ISSN 0308-5589

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

FISHERIES RESEARCH TECHNICAL REPORT

No. 45

The field assessment of effects of dumping wastes at sea: 1 an introduction

M.G. NORTON and M.S. ROLFE

LOWESTOFT, 1978

The authors:
M.G. Norton Ph. D. is a Principal Scientific Officer and M.S. Rolfe is a Higher Scientific Officer in the Marine Environment Protection Division of the Directorate of Fisheries Research. Both are stationed at the Fisheries Laboratory, Burnham-on-Crouch, Essex.

Fish. Res. Tech. Rep., MAFF Direct. Fish. Res., Lowestoft, 45, 9pp.

CONTENTS

FISHERIES RESEARCH TECHNICAL REPORT NUMBER 45

THE FIELD ASSESSMENT OF EFFECTS OF DUMPING WASTES AT SEA: 1. AN INTRODUCTION

by

M G Norton and M S Rolfe

1. Introduction

This report outlines the responsibilities of the Ministry of Agriculture, Fisheries and Food (MAFF) in the control of dumping, defines the objectives of monitoring dumping areas and sets out the philosophy which determines the detailed planning of surveys to assess the effects of waste disposal at sea.

The second report will detail the methodology employed in surveys, including sampling techniques, laboratory analysis and data processing. Subsequent reports will present the results of surveys in specific areas.

2. MAFF's responsibilities under the Dumping at Sea Act, 1974

MAFF has exercised a responsibility for the control of marine pollution from the disposal of Wastes from ships by dumping since the early 1960s, when a voluntary control scheme invited companies or other organisations involved in the dumping of wastes to apply for its approval of their activities. These applications were considered and where no significant adverse effects on the marine environment were expected consents for the disposal of certain wastes to specific dumping areas were granted. By the early 1970s nearly all industrial wastes and sewage sludges dumped at sea were included within this voluntary scheme. In 1972 the Oslo Convention was concluded whereby the countries bordering the North Sea and North-East Atlantic agreed on common measures to control marine pollution caused by dumping. The London Convention applicable on a global scale was also concluded in 1972. Following this, the UK introduced the Dumping at Sea (DAS) Act which entered into force on 27 June 1974. The UK has since ratified both the Oslo and London Conventions.

The DAS Act makes it an offence to dump (or load for the purposes of dumping) any material in the sea from a vehicle, ship, aircraft, hovercraft or other marine structure without a licence from the relevant licensing authority, and except in accordance with the conditions of the licence. In England and Wales MAFF is the licensing authority. It is the responsibility of the licensing authority under the Act to "have regard to the need to protect the marine environment, and the living resources which it supports, from any adverse consequences of dumping .....".

In order to discharge this responsibility, it is necessary to

i. exercise predischarge controls on wastes, so that wastes which are likely to have significantly deleterious effects on the marine environment are either not licensed, or their discharge is made under conditions which overcome potential adverse effects,

ii. enforce the Act to ensure that the predischarge controls are observed,

iii. carry out surveys of the areas licensed for the disposal of wastes to ensure that the marine environment and its resources are being protected.

The essential predischarge licensing controls require the consideration of a number of factors, including the characteristics and properties of the waste and the proposed receiving area. These have been discussed at length elsewhere (Wood, 1973 and Norton, 1976) and it is not proposed to repeat that discussion here. Likewise the importance of enforcement has been explained (Norton, 1976).

The third part of MAFF's control programme as itemised above is an essential means of supplementing the first two controls, and its primary objective is to provide the necessary scientific data which can confirm whether the predischarge controls have, as intended, prevented any adverse effects on the receiving area. The survey results may also be of considerable relevance for other reasons: first they may improve our knowledge of general physical, chemical or biological processes in the marine environment; second, they may reveal effects which were not predictable in quantitative terms in the predischarge assessment, and which therefore improve and update the initial basis for licensing controls; finally, they provide the necessary evidence to demonstrate within the international conventions on dumping control that the UK's pollution control measures are having the necessary effect in ensuring that the dispersive and assimilative capacities of the marine environment are not exceeded so as to cause environmental damage.

