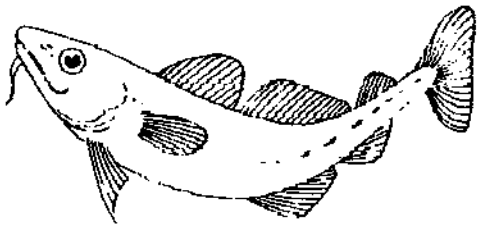
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AQUATIC ENVIRONMENT MONITORING REPORT

Number 44



Monitoring and Surveillance of Non-Radioactive Contaminants in the Aquatic Environment and Activities Regulating the Disposal of Wastes at Sea, 1993

MAFF

Directorate of Fisheries Research
Lowestoft, 1995

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

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LOWESTOFT
1995

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Staff responsible for the projects described in this report are listed in Annex 1.

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FOREWORD

In 1990, MAFF issued the first of its reports on monitoring of non-radioactive contaminants under the title 'Monitoring and Surveillance of Non-Radioactive Contaminants in the Aquatic Environment'. That report related to data collected in the years 1984-87 and since then reports have been published annually, with the most recent relating to data collected during a single year. This, the sixth report in the series, continues that recent pattern and relates to data collected during 1993.

As with the previous reports this issue gives information on the main monitoring projects conducted by staff based at the Burnham-on-Crouch laboratory, together with a summary of the data and a brief interpretation of the significance of the findings. Although most of the work was conducted in coastal or estuarine waters, some was undertaken in freshwaters in relation to investigations as to the scale of run-off of pesticides from agricultural land. A summary of this is included in Section 12.

As with the more recent reports, in addition to the general coverage of monitoring programmes, this report includes information, originally published separately, on activities in the field of licensing of sea disposal carried out under Part II of the Food and Environment Protection Act 1985 (FEPA II). This is presented as Section 13 of the present report. Section 14 of the report describes the related licensing activities and includes details of licences issued by the authorities for Scotland and Northern Ireland in order to provide statistics for the UK as a whole. The last section of the report relates to activities undertaken to protect marine fisheries interests from the potentially damaging effects of discharges from pipelines directly into the sea e.g. from sewage works.

The report thus covers a broad range of studies and reflects the diverse nature of the many contaminants and situations that merit investigation as well as the monitoring which forms part of national and international programmes. The programme continues in order to ensure that MAFF has as accurate and comprehensive as possible a picture of the trend and pattern of non-radioactive contamination in UK waters and can respond to issues of concern promptly and effectively.

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BACKGROUND TO THE WORK

The Fisheries Laboratory at Burnham-on-Crouch forms a Section of the Aquatic Environment Protection Division of the Directorate of Fisheries Research within the Ministry of Agriculture, Fisheries and Food (MAFF). The Laboratory's primary responsibility is to provide advice to MAFF Ministers and to other Government departments on all aspects of non-radioactive contaminants in the aquatic environment. The advice is used in the formulation of scientifically-based pollution control measures, enforced through Acts of Parliament.

The most direct of these is a duty to licence and thereby control the deposit of material in the sea. The statutory requirements for this are laid down in Part II of the Food and Environment Protection Act (1985) (FEPA) (Great Britain - Parliament, 1985(a)). Scientific and Technical aspects of licence applications are evaluated by inspectors at the Burnham Laboratory and regular visits are made to licence holders to discuss the terms of licences and to ensure that conditions stipulated in the licence are being met. An integral part of the scientific assessment process is the design and conduct of a marine disposal site monitoring programme. The environmental conditions at marine disposal sites are monitored by the Laboratory's Environmental Assessment team. The results of monitoring programmes allow MAFF to take action if unacceptable impacts do occur and also provide the basis for future licensing policy. Disposal at sea is regulated internationally by the Oslo and London Conventions and the monitoring programme allows the Government to demonstrate that it takes these obligations for the wider marine environment seriously. Some examples of monitoring investigations and licensing related data are included in this report.

Under the Water Resources Act (1991) (Great Britain - Parliamant 1991), MAFF has the responsibility of statutory consultee for all discharges to controlled (tidal) waters. Each discharge must be consented and the consent will specify the substances the discharge may contain as well as limit concentrations and loads as appropriate. Fishery implications are assessed at Burnham-on-Crouch and take into consideration such factors as resources in the area, toxicity of the effluent, local hydrographic conditions and any standards set out in national policy or EC Directives.

Scientists at the laboratory also contribute to the control of pollution in other areas of industrial activity affecting the marine environment, including the offshore oil and gas industry and marine aggregate extraction.

To ensure that its advice on these specific activities covers the widest possible range of conflicts of interest, the Burnham-on-Crouch Laboratory conducts a more general programme of monitoring, which forms the basis of MAFF's contribution to the National Monitoring Programme as well as fulfilling international monitoring commitments. Samples of sea water, sediment and marine organisms are collected each year in which a wide range of chemical determinands are measured. They include, trace metals, organochlorine pesticides and polychlorinated biphenyls (PCBs). This programme provides valuable information on the quality of the marine environment, against which areas such as disposal sites can be assessed. It also aims to ensure that where potentially harmful substances occur, concentrations do not reach levels that present an unacceptable risk to either marine organisms or human consumers of marine produce. Most of this work is carried out in accordance with procedures agreed under the auspices of organisations such as the International Council for the Exploration of the Sea (ICES), the Joint Monitoring Group (JMG) of the Oslo and Paris Commissions and, more recently, the North Sea Task Force.

All the pesticides used in the UK have to be approved by the Ministry's Pesticide Safety Directorate and the Advisory Committee on Pesticides (ACP). The Burnham-on-Crouch Laboratory provides advice on risk assessment to the ACP and has conducted extensive research on pesticide leaching and run-off, the data from which are being used to validate improved computer models of leaching and run-off.

In relation to particular measures of control, the Laboratory undertakes monitoring to demonstrate UK compliance with the European Council Directive on mercury discharges and similar requirements under the Paris Commission. It also undertakes work to assess the effectiveness of control measures taken, under Part II of FEPA, 1985, to regulate the use of antifouling paints containing tributyltin (TBT) oxide.

The Laboratory's programme of aquatic studies has been developed over more than 25 years. During this period the Laboratory has achieved a number of environmental protection successes and as a consequence of its work has established a worldwide reputation in the field of aquatic environmental research.

1. MONITORING OF CONTAMINANTS IN FISH AND SHELLFISH

1.1 Introduction

Data on the concentrations of a range of contaminants in fish and shellfish are reported regularly in the Directorate of Fisheries Research Aquatic Environment Monitoring Report series. In the main, information is gathered specifically for national or international monitoring programmes, for which there is an agreed list of 'core' species, deliberately restricted in number to ensure compatibility and comparability between participants in the programmes.

On 1 January 1993, two EC Directives came into force for which data from more widespread monitoring of fish and shellfish species will be necessary – Directive 91/493/EEC (European Communities, 1991(a)) laying down the health conditions for the production and placing on the market of fishery products and the more specific 91/492/EEC (European Communities, 1991(b)), covering the production and placing on the market of live bivalve molluscs. The Directives require, amongst other things, that the level of heavy metals and organochlorine residues in marketed fish and shellfish are such that acceptable/permissible daily or weekly dietary intakes are not exceeded. A subsequent development was the Decision by the Commission in May 1993 (93/351/EEC) (European Communities, 1993) that the total mercury content of the edible parts of fishery products should not exceed 0.5 mg kg^{-1} fresh weight – increased to 1.0 mg kg^{-1} for some species, which are listed in an Annex.

In the course of carrying out sampling for the various monitoring programmes, non-core species are also obtained and analysed on an opportunistic basis. The following provides a summary of the resultant information which might be utilised to help fulfil monitoring obligations arising from EC Directives 91/492 and 91/493. Full details of the analytical methods employed by the Burnham-on-Crouch Laboratory are given in Jones and Laslett (1994) for metals and Allchin *et al*. (1989) for organochlorine pesticides and PCBs.

It should be noted that the method of analysis for metals was changed in 1993, from atomic absorption spectrometry (AAS) to inductively coupled plasma-mass spectrometry (ICP-MS), allowing lower detection limits

1.2 Contaminants in fish muscle

A considerable amount of data has been reported on the core monitoring species cod, whiting, dab and flounder (e.g. MAFF, 1994). Information collected on other (non-core) species is summarised in Table 1 with the full data listed in Appendix 1. There is no indication from these or the other recently published data, that

Table 1. Ranges of mean concentrations of metals in bulked fish muscle for non-core species

Species	Range of mean concentrations (mg kg^{-1} wet weight)			Dry weight (%)
	Hg	Cu	Zn	
Bass	0.22	0.25	4.0	24
Black bream	0.06	0.35	3.7	24
Brill	0.03	0.28	5.0	20
Dover sole	0.06 - 0.10	0.13 - 0.35	3.5 - 4.5	20 - 22
Hake	<0.01 - 0.02	0.13 - 7.5	2.8 - 3.6	19 - 21
Lemon sole	0.03 - 0.05	<0.09 - 0.18	2.7 - 3.0	21 - 22
Monkfish	0.06	0.17	4.3	17
Plaice	0.03 - 0.13	<0.09 - 0.28	3.8 - 6.0	17 - 23
Red gurnard	0.02 - 0.12	0.20 - 0.24	3.7 - 3.8	23 - 25
Red mullet	0.08 - 0.15	0.23 - 0.29	2.4 - 3.5	23 - 29
Scad	0.04 - 0.05	0.50 - 0.66	3.1 - 3.6	24 - 27
Thornback ray	0.05 - 0.11	0.30 - 0.48	3.2 - 4.8	22 - 24

Note: Single value indicates only one sample of that species obtained
Mean concentration = mean of duplicate bulked analyses

levels of metal contaminants in fish muscle pose any problem from a human health point of view. Concentrations of mercury are all well below the limits given in Commission Decision 93/351/EEC, though data remain sparse for some species, especially for a number of those listed in the Annex to the Decision. Cadmium and lead concentrations are not measured in fish muscle as previous work has indicated that concentrations are extremely low.

Recent concentrations of organochlorine residues found in fish muscle are given in Appendix 2. Relatively few results are available (and from 'core' species only) since previous monitoring has indicated that organochlorines are not accumulated to any great extent in white fish muscle, because of the low level of fat in this tissue (normally <1%). It is usually the results from the analysis of lipid-rich fish liver that are used as an indicator of the level of organochlorine contamination and fish muscle is only analysed where the concentration of an organochlorine contaminant in liver is found to be exceptionally high. As found in earlier surveys, the levels of organochlorine contaminants in the white-fish muscle samples are not of concern from a human health point of view.

Concentrations of organochlorine residues are (as would be expected) higher in 'oily' fish, such as herring and mackerel (e.g. Franklin, 1987). Recent data are not yet available for these species; samples were collected in 1994 and the results from these will be reported in a future publication in this series.

1.3 Contaminants in shellfish tissue

A considerable amount of data has been reported in earlier MAFF publications on the blue mussel (*Mytilus edulis*), a core species for most international monitoring programmes (e.g. MAFF, 1992(a)). Studies have also been carried out recently on concentrations of metals in the brown crab (*Cancer pagurus*) (MAFF, 1991), the cockle (*Cerastoderma edule*) (MAFF, 1993(a)) and the oyster (*Ostrea edulis*) from the Fal (MAFF, 1994). Metal levels found in some other shellfish species are summarised in Table 2 with the full data listed in Appendix 3. Mercury concentrations were highest in lobster tail, for copper they were highest in the body tissue of spider crab, zinc and cadmium concentrations were unusually high in whole whelks (concentrations in the muscle only were much lower) and the highest concentrations of lead were found in queens. However, none of the concentrations found in this or any of the earlier work exceed UK standards/guidelines for metal contaminants in shellfish (listed in Annex 2).

Like white fish muscle, the fat content of shellfish tissue is low (generally 1% or less) and concentrations of organochlorine residues have consequently been of little cause for concern (Franklin, 1987; Murray, 1981). Few recent data have therefore been collected, though some information was obtained on mussels in support of a biological effects study (scope for growth) carried out by staff of the Plymouth Marine Laboratory (PML) (MAFF, 1993(a)).

A requirement of the Shellfish Hygiene Directive 91/492/EEC was the classification of shellfish harvesting areas according to the extent to which shellfish sampled from them were contaminated with *E. coli* or faecal coliforms. Classifications for England and Wales were produced in July 1993 and July 1994. Although the general monitoring data described above indicate few problems exist with chemical contaminants in shellfish, it is recognised that more specific information is required, directly related to the localised bivalve shellfish beds listed in the classification. Further monitoring is therefore planned on these beds, focusing on trace metal concentrations.

Table 2. Ranges of mean concentrations of metals in non-core species of shellfish

Species	Tissue	Range of mean concentrations (mg kg^{-1} wet weight)					Dry weight (%)
		Hg	Cu	Zn	Cd	Pb	
Molluscs							
Clams	W	<0.01 - 0.03	1.6 - 5.3	16 - 41	<0.06 - 0.17	<0.6 - 1.2	14 - 20
Queens	M	<0.01 - 0.02	0.5 - 2.3	25 - 53	0.11 - 0.19	<0.7 - 1.1	21 - 24
	G	0.01 - 0.02	1.8 - 2.4	21 - 57	0.17 - 0.5	<0.7 - 1.3	13 - 16
Scallops	M	<0.01 - 0.02	0.26 - 0.34	17 - 55	0.27 - 0.68	<0.7	18 - 25
	G	<0.01 - 0.03	2.0 - 4.4	32 - 75	0.11 - 1.1	<0.7	8 - 21
Whelks	W	0.1 - 0.31	19 - 139	104 - 493	0.9 - 2.9	<0.6 - 0.94	19 - 26
Winkles	W	0.03 - 0.07	2.1 - 36	12 - 32	0.05 - 6.1	0.70 - 0.96	17 - 29
Crustacea							
Lobster	C	0.07 - 0.27	18 - 25	34 - 50	<0.08	<0.6	15 - 26
	T	0.17 - 0.36	8.4 - 14	15 - 18	<0.03 - 0.11	<0.6	22 - 25
Nephrops	T	<0.01 - 0.14	6.7 - 11	12 - 17	<0.07	<0.7	21 - 29
Shrimp (brown)	W	0.02 - 0.06	6.8 - 8.5	14 - 18	0.06	<0.6	23 - 26
Shrimp (pink)	W	<0.01 - 0.07	7.6 - 9.3	14 - 16	<0.06 - 0.09	<0.6	26 - 29
Spider Crab	C	0.05 - 0.10	8.1 - 22	55 - 92	<0.06 -0.09	<0.6 - 0.7	18 - 26
	B	0.06 - 0.09	44 - 174	39 - 72	1.9 - 2.9	<0.6	19 - 24

Note: W = whole M = muscle G = gonad T = tail C = claw B = body

2. THE USE OF BIOASSAYS TO ASSESS THE QUALITY OF MARINE SEDIMENTS AND WATER

2.1 Whole sediment bioassays

2.1.1 Introduction

In surveys carried out prior to 1992, the toxicity of sediments was assessed using the oyster embryo technique, which exposed the larvae to sediment elutriates. Limitations (see MAFF, 1991, 1992(a), 1993(a) and 1994) associated with this method, e.g. it does not mimic the exposure of animals which dwell in the sediment, led to the development of whole sediment methods using animals that live in and feed directly on the sediments. One bioassay using the lugworm *(Arenicola marina)* was deployed in the 1992 survey for the first time (see MAFF, 1994). In 1993, two whole sediment bioassays were deployed. The *A. marina* bioassay was deployed onboard a MAFF research vessel (*RV CIROLANA* cruise 6, 9 June-1 July 1993) and the other bioassay using the marine amphipod *Corophium volutator* was carried out on the same sediments back in the laboratory.

2.1.2 Methods

Arenicola marina bioassay
Full details of the methods used in this bioassay have previously been described in MAFF, 1994.

Briefly, the worms are placed in containers containing sediment and overlying static water. The worms burrow into the sediment and after a 10-day exposure are sieved out and the number of surviving worms recorded. During the test, daily observations are made on the feeding behaviour by counting the number of casts.

Corophium volutator bioassay
C. volutator is a marine amphipod which can be found in the intertidal and subtidal sediments on the foreshore of most estuaries. They are collected and sieved from their native sediment and maintained in 40-litre aquaria with a layer of sediment, running sea water and aeration for a minimum period of 5 days before the start of a test. Mortality is measured after a 10-day exposure period. Ten adults are placed in each of three replicate 1-litre glass beakers containing a 2-cm layer of sediment with overlying filtered sea water to the 800-ml mark and aeration. At the end of the exposure period, the sediment is sieved and the number of surviving amphipods recorded.

2.1.3 Results

The results are presented in Table 3 (only results significantly different from the control are shown – full results are given in Appendix 4). A total of 41 stations was sampled and the sediments tested for toxicity. Sediments from three stations were acutely toxic to *A. marina* – Queen Alexandra Bridge on the Wear estuary (100% mortality) and Redcar Jetty and ICI No. 4 Buoy on the Tees estuary (100% and 33% mortality respectively). The total number of casts produced in the controls was 38, 39 and 50 respectively for the three test runs. Feeding activity was disrupted in sediments that were acutely toxic but also in some of those where low or zero mortality was recorded, e.g. Southampton Water (E. Bramble Buoy) where mortality was 0 and the number of casts produced was 0, and Thames (Outer Gabbard) where mortality was 0 and the number of casts produced was only 7.

Sediments from two stations on the Tees (Redcar Jetty and ICI No. 4 Buoy) were shown to be significantly toxic to *C. volutator*, with 100% and 93% mortality respectively. Both of these were also acutely toxic to *A. marina*.

2.1.4 Discussion

Sediments from two locations on the River Tees estuary were acutely toxic to both *A. marina* and *C. volutator*. Differential responses were found at one location on the Wear where 100% mortality of *A. marina* occurred but only 3% mortality was found with *C. volutator*. This indicates that the organisms are responding with different susceptibility to sediment properties and/or contaminants. It is therefore appropriate to use a range of tests to assess sediment toxicity, particularly within a regulatory framework such as assessing dredged material for disposal at sea. The feeding rate of *A. marina* can be used as a sensitive sublethal endpoint, although further work is required to assess the effects of different substrate type and organic matter on feeding rate.

2.2 Water quality bioassays

2.2.1 Introduction

Previous reports in this series have described the deployment of the oyster embryo bioassay for measuring water quality (see MAFF, 1992(a), 1993(a) and 1994). Results of monitoring over four consecutive years have shown that water quality is good in offshore and coastal waters around England and Wales. Only on isolated occasions for industrialised estuaries and near waste disposal grounds has reduced water quality been measured. These results are encouraging as far as the

Table 3. CIROLANA 6/93: 10-day sediment bioassays using the lugworm Arenicola marina and Corophium volutator. (Only results significantly different from the control are shown – full results are given in Appendix 4)

Station No.	Location	*Arenicola*		*Corophium*		
		% mortality	Total casts in 10 days	% mortality		
		Test 1		**Test 1**	**Test 2**	**Test 3**
Control	**Shoebury Sand**	**0**	**38**	**20**		
3	Tweed (Berwick/Tweed Bridges)	0	25*	13		
7	Off Tyne	13	28*	10		
8	Tyne (anchor)	0	28*	20		
16	Tyne (Hebburn)	7	23*	10		
17	Wear (anchor)	0	28*	7		
18	Wear (Sandy Point)	13	18*	13		
19	Wear (Queen Alexandra Bridge)	100	2*	3		
21	Tees (Redcar jetty)	100	0*	100**		
		Test 2				
Control	**Shoebury Sand**	**0**	**39**	**20**	**43**	
25	Southern Bight (Smiths Knoll)	0	16*		43	
26	Thames (Outer Gabbard)	0	7*		40	
28	South Varne	0	18*		47	
S2	Wash (Ouse, Freebridge)	20	17*	0		
S4	Humber (Spurn Head)	0	18*	13		
S5	Humber (North Killingholme)	0	28*	0		
S9	S'hampton Water (E. Bramble buoy)	0	0*		47	
		Test 3				
Control	**Shoebury Sand**	**0**	**50**			**10**
34	Poole Harbour: Holes Bay	0	39*			13
35	Poole Harbour: Brownsea buoy	0	33*			13
94	River Tees: No 8 buoy	0	34*			37
96	River Tees: ICI No 4 buoy	33	0*			93**
97	River Tees: No 25 buoy	0	37*			23

Note: Comparisons significantly different from control casting at the 0.05 level (Dunnetts t-test) are indicated by ''*
*Corophium mortality significantly different from control (ANOVA, p<0.05) indicated by '**'*

general water quality of England and Wales is concerned. However, the robustness of the oyster embryo bioassay is offset by its relatively poor sensitivity in terms of responses to contaminants. Work to improve the sensitivity is in progress. An alternative approach is to manipulate the sample so that the constituents are concentrated into a range in which the assay is responsive, for example using liquid/solid or liquid/liquid extraction techniques. Successful research during the past two years (Thain and Kirby, 1994) has led to the routine deployment of such a technique on two cruises in 1993, (*RV CIROLANA* 6, 9 June-1 July and *RV CORYSTES* 8, 1-19 October).

2.2.2 Method

Full details of the methods used are described in Thain and Kirby (1994). Briefly, 40 l water samples are extracted with hexane, evaporated and resuspended in acetone. Serial dilutions of this extract are prepared giving a range of 1000, 500, 250, 100, 50 and 10 times the original environmental concentrations. Each test concentration is assayed using the copepod *Tisbe battagliai*. Median lethal concentrations (LC50) and 95% confidence limits are calculated at 24 h and 48 h and expressed as concentration factors of the original sea water sample.

2.2.3 Results

The toxicity of the extracts to *T. battagliai* are summarised in Table 4 (full results are shown in Appendix 5) for the June and October cruises. The survey included a range of offshore, nearshore and estuarine stations. The response from the bioassay showed that there were marked differences between the sites. In general toxicity concentration factors (TCF) were >600 for offshore waters, between 100 to 600 for coastal waters and clean estuaries, and, below 100 in urbanised and industrialised estuaries. At one site on the River Tees at Redcar Jetty the concentration factor was less than 10.

Table 4. Toxicity results of liquid/liquid extracts to T. battagliai (results are given as toxicity concentration factors)

Location	Mean LC50			
	June 1993		October 1993	
	24 hr	48 hr	24 hr	48 hr
Estuarine sites				
Tyne (Hebburn)	520	190	315	164
Wear (Q.Alexandra Bridge)	56	16	102	31
Tees (Victoria Bridge)	210	140	78	27
Tees (ICI No. 4 Buoy)	98	50		
Poole Harbour (Holes Bay)	190	100	295	114
Poole Harbour (Brownsea Buoy)	500	270	295	103
Tamar (Hamoaze)	350	200		
Mersey (Tranmere Oil Terminal)	140	85	182	115
Mersey (Eastham Lock)	190	105	124	84
Dee (No. 2 Buoy)	500	280		
River Lune (No. 1 Buoy)	>1000	550		
Wear (Sandy Point)			135	51
Tyne (North Shields)			415	148
Blyth (North Harbour)			515	300
Blyth (South Harbour)			590	247
Tees (Redcar jetty)			<10	<10
Southampton Water (Netley Buoy)			413	180
Southampton Water (Cadland Buoy)			260	125
Mersey (Canada Buoy)			320	141
Nearshore sites				
Tyne - (anchor high tide)	850	660		
Tyne (anchor)	610	400	380	284
Wear (anchor)	620	320	165	108
Tees (anchor)	310	215	73	46
Solent			465	148
Poole Harbour (anchor)	>1000	440	395	200
Plymouth Sound (anchor)	250	190		
Ribble (anchor)	850	425		
Dee (anchor)	800	500		
Morcambe Bay (anchor)	580	470		
Blyth			260	198
Liverpool Bay (Burbo Bight)	795	340	740	210
Offshore sites				
Off Tyne/Tees	>1000	450		
Dogger Bank	800	610		
Off Humber/Wash	800	485		
Off Tees	850	570		
Off Humber	710	515		
Off Wash	460	345		
Southern Bight (Smiths Knoll)	560	360		
Thames (Outer Gabbard)	920	560		
Thames (Warp)	>1000	540		
South Varne	>1000	760		
Off Selsey Bill	>1000	>1000		
Central Channel	415	300		
Western Approaches	>1000	950		
Celtic Deep	>1000	850		
Newquay	>1000	740		
Cardigan Bay	>1000	860		
Off Cardigan Bay	930	830		
Irish Sea	>1000	850		

Note: All LC50 figures are quoted as concentration factors. All samples were taken at low tide unless otherwise stated

2.2.4 Discussion and conclusion

The use of liquid /liquid extraction techniques in conjunction with the *T. battagliai* test has allowed the comparison of water quality in estuarine, inshore and offshore waters, which was not possible with previous bioassay techniques.

The present extraction method is restricted to a narrow range of relatively non-polar organic substances. Clearly the scope of the test can be manipulated by selecting an extracting solvent of different polarity which will recover a different profile of constitutents. In addition, we are investigating methods of concentrating trace metals. The test has many positive attributes; it is rapid, it can be deployed at sea on-board a research vessel, it provides a measurable response which can be used for mapping biological water quality, comparisons can be made between sites and, integrated samples (with respect to time and space) can be tested.

