ISSN 0142-2499

AQUATIC ENVIRONMENT MONITORING REPORT
Number 25

Second Report of the Marine Pollution Monitoring Management Group's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites

MAFF
Directorate of Fisheries Research
Lowestoft, 1991

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

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LOWESTOFT
1991

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Aquat. Environ. Monit. Rep., MAFF Direct. Fish Res., Lowestoft, (25): 39 pp.

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FOREWORD

This, the second report of the Co-ordinating Group on the Monitoring of Sewage-Sludge Disposal Sites (CGMSD), describes the progress made by the Group during 1989.

The Group was established in 1987 when, following a review of existing monitoring, it had become apparent to the Marine Pollution Monitoring Management Group (MPMMG) that UK effort and resources, applied to scientific investigations and monitoring of the impact of sea disposal of sewage sludge, were unco-ordinated and contained many inconsistencies.

The Group's first report addresses these problems directly and contains a set of environmental quality objectives (EQOs) with the appropriate environmental quality standards (EQSs) which have common applicablity and represent good technical and environmental practice.

That first report also provides details of procedures to be followed when conducting monitoring of fish diseases, certain microbiological components, benthic community structure, metals in sediments and a number of method-determined sampling and analytical procedures. This report continues with this theme of guidance and includes details of procedures for biological effects studies that can be used to provide evidence of deterioration in environmental quality as a consequence of sewage-sludge disposal. The report also provides details of the progress made in 1989 in defining EQSs for some of the EQOs which are more difficult to quantify.

An assessment is made of the results of monitoring conducted in 1988 and the extent to which these results can be used to meet the desired goals of monitoring methods in the final report. Details are also given of the monitoring of sewage-sludge disposal sites, carried out during 1989 by the various licensees operating throughout the UK and by the licensing authorities (DAFS(now SOAFD*)/DoE(NI)/MAFF).

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EXECUTIVE SUMMARY

This is the second report to be produced by the Marine Pollution Monitoring Management Group's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites (CGMSD). The Group is charged with giving advice on procedures to be adopted in a co-ordinated programme of monitoring of sewage-sludge disposal sites and with reviewing the extent to which that advice is successfully applied.

This report contains a brief general introduction (Section 1) which outlines the events leading to the establishment of the CGMSD and its terms of reference. This is followed by an outline of the activities of the CGMSD and its various task teams (Sections 2 and 3). Section 4 of the report reviews the results of monitoring conducted in 1988 and compares the procedures against those advocated by the CGMSD and the extent to which the results demonstrate compliance with the environmental quality objectives (EQOs) and standards (EQSs) established by the CGMSD. Section 5 provides a summary of the work undertaken at the various sewage-sludge disposal grounds in 1989 by both licensees and licensing authorities.

The report recognises that monitoring programmes need to maintain a certain degree of continuity and that the first set of recommendations from the CGMSD were only published late in 1989. It would therefore be unreasonable to expect that disposal ground surveys carried out in 1988, or even in 1989, would fully comply with recommendations of the CGMSD. Nor would they necessarily have been directed at the particular objectives and standards proposed in the first report. Indeed, advice on certain techniques and standards is still being generated. Nevertheless, it is apparent that the CGMSD has already had an impact on programmes conducted in 1988 and that the results of the 1989 programme should be more directly capable of comparison with established EQSs than has previously been possible.

In the context of further defining EQSs, work is still in progress on the definition of acceptable levels of change in benthos and contaminant levels in sediments. Sub-sections 3.2 to 3.4 of the report describe the approaches being taken and the outcome, at least initially, seems likely to be based on what level of change is detectable. Such a position would be consistent with present public perceptions that the disposal of sewage sludge should not cause a detectable impact.

As was to be expected, some deficiencies in the techniques used in the monitoring carried out in 1988 are apparent when judged against the objectives defined by the CGMSD. For example, several past programmes featured inadequate replication of samples to permit statistically valid time trend analysis, despite the fact that the stated aim of the studies was to detect change. These deficiencies do however serve to illustrate the need to improve techniques according to the guidelines published in the CGMSD's first report. They also serve to identify certain confusions as to sampling practices, e.g. the permissible mesh-size of fishing nets used specifically for research purposes.

Given these problems, it is difficult to draw many firm conclusions from the 1988 results in relation to the EQOs and EQSs proposed in the 1989 report of the CGMSD. However, it is clear that the health of the ecosystem and quality of the environment is acceptable at all disposal sites. Marked effects are apparent only at the Garroch Head site because this is recognised as a disposal site with only limited dispersion. Even at this site, there are no unacceptable effects outwith the mixing zone. The quality of commercially exploited fish caught on, or close to, the disposal grounds is acceptable in terms of contaminant levels for human consumption and there is no evidence that fish are more diseased in these areas than elsewhere. There is a clear need to maintain continuity of programmes and not to change survey systems without good cause, and certainly not without intercomparison with earlier approaches. Several studies in the past exhibited a marked lack of consistency. The only major effect identified was pin-pointed by surveys at several grounds and was directly attributable to litter. The CGMSD considers that the quantity and presence of litter reported at several UK disposal grounds is unacceptable in terms of the aesthetic EQS. The situations are being investigated and, where it is appropriate, steps will be taken to rectify the problems arising from sludges.

1. INTRODUCTION

In 1985, following a review of monitoring, as it was then conducted at the various sewage-sludge disposal sites around the UK, the Marine Pollution Monitoring Management Group (MPMMG) concluded that proper monitoring goals needed to be specified and that standards were required against which it would be possible to assess whether or not detectable effects were occurring and whether they were acceptable. In order to achieve this task and to co-ordinate monitoring so far as practicable, it was agreed that a Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Grounds (CGMSD) should be established. Following discussions with the then Water Authorities Association, and others, the CGMSD met for the first time on 3 September 1987 with the following terms of reference:

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

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

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

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

(v) to advise on responses to technical issues arising at the Conventions;

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

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

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

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

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

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

The CGMSD published its first report in the autumn of 1989 (MAFF, 1989) and although this did not include results of monitoring conducted in 1987, for a variety of mainly administrative reasons, it did include a summary of the monitoring investigations conducted at the various sewage-sludge disposal sites around the UK in 1988. More importantly, it specified for the first time a set of common EQOs and defined a set of EQSs by which fulfilment of the objectives could be judged. Equally importantly, the report included detailed guidelines on how monitoring should be carried out for method-determined parameters such as organic carbon and Eh, for microbiological determinands useful as an indicator of the initial fate of sludge, and biological determinands. In the latter case, the emphasis was on techniques for assessing the impact on benthos and the numbers of diseased fish in a particular area relative to control sites. Details were also provided on the methods to be followed for monitoring metals in sediments from sewage-sludge disposal sites.

It will be noted, from the foregoing outline of the contents of the first report of the CGMSD, that organic contaminants were not considered in the first report and that the section on biological effects was restricted to two main indications of possible biological impact, viz: benthos change and diseases in fish. Work continued in these areas during 1989 and the report which follows provides details of the progress made on these and other matters related to monitoring of sewage-sludge disposal sites. Also included in the report this year is a review of the results of monitoring conducted in 1988 and a summary of monitoring carried out in 1989.

A list of members of the CGMSD in 1989 is given at Annex 1.

2. TASKS UNDERTAKEN BY THE CGMSD IN 1989

2.1 General activities

From the start, the CGMSD was intended to be a group which advises on policy and, where the advice is adopted, demonstrates, through its reports, how the advice is being implemented. As such, it was expected that some of the detailed work of defining procedures for monitoring would have to be undertaken by specialist task teams. This has in fact proved to be a very successful mode of operation and most of the detailed guidance on monitoring methods published in the first report was produced by specialist task teams working under the general guidance of the CGMSD. This practice has continued during 1989 with specialist task teams undertaking the following investigations:

(i) examining the methods available for assessing biological effects other than those affecting benthic species structure and fish diseases and advising on those that currently appear suitable for adoption in monitoring at sewage-sludge disposal sites;

(ii) advising on suitable standards by which the acceptability of benthos change can be assessed;

(iii) advising on suitable standards by which the acceptability of change in the levels of metals in sediments can be assessed and conducting an appropriate series of intercomparison exercises aimed at establishing comparability of data for concentrations of metals produced by different groups involved in monitoring; and

(iv) describing the methods to be used for measuring organic chemical contaminants in the marine environment, with special emphasis initially on sediments.

In the course of 1989, the CGMSD met on three occasions to review progress by its task teams, to plan its future activities, and to discuss ways in which itself, its task teams or its parent group (the MPMMG) should respond to external initiatives and pressures.

The work of the CGMSD during 1989 and the first two months of 1990 was conducted against a background of well-orchestrated, but generally ill-founded, criticism of the use of the sea for disposal of wastes generally, but particularly the disposal at sea of industrial wastes and sewage sludges. Whilst it is not part of the CGMSD's role to examine the availability of alternative disposal routes, the CGMSD is aware that, at least for some of the larger conurbations, establishing alternatives will not be easy. This is because sludge disposal strategy and the location of sewage treatment works has been planned with sea disposal as a viable outlet. Accordingly, the CGMSD has operated, and will continue to operate, on the basis that its remit is to establish the impact which sewage-sludge disposal at sea has on the marine environment. The CGMSD will not hesitate to draw attention to any failures in compliance with objectives or standards. Equally, the CGMSD reports will, if appropriate, record the fact that standards are met and that there is a lack of adverse effects. This position is not affected by the UK Government's decision to phase out sewage-sludge disposal by 1998. Rather, the continuation of the CGMSD and its activities is seen as an essential component of defence against continued criticism of sewage-sludge disposal at sea, in the short term. Continuation of the work is also considered desirable in the event that, should the longer-term alternative sludge disposal strategies prove defective, attention could once more turn to sea disposal. If at some stage this course were followed, the results of studies of long-term sewage-sludge disposal operations, particularly if continued after cessation, will be extremely useful.

To this end, the CGMSD has continued to pursue its initial guiding principle that, wherever possible, common goals should be met at all sites and that procedures used for monitoring for a particular purpose should be harmonised. It is of course recognised that different sewage-sludge disposal sites have different characteristics and that these have to be allowed for in the adopted procedures. Thus, for example, it is considered pointless to advocate detailed grab surveys and analysis of sediment particle size structure and meiofauna for an area of hard ground. Nevertheless, it is considered that for most purposes common objectives can be set, even if the standards by which compliance is judged differ according to local circumstances. The task teams have been requested not to seek to promote single common methods except where this is essential to ensure comparability in that which is actually measured. The overall aim of harmonisation is to produce reliable and comparable data, preferably between different sites, but particularly at a single site. The CGMSD is also actively seeking to ensure that all monitoring conducted at disposal sites is justifiable in relation to the defined objectives. Thus Section 4 of this report assesses the results of monitoring in 1988 with this goal in mind. However, in this context, it must be noted that, as the CGMSD only commenced working late in 1987 and its first report was not widely available until late in 1989, criticism of work carried out in 1988 relates essentially to a pre-CGMSD era. In future reports, such criticism should be less frequent on monitoring conducted in 1989, and especially from 1990 onwards.

2.2 Activities undertaken at the direct request of the MPMMG

In the course of the year, the CGMSD was called upon by its parent group (the MPMMG) to advise on the content of a proposed report by Greenpeace on Dumping Sewage Sludge at Sea (internal document). After detailed examination of the report, the CGMSD concluded that it gave a good and fair summary of the situation and what had been published, so far as the type of monitoring and the results obtained were concerned. The conclusions as to impact were however considered somewhat speculative and unsupported by the sort of detailed field and laboratory investigations which the report itself suggested should be carried out. The CGMSD considered that the report's proposals for the direction which future monitoring should take were constructive but concluded that, with one exception, investigation of phytoplankton blooms, all were being addressed either by the new forms of monitoring proposed in the CGMSD's first report or were under consideration by the task teams for future proposals. These issues relate to pathogens, bioassays for organic micropollutants, fish diseases and far-field effects. The CGMSD considered that an investigation of phytoplankton blooms related to sewage-sludge disposal could only be considered in relation to the occurrence of phytoplankton blooms in general. The MPMMG has since accepted this view and has established a small group to recommend a common reporting procedure with a view to obtaining more comprehensive data on temporal and spatial occurrences of blooms.

In accepting the report of the CGMSD and its Benthos Task Team, the MPMMG noted a number of proposals for future activity and sought advice on whether these were essential and/or would be practical. After further consideration, the CGMSD decided to recommend as follows:

(i) Provision of an updating service for taxonomic information. There is clearly a need for such a service and in the long term it was felt that it might be undertaken by the Plymouth Marine Laboratory. In the shorter term, the task would be undertaken, on a relatively informal basis, by the Association of Directors and River Inspectors of Scotland (ADRIS) Group.

(ii) Intercalibration for identification of the benthos. This is clearly linked to the updating of taxonomic information and is essential for data comparability. The value of existing taxonomic workshops was recognised but the CGMSD felt that the licensing authorities could do more to promote such workshops, to encourage interlaboratory comparisons, and to set quality control targets as part of conditions set out in the disposal licence. The Benthos Task Team has been asked to initiate an intercomparison exercise as soon as practicable.

(iii) The Benthos Task Team had proposed the establishment of a common coding system for benthos. This is considered to be a desirable goal and it is expected that a recommendation on a common coding system will be made in 1990.

(iv) The Benthos Task Team had proposed that the use of less intensive techniques should be evaluated and the CGMSD agreed that a developmental exercise be undertaken. This in fact has been taken up by the task team in 1990, and a recommendation will arise from this work. The approach appears to show considerable promise.

(v) The Benthos Task Team had suggested there was a need for an evaluation of the usefulness of epifaunal sampling. The CGMSD felt that the licensing authorities themselves had sufficient experience to be able to advise on the types of situation where such studies would be appropriate and, in those cases, on how to carry out the work. The Benthos Task Team is undertaking a further review of sampling methods in 1990.

(vi) A proposal had been put forward that a computer-based package for data analysis be introduced. The CGMSD confirmed that this would be a desirable goal and that ideally a single type of package should be used in all cases.

(vii) The CGMSD had charged the Benthos Task Team with the issue of proposing standards by which to judge compliance with the objectives of maintenance of the ecosystem and preservation of the marine environment. The task team subsequently had suggested that this would not be possible without considerable research effort. However the CGMSD considered that it would be practicable to define the limits above which change is clearly detectable and not acceptable; the task team has been giving active consideration to this. A report is expected during 1990 and details will be included in the next report of the CGMSD.

3. PROGRESS BY THE TASK TEAMS

A list of the various task teams (and their membership) operating in 1989 is given at Annex 2.

3.1 Biological effects

In recent years, considerable attention has been paid to the possibility that marine organisms might be adversely affected by sub-lethal concentrations of contaminants but that these effects would go undetected by the currently used studies on biological effects. Several techniques have been proposed for detecting sub-lethal effects and the CGMSD established a specialist task team to examine this applicability to the assessment of the impact of sewage-sludge disposal at sea. The task team was asked specifically not to advise on the tests which were available but on those that would give results, interpretable in relation to the specified objective — maintenance of an essentially unchanged ecosystem in the disposal area.

The task team made good progress during 1989 and produced a comprehensive review of the situation and a set of recommendations as to which tests might be applied at that time or which might be applicable in the reasonably near future. Several tests were initially considered in detail. Of these, the oyster embryo test and that of feeding rate in *Mytilus* were considered to be immediately applicable. Four more types of test (zooplankton tests, 'Microtox' test, planktonic algae tests and a polychaete enzyme activity test) were considered to need further proving trials but to be worth recommending with that proviso. The remainder were considered to be unsuitable for selection, with three types of test specifically being advised against at this stage (fish egg and fish larvae tests, the hydroid test, and tests using infaunal invertebrates other than the polychaete enzyme activity test).

An outline of the conclusions of the task team and the basis for them is provided in Annex 3. The full report has been published separately in MAFF's Aquatic Environment Monitoring Report series (MAFF, 1990(a)) and includes draft protocols for conducting the selected tests.

