63 \mu\text{m}</math> fraction of the sediment.
- Additional sediment samples were taken at 5 stations for the analysis of PCBs.

5.6 MAFF survey of the Barrow Deep sewage-sludge disposal site, December 1993

- Sediment samples were taken, using a Day grab, from the sites shown in Figure 34 and a number of sites within each of the three sampling boxes.
- Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <math><2 \text{ mm}</math> fraction of the surface 0-1 cm of the sediments. Carbon and Nitrogen were determined in the <math><63 \mu\text{m}</math> fraction of these samples.

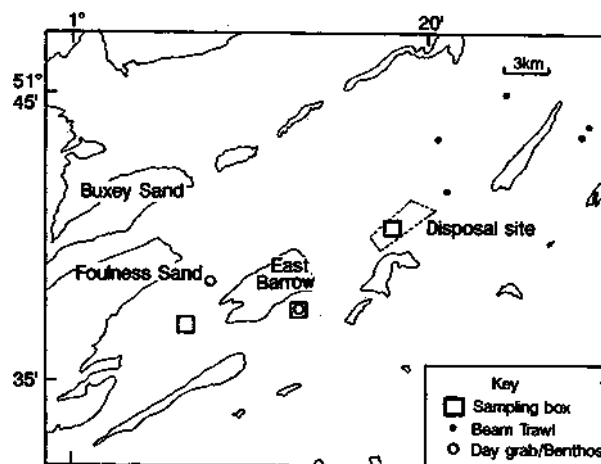


Figure 34. MAFF survey of the Barrow Deep sewage-sludge disposal site, December 1993

- Benthic infauna was identified and enumerated in samples from the two sites shown.
- Beam trawl samples were taken for the assessment of litter. Benthic infauna was identified and enumerated at a selected number of these sites.

5.7 Thames Water survey of the Barrow Deep sewage-sludge disposal site, 1993

- (a) Four sediment samples were collected using a Day grab, at each of the stations shown in Figure 35.
- (b) A sub-sample was taken from the first grab, using a 2.5 cm diameter plastic corer, for the analysis of particle size distribution.
- (c) The remainder of the first sample was retained for the identification and enumeration of macrofauna. At 15 of the sites two additional samples were taken for the analysis of the benthic fauna.
- (d) A surface sediment scrape was taken from the second grab for the enumeration of Group D faecal streptococci.
- (e) Total organic carbon and total nitrogen were determined in the surface (0-2 cm) of sediment from the third sample.
- (f) Metals (Cd, Hg, Pb and Zn) were determined in the surface (0-2 cm) of the sediment from the final grab.
- (g) Additional samples were taken at three sites for the analysis of a range of organochlorine pesticides and PCBs.

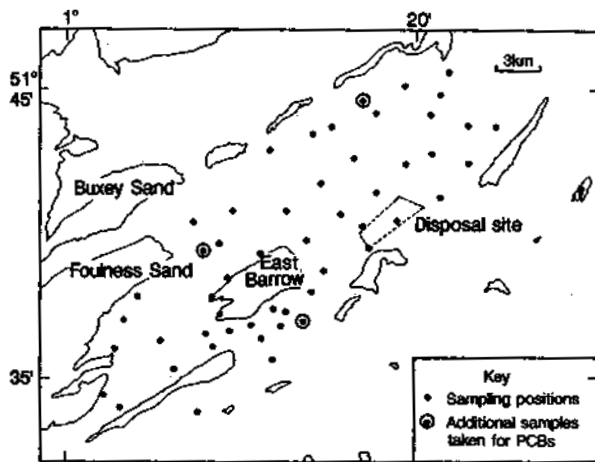


Figure 35. Thames Water Survey of the Barrow Deep sewage-sludge disposal site, 1993

5.8 Southern Water survey of the Nab sewage-sludge disposal site, June 1993

- (a) Sediment samples were collected from the sites shown in Figure 36.