3. SURVEYS OF THE EPIFAUNA IN UNITED KINGDOM AND ADJACENT WATERS

3.1 Introduction

In 1990, several stations in the North Sea and English Channel were established by the North Sea Task Force (NSTF) for the sampling of water, sediments and biota. The purpose was to generate new information on the concentrations of contaminants and on the 'well-being' of biological systems as a contribution to a Quality Status Report for the 1995 Ministerial North Sea Conference (North Sea Task Force, 1993). At the same time, a sampling regime (the 'National Monitoring Plan': NMP) was developed specifically for UK estuarine, coastal and offshore waters and the first round of sampling for this programme was completed in 1994.

At all of these monitoring stations, the main target for field assessment of the indigenous biota has been the animals living within bottom sediments, i.e. the infauna. Between 1992 and 1994, during MAFF visits to both NSTF and NMP stations, the opportunity was also taken to sample animals inhabiting the surface of sediments, i.e. the epifauna, by means of small trawls. Although this group (which includes starfish, crabs and shrimps) is likely to be the most familiar to non-specialists and the public at large, it has received much less scientific attention than the infauna, largely due to sampling difficulties. The survey therefore aimed to redress the balance by providing an insight into the distribution and relative abundance of epifaunal taxa over a much wider geographical range than has previously been attempted in surveys of benthic populations around the UK coastline.

3.2 Methods

A standard two-metre Lowestoft beam trawl (see Riley *et al.*, 1986), was deployed for approximately five minutes across each station at minimal speed or whilst drifting. The 'start' (locking of winch following seabed contact) and 'end' (commencement of hauling) positions were recorded. On retrieval, an estimate of sample volume was made, along with a summary of the contents, noting especially the presence of stones, rock, etc., and any anthropogenic debris. The sample was then sorted on deck over a 5 mm mesh sieve, with specimens being identified and enumerated either immediately or in the ship's laboratory. Any problematic specimens were preserved in formalin for identification later on return to land.

In the following account, the faunal data are reported as numbers per tow, i.e. unadjusted for tow length, which averaged about 400 m.

3.3 Results

Sediments
Sampling stations in the southern North Sea were characteristically sandy in nature. Sand and mud in varying proportions were associated with stations in inner Liverpool and Morecambe Bays, north west England, and off the Tyne, north east England. Deeper-water substrates in the northwestern North Sea were gravelly, as were those in coastal waters off eastern England. Samples from the English Channel, Celtic and Irish Seas were also predominantly gravels.

Litter content
Litter of recent human origin was identified at some 60% of stations. However, the quantity was minimal except in some coastal areas, notably the Thames estuary and Liverpool Bay, where items arising from pipeline discharges of domestic sewage or the deposition of sewage sludge from ships were encountered.

Fauna
The apportioning of taxa across major groups (Table 5) showed that bryozoans, crustaceans and molluscs were the dominant groups, with hydroids and fish also being well represented. The total across all animal groups amounted to 344 taxa. Relatively few were widespread throughout the sampling area and 120 were single occurrences, illustrating a well-established phenomenon that most species in nature are 'rare'. The five most frequently encountered taxa were Paguridae (hermit crabs), *Asterias rubens* (common starfish), *Liocarcinus holsatus* (swimming crabs), *Ophiura* spp (brittle-stars) and Gobiidae (gobies).

Table 5. Numbers of taxa allocated to each major faunal group

Bryozoa	64
Crustacea	59
Mollusca	56
Hydrozoa	38
Pisces	34
Porifera	23
Anthozoa	22
Echinodermata	21
Ascidiacea	15
Other Groups	12
Total	344

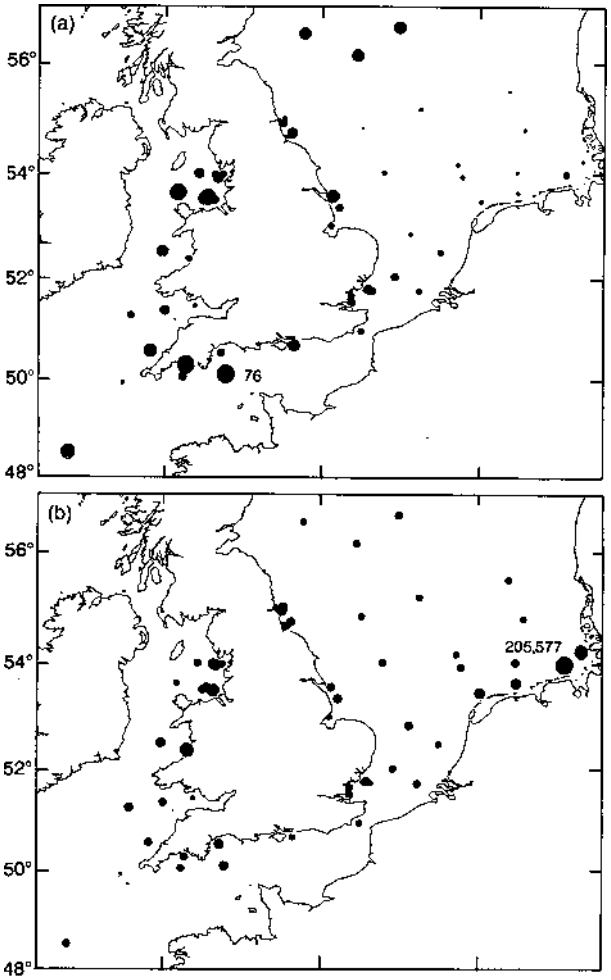


Figure 1. Numbers of taxa (a) and individuals (log-transformed) (b), in two-metre beam trawl samples. Circles are scaled relative to the highest value encountered, as specified on the plots

Figure 1(a) shows that high numbers of taxa tend to occur in the north and west of the sampling area in association with coarser substrates. The distribution of animal densities (Figure 1(b)) is more even, although very high numbers were occasionally encountered at inshore locations.

Relationships between total numbers of taxa and (log-transformed) individuals per trawl and a range of environmental variables were further explored through correlation analysis. There was a significant positive correlation between taxa and sediment 'coarseness', and a significant negative relationship with densities. The former was to be expected, as the mixed gravelly areas provide a much greater array of attachment points and refuges, compared with uniform muddy areas (see Figure 1(a)). The latter reflects a capacity for muddy sand or muddy substrates, especially close inshore, to support very high densities of common species such as brittle-stars (see Figure 1(b)). Negative correlations between numbers of taxa, longitude and, to a lesser degree, latitude appear to be largely a function of coincident trends in substrate type (and depth) rather than of any other environmental constraint on distribution. There were no correlations between faunal variables and the month of sampling.

Multivariate classification analysis was conducted on presence/absence data and the outcome is shown in Figure 2. Much of the southern North Sea supports an epifauna characteristic of soft substrates with an

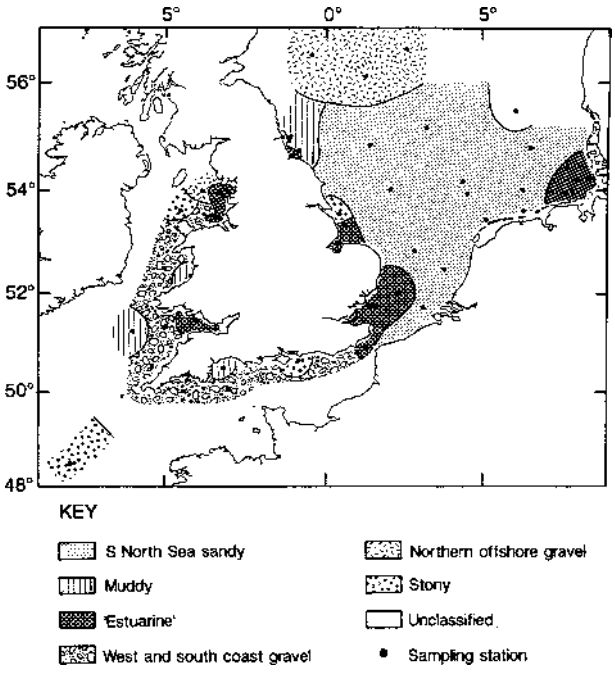


Figure 2. Assemblage types identified from cluster analysis of presence/absence data. With the exception of the 'Estuarine' group, these are named by reference to the predominant substrate types along the trawl tows

appreciable coarse component. Influences associated with estuarine efflux (or human activities) are evident at near-shore sites off the estuaries of the Elbe/Weser, Thames, Humber, Tees and Mersey/Dee, and within the Bristol Channel and Morecambe Bay, where a comparable fauna is encountered. Elsewhere, gravelly substrates off the south and west coasts support a similar fauna which is distinguishable from a northerly cluster comprising three stations in the North Sea and one off Morecambe Bay in the northeastern Irish Sea.

Another 'coarse ground' cluster is, surprisingly, represented by stations which are widely separated both geographically and in terms of depth. For example, a station off the Humber at 20 m was linked with one in the South West Approaches at 170 m. The presence of a distinctive bryozoan and sponge fauna associated with the stony substrates may contribute to the similarity between stations. Finally, muddy localities in Lyme Bay (south west England) and Cardigan Bay (West Wales), and in the Celtic Deep on the western side, share similarities with the fauna of muddy substrates off the Tyne estuary, north east England. These stations can be characterised by the presence of the Norway lobster *Nephrops norvegicus* and the turret shell *Turritella communis.*

3.4 Discussion

This is the first time that an assessment of the epifauna using standard methods has been conducted over such a wide geographical scale and, when completed, the survey results should provide a valuable 'baseline' for future work directed at this group of biota. The information may also be useful to conservation organisations who have an interest in identifying subtidal assemblages, especially in offshore areas (e.g. Doody *et al.* (eds), 1993). Comparable but more intensive surveys of the North Sea epifauna have been reported by, for example, Dyer *et al.*, 1983, Frauenheim *et al.*, 1989 and Duineveld and van Noort, 1990. Despite differences in sampling methodology, all three identified a broad division between a 'northern' and 'southern' fauna approximately along the northern edge of the Dogger Bank, a finding which is comparable with the outcome of the present survey. This division was similar to that proposed by Glemarec (1973) for the North Sea, based upon thermal stability of the water-column.

Duineveld and van Noort (1990) found no significant relationship between the distribution of assemblages and that of sediment type, at least as measured by the % silt/clay content of grab samples. The authors speculated that the paucity of attached epifaunal species (such as anemones, ascidians and sponges) in the southern North Sea might be due to the high intensity of commercial beam trawling.

Preliminary analysis of the present data indicates that coastal influences (proximity to large estuaries) and substrate type largely determine community composition. Furthermore, for any one sediment category, the majority of characterising taxa show no sign of being limited in their distribution over the latitudinal range of this survey. However, coverage of the UK coastline is presently incomplete, and further samples from the coasts of Scotland and Northern Ireland await inclusion in the analysis.

Because of inherent uncertainties about the efficiency of operation of the beam trawl at the seabed, especially in areas of rough ground, it is appropriate to treat the data on a presence/absence or, at most, 'semi-quantitative' basis. Trawling has the advantage of providing samples which are integrated over much wider areas than is feasible with traditional grab samplers; the latter are in any case unsuitable devices for the collection of larger or more motile species. However, beam trawls will select for coarser material such as stones and shell, and this may have the effect of clouding the distinction between a predominantly coarse and a predominantly fine substrate type, at least with respect to the presence or absence of sessile species such as hydroids, bryozoans and anemones.

Relationships between animal distributions and natural and anthropogenic influences will be further examined when the data set is complete.

4. SURVEYS OF CONTAMINANTS IN MARINE MAMMALS

Since the seal epizootic of 1988, the Directorate of Fisheries Research (DFR) has participated in a collaborative programme investigating the possible role of contaminants in promoting the susceptibility of marine mammals to disease. This programme has combined information on strandings with the provision of samples for pathological and chemical analyses. A recent report (Law, 1994) has documented the methodology used in this study and also presents data for metals and/or organochlorines (primarily chlorobiphenyls) in tissues from 275 marine mammals. These were mostly cetaceans and included 137 harbour porpoises. Appendix 6 summarises the maximum values observed in liver tissue for each of the heavy metals measured (chromium, nickel, copper, zinc, cadmium, mercury and lead), the five highest values are given in each case against species and location. The most striking patterns are seen in the distributions for mercury and lead. In the case of mercury, all the highest values (up to 430 mg kg^{-1} wet weight) were found in grey seals from the vicinity of Liverpool Bay. For lead, the highest values (up to 7 mg kg^{-1} wet weight) were also found around

Liverpool Bay, but occurred in both grey seals and cetaceans. This 'hot-spot' for mercury and lead is the result of contamination deriving from mainly historic discharges from local industries (Law *et al*., 1992).

The unusually high concentrations of cadmium (up to 65 mg kg^{-1} wet weight) found in one pilot whale, and those seen in common and striped dolphins, are thought to relate to prey preference. Such high concentrations occur in a range of cetacean species and locations around the world, and are generally higher in kidney tissue than in liver. Further study of the dynamics and possible effects of cadmium in marine mammals would be of merit (Law, in press).

Copper and zinc are essential trace elements and their concentrations are homeostatically controlled in mammal tissues. Although some of the concentrations reported here (up to 160 mg kg^{-1} wet weight for copper and 268 mg kg^{-1} wet weight for zinc) are above the suggested normal range, it is thought that only for one animal (porpoise SMRU91-16) does this represent a possible failure of homeostasis (Law, in press).

To date, few data exist in the literature for chromium and nickel, and any assessment of the significance of these values (up to 5.6 and 2.1 mg kg^{-1} wet weight respectively) is impossible at present (Law, in press).

Appendix 7 indicates the twenty highest values given in the report for concentrations of chlorobiphenyls (CB) in cetacean blubber, as the sum of the ICES 7 congeners (CB28 + CB52 + CB101 + CB118 + CB138 + CB153 + CB180). The highest concentration (72 mg kg^{-1} wet weight) was found in a bottlenose dolphin from Borth (Cardigan Bay, West Wales), an area where extremely high concentrations have been found previously in two other bottlenose dolphins (ICES 7 = 90 and 99 mg kg^{-1} wet weight) (Law and Allchin, 1994(a)). Approximately one-third of the animals listed in Appendix 7 are common dolphins, which is rather surprising, as this is essentially an offshore species. The concentrations found in bottlenose dolphins in Cardigan Bay, an area not generally considered to be highly contaminated, are higher than those seen in a similar population, resident or semi-resident, within the Moray Firth in Scotland. The reasons for this and the likely significance are still topics of study.

The relative threats posed to mammal populations by pollution and other influences such as bycatch of mammals in fishing gear and the availability of prey species, are currently of major interest (see e.g. Reijnders, 1992) and will be the subject of international initiatives which are being pursued during the next few years.

SEA WATER

5. TRIAZINE HERBICIDES (SIMAZINE AND ATRAZINE)

Samples of sea water were taken during *RV CIROLANA* cruise 6 (9 June-1 July 1993) for the determination of the triazine herbicides, atrazine and simazine. The results are shown in Appendix 11.

Simazine and atrazine were readily detectable in estuarine and inshore waters, with the highest values recorded during this survey occurring at Station 62 in the River Mersey which yielded concentrations of simazine and atrazine of 28.5 and 20.8 ng l^{-1} respectively. High concentrations of these herbicides were also recorded in samples from the River Mersey in previous years – in 1992 concentrations of simazine and atrazine up to 37 and 42 ng l^{-1} were found in the estuary (MAFF, 1994). These levels are however well within the proposed UK Environmental Quality Standard (EQS) for the protection of saltwater life of 2 µg l^{-1} (equivalent to 2000 ng l^{-1}) and as such are not thought to be biologically significant (Law *et al*., 1994). Restrictions on the non-agricultural use of simazine and atrazine have been introduced recently in the UK. It is therefore unlikely that concentrations in sea water will increase in the future and further large scale surveys on the scale reported here will be unjustified. Concentrations at offshore stations are consistently low and surveys should be restricted to rivers and estuaries where the expected reduction in concentrations can best be demonstrated.

6. ALPHA- AND GAMMA-HEXACHLORO-CYCLOHEXANES

A fifth survey of a- and g-hexachlorocyclohexanes (a- and g-HCH) residues in sea water was undertaken during *RV CIROLANA* cruise 6, (9 June-1 July 1993). The results are shown in Appendix 11. This included samples collected in the English Channel as part of the follow-up studies conducted since the loss of *MV PERINTIS*. *MV PERINTIS* sank in the Channel in March 1989 and a consignment of 5.8 tonnes of g-HCH (Lindane) packed in a freight container was amongst the items lost (MAFF, 1991).

The concentrations of g-HCH in sea water taken from the Channel as part of these follow-up studies were similar to those in previous surveys and do not indicate any increase in concentrations of lindane nor therefore, the whereabouts of the lost container (Law and Allchin, 1994(b)). This is consistent with the assessment made by a joint Anglo-French response assessment team soon after the loss of the container, in that any leakage that occurred would be slow and unlikely to result either in significantly increased levels of g-HCH in the water column, or as a consequence uptake by fish and shellfish in the area.

As in previous years, the data for a- and g-HCHs from the rest of the survey indicate that concentrations at all stations are consistently below the UK EQS value for estuarine and sea water of 20 ng l^{-1}. Perhaps predictably, the highest concentrations were found at the estuarine and coastal stations, with concentrations decreasing rapidly offshore. In 1993, the maximum concentration of g-HCH observed was 4.6 ng l^{-1}, in both the River Blyth and Poole Harbour (Stations 34 and 91). The highest concentration found in 1992 was 7.2 ng l^{-1} at a station in the River Wear (MAFF, 1994). Data have been gathered each year since 1989 and provide little justification for continued monitoring effort other than a low-level of 'tripwire' monitoring in the English Channel (Law and Allchin, 1994(b)).

7. VOLATILE ORGANIC COMPOUNDS

7.1 Introduction

The first surveys of volatile organic compounds in UK waters undertaken by the Burnham Laboratory were completed in 1992. These were published in Aquatic Environment Monitoring Report Number 40 (MAFF, 1994) and in Marine Pollution Bulletin (Dawes and Waldock, 1994). In 1993, the surveys were repeated in order to confirm the earlier results and to obtain some information on short-term temporal variability of concentrations of volatiles in the Tees Estuary.

7.2 Method

The methods used were the same as those deployed in the earlier work. All analyses were carried out using a commercially built purge and trap analyser. The system consists of an automatic sampling system capable of transferring 10 ml of water sample from a 40 ml 'EPA vial' to a purge vessel. The sample is then purged with helium for a pre-set time and the volatile compounds collected in a cryotrap composed of a length of fused silica which is cooled to -193°C by liquid nitrogen. The volatile compounds are then released by pulsed heating to a fused silica column in a gas chromatograph, and finally analysed using a quadrupole mass spectrometer in the multiple-ion detection mode.

7.3 Results

Fourteen volatile compounds were measured in samples from offshore and estuarine locations during research cruises on *RV CIROLANA* in June 1993 and *RV CORYSTES* in October 1993. Detailed results are listed in Appendix 12. All compounds were found at detectable concentrations in at least some samples,with bromoform and chloroform being the most commonly detected compounds. The concentrations of the individual compounds in offshore waters, were below analytical detection limits and were generally low within estuaries. The notable exceptions were in the Mersey, Tyne and particularly the Tees estuary. Concentrations of chloroform for the Tees, measured on four separate occasions during the 1993 cruises, are compared in Figure 3 with values found at the same sites in 1992. The highest concentration measured (118 µg l^{-1}) was at least 4700 times higher than in the open sea and ten times higher than the EQS of 12 µg l^{-1} proposed by the EC.

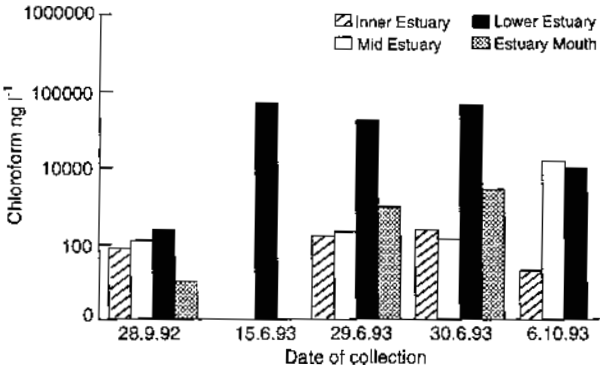


Figure 3. Concentrations of chloroform (ng l^{-1}) in samples of water collected from the Tees in 1992 and 1993. Note the y axis is a logarithmic scale

7.4 Conclusions

Diffuse bromination reactions occur in sea water converting chloroform into bromoform, and not surprisingly, concentrations of bromoform were elevated at the same sites, However trace concentrations of bromoform were found at many other locations e.g. Cardigan Bay, reasonably far away from anthropogenic inputs, suggesting natural production from marine algae.

Six of the other twelve volatile compounds measured in the Tees exceeded microgram per litre concentrations at one site, EDC (1-2-dichloroethane), BDCM (bromodichloromethane), toluene, benzene, o-xylene, and 124TMB (1,2,4-trimethylbenzene).

Present or proposed environmental standards for volatile compounds are 10 µg l^{-1} for 1,2-dichloroethane

(90/415/EEC) (European Communities, 1990), trichloroethylene and tetrachloroethylene (86/280/EEC) (European Communities, 1986). Use of 1,1,1-tricholoroethane is scheduled to be phased out by 2005 under the provisions of the Montreal Protocol.
Eight of the twelve volatile compounds detected were present on each of the five sampling occasions at the same site on the Tees, and profiles of measured concentrations were generally similar each time. The data suggest that the inputs of the same variety of compounds occurred regularly during 1992 and 1993, but for some compounds e.g. toluene, ethylbenzene, o-xylene and trimethylbenzene, inputs were probably more intermittent and occasionally high.

At present interpreting the potential for biological effects caused by this changing mixture of volatile substances is difficult. Bioassays deployed on water from the same sites (see Section 2) were based on concentrated organic fractions of contaminants and the methodology does not allow quantitative recovery of volatile materials. Bioassays based on static renewal systems on whole water column samples also underestimate toxicity due to loss of volatiles to the air during testing. All three surveys in 1992 and 1993 suggest that at most sites studied, concentrations of volatile organic compounds are well below those thought to be hazardous to aquatic species, but future work will be focused on estuaries such as the Tees and the development of bioassay techniques to assess the combined effects of complex mixtures of volatile compounds.

8. HYDROCARBONS

Hydrocarbons enter the marine environment from a variety of sources, including sewage and industrial discharges, as well as from direct oil spills.

Concentrations of total hydrocarbons (THCs) were determined at sea in surface (1 m) water samples from 85 stations (see Appendix 11), using ultra-violet fluorescence spectrometry (Law *et al.*, 1988) in order to investigate the distribution of these contaminants in marine waters. Samples were quantified against Ekofisk crude oil at excitation and emission wavelengths of 310 and 360 nm respectively, and synchronous excitation-emission spectra (Dl = 25nm) were recorded for all samples. Low concentrations of THCs were found offshore, in the range < 0.2 to 1.5 µg l^{-1} Ekofisk crude oil equivalents (n = 28). Higher concentrations were found at some estuarine locations, the mean value for all such sites being 16 µg 1^{-1} (n = 46). The highest concentration of THCs (120 µg l^{-1}) was found in a sample from the River Tees (Redcar jetty, Station 21). High concentrations of THCs were also found at the Redcar jetty site when sampling was conducted later in the cruise on consecutive low tides: Stations 95 and 100; 64 and 63 µg l^{-1} respectively. In previous years the highest concentrations of THCs have also been observed at Redcar jetty; 1990, 55 µg l^{-1}; 1991, 48 µg l^{-1}; 1992, 64 µg l^{-1}. High concentrations of a number of individual polycyclic aromatic hydrocarbons (PAH) were also determined at Stations 21, 95 and 100 in 1993 (see Section 9).

Extracts from samples for which the concentration of THCs was greater than approximately 10 µg l^{-1} were also analysed in the laboratory using high-resolution (capillary) gas chromatography after alumina clean-up. As in previous years (MAFF, 1992(a), 1993(a), 1994), none of the traces showed evidence of any fresh oil inputs. Two examples from the River Tees are given in Figure 4. Figure 4(a) shows the chromatogram obtained for Station 96 (ICI no. 4 buoy), and Figure 4(b) that for Station 21 (Redcar jetty). The ICI no. 4 buoy is approximately 2.4 km upstream of Redcar jetty, and the two chromatograms show different distributions of peaks. At Station 96 the chromatogram is dominated by a peak with a retention time of approximately 13.5 minutes, although smaller peaks are evident throughout the chromatogram. At Station 21, many peaks due to volatile and semi-volatile compounds are evident, both overlapping the rear of the solvent peak and up to a retention time of 20 minutes. Both extracts were concentrated to a similar degree and analysed within the same batch and the traces are, therefore, directly comparable.