3.2 Standards for determination of change in the benthos

As outlined in Sub-section 2.2 (point vii), in response to a request by the CGMSD for definition of a standard against which to judge compliance with maintenance of the ecosystem /preservation of environmental objectives, the Benthos Task Team had suggested that a research programme would be required. The CGMSD accepted that in order to define such change accurately, and in a strictly scientific way, some research effort would be necessary. However, the CGMSD did consider that, from a practical standpoint, it should be possible to define limits to the detectability of change and concluded that a newly constituted task team should be asked to do this. A Benthos Task Team with revised membership was duly formed. As a starting point for discussion, the CGMSD suggested a standard of a 20% change in biomass and/or diversity as this might indicate a level of change that would be both detectable and probably unacceptable. The task team is considering this and confidently expects to produce a report in 1990.

3.3 Monitoring of metals

The first report of the CGMSD (MAFF, 1989) included, at Annex 6, recommendations for the procedures to be followed for sampling and analysis when monitoring the levels of metals in sediments on sewage-sludge disposal grounds. Annex 6 also includes details of a three-stage intercomparison exercise planned by the specialist task team which was established to consider matters related to monitoring of metals. Progress with this intercomparison programme was seriously affected by the privatisation of the water industry and no real headway was made. The exercise aims to assess the comparability of sieving techniques by different laboratories, comparability of digestion procedures, with analyses of all digests by one laboratory and, finally, comparability of the results of sieving, digestion and analysis by the individual laboratories. Only the first of these aims was completed in 1989. The results showed good intercomparability for the standard sediment sample, regardless of whether plastic or metal sieves were used. The task team are however continuing to recommend the use of plastic sieves to eliminate the possibility of metal contamination. Plans for the next two phases remain valid and it is hoped that further progress will be made in 1990.

Meanwhile, the CGMSD has charged the task team with producing suitable standards against which to judge the acceptability of levels of metals in sediments in sewage-sludge disposal areas. Work on this aspect is, as yet, incomplete but is being approached on two fronts. The first attempts to establish levels which, if exceeded, might be expected to affect benthic species adversely. Such a set of standards is clearly desirable but progress will involve assessing that fraction of the metals which are biologically available and/or significant. Recognising these difficulties, the second approach attempts to assess the degree of change in levels of metals in sediments which can be measured with confidence, taking account of spatial and analytical variability. It is expected that the task team will report in 1990.

3.4 Monitoring of organics

The CGMSD recognised at an early stage the need to harmonise approaches to monitoring of organic contaminants in sewage-sludge disposal areas. However, recognising the uncertainties over the contaminants which would be of interest and the doubts about levels actually present in sludges, the CGMSD decided to delay establishing a task team to examine the key issues, at least until the basic groundwork for objectives had been set by the CGMSD and by the Methods-Determined Parameters Task Team for organic carbon in sediments. This groundwork was completed in 1988 and details were included in the first report of the CGMSD (MAFF, 1989). Accordingly, a specialist task team to advise on organic micro-pollutants was established early in 1989. It was charged initially with developing detailed advice on methods of sampling and analysis of organic micro-pollutants in sediments and, on completion of this task, with organising and conducting any intercomparison exercises that might be necessary.

The task team met on two occasions during 1989 but, as with the Metals Task Team, progress was seriously affected by privatisation of the water industry. After some uncertainty as to the organic micro-pollutants to be considered, the task team has been concentrating attention on those of direct interest to the Oslo and London Commissions and the licensing authorities. The substances identified for priority treatment were PCBs (for the time being quantified as Aroclor 1254 pending demonstrated capability by most laboratories to determine individual chlorobiphenyl congeners) α, β and γ HCH, HCB, DDT and its main metabolites TDE and DDE, and dieldrin. In addition, where common methodology allows, attention will be paid to 'Red List' substances (DoE, 1990): the opportunity for this is expected to be limited.

The task team has decided to make the maximum use possible of existing publications and to this end is seeking to update and expand the existing Standing Committee of Analysts Methods for Examination of Waters and Associated Materials (Anon., 1985). The task team has also drawn up plans for the exchange of standard solutions of organochlorine and organophosphorus pesticides and of two standard mix solutions of PCB. The analysis of these samples is expected to be completed during the first half of 1990. It is hoped that the next report of the CGMSD will include detailed guidelines on methods to be used for sampling and analysis of the main organic micropollutants of interest to the licensing authorities.

The Organics Task Team is likely to continue its work for at least the next two years i.e. through 1991, as are the task teams dealing with metals and benthos. The CGMSD will continue to direct and co-ordinate the activities of the three task teams and will focus increasingly on the production of annual reports reviewing monitoring at sewage -sludge disposal sites. These reports will seek, in particular, to assess the extent to which the guidelines established by the CGMSD are followed and the extent to which compliance with EQOs and EQSs has been demonstrated.

4. REVIEW OF MONITORING AT SEWAGE-SLUDGE DISPOSAL GROUNDS DURING 1988

4.1 Introduction

One of the main aims of the CGMSD is to assess the extent to which programmes of monitoring at disposal sites meet the goals described in their first report (MAFF, 1989). This Section describes some examples of work carried out in 1988 and discusses the value of various techniques in fulfilling the requirements of the CGMSD. The CGMSD guidelines for analytical methodology (MAFF, 1989) were generally used in 1988. However, as some recommendations were not finalised until 1989, some 1988 surveys, particularly those which form part of a long time series, used previously established techniques.

The following discussion is arranged according to the various EQOs set by the CGMSD (MAFF, 1989); any relevant EQSs are given at the start of each section.

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

Aesthetic problems are likely to arise if floatables and sewage-sludge debris (large detrital material of sewage origin, including plastics, condoms and tampons) are present in the sewage-sludge disposal area. The CGMSD considers that the only acceptable standard is that these materials should not be found to occur in the area of disposal, either in surface trawls or in bottom trawls, dredge or grab samples. If significant evidence of such solids is found in the area of disposal, screening of the inflow effluent or the outflow sludge may have to be undertaken. Since it is conceivable that not all of the sewage-derived solids are from the disposal of sludge, the CGMSD has recommended that subsequent compliance with the standard should be checked, primarily by monitoring sludge quality at the point of loading, to ensure no retention of solids on a 5mm sieve.

Suitable measures for assessment of this EQO are turbidity and the presence of floatables and persistent sewage debris. No measurements of turbidity or floatables were reported for 1988 but observations of litter were made at the Tyne, Plymouth, Garroch Head, Bell Rock and St Abbs sites.

Litter was common in beam trawl samples collected at the Tyne site (Table 1). Much of the litter was sewage-derived and included tissue paper, tampons, sanitary towels, hair and vegetable matter (largely potato peelings and tomato skins).

Table 1. Litter collected in beam trawl samples at the Tyne sewage-sludge disposal ground, May 1988.

Station 276	Station 277
Rubber 0-ring	Nylon twine
String	Cardboard
Tissue paper (common)	Cigarette filters (common)
Sanitary towels (common)	Cellophane
Hair	Plastic wrapping
Cellophane (common)	Tampons
Cigarette butts (common)	Tissue paper (common)
Matches	Sanitary towels (common)
Vegetable matter	Silver foil
Silver foil	Hair
Plastic wrappings	Vegetable matter(common)
Tampons	Elastic bands

In contrast, samples collected at the Plymouth site (in beam trawls) contained only small quantities of litter which included no sanitary products (Table 2). Beam trawl samples taken at the Exeter disposal site also contained no litter.

At Garroch Head, observations were made on litter collected during sampling for fish using an otter trawl. It was noted that markedly fewer materials, obviously attributable to sludge disposal, were collected from trawls across the disposal site than in previous years.

Table 2. Litter collected in beam trawl samples at the Plymouth sewage-sludge disposal ground, December 1988.

Station 65	Station 69
Cigarette butts (3) Cellophane (1 piece) Plastic (1 piece) Tissue (a few pieces) Foil (1 piece)	Shoes (2) Twine Cellophane (several pieces)
Station 66	**Station 70**
String (1 piece) Cellophane (1 piece) Rag (1 piece)	String (1 piece) Cellophane (1 piece)
Station 68	**Station 71**
Cellophane (1 piece)	Electric flex (1 piece) Shoe

At St Abbs, trawls from both control and disposal sites yielded similar quantities of anthropogenic material and both contained sewage-derived material (Table 3). Anthropogenic material was also found at both the control and disposal sites at Bell Rock, although material clearly identifiable as being sewage-derived was only found at the control site (Table 4).

Grab samples and underwater video images taken at the Bristol Channel disposal site did not reveal any evidence of sewage-derived litter. It should, however, be noted that these techniques sample only small areas

Table 3. Litter collected in otter trawl samples at the St Abbs disposal site and the control site, June 1988.

	Station 13	Control
Sanitary towel	2	1
Rubber glove		1
Plastic bags	1	1

Table 4. Litter collected in otter trawl samples at the Bell Rock disposal site and the control site, April 1988.

	Station 13	Control
Sanitary towel		1
Rubber glove	1	
Cardboard	+	
Tin (Coke can)	1	
Nylon string	+	
Plastic wallet	1	
Vodka label	+	
Tyre fragments	+	•
Wooden branch	+	

+present

of sediment and could not reveal anything other than gross litter contamination.

The sensitivity of the sampling technique should also be considered in the case of trawl samples. Only large debris was collected by the otter trawls used at the Scottish sites, while finer material was sampled by the fine mesh beam trawls used at the English sites. The difference in mesh size between these two pieces of equipment undoubtedly leads to a difference in sensitivity in assessing compliance with the EQS. Fine mesh net of the type used by MAFF at the Tyne and Plymouth sludge disposal sites is preferable for the purpose of assessing litter, but special permission to use such nets must be obtained from the appropriate Government Departments (i.e. MAFF*, DAFS+ and DANI§). It should be noted that such nets should not be used in surveys conducted for the purpose of fish disease assessment as this would not be in accordance with the ICES# or CGMSD guidelines for such surveys.

Applying the standard set by the CGMSD, the data for the Garroch Head, Bell Rock and Tyne disposal sites, indicates that screening is probably necessary while at the Plymouth and Exeter sites conditions appear to be acceptable. These findings are in accordance with that which is known about the nature of the sludges produced at the works in question.

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

No data specifically relating to sewage-sludge disposal

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+ Department of Agriculture and Fisheries for Scotland
§ Department of Agriculture, Northern Ireland
 # International Council for the Exploration of the Sea

Table 5. Concentrations of mercury in fish muscle in Liverpool Bay during 1988.

Species	Number of fish analysed	Mean length of fish (cm)	Mean concentration (mg kg^{-1} wet weight)	Range of concentrations (mg kg^{-1} wet weight)	Standard deviation of data sets
Cod	25	34.3	0.17	0.06-0.27	0.04
Whiting	30	35.9	0.37	0.11-0.64	0.15
Plaice	25	30.8	0.15	0.07-0.27	0.06
Sole	24	26.9	0.15	0.06-0.31	0.06
Flounder	29	33.2	0.26	0.07-0.46	0.10
Dab	25	25.2	0.19	0.05-0.35	0.08
All fish	158		0.20*		

**Weighted mean is based on the relative contribution of each species to the 1988 commercial landings from the area.*

sites were reported, although the national monitoring programme operated by MAFF and DAFS deals with the quality of fish around the coast of England and Wales and includes disposal site areas. These data continue to indicate compliance with EC and OSPARCOM EQSs for mercury (see Table 5) and the levels of other contaminants are not such as to give cause for concern in relation to human health. Full details of the monitoring surveys for England and Wales are published periodically in MAFF's Aquatic Environment Monitoring Report series (see for example MAFF, 1990(b)), and by DAFS in their Scottish Fisheries Research report series.

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

Samples of fish from control and disposal sites were examined in the Garroch Head region. No significant differences were noted between the areas in either external or internal abnormalities of fish. Human enteric bacteria were detected in the guts of fish caught at the disposal site, though not in those at the control sites. While this indicates that sampling was undertaken in the sewage-sludge disposal area, it is not expected that the presence of such bacteria poses a threat either to the fish or to any human consumer of the fish.

At the Garroch Head site (see Tables 6 and 7) fewer than 50 fish were examined for abnormalities which are expected to be present in less than 10% of the population. Similarly, samples of fish taken at the Forth sites were also rather small for statistically valid conclusions to be drawn. However, there was no evidence that fish health was unduly compromised by contaminants derived from sewage sludge.

The main conclusion to be drawn for this work is that future sampling should be carried out in line with the

Table 6. Total fish catch at the Garroch Head disposal site, June 1988.

Fish species	Number	Size range (cm)	Gross pathology
Saithe	33	22.5-32.9	NAD
Plaice	19	14.2-22.1	One fish with severe inflammation and necrosis of tail muscle
Whiting	2	21.6-22.0	NAD
Common dab	2	15.7-19.7	NAD
Norway pout	2	16.2-20.8	NAD
Herring	2	23.6-27.3	NAD
Long rough dab	1	19	NAD
Poor cod	1	13.4	NAD

NAD = No abnormality detected.

Table 7. Total fish catch at the Clyde control site, June 1988

Fish species	Number	Size range (cm)	Gross pathology
Hake	16	12.2-19.0	NAD
Plaice	6	18.0-22.8	NAD
Saithe	3	25.0-27.8	NAD
Whiting	3	25.4-31.5	NAD
Flounder	1	29.2	NAD
Witch	1	33.3	NAD
Poor cod	1	18.8	NAD
Norway pout	1	19.0	NAD
Gurnard	1	17.5	NAD

NAD = No abnormality detected.

CGMSD guidelines (MAFF, 1989). In fact, the protocols which are now followed have been brought into line with the CGMSD guidelines, but different species may continue to be used when recommended species are not available in sufficient numbers, as at the Scottish sewage-sludge disposal sites.

4.5 EQO: Protection of the eco-system to ensure that it is typical for the type of area concerned.

The CGMSD lists three main criteria for assessment: benthic diversity, water quality and sediment quality. The CGMSD task teams are presently working on standards for benthic and sediment quality and many water quality standards already exist. This Sub-section deals with benthic communities and diversity, sediment quality being considered in Sub-section 4.6.

The benthic fauna at both the Clyde and Forth sites have been studied annually over a number of years. These investigations demonstrate the value of relative continuity in sampling design and methodology. Only by this means can natural variability begin to be understood. The matter is essentially site-specific and local, as there are no pre-defined limits which apply uniformly to all marine benthic communities around the UK coastline, because of the widely differing environmental conditions and anthropogenic influences which prevail.

Nevertheless, certain types of responses of the benthos to organic enrichment are predictable, and this is well illustrated by work at Garroch Head. Because of low-energy conditions, the local impact of sludge, as measured by a variety of techniques, is marked. Further, because of apparently limited dispersion, the gradient of response from a grossly altered fauna at the centre of the disposal area, through a transitional zone to a 'healthy' one, can be traced by means of line transects employing a limited number of stations.

A comparison of 1988 monitoring data with that of previous years (1979-1987), showed that the biomass at the centre of the disposal site was much reduced in 1988. However, beyond 2 km from the centre, there was evidence of a decline in the overall level of enrichment. This decline was tentatively ascribed to more accurate positioning of the disposal vessel at the centre of the site.

While the general pattern of highly localised effects of enrichment was identifiable in the monitoring data from all years, it is clear that the magnitude of benthic changes between years can be quite marked at individual sites. Much of this variability may be due to natural causes, and emphasises the importance of:

(i) year-on-year continuity in monitoring activities;

(ii) excepting the unlikely event of a widespread catastrophic change, the importance of *more than one year's monitoring data* for the benthos in order to establish with confidence if any trends are occurring and may be anthropogenically induced.

The results of monitoring studies at the Forth sites contrast with those at Garroch Head: this can be explained by the more recent history of sewage-sludge disposal at the Forth sites, and the dispersive hydrographic characteristics of the sites. The data on benthic infauna were analysed by a variety of univariate and multivariate statistical methods. Most of the variability was accounted for by natural factors, but there was some evidence, notably the occurrence of the 'pollution-indicator' species *Capitella capitata*, that the benthos were responding to marginal enrichment at the less dispersive St Abb's site. The study acknowledged the future need for a more rigorous analysis of time trends in the data, which in turn will require more data. Thus, for example, both studies demonstrate the importance of parallel measures of physico-chemical properties of the sediments for the interpretation of changes in the benthos.