3. General considerations in the design of monitoring programmes

Each year approximately 250 different licences are issued in England and Wales for a variety of wastes within the general classes: sewage sludges, industrial wastes, colliery wastes, fly ash and dredgings. These licences involve approximately 80 dumping sites. Some of these areas have been surveyed since MAFF started its monitoring programmes in 1970, and a number of surveying techniques have been used. The location of the areas studied is shown in Figure 1 and the content of the surveys in Appendix I.

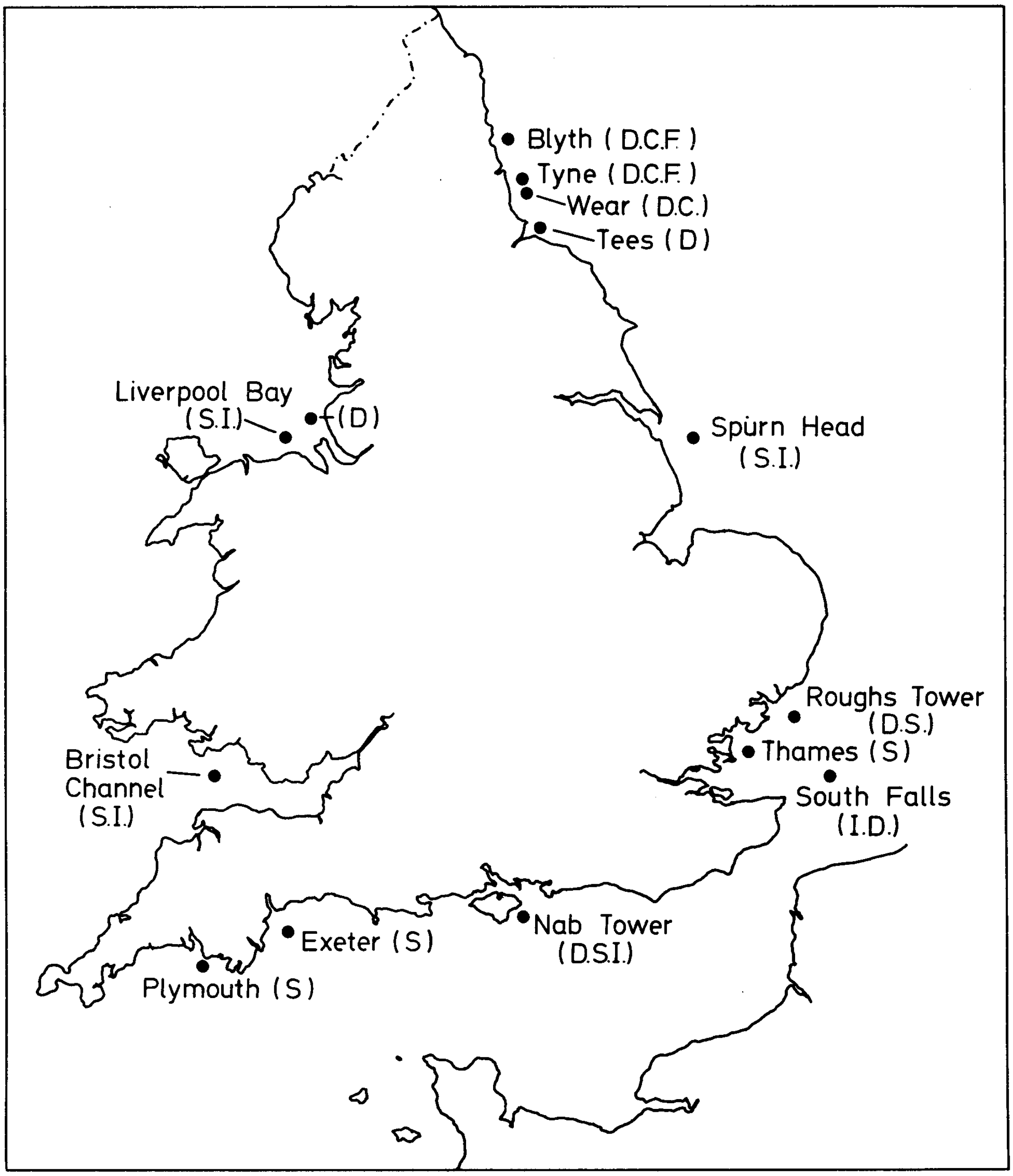

Figure 1 Position of dumping grounds which have been monitored by MAFF surveys 1970-77.