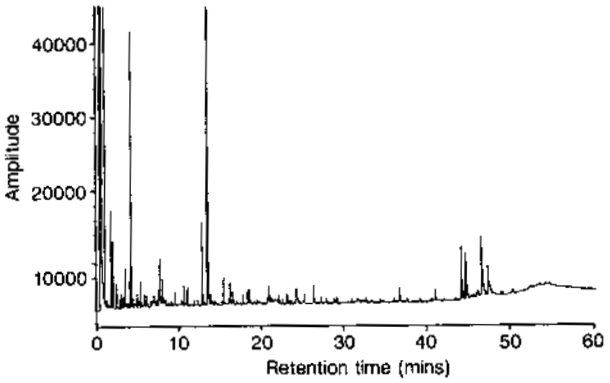


Figure 4(a). Gas chromatogram of a surface water sample from Station 96 (ICI no. 4 buoy)

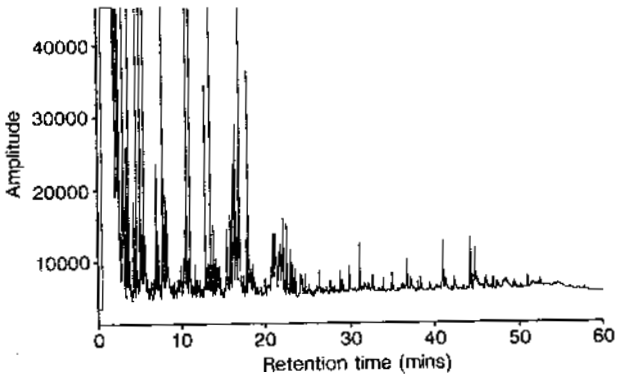


Figure 4(b). Gas chromatogram of a surface water sample from Station 21 (Redcar Jetty)

The sample extracts from Stations 21 and 100 were also investigated by coupled gas chromatography/mass spectrometry (GC/MS) using a Finnigan-MAT ITS-40 ion-trap instrument. Mass spectra obtained were searched against the NIST (National Institute of Standards and Technology, Gaithersburg, USA) library, and compounds tentatively identified. These identifications have not been confirmed by injection of authentic standard materials and the comparison of spectra and retention times. In particular, this would assist in the assignment of structural isomers, as the mass spectra of isomeric compounds are usually very similar. Compounds yielding a fit value greater than 900 (out of 1000) in the library-search procedure are listed in Appendix 13 against scan number, which gives some indication of their relative retention on a 5% phenyl methyl silicone stationary phase. Information derived for both stations has been combined in the Table. For comparison with Figure 4, phenanthrene (scan number 1689) would have a retention time around 25 minutes under the GC conditions applied. Some of the compounds named are probably oil-derived (such as the dimethyl and trimethyl benzenes), whereas others (such as trichloroethylsilane, nonylphenol and butyl octyl phthalate (the butyl octyl ester of 1,2-benzene-dicarboxylic acid)) are probably derived from industrial sources. Law *et al.* (1991) carried out a similar study covering the Tees and a number of other UK estuaries in 1988/89, and identified 49 organics compounds in Tees waters. Bioassays conducted using both oyster embryo (*Crassostrea gigas*) and *Tisbe battagliai* techniques have shown the waters of the River Tees have the highest toxicity of any of the estuaries studied (Matthiessen *et al*., 1993; Section 2 of this report). An ecotoxicological assessment of industrially derived organic chemicals in surface waters by Matthiessen *et al.* (1993) concluded that the compounds detected were probably contributing jointly to the toxicity observed when bioassays were deployed in the estuary, although there is presently insufficient understanding to allow joint toxicity to be calculated or predicted.

9. POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAH) are ubiquitous environmental contaminants and derive mainly from anthropogenic sources. Many are toxic to aquatic organisms, and the metabolites of some of the higher weight PAH are active carcinogens (Law and Biscaya, 1994). They are not included in the initial core programme of the National Monitoring Plan, but are included in the list of additional (voluntary) determinands (MPMMG, 1994). Further information on their occurrence is required from restricted surveys before their inclusion in the core programme can be considered.

In 1993, the first survey of polycyclic aromatic hydrocarbons (PAH) in the waters around England and Wales was conducted alongside the NMP programme. Fifteen unalkylated PAH compounds were determined in sea water samples from 75 stations by means of high-performance liquid chromatography (HPLC) with UV fluorescence detection (Dawes and Law, in press). At estuarine sites, PAH were determined in both filtered and unfiltered samples; at offshore locations where the concentration of suspended matter was low unfiltered samples only were analysed. Some of the data are presented in Appendix 14. Concentrations of all the PAH were low or below the limits of detection in offshore samples, whilst higher concentrations were found in industrialised estuaries. For PAH (as for total hydrocarbons – see Section 8), the highest concentrations were found in the lower Tees estuary at a station off Redcar jetty. The major PAH found were 2- to 4-ring compounds (naphthalene to pyrene), with naphthalene consistently occurring at $\mu g\ l^{-1}$ concentrations in samples from the Tees. The samples taken off Redcar jetty showed particularly high concentrations of a number of 2-3 ring PAH (naphthalene, acenaphthene, fluorene and phenanthrene). Johnston *et al.* (1991) identified a similar range of low molecular weight PAH in samples from discharges originating within a steel manufacturing complex at Redcar, and this seems likely to be the source of our own elevated values. Another interesting feature of the data is the relatively high concentrations (up to 1090 $ng\ l^{-1}$) of the higher molecular weight PAH (phenanthrene to benzo[*ghi*]perylene – Appendix 14) seen in samples from the two stations on the Thames east of London. These could arise as a result of the combustion of fossil fuels in the urban conurbation to the west, transported by the prevailing winds.

These are preliminary results from a single survey and they will be supplemented with a second set taken in 1994, prior to full interpretation.

No data from estuarine locations were presented in the recently published Quality Status Report (QSR) of the North Sea (North Sea Task Force, 1993) and so no assessment of the relative significance of these concentrations can be made at the present time. However, the QSR recommended further research be conducted on the sources and biological effects of PAH.

10. SURFACTANT RESIDUES IN UK ESTUARIES

10.1 Introduction

Alkylphenolpolyethoxylates (APEOs) have been used widely since the 1940s as surfactants in a variety of industrial, household and commercial applications. In 1992, UK consumption was in the range 16 000 to 19 000 tonnes, of which an estimated 37% (approximately 6500 tonnes per year) was released into the aquatic environment (Department of the Environment, 1993).

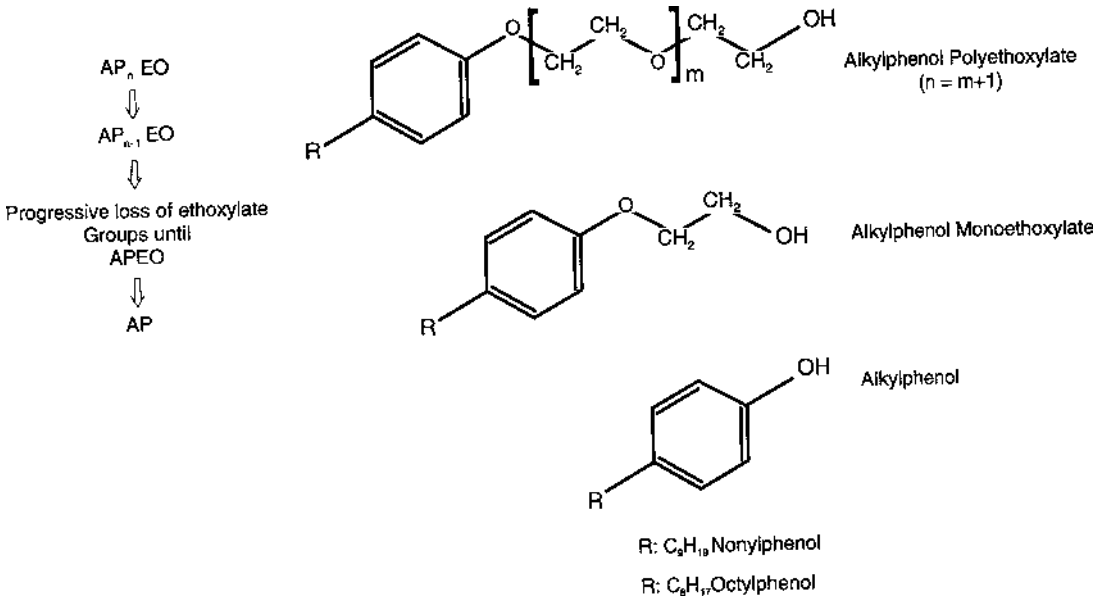


Figure 5. Biotransformation of alkylphenolpolyethoxylates to alkylphenols

Concern has increased recently about the use of APEOs because of their relatively stable biodegradation metabolites nonylphenol and octylphenol, which are generated by the breakdown of products containing APEOs, particularly during sewage treatment (Giger *et al*., 1984; Figure 5). Nonylphenol has been demonstrated to be toxic to both marine and freshwater species (Comber *et al*., 1993; Waldock and Thain, 1986), to induce an estrogenic response in male trout (Jobling and Sumpter, 1993) and to bioaccumulate in freshwater organisms (Ahel *et al*., 1993). Concern over their possible environmental effects has led to a voluntary ban on the use of APEOs in domestic products in the UK and usage in other European countries is declining. Despite their high inputs and potential toxicity there are few data available on aquatic concentrations of alkylphenols in Britain; accordingly a survey of concentrations of nonylphenol and octylphenol in estuaries was carried out in October 1993.

10.2 Method

The method used for the detection of nonylphenol and octylphenol is based on the use of solid phase extraction (SPE) cartridges. Samples of 300 ml (for dissolved alkylphenols) and 200 ml (for total alkylphenols) of estuarine water from 1 m depth were extracted onto a C18 SPE column, following the addition of an internal standard. The columns were eluted with ethyl acetate and dichloromethane and the extract dried over anhydrous sodium sulphate. Nonylphenol and octylphenol were determined by gas chromatography/quadropole mass spectrometry in the multiple-ion detection mode.

10.3 Results

Overall, concentrations of alkylphenol were very low (Table 6). Over 80% of the estuarine samples contained less than 0.1 µg l^{-1} (i.e. 100 ng l^{-1}) total nonylphenol (Figure 5) reflecting the rapid dilution of wastewaters by freshwater and inflowing sea water in the estuaries. These concentrations confirm earlier surveys by the laboratory which reported 314 ng l^{-1} and 160 ng l^{-1} nonylphenol in the Mersey estuary in 1989 and 1990 respectively (MAFF, 1992(a)).

The highest concentrations of total nonylphenol recorded were in the River Tees; up to 27 µg l^{-1} was measured adjacent to a discharge serving a tanker washing facility at Portrack and 5.2 µg l^{-1} at Redcar jetty a station at the heavily industrialised mouth of the estuary. High levels of octylphenol (13 µg l^{-1} total) were also found at Redcar Jetty. Elsewhere octylphenol levels were below the detection limit.

10.4 Discussion

Concentrations in all estuaries except the Tees were 2-3 orders of magnitude below those which produce chronic or acute toxic effects in fish and invertebrates and the biological impact of alkylphenols in these estuaries is expected to be very low. However, at the mouth of the Tees concentrations were considerably higher and approached chronic effect levels. The major UK production facility for nonylphenol is sited at Billingham, the discharges from which enter tributaries of the River Tees. At Wilton the nonylphenol is ethoxylated to produce APEOs and wastewater containing

Table 6. Concentrations (µg l^{-1}) of alkylphenols in UK estuaries

Site	Dissolved nonylphenol	Total extractable nonylphenol	Dissolved octylphenol	Total extractable octylphenol
Wear				
Wear Alexandra Bridge	0.07	0.08	<0.1	<0.1
Wear Sandy Point	0.04	0.04	<0.1	<0.1
Wear Anchor	0.05	0.04	<0.1	<0.1
Tees				
Tees Victoria Bridge	0.08	0.09	<0.1	<0.1
Tees Redcar jetty	3.1	5.2	10	13
Tees Portrack Outfall	8.2	27	<0.1	<0.1
Tees no. 4 Outfall	1.3	2.0	0.3	0.5
Tyne				
Tyne Hebburn	0.03	0.03	<0.1	<0.1
Tyne North Shields	0.04	0.04	<0.1	<0.1
Tyne Anchor	<0.03	<0.03	<0.1	<0.1
Blyth				
Blyth North Harbour	0.04	0.07	<0.1	<0.1
Blyth South Harbour	0.03	0.04	<0.1	<0.1
Mersey/ Liverpool Bay				
Mersey Eastham Lock		0.32		<0.1
Mersey Tranmere Oil Terminal		0.17		<0.1
Mersey Seacombe Ferry		0.08		<0.1
Mersey Canada Buoy		0.13		<0.1
Poole Harbour				
Poole Harbour Hales Buoy		0.05		<0.1
Poole Harbour Brownsea Buoy		<0.03		<0.1
Poole Anchor		<0.03		<0.1
Southampton Water				
SH Netley Buoy		<0.03		<0.1
SH Cadland Buoy		<0.03		<0.1
SH Tanker Terminal		<0.03		<0.1
SH Calshot Buoy		<0.03		<0.1
Solent Anchor		0.03		<0.1

~0.5% APEOs is discharged to the estuary. Although the free alkylphenol content of APEOs is low, the Tees probably receives one of the largest alkylphenol inputs of any estuary in the UK.

A proportion (approximately 15%, (Department of the Environment, 1993)) of the nonylphenol entering UK coastal waters enters in sewage sludge disposed of offshore; up to 4 mg g^{-1} dry weight of nonylphenol has been found in digested sewage sludge (Waldock and Thain, 1986), but dispersion and dilution rapidly reduces nonylphenol concentrations offshore. Sewage sludge disposal at sea will cease at the end of 1998 and total UK production of APEOs is predicted to fall to 2000 tonnes a year by 1999. As a result, concentrations of alkylphenol in UK estuaries are expected to decline.

Work is continuing at the Burnham-on-Crouch Laboratory on the occurrence and potential biological effects of alkylphenols in rivers in England and Wales.

11. CONCENTRATIONS OF METALS IN THE SEDIMENTS OF THE WESTERN NORTH SEA AND ASSOCIATED ESTUARIES

11.1 Introduction

Sediments are widely recognised as a suitable medium for assessing environmental quality, since they reflect and integrate contaminant inputs to the marine environment, allowing sources and sinks to be identified (e.g. ICES, 1989). This was one of the main reasons which led the Joint Monitoring Group (JMG) of the Oslo and Paris Commissions to initiate an international programme to assess the spatial distribution of metal and organic contaminants in marine sediments throughout the shelf seas around western Europe.

Seabed samples for this 'JMG Baseline Sediment Study' were collected in 1990 and 1991. Further sampling was carried out in 1992/93 in the major estuaries along the east coast of England in preparation for the UK National Monitoring Programme. This Section discusses the trace metal data produced from samples collected from the western North Sea (Figure 6) for these two programmes by the Burnham-on-Crouch Fisheries Laboratory. The UK part of the international study was funded jointly by MAFF and the Department of the Environment (DoE).

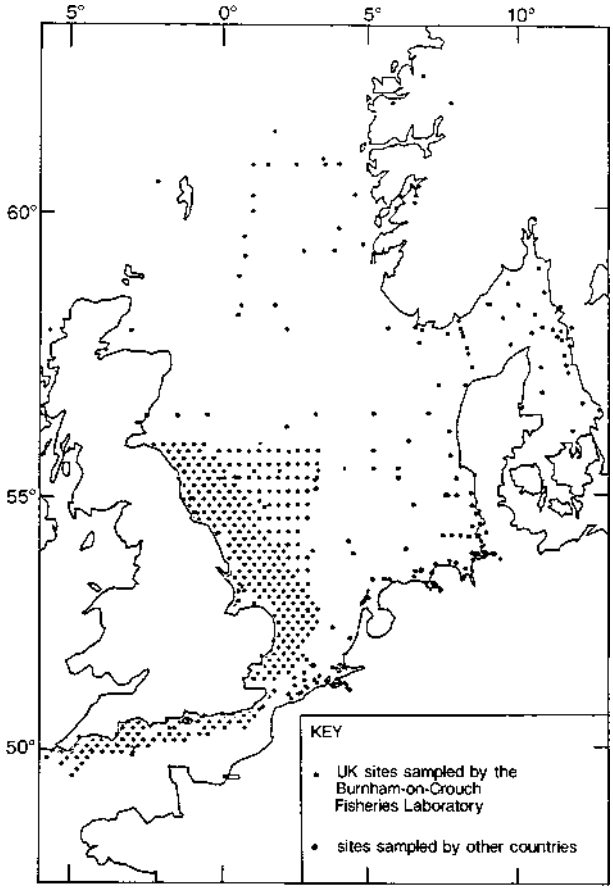


Figure 6. Map of sampling locations for the JMG Baseline sediment survey 1990/ 1991

The sediments were analysed for a range of elements including aluminium, lithium, cadmium, copper, chromium, mercury, lead and zinc. Detailed analysis of such sediment information is only possible after compositional variations due to mineralogical and grain-size differences have been taken into account by using a normalisation procedure. In the present study the technique used was based on a metal/normaliser (in this case lithium) regression model with the calculation of residuals about the regression line. Details of the methodology employed have been described by Rowlatt and Lovell (1994).

11.2 Results

The residuals were plotted as distribution charts (Figure 7(a) and (b) are given as examples), the radius of the circle being proportional to the value of the residual. The figures show the relatively large residuals in the samples from the east coast estuaries. Overall the picture is one of higher values near to shore, particularly close to and in estuaries. The higher values of various metals are associated with different estuaries; for example, the Tyne (Cd, Cu, Pb, Zn), Tees (Cu, Cr), Humber (Cr) and Thames (Cu, Hg).

Chromium values were relatively high near the coast, but this element also showed an area of relatively high values at the centre of the Dogger Bank. Cadmium values were relatively high along the northern edge of the Bank.

Lead and zinc values were higher near the coast than offshore with the highest values occurring off the north-east coast of England.

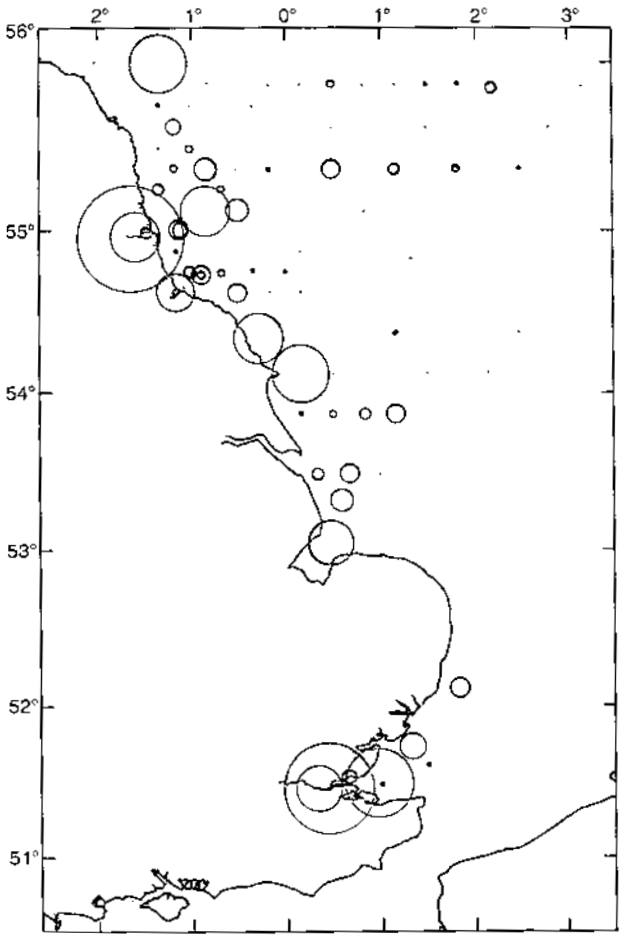


Figure 7(a). Residual values around the relationship between mercury and lithium

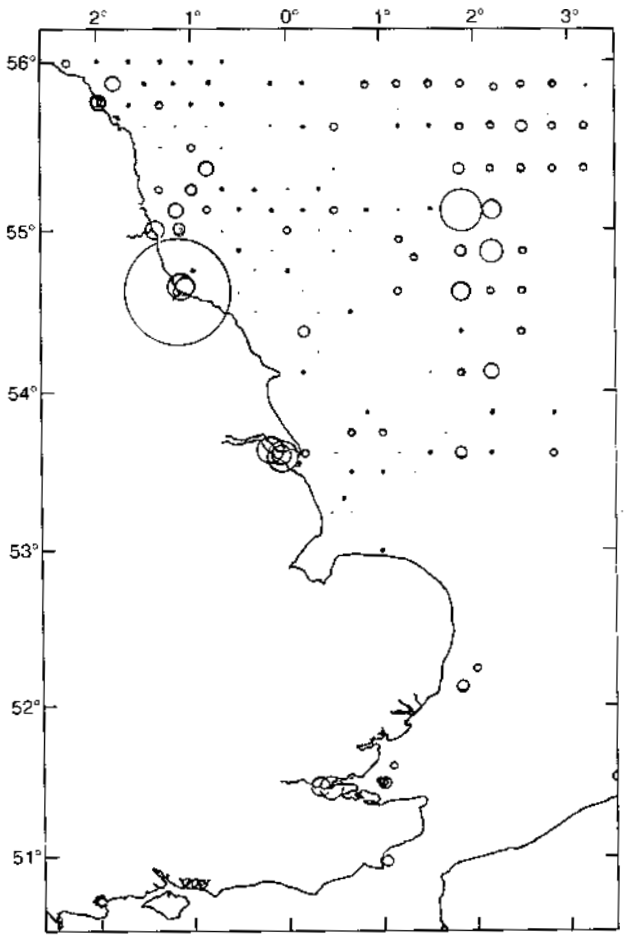


Figure 7(b). Residual values around the relationship between chromium and lithium

11.3 Discussion

Residual values of metal after normalisation are generally higher in the coastal zone and around estuaries than offshore, allowing the deduction to be made that inputs from rivers and land are significant sources of excess metals in sediments. The largest effects of these inputs are limited to areas close to and in estuaries and these effects may be magnified by circulation patterns which trap contaminant-bearing fine particles.

The degree of enrichment varies for each element and for each estuary and coastal zone, indicating that local factors play an important role in determining sediment quality. For example, the relatively high normalised values of lead and zinc in the Tyne and off the north-east coast of England are probably due to a combination of several local factors, including inputs from weathering and erosion of the highly mineralised Pennine Hills, the effects of past mining activities in the hills and industrial discharges to the rivers Tyne and Tees. Concentrations of chromium and copper are relatively high in the Tees as are copper and mercury in the Thames, probably due to industrial sources.

The Dogger Bank is also an area of interest, due to its relatively high normalised values of cadmium and chromium. As the sediments between the coastal zone and the Bank are apparently not greatly elevated in these metals, it is unlikely that the elevations at the Bank are due to adjacent coastal sources (including anthropogenic inputs). It is possible that the higher values of cadmium are due to bioconcentration in phytoplankton and sedimentation at the end of the spring bloom. In the case of chromium, which is likely to have minimal involvement with phytoplankton, the elevated residuals may be due to a natural process such as progressive erosion exposing underlying sediments richer in this element. The analysis of core samples and the mineralogical analysis of the sediments may provide definitive answers to this problem. Work is proceeding on both these topics.

11.4 Conclusion

The results show that the concentrations of excess metals are relatively high in most estuaries, although each estuary is enriched with a different suite of metals. This information can be used in efforts to

control discharges to estuaries and improve their quality.

The present study concentrates on industrialised estuaries where the effects of man's activities are most pronounced. A companion survey is presently underway of areas supporting less industry. This, together with the JMG data, will be used in a National Rivers Authority (NRA) General Quality Assessment of estuaries around England and Wales which will be used to help in the definition and assessment of a strategy to improve water quality.

Using 'pre-industrial' data from cores, the effects of human discharges to estuaries may be quantified. This will allow considered steps to be taken to control contaminant discharges and the subsequent assessment of the effectiveness of those controls through time.

FRESH WATER

12. PESTICIDE RUN-OFF AT ADAS ROSEMAUND; FINAL SUMMARY DATA

12.1 Introduction

Since 1987, concentrations of pesticides have been monitored between November and May each year in field drains and a stream on the experimental farm operated by the Agricultural Development and Advisory Service (ADAS), Rosemaund in Herefordshire. The work was conducted in collaboration with a number of other organisations including ADAS, the Building Research Establishment, the Institute of Hydrology, the National Rivers Authority, the Universities of Essex and Birmingham and the Soil Survey and Land Research Centre. Earlier reports of this work can be found in MAFF (1992(a), 1993(a) and 1994), and most of the data have been published elsewhere or are in press (ADAS, 1990, 1991 and 1994; Brooke and Matthiessen, 1991; Williams *et al*., 1991; Matthiessen *et al*., 1992; Matthiessen *et al*., 1994; Williams *et al*., 1995; Matthiessen *et al*., 1995).

The main objective of the work was to monitor the concentrations of pesticides resulting from normal arable agriculture, which occur in surface waters during and immediately after rainstorms. The reason for studying these phenomena at ADAS Rosemaund is that the soil type (cracking clay) and underlying impermeable rock strata maximise the rapid transport of soil water to the field drainage system and hence to the stream. The concentrations of pesticides observed there are thus likely to be at the upper end of the range for UK surface waters, although it is worth noting that approximately 28% of British soils have a hydrological regime in which by-pass flow through cracks and other macropores is an important feature. The data are therefore expected to be of considerable use in improving the aquatic risk assessment of pesticides.