In both studies, only two replicates for benthic infauna were taken at each sampling station. Since, in the absence of adequate replication, the early detection of subtle directional changes is difficult, especially on the periphery of sludge influence, the two replicates would not normally be considered to be adequate to detect changes with certainty. However, it is clear that the magnitude of spatial change occurring along transects at Garroch Head is very marked, at least in the central zone.

Both studies included qualitative assessment of the epifauna at the disposal ground and reference areas, though the following comments relate to studies in 1987 for Garroch Head (MAFF, 1989). Greater uncertainties exist regarding the efficiency with which the epifaunal component is sampled, a problem which is of course common to most trawl sampling procedures. However, it is clear that changes in this component match those for the infauna in response to gross enrichment (Garroch Head). Such data are valuable, because they broaden the scope of assessment of biological impact to include (*inter alia*) commercial species, and because they give a relatively rapid return on sampling effort.

Greater harmonisation in epifaunal sampling and analytical methodology is required, including a more precise definition of the species present in the epibenthic community. For example, trawl sampling cannot be considered ideal for sampling very small epibenthic crustacea such as amphipods. Neither can 'chance' occurrences of sedentary infaunal polychaetes be considered relevant in any quantitative sense.

The Garroch Head study has for some years included a 'control' (or more strictly a 'reference') site some 8 km from the centre of the disposal ground, and this appears to provide an adequate benchmark against which changes in the benthic fauna, in response to sludge disposal, and their spatial extent along station transects, can be assessed. An additional reference site was established in 1988.

All stations at the Forth disposal areas, at which infauna were sampled, fell within 2 km of the disposal site. However, as with Garroch Head, it is clear that the dispersion of sludge tracers is not uniform over all sampling stations, and hence comparisons between sites should allow the progression of any effects of enrichment (intensity and spatial extent) to be evaluated. In both cases, the onset of changes greater than those previously observed may be used as a trigger for wider geographical study.

The whole question of 'control' areas in monitoring biological effects of pollution is a difficult one, and requires greater attention in the planning of future surveys, particularly in view of the dependence of the EQS philosophy on comparative evaluation.

In biological studies, there are three issues of particular concern:

(a) the requirement for similar environmental conditions to prevail at 'treatment' and 'control' sites, so as to increase the probability that fluctuations due to *natural* causes will be in synchrony, for example, an uncontaminated inshore rock assemblage is not an ideal benchmark against which to assess changes in offshore mud populations;

(b) the presence of other anthropogenic influences which may further limit the scope for selection of 'control' sites; and

(c) detection limits.

The last is a function notably of background 'noise' and field sampling error. Despite (or in some cases because of) these constraints, many studies of 'point-source' discharges show that demonstrable effects on benthic *communities* tend to occur well within the zone of contamination defined by appropriate physical or chemical tracers, i.e. benthic communities are particularly appropriate for the identification of 'near-field' effects. Identification of changes at the individual or population levels by alternative measures may ultimately prove to be most useful as a routine for 'far-field' assessment of impact. The development of such measures, and their interface with the responses of indigenous communities, is an area of active current research. It was with this in mind that the CGMSD established a task team to look into and advise on such methods (see Section 3.1).

4.6 EQO: Maintenance of the receiving environment without distinguishable change

The CGMSD task teams on metals and organic contaminants in sediments are presently developing standards and the necessary sampling guidelines for use in assessing compliance. One of the main areas of this work will be the degree of replication required to assess spatial and temporal changes in sediments. Most of the surveys carried out in 1988 did not take into account the need for such replication.

Surveys of carbon and metals in sediments off the north-east coast of England have indicated a general decrease in concentrations offshore and relatively high concentrations around the mouth of the Tyne. These

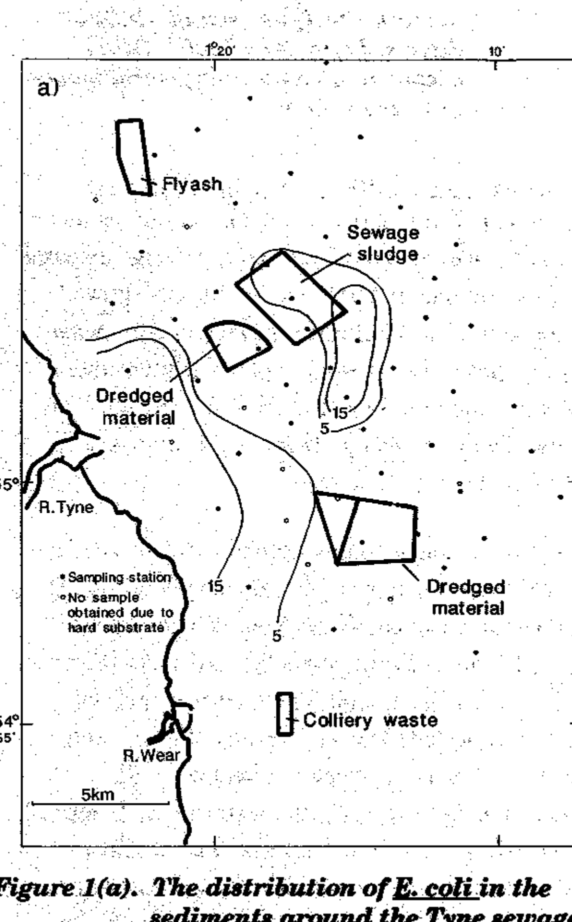

Figure 1(a). The distribution of E. coli in the sediments around the Tyne sewage-sludge disposal site, May 1988. Other disposal sites receiving solid wastes are also shown.

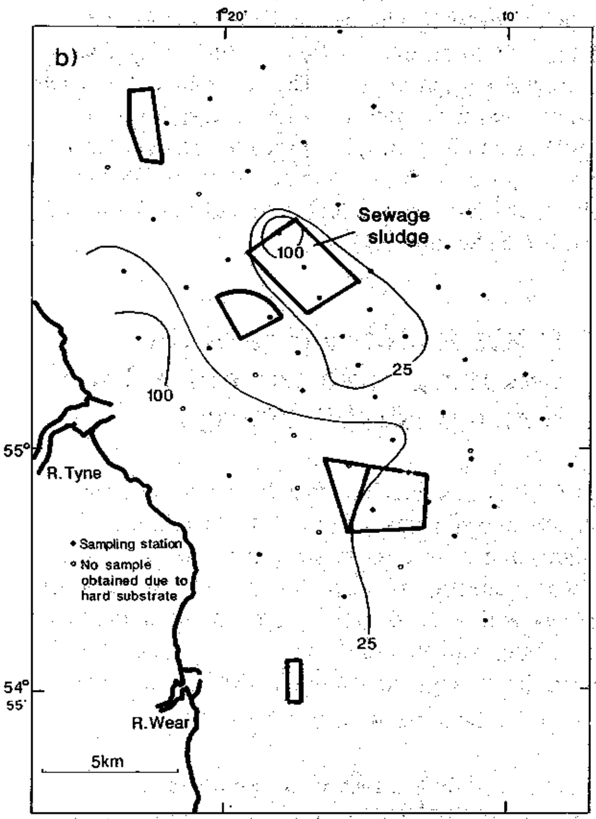

Figure 1(b). The distribution of Group D faecal streptococci in the sediments around the Tyne sewage-sludge disposal site, May 1988. Other disposal sites receiving solid wastes are also shown.

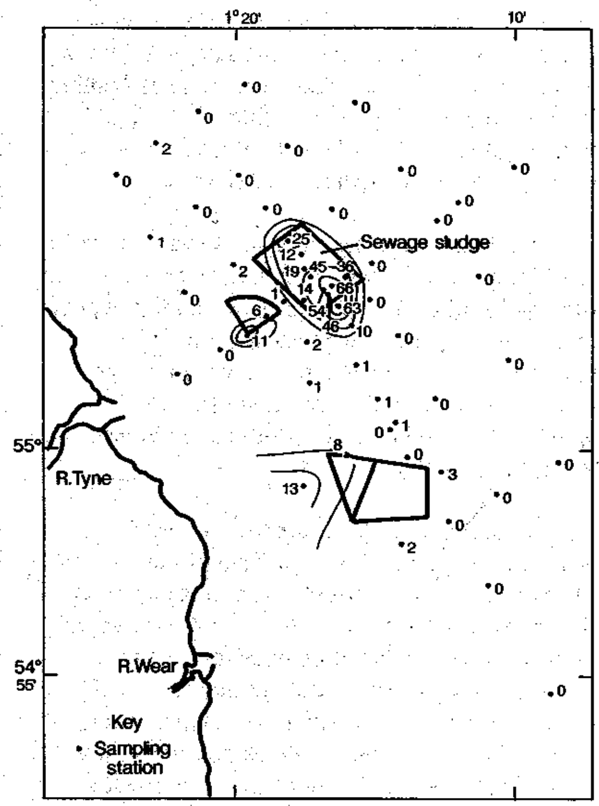

Figure 2. The distribution of tomato pips in the sediments around the Tyne sewage-sludge disposal site, March 1985.

two factors make it difficult to define a sampling transect which would give an uncomplicated picture of any contamination at the Tyne sewage-sludge disposal site. For example, if a north-south transect showed elevations in concentration in the area of the sewage-sludge disposal site, it would not be clear whether these were due to sludge or to the effects of the Tyne outflow. To avoid such problems, grid surveys have been used in subsequent years.

Surveys of sediment quality around the Tyne site have included determinations of faecal bacteria (Group D faecal streptococci and *E. coli*) and tomato pips to identify the area of sewage-sludge settlement (Figures 1 and 2) in which any build-up of carbon or metals would be expected to occur. Results of analyses for carbon and metals of samples collected in 1988 (Figures 3 and 4(a-f)) show the regional offshore trend and the effects of the river outflows but, with the possible exception of chromium, do not show any evidence of an effect at the sewage-sludge site. To avoid such problems, surveys at the Tyne site are based on a grid design.

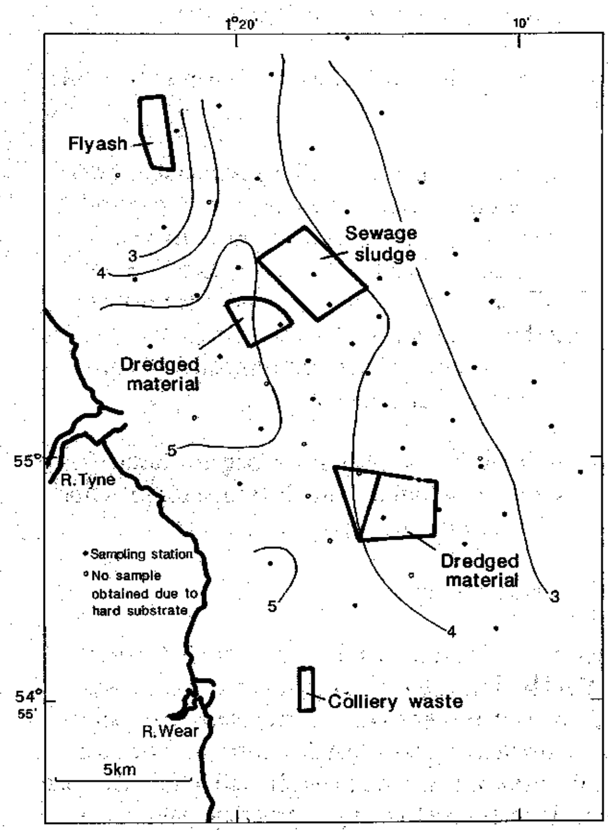

Figure 3. The distribution of organic carbon in the sediments around the Tyne sewage-sludge disposal site, May 1988.

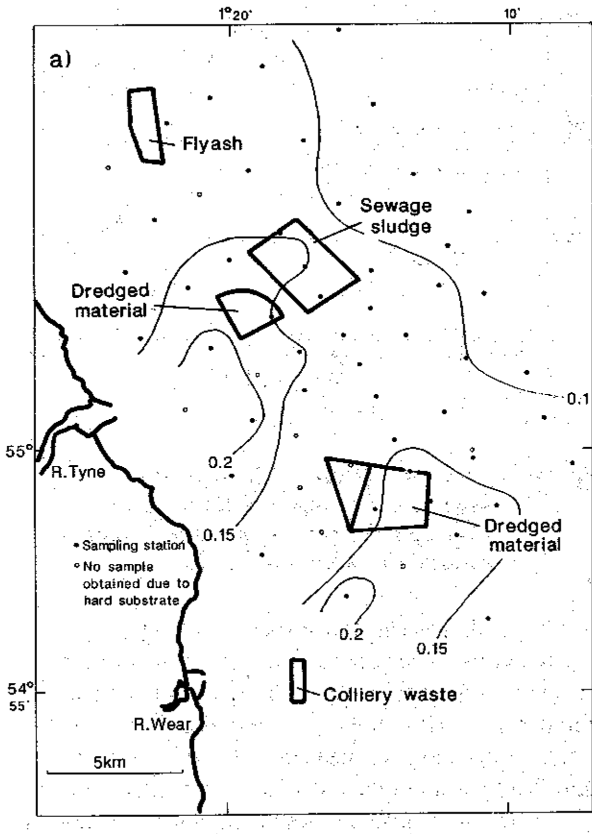

Figure 4(a). The distribution of mercury in the sediments around the Tyne sewage-sludge disposal site, May 1988.

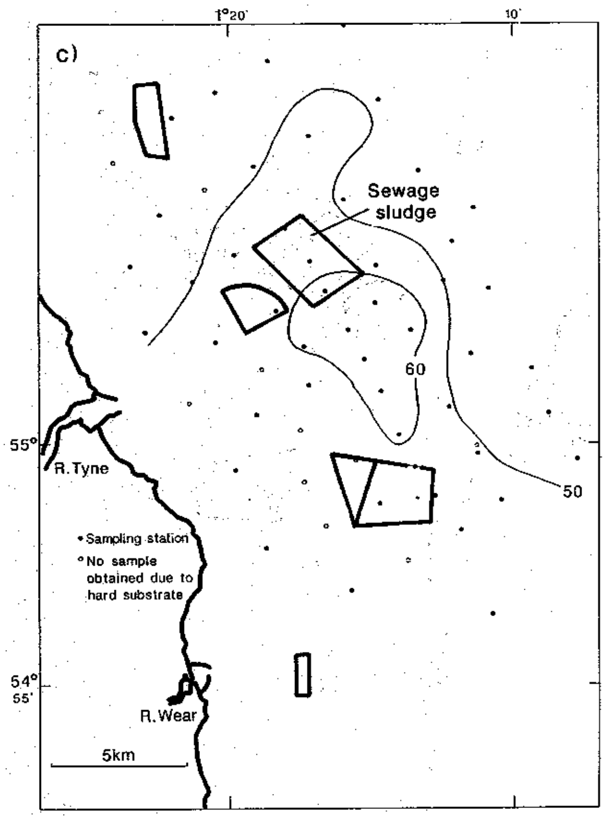

Figure 4(c). The distribution of chromium in the sediments around the Tyne sewage-sludge disposal site, May 1988.