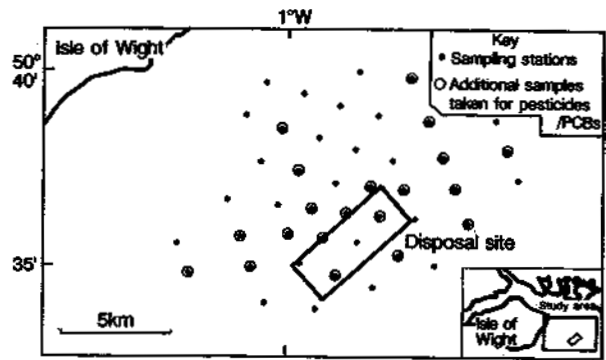


Figure 36. Southern Water survey of the Nab sewage-sludge disposal site, June 1993

- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <math><63 \mu\text{m}</math> fraction of the surface 0-1 cm of the sediment. Carbon and nitrogen were also determined in these samples.
- (c) Faecal bacteria (*E. coli*, faecal streptococci and *Clostridium*) were enumerated in surface scrapes of the sediment.
- (d) Additional samples were taken from a number of stations for the determination of pesticide residues and PCBs.

5.9 MAFF survey of the Bristol Channel sewage-sludge disposal site, May 1993

- (a) Samples were collected by scallop dredge from the 2 stations shown in Figure 37, for the assessment of litter. The samples formed part of a litter survey at sewage-sludge disposal sites.

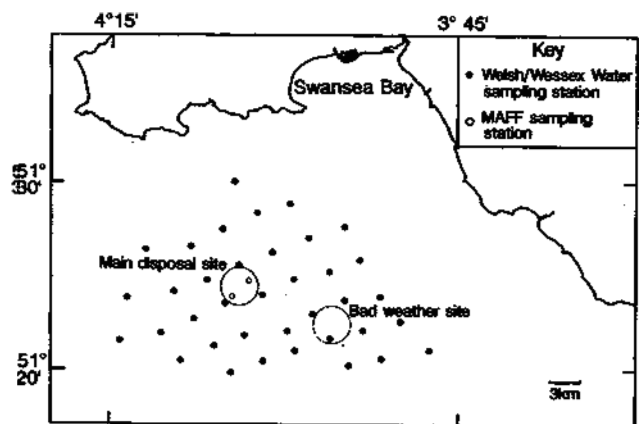


Figure 37. MAFF and Welsh/Wessex Water surveys of the Bristol Channel sewage-sludge disposal site, September 1993

5.10 Welsh/Wessex Water surveys of the Bristol Channel sewage-sludge disposal site, September 1993

- (a) Sediment samples were collected by Day grab at the stations shown in Figure 37.
- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <math><63 \mu\text{m}</math> fraction of the surface 0-1 cm of the samples. Organic carbon and total nitrogen were also determined in these samples.
- (c) Benthic infauna were identified and enumerated in samples from a selected number of these sites.
- (d) PCBs and pesticide residues were determined at 6 sites.
- (e) Samples were collected from the transect sites shown in Figure 38.
- (f) Metals, carbon and nitrogen were determined in these samples.
- (g) Benthic infauna were identified and enumerated in these samples.
- (h) The Microtox test was applied to sediment samples from all transect stations plus selected stations shown in Figure 37.
- (i) Trawls were carried out at three sites across the main grid for the assessment of litter.

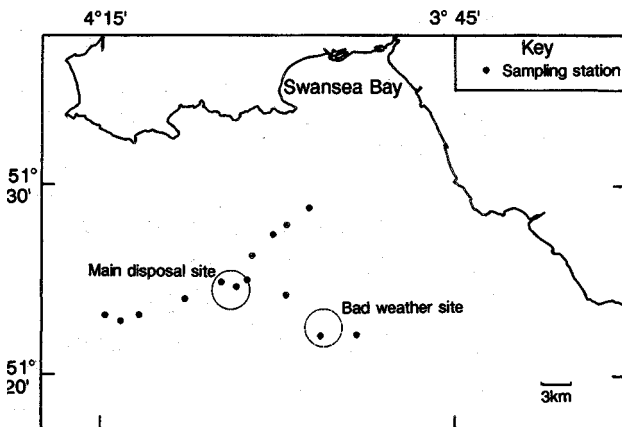


Figure 38. Welsh/Wessex Water transect survey of the Bristol Channel sewage-sludge disposal site

5.11 MAFF survey of the Liverpool Bay sewage-sludge disposal site, May and September 1993

- (a) Sediment samples were collected by Day grab from the stations shown in Figure 39(a)
- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <math><90 \mu\text{m}</math> fraction of the surface 0-1 cm of the sediment.
- (c) A 2 m beam trawl was deployed at the three, stations shown in Figure 39(a) and the samples assessed for litter content. These samples formed part of a litter survey at sewage-sludge disposal sites.