Another major objective has been to use the field data to assist the development of computerised models of the way in which pesticides translocate to surface waters. If such models can be validated adequately with reliable data, they might ultimately be used for predicting the environmental concentrations of new pesticides before they are formally approved for introduction. A secondary objective at ADAS Rosemaund has been the deployment of *in situ* bioassays in the stream to monitor the potential biological effects of pesticide run-off.

This report is intended to provide a summary of the monitoring data now that the fieldwork has come to an end, to highlight the significance of the results, and to make recommendations for further action.

12.2 Results

Full details of the methods used have been described in the publications referred to above. It is sufficient to note that attention has largely focused on the period during and immediately after rainstorms of ≥ 10 mm day^{-1}, because it is these which have been found to cause the most significant translocation of pesticides. The data to be described here refer to a field drain issuing from one of the treated fields, and to a point on the receiving stream approximately 100 m downstream of the drain. Comprehensive data were obtained for 19 pesticides, including such diverse groups as phenoxy acid, benzoic acid, pyridine, dinitroaniline and triazine herbicides, a morpholine fungicide, as well as organochlorine, pyrethroid, carbamate and organophosphate insecticides. Most were chosen for study because of their relative water solubility, and hence their predisposition to leach into field drains, but a few hydrophobic substances were also studied.

Typically, the drain and stream flowrates increased rapidly within a few hours of significant (approx. 10 mm) rainfall and the peak concentrations of pesticides were generally seen to coincide with the peak of the hydrograph. Unless rainfall was unusually prolonged, the hydrograph usually decreased again (though at a slower rate) to the pre-rain level within 24 h and concentrations of pesticides mirrored this pattern. The general theme was therefore one of sharp but transient pesticide spikes often interspersed with many days when concentrations of pesticides were below detection limits.

A summary of the data for each pesticide is given in Appendix 15. Rainfall events have been tabulated for which the flow-weighted mean concentration of pesticide was a maximum for the pesticide in question. The maximum and mean concentrations found in the stream during the relevant events are shown in Figure 8. It is interesting to note that, almost irrespective of chemical type, or even of application rate, mean concentrations in the drain generally exceeded 0.5 µg l^{-1} (range 0.005 - 37.2 µg l^{-1}; mean 5.9 µg l^{-1}), and mean concentrations in the stream generally exceeded 0.1 µg l^{-1} (range <0.01 - 10.6 µg l^{-1}; mean 2.0 µg l^{-1}). Maximum concentrations were 0.02 - 58.4 µg l^{-1} in the drain and <0.01 - 26.8 µg l^{-1} in the stream. However, despite these unexpectedly high peak levels, it is noteworthy that the total amount of pesticide mobilised during any rainfall event never exceeded 0.7% of that applied to the relevant catchment area, and were often less than 0.001% of that applied. This is partly due to the fact that the degradation of many pesticides in the soil was rapid.

The data for the pyrethroid insecticide deltamethrin and the dinitroaniline herbicide trifluralin (which showed peak concentrations of 1.9 and 0.9 µg l^{-1}, respectively) are particularly surprising because the chemical properties of these substances (they both adsorb strongly to particulates) are such that one would not expect them to leach in significant amounts. The explanation for these results is that, particularly with deltamethrin, the majority of the detected residues were adsorbed on fine particulates which moved down soil macropores during heavy rainfall and thus entered the field drains and the stream. It should be noted, however, that the strength of this adsorption would be expected to mitigate the high toxicity of deltamethrin to much aquatic life by minimising bioavailability. This expectation was tested by bioassaying stream sediments after deltamethrin run-off, using the sediment-dwelling insect larva *Chironomus riparius*. No significant toxicity (mortality or growth-inhibition) was indeed detected.

However, the water-soluble pesticides are much more bioavailable. In order to determine whether the transient peak concentrations in the stream could present a risk to stream fauna, an *in situ* bioassay which measured mortality and feeding rate of the amphipod crustacean *Gammarus pulex* was deployed in the stream on three separate occasions after pesticide application to fields upstream. The pesticides in question were the phenoxy acid herbicide dichlorprop, the carbamate insecticide/nematicide carbofuran, and the organophosphate insecticide chlorpyrifos (Matthiessen *et al*., 1995). Dichlorprop is of low toxicity to crustacea and failed to cause any bioassay responses, but both carbofuran and chlorpyrifos caused feeding rate reductions and extensive mortalities during the two rainfall events which were

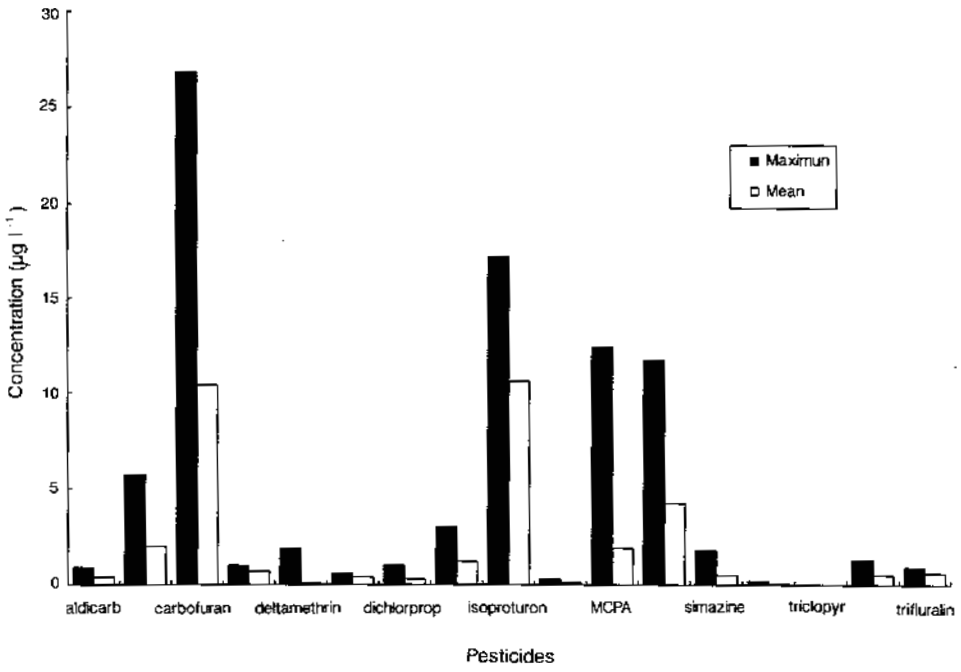


Figure 8. Maximum and flow-weighted concentrations of pesticides in Rosemaund stream for those rainfall events which produced the largest mean concentration

monitored. Furthermore, several additional events during which bioassays were not deployed also gave rise to concentrations which would have been expected to cause mortalities. Unpublished data suggest that the fauna in the Rosemaund stream are significantly impoverished, so it appears that pesticide run-off could at least be contributing to actual environmental impacts. No attempt has been made to deploy plant-based bioassays, so the potential adverse influence of the many herbicides which reach the stream in appreciable quantities cannot be assessed at present. However, peak concentrations of at least three herbicides (isoproturon, trifluralin and atrazine) approached or exceeded Environmental Quality Standards proposed by the National Rivers Authority (National Rivers Authority, 1994) and the Department of the Environment (Department of the Environment, 1989 and 1990).

If pesticide risk assessments are to be improved, it will be necessary to build models which can predict the concentrations of candidate pesticides in headwater streams. A detailed description of model validation work which has been conducted with the Rosemaund data has been published elsewhere (Di Guardo *et al*., 1994). This has shown that a simple model based on fugacity theory (SoilFug) was able to predict with reasonable accuracy the mean concentrations of 7 out of 10 pesticides during 59 rainfall events at Rosemaund. The exceptions were the phenoxy acids whose concentrations were over-predicted, possibly because the extent to which they are adsorbed in soils has not been accurately measured. SoilFug has had similar success in predicting concentrations of pesticides in two Italian catchments. There is thus some scope in the future for predicting and managing the risks of those pesticides which present the greatest threat to headwater streams.

12.3 Conclusions

1. Normal arable agriculture conducted on cracking clay soils with field drainage is likely to produce transiently elevated concentrations of a large range of pesticides in adjacent headwater streams and ditches after rainstorms. Mean concentrations in the Rosemaund stream during entire rainfall events can be as high as 10 $\mu g\ l^{-1}$, and maxima (which only persist for a few hours) can exceed 25 $\mu g\ l^{-1}$. Almost irrespective of chemical properties and application rates, peak levels of individual pesticides in the Rosemaund stream during autumn and winter are rarely less than 0.5 $\mu g\ l^{-1}$.

2. Soil structure is thus probably more important than chemical properties in determining aquatic environmental exposure, but simple partitioning models such as SoilFug which employ basic physicochemical information nevertheless show promise in the prediction of ‘worst case’ environmental concentrations.

3. Despite their transience, the elevated levels of some insecticides are able to cause harmful impacts on sensitive stream fauna, and it is probable that certain herbicides are adversely affecting algae and aquatic plants. Such effects are likely to be confined to headwater streams and ditches because there will be substantial dilution downstream by uncontaminated water.

4. These findings have significant implications for pesticide risk assessments in the UK and elsewhere because they imply that headwater streams are being damaged by some currently approved pesticides. In the UK, no attempt is made at present to predict the concentrations of pesticides which are likely to occur in headwater streams as the result of leaching and by-pass flow. The reason for this is partly the absence, hitherto, of suitable predictive models. However, it may also partly result from an historical concern with impacts on fisheries in larger rivers, to the exclusion of consideration for the substantial conservation significance of some headwaters.

DISPOSAL AT SEA: ENVIRONMENTAL ASSESSMENT STUDIES

13. BENTHIC MONITORING AT THE TYNE SEWAGE-SLUDGE DISPOSAL SITE, 1986-1993

13.1 Introduction

Since approximately 1980, sewage sludge has been deposited at a site some 10 km off the Tyne estuary . The amount has been relatively constant since 1984, at about 500 000 wet tonnes annually. Although only the third largest sewage-sludge disposal site around England and Wales, in terms of quantities disposed of, the location is of particular interest for four reasons:

(i) from the outset, the area was recognised to be one of some sensitivity in view of the proximity of commercial fishing interests, especially a *Nephrops* ground;

(ii) it was known to be relatively low on a dispersive scale developed for sewage-sludge disposal sites around the England and Wales coastline;

(iii) because of its short history of usage, the site offered a rare opportunity to follow any changes that might occur immediately following commencement of disposal;

(iv) annual monitoring at this site has now been conducted over a sufficiently long period to allow a more detailed evaluation of trends than has hitherto been possible.

Earlier results from biological monitoring of this sea disposal operation were reported by Rees *et al.* (1985, 1992) and MAFF (1993(a)), while trends in concentrations of trace metals and faecal bacteria within sediments were reported by Rowlatt *et al.* (1989) and MAFF (1993(a)). Evidence was found of marginal enrichment of benthic populations in the immediate vicinity of disposal, accompanied by elevations in physical indicators of sludge contamination, notably tomato pips. These changes were judged to be within acceptable bounds, when assessed against proposed 'Environmental Quality Standards' at sewage-sludge disposal sites (Rees and Pearson, 1992; MAFF, 1992(b) and 1993(b)).

The following account provides an up-date on the monitoring of temporal trends at regularly sampled stations. It also includes data from a reference station some 14 km to the north of the disposal site which has been sampled annually since 1989 and reported by Boyd (1994).

13.2 Methods

Stations were sampled annually in May by means of a 0.1 m^2 Day Grab.

13.2.1 Macrofauna

Five samples were taken at each station and, after subsampling for particle size analyses, the macrofauna retained on a 0.5 mm mesh sieve were preserved for later laboratory analysis. Further details of methodology, including the rationale for selection of stations, are given in Rees *et al.* (1992). Until recently, only three of the five samples were routinely worked up and this number has been used in the following analyses, to allow direct comparisons with earlier data.

Unless otherwise stated, the data are presented as means with Least Significant Intervals (see Andrews *et al.*, 1980); means whose intervals do not overlap may be deemed to be significantly different at the 95% probability level.

13.2.2 Trace metals

Samples were collected from stations randomly positioned in a sampling zone centred on the area of sludge settlement at the southern edge of the disposal site.

Details of the field sampling and other methods used were reported in Section 15 of an earlier report in this series (MAFF, 1993(a)).

13.3 Results

Stations were located approximately along the 50 m contour (Figure 9), one at the southern edge of the disposal site, and the other two some 14 and 8 km to the north and south, respectively. The southern 'reference' station is close to a dredgings disposal site (see Figure 9), and any effects on the benthos arising from the dispersal of material from this source could complicate assessment of the consequences of sewage-sludge disposal.

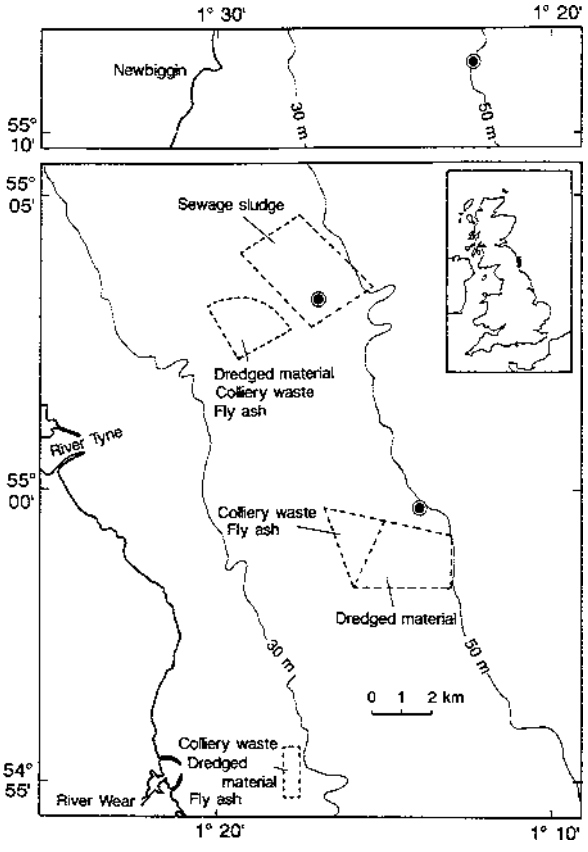


Figure 9. Location of benthic stations off the Tyne estuary

Although the data have provided no evidence of such effects, complementary sampling at a more distant site to the north commenced in 1989, in order to provide a second reference point.

(i) Sediments

Levels of organic carbon in the <63 micron fraction (Figure 10(a)) were significantly higher at the disposal site in 1987 and 1988. Otherwise, the values at all three stations were generally similar and relatively high (at about 4%), on account of naturally-occurring coal in this coastal region.

With the exception of 1986, sediments at the disposal site were marginally coarser and better sorted than at the southern reference site (Figure 10(b)), with little variation between years. In contrast, there was substantial fluctuation in medians at the northern reference site (Figure 10(b)) reflecting a variable coarse shell content in some years. No long-term trends were evident from silt/clay content (Figure 10(c)), although exceptionally high levels were found at the disposal site in 1986. Sediments at the disposal site contained large numbers of tomato pips throughout the sampling period (Figure 10(d)), a clear indicator of sludge contamination, but there is no evidence of net accumulation with time. The occasional presence of pips at the southern reference site suggests southward dispersal, approximately along the tidal axis (see MAFF, 1993(a)).

Figure 11 is an example of trace metal levels, it shows the variation in sediment lead at the disposal site

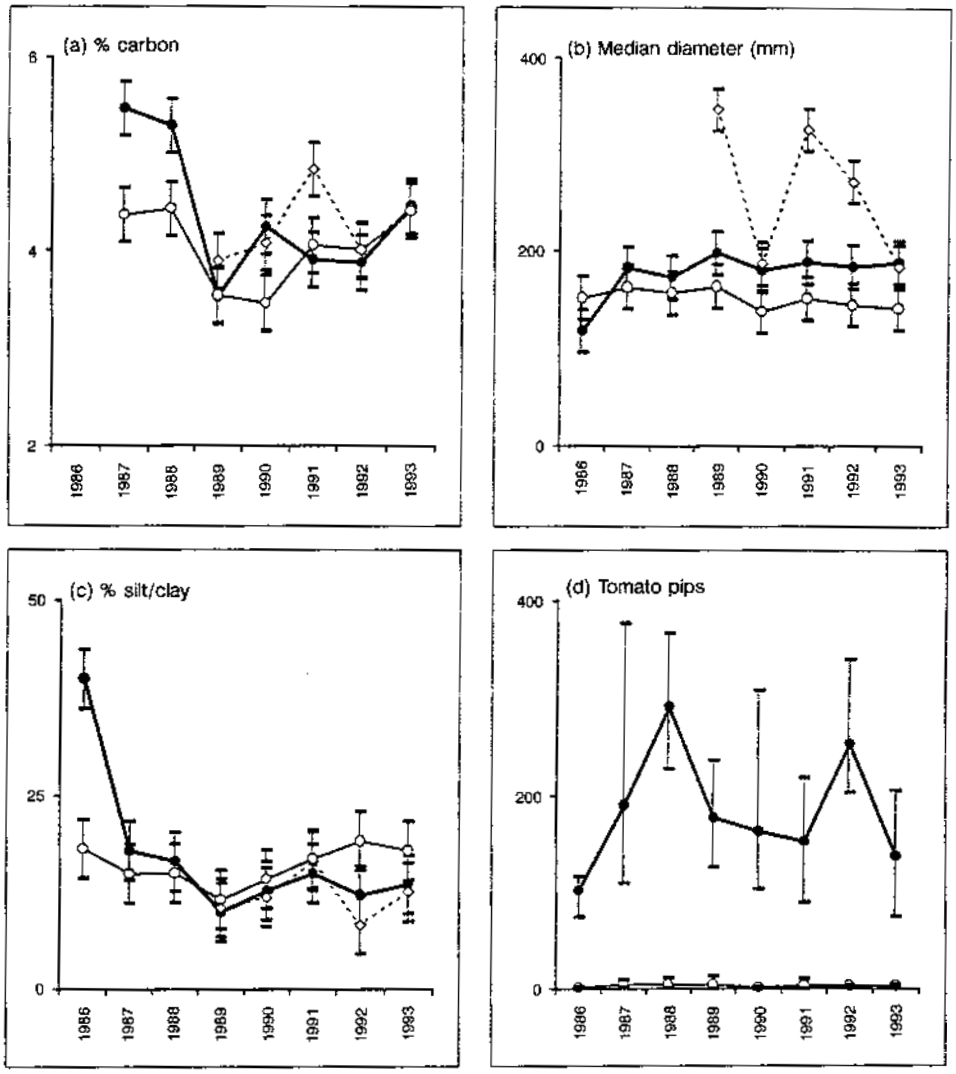


Figure 10(a-d). Changes in carbon (%) and physical properties of sediments off the Tyne estuary. Data are expressed as means with 95% Least Significant Intervals, excepting tomato pips, where ranges about the means are given. (Closed circles: sewage-sludge disposal site; open circles: southern reference site; diamonds: northern reference site)

between 1987 and 1993. There has been a decrease in the concentration of sediment lead at the site followed by stabilisation. Similar results were recorded for mercury and copper.

The concentrations of lead over this period were below the 'action level' (160 mg kg^{-1}) defined by the Group Co-ordinating Sea Disposal Monitoring (GCSDM) to protect the ecosystem. In 1993, concentrations were approximately half the action level. Concentrations of mercury, cadmium, chromium, copper and zinc were also well below the relevant GCSDM 'action levels'.

(ii) Fauna

Previous studies at the Tyne site have suggested that the effects of sewage-sludge disposal were manifested by a marginal enhancement in the densities of taxa which were naturally present elsewhere in the area, i.e. there was no evidence of a substantial change in the structure of the community. Figure 12(a) shows that densities

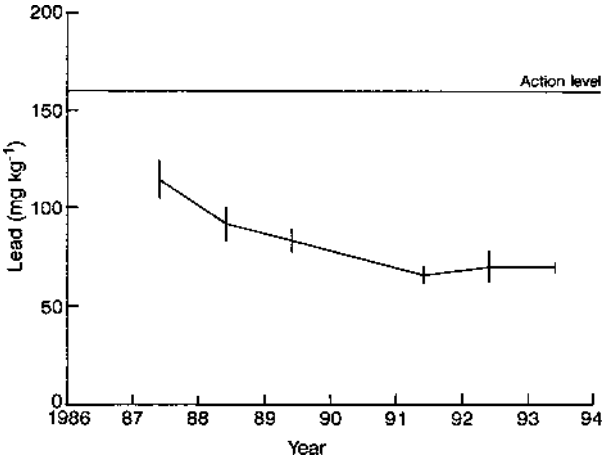


Figure 11. Concentrations of lead in the <63 µm fraction of sediment at the Tyne sewage-sludge disposal site. Bars indicate 1 standard error about the mean

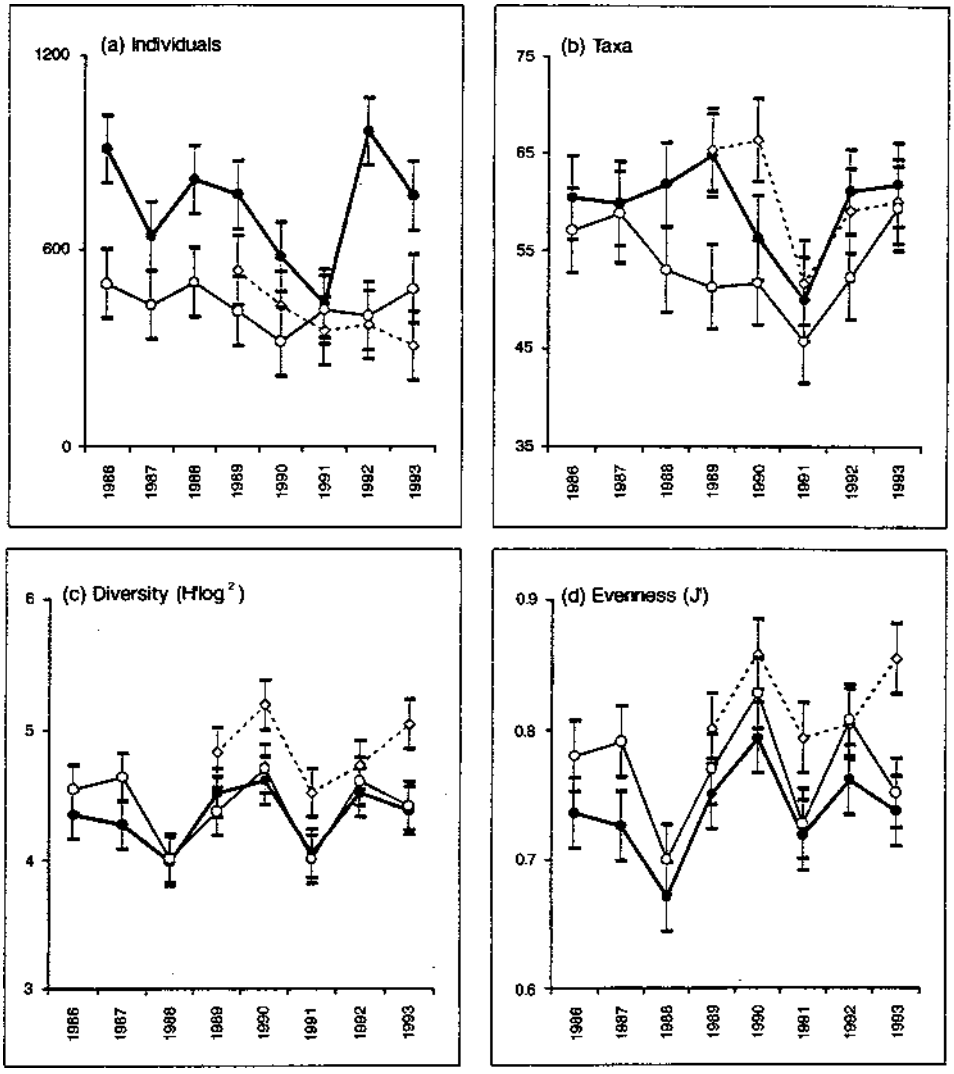


Figure 12(a-d). Trends in univariate measures for the macrofauna off the Tyne estuary. Data are expressed as means per 0.1 m^2 with 95% Least Significant Intervals. (Closed circles: sewage-sludge disposal site; open circles: southern reference site; diamonds: northern reference site)

were generally significantly higher at the disposal site. Numbers of taxa also tended to be somewhat higher at the disposal site compared with the southern reference site (and comparable with those at the northern site: Figure 12(b)), but the differences were not usually statistically significant.

Although not sustained over all years, there is some evidence of synchronicity in changes over time between sites, for example in densities at the disposal site and at the southern reference site between 1986 and 1990 (Figure 12(a)). When the data for each station are summarised in the form of the Shannon-Wiener diversity index (Shannon and Weaver, 1949) and its complementary index of 'evenness' (a measure of the apportioning of individuals among the species), changes are very clearly synchronous with time (Figure 12(c) and (d)). This appears to indicate similarity in the influence of natural environmental factors across all sites, and hence provides support for the validity of between-site comparisons of trends.