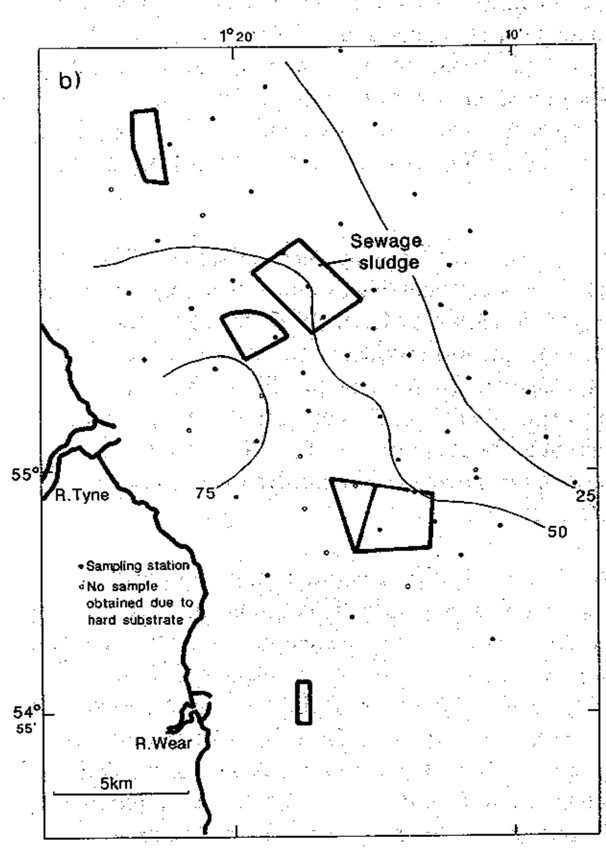

Figure 4(b). The distribution of copper in the sediments around the Tyne sewage-sludge disposal site, May 1988.

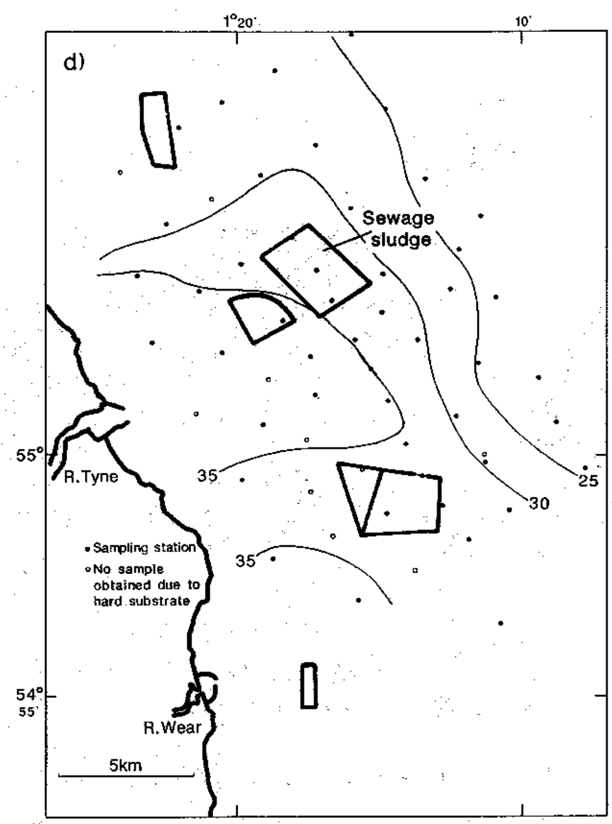

Figure 4(d). The distribution of nickel in the sediments around the Tyne sewage-sludge disposal site, May 1988.

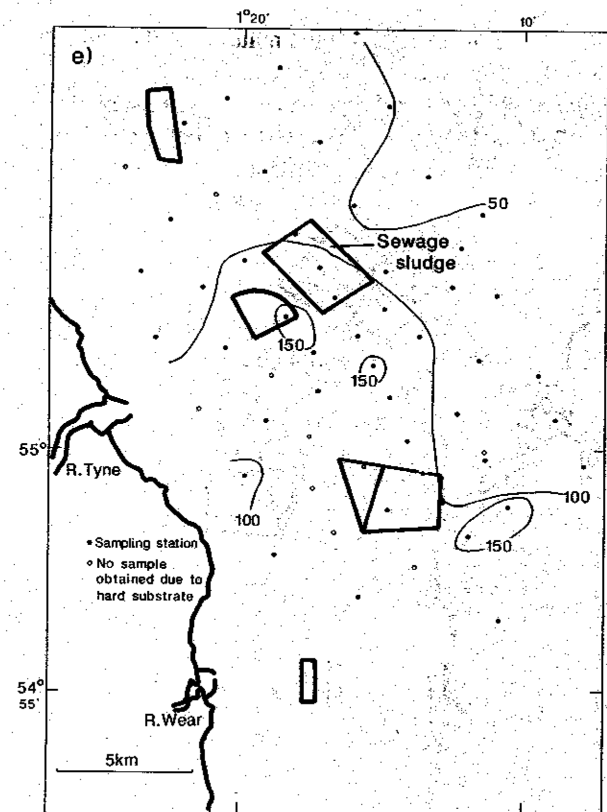

Figure 4(e). The distribution of lead in the sediments around the Tyne sewage-sludge disposal site, May 1988.

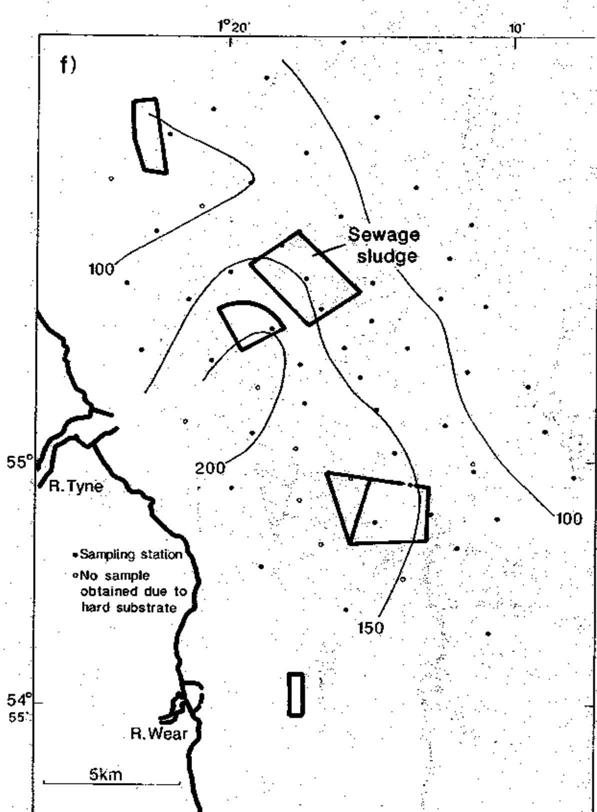

Figure 4(f). The distribution of zinc in the sediments around the Tyne sewage-sludge disposal site, May 1988.

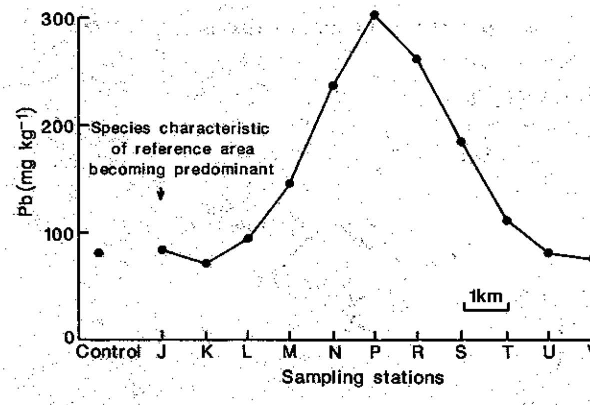

Figure 5. Concentrations of lead in whole sediments along a N-S transect through the Garroch Head sewage-sludge disposal site, 1989.

Together with these spatial surveys, a box-grid sampling method has been used to test for year-on-year changes in sediment quality at the Tyne site and at a reference site. This technique combined 27 closely spaced samples to give measures of mean sediment quality and variability and can be used to assess the significance of changes in these parameters. Although the programme is only in the early stages, there appears to be little change between 1987 and 1988 at the site. Rigorous statistical analysis of the data will be possible in the future when several years' data have been obtained. This work forms the basis of MAFF's component of studies at the Tyne site and will be examined in conjunction with the work carried out by Northumbrian Water under the self-monitoring scheme. Similar sampling regimes are presently being used at the Nab, Plymouth and Liverpool Bay disposal sites.

In contrast to the Tyne site, the sediments at Garroch Head show considerable evidence of sludge accumulation as evidenced by large elevations of carbon, metal and organochlorine concentrations at the centre of the disposal site (see, for example, Figure 5). The area most strongly affected is considered to be a mixing zone and, for the purposes of an EQO, sediments outwith this area may be compared with those at a reference site.

Attempts to identify temporal changes in sediment quality at Garroch Head are confounded by two factors. First, there was a change in analytical methodology for metals in 1986 when responsibility for analysis passed from the SMBA* to the Department of the Strathclyde Regional Chemist. The methods used by the latter resulted in a higher degree of extraction of metals from the sediment. Thus, there is a pronounced discontinuity in temporal data which, despite some degree of intercalibration between the two laboratories,

** Scottish Marine Biological Association* leads to uncertainty in any comparisons of pre-1986 data with those produced later. Second, only single grab stations were sampled and consequently no variability data are available for use in statistical tests of differences between years. This lack of replication affects not only temporal comparisons but also precludes rigorous comparison of control and test stations sampled at the same time.

Despite the limitations described above, it is possible to draw some tentative conclusions from the available data for the period 1986-1988. Concentrations of metals at the centre of the site have remained similar from year to year during the period, with the possible exception of arsenic which had a mean concentration of 39 mg kg^{-1} (total sediment dry weight) in 1987 and 52 mg kg^{-1} (total sediment dry weight) in 1988. At 1 km from the centre of the site, there was a tendency towards increasing concentrations of copper from 1987 to 1988 with increases from 157 to 217 mg kg^{-1}, 280 to 360 mg kg^{-1} and 302 to 368 mg kg^{-1} (all total sediment dry weights) at various positions around the site. At some locations 1 km from the centre of the site, there have also been apparent increases in concentrations of mercury and arsenic. Also, concentrations of copper appear to have increased slightly at some locations 2 and 3 km from the centre of the site.

The 1988 data for the locations outwith the mixing zone show metal concentrations similar to those at the reference station but, without further replication, it is impossible to make any statement concerning the degree of similarity.

Samples of sediment taken at Bell Rock disposal site were sieved at < 2 mm and the finer fraction analysed for contaminants. Although the choice of this size fraction for analysis is at variance with the advice of the CGMSD, which has recommended the use of the < 63 μm fraction, it does allow continuity with the earlier data which were all based on the < 2 mm fraction, which was initially selected because there is very little sediment < 63 μm at this site.

There was an increase in the quantity of fines, from < 7% at all stations in the disposal site in 1987 to >9% at most sites in 1988. However, little difference was found between the 1987 and 1988 data for the concentrations of carbon and metals in the < 2 mm fraction, with the exceptions of arsenic and copper which showed an increase at both the disposal and control sites. Since the fine sediment usually contains most of the contaminant metals, and an increase in fines would be expected to manifest itself as an increase in the concentration of metals, the lack of a detectable increase in concentrations of contaminant metals is probably attributable to analyses being based on the < 2 mm fraction of the sediment. This is known not to contain much metal in the area in question.

The presence of sewage-derived material at the control station does not necessarily call into question its validity as a true control for comparison with stations at the disposal site , since it is believed that such material may be derived from commercial shipping and/or fishing vessels operating in the area.

As well as giving comparisons between stations at the control and disposal sites, the Bell Rock report also compares the composition of sediments from impacted areas (as defined by coprostanol content) with those from non-impacted areas. There was little difference in concentrations of carbon or metals between these two groups of stations. However, it must be noted that, as coprostanol is biodegradable, an area appearing contaminated in one annual survey may not appear so in another. Comparing such stations would only give a measure of the effects of recent input and would not indicate the effects over a long period, unless affected stations were consistently compared with those not affected. At present, it is not clear whether this requirement is fulfilled by the existing sampling sites.

Various other surveys were carried out in 1988 and some of the conclusions are given below.

Grid surveys of sediments were carried out by Water Companies at the Nab and Bristol Channel disposal sites. These surveys were designed to identify any spatial variations in benthic communities, bacteria, carbon and trace metal contents of the sediments around the disposal sites which might be attributable to sewage-sludge disposal. No evidence of any such variation was observed.

No evidence of any significant effects of sewage sludge on metal concentrations was found in MAFF surveys at the Humber and Falls disposal sites.

A grid survey of the Liverpool Bay sewage-sludge disposal site revealed elevated concentrations of mercury and arsenic in the disposal site area, an observation which accords with the observations of metal enrichment made by Norton *et al* (1984).

The main conclusions to be drawn from consideration of data on metals in sediments are as follows:

(1) All sites examined, other than Liverpool Bay, comply with the EQO set by the CGMSD. In the case of Liverpool Bay, it will not be possible to assess compliance until a mixing zone has been defined, although it appears probable that this area will also be found to be acceptable.

(2) Replicate sampling is vital for rigorous comparison of locations between years and between disposal site and reference site. This topic is presently being dealt with by CGMSD task teams.

(3) Changes in analytical method or laboratory should be avoided if possible, but if essential should be accompanied by an intercalibration exercise.

4.7 Overall conclusions from the review of monitoring in 1988

The health of the ecosystem and quality of the environment is acceptable at all disposal sites. Marked effects are apparent only at the Garroch Head site, because this is recognised as a disposal site with only limited dispersion. Even at this site, there are no unacceptable effects outwith the mixing zone.

Litter is present at several UK disposal grounds. The CGMSD considers this is unacceptable in terms of the aesthetic EQS. The situations are being investigated and, where it is appropriate, steps will be taken to rectify the problems arising from disposal of sludges.

The limited spatial effects of elevated concentrations of metals in sediments, previously observed in Liverpool Bay, are still detectable but show no increasing trend.

Adoption of the monitoring programmes and the techniques advocated by the CGMSD began early in 1988 and this has been reflected in the greater comparability of monitoring since that time. This progress of greater harmonisation of methods has been strengthened following publication of the first report and this augurs well for continuing improvement to monitoring programmes.

5. MONITORING ACTIVITIES AT SEWAGE-SLUDGE DISPOSAL GROUNDS IN 1989

5.1 Introduction

During 1989, monitoring surveys were carried out at the following disposal grounds: Tyne, Humber, Roughs Tower, Thames (Barrow Deep), Nab, Exeter,

Table 8. Summary of procedures used in monitoring surveys at sewage-sludge disposal grounds in 1989

Area/authority	Sediment					Benthos, epibenthos	Water bioassay/ quality	Fish disease	Underwater video	Litter assessment
	Metals	C/N	Organic micro-contaminants	Micro-biology	Chemical tracer					
Tyne										
MAFF	+	+	+			+	+	+		+
Northumbrian Water	+					+			+	
Humber										
MAFF			+			+				
Roughs Tower										
MAFF	+	+		+		+				
Anglian Water	+				+					
Barrow (Thames Estuary)										
MAFF	+	+				+				
Nab										
MAFF	+	+				+				
Southern Water	+	+	+	+						
Exeter										
MAFF	+	+	+	+		+				
Plymouth										
MAFF	+	+		+		+				
Bristol Channel										
Welsh/Wessex Water							+			
Liverpool Bay										
MAFF	+	+	+							
North-West Water	+				+	+	+	+		
North Channel										
DOE(NI)	+			+		+				
Garroch Head										
SMBA	+	+	+			+	+	+		
DAFS				+						
Bell Rock										
FRPB	+	+	+			+		+		
DAFS						+		+		
St Abbs										
FRPB	+	+	+			+		+		
DAFS						+		+		

Plymouth, Bristol Channel, Liverpool Bay, North Channel, Garroch Head, Bell Rock and St. Abb's.

Short summaries of the various surveys are given in the following sub-sections. As far as possible, the surveys were carried out in accordance with the advice of the CGMSD task teams. However, it is important that data are comparable on a year-by-year basis and so the switch-over to new methods will take place over several years and, in some cases, earlier methods will be maintained indefinitely.

Differences in environmental characteristics between disposal grounds (e.g. in substrate type or hydrography) mean that while the objectives of monitoring are similar, the range of methods used may differ. Also the range of methods used at any given site may change from survey to survey as a result of increased understanding of the system under study, or due to some measurements being needed less frequently than others.

A summary of the techniques used on the different disposal grounds in 1989 is given in Table 8.