C = colliery waste
D = dredgings
F = fly ash
I = industrial waste
S = sewage sludge

This experience has allowed a comparative assessment to be made of a number of monitoring techniques and approaches and in particular of the most effective use of limited resources to survey a large number of dumping sites. In designing monitoring programmes to gain the maximum information, it is necessary to consider the expected effects of each type of waste as well as the monitoring philosophy to be applied.

3.1 Types of waste disposal licensed and their implications

A schematic summary of the potential pathways and effects of a dumped waste is given in Figure 2. This illustrates that a waste may affect marine organisms and the physical and chemical properties of water and sediment whether in the water column or on the sea-bed. A monitoring programme applied to measure all the possible determinands in Figure 2

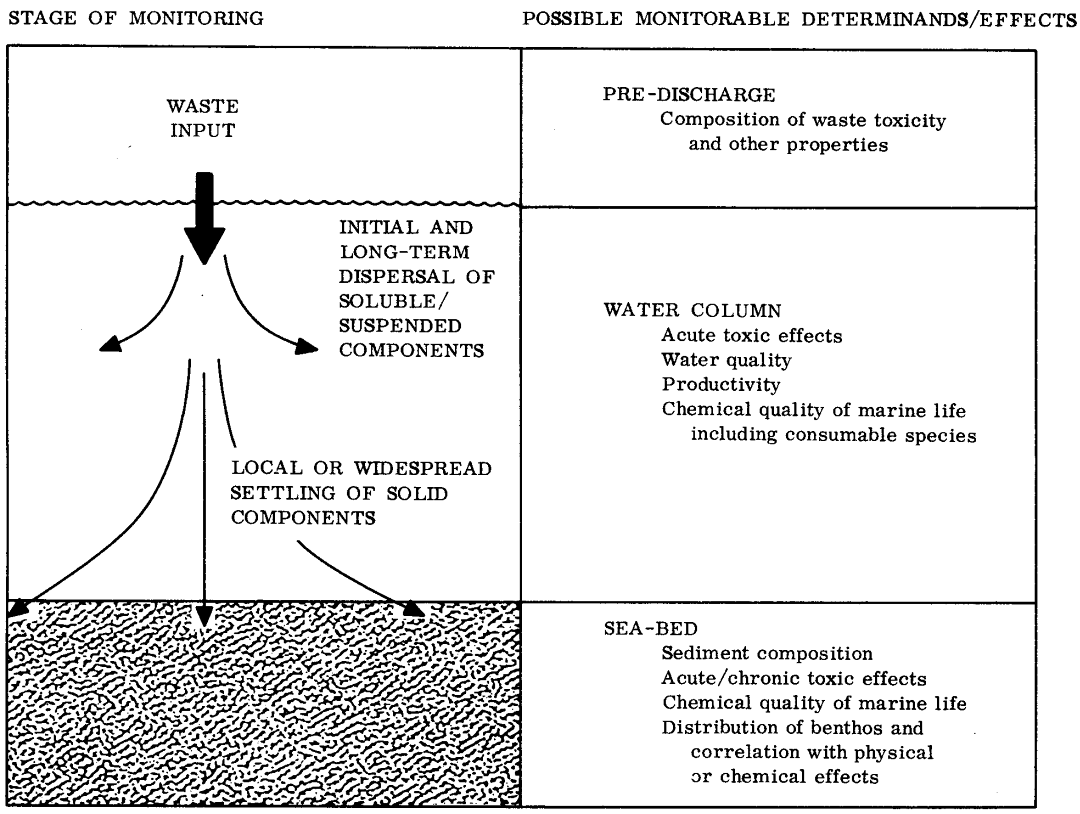

Figure 2 Dumping of wastes at sea: the system to monitor.

would be extremely demanding of resources, but from experience it has been found that effective monitoring can be achieved by concentrating effort on the water column or the sea-bed according to the type of waste. This selection can be made on the basis of whether the main effects are expected:

i. on the sea-bed (i.e. in solid waste disposal areas receiving colliery wastes, fly ash or dredgings),

ii. in the water column (i.e. in areas receiving soluble industrial wastes),

iii. in both the water column and on the sea-bed (i.e. in areas receiving sewage or industrial sludges).