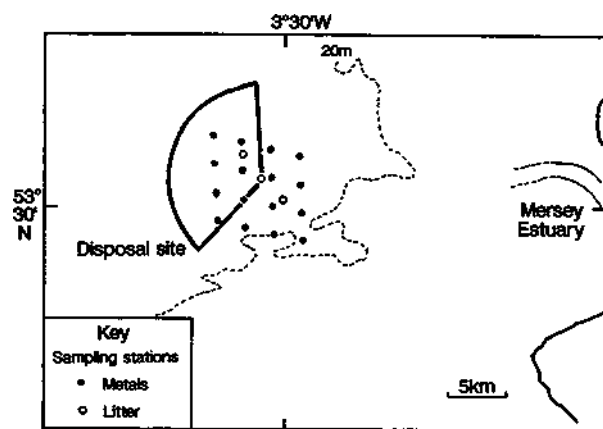


Figure 39(a). MAFF survey of the Liverpool Bay sewage-sludge disposal site, 1993

5.12 North West Water survey of the Liverpool Bay sewage-sludge disposal site, 1993

- (a) Sediment samples were collected from the sites shown in Figure 39(b).

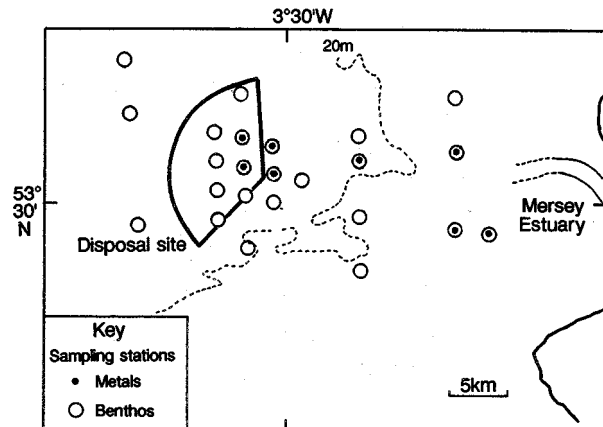


Figure 39(b). North West Water survey of the Liverpool Bay sewage-sludge disposal site, 1993

- (b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <math><90\ \mu\text{m}</math> fraction of the surface 0-1 cm of the sediment.
- (c) Samples for the identification and enumeration of benthic infauna, were collected from 8 of the sites shown in Figure 39(b) and in addition from 2 reference and 2 treatment sites using mini grids of 7 foci.
- (d) Sediments from 11 of the metal sites were analysed for PCBs.

5.13 DoE (NI) survey of the North Channel sewage-sludge disposal site, 1993

- (a) Sediment samples were collected from the sites shown in Figure 40. Site F11 was not sampled due to operational constraints. The majority of sites were sampled with a 0.1 m² stainless steel Day Grab. The following sites were sampled by a pipe dredge due to the nature of the seabed (F3, F6, F8, F9, M7, M9 M10, M11).
- (b) Faecal bacteria (*E. coli*, group D faecal streptococci and *Clostridium*) were enumerated in surface scrapes of the sediment at all the sites sampled.
- (c) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <math><63\ \mu\text{m}</math> fraction of the surface 0-1 cm of all the F sites.
- (d) CHN values were determined for all the sites sampled. Trace organics and particle size analysis were also determined at these sites.
- (e) Benthic infauna were identified and enumerated in three replicates from each F sampling site, sieve size 0.5 mm. The numbers of tomato pips were also recorded.
- (f) A towed sledge video survey of the disposal site and surrounding area was conducted during August 1993. No sewage derived objects were observed during a survey of an estimated 6600 m² of seabed.

5.14 Scottish Marine Biological Association/Strathclyde Regional Council survey of the Garroch Head sewage-sludge disposal site, May 1993

- (a) Sediment samples were collected at the stations shown in Figure 41.