5.2 MAFF survey of the Tyne sewage-sludge disposal site, May 1989

(a) Sediment samples were collected at the stations shown in Figure 6.

(b) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples. The samples form part of a study of temporal trends in sediment quality at the disposal ground.

(c) Sediment samples were also collected from the stations shown in Figure 7. PCBs and pesticide residues have been determined in the surface 0-1 cm of the sediment. Benthic infauna will be identified and enumerated in separate sediment samples collected at these stations.

(d) Samples of dab and cod were collected at the stations shown in Figure 8 for the assessment of disease incidence.

(e) Beam trawl samples were collected at the sites shown in Figure 7, and analysed for the presence of epifauna and any sludge-derived litter.

(f) Water samples were collected from the sludge slick shortly after disposal and their toxicity was assessed using an oyster embryo bioassay technique.

(g) Video records of the slick were made to allow an assessment of the frequency of artefacts floating in the water.

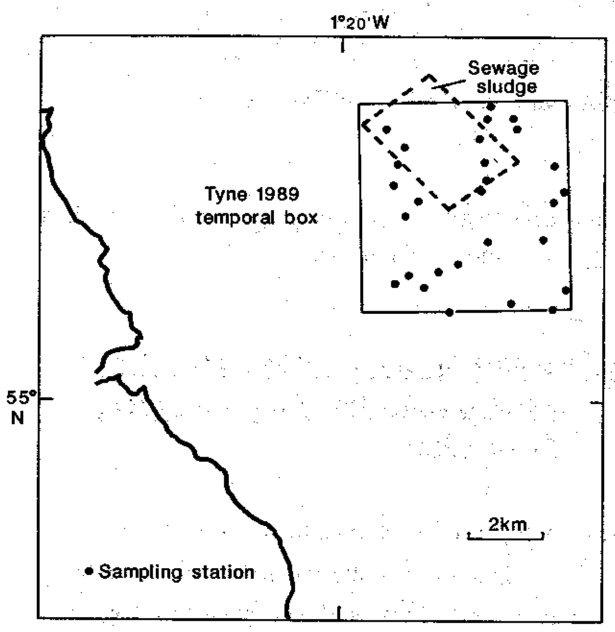

Figure 6. MAFF sediment survey at the Tyne sewage-sludge disposal site, May 1989.

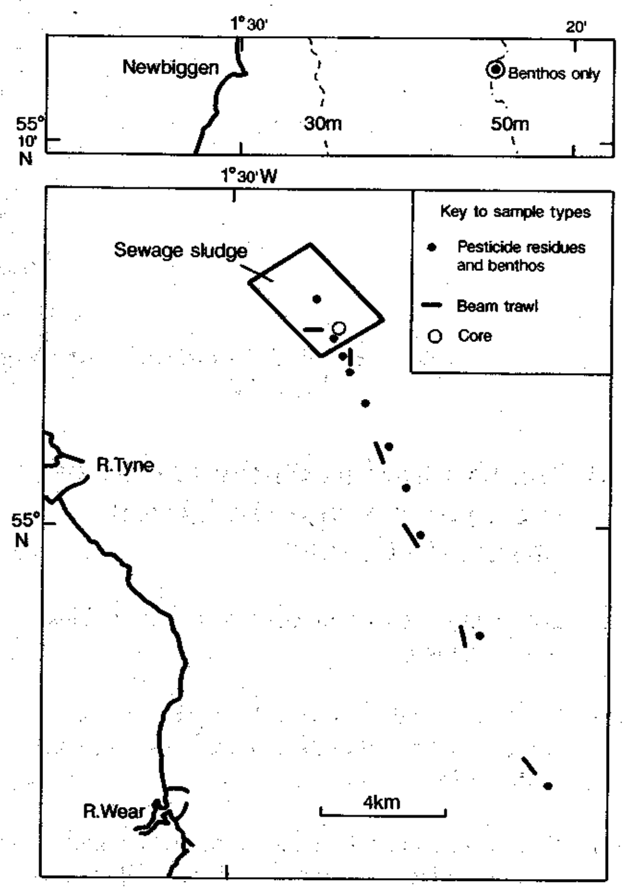

Figure 7. MAFF survey of PCBs/benthos at the Tyne sewage-sludge disposal site, May 1989.

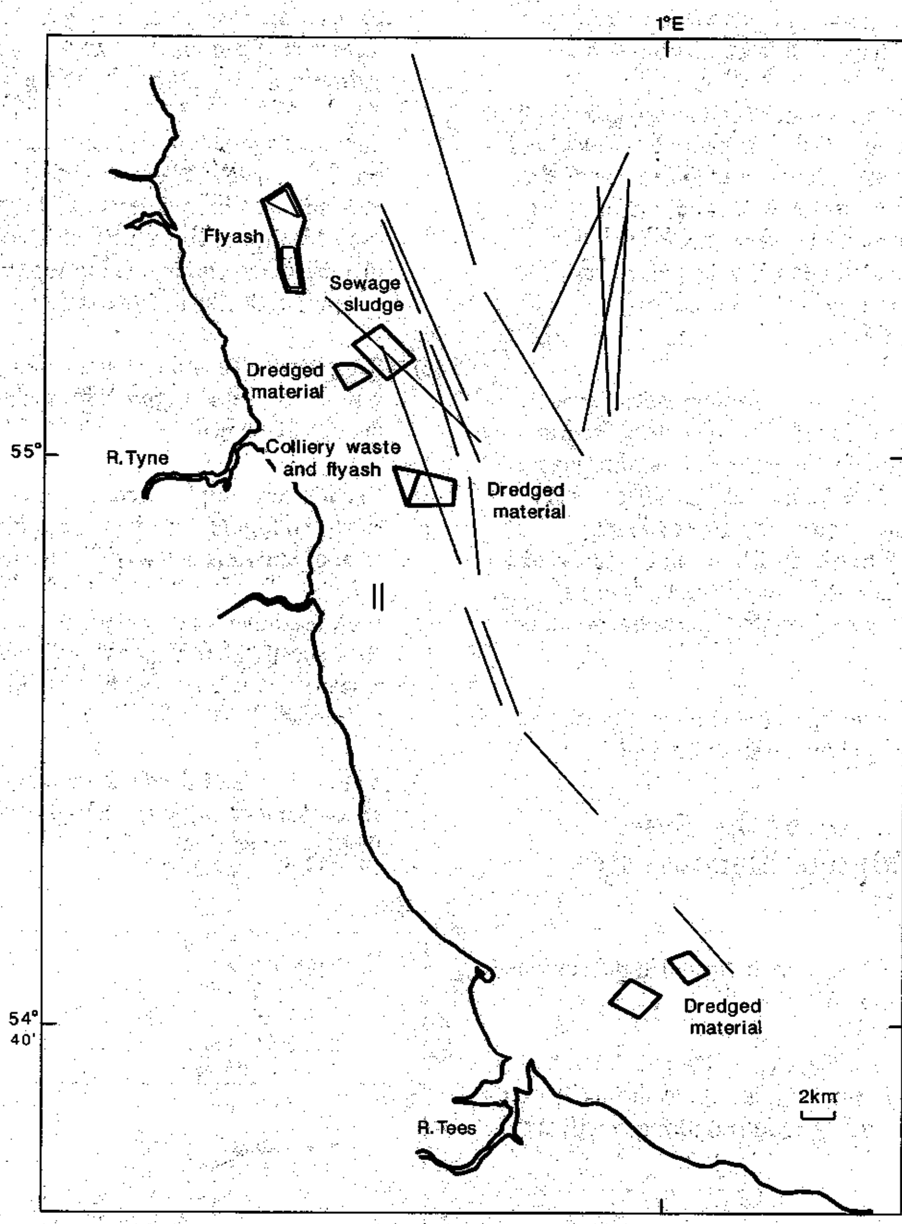

Figure 8. MAFF fish disease survey off the north-east coast of England, May 1989.

5.3 Northumbrian Water survey of the Tyne sewage-sludge disposal site in 1989

(a) Sediment samples were collected at the stations shown in Figure 9.

(b) Samples from these sites will be analysed for Hg, Cd, Pb and Zn in the fine fraction (< 63 µm) of the surface 0-1 cm.

(c) Benthic infauna will be identified and enumerated in samples from the sites shown (Figure 9).

(d) Beam trawl hauls were made at six sites (Figure 9) during May, June, August and November.

(e) Underwater video surveys were carried out at the sites shown (Figure 9).

5.4 MAFF survey of the Humber sewage-sludge disposal site, May 1989

(a) Samples of the horse-mussel (*Modiolus modiolus*) were collected at the stations shown in Figure 10. These will be analysed for Hg, Cd, Cu, Pb and Zn as part of a study of temporal trends in chemical quality of the mussel population.

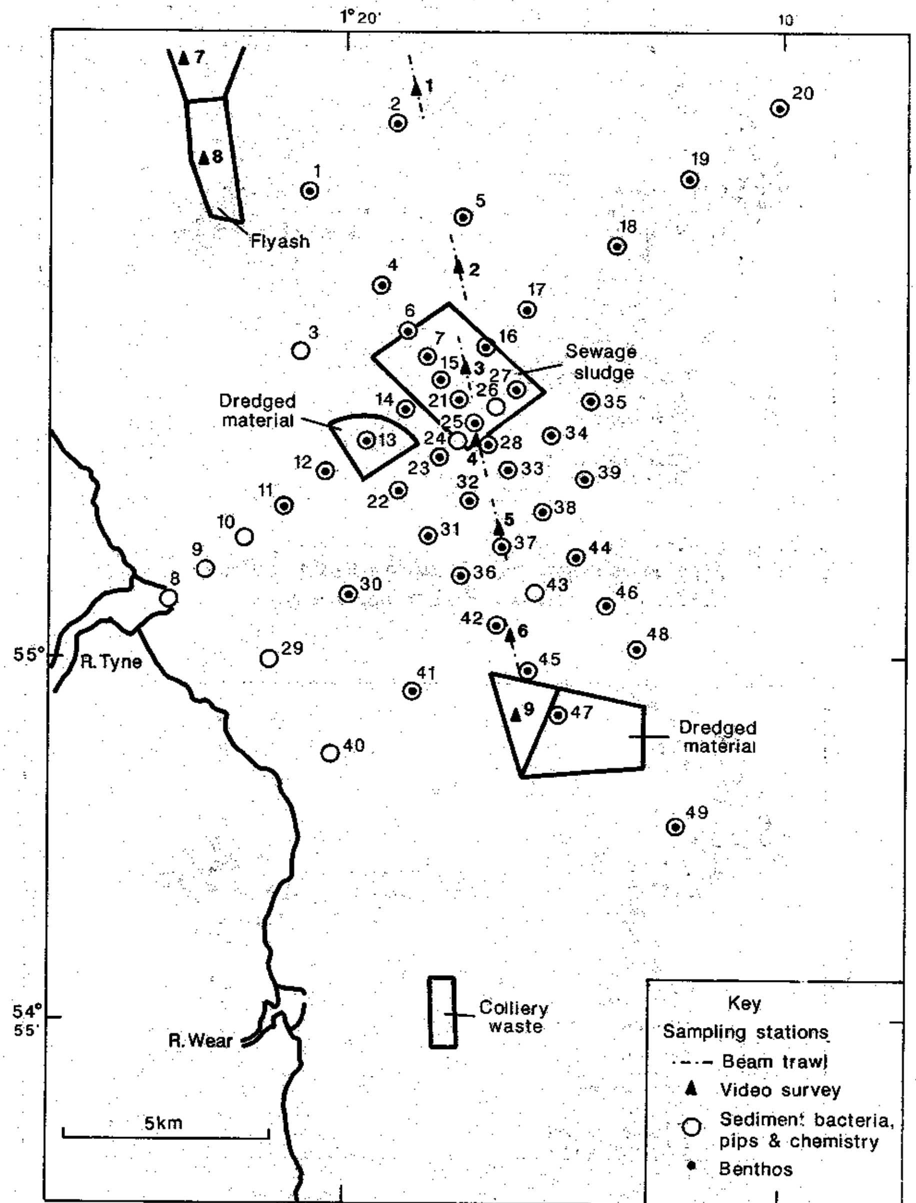

Figure 9. Northumbrian Water survey of the Tyne sewage-sludge disposal site, May-November 1989.

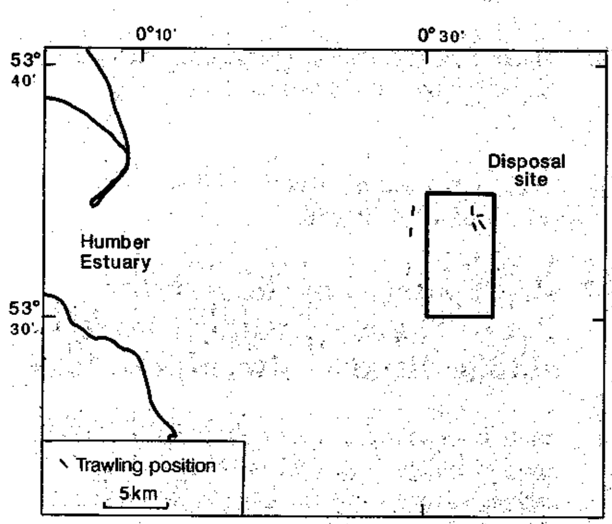

Figure 10. MAFF survey of <u>Modiolus modiolus</u> at the Humber sewage-sludge disposal site, May 1989.

5.5 MAFF survey of the Roughs Tower sewage-sludge disposal site, December 1989

(a) Sediment samples were collected at the stations shown in Figure 11.

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

(c) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples.

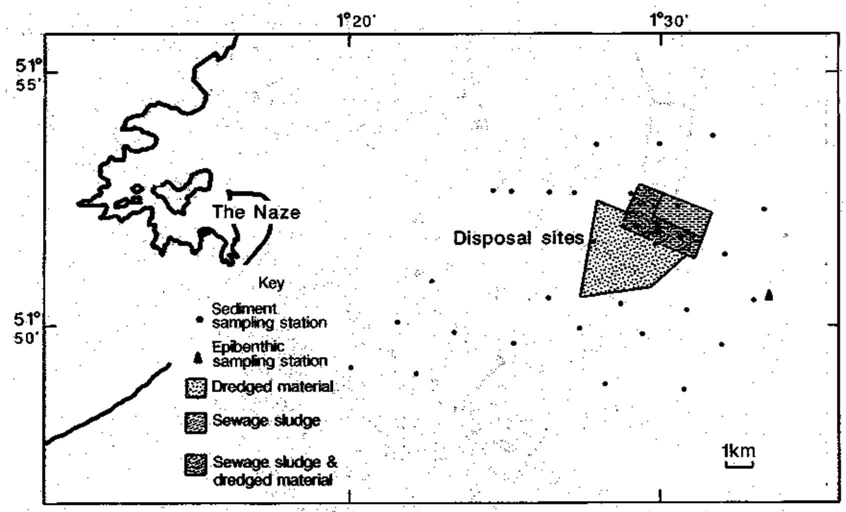

Figure 11. MAFF sediment survey at the Roughs Tower sewage-sludge disposal site, December 1989.

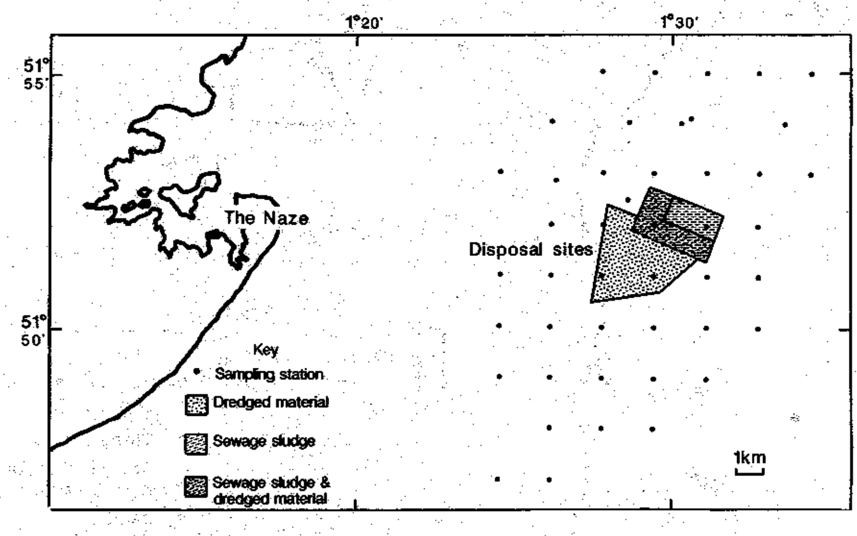

Figure 12. Anglian Water sediment survey at the Roughs Tower sewage-sludge disposal site, October 1989.