This initial classification allows limited resources to be applied where they are likely to generate data of the maximum relevance.

3.2 Monitoring philosophy and levels of investigation

From a knowledge of the physical and chemical composition of the wastes, it is normally possible to define a monitoring programme to determine the distribution and fate of the dumped material and the extent of its effect on the physical and chemical properties of the water column and/or sediments. In seeking to assess damage to the marine environment, however, it is necessary to determine the extent of any biological effects caused by the dumping operation.

Although biota may be monitored in both the water and sediment, there are several factors which favour the monitoring of the benthos. First, toxic effects on planktonic species in the water column may be avoided by adequate predischarge controls and, in well mixed waters, dumping will rarely take place twice in the same body of water, thus making cumulative effects unlikely. The benthos, however, being relatively immobile and long-lived, may be subject to physical and chemical changes and to the accumulation of dumped material from successive dumpings and may thus reflect the influence of dumping over a long preceding period. Secondly, the assessment of biological effect presumes a capability to distinguish the effects of dumping from natural variations in the abundance and species composition of the biota. Variations in planktonic species in the water column (both spatial and temporal) with respect to a fixed point such as an outfall or dumping site are very great, whereas the natural variability of benthic organisms, though still appreciable, is considerably less.

Even where attention is restricted to the benthos, however, many workers would contend that long term studies extending over many years are necessary for an understanding of even the basic ecology of benthic communities. In many studies, the cause of any ecological changes has remained obscure and it has only rarely been possible to distinguish man-induced effects against the background of erratic natural fluctuations which are typical of all animal communities, not least of those in the marine environment (Lewis, 1972; Gray, 1976). Therefore, when a large number of offshore sites need to be investigated on a regular basis, a detailed approach may be prohibitively demanding of resources, and a more cost-effective approach, still compatible with the monitoring objectives, is required. Consequently, a number of biological monitoring techniques have been evaluated over the past seven years.

From 1970, the approach was based on laboratory identification of animals separated from the sediment using, generally, a 0.5 mm mesh sieve (Shelton, 1971). Unfortunately, work-up of data was limited by the absence of computer programs and few significant results accrued from considerable effort in the field and in the laboratory. This poor return for effort led to the development of a method of rapid assessment which was described by White, Rolfe and Hardiman (1974). This was designed to identify merely gross effects on the benthos and was based on the identification of only those specimens which could be picked out from 2 mm sievings while on the survey vessel. A few unidentified specimens were subsequently identified back at the laboratory. This technique required only a fraction of the staff time needed for the full laboratory identification procedure, yet without the computer-aided analysis of data provided virtually as much information. 'Rapid assessment' surveys were carried out during 1974 and part of 1975 at a number of dumping grounds.

In 1975, when computer techniques for multivariate statistical analysis of the benthic data became available, consideration was given to the possibility of distinguishing significant ecological changes by examination of *spatial* variations in the benthos and the physical and chemical characteristics of the sediments. Although objective, computer-assisted analysis allowes a more detailed treatment of ecological data, the need for a subjective element in the final assessment remains.

To interpret the more detailed data for benthos, an understanding of the sediment characteristics of the area is essential, first to quantify the physical and chemical changes that have occurred in the sediment as a result of dumping and second to determine whether changes in sediment were responsible for any biological changes observed. Additionally, a knowledge of sediment dynamics enables the dispersive characteristics of the area to be assessed.

Since 1975, therefore, selected dumping grounds have been investigated using more intensive benthos and sediment surveys and the results have been compared with those of the earlier surveys described above. These studies have allowed more detailed conclusions as to the biological effects of some waste disposal operations to be reached, but the resources required for such studies limit their regular use.

As a result of experience gained, we have therefore sought to characterise each of the major dumping areas by an initial *intensive survey* in biological, chemical and physical terms which is used as a reference point for future surveys. A survey carried out before dumping started is often regarded as a 'baseline study'. However, where the dumping has already commenced (e.g. in the Thames estuary dumping started ca 1890), it is referred to as a 'bench-mark' study.

The intensive survey is very demanding of resources and it it not possible or necessary to repeat such a survey of all dumping areas at frequent intervals. Consequently, less intensive *routine monitoring* is carried out every year or so, measuring those determinands which provide an early warning of significant adverse changes. The intensive survey is repeated at longer intervals, determined by the nature and quantity of dumping inputs, the characteristics of the area and the results of the routine monitoring.