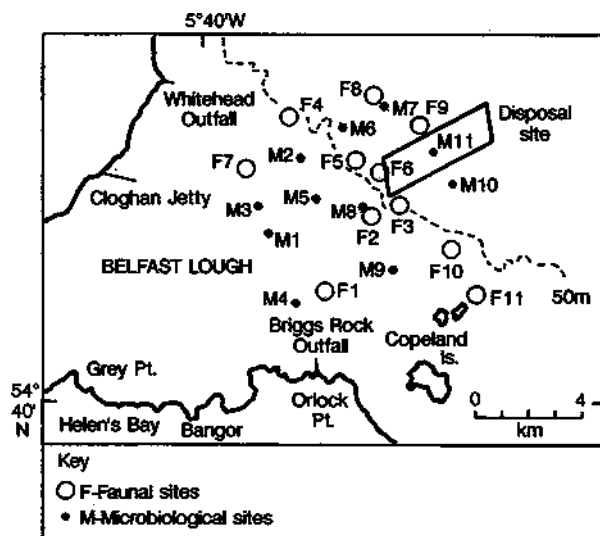


Figure 40. DoE(NI) survey of the North Channel sewage-sludge disposal site, April 1993

- (b) Dissolved oxygen was determined in the water immediately above the sediment surface.
- (c) Metals, (As, Cd, Cr, Cu, Fe, Hg, Ni, Pb and Zn) were determined in whole samples of the surface 0-1 cm of the sediment. Carbon, nitrogen, PCBs and pesticide residues were also determined in these samples.
- (d) Eh and pH measurements were made on core samples from all sites, at 1 cm intervals to a maximum depth of 10 cm.
- (e) Two grab samples were collected from each of eight stations and sieved on a 1 mm mesh. Benthic infauna were identified and enumerated.
- (f) Otter trawls were deployed at two stations. Epifauna will be identified to species level and enumerated.
- (g) Histopathological and microbiological investigations will be carried out on fish collected from the trawls.

5.15 Scottish Office Agriculture and Fisheries Department (SOAFD) survey of the Garroch Head sewage-sludge disposal site, 1993

- (a) Samples of plaice were collected for organic contaminant analyses, as a supplement to existing temporal trend monitoring programmes. This project will continue in future years.

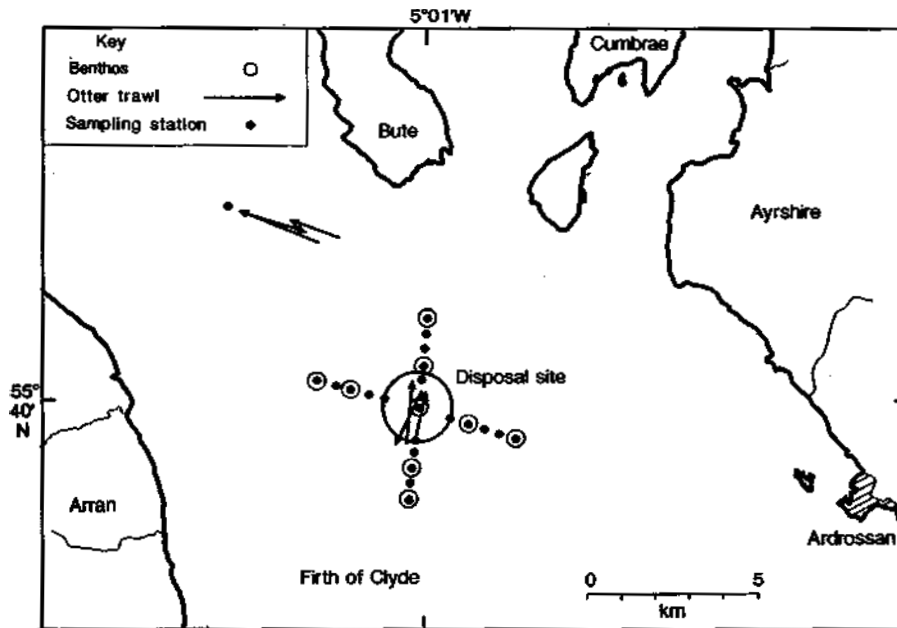


Figure 41. Scottish Marine Biological Association/Strathclyde Regional Council survey of Garroch Head sewage-sludge disposal site, April 1993

5.16 Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1993

- (a) Sediment samples were collected from the stations shown in Figure 42.
- (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, 27, 23 and 25, for the enumeration of macrobenthos, fruit pips and faecal bacteria (group D faecal streptococci).