Values of diversity and evenness indices are generally highest at the northern reference site. There are no significant differences in diversity at the disposal site and southern reference site; marginally lower values of evenness at the disposal site are consistent with earlier inferences concerning an enhancement in numbers of common species in response to sludge disposal.

There is no clear evidence from the summary measures of Figure 12(a-d) of directional change over the sampling period. However, when the numerical data are split into the major component groups of the benthos, some trends begin to emerge. For example, there is a tendency towards an increase in densities of molluscs (Figure 13(a)). Common species which largely explain such changes are shown in Figure 13(b-d). Particularly noticeable are upward trends in *Thyasira* (b) and *Abra* (c)

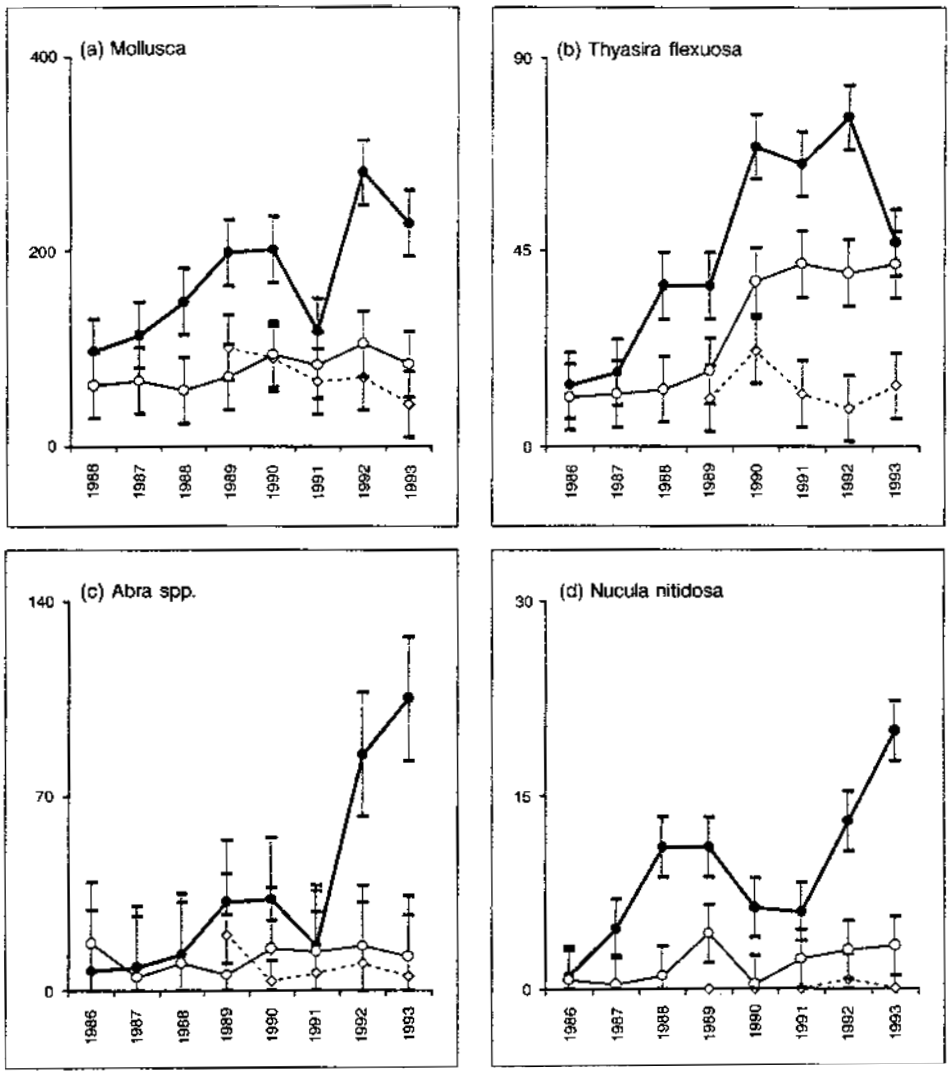


Figure 13(a-d). Trends in densities of molluscs (a) and of a range of numerically dominant bivalve taxa (b-d) off the Tyne estuary. Data are expressed as mean numbers per 0.1 m^2 with 95% Least Significant Intervals. (Closed circles: sewage-sludge disposal site; open circles: southern reference site; diamonds: northern reference site). Note different scales

at the disposal site. *Thyasira* has been cited as an indicator of organic enrichment (Lopez-Jamar *et al.*, 1987) and hence increased densities might suggest an incipient influence of sewage-sludge disposal. If so, then this might indicate that the southern reference site may also be influenced by the disposal operation, although the findings for *Abra* would suggest otherwise.

Criteria for assessing the acceptability of benthic changes in response to sewage-sludge disposal have been recommended by the Group Co-ordinating Sea Disposal Monitoring (GCSDM) (MAFF, 1993(b)). These have been applied to comparisons between the disposal site and, respectively, the northern and southern reference sites, in Figure 14(a-d). As previously reported (Rees and Pearson, 1992), for the comparison between the disposal site and the southern reference site, ratios of abundance significantly in excess of zero remain indicative of marginal enrichment but, as for the ratio of numbers of taxa, remain within acceptable bounds. This is also true for the comparisons between the disposal site and northern reference site over a shorter time period.

A 'Quality Standard' aimed at maintenance of the *status quo* at reference stations was also proposed by the GCSDM (MAFF (1993(b)). However, since it requires the derivation of a 'baseline' value from at least the first three years for which comparative data are available, the scope for application to Tyne data is presently limited, as sampling at the northern reference site only commenced in 1989. Even so, an examination of changes in faunal statistics showed that they presently remain within the set boundaries.

13.4 Discussion

13.4.1 Trace metals

The data for trace metals in sediments at the Tyne disposal site provide an example of the effectiveness of regulations for sewage sludge disposal for controlling the impact of this waste on the marine environment. They also show that the concentration of lead is well below the level which may cause harm to the ecosystem (the 'action level').

13.4.2 Macrofauna

The main objectives of this work were to identify impacts on the benthic fauna arising from sewage-sludge disposal, and to establish whether there were any adverse changes with time which might signal the need for management action to reduce the quantities discharged.

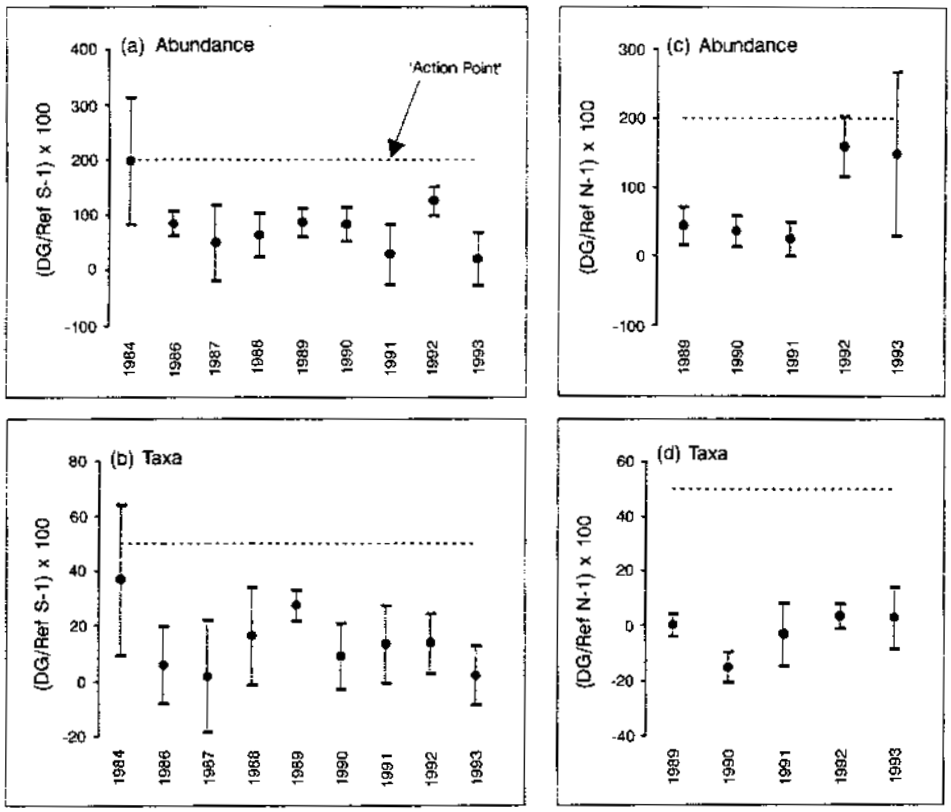


Figure 14(a-d). Means with 95% confidence intervals for pairwise comparisons of univariate measures at the Tyne sewage-sludge disposal site; (a-b): disposal site and southern 'reference' station; (c-d): disposal site and northern 'reference' station. (Proposed 'Action Points' for acceptable change are super-imposed)

The conclusion from earlier surveys was that the benthic macrofauna showed evidence of mild organic enrichment in the immediate vicinity of the disposal site. This took the form of enhanced abundances of certain species indigenous to the general area, but was not accompanied by a proliferation of classical 'indicator' species such as the polychaete worm *Capitella*, or by elimination of rarer species. Thus there was no evidence of structural change in community composition, such as has been observed at the Garroch Head sewage-sludge disposal site off the west coast of Scotland (e.g. Pearson, 1987), an area of gross organic enrichment.

The present results from annual monitoring at representative stations support the earlier conclusions and furthermore provide no evidence of deleterious changes in the benthic fauna with time. The natural dispersive properties of the receiving environment off the Tyne (although somewhat lower than at many other locations off the coast of England) therefore appear to have ensured that no unacceptable biological 'cost' has been incurred as a result of the disposal of sewage sludge at current levels.

An examination of trends in a range of individual taxa does, however, provide a useful reminder that change rather than stability is the norm for benthic species at the population level. As a consequence, it is most important that evaluations of the effects of waste disposal at a location are made against a suitable 'reference' point which is (as far as possible) distinctive only in terms of its distance from the discharge point.

The concentration of effort into the sampling of a limited number of stations has several advantages:

(i) replicate samples from individual stations are more amenable to the assessment of temporal trends;

(ii) it is easier to draw statistical comparisons between stations, especially with regard to any standards set for permissible change arising from waste disposal or other human activity;

(iii) in general, a reduced sampling effort is required on each occasion, compared with grid surveys which aim to describe wider spatial patterns in the sampling area.

The adoption of such a strategy pre-supposes a good knowledge of the local environment and of likely transport pathways for dispersing waste material. Furthermore, its effectiveness will also depend upon local conditions. For example, in a very heterogeneous environment it may be very difficult to locate reference stations which closely resemble those within the sphere of waste influence. In all cases, the continued 'representativeness' of annually sampled stations will require periodic checking against the outcome of spatially extensive surveys. At the present site, this requirement is met by a combination of transect-sampling by MAFF and grid-sampling over a wider area by the licensee (Northumbrian Water) in fulfilment of the Food and Environment Protection Act (FEPA) 'self-monitoring' commitment (see Rowlatt *et al*., 1991) which is a condition of the disposal licence.

DEPOSITS IN THE SEA: LICENSING AND RELATED ACTIVITIES

14. LICENSING OF DEPOSITS IN THE SEA

14.1 Introduction

This section gives information about the licensing of deposits in the sea during 1993 under Part II of the Food and Environment Protection Act (1985) (FEPA)(Great Britain - Parliament, l985(a)). It fulfils an undertaking given to Parliament by the Government to report on the licensing, enforcement and monitoring of activities related to the disposal of wastes at sea.

In accordance with that undertaking and for convenience, licensing statistics for Scotland and Northern Ireland are included in this Section to provide statistics for the UK as a whole.

This report also includes statistics of other deposits in the sea which are principally for construction purposes.

14.2 Legislation and licensing authorities

The disposal of waste at sea**,** as opposed to discharge into the sea via pipelines, is controlled by a system of licences issued under Part II of FEPA. Certain operations (e.g. deposit of scientific instruments, navigation aids), are exempt from licensing under the Deposits in the Sea (Exemptions) Order 1985 (Great Britain - Parliament, 1985(b)). In England and Wales, the

licensing function rests with MAFF and in Scotland with the Scottish Office Agriculture and Fisheries Department (SOAFD). In Northern Ireland, the issuing of licences is the responsibility of the Department of the Environment for Northern Ireland (DoE(NI)).

Section 147 of the Environmental Protection Act (1990) (Great Britain-Parliament, 1990) provides for further additional material about sea disposal activities to be added to the public registers, established under FEPA. In future the registers will also contain information about applications, breaches of the legislation and enforcement action.

14.3 Enforcement

Scientists from the Burnham-on-Crouch Laboratory have powers to enforce licence provisions by visits to production units, storage sites and disposal vessels. They may also take samples and check records, including logbooks. They carried out 7 inspections in 1993. The Sea Fisheries Inspectorate, with staff based on the coast, detects unlicensed disposal operations and enforces licence conditions relating to the disposal of the wastes in the designated disposal area. They made 186 inspections in 1993.

In Scotland, similar enforcement powers are held by staff of the SOAFD Marine Laboratory, Aberdeen and by the Scottish Fisheries Protection Agency (SFPA). The Marine Laboratory made 10 inspections in 1993 and a further 28 visits were made by the SFPA. In Northern Ireland, 13 inspections were made in 1993.

MAFF investigated, in detail, 3 alleged cases of licence infringement during 1993. In the first, a barge was scuttled off the coast of south west England. When MAFF pointed out that it was illegal to dispose of a vessel in this way without a licence, it was refloated and towed ashore to allow its owner to cut it up and dispose of it as scrap. Consideration was given to prosecution for the inital scuttling but this was not pursued when the barge was refloated. In any case the owner was prosecuted under other legislation and had gone into bankruptcy. Detailed discussions were held with a harbour, also in the south-west, which had been refused a licence for the deposit of dredged material because of high levels of contamination. The harbour company was given a licence to deposit the material in a bunded and lined area of the harbour, but in fact proceeded to use this area for depositing other waste material. They were warned in the strongest terms about the consequences of their action, both at meetings and in correspondence, but no legal proceedings were pursued. Finally a case is being taken against a dredging company and harbour in the south-east of England arising from falsification of a log book. A number of unlicensed activities were also followed up.

In Scotland 4 cases were investigated, 2 involving unlicensed operations; one allegation proved to be unfounded and in the fourth case, which involved a dredger failing to dump at the designated disposal site, a warning letter was issued stressing the need to comply with licence conditions.

14.4 Report on licensing activities

Tables 7-11 give details, over the period 1989-1993, of the number of sea disposal licences issued, the quantity

Table 7(a). Solid industrial wastes licensed for disposal at sea in 1993 [1]

Licensed Quantity (t)	Company and source of waste	Description of waste	Disposal sites	Quantity Deposited (t)
	British Coal Collieries			
500,000	Seaham	Minestone	Bankside at Seaham	0
600,000	Easington	Minestone	Foreshore at Easington	172,919
600,000	Ellington	Minestone	Foreshore at Ellington	613,570
100,000	Point of Ayr	Minestone	Foreshore at Point of Ayr	57,043
* [2]	Wearmouth	Minestone	Sunderland/Souter Point	561,745 [3]
* [2]	Westoe	Minestone	Souter Point/North Tyne/Sunderland	201,757 [3]
* [2]	Wearmouth/Westoe	Mine tailings	Souter Point/North Tyne/Sunderland	598,636 [3]

Notes: [1] *No solid industrial wastes were licensed or disposed of in Scotland or Northern Ireland during the period covered by this report*
[2] *No licences were issued in 1993*
[3] *Disposed of under licences issued in 1992*
Licensed quantities*: licences were issued throughout the calendar year 1993 and were generally valid for twelve months*
Tonnages deposited*: relate to quantities deposited in the calendar year 1993, which may be covered by two licences, including one issued in 1992*

Table 7(b). Summary of solid industrial waste licensed and deposited at sea in the period 1989-1993[1]

Country	Year	Licences issued	Licensed quantity (t)	Wet tonnage deposited	Quantities of metal contaminants in wastes deposited (t)						
					Cd	Cr	Cu	Hg	Ni	Pb	Zn
England and Wales	1989	10	5,928,917	4,835,508	0.28	24	200	0.24	68	245	481
	1990	9	6,575,000	4,919,654	0.29	24	182	0.21	64	223	441
	1991	8	5,750,000	4,530,860	0.28	23	172	0.21	60	212	414
	1992	8	5,080,000	3,649,727	0.22	18	133	0.16	46	163	319
	1993	4	1,800,000	2,205,670	0.14	12	98	0.09	36	117	241
Scotland	1989	0	0	102	0.00	0	0	0.00	0	0	0
	1990	0	0	0	0.00	0	0	0.00	0	0	0
	1991	1	300	460	0.00	0	0	0.00	0	0	0
	1992	0	0	0	0.00	0	0	0.00	0	0	0
	1993	0	0	0	0.00	0	0	0.00	0	0	0
UK total	1989	10	5,928,917	4,835,610	0.28	24	200	0.24	68	245	481
	1990	9	6,575,000	4,919,654	0.29	24	182	0.21	64	223	441
	1991	9	5,750,300	4,531,320	0.28	23	172	0.21	60	212	414
	1992	8	5,080,000	3,649,727	0.22	18	133	0.16	46	163	319
	1993	4	1,800,000	2,205,670	0.14	12	98	0.09	36	117	241

Notes: [1] No solid industrial wastes were licensed or disposed of in Scotland or Northern Ireland in the period covered by this report
For information on licensed quantities and tonnages deposited see footnote to Table 7(a)

of waste licensed, and the quantity actually deposited, together with information on those contaminants in the wastes which the UK is required to report internationally to meet obligations under the Oslo and London Conventions (Great Britain - Parliament, 1972(a-b)).

14.5 Licensing of industrial waste and minestone disposal

As noted in the previous report, disposal of both liquid and solid industrial waste at sea ended in 1992.

Disposal of minestone (a material which is accepted internationally as inert in the marine environment) on beaches and at sea, decreased sharply in 1993 as mines at Easington, Seaham and Westoe ceased operations. Details of licences and contaminant levels in the material actually deposited are provided in Tables 7(a) and 7(b) respectively.

14.6 Licensing of sewage sludge disposal

Table 8(a) gives details of licences issued for the disposal of sewage sludge at sea. Total quantities of key metallic contaminants in sewage sludge actually disposed of at sea are shown in Table 8(b). Figure 15 shows the location of the disposal sites for sewage sludge and the quantities deposited at each site.

Table 8(a). Sewage sludge licensed for disposal at sea in 1993

Country	Licensed quantity (t) [1]	Company and source of waste	Disposal sites	Quantity deposited (t) [1]
England and Wales	80,000	Anglian Water (Cliff Quay STW, Ipswich)	Roughs Tower	74,200
	65,000	Anglian Water (Colchester STW)	Roughs Tower	73,760
	150,000	Anglian Water (Tilbury STW)	Roughs Tower	135,650
	461,000	Northumbrian Water (Howdon, Chester-le-Street, Cramlington, Washington STWs)	Tyne/Spurn Head	457,500
	105,000	Northumbrian Water (Portrack, Billingham, Guisborough, Ayton STWs)	Tyne/Spurn Head	67,712
	1,965,000	North West Water (Davyhulme, Liverpool, Warrington STWs)	Liverpool Bay	1,979,641
	5,000	North West Water (Walney Island)	Liverpool Bay	3,600
	300,000	Southern Water (Woolston, Portswood, Millbrook, Slowhill Copse STWs)	Nab Tower	268,016
	58,000	South West Water (Countess Wear STW)	Lyme Bay	57,421
	55,000	South West Water (Plympton, Radford, Camel's Head, Ernesettle, Ivybridge, Saltash, Newton Ferrers STWs)	Plymouth	48,766
	4,500,000	Thames Water (Beckton, Crossness, Riverside, Deephams STWs)	Barrow Deep	4,432,314
	140,000	Yorkshire Water (Knostrop STW)	Spurn Head	135,076
Scotland	500,000	Lothian Regional Council	St Abb's Head/Bell Rock	314,340
	2,500,000	Strathclyde Regional Council	Garroch Head	1,632,000
Northern Ireland	243,200	Dept. Environment (Northern Ireland)	Belfast Sludge	243,200 [2]

Notes: [1] All figures are for tonnage in wet weight
[2] Disposed of by DOE (NI) Water Services under an administrative authorisation
STW = Sewage Treatment Works
For information on licensed quantities and tonnages deposited see footnote to Table 7(a)

Table 8(b). Summary of sewage sludge licensed and deposited at sea in the period 1989-1993

Country	Year	Licences issued	Licensed quantity (t)	Wet tonnage deposited	Quantities of metal contaminants in wastes deposited (t)						
					Cd	Cr	Cu	Hg	Ni	Pb	Zn
England and Wales	1989	15	8,321,305	7,373,212	2.17	85	128	0.94	18	157	297
	1990	14	8,553,579	7,098,944	1.76	68	113	0.88	18	109	238
	1991	14	8,373,569	7,449,084	1.88	67	121	0.92	17	103	269
	1992	12	7,985,000	7,739,369	1.70	61	123	0.85	17	93	273
	1993	13	7,884,000	7,733,656	1.09	49	112	0.65	15	74	216
Scotland	1989	2	2,300,000	1,940,575	0.46	53	32	0.17	3	24	58
	1990	2	3,000,000	1,946,430	0.27	34	30	0.16	3	18	39
	1991	2	3,000,000	1,984,035	0.24	35	41	0.10	3	20	44
	1992	2	3,000,000	1,984,525	0.21	30	36	0.10	2	18	40
	1993	2	3,000,000	1,946,340	0.19	18	26	0.07	3	18	35
Northern Ireland	1989	1	80,000	329,060 *	0.05	3	4	0.03	1	3	12
	1990	1	80,000	290,030 *	0.03	2	3	0.04	0	2	11
	1991	1	80,000	302,370 *	0.04	2	3	0.04	0	3	11
	1992	0	0	261,000 $	0.04	2	3	0.02	0	3	10
	1993	0	0	243,200 @	0.04	2	3	0.02	0	3	9
UK total	1989	18	10,701,305	9,642,847 *	2.68	141	164	1.14	22	184	367
	1990	17	11,633,579	9,335,404 *	2.06	104	147	1.07	21	129	288
	1991	17	11,453,569	9,735,489 *	2.15	104	165	1.06	20	125	325
	1992	14	10,985,000	9,984,894 $	1.95	93	163	0.97	19	114	323
	1993	15	10,884,000	9,923,196 @	1.31	69	141	0.75	18	95	260

*Notes: * Includes 200,000 t disposed of by DoE(NI) Water Services under an administrative authorisation*
$ Includes 261,000 t disposed of by DoE(NI) Water Services under an administrative authorisation
@ Includes 243,200 t disposed of by DoE(NI) Water Services under an administrative authorisation
For information on licensed quantities and tonnages deposited see footnote to Table 7(a)

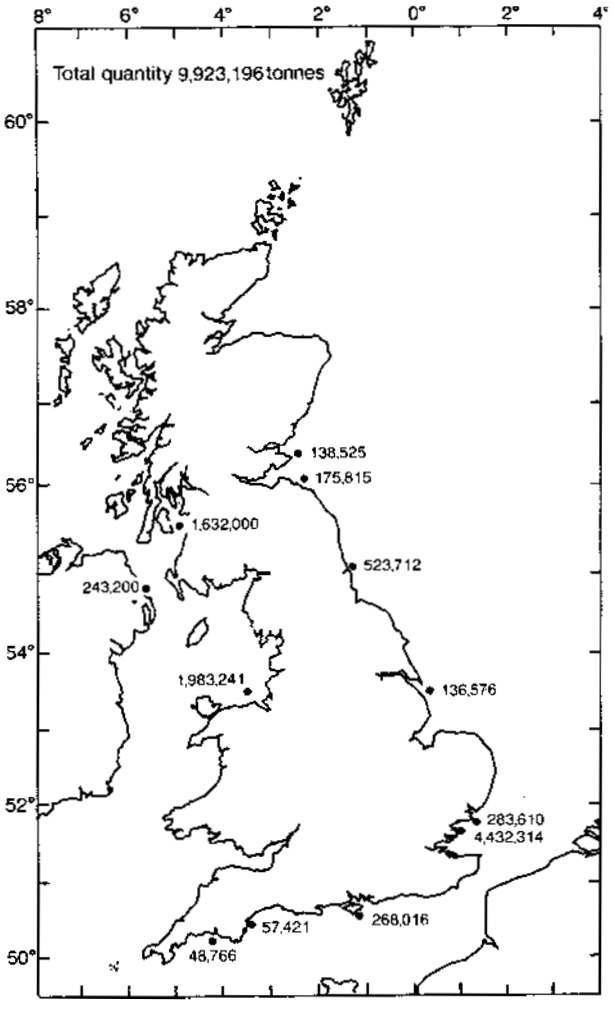


Figure 15. Sewage sludge deposited at sea in 1993

At the 1987 Second International Conference on the Protection of the North Sea, (Department of Environment, 1987), the Government indicated it was taking urgent action to reduce the contamination by persistent, toxic or bioaccumulable materials present in sewage sludge deposited in the North Sea and to ensure that the quantities of such contaminants disposed in the North Sea did not increase above 1987 levels. Earlier reports explained that to apply this control, limits were set for a series of key contaminants deposited under each licence. Table 9 compares the aggregate figures (in tonnes) authorised for disposal in the North Sea in 1993 with the estimated quantity at 1987 licensed levels.