(d) The larger (> 5 mm) benthic infauna were identified and enumerated in sediment samples.

(e) Epibenthic samples were collected using anchor and rock dredges at the sites shown in Figure 11.

5.6 Anglian Water survey of the Roughs Tower sewage-sludge disposal site, October 1989

(a) Sediment samples were collected at the stations shown in Figure 12.

(b) Metals (Hg, Cd, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment.

(c) Coprostanol will be determined in the surface 0-1 cm of the sediment.

5.7 MAFF survey of the Barrow Deep (Thames Estuary) sewage-sludge disposal site, March 1989

(a) Samples of sediment were collected from known areas of sludge settlement and analysed for carbon, nitrogen, Hg, Cd, Cu, Cr, Ni, Pb and Zn (Figure 13).

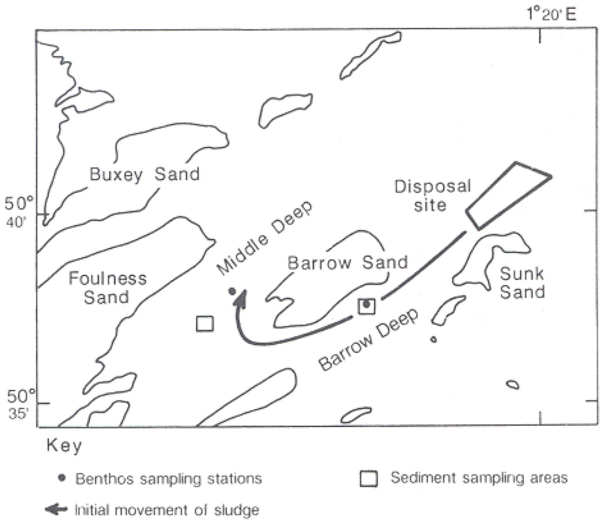

Figure 13. MAFF survey of the Barrow Deep sewage-sludge disposal site, March 1989.

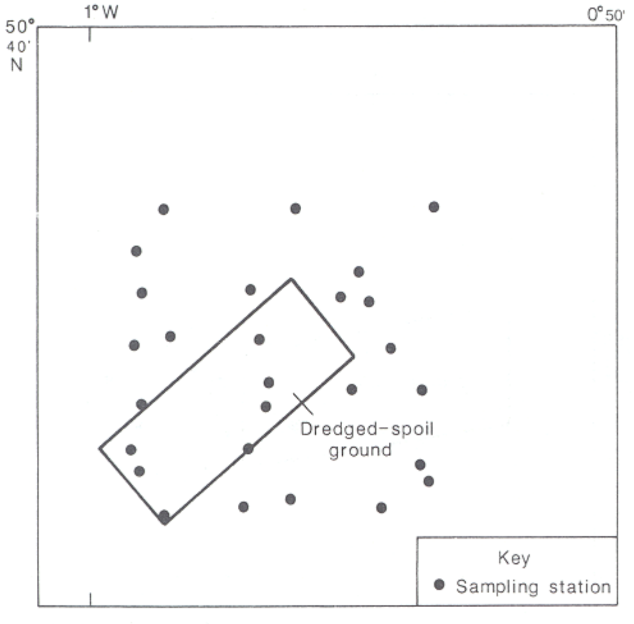

Figure 14. MAFF survey of the Nab sewage-sludge disposal site, December 1989.

(b) Samples were also collected for benthic infauna analysis (Figure 13). Samples of both metals and benthos form part of studies on temporal trends.

5.8 MAFF survey of the Nab sewage-sludge disposal site, December 1989

(a) Sediment samples were collected at the stations shown in Figure 14.

(b) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples. The samples form part of a study of temporal trends in sediment quality at the disposal site.

(c) Sediment samples were also collected by anchor dredge, for analysis of the benthos and particle-size. This survey was designed to study both the sewage-sludge disposal site and also the nearby areas of aggregate extraction.

5.9 Southern Water survey of the Nab sewage-sludge disposal site, August 1989

(a) Sediment samples were collected at the stations shown in Figure 15.

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

(c) Metals (Hg, Cd, Cu, Ni, Cr, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples. Pesticide and PCB residues will also be identified in selected samples.

5.10 MAFF survey of the Exeter sewage-sludge disposal site, December 1989

(a) Sediment samples were collected at the stations shown in Figure 16.

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

(c) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples.

(d) Sediment samples were collected from the area of highest bacterial counts for the determination of PCBs and pesticide residues.

(e) Benthic infauna will be identified and enumerated in separate sediment samples.

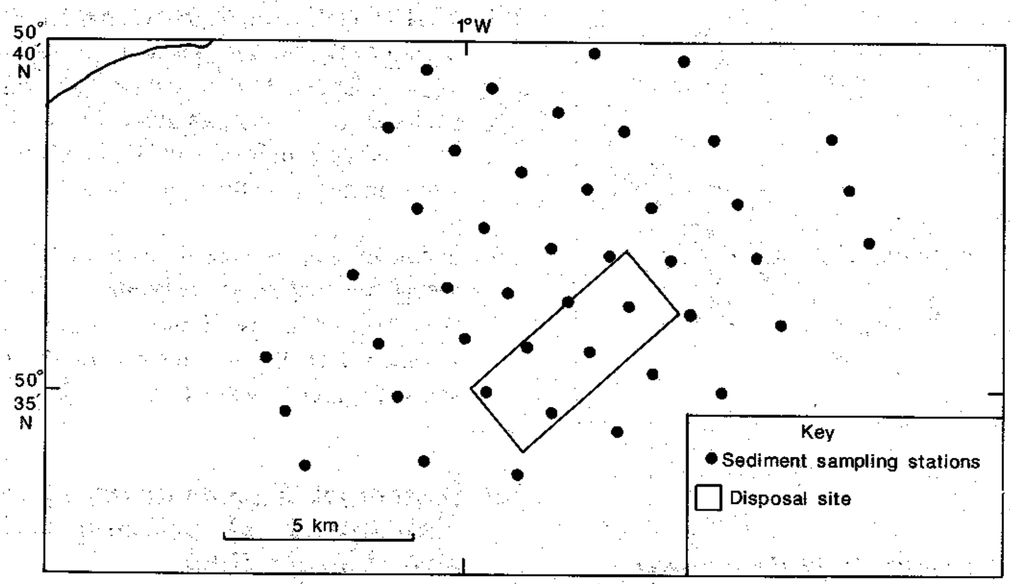

Figure 15. Southern Water survey of the Nab sewage-sludge disposal site, August 1989.

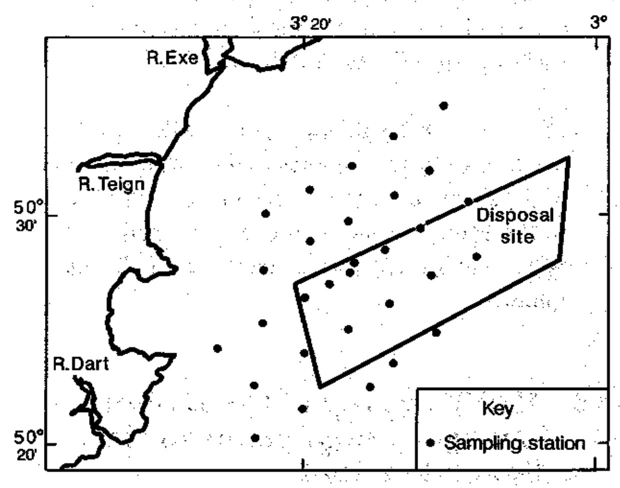

Figure 16. MAFF survey of the Exeter sewage-sludge disposal site, December 1989.

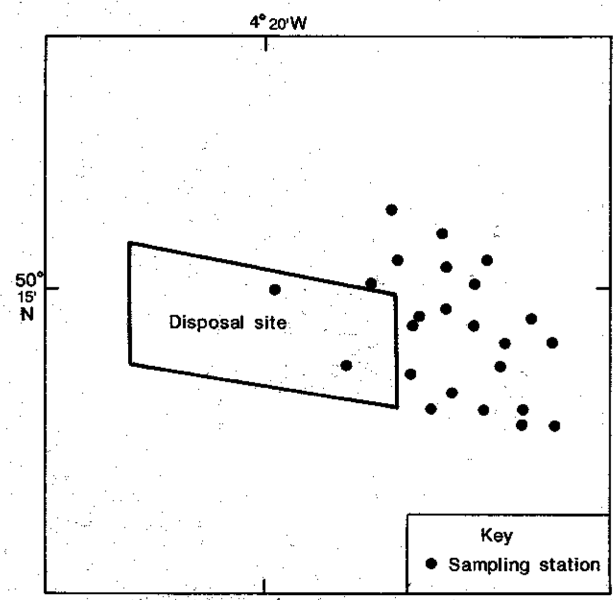

Figure 17. MAFF survey of the Plymouth sewage-sludge disposal site, December 1989.

5.11 MAFF survey of the Plymouth sewage-sludge disposal site, December 1989

(a) Sediment samples were collected at the stations shown in Figure 17.

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

(c) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples. The samples form part of a study of temporal trends in sediment quality at the disposal ground.

(d) Benthic infauna will be identified and enumerated in sediment samples collected at selected sites (see Figure 17).

5.12 Wessex Water surveys of the Bristol Channel sewage-sludge disposal site, July and September 1989

(a) A series of 315 water samples from the disposal grounds were analysed for bacteria (total coliforms, faecal coliforms and faecal streptococci), and nutrients (nitrite, nitrate, ammonium, phosphate, silicate and total organic nitrogen). Eighty of these samples were also analysed for enteroviruses.

5.13 MAFF survey of the Liverpool Bay sewage-sludge disposal site, September 1989

(a) Sediment samples were collected at the stations shown in Figure 18.

(b) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon and nitrogen will also be determined in these samples.

(c) Samples of sediment were also collected at selected stations for the determination of PCBs and pesticide residues (see Figure 18).

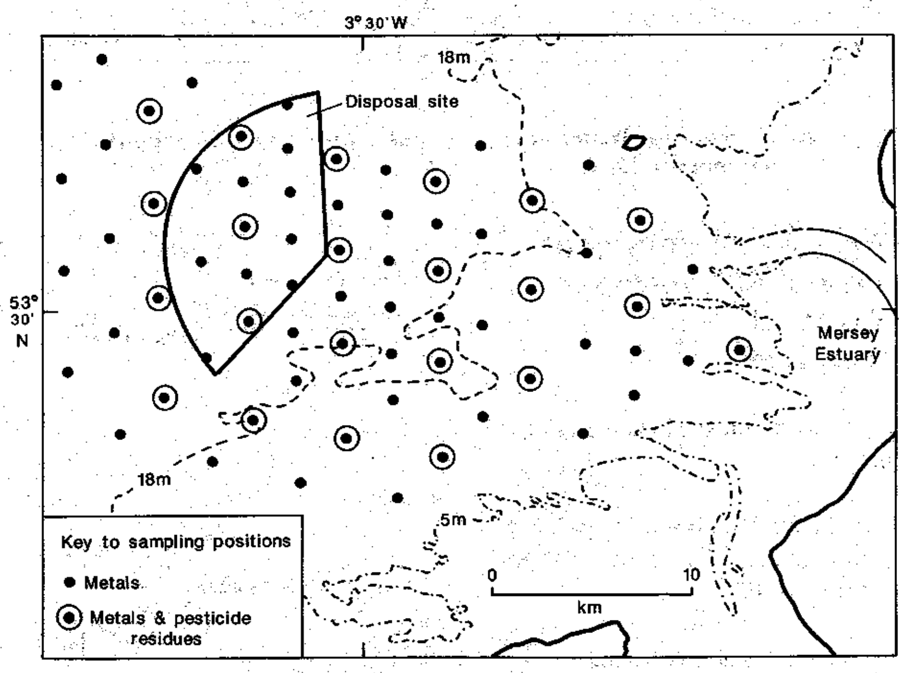

Figure 18. MAFF survey of the Liverpool Bay sewage-sludge disposal site, September 1989.

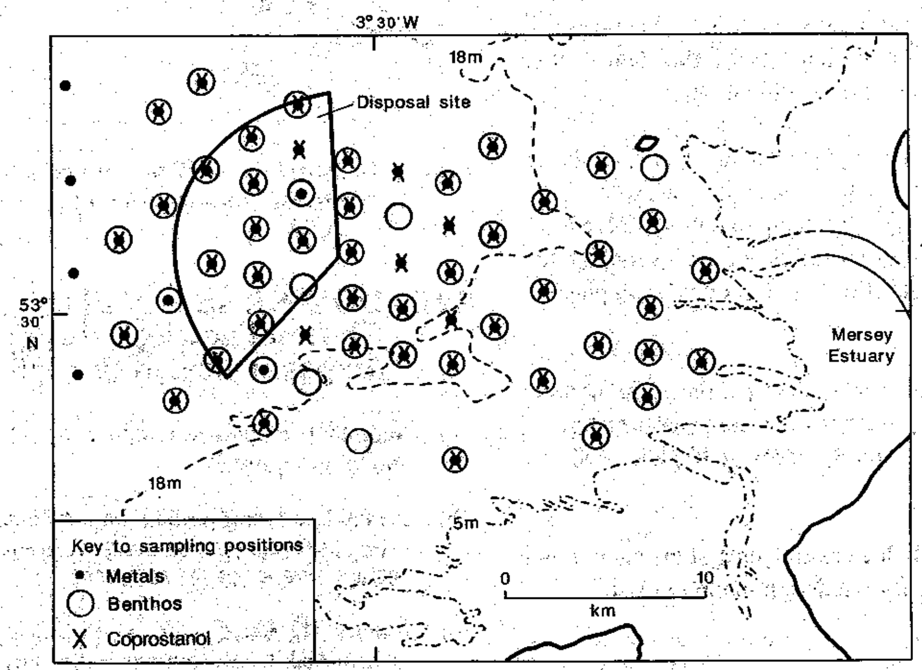

Figure 19. North-West Water survey of the Liverpool Bay sewage-sludge disposal site, September 1989.

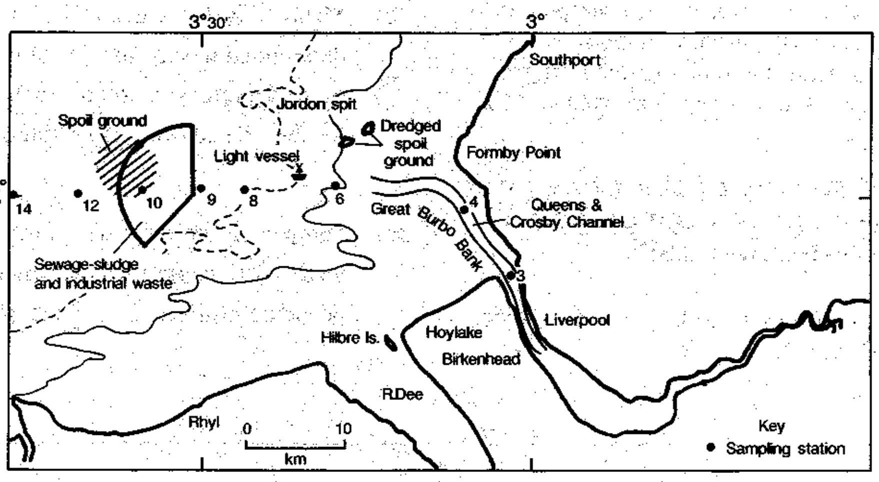

Figure 20. North-West Water survey of water quality in Liverpool Bay, September 1989.