- (d) Sediment samples from stations C, 1, 3, 9, 11, 13, 15, 23, 25, 27 and 29 were analysed for organochlorines (HCB, aldrin, α -HCH, β -HCH, dieldrin, ppDDT, ppTDE, ppDDE and PCB).
- (e) Aggasiz trawl samples were taken at stations C and 13, for the identification and enumeration of fish species. Adult fish were examined for lesions, histopathology and microbiology.

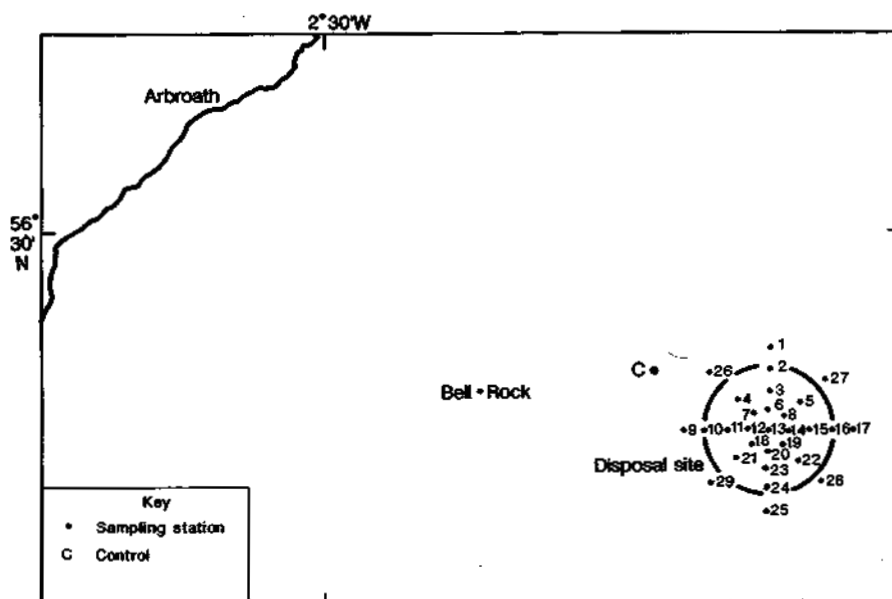


Figure 42. Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1993

5.17 Scottish Office Agriculture and Fisheries Department (SOAFD) survey of the Bell Rock sewage-sludge disposal site, 1993

- (a) Forty-two sediment samples were collected, twenty nine for heavy metal analysis and thirteen for faecal coliforms, faecal streptococci and *Clostridium perfringens* spore determinations. At the Bell Rock reference site four samples were collected for the same analyses and determinations.
- (b) Sea water samples were collected from three discrete depths at 11 sampling stations (including a control station) for suspended solids measurements and enumeration of faecal coliforms and faecal streptococci. In addition, at each station, vertical transmissometer profiles and echosounder studies were undertaken.
- (c) Samples of two fish species were collected for heavy metal analyses.

5.18 Forth River Purification Board/Lothian Regional Council survey of the St Abbs Head sewage-sludge disposal site, June 1993

- (a) Sediment samples were collected from the stations shown in Figure 43.

- (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, β -HCH, dieldrin, ppDDT, ppTDE, ppDDE and PCB).
- (e) Other trawl samples were taken at stations C and 13 for the assessment of fish diseases.