Although the bulk of these contaminants comes from general domestic sources rather than industry, the licence levels for 1993 were below both the 1987 baseline figures and below the 1992 levels.

14.7 Licensing of dredged material disposal

The bulk of the dredged material licensed for disposal at sea is silt and sand, but coarse sand and shingle can occur in 'maintenance' dredging, and shingle, cobbles, rocks and heavy clay can be present in 'capital' material arising, for example, from channel development and deepening. Table 10 shows the numbers of licences issued, the quantity licensed, and the quantity deposited, together with figures for the quantity of a range of trace

Table 9. Contaminants in sewage sludge authorised for disposal in the North Sea in 1993 compared against estimated quantities (tonnes) in 1987

Year	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1987	3.7	56.2	133.6	1.2	19.4	146.4	468.2
1993	2.0	39.3	123.0	1.0	14.9	114.8	295.5

Table 10. Summary of dredged material licensed and deposited at sea in the period 1989-1993

Country	Year	Licences issued	Licensed quantity (t)	Wet tonnage deposited	Quantities of metal contaminants in wastes deposited (t)						
					Cd	Cr	Cu	Hg	Ni	Pb	Zn
England	1989	138	66,408,100	40,810,718	18.6	1,234	1,037	9.3	638	1,877	4,938
and Wales	1990	135	63,983,920	33,728,978	12.2	1,023	834	6.8	484	1,426	3,724
	1991	108	57,782,520	39,886,812	7.4	1,189	773	7.0	518	1,263	3,394
	1992	123	55,741,813	24,243,998	6.0	812	512	4.2	291	876	2,271
	1993	110	66,074,966	26,086,503	7.3	875	606	5.2	458	1,004	2,461
Scotland	1989	27	4,252,950	3,154,756	1.1	106	106	1.3	40	141	313
	1990	21	3,031,960	2,109,114	0.8	67	64	0.8	30	106	207
	1991	26	5,147,245	2,788,611	0.6	70	53	0.6	22	79	167
	1992	35	5,920,005	3,841,296	0.9	108	82	1.7	39	111	245
	1993	26	3,174,050	2,025,525	0.3	55	37	0.8	16	46	103
Northern	1989	6	383,300	338,521	0.1	2	2	0.0	2	2	7
Ireland	1990	6	261,700	317,082	0.1	3	3	0.0	3	5	8
	1991	10	807,400	519,049	0.1	2	2	0.1	3	2	6
	1992	7	2,956,601	891,087	0.3	2	3	0.2	2	3	10
	1993	7	996,500	1,754,228	0.8	8	17	0.4	9	18	53
UK total	1989	171	71,044,350	44,303,995	19.8	1,343	1,145	10.6	679	2,021	5,258
	1990	162	67,277,580	36,155,174	13.2	1,093	900	7.6	518	1,537	3,939
	1991	144	63,737,165	43,194,472	8.1	1,260	828	7.8	543	1,344	3,566
	1992	165	64,618,419	28,976,381	7.2	923	597	6.1	332	990	2,527
	1993	143	70,245,516	29,866,256	8.4	938	661	6.4	483	1,068	2,617

Notes: For information on licensed quantities and tonnages deposited see footnote to Table 7(a)

metals which enter the sea in the dredged materials. As noted in previous reports, a proportion of the trace metals in dredged material is natural and occurs within the mineral structure or is otherwise tightly bound, such that it will not be available to marine organisms. Figure 16 shows the main disposal sites used in 1993 and the quantities deposited at each site.

The previous report drew attention to the fact that all applicants for licences are now required to consider in greater detail, alternative disposal options including beneficial uses for dredged material. During the year considerable work was undertaken to establish beneficial uses for dredgings arising from the deepening of the approach channel at Harwich.

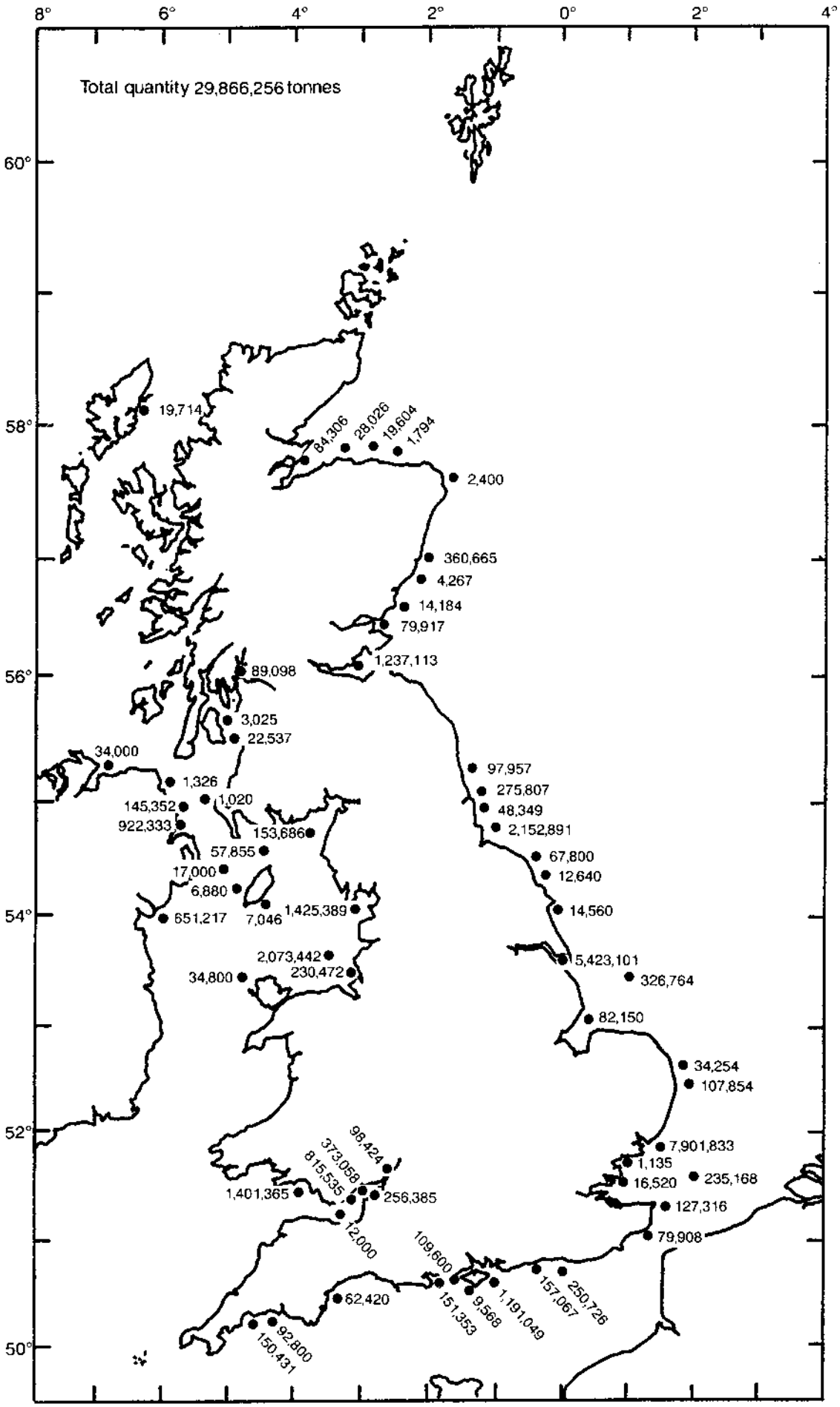


Figure 16. Dredged material deposited at sea in 1993

Table 11. Other categories of licence issued in 1993

Licence	England and Wales	Scotland	Northern Ireland	Total
Construction-new and renewal	208	73	8	289
Tracers, biocides, etc.	21	1	0	22
Burial at sea	11	1	0	12

14.8 Other materials deposited at sea

Under Part II of FEPA, licences are also required for certain activities other than for the disposal of wastes, but nevertheless involving the deliberate deposit of articles or substances in the sea. The majority of such cases relate to construction works below mean high water. Each licence application is carefully considered, in particular, to assess the impact upon tidal and intertidal habitat, hydrological effects and potential interference to others.

Further activities involved the use of tracers, the application of biocides and burials at sea. Generally, the anticipated environmental impact from contaminants is minimal and little or no monitoring is required. Table 11 shows the numbers of such licences issued in 1993.

15. ADVICE ON FISHERY IMPLICATIONS OF PIPELINE DISCHARGES

This section gives a brief summary of activities carried out during 1993 in connection with the provision of advice on fishery implications of pipeline discharges. The background to this work in relation to MAFF's responsibilities as a statutory consultee under the Water Resources Act 1991 (Great Britain - Parliament, 1991), is described in previous reports in this series (MAFF, 1991, 1992(a), 1993(a) and 1994).

Table 12 shows the number of applications for each type of effluent sent to MAFF for comment during 1993.

As in previous years, the majority of the applications received during 1993 were for sewage discharges. About 25% of these were in connection with major resewerage schemes; the remainder were mainly for positive determination of 'deemed' consents for existing discharges. Since many of the 'deemed' consents related to discharges which were scheduled for replacement or upgrading within a few years, advice was mainly aimed at preventing any deterioration during the interim period and, if necessary, making recommendations about the longer term requirements. Those discharges which were not due to be replaced were generally very small and, unless they were suspected of causing problems for fisheries in the past, were accepted without comment from MAFF.

Discharges of domestic sewage to coastal waters pose few problems for species other than bivalve shellfish, unless they contain persistent plastics or other material which could foul fishing gear. These should be significantly reduced once upgrading is complete of all major discharges in order to comply with the requirements of Directive 91/271 concerning urban waste water treatment (European Communities, 1991(a)).

EC Directive 91/492 laying down the health conditions for the production and the placing on the market of live bivalve molluscs (European Communities, 1991(b)) took effect on 1 January 1993. This Directive on shellfish hygiene requires member states to classify all commercially harvested beds of bivalve molluscs according to levels of microbiological contamination in the shellfish flesh. The degree of contamination determines whether the shellfish may be marketed without treatment (Category A), or whether they must be purified (Category B), or relaid in cleaner water then purified or heat treated by an approved process (Category C) before sale. The classification of each bed is determined by MAFF's Fish Diseases Laboratory at Weymouth following an assessment of data collected throughout the year by 'local food authorities'.

Table 12. Discharge consent applications assessed by MAFF during 1993

Sewage (including storm and emergency overflows)	Trade effluent	Surface water	Total
492	42	45	579

In 1993, 67% of the beds were classified as Category A or B; the remainder were Category C or unclassified (i.e. harvesting prohibited). It is likely that many of the Category C beds, as well as those from which harvesting is prohibited, will no longer be viable because of practical difficulties with relaying of shellfish in clean areas. MAFF's main aim in advising on sewage discharges in these areas, has therefore been to press for improvements which will achieve a minimum of Category B as soon as possible.

Many of the shellfish beds are in areas where major resewerage schemes are either underway, or are at the planning stage. These schemes are targeted at meeting statutory obligations, of which the most significant are EC Directive 76/160 concerning the quality of bathing water (European Communities, 1976) and EC Directive 91/271 concerning urban waste water treatment (European Communities, 1991(a)). However, the Directive on shellfish hygiene does not place a statutory obligation on Member States to maintain a particular quality of shellfish harvesting area, it merely requires that shellfish undergo the level of treatment before sale which is appropriate to the classification of the bed. The Water Companies are therefore under no obligation to design or modify a scheme for the sole purpose of reducing contamination of shellfish by sewage micro-organisms. Improvements in shellfish classifications are therefore only likely to be achieved where a scheme is being designed for other purposes, and where the specific requirements of shellfish water quality can be accommodated at no extra cost.

Throughout the year, MAFF has used its role as statutory consultee to try and negotiate the best possible advantage for shellfisheries in the design of such schemes (e.g. increased level of treatment, better outfall location or lower storm overflow frequency). However, the absence of a statutory requirement for Water Companies to take account of shellfish needs has made it increasingly difficult to achieve significant changes. In the early part of the year, MAFF therefore instigated discussions with the National Rivers Authority Head Office and DoE in an attempt to improve this situation, and to define national policy with regard to sewage discharges to shellfish areas.

All of the applications for major trade effluent discharges received during 1993 were for determination of 'deemed' consents for existing discharges. Many of these included proposals for significant reductions in inputs of hazardous materials, either immediately, or as a result of phased improvements, and required no comment from MAFF on fishery implications. However, a small number of effluents was identified as containing materials which are of particular concern to fisheries, such as tributyltin (TBT). In such cases, recommendations were made for tighter consent limits, phased reductions in loads discharged, or incorporation of a toxicity condition in the consent.

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ANNEX 1. Areas of monitoring mentioned in the text and staff responsible for the projects

BIOTA

Contaminants in marine fish and shellfish	A Franklin J Jones
Bioassay techniques	J E Thain Y Allen M Kirby
Epifauna	H L Rees M Pendle
Contaminants in marine mammals	R J Law

SEA WATER

Triazine herbicides	C R Allchin
Hexachlorocyclohexanes	C R Allchin
Volatile organic compounds	M J Waldock
Hydrocarbons	R J Law
Polycyclic aromatic hydrocarbons	R J Law
Surfactants	M Blackburn

SEDIMENTS

Metals	S Rowlatt D Lovell

FRESHWATER

Pesticides	P Matthiessen R Rycroft

DISPOSAL AT SEA: ENVIRONMENTAL ASSESSMENT STUDIES

Sewage sludge disposal sites	H L Rees S M Rowlatt

DEPOSITS IN THE SEA: LICENSING AND RELATED ACTIVITIES

Licensing	G Boyes C M G Vivian
Pipeline discharges	F L Franklin

ANNEX 2. Standards/guidelines for contaminants in fish and shellfish

A2.1 Metals

(a) Mercury

The European and Paris Commissions have adopted an Environmental Quality Standard (EQS) for mercury, which requires that the mean concentration of mercury in the flesh of a representative sample of fish, locally caught from areas receiving significant inputs of mercury, shall not exceed 0.3 mg kg^{-1} on a wet weight basis (EC Directive Nos. 82/176 and 84/156 - European Communities, 1982 and 1984).

Community Decision 93/351 EEC (European Communities, 1993) applies to samples of fishery products. This states that the mean total mercury content of the edible parts of fishery products must not exceed 0.5 mg kg^{-1} fresh weight, increased to 1.0 mg kg^{-1} fresh weight for some species listed in an annex.

For the purposes of the Joint Monitoring Programme (JMP) of the Oslo and Paris Commissions, the following arbitrary, purely descriptive, guidelines have been adopted.

Level	Fish flesh and crustaceans	Molluscs
Lower	<0.1 mg kg^{-1} wet weight	<0.6 mg kg^{-1} dry weight
Medium	0.1-0.3 mg kg^{-1} wet weight	0.6-1.0 mg kg^{-1} dry weight
Upper	>0.3 mg kg^{-1} wet weight	>1.0 mg kg^{-1} dry weight

(b) Cadmium

There are no standards or guidelines in England and Wales for fish flesh. The expected values are <0.2 mg kg^{-1} wet weight.

The JMP guidelines for cadmium in mussels are as follows:

Level	Mussel tissue	Approximate equivalent
Lower	<2 mg kg^{-1} dry weight	(<0.4 mg kg^{-1} wet weight)
Medium	2-5 mg kg^{-1} dry weight	(0.4-1.0 mg kg^{-1} wet weight)
Upper	>5 mg kg^{-1} dry weight	(>1.0 mg kg^{-1} wet weight)

From past DFR work, 'expected' values (i.e. using data from estuaries not known to be severely contaminated) would be up to 0.3 mg kg^{-1} wet weight for crustaceans but up to 10 mg kg^{-1} wet weight for crab 'brown' meat.

(c) Lead

From the Lead in Food Regulations 1979 (Great Britain - Parliament, 1979): lead in fish should not exceed 2.0 mg kg^{-1} wet weight, and lead in shellfish 10.0 mg kg^{-1} wet weight.

From past work, 'expected' values are 0.2-0.3 mg kg^{-1} wet weight in fish, up to 1.0 mg kg^{-1} wet weight in crustaceans, and up to 4.0 mg kg^{-1} wet weight in some molluscs.

(d) Copper

From the Food Standards Committee's Report on Copper (MAFF, 1956), revised recommendations for limits for copper content of food are as follows:

> 'levels of copper in food should not exceed 20 mg kg^{-1} wet weight (but higher levels in shellfish are permitted if copper is of natural occurrence).'

From past DFR work, 'expected' levels in fish are up to 0.6 mg kg^{-1} wet weight (in excess of 1.0 mg kg^{-1} wet weight in fatty fish such as herring) up to 5.0 mg kg^{-1} wet weight for molluscs (with very much higher values for some gastropods) and 20-30 mg kg^{-1} wet weight for crustaceans.

(e) Zinc

From the Food Standards Committee's Report on Zinc (Ministry of Food, 1953), as a guideline:

> 'levels of zinc in food should not exceed 50 mg kg^{-1} wet weight (but higher levels are permitted in food which naturally contain more than 50 mg kg^{-1}, such as herring and shellfish).'

'Expected' values commonly found are up to 6.0 mg kg^{-1} wet weight in most fish flesh, (though up to 10 mg kg^{-1} in flounder and considerably more in fatty fish), up to 100 mg kg^{-1} wet weight in crustaceans and well in excess of 100 mg kg^{-1} wet weight for some molluscs.

A2.2 Pesticides/PCBs

There are no standards in fish and shellfish from England and Wales.

(a) HCB

The 'expected' value is up to 0.10 mg kg^{-1} wet weight in fish liver.

(b) HCH

Codex Alimentarius Commission's maximum residue limit (MRL) (FAO/WHO, 1987) is 2 mg kg^{-1} in meat fat for g-HCH. The 'expected' values are up to 0.05 mg kg^{-1} wet weight for each of a- and g-HCH in fish liver.

(c) Dieldrin

Codex Alimentarius Commission's MRL is 0.2 mg kg^{-1} in meat fat. The 'expected' values are 0.2-0.3 mg kg^{-1} wet weight in fish liver.

(d) Total DDT

Codex Alimentarius Commission's MRL is 5 mg kg^{-1} in meat fat. The 'expected' values are up to 0.5 mg kg^{-1} wet weight for each of DDE, TDE and pp DDT in fish liver.

(e) PCBs

JMP guidelines are as follows (all mg kg^{-1} wet weight):

Level	Fish muscle	Cod[1] liver	Flounder[2] liver	Molluscs	Crustaceans
Lower	<0.01	<2.0	<0.50	<0.02	<0.01
Medium	0.01-0.05	2.0-5.0	0.50-1.0	0.02-0.10	0.01-0.05
Upper	>0.05	>5.0	>1.0	>0.10	>0.05

[1] *Values used for all roundfish in this report*

[2] *Values used for all flatfish in this report*

A2.3 References

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APPENDICES

These appendices contain the raw data associated with the work carried out by the Burnham-on-Crouch Laboratory in 1993. Although not all of the data are referred to in the report, they are included here for completeness.

Appendix 1. Concentrations of metals in bulked fish muscle for non-core species

Species/Area	Date collected	Number of fish	Mean length (cm)	Mean concentration (mg kg^{-1} wet weight)			Dry weight (%)
				Hg	Cu	Zn	
Bass							
Southampton Water	Sep-93	5	37.0	0.22	0.25	4.0	24
Black bream							
Lyme Bay	Oct-90	25	18.2	0.06	0.35	3.7	24
Brill							
Outer Humber	Feb-91	8	26.0	0.03	0.28	5.0	20
Dover sole							
Off Hull	Jun-92	25	22.8	0.06	0.35	4.6	21
Thames	Jan-92	7	28.6	0.08	0.13	4.4	22
Rye Bay	Oct-90	25	26.3	0.08	0.20	4.5	22
Liverpool Bay	Mar-93	7	27.5	0.07	0.20	3.7	20
Morecambe Bay	Oct-92	20	24.3	0.10	0.33	3.5	22
Hake							
Off Plymouth	Oct-91	11	37.7	0.02	4.8	3.2	21
Sole Bank	Mar-93	25	21.8	0.02	0.18	3.3	20
Celtic Sea	Mar-93	25	24.1	0.01	0.13	3.0	19
Bristol Channel	Oct-91	24	29.5	<0.01	0.15	2.8	20
Cardigan Bay	Oct-91	8	36.2	0.02	7.5	3.6	21
Lemon sole							
Lyme Bay	Jan-92	21	25.4	0.05	0.18	3.0	21
Off Portland	Jan-92	10	32.0	0.03	<0.09	2.7	22
Monkfish							
Celtic Deep	Aug-93	-	-	0.06	0.17	4.3	17
Plaice							
Tyne	Feb-94	25	26.7	0.03	0.15	4.1	18
Thames	Jan-92	9	26.7	0.06	<0.09	3.8	19
Rye Bay	Jul-92	21	31.4	0.07	0.14	6.0	23
Liverpool Bay	Mar-93	25	27.5	0.13	0.18	4.0	17
Morecambe Bay	Oct-92	24	26.4	0.08	0.28	6.0	22
Red gurnard							
Off Plymouth	Oct-93	7	19.4	0.02	0.24	3.8	23
Cardigan Bay	Oct-93	10	27.1	0.07	0.21	3.8	25
Liverpool Bay	Oct-93	25	21.0	0.12	0.20	3.7	25
Red mullet							
Thames	Jun-90	10	17.4	0.08	0.29	3.5	23
Off Brighton	Oct-91	20	25.1	0.10	0.23	3.3	27
SE of Start	Oct-91	11	26.0	0.15	0.26	2.4	29
Scad							
Offshore Lyme Bay	Oct-90	24	24.7	0.04	0.50	3.1	27
Inshore Cardigan Bay	Oct-91	25	27.8	0.05	0.66	3.6	24
Thornback ray							
Off Southwold	Oct-90	6	55.3	0.11	0.33	4.6	22
Thames	Oct-92	2	77.8	0.05	0.48	4.4	23
Rye Bay	Oct-90	6	32.3	0.07	0.43	4.8	23
Lyme Bay	Oct-90	12	-	0.10	0.30	3.2	24

Note: Mean concentration = mean of duplicate bulked analyses

Appendix 2. Organchlorine pesticide residues and PCBs in bulked fish muscle

Area	Species	Date caught	Number of fish	Mean length (cm)	Mean concentration (mg kg^{-1} wet weight)								Lipid (%)
					HCB	a - HCH	g - HCH	Dieldrin	ppDDE	ppTDE	ppDDT	PCB	
Humber	Cod	Jun-92	25	23.4	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<1
	Whiting	Jun-92	18	22.3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<1
Thames	Whiting	Nov-92	25	32.6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<1
Liverpool Bay	Whiting	Apr-92	25	32.1	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.012	<1
	Dab	Apr-92	25	22.7	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.024	<1
	Flounder	Mar-92	25	28.6	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.019	<1
Morecambe Bay	Dab	Oct-92	14	28.9	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.025	1