5.14 North-West Water survey of the Liverpool Bay sewage-sludge disposal site, September 1989

(a) Sediment samples were collected at the stations shown in Figure 19.

(b) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment (Figure 19).

(c) Samples of sediment were also collected at selected stations for the determination of coprostanol (Figure 19).

(d) Samples of sediment were collected at the stations shown in Figure 19 for the identification and enumeration of benthic infauna.

(e) Water quality samples were taken at sites shown in Figure 20. Surface water samples were analysed for salinity, temperature, dissolved oxygen, suspended solids, nitrate, nitrite, ammonia, phosphate, silicate, chlorophyll and phaeopigments.

(f) Fish were sampled at the sites shown in Figure 21. Mercury and arsenic were determined in muscle from samples of about 30 plaice and whiting.

(g) Samples of fish were collected at the sites shown in Figure 21 for the determination of fish diseases.

(h) The toxicity of recently dumped sludge was assessed using a test on development of mussel embryos.

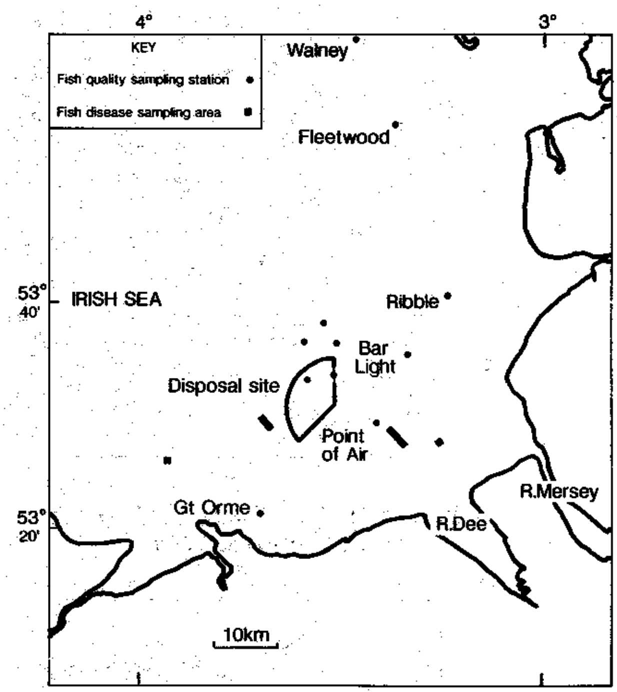

Figure 21. North-West Water surveys of fish quality and disease in Liverpool Bay 1989.

5.15 DOE(NI) survey of the North Channel sewage-sludge disposal site, May 1989

(a) Sediment samples were collected at the stations shown in Figure 22.

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

(c) Metals (Hg, Cd, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment.

(d) Beam trawls were used to collect samples of epifauna (Figure 22).

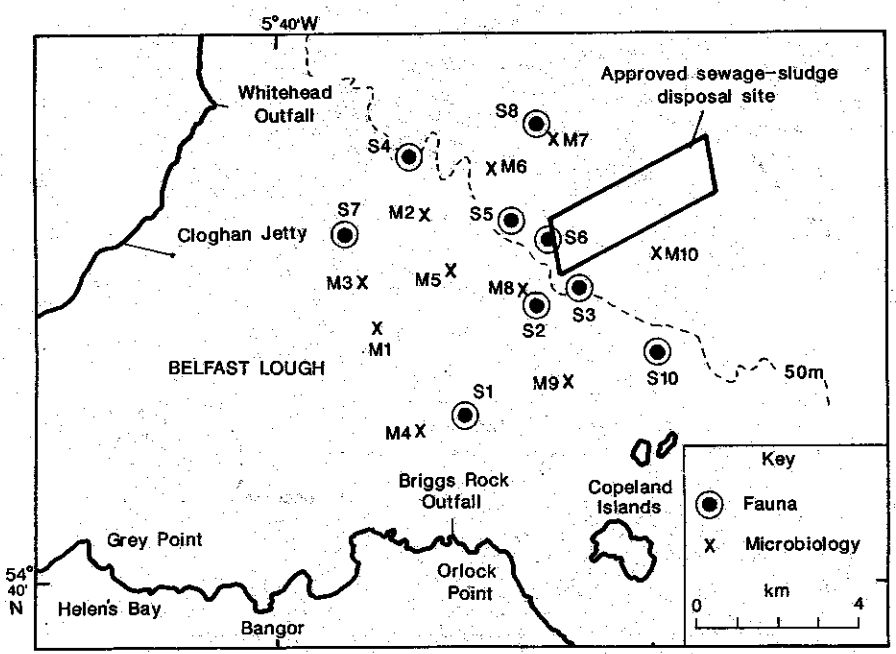

Figure 22. DOE(NI) survey of the North Channel sewage-sludge disposal site, May 1989.

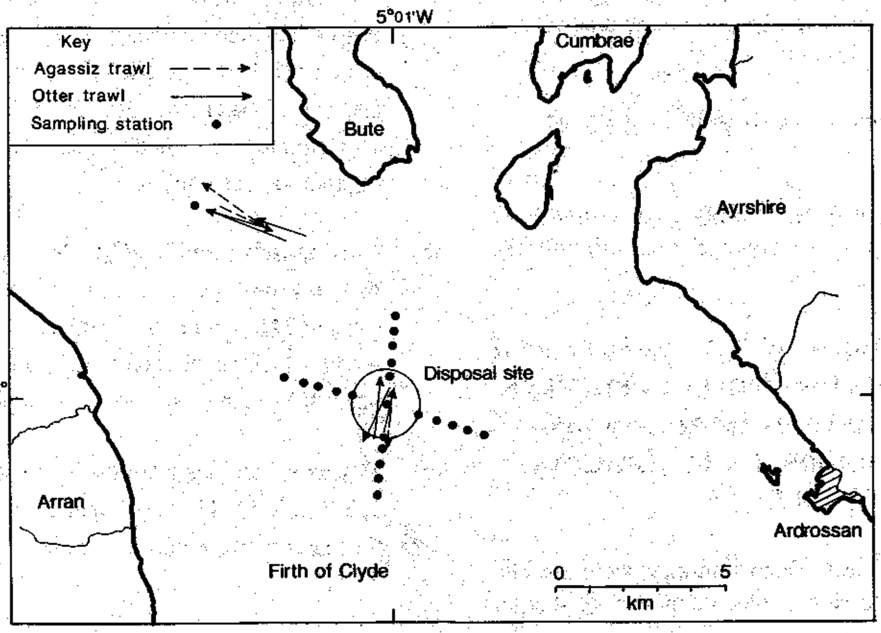

Figure 23. Scottish Marine Biological Association/Strathclyde Regional Council survey of Garroch Head sewage-sludge disposal site, May 1989.

5.16 Scottish Marine Biological Association/Strathclyde Regional Council survey of the Garroch Head sewage-sludge disposal site, May 1989

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

(b) Metals (Hg, As, Cd, Co, Cu, Cr, Ni, Pb and Zn) will be determined in sub-samples of the surface 0-1 cm of the sediment. Carbon, nitrogen and organochlorines will also be determined in these samples.

(c) Benthic infauna and epifauna (including demersal fish) will be identified and enumerated at selected sites (Figure 23).

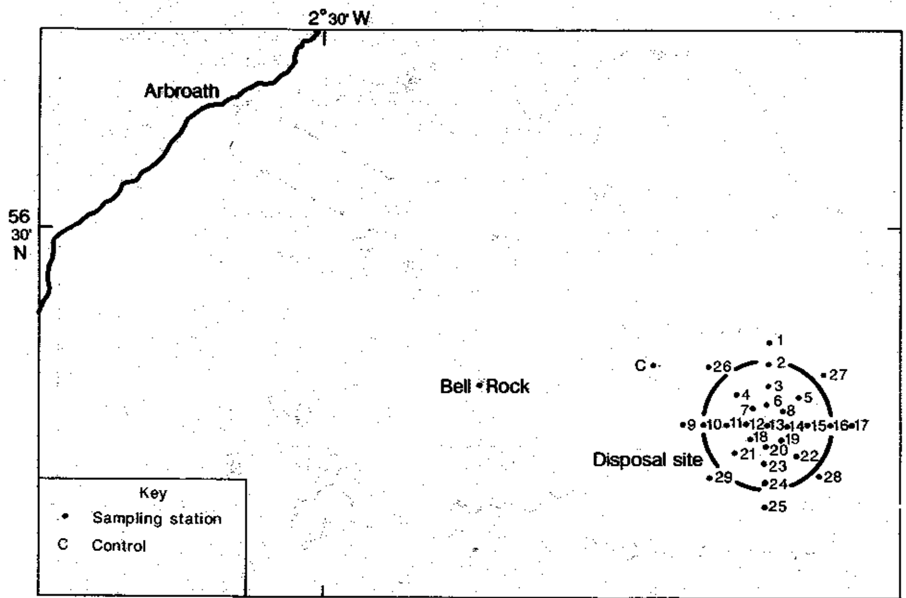

Figure 24. Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, August 1989.

(d) Oxygen content, salinity and temperature of the water immediately above the sediment surface were also determined.

(e) Eh and pH measurements were made on the sediment samples.

(f) Histopathological and microbiological investigations of fish species were carried out (Figure 23).

5.17 Department of Agriculture and Fisheries for Scotland surveys of the Garroch Head sewage-sludge disposal site, January and April 1989

(a) Acoustic backscattering techniques were used to study the dispersion of plumes of sewage sludge.

(b) The distribution of *Clostridium* spores was determined in sediments around the disposal site.

5.18 Forth River Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1989

(a) One sediment sample was taken from each of the stations shown in Figure 24 and examined for physical appearance, carbon, nitrogen and metals (Cu, Zn, Cd, Pb, Cr, Ni, Fe). Samples from stations C (control) 1, 3, 9, 11, 13, 15, 17, 23 and 25 were also examined for particle size and organochlorine content.

(b) Two Agassiz trawls and one otter trawl sample were taken at each of stations C and 13 (Figure 24). Adult fish in the catch were examined for lesions, histopathology and microbiology. A full list of species was prepared.

(c) Two grab samples were taken at each of stations 1, 3, 9, 11, 13, 15, 17, 23 and 25 and examined for macrobenthos and fruit pips.

5.19 Department of Agriculture and Fisheries for Scotland survey of the Bell Rock sewage-sludge disposal site, May 1989

(a) Studies were made of benthic infauna around the disposal site.

(b) Fish samples for disease assessment were collected from the disposal site and a reference site.

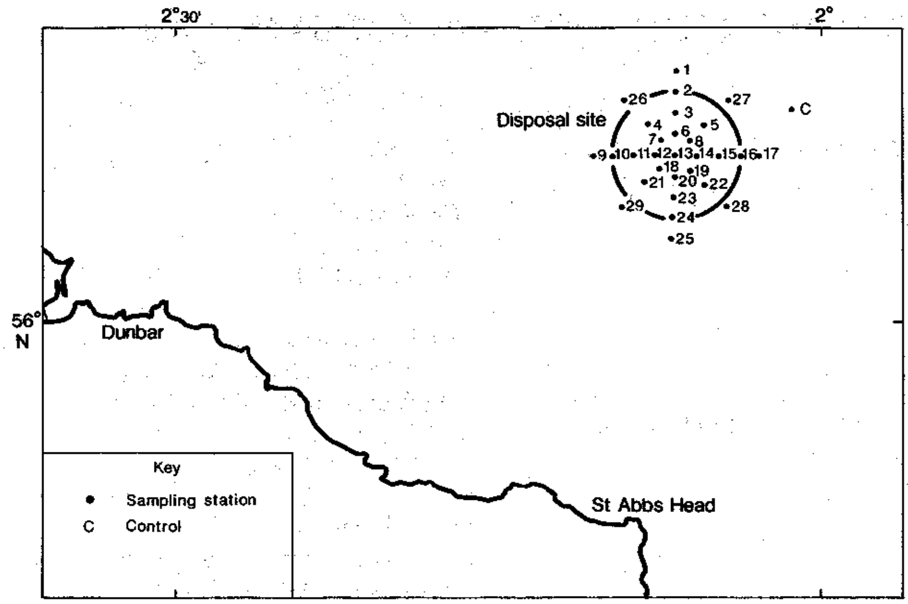

Figure 25. Forth River Purification Board/Lothian Regional Council survey of the St Abbs sewage-sludge disposal site, June 1989.

5.20 Forth River Purification Board/Lothian Regional Council survey of the St Abb's Head sewage-sludge disposal site, June 1989

(a) One sediment sample was taken from each of the stations shown in Figure 25 and examined for physical appearance, particle size, carbon, nitrogen and metals (Cu, Zn, Cd, Pb, Cr, Ni, Fe). Samples from stations C (control) 1, 3, 9, 11, 13, 15, 17, 23, 25, 27 and 29 were also examined for organochlorine content.

(b) Two Agassiz trawls and one otter trawl sample were taken at each of stations C and 13 (Figure 25). Adult fish in the catch were examined for lesions, histopathology and microbiology. A full list of species was prepared.

(c) Two grab samples were taken at each of stations 1, 3, 9, 11, 13, 15, 17, 23, 25, 27 and 29 and examined for macrobenthos and fruit pips.

5.21 Department of Agriculture and Fisheries for Scotland survey of the St Abb's Head sewage-sludge disposal site, May 1989

(a) Studies were made of benthic infauna around the disposal site.

(b) Fish samples for disease assessment were collected from the disposal site and a reference site.

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ANNEX 1. MEMBERSHIP OF THE CGMSD IN 1989

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ANNEX 3. UTILITY OF EXPERIMENTAL MEASURES OF BIOLOGICAL EFFECTS FOR MONITORING MARINE SEWAGE-SLUDGE DISPOSAL SITES

A3.1 Introduction

A summary of procedures for the monitoring of benthic communities at UK sewage-sludge disposal sites was given in the CGMSD Annual Report for 1988 (MAFF, 1989). The benthos have been the traditional target for assessments of biological effects at the sea bed, for reasons given in that report.

In recent years, increasing attention has been focused on alternative measures of biological effects, with the aim of improving the capability to detect and interpret effects of pollution in a cost-effective manner, and of widening the scope of assessment of impact beyond a sole concern with the structure of benthic communities.

Accordingly, the CGMSD requested a specialist task team to evaluate the present status of such measures, whose terms of reference were as follows:

(i) to examine the utility of alternative biological effects measures for use in UK sewage-sludge disposal site monitoring;

(ii) to make recommendations on the suitability of techniques:

  (a) for immediate application and, where appropriate, to present standard procedures; and

  (b) for further development, and to allocate priorities for their evaluation.

The team met during 1989, and a summary of their findings is given below. A full account of the work has been published separately in MAFF's Aquatic Environment Monitoring Report series (MAFF, 1990). This will provide the necessary detail on a range of selected tests, and on the criteria which were used for assessing their utility, both of which are referred to below. Draft protocols for conducting the top-ranked tests will also be specified.

A3.2 Rationale for test selection

The task team considered only those tests which on present evidence have shown potential, or are close to doing so, for specific application in routine surveys of sewage-sludge disposal sites. In selecting these tests, priority was therefore given to those which had previously been deployed with some success at UK sites, and which appeared to be the most relevant in terms of assessments of field effects at the population level. (It should be noted that studies on fish pathology and diseases have been dealt with separately in the CGMSD Annual Report for 1988 (MAFF, 1989), and so are not considered here.)

The following tests (or classes of tests) were chosen for detailed evaluation:

- physiological indices of sub-lethal stress (especially feeding rate in *Mytilus*);
- hydroid test;
- fish egg and fish larvae tests;
- bivalve embryo test (especially the oyster embryo test);
- planktonic algal tests;
- zooplankton tests (especially those of copepods and mysids);
- microbiological tests (especially the 'Microtox' test); and
- infaunal invertebrate tests (especially that of polychaete enzyme activity).