In the following sections 4, 5 and 6 the above philosophy is applied to the different types of waste disposal areas to describe the form of the monitoring programme required in each case.

4. Monitoring requirements for solid waste disposal areas

In this category are those wastes which have an effect primarily at the sea-bed. They include colliery waste, fly ash and dredge spoils which account for the largest quantities of 'waste' dumped. The number of areas involved is: colliery waste 4, fly ash 3 and dredgings $\sim$60. The approximate positions of the principal areas are shown in Figure 1 and a summary of the techniques employed is given in Appendix I.

4.1 Colliery waste and fly ash disposal areas

Since these wastes have no soluble components and settle rapidly, the monitoring techniques employ bottom sampling methods. Physical and chemical analysis of sediment and benthos enumeration have shown the location of existing spoiled areas, the degree of movement of dumped materials after dumping (both by movement within the sediment and in suspension) and the effects on the benthos.

The results of some of these studies confirm that the primary effect is one of physical blanketing, which may result in depletion of the benthos and destruction of shellfish habitat. Quantitative results currently under review may clarify the extent of subsidiary effects on the fringes of the dumping areas where some movement of abraded dumped material occurs.

Intensive 'bench-mark' surveys have demonstrated the extent of historical damage caused by dumping, which preceded the Oslo Convention and its ensuing statutory controls. While dumping is maintained in the areas already affected, little additional environmental damage will occur. There thus appears to be little justification for repeated surveys of the affected areas at frequencies greater than every 5-10 years. The effect of dumping on the benthos is fairly well defined, and future routine monitoring surveys will therefore have as their main objective the determination of the extent of physical changes to the sea-bed and the definition of the affected area relative to earlier surveys. This will probably be done by a combination of bottom sampling and surveying techniques such as side-scan sonar. In this way the effectiveness of the controls on the site of dumping may be assessed independently of the licensing authority's enforcement activities (Section 2).

4.2 Dredgings disposal areas

Although disposal of harbour dredgings is also likely to have effects on the marine environment as a result of physical blanketing, the effects may differ from those caused by colliery wastes and fly ash. Thus, dredgings may be highly polluting due to their anoxic quality or contamination with heavy metals, oil, organochlorine compounds etc. Since they generally consist of accumulated marine sediment, the identification of areas of deposit may be less straightforward than with colliery waste and fly ash. Furthermore dredgings vary from thin silts derived from maintenance dredging to boulder clay from capital works, e.g. new excavations.

The 60 areas allocated for the disposal of dredgings off England and Wales were selected primarily on the basis of their lack of interference with navigation and commercial fishing. Many of these areas were designated as spoil grounds for many years before attention was directed towards the need to regulate disposal to the marine environment.

To monitor the effects of disposal in all of these areas would be extremely wasteful of resources, because the environmental effects of dredge spoil disposal are usually similar in several areas. Furthermore, there is often no practicable alternative to dredge spoil disposal at sea due to the absence of land reclamation sites. Nevertheless, the quantities of sediment and contaminants contained in dredgings in certain areas may represent a major source of some substances, particularly trace metals. Consequently, rather than monitoring each area, a limited amount of monitoring effort has been directed to specific investigations of selected areas in order to widen knowledge of the general environmental effects of dredge spoil dumping. These studies have investigated the biological impact of different types of dredge spoil, the possible transfer of pollutants from the dredgings to marine life, and the rate of change of deposits after dumping (i.e. physical movement, weathering, recolonisation etc). Although they have not been very detailed to date, the limited experience obtained leads to the conclusion that the adverse impact of dredge spoil disposal is best minimised by restricting the dumping area to as small an area as practicable where it will not affect fisheries or navigation and by adopting measures adequate to ensure that dumping takes place within that area.

Although this low level of monitoring is sufficient for long-established disposal sites, the selection of a new site usually justifies a more detailed survey of the disposal area before and after dumping starts. Such surveys usually investigate:-

i. the sea-bed topography, structure and stability, and the extent of subsequent accumulations,

ii. the distribution and changes in the benthos,

iii. normal water quality variations (particularly those likely to be affected by dumping, e.g. suspended solids), and

iv. the chemical quality of selected marine organisms.