Appendix 3. Concentrations of metals in non-core species of shellfish

Species/Area	Date collected	Number of shellfish	Mean length (cm)	Tissue	Mean concentration (mg kg^{-1} wet weight)					Dry weight (%)
					Hg	Cu	Zn	Cd	Pb	
MOLLUSCS										
Clams										
Swale (*Venerupis*)	Aug-93	26	3.7	W	0.03	2.0	22	0.17	<0.6	14
Southampton (*Mercenaria*)	Nov-85	10	8.9	W	<0.01	5.3	41	0.10	1.2	18
Poole Harbour (*Venerupis*)	Jul-92	20	5.0	W	<0.01	1.6	16	<0.06	<0.6	20
Queens										
Off Humber	Oct-93	12	7.8	M	<0.01	0.50	25	0.11	0.38	21
				G	0.01	1.8	21	0.17	0.31	16
Offshore Portland	Jan-92	40	5.7	M	0.02	1.2	47	0.19	<0.7	21
				G	0.02	2.0	57	0.41	<0.7	16
Bristol Channel	Oct-91	20	5.4	M	<0.01	0.92	50	0.17	1.1	22
Cardigan Bay	Oct-93	12	7.7	M	0.01	2.0	40	0.16	0.70	24
				G	0.01	-	46	0.50	0.93	14
Liverpool Bay	Oct-91	20	5.1	M	<0.01	2.3	53	0.19	1.0	22
				G	0.01	2.4	56	0.41	1.3	13
Scallops										
Plymouth	Oct-93	12	9.8	M	<0.01	0.33	43	0.27	0.57	22
				G	<0.01	3.2	32	0.11	0.43	15
Fowey	Jul-91	10	11.1	M	0.02	0.26	17	0.35	<0.7	18
				G	0.02	1.6	28	0.21	<0.7	8
South of Isle of Man	Nov-87	10	13.3	M	0.02	0.31	18	0.47	<0.6	25
				G	0.03	2.0	39	0.42	<0.6	16
Brixham	Aug-87	10	11.7	M	0.02	0.34	55	0.68	<0.6	23
				G	0.03	4.4	75	1.1	<0.6	21
Whelks										
Off Tees	Oct-93	12	12.1	W	0.10	139	493	2.9	0.94	24
Outer Silver Pit	Mar-92	12	10.9	W	0.10	19	122	0.90	<0.9	19
Bristol Channel	Oct-91	12	9.4	W	0.10	22	104	2.0	<0.7	26
Anglesey	Sep-94	10	8.9	M	0.07	19	18	0.07	0.04	25
				G+V	0.17	162	285	2.2	0.34	27
Liverpool Bay	Sep-89	10	8.9	W	0.31	27	395	1.9	<0.6	26
Winkles										
River Tees	May-94	50	-	W	0.03	17	15	0.05	0.71	17
Lynmouth	Jun-90	50	2.2	W	0.07	15	12	0.22	0.7	18
Hinkley Point	Aug-87	47	1.5	W	0.07	2.1	32	6.1	0.77	29
Parton	Sep-90	25	2.4	W	0.05	36	27	3.3	0.96	23
CRUSTACEA										
Lobster										
Seaham	Sep-87	5	26.1	C	0.07	23	41	<0.03	<0.6	18
				T	0.19	14	16	0.11	<0.6	23
Whitby	Sep-87	5	26.6	C	0.11	18	34	<0.06	<0.6	15
				T	0.27	9.2	15	<0.06	<0.6	22
Plymouth	Sep-87	3	35.1	C	0.18	24	50	<0.03	<0.6	26
				T	0.36	11	17	<0.03	<0.6	25
Brixham	Aug-87	5	31.3	C	0.27	21	42	<0.08	<0.6	18
				T	0.33	8.4	15	<0.06	<0.6	25
Llewyn Peninsula	Jul-87	5	26.8	C	0.12	25	43	<0.06	<0.6	18
Nephrops										
Blyth	Dec-91	25	9.8	T	<0.01	6.7	12	<0.07	<0.7	23
Tyne	Oct-93	25	11.6	T	0.13	6.9	15	0.04	<0.6	21
Bristol Channel	Oct-91	25	10.2	T	0.04	7.0	13	0.04	<0.6	22
Off Tees	Nov-86	21	15.1	T	0.14	11	17	<0.07	<0.6	29
Shrimp (brown)										
Humber	Aug-89	50	-	W	0.02	8.5	18	0.06	0.23	26
Liverpool Bay	Sep-89	50	-	W	0.06	6.8	14	0.06	<0.6	23
Shrimp (pink)										
Tyne	Jun-87	30	-	W	0.07	8.9	16	0.09	<0.6	26
Bristol Channel	Oct-91	50	-	W	0.02	7.6	14	<0.06	<0.1	29
Inshore Cardigan Bay	Oct-91	50	-	W	<0.01	9.3	14	<0.06	<0.1	29
Spider Crab										
Brixham	Aug-87	5	13.2	C	0.09	8.1	55	<0.06	0.7	18
				B	0.09	44	40	1.9	<0.5	24
Newlyn	Jul-87	5	15.0	C	0.10	13	79	<0.06	<0.6	21
				B	0.07	120	52	2.1	<0.6	21
St Ives	Jul-87	5	16.3	C	0.05	13	68	0.09	<0.6	21
				B	0.07	61	41	2.4	<0.6	23
Padstow	Jul-87	5	14.8	C	0.08	22	83	<0.06	<0.6	26
				B	0.06	130	39	2.0	<0.6	19
Milford Haven	Jul-87	5	16.5	C	0.1	10	92	<0.06	<0.6	24
				B	0.08	174	72	2.9	<0.6	20

Appendix 4. CIROLANA 6/93: 10 day sediment bioassays using the lugworm Arenicola marina and Corophium volutator

Station No.	Location	*Arenicola*		*Corophium*		
		% mortality	Total casts in 10 days	% mortality		
		Test 1		**Test 1**	**Test 2**	**Test 3**
Control	Shoebury Sand	0	38	20		
1	Tweed (anchor)	0	47	13		
2	Tweed (buoy off Spittal Point)	7	35	30		
3	Tweed (Berwick/Tweed Bridges)	0	25*	13		
5	Blyth (South Harbour Entrance)	7	30	23		
6	Blyth (North Blyth)	7	35	13		
7	Off Tyne	13	28*	10		
8	Tyne (anchor)	0	28*	20		
9	Off Tyne/Tees	13	40	30		
10	Dogger Bank	0	40	15		
11	North of Freisland Junction	0	31	10		
12	Of Humber/Wash	0	37	10		
13	Off Tees	0	32	0		
14	Tyne (anchor)	13	29	13		
15	Tyne (Lloyd's hailing station)	0	41	27		
16	Tyne (Hebburn)	7	23*	10		
17	Wear (anchor)	0	28*	7		
18	Wear (Sandy Point)	13	18*	13		
19	Wear (Queen Alexandra Bridge)	100	2*	3		
21	Tees (Redcar jetty)	100	0*	100**		
22	Tees (Victoria Bridge)	0	30	27		
		Test 2				
Control	Shoebury Sand	0	39	20	43	
25	Southern Bight (Smiths Knoll)	0	16*		43	
26	Thames (Outer Gabbard)	0	7*		40	
27	Thames (Warp)	0	44		33	
28	South Varne	0	18*		47	
S1	Wash (Ouse, Stowe Bridge)	0	41	0		
S2	Wash (Ouse, Freebridge)	20	17*	0		
S3	Wash (Ouse, The Point)	0	39	3		
S4	Humber (Spurn Head)	0	18*	13		
S5	Humber (North Killingholme)	0	28*	0		
S8	S'hampton Water (Dock Head)	0	30		13	
S9	S'hampton Water (E. Bramble buoy)	0	0*		47	
S10	S'hampton Water (Hook buoy)	0	48	23		
		Test 3				
Control	Shoebury Sand	0	50			10
34	Poole Harbour: Holes Bay	0	39*			13
35	Poole Harbour: Brownsea buoy	0	33*			13
60	Burbo Bight	0	49			13
62	Mersey (Seacombe Ferry)	13	47			0
63	Mersey (Tranmere oil terminal)	0	51			7
66	Liverpool Bay	0	56			23
94	River Tees: No 8 buoy	0	34*			37
96	River Tees: ICI No 4 buoy	33	0*			93**
97	River Tees: No 25 buoy	0	37*			23

Note: Comparisons significantly different from control casting at the 0.05 level (Dunnetts t-test) are indicated by ''*
*Corophium mortality significantly different from control (ANOVA, $p<0.05$) indicated by '**'*
See Appendix 8 for station details

Appendix 5. Toxicity results of liquid/liquid extracts to T. battagliai

Location	LC50 (95% confidence limits)			
	June 1993		October 1993	
	24 hr	48 hr	24 hr	48 hr
Tyne - (anchor high tide)	850 (669-1080)	660 (537-812)		
Off Tyne/Tees	>1000	450 (331-612)		
Dogger Bank	800 (661-968)	610 (504-738)		
Off Humber/Wash	800 (661-968)	485 (357-660)		
Off Tees	850 (691-1046)	570 (487-667)		
Blyth			260 (191-354)	198 (141-277)
Blyth (South Harbour)			590 (468-743)	247 (170-358)
Blyth (North Harbour)			515 (454-585)	300 (248-363)
Tyne (anchor)	610 (521-714)	400 (345-548)	380 (319-452)	284 (183-440)
Tyne (Hebburn)	520 (377-718)	190 (143-253)	315 (232-428)	164 (122-220)
Tyne (North Shields)			415 (288-598)	148 (117-188)
Wear (anchor)	620 (500-769)	320 (267-384)	165 (125-218)	108 (74-157)
Wear (Q. Alexandra Bridge)	56 (40-79)	16 (10-25)	102 (74-141)	31 (19-50)
Wear (Sandy Point)			135 (98-186)	51 (29-90)
Tees (anchor)	310 (248-388)	215 (178-260)	73 (57-93)	46 (36-59)
Tees (Victoria Bridge)	210 (176-250)	140 (104-189)	78 (50-122)	27 (17-42)
Tees (Redcar jetty)			<10	<10
Tees (ICI No. 4 Buoy)	98 (68-145)	50 (38-66)		
Off Humber	710 (587-859)	515 (460-577)		
Off Wash	460 (333-581)	345 (288-414)		
Southern Bight (Smiths Knoll)	560 (418-750)	360 (286-454)		
Thames (Outer Gabbard)	920 (742-1141)	560 (361-868)		
Thames (Warp)	>1000	540 (397-734)		
South Varne	>1000	760 (538-1131)		
Off Selsey Bill	>1000	>1000		
Southampton Water (Netley Buoy)			413 (325-525)	180 (144-225)
Southampton Water (Cadland Buoy)			260 (193-351)	125 (91-173)
Solent			465 (358-605)	148 (108-203)
Poole Harbour (anchor)	>1000	440 (345-561)	395 (260-600)	200 (126-318)
Poole Harbour (Holes Bay)	190 (135-268)	100 (72-139)	295 (230-378)	114 (84-155)
Poole Harbour (Brownsea Buoy)	500 (318-785)	270 (179-408)	295 (197-443)	103 (71-150)
Central Channel	415 (335-515)	300 (244-369)		
Plymouth Sound (anchor)	250 (221-283)	190 (160-226)		
Tamar (Hamoaze)	350 (267-459)	200 (152-264)		
Western Approaches	>1000	950 (586-1539)		
Celtic Deep	>1000	850 (556-1301)		
New Quay	>1000	740 (630-893)		
Cardigan Bay	>1000	860 (782-946)		
Off Cardigan Bay	930 (838-1032)	830 (680-1013)		
Burbo Bight	795 (636-994)	340 (291-398)	740 (583-940)	210 (153-288)
Mersey (Tranmere Oil Terminal)	140 (114-172)	85 (70-103)	182 (149-222)	115 (77-171)
Mersey (Eastham Lock)	190 (160-225)	105 (89-124)	124 (91-169)	84 (66-107)
Mersey (Canada Buoy)			320 (254-403)	141 (114-175)
Ribble (anchor)	850 (654-1105)	425 (343-527)		
Dee (anchor)	800 (611-1048)	500 (368-680)		
Dee (No. 2 Buoy)	500 (382-655)	280 (178-440)		
Irish Sea	>1000	850 (594-1216)		
Morecambe Bay (anchor)	580 (443-760)	470 (362-611)		
River Lune (No. 1 Buoy)	>1000	550 (423-715)		

Note: All LC50 figures are quoted as concentration factors. All samples were taken at low tide unless otherwise stated
See Appendix 8 for station details

Appendix 6. Maximum concentrations (mg kg^{-1} wet weight) of seven trace metals in marine mammal livers, with species and locations of strandings

Metal	Reference no.	Species	Location	Concentration
Cr	SW1991/55	PW	Redcar, NE England	5.6
	SW1991/17	HP	Joss Bay, SE England	4.4
	SW1991/11	SD	Mill Haven, West Wales	3.7
	SW1991/9	WSD	Saunton Sands, SW England	2.8
	SW1991/2	MW	Carmarthen Bay, South Wales	2.1
Ni	LAW-32	GS	New Quay, West Wales	2.1
	IC1991/1	CD	Porthcawl, South Wales	1.2
	SW1991/2	MW	Carmarthen Bay, South Wales	1.2
	LAW-34	GS	Llandudno, North Wales	1.2
	SW1991/55	PW	Redcar, NE England	1.1
	SW1990/100	HP	Shell Island, North Wales	1.1
Cu	LAW-03	HP	Islay, NW Scotland	160
	LAW-04	HP	Debyhaven Bay, Isle of Man	120
	SW1990/88	CD	Truro, SW England	81
	LAW-18	HP	South Wales	79
	SW1991/59	HP	Gorleston, E England	76
Zn	SW1991/115	BD	Beaumaris, North Wales	268
	SW1991/120	HP	Burry Port, South Wales	181
	SW1991/14	HP	Wherrytown, SW England	174
	SMRU91-16	HP	Port Erin, Isle of Man	162
	SW1990/65	HP	Aberdyfi, West Wales	150
Cd	SW1991/55	PW	Redcar, NE England	65
	SW1990/20	SD	Aberystwyth, West Wales	11
	SW1990/47	CD	Wapping, East London	9.0
	SW1990/4	SD	Carmarthen Bay, South Wales	8.4
	SW1991/137	CD	Aberavon Sands, South Wales	6.5
Hg	LAW-26	GS	West Kirby, Merseyside	430
	LAW-29	GS	Mostyn, North Wales	370
	SS1991/41	GS	Hoylake, Merseyside	301
	LAW-39	GS	West Kirby, Merseyside	280
	LAW-38	GS	Port Erin, Isle of Man	220
Pb	LAW-38	GS	Port Erin, Isle of Man	7.0
	SW1989/43a	HP	Hoylake, Merseyside	4.3
	SW1989/49	WBD	West Kirby, Merseyside	3.8
	SS1991/23	GS	Blackpool, NW England	1.9
	LAW-28	GS	West Kirby, Merseyside	1.8

Note:

GS	*Grey Seal*	*Halichoerus grypus*
HP	*Harbour porpoise*	*Phocoena phocoena*
CD	*Common dolphin*	*Delphinus delphis*
BD	*Bottlenose dolphin*	*Tursiops truncatus*
SD	*Striped dolphin*	*Stenella coeruleoalba*
WSD	*White-sided dolphin*	*Lagenorhyncus acutus*
WBD	*White-beaked dolphin*	*Lagenorhyncus albirostris*
PW	*Long-finned pilot whale*	*Globicephala melas*
MW	*Minke whale*	*Balaenoptera acutorostrata*

Appendix 7. Maximum concentration (as sum of ICES 7 CBs; mg kg^{-1} wet weight) of chlorobiphenyls in marine mammal blubber, with species and location of stranding

Reference number	Species	Location	ICES7
SW1991/42	BD	Borth, West Wales	72.1
SW1991/136	HP	Cardigan Island, West Wales	52.9
SW1991/14	HP	Wherrytown, SW England	52.7
SW1990/68	CD	Stoke Beach, SW England	49.0
SW1990/78	CD	Seaton Beach, SW England	46.6
SW1990/96	HP	Penzance, SW England	43.7
SW1990/97	CD	Porthmeor, SW England	43.4
SMRU90-55	HP	River Blackwater, SE England	43.3
SW1992/1	CD	Looe Beach, SW England	41.6
SW1991/120	HP	Burry Port, South Wales	38.2
SW1991/10	CD	Harlech, North Wales	36.0
SW1991/112	HP	Hornsea, NE England	32.9
SW1991/104	HP	Hornsea, NE England	32.5
SW1991/23	HP	Bridlington, NE England	30.0
SW1990/103	CD	Eastbourne, S England	29.2
SW1990/88a	PW	Maenporth, SW England	29.1
SW1990/77b	HP	Llanelli, South Wales	27.9
SW1992/3	CD	Porthleven, SW England	27.8
IC1990/4	HP	Caenarvon, North Wales	26.9
SW1991/17	HP	Joss Bay, SE England	24.2

Note: species as in Appendix 6

Appendix 8. Stations sampled during CIROLANA 6, 9 June-1 July 1993

Station	Date	Position	Location	NMP
1	10-Jun	55° 45.79' N 1° 57.83' N	Tweed (anchor)	
2	10-Jun	55° 45.83' N 1° 59.58' W	Tweed (buoy off Spittal Point)	
3	10-Jun	55° 46.12' N 2° 00.35' W	Tweed (Berwick/Tweed Bridges)	
4	11-Jun	55° 07.17' N 1° 27.79' W	Blyth (anchor)	
5	11-Jun	55° 07.30' N 1° 29.7' W	Blyth (South Harbour entrance)	
6	11-Jun	55° 08.10' N 1° 30.75' W	Blyth (North Blyth)	
7	11-Jun	55° 00.45' N 1° 08.10' W	Off Tyne	245
8	12-Jun	55° 01.25' N 1° 23.62' W	Tyne (anchor)	
9	12-Jun	54° 50.06' N 1° 19.91' E	Off Tyne/Tees	285
10	13-Jun	55° 10.23' N 3° 09.50' E	Dogger Bank	
11	13-Jun	54° 08.61' N 4° 20.16' E	North of Friesland Junction	
12	13-Jun	54° 00.02' N 1° 59.77' E	Off Humber/Wash	345
13	14-Jun	54° 44.06' N 0° 53.04' W	Off Tees	295
14	14-Jun	55° 01.79' N 1° 22.35' W	Tyne (anchor)	
15	14-Jun	55° 00.47' N 1° 25.84' W	Tyne (Lloyd's hailing station)	235
16	14-Jun	54° 59.09' N 1° 31.49' W	Tyne (Hebburn)	225
17	14-Jun	54° 56.23' N 1° 19.77' W	Wear (anchor)	
18	14-Jun	54° 55.05' N 1° 21.43' W	Wear (Sandy Point)	275
19	14-Jun	54° 54.80' N 1° 24.24' W	Wear (Queen Alexandra Bridge)	265
20	15-Jun	54° 41.65' N 1° 08.03' W	Tees (anchor)	
21	15-Jun	54° 37.40' N 1° 09.34' W	Tees (Redcar jetty)	325
22	15-Jun	54° 33.52' N 1° 18.33' W	Tees (Victoria Bridge)	315
23	15-Jun	52° 31.97' N 0° 19.95' E	Humber	375
24	15-Jun	53° 03.96' N 0° 29.35' E	Wash	385
25	16-Jun	52° 49.90' N 2° 50.16' E	Southern Bight (Smiths Knoll)	395
26	16-Jun	52° 00.13' N 2° 19.92' E	Thames (Outer Gabbard)	475
27	16-Jun	51° 30.87' N 0° 58.09' E	Thames (Warp)	465
28	17-Jun	50° 56.01' N 1° 16.77' E	South Varne	485
29	17-Jun	50° 45.03' N 0° 10.07' W	Perintis 1	
30	17-Jun	50° 39.98' N 0° 29.98' W	Perintis 2	
31	17-Jun	50° 39.01' N 0° 50.41' W	Selsey Bill/Perintis 3	495
32	17-Jun	50° 30.02' N 1° 30.05' W	Perintis 4	
33	17-Jun	50° 38.50' N 1° 52.83' W	Poole Harbour (anchor)	
34	17-Jun	50° 43.30' N 1° 59.93' W	Poole Harbour: Holes Bay (Cobb's Quay)	
35	17-Jun	50° 41.15' N 1° 57.35' W	Poole Harbour: Brownsea buoy (no. 42)	
36	17-Jun	50° 30.02' N 1° 59.96' W	Perintis 5	
37	17-Jun	50° 30.01' N 2° 39.95' W	Perintis 6	
38	18-Jun	50° 04.57' N 3° 00.32' W	Central Channel/Perintis 7	535
39	18-Jun	50° 20.75' N 4° 08.86' W	Plymouth Sound (anchor)	
40	18-Jun	50° 25.20' N 4° 11.98' W	Tamar (South Tamar buoy)	
41	18-Jun	50° 22.93' N 4° 11.60' W	Tamar (Hamoaze)	565
42	18-Jun	50° 01.94' N 4° 21.90' W	Off Plymouth Sound (MBA station E1)/Perintis 8	585
43	18-Jun	49° 35.07' N 5° 15.20' W	Perintis 9	
44	19-Jun	49° 09.98' N 6° 09.98' W	Perintis 10	
45	19-Jun	48° 49.88' N 7° 05.06' W	Perintis 11	
46	19-Jun	48° 30.01' N 8° 00.05' W	Western Approaches	595
47	20-Jun	51° 14.80' N 5° 59.90' W	Celtic Deep	605
48	20-Jun	51° 15.31' N 6° 00.09' W	Celtic Deep	605
49	20-Jun	51° 15.21' N 6° 00.50' W	Celtic Deep	605
50	20-Jun	51° 15.00' N 6° 00.35' W	Celtic Deep	605
51	20-Jun	51° 14.80' N 6° 00.33' W	Celtic Deep	605
52	20-Jun	51° 14.81' N 5° 59.93' W	Celtic Deep	605
53	20-Jun	51° 14.79' N 5° 59.64' W	Celtic Deep	605
54	20-Jun	51° 15.03' N 5° 59.66' W	Celtic Deep	605
55	20-Jun	51° 15.16' N 5° 59.60' W	Celtic Deep	605
56	20-Jun	51° 17.94' N 3° 32.91' W	Severn (Nash Point)	615

Appendix 8. continued

Station	Date	Position	Location	NMP
57	21-Jun	52° 13.96' N 4° 21.22' W	New Quay	
58	21-Jun	52° 21.45' N 4° 10.56' W	Cardigan Bay	655
59	21-Jun	52° 30.31' N 4° 59.99' W	Off Cardigan Bay	665
60	22-Jun	53° 28.61' N 3° 16.04' W	Burbo Bight	705
61	22-Jun	53° 31.83' N 3° 08.80' W	Mersey (C1 buoy)	765
62	22-Jun	53° 24.56' N 3° 00.48' W	Mersey (Seacombe Ferry)	755
63	22-Jun	53° 23.70' N 2° 59.70' W	Mersey (Tranmere oil terminal)	
64	22-Jun	53° 19.40' N 2° 56.85' W	Mersey (Eastham Lock)	
65	22-Jun	53° 40.36' N 3° 10.05' W	Ribble (anchor)	
66	22-Jun	53° 30.00' N 3° 41.63' W	Liverpool Bay	715
67	23-Jun	53° 28.67' N 3° 16.20' W	Dee (anchor)	
68	23-Jun	53° 26.10' N 3° 17.00' W	Dee (HE2 buoy/Hilbre Swash)	
69	23-Jun	53° 37.74' N 4° 29.74' W	Irish Sea	775
70	24-Jun	53° 58.73' N 3° 03.38' W	Morecambe Bay (anchor)	
71	24-Jun	53° 58.60' N 3° 00.00' W	River Lune (no. 1 buoy)	
72	24-Jun	53° 57.70' N 3° 02.50' W	Off Lune/Wyre (Fairway no. 1 buoy)	785
73	24-Jun	53° 44.10' N 2° 59.60' W	River Ribble: Lytham St. Anne's	
74	24-Jun	53° 44.70' N 2° 56.20' W	River Ribble: Lytham Creek	
75	24-Jun	53° 44.50' N 2° 54.70' W	River Ribble: Freckleton Saltings	
76	24-Jun	53° 44.00' N 2° 51.70' W	River Ribble: Asland confluence	
77	24-Jun	53° 58.05' N 3° 20.10' W	Off Morecambe Bay	795
78	24-Jun	54° 00.01' N 3° 50.08' W	SE Isle of Man	805
79	25-Jun	53° 52.58' N 5° 33.46' W	AEP3 mooring	
80	25-Jun	53° 52.58' N 5° 33.46' W	AEP3 mooring	
81	25-Jun	54° 45.00' N 3° 59.56' W	Off Solway	25
82	26-Jun	55° 20.04' N 5° 05.12' W	Firth of Clyde	35
83	27-Jun	57° 59.97' N 5° 40.03' W	Minches	85
84	27-Jun	58° 00.04' N 3° 00.00' W	Moray Firth	105
85	28-Jun	56° 29.96' N 1° 30.00' W	Off Tay/Forth	165
86	28-Jun	55° 45.76' N 1° 57.84' W	Off Tweed	
87	28-Jun	55° 45.83' N 1° 59.58' W	Tweed (buoy off Spittal Point)	
88	28-Jun	55° 46.12' N 2° 00.35' W	Tweed (Berwick/Tweed Bridges)	
89	29-Jun	55° 07.07' N 1° 27.46' W	Off Blyth	
90	29-Jun	55° 07.30' N 1° 29.70' W	Blyth (South Harbour entrance)	
91	29-Jun	55° 08.10' N 1° 30.75' W	Blyth (North Blyth)	
92	29-Jun	55° 00.52' N 1° 08.04' W	Offshore Tyne	245
93	29-Jun	54° 41.59' N 1° 08.08' W	Off Tees	
94	29-Jun	54° 38.52' N 1° 08.66' W	River Tees: No. 8 buoy	
95	29-Jun	54° 37.40' N 1° 09.34' W	River Tees: Redcar jetty	325
96	29-Jun	54° 36.22' N 1° 09.90' W	River Tees: ICI No. 4 buoy	
97	29-Jun	54° 35.30' N 1° 11.40' W	River Tees: No. 25 buoy	
98	30-Jun	54° 41.60' N 1° 07.99' W	Off Tees	
99	30-Jun	54° 38.52' N 1° 08.66' W	River Tees: No. 8 buoy	
100	30-Jun	54° 37.40' N 1° 09.34' W	River Tees: Redcar jetty	325
101	30-Jun	54° 36.22' N 1° 09.90' W	River Tees: ICI No. 4 buoy	
102	30-Jun	54° 35.30' N 1° 11.40' W	River Tees: No. 25 buoy	
S1	13-Jun	52° 38.20' N 0° 22.15' E	Wash (Ouse, Stowe Bridge)	405
S2	13-Jun	52° 44.38' N 0° 23.28' E	Wash (Ouse, Freebridge, King's Lynn)	415
S3	13-Jun	52° 47.04' N 0° 22.45' E	Wash (Ouse, The Point, King's Lynn)	425
S4	14-Jun	53° 33.75' N 0° 05.66' E	Humber (Spurn Head)	335
S5	15-Jun	53° 41.57' N 0° 05.66' E	Humber (North Killingholme)	365
S6	16-Jun	51° 27.92' N 0° 18.00' E	Thames (West Thurrock)	445
S7	16-Jun	51° 29.67' N 0° 28.46' E	Thames (Mucking)	455
S8	17-Jun	50° 52.95' N 1° 23.30' W	Southampton Water (Dock Head)	505
S9	18-Jun	50° 51.14' N 1° 12.77' W	Southampton Water (E. Bramble buoy)	515
S10	17-Jun	50° 49.59' N 1° 18.29' W	Southampton Water (Hook buoy)	525