As can be seen, most of those selected were tests on whole organisms. Regarding biochemical indices, determination of polychaete enzyme activity was chosen because of the notable efforts that have been made to link observed changes near to waste disposal sites with those occurring in the benthos at the population level.

The measurement of bacterial luminescence as an indicator of water quality (available commercially as the 'Microtox' test) was selected as an example of an established 'off the shelf' method, which appeared to have potential for identifying impacts of sewage-sludge disposal, when used in conjunction with other measures.

Note. Of special relevance to the implementation of the present recommendations will be a report of an ICES/IOC sea-going Workshop on Biological Effects of Contaminants, which was based at Bremerhaven in March 1990 (in preparation). This included the application of a variety of measures along a gradient of contamination arising from a North Sea oil platform, and should provide a substantial amount of new information regarding the utility of these measures in monitoring programmes.

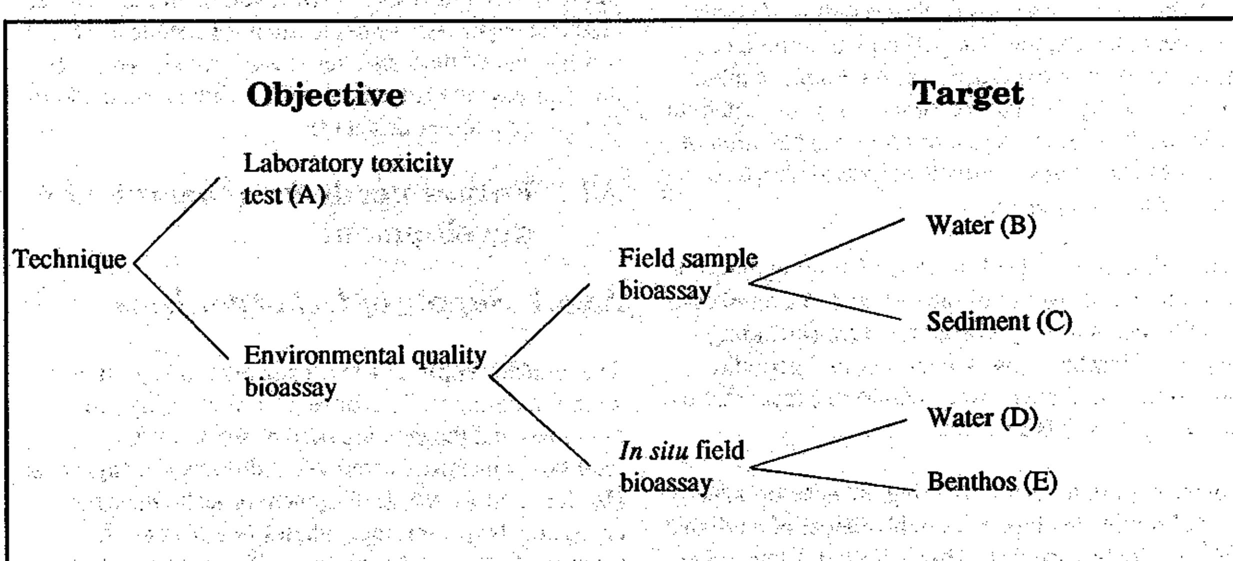
A3.3 Recommended tests

Selected tests were scored on a scale of 1-5 against a range of criteria which determine their utility in sewage-sludge disposal site monitoring. Additionally, the criteria were weighted (also on a scale of 1-5) according to their perceived importance. In the case of four criteria, this weighting differed according to whether the technique was to be employed as a laboratory toxicity test or as a bioassay of environmental quality (Table A3.1).

The tests were allocated to five categories (A-E) in order to account for the major objectives and environmental targets, as shown in the diagram below.

Table A3. 1. Weighting of criteria for selection of techniques according to their mode of deployment (1-5).

Criterion	Bioassay	Toxicity test
Availability of species	5	5
Importance of species (ecological/economic)	4	2
Cost-effectiveness	3	3
Ease of use	4	3
Rapidity of test	2	5
Genetic uniformity	1	1
Data quality (precision)	5	5
Bioaccumulation potential	3	3
Integration of effects	5	5
Sensitivity	5	5
'Discrimination'	5	5
Relevance of technique to populations	5	4



In a number of cases, a particular test can fulfil more than one role.

Full details of the test scores have been published separately (MAFF, 1990). It should be emphasised that the scoring system was limited in scope to an assessment of utility in sewage-sludge disposal site monitoring, and so did not address the suitability of these tests to meet other environmental monitoring objectives.

Whilst the ranking by scores provided a very useful aid to the short-listing of promising tests, the final decision inevitably took special account of the present state of development of the various test procedures, and hence the practical implications for immediate routine deployment. This led to the following choices.

(i) Recommended for routine application:

- oyster embryo test;

- test on feeding rate in *Mytilus* (with qualifications on cost and difficulties in interpretation in some cases).

(ii) Recommended for routine application, subject to further R and D and/or refinement of protocol (in rank order of scores):

- zooplankton tests (copepods, mysids);
- 'Microtox' test (with qualification regarding 'relevance' as presently understood);
- planktonic algal tests (with qualification regarding interpretation of stimulatory effects);
- test on polychaete enzyme activity;

(iii) Not recommended for routine application at the current state of development/knowledge:

- fish egg and fish larvae tests;
- other tests using infaunal invertebrates;
- hydroid test.

Regarding implementation of the recommendations, one aspect identified as being of critical importance was the transfer of expertise to allow routine application by presently inexpert personnel. It is important to emphasise that the transition to routine application of most of the measures of effects discussed above has yet to be made in a regulatory context.

There will thus be a 'lead-in' time of varying duration depending on the nature of the test, and in a number of cases this may have significant resource (including manpower) implications. Given this, and periodic intercalibration, there is every reason to expect that the tests will give reliable results.

Another important factor affecting the development of regional routines will be the establishment of a reliable supply of the test species. This is further discussed in Sub-section A3.4 below.

The oyster embryo test has the advantage that it deals with a familiar and commercially important species. Moreover, the test is not complicated by the necessity to provide an external food source for the duration of the experiment. The wider significance of effects determined from the 'Microtox' test has yet to be established. Both these tests are amenable to controlled experimentation in the laboratory, and hence the potential exists for calibrating responses in the field and the laboratory.

However, it should be noted that when applied to water samples from the field, both the above tests will necessarily provide only 'snapshots' of the intensity and spatial extent of effects. Reproducibility in these terms would depend on identical environmental conditions (e.g. wind and wave action) prevailing from one sampling period to the next — an improbable occurrence.

Physiological stress tests as field bioassays have the advantage of being longer-term integrators, and therefore should be more amenable to temporal comparisons. However, an unambiguous outcome is at least partly dependent on the availability of suitable food, both in nature during field deployment, and in controlled laboratory conditions during test procedures. Note that, in contrast to the oyster embryo and 'Microtox' tests, the logistics and costs of deployment of caged mussels would normally dictate limitation of effort to a few key sites.

Therefore, regarding the potential for derivation of Environmental Quality Standards from field bioassays, physiological stress tests show promise, along with other methods involving *in situ* benthic species (e.g. polychaete enzyme activity) which have been exposed to the disposal operation for months or years. Laboratory tests of sediment toxicity also appear to have a future role in this respect. However, in all these cases, practical experience of deployment of such tests at sewage-sludge disposal sites is too limited, and hence the data-base inadequate, to permit firm recommendations to be made at this stage.

A3.4 Future needs for research and development

A3.4.1 Supply of test organisms

The reliable supply of test organisms is a key factor determining the success of regular monitoring programmes, and the development of stock-holding facilities is therefore essential. Additionally, support is also required for the development of techniques for cryogenically preserving gametes or embryos. If successful, this would greatly facilitate the application of a number of test procedures which depend on consistent supplies of these sensitive stages. Presently, much of the research in this area is carried out in connection with commercial shellfish farming.

A3.4.2 Sediment tests

The high-scoring tests were water-column tests (though these can be used for sediment elutriates). Accordingly, there is a need to give high priority to future work aimed at development and comparative assessment of the utility of a wider range of invertebrate assays of direct sediment toxicity. This would be as a complement to traditional studies on benthic communities, which presently remain the most suitable way to assess sediment quality in the field.

The outcome of a Workshop in March 1990 under ICES/IOC auspices (in preparation), which included the conduct of sediment bioassays along a point-source gradient, will be of particular interest in this context.

A3.4.3 Review of test protocols

For tests which have not yet been widely applied, the probable outcome of an evaluatory phase at disposal sites will be limited modifications of test procedures, and hence allowance must be made for future improvements in protocols for their conduct; this might, for example, take the form of a standing review. There will also be a need to ensure continued interaction between those engaged in research on the one hand, and in routine application on the other.

A3.4.4 Intercalibration of methods

Periodic intercalibration of methods between laboratories is important to maintain quality control, and is especially important where comparisons are to be made between results from different disposal site locations.

A3.4.5 Pre-test sample manipulations

Research into methods for concentrating contaminants found in water samples is of interest in connection with monitoring sewage-sludge disposal sites. Such methods include XAD resins for organic compounds, C18 for organo-metallics, and 8-hydroxyquinoline for metals. These may permit the establishment of response thresholds, and could have particular significance at dispersive sewage-sludge disposal sites where, in practice, contaminant concentrations in most water samples will be relatively low. Such methodology would then allow the determination of the extent to which concentrations encountered in field samples would have to be increased in order to initiate a response.

Another potentially important application concerns the facility to take integrated water samples over periods of hours at and around disposal sites.

A3.4.6 Other needs

In view of the existence of a number of potentially useful biological effects tests which, for a variety of reasons, are not presently considered suitable for routine application at UK sewage-sludge disposal sites, then their deployment at these sites, in an applied research context, deserves every encouragement.

A3.5 An inventory of practical issues relevant to the adoption of a biological effects monitoring programme

Recognising the presently limited experience of deployment of biological effects measures at sewage-sludge disposal sites, the above assessment has necessarily concentrated on an assessment of the *potential* utility of a range of currently available methods, and this has led to a series of recommendations concerning future applications.

Critical to the success of any biological effects monitoring programme will be a precise formulation of the local objectives to be met, followed by an appraisal of the capability of the test(s) to meet these requirements. This appraisal will require consideration of a range of methodological and environmental factors, in order to ensure an unambiguous outcome. A summary of the practical issues to be considered prior to the development of a routine programme is given below.

A3.5.3 Desk study

Environmental variables: Tidal and residual currents, depth and turbidity of water, and the nature and distribution of sediments will be important in test selection and sampling design.

Disposal practice quantity and quality: This will notably influence the timing of sampling for conducting short-term tests, as well as site location.

Other inputs/activities: This is important for the interpretation of test results, and may also influence the location of sampling sites.

Other studies of the locality: These may help in a number of ways in the identification of the most appropriate environmental target, and in enhancing the design of a sampling programme.

It will be clear from the above that the influence of natural and man-made factors acting in combination may have a considerable bearing both on the choice of tests and the efficiency of their conduct. In some circumstances, a desk appraisal of cost-effectiveness might lead to the conclusion that no field test presently available can guarantee an unambiguous outcome.

A3.5.4 Planning and design of sampling programme

Identification of target water/sediment: This should become apparent from the desk study.

Clarification of objectives: short-/long-term tests: In a highly dispersive area, the main concern might be with the immediate impact in the water-column around the disposal site following a single discharge; in zones of known long-term accumulation, the concern might be with any biological effects integrated over an appreciable time period, probably at or near the sea bed, but not necessarily near the disposal site.

Selection of test: This will be determined in part by the above considerations, and in part by the availability of tests which are presently suited for routine deployment.

Pre-survey calibration of response with dilutions of waste: This will be easier for short-term tests (e.g. the oyster embryo test), but in principle should be feasible for all tests. In some circumstances, the outcome could have important implications for the detection of initial waste impact in the field, because of the variable but usually high rate of initial dilution following discharge from ships.

Definition of acceptable level of change: Such a task will be difficult in the absence of base-line data, or of a full understanding of the 'relevance' of test results to field populations. However, at an appropriate distance from a discharge, a management criterion might be no change (acceptable or otherwise) relative to the background. With careful experimental design, it should be possible to achieve a coefficient of variation of 20% of the mean for both the oyster embryo and mussel-feeding tests at any given site, though the effort required is likely to vary appreciably from one location to another and will ultimately depend for confirmation on field experience. Clearly, a sound knowledge of dispersal pathways will be required to allow selection of appropriate sampling sites.

Grid/transect/profile in relation to disposal practice: The selection of sampling locations, and the number, will be considerably aided by prior knowledge of the receiving area (see above). The choice of a grid or transect design will depend *inter alia* on the complexity of the dispersive process. In the simplest and best understood cases, sampling to meet the requirements for adequate spatial and time comparisons may be achievable with very few stations. Profiles will be necessary to establish the rate of vertical as against horizontal mixing. For some tests (e.g. that on caged mussels) the number of stations will probably be limited by cost and logistical constraints.

Number of samples required: This will be dictated by the required precision of the results in order to meet specified objectives, and will inevitably vary from site to site. For long-term tests (e.g. using caged animals) the risks of accidental loss of samples as a result of weather or human activities must also be taken into account.

Supply of test organism(s): This may influence the timing of surveys; consistency of stock may be very important when it comes to year-on-year comparisons.

Adequacy of facilities on vessel: Clearly, a pre-survey review of requirements for conducting sampling and test procedures at sea is essential.

Adequacy of trained staff: This requirement is self-evident, and will have been costed at an early stage in the planning process.

A3.5.5 Execution of tests

Method: For short-term tests, standard procedures should be followed for sampling water or sediments in the field, and for subsequent testing in the laboratory.

For long-term exposure tests in the field (e.g. employing *in situ* caged animals) the appropriate organisations will already have been consulted regarding the survey plan, and advice as to the suitability of station locations will have been sought where necessary. It will be essential to adequately buoy and mark all deployed cages in accordance with maritime requirements.

Parallel measures: Especially in the case of short-term tests, it is most important that determination of an appropriate range of physico-chemical and biological variables is made on samples taken in parallel with those for the test. These will typically include tests on salinity, temperature, turbidity, relevant contaminants and chlorophyll.

Clearly, the presence of a planktonic bloom may induce a widespread reduction in water quality, even though the cause may be entirely natural.

Weather conditions: Weather conditions preceding and during sample collection may have an important influence on the dispersive process for wastes which have recently been disposed of, and hence could account for much of the variability in intensity of effects between sampling occasions for short-term tests of water-column samples. For long-term tests (i.e. those spanning weeks or months of exposure in the field) weather effects will tend to even out in accordance with natural expectations; however, even seasonal norms cannot be guaranteed, and hence accurate records should be kept.

A3.5.6 Frequency of sampling

This will depend on the objectives to be met (see above), but will be higher (typically once per year for long-term tests) for a new disposal operation. Other factors determining frequency will be the perceived sensitivity of the area in scientific or other terms, and changes to the quantity and/or quality of the waste discharged.

A3.5.7 Interpretation and reporting procedures

Interpretation of trends: For short-term tests, this will initially involve an examination of spatial pattern on grids or transects and, as monitoring data are accumulated, any changes in these patterns with time.

For long-term tests, a similar approach will be adopted, though in general fewer sites will have been sampled, and a more detailed comparison of differences between sites will be of greater interest, because the results will represent a time integral of any effects of waste disposal. Greater confidence may also be placed in examinations of year-on-year trends at key sites, because of this factor.

Correlation with other variables: This will involve correlation of test results with simultaneous measurements of water or sediment quality. The findings should also be examined in relation to those from other monitoring activities (e.g. tests on sediments and benthos), and hydrographic data. Effort should continually be made to improve integration between the various monitoring efforts.

Intercalibration between surveys/locations: These exercises will be very important to ensure temporal consistency and, where appropriate, to allow comparisons between studies of different waste disposal activities. The results of such exercises should be annexed to full monitoring reports.

A3.6 Appendix references

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

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AQUATIC ENVIRONMENT MONITORING REPORT Number 25