5. Monitoring requirements for soluble waste disposal areas

The UK has designated five areas for the disposal of wastes from the chemical and petrochemical industries containing no insoluble components. Such wastes are tested for their acute toxicity before licences are issued, and the conditions of the licence require the rate of discharge to be low enough to avoid acute toxic effects in the wake of the dumping vessel. Licences are not issued for wastes containing substances known to bioaccumulate in marine organisms. Hydrographic investigations before the onset of discharge also allow the longer term dispersion of the diluted waste to be predicted. Sites are selected on the basis of favourable dispersion characteristics and avoidance of areas of importance for fisheries, (including spawning, larval and nursery grounds).

Since the major components of these wastes are soluble and dispersion in the ship's wake is rapid, the possibility of detecting effects outside the immediate wake is considered to be remote. As in each of the five areas the size of the disposal operations was small (less than 100,000 tonnes per year) these disposal areas have not been monitored. Recently, however, an increase in the amount of waste to be dumped in one of these areas has led to a reconsideration of this policy and a monitoring programme may be necessary.

Since the discharge is into deep water (>50 m) and the waste contains no suspended particles which will settle it is unlikely that benthos or sediments will be affected in any way. If any effects are to be found they will be in the water column. Where the waste contains a high concentration of a single chemical (e.g. nutrients such as NO_3^-, NH_4^+) the dispersion may be monitored through water quality measurements. The selection of a method of biological monitoring is less straightforward, however, due to the high natural variability in the communities of plankton and fish. Consequently, techniques for the measurement of the biological quality of sea water are being assessed. If such methods are shown to be effective they will be used to detect any widespread change in the 'biological quality' of the water in the dumping areas. In the event of any significant change being detected, other monitoring techniques might be required to establish whether significant biological changes had taken place in the dumping area itself.

6. Monitoring requirements for sewage sludge disposal areas

Sewage sludges (and some industrial wastes) contain particulate and soluble components and may affect the water column and the sea-bed. In addition, dynamic processes may take place on discharge which affect the distribution of certain substances between these two phases. Consequently, most of the determinands which are monitorable within the water column and on the sea-bed (Figure 2) are measured at the ten dumping grounds used off England and Wales.

For the reasons given in Section 3, priority has been given to determining effects at the sea-bed. Surveys have thus concentrated on analysing sea-bed sediments and enumerating and identifying the benthos. This has been supported by collection of samples of commercial fish and shellfish for chemical analysis. The effects on the biota of physico-chemical changes in the sediments have been determined in some areas. Additionally, recent surveys have sought benthos samples for chemical analysis to link tissue and sediment metal levels, and have also employed other techniques such as microbiology, hydrography and sedimentology to improve knowledge of sewage sludge settling patterns. Much raw data have been gathered and reports of studies made in specific areas, with assessments of the effects of sewage sludge dumping, are in preparation.

The studies which have been made by MAFF laboratories have in some areas been supplemented by special investigations such as those commissioned by the Department of the Environment in Liverpool Bay and by Regional Water Authorities in other areas.

In sewage sludge dumping areas it is necessary to determine the short, medium and long term fate of the sludge and its persistent components (e.g. metals), and its effects on the physical and chemical characteristics of the receiving area. The biological effects, including those on fish and shellfish quality, must also be determined. These aspects are discussed in detail below.

6.1 Distribution of sewage sludge and physical/chemical effects

In monitoring the effects of sewage sludge dumping it is essential to have some understanding of the physical/chemical effects and the dispersion pattern of the dumped waste in the water column and sediments. The collection of data on these subjects from a number of dumping grounds is now well advanced following the completion of bench-mark studies in a number of areas. When completed the results for each area will be published and reviewed to allow the selection of determinands to be used as the basis of future routine monitoring programmes.

6.1.1 *In the water column*

Sewage sludge disposals on a large scale may have a sufficiently widespread effect to warrant water quality monitoring, since recent evidence suggests that a number of components, including metals normally associated with the particulate phase of the sludge, may be solubilised in oxygenated saline waters (Rohatgi and Chen, 1975). Consequently, exploratory surveys are being planned to establish the detailed distribution of dissolved and particulate metals and nutrients in the water column at the main sewage sludge dumping areas. This work will be part of an applied research programme rather than a routine monitoring operation, and will also link with laboratory experiments on sludge/water column interactions.