5.19 Scottish Office Agriculture and Fisheries Department (SOAFD) survey of the St Abbs Head sewage-sludge disposal site, 1993

- (a) A total of 4342 common dab from the St Abbs Head and Bell Rock disposal sites and the relevant reference areas were examined for disease by standardised ICES methods (ICES, 1989(b)). Similarly, 353 cod, 715 haddock and 398 herring were sampled for disease examination.
- (b) Seventy four sediment samples were collected, 35 for heavy metal analysis, 26 for particle size analysis and 13 for faecal coliforms, faecal streptococci and *Clostridium perfringens* spore determinations. At the St Abbs Head reference site, four sediment samples were

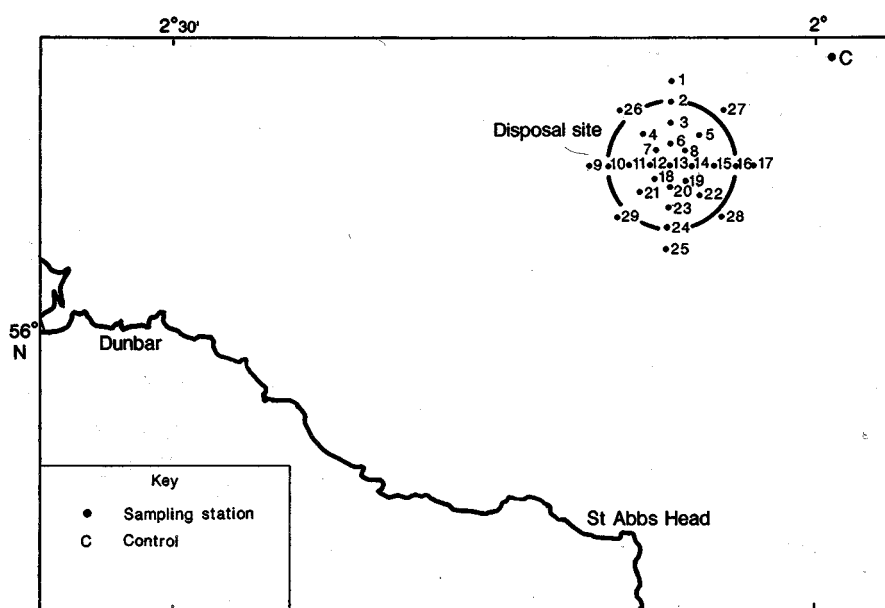


Figure 43. Forth River Purification Board/Lothian Regional Council survey of the St Abbs Head sewage-sludge disposal site, June 1993

collected for the same analyses and determinations.

- (c) Samples of three fish species were collected for heavy metal analyses.
- (d) Sea water samples were collected from three discrete depths at 10 sampling stations (including a control station) for suspended solids measurements and enumeration of faecal coliforms and faecal streptococci. In addition, at each station, vertical transmissometer profiles and echosounder studies were undertaken.

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ANNEX 1. DEFINITIONS OF EQOs AND EQSs

A1. Environmental quality objectives for sewage-sludge disposal sites: definitions

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

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

A2. Environmental quality standards for sewage-sludge disposal site: 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
Fish disease		No significant increase in prevalence 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
	Outwith the zone of immediate effect	Water quality
Benthic fauna		No deviation from control sites

A3. Environmental quality objectives for dredged material disposal sites: definitions

The following EQOs are proposed by the GCSDM for dredged material disposal sites:

Use	Objective	Notes
A3.1 Coastal zone maintenance	As a consequence of the dredged material disposal, the coastline should not be more or less subject to coastal erosion than previously	This assumes that under most circumstances the existing coastline is to be maintained. Occasions may arise where coastal nourishment is regarded favourably (in which case disposal would be regarded as ‘beneficial use’)
A3.2 Amenity use	Dredged material disposal should not result in changes to the nature of a nearby bathing beach, nor should recreational diving, other water contact sports, nature conservation or sites of historical interest in nearby areas be affected by increased turbidity or siltation. Extraneous material e.g. wires, cables, scrap iron etc. should not be allowed to litter the seabed	
A3.3 Navigational use	The dredged material should not be deposited near to or in areas where navigational use would be prejudiced	This implies no major physical change in the nature of the seabed and no diminution of the suitability of the product for human consumption
A3.4 Fishing	There should be no interference with normal fishing activity, and the quality of the product in terms of safety for human consumption should not be adversely affected	This implies no major physical change in the nature of the seabed and no diminution of the suitability of the product for human consumption
A3.5 Protection of commercial species	Preservation of the general well-being of commercially exploited species	Probably little different in practice to Use A3.6
A3.6 General ecosystem conservation	Outwith the immediate deposition zone aquatic life should not be adversely affected and the ecosystem should be typical of coastal water of similar physical characteristics and latitude	This includes avoidance of import of pest species and disease and excludes change if it is regarded as beneficial
A3.7 Preservation of the natural environment	Outwith the immediate disposal zone the quality of the environment should be indistinguishable from that of the adjacent estuarine or marine environment	This requirement stems from North Sea Conference agreements. In practice it will be little different to Use A3.6

A4. Environmental quality standards for dredged material disposal sites: definitions

It is not possible at this stage to assign numerical standards in all cases. Accordingly, the GCSDM has listed the criteria and the basis on which the standards are expected to be judged.