The determination of water quality in sewage sludge dumping areas also includes the routine measurement of dissolved oxygen where it is necessary to supplement existing surveys carried out by the relevant Regional Water Authorities.

Where considered necessary, dispersion processes through the water column have been investigated using 26-h hydrographic stations in which water and sediment movements are measured. More detailed surveys involving deployment of moored current meters and releases of sea-bed drifters are occasionally used.

6.1.2 *In the sediment*

During recent studies techniques have been developed for the bacterial analysis of faecal organisms in sediment (Ayres, 1977). The results indicate the distribution of sewage solids from which the initial transport paths of settled sludge particulates may be inferred. The method is at present only qualitative, due to uncertainty concerning the half-life of coliforms and *E. coli* in the water column or in sediment.

Studies of the redox potential (Eh) and organic content of sediments have given some insight into the fate of organic particulates, but in some areas difficulty may be found in separating the effect of sewage sludge dumping from that of other discharges. The interpretation of metal levels in sediments is subject to similar difficulties but may be further confused by the varying background levels derived from geological sources. The solubilisation of the metal in the particulate phase of sewage sludges also influences the distribution of metals in sediment.

6.2 Biological effects of sewage sludge disposal

Intensive surveys of the biological effects of sewage sludge disposal have been completed or are in progress for most disposal areas. Some of the studies have been made in co-operation with other organisations (i.e. with the Department of the Environment in Liverpool Bay; with the Northumbrian Water Authority for a disposal operation planned to start off the mouth of the River Tyne). These surveys have established the biological effects of sewage sludge disposal on benthic communities in greater detail than hitherto and have thus provided useful bench-marks for future surveys. Because of the large effort that detailed benthic studies require, future routine monitoring of sites will not generally include biological surveys, except in certain areas where there may be a need for the selection of a limited number of control stations to allow surveillance to continue. Intensive benthic surveys will however be repeated periodically, the frequency depending on the characteristics of each area, any proposed change in the disposal practices and the results of routine surveys.

6.3 Effects on fish and shellfish quality

In addition to the effects on biological communities, some of the persistent components of sewage sludge (trace metals, PCB's, pesticides etc) may affect the quality of species of direct commercial interest to man. This may be direct, e.g. caused by dumping of waste on non-mobile species of exploited shellfish, or indirect in that it may affect the quality of food through the marine food chain.

MAFF operates an extensive national programme for the monitoring of the chemical quality of fish and shellfish landed at UK ports (Portmann, in press). This is supplemented by the collection for analysis of special samples of fish and shellfish from dumping areas, as well as benthic species from some areas, to seek links between the levels of metals in sediments, in benthic organisms and in fish.

7. Future developments

The considerations which have led to the definition of MAFF's current policy on the monitoring of dumping areas have been set out, and results of surveys carried out under this policy will be published. It should be recognised however, that the technology available for monitoring may change, the requirements under national and international agreements may develop, and experience may also lead to the re-evaluation of existing monitoring approaches. Consequently, the policy may develop further over the next few years.

8. References

AYRES, P.A., 1977 The use of faecal bacteria as a tracer for the disposal of sewage sludge in the sea. Mar. Pollut. Bull., 8 (12), 283-285.

GRAY, J.S., 1976. Are marine base-line surveys worthwhile? New Scient., 70 (998), 219-221.

LEWIS, J.R., 1972. Problems and approaches to base-line studies in coastal communities. pp. 401-404 In: Ruivo, M. (ed), Marine Pollution and Sea Life. Fishing News (Books), London. 624pp.

NORTON, M.G., 1976. The operation of the Dumping at Sea Act, 1974. Chemy Ind., 19, 629-634.

ROHATGI, N. and CHEN, K.Y., 1975. Transport of trace metals by suspended particles on mixing with sea water. J. Wat. Pollut. Control Fed., 47(9), 2298-2316.

SHELTON, R.G.J., 1971. Sludge dumping in the Thames Estuary. Mar. Pollut. Bull., 2 (2), 24-27.

WHITE, I.C., ROLFE, M.S. and HARDIMAN, P.A., 1974. Disposal of wastes at sea, Part III. The field assessment of effects. ICES CM 1974/E:25, 14pp (Mimeo).

WOOD, P.C., 1973. Disposal of sludge to sea. Paper No 8, pp 103-112, In Proc. of Symp. Disposal of municipal industrial sludges and solid toxic wastes. Inst. Water Poll. Control, Maidstone. 119pp.

PORTMANN, J.P., In prep. Chemical monitoring of residue levels in fish and shellfish landed in England and Wales during 1970-73. Fish. Res. Tech. Rep., MAFF Direct. Fish. Res., Lowestoft.

APPENDIX I Location and types of monitoring employed at dumping areas used for the disposal of wastes

Area	Co-ordinates		Type of waste disposal	Techniques employed in monitoring*
Blyth	55°07'24"N 55°07'42"N 55°06'40"N 55°05'58"N 55°04'44"N	01°23'42"W 01°22'03"W 01°23'33"W 01°23'12"W 01°21'34"W	Colliery waste Fly Ash Dredgings	1 2 4 6 7 8
Tyne	54°59.7'N 54°58.0'N 54°56.9'N and ¼ mile offshore	01°16.7'W 01°15.8'W 01°15.8'W	Colliery wastw Fly Ash Dredgings	1 2 4 5 6 7 8 9 10
Wear	54°55.6'N 54°55.6'N 54°54.7'N 54°54.7'N	01°18.0'W 01°17.5'W 01°17.5'W 01°18.0'W	Colliery waste Dredgings	1 2 4 5 6 7 8
Tees	54°40'47"N 54°41'02"N 54°41'31"N 54°40'13"N	01°03'29"W 01°00'16"W 01°02'14"W 01°00'30"W	Dredgings	1 2 4 6 7 8
Spurn Head	Between 53°30'N 00°30'E	 53°35'N 00°35'E	Sewage sludge Industrial wastes	1 2 4 5 6 7 8 9 10
Roughs Tower	51°52'46"N 51°52'12"N 51°51'18"N 51°51'56"N	01°29'29"E 01°31'39"E 01°31'06"E 01°28'57"E	Dredgings Sewage sludge	1 2 3 4 6 7 8 9
Thames	51°41'15"N 51°40'45"N 51°49'13"N 51°39'44"N	01°18'42"E 01°20'18"E 01°17'21"E 01°17'57"E	Sewage sludge	1 2 3 4 5 6 7 8
South Falls	51°35'N 51°35'N 51°30'N 51°30'N	01°58'E 02°00'E 02°00'E 01°57'E	Industrial wastes	6 8
Nab Tower	50°36'57"N 50°36'06"N 50°34'04"N 50°35'00"N	00°56'09"W 00°55' W 00°58'33"W 00°59'48"W	Dredgings Sewage sludge Industrial wastes	1 2 4 5 6 7 8 9
Exeter	50°27'N 50°32.5'N 50°28'N 50°22.5'N	03°20.8'W 03°01.8'W 03°02.5'W 03°19.1'W	Sewage sludge	1 2 3 4 5 6 7 8 9

APPENDIX I - contd

Area	Co-ordinates		Type of waste disposed	Techniques employed in monitoring*
Plymouth	50°14.9'N 50°13.5'N 50°15.5'N 50°14.0'N	04°07.5'W 04°07.5'W 04°12.5'W 04°12.5'W	Sewage sludge	1 2 3 6 7 8
British Channel	within 1 mile of 51°24.5'N	 04°04'W	Sewage sludge Industrial wastes	1 2 4 6 7 8 10
Liverpool Bay	between 53°30.5'N 03°34.0'W	 53°35.5'N ·3°36.5'W	Sewage sludge Industrial wastes	1 2 3 6 7 8

*Number key

1. Physical analysis of sediments.
2. Chemical analysis of sediments.
3. Microbiological examination of sediments.
4. Observations of the sea-bed with side scan sonar.
5. Observations of the sea-bed with underwater camera.
6. Identification and enumeration of benthic animals.
7. Chemical analysis of selected benthic species.
8. Measurement of chemical quality of fish and shellfish.
9. Hydrographic studies with current meters.
10. Hydrographic studies with sea-bed drifter releases.

Bas 45617/0393 1,100 2/78 P