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

<u>EQO</u>	<u>Criteria</u>	<u>Basis of Standard</u>
A4.1 Coastal zone maintenance	Position Mean High Water Spring Tide (MHWST) and nature of shoreline	No significant change
A4.2 Amenity use	Turbidity	No significant increase
	Siltation	No siltation cover of seabed artefacts/wrecks
	Litter	No material extraneous to seabed material to be deposited
A4.3 Navigational use	Depth	Depth of water in navigable/ navigated areas to be within defined limits
A4.4 Fishing	Seabed	Trawl grounds not to be physically altered/obstructed
	Microbiological contamination	Measured levels in the product to be below those prescribed public health authorities/MAFF and EC legislation
	Chemical contamination	Measured levels in the product to be below prescribed limits
A4.5 Protection of commercial species	Water column and benthic habitat	No significant siltation of habitat and no toxic effects from dredged material
	Fish disease	No significant increase in prevalence compared to normal
A4.6 Ecosystem maintenance	Benthic diversity	Deviation from control site(s) to be within normal limits
<u>AND</u>		
A4.7 Protection of the environment	Water quality	Dissolved oxygen levels not to be significantly suppressed and toxic substances not to be released into water column at harmful concentrations
	Sediment texture and quality	No significant change in grain size distribution. No toxic effects on benthic species. No persistent increase in concentration of contaminants.
	Benthic fauna	No deviation from control sites

ANNEX 2.MEMBERSHIP OF THE GCSDM IN 1993

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ANNEX 3.TASK TEAMS AND THEIR MEMBERSHIP IN 1993

Metals

Dr S M Rowlatt (Chairman)
MAFF

Dr I Davies
SOAFD

Mr E Donaldson
Department of Economic Development (NI)

Dr D Harper
Forth River Purification Board

Dr P Head
North West Water Ltd

Mr J Webster
Lothian Regional Council

Dr J Towner
EAG Ltd

Mr B Miller
Clyde River Purification Board

Dr S Blake
WRc

Benthos

Dr H Rees (Chairman)
MAFF

Mr I Codling
WRc

Dr S Hull
Forth River Purification Board

Dr M Elliot
University of Hull

Mr D Moore
SOAFD

Mr J Pomfret
Analytical and Environmental Services Ltd

Dr T Pearson
Scottish Environmental Advisory Services

Mr I Rees
University College of North Wales

Dr M Service
DANI

Dr J Cotter
MAFF

Mr N Shillabeer
ICI (Brixham Laboratory)

Dr R Warwick
Plymouth Marine Laboratory

T Mercer
NRA Northumbria

Organics

Dr I Ridgway (Chairman)
Forth River Purification Board

Mr C Allchin
MAFF

Dr B Crathorne
WRc

M Cunningham
Strathclyde Regional Council

Mr E Donaldson
Department of Economic Development (NI)

G Firth
NRA Yorkshire Region

Dr A Kelly
SOAFD

Mr R Law
MAFF

Mr H Rogers
WRc

Mr M Tombs
North West Water plc

Mr J Webster
Lothian Regional Council

Mr D Yeoman
Strathclyde Regional Council

Sediment Bioassay

Dr B Roddie (Chairman)
ERT

Mr J Thain
MAFF

Dr R Stagg
SOAFD

R Fleming
WRc

Mr G Whale
Shell Research

P Hale
IRTU (NI)

J Redshaw
CRPB

Dr S Rowlatt
MAFF

Comprehensive Studies

W Halcrow (Chairman)
Forth River Purification Board

I A Jack (Secretary)
Forth River Purification Board

S Malcolm
MAFF

R A Milne
NRA - Welsh Region

P C Nicholas
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H Rees
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