Appendix 9. Water column data for stations sampled during CIROLANA 6, 9 June-1 July, 1993

Station	Depth (m)	Salinity	Temperature (°C)	Concentrations of nutrients (µmol l^{-1})					Sediment type
				Phosphate	Silicate	Nitrate	Nitrite	Ammonia	
1	16	31.852	10.4	0.58	2.5	14	0.33	5.9	sand
2	2.8	2.0	18.5	1.1	28	150	3.3	3.7	sand
3	1.7	0.360	18.6	1.1	27	152	3.1	2.4	sand/shell
4	20	34.062	10.5	0.32	2.9	2.1	0.39	6.0	NS
5	7.0	32.945	11.6	2.9	9.3	11	1.2	15	sand
6	8.5	30.0	12.5	3.2	8.1	27	1.0	50	sand/stones
7	69	33.778	12.0	0.24	4.1	2.2	0.55	3.5	mud
8	19	NS	10.4	NS	NS	NS	NS	NS	sand/mud
9	29	34.835	12.3	0.21	1.0	1.9	0.15	4.2	sand/shell
10	29	35.100	14.3	0.26	1.0	0.56	0.14	3.5	sand
11	49	34.805	15.3	0.02	1.0	1.5	0.14	2.4	mud (anoxic > 2cm)
12	73	34.801	12.9	0.26	0.8	1.4	0.1	3.0	mud
13	54	34.020	11.7	0.08	1.6	2.7	0.19	3.0	sand/mud
14	31	34.116	10.4	0.22	1.5	2.0	0.18	3.0	sand/mud
15	11	24.0	12.5	4.6	18	26	2.2	49	sand/shell
16	6.8	20.251	12.8	2.1	25	39	3.3	35	mud (anoxic)
17	20	33.831	10.8	0.75	2.9	4.7	0.36	4.9	mud/sand
18	NR	33.145	NR	9.8	30	90	11	40	sand
19	NR	NR	NR	20	64	212	19	86	mud (anoxic)
20	23	33.408	11.2	0.81	19	5.5	1.3	35	NS
21	2.5	20.843	13.0	6.3	28	1050	180	1460	mud (anoxic)
22	1.7	1.765	14.4	11	35	228	5.9	40	sand
23	13	33.048	13.4	0.37	2.8	24	0.39	< 0.5	NS
24	32	33.868	14.9	0.15	0.9	2.0	0.36	3.1	NS
25	35	35.169	12.8	0.15	0.9	1.7	0.14	2.3	sand
26	49	35.356	13.4	0.28	2.5	0.9	1.0	3.5	sand/shell
27	16	33.996	16.7	1.6	2.6	18	0.76	6.6	mud/sand
28	34	35.363	13.4	0.12	1.8	1.5	0.23	1.6	sand/shell
29	23	35.318	14.3	0.1	1.6	0.5	0.19	1.4	NS
30	22	35.192	13.8	0.09	1.4	0.7	0.17	1.4	NS
31	19	34.716	15.7	0.25	1.6	0.6	0.11	1.6	NS
32	37	34.775	14.1	0.65	2.6	3.0	0.33	2.3	NS
33	17	34.396	15.6	0.11	1.0	0.4	0.12	1.4	shell/stones/sand
34	2.2	26.761	18.2	7.2	19	31	2.3	61	mud
35	14	34.094	15.7	0.82	2.2	1.1	0.3	3.1	sand
36	37	35.058	14.0	0.19	1.8	0.4	0.23	1.6	NS
37	43	35.156	13.6	0.28	1.5	1.0	0.19	1.4	NS
38	66	35.198	13.3	0.09	1.0	0.7	0.15	1.7	sand/shell/stones
39	9.6	31.287	13.9	0.54	10	18	1.3	6.1	sand
40	3.1	5.703	15.0	1.2	53	122	1.6	9.2	mud
41	15	16.697	14.9	1.1	37	83	1.7	14	mud
42	75	35.039	14.2	0.12	0.9	1.2	0.12	1.6	sand/shell
43	92	35.227	13.7	0.23	9.9	12	1.2	3.3	NS
44	117	35.347	14.1	0.11	2.9	1.8	0.38	0.7	NS
45	140	35.382	14.6	0.1	2.3	0.5	0.3	2.4	NS
46	168	35.448	14.8	0.04	1.1	0.23	0.17	1.9	shell
47	96	35.029	13.8	0.3	5.2	0.39	0.71	1.9	mud
48	97	NS	NR	NS	NS	NS	NS	NS	mud
49	97	NS	NR	NS	NS	NS	NS	NS	mud
50	98	NS	NR	NS	NS	NS	NS	NS	mud
51	97	NS	NR	NS	NS	NS	NS	NS	mud
52	97	NS	NR	NS	NS	NS	NS	NS	mud
53	96	NS	NR	NS	NS	NS	NS	NS	mud
54	97	NS	NR	NS	NS	NS	NS	NS	mud
55	97	NS	NR	NS	NS	NS	NS	NS	mud
56	27	29.692	15.4	2.3	16	59	2.0	2.3	NS

Appendix 9. continued

Station	Depth (m)	Salinity	Temperature (°C)	Concentrations of nutrients (µmol l^{-1})					Sediment type
				Phosphate	Silicate	Nitrate	Nitrite	Ammonia	
57	22	33.686	14.1	0.25	2.1	3.2	0.25	2.4	mud/stones
58	24	33.116	15.8	0.35	3.2	1.0	0.39	2.5	mud
59	80	34.652	13.7	0.29	1.1	2.4	0.03	3.1	sand/mud/shell
60	13	31.358	15.2	1.3	5.2	1.7	0.5	4.2	sand over anoxic mud
61	17	29.220	15.5	2.7	11	28	1.2	18	NS
62	15	20.669	15.8	6.3	40	114	43	90	sand/shell
63	NR	18.739	NR	6.4	46	125	50	112	sand
64	NR	16.393	NR	7.7	59	143	49	136	anoxic mud
65	16	31.817	15.1	0.95	2.1	1.3	0.24	6.3	sand
66	35	33.212	13.2	0.53	0.7	1.6	0.08	2.4	sand/shell
67	13	31.419	15.4	1.8	5.6	3.7	0.71	13	NS
68	7.5	31.858	15.2	1.1	5.5	0	0.69	3.3	NS
69	68	33.903	11.8	0.7	2.8	6.0	0.36	3.8	sand/stones/shell
70	16	31.426	15.5	0.81	0.8	0.9	0.09	3.1	fine sand
71	9.4	31.591	15.0	0.9	0.9	1.2	0.07	4.9	sand
72	11.9	31.458	15.7	0.83	0.6	1.0	0.05	3.1	sand
73	NR	31.058	NR	2.0	2.6	14	0.31	8.4	NS
74	NR	31.402	NR	1.8	2.3	8.4	0.27	7.3	NS
75	NR	31.300	NR	1.8	2.3	8.5	0.27	7.3	NS
76	NR	28.881	NR	4.6	4.8	33	0.58	17	NS
77	19	32.636	14.0	0.51	0.8	1.6	0.1	3.5	mud
78	37	32.797	14.1	0.33	0.5	0.2	0.03	2.1	sand/shell
79	105	NS	NR	NS	NS	NS	NS	NS	NS
80	105	NS	NR	NS	NS	NS	NS	NS	NS
81	23	31.9	13.0	0.43	1.4	0.45	0.15	3.1	mud
82	57	32.529	12.5	0.22	1.1	0.86	0.14	2.7	mud
83	101	34.627	10.5	0.65	2.3	4.1	0.41	1.9	mud
84	61	34.799	11.1	0.72	5.8	7.0	0.84	1.9	sand
85	61	34.576	11.5	0.19	0.8	2.5	0.09	2.0	sand/shell
86	16	33.644	12.8	NS	NS	NS	NS	NS	NS
87	2.0	4.779	17.4	NS	NS	NS	NS	NS	NS
88	1.8	0.759	19.1	NS	NS	NS	NS	NS	NS
89	20	34.001	11.6	0.45	2.0	1.3	0.22	1.9	NS
90	9.4	32.873	13.0	1.8	4.2	2.1	0.52	9.2	NS
91	6.0	30.285	13.7	2.5	6.7	8.2	0.8	18	NS
92	71	34.074	12.1	0.67	6.1	2.5	0.76	2.6	NS
93	23	33.873	13.1	1.2	1.9	7.3	0.21	110	NS
94	11	32.812	15.4	1.1	13	28	1.6	119	sand/stones
95	21	26.802	16.3	5.9	14	270	1.7	680	NS
96	7.4	27.770	15.5	6.0	12	50	1.4	780	tar/stones
97	4.0	27.221	13.7	7.8	13	77	1.6	1020	anoxic mud
98	24	33.569	13.5	0.8	4.2	16	0.5	35	NS
99	4.5	31.562	14.3	0.72	4.9	89	0.58	238	NS
100	22	25.338	14.3	5	16	730	1.9	470	NS
101	13	26.559	14.1	5.6	11	98	1.4	670	NS
102	8.3	26.088	14.1	7.5	11	57	1.4	721	NS
S1	NR	0.461	NR	27	96	520	12	7.5	sand
S2	NR	0.668	NR	18	77	573	11	14	mud
S3	NR	0.770	NR	15	73	484	17	71	mud
S4	NR	29.812	NR	0.62	4.2	44	0.53	3.1	sand
S5	NR	4.363	NR	2.8	46	238	4.3	4.9	mud
S6	NR	NR	NR	NS	NS	NS	NS	NS	mud
S7	NR	28.344	NR	11	8.1	127	1.1	4.7	NS
S8	NR	29.982	NR	2.6	19	37	2.3	12	mud
S9	NR	NR	NR	NS	NS	NS	NS	NS	NS
S10	NR	NR	NR	NS	NS	NS	NS	NS	sand

Appendix 10. Concentrations of dissolved trace metals in sea water samples collected during CIROLANA 6, 9 June-1 July 1993

Station	Concentration (µg l^{-1})						
	Cd	Cu	Mn	Ni	Pb	Zn	Co
2	0.013	2.11	6.39	0.65	0.209	0.98	0.038
3	0.038	3.28	2.82	0.57	0.285	0.77	0.034
5	0.025	1.12	89.61	0.71	0.158	3.99	0.121
6	0.023	0.84	159.41	0.92	0.192	3.81	0.138
7	0.012	0.35	2.12	0.28	0.024	0.48	0.023
9	0.013	0.20	1.08	0.27	0.018	0.27	0.012
10	0.012	0.21	1.50	0.24	0.014	0.15	0.017
11	0.015	0.33	2.65	0.36	0.012	0.21	0.035
12	0.013	0.22	1.92	0.26	0.022	0.41	0.018
13	0.011	0.20	0.49	0.22	0.012	0.17	0.013
14	0.012	0.20	1.33	0.27	0.018	0.18	0.014
15	0.030	2.24	40.11	1.19	0.196	-	0.178
16	0.030	1.05	65.17	1.52	0.293	12.27	0.224
18	0.021	1.71	43.43	1.90	0.744	5.07	0.166
19	0.029	2.18	36.76	2.95	2.041	8.60	0.116
21	0.018	-	51.10	2.73	1.174	1.91	0.544
22	0.021	1.97	11.90	1.33	2.272	4.81	0.053
23	0.034	0.73	1.36	0.83	<0.020	0.63	0.030
24	0.017	0.69	11.83	0.55	0.029	0.47	0.066
25	0.014	0.35	1.76	0.41	<0.020	0.32	0.028
26	0.010	0.24	0.39	0.28	<0.020	0.30	0.018
27	0.024	0.86	0.92	0.72	0.029	0.70	0.034
28	0.013	0.24	0.91	0.28	<0.020	0.28	0.021
31	0.013	0.47	1.06	0.43	<0.020	0.27	0.065
34	0.101	2.90	8.28	4.20	0.108	4.59	0.439
38	0.011	0.18	0.62	0.34	0.154	0.55	0.007
40	-	4.11	26.35	1.28	2.338	6.28	0.168
41	0.028	3.41	38.44	1.76	2.104	6.45	0.236
42	0.009	0.22	1.09	0.22	0.046	0.26	0.015
46	0.007	0.09	0.29	0.22	<0.020	0.12	0.007
47	0.017	0.18	0.26	0.19	<0.020	0.13	0.004
56	0.104	1.32	0.35	0.83	0.047	2.23	0.015
58	0.021	0.61	1.80	0.36	0.032	0.73	0.038
59	0.012	0.29	0.80	0.24	0.017	0.36	0.01
60	0.014	1.08	11.48	0.66	0.128	0.97	0.061
61	0.016	1.99	15.93	4.78	1.612	7.87	0.168
62	0.018	1.67	2.81	1.48	0.529	3.74	0.04
66	0.024	0.66	5.23	0.38	0.041	0.74	0.027
68	0.019	1.03	13.05	0.54	0.214	2.17	0.06
69	0.023	0.50	0.63	0.34	0.022	0.74	0.009
72	0.032	1.22	1.71	0.57	0.074	1.05	0.023
77	0.027	0.87	5.67	0.47	0.056	0.85	0.033
78	0.035	0.81	7.41	0.45	0.049	0.79	0.026
S1	0.040	3.01	3.10	3.54	0.423	3.16	0.191
S2	0.022	2.52	4.12	3.63	0.544	2.59	0.232
S3	0.010	1.83	5.71	3.84	0.742	2.81	0.206
S4	0.065	1.90	3.89	1.55	0.190	1.34	0.055
S5	0.102	4.62	18.57	4.03	0.409	4.79	0.054
S6	0.086	4.37	6.58	4.59	1.143	13.00	0.148
S7	0.054	2.18	2.63	2.01	0.328	4.61	0.075
S8	0.020	1.43	8.76	0.80	0.068	1.74	0.127
S10	0.012	1.89	5.68	0.45	0.055	6.61	0.067

Note: See Appendix 8 for station details

Appendix 11. Organic contaminants in sea water samples collected during CIROLANA 6, 9 June-1 July, 1993. (Concentrations are in ng l^{-1} except total hydrocarbons (THC) which are µg l^{-1} Ekofisk crude oil equivalents)

Station	Location	NMP	Alpha HCH	Gamma HCH	Simazine	Atrazine	THC
1	Tweed (anchor)		0.18	0.33	<0.6	0.87	0.6
2	Tweed (buoy off Spittal Point)		0.13	1.3	3.4	3.1	2.0
3	Tweed (Berwick/Tweed Bridges)		0.14	1.6	3.1	2.3	2.2
4	Blyth (anchor)		0.18	0.26	0.5	0.4	0.2
5	Blyth (South Harbour entrance)		0.17	0.58	2.6	2.4	4.1
6	Blyth (North Blyth)				13.4	15.8	11
7	Off Tyne	245	0.15	0.28	0.49	0.44	0.9
8	Tyne (anchor)				<0.6	0.33	
9	Off Tyne/Tees	285	0.15	0.33	0.46	0.32	0.4
10	Dogger Bank		0.16	0.44			0.5
11	North of Friesland Junction		0.14	0.88	1.1	1.4	0.7
12	Off Humber/Wash	345			0.54	0.5	0.2
13	Off Tees	295	0.18	0.31	0.4	0.4	1.5
14	Tyne (anchor)		0.14	0.21	0.96	0.95	0.3
15	Tyne (Lloyd's hailing station)	235	0.15	1.5	5.2	13.6	7.7
16	Tyne (Hebburn)	225	0.12	0.76	6.1	10.1	14
17	Wear (anchor)		0.12	0.23	0.4	0.67	2.1
18	Wear (Sandy Point)	275	0.12	2	4.5	26.9	15
19	Wear (Queen Alexandra Bridge)	265	0.14	3.8	1.7	6.5	14
20	Tees (anchor)		0.16	0.47	0.9	1.7	4.7
21	Tees (Redcar jetty)	325	0.15	1.9	11.5	18.7	120
22	Tees (Victoria Bridge)	315	0.16	3.4			13
23	Humber	375	0.19	0.79	0.84	0.85	0.7
24	Wash	385	0.16	1.2	1.1	0.9	0.5
25	Southern Bight (Smiths Knoll)	395	0.12	0.94	0.4	0.48	0.4
26	Thames (Outer Gabbard)	475	0.13	1.8	0.41	0.57	0.4
27	Thames (Warp)	465	0.14	1.9	3.2	3.5	1.1
28	South Varne	485	0.1	0.6	0.42	1	0.5
29	Perintis 1		0.1	0.96			
30	Perintis 2		0.12	0.89			
31	Selsey Bill/Perintis 3	495	0.16	1.3	1.3	2.7	1
32	Perintis 4		0.14	1.1			
33	Poole Harbour (anchor)		0.16	1.5	0.69	3.1	0.4
34	Poole Harbour: Holes Bay (Cobb's Quay)		0.16	4.6			4.7
35	Poole Harbour: Brownsea buoy (no. 42)		0.19	1.9			1.6
36	Perintis 5		0.1	0.7			
37	Perintis 6		0.12	0.7			
38	Central Channel/Perintis 7	535	0.1	0.43	1.2	2.8	0.4
39	Plymouth Sound (anchor)		0.11	0.71	0.54	4.1	1.6
40	Tamar (South Tamar buoy)			0.39			9.8
41	Tamar (Hamoaze)	565		0.8			5.4
42	Off Plymouth Sound (MBA station E1)/ Perintis 8	585	0.11	0.64			0.3
43	Perintis 9		0.1	0.37			
44	Perintis 10			0.36			
45	Perintis 11		0.14	0.97			
46	Western Approaches	595	0.14	0.28			<0.2
47	Celtic Deep	605					0.3
56	Severn (Nash Point)	615					5.5

Appendix 11. continued

Station	Location	NMP	Alpha HCH	Gamma HCH	Simazine	Atrazine	THC
57	New Quay						0.7
58	Cardigan Bay	655					0.5
60	Burbo Bight	705					5.6
61	Mersey (C1 buoy)	765		0.45			9.1
62	Mersey (Seacombe Ferry)	755	0.97	2.9	28.5	20.8	15
66	Liverpool Bay	715	0.11	0.32	1.4	1.1	1.2
67	Dee (anchor)						2.6
68	Dee (HE2 buoy/Hilbre Swash)		0.11	0.67	1.3	1.9	3.1
69	Irish Sea	775	0.09	0.21	2.4	3.1	0.3
70	Morecambe Bay (anchor)		0.06	1.5	2.4	3.1	4.2
71	River Lune (no. 1 buoy)		0.24	1.4	4.6	4.1	5.6
72	Off Lune/Wyre (Fairway no. 1 buoy)	785	0.24	1.3	4.6	4.3	3.8
77	Off Morecambe Bay	795	0.22	0.9	2.2	1.5	0.9
78	SE Isle of Man	805	0.19	0.19			0.2
81	Off Solway	25	0.25	0.14			0.6
82	Firth of Clyde	35	0.21	0.2			2.0
83	Minches	85	0.2	0.27			0.4
84	Moray Firth	105	0.14	0.51			<0.2
85	Off Tay/Forth	165	0.17	0.8			<0.2
86	Off Tweed		0.16	0.8			0.4
87	Tweed (buoy off Spittal Point)		0.14	1.3			2.3
88	Tweed (Berwick/Tweed Bridges)		0.1	1.5			2.5
89	Off Blyth						1.7
90	Blyth (South Harbour entrance)						2.8
91	Blyth (North Blyth)		0.18	4.6			6.0
92	Offshore Tyne	245	0.08	0.14			0.8
93	Off Tees		0.2	0.48			0.7
94	River Tees: No. 8 buoy		0.2	0.72			7.4
95	River Tees: Redcar jetty	325	0.68	2.6			64
96	River Tees: ICI No. 4 buoy		0.25	1.9			31
97	River Tees: No. 25 buoy		0.16	2.4			27
98	Off Tees		0.15	0.41			4.0
99	River Tees: No. 8 buoy						23
100	River Tees: Redcar jetty	325	0.63	2.1			63
101	River Tees: ICI No. 4 buoy		0.15	1.7			23
102	River Tees: No. 25 buoy		0.18	2.3			25
S1	Wash (Ouse, Stowe Bridge)	405					11
S2	Wash (Ouse, Freebridge, King's Lynn)	415					10
S3	Wash (Ouse, The Point, King's Lynn)	425					20
S4	Humber (Spurn Head)	335					12
S5	Humber (North Killingholme)	365					86
S6	Thames (West Thurrock)	445					21
S7	Thames (Mucking)	455					4.9
S8	Southampton Water (Dock Head)	505					5.8
S9	Southampton Water (E. Bramble buoy)	515					9.1
S10	Southampton Water (Hook buoy)	525					12

Note: See Appendix 8 for station details

Appendix 12. Volatile organic concentrations (ng l^{-1}) in water samples collected during CIROLANA 6, 9 June-1 July 1993 and CORYSTES 10, 1-19 October 1993

Station	Location	cfm	111-t	edc	ctet	tric	bdcm	tol	dbcm	perc	bfm	benz	ebenz	o-xyl	1,2,4-tmb
CIROLANA 6/93															
1	Tweed (anchor)	<25	<30	<10	<5	<30	<5	<40	<5	<10	79	36	<10	<10	<10
2	Tweed (buoy off Spittal Point)	<25	<30	<10	<5	<30	<5	<40	<5	13	38	<25	<10	<10	<10
3	Tweed (Berwick/Tweed Bridges)	<25	<30	<10	<5	<30	<5	<40	<5	13	18	<25	<10	<10	15
4	Blyth (anchor)	<25	<30	<10	<5	<30	<5	<40	<5	<10	73	<25	<10	<10	32
5	Blyth (South Harbour entrance)	<25	<30	<10	<5	<30	<5	<40	12	15	146	<25	<10	<10	<10
6	Blyth (North Blyth)	77	76	<10	<5	31	<5	<40	<5	28	93	<25	<10	<10	<10
7	Off Tyne	<25	<30	<10	<5	<30	<5	<40	<5	<10	19	<25	<10	<10	<10
8	Tyne (anchor)	<25	<30	<10	<5	<30	<5	<40	<5	<10	150	<25	<10	<10	<10
9	Off Tyne/Tees	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
10	Dogger Bank	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
11	North of Friesland Junction	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
12	Off Humber/Wash	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
14	Tyne (anchor)	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	28	<10	<10	<10
15	Tyne (Lloyd's hailing station)	139	64	<10	<5	<30	<5	<40	<5	43	62	<25	<10	<10	<10
15 rpt	Tyne (Lloyd's hailing station)	136	<30	24	<5	<30	<5	<40	<5	37	39	<25	<10	<10	11
16	Tyne (Hebburn)	58	<30	<10	<5	<30	<5	<40	<5	29	23	<25	<10	<10	<10
16 rpt	Tyne (Hebburn)	55	57	<10	<5	<30	<5	<40	<5	26	27	<25	<10	<10	<10
17	Wear (anchor)	25	<30	<10	<5	<30	<5	<40	<5	<10	57	<25	<10	<10	<10
18	Wear (Sandy Point)	84	<30	<10	<5	520	<5	<40	<5	<10	42	<25	<10	<10	<10
19	Wear (Queen Alexandra Bridge)	159	61	<10	<5	3460	<5	<40	<5	<10	21	<25	<10	<10	<10
20	Tees (anchor)	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
21	Tees (Redcar jetty)	64900	<30	114300	28	221	2202	17700	540	137	164	104800	<10	30000	3700
22	Tees (Victoria Bridge)	134	<30	126	<5	<30	<5	<40	<5	16	<10	<25	<10	<10	<10
23	Humber	<25	<30	<10	<5	<30	<5	<40	<5	<10	47	<25	<10	<10	<10
24	Wash	36	<30	<10	<5	<30	<5	<40	<5	<10	17	<25	<10	<10	16
25	Southern Bight (Smiths Knoll)	<25	<30	<10	<5	<30	<5	<40	<5	<10	14	<25	<10	<10	<10
28	South Varne	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
31	Selsey Bill/Perintis 3	<25	<30	<10	<5	<30	<5	<40	<5	<10	26	<25	<10	<10	<10
33	Poole Harbour (anchor)	<25	<30	<10	<5	<30	<5	<40	<5	<10	28	<25	<10	<10	<10
34	Poole Harbour:														
	Holes Bay (Cobb's Quay)	39	78	30	<5	<30	<5	<40	<5	22	30	<25	<10	<10	<10
35	Poole Harbour:														
	Brownsea buoy (no. 42)	<25	<30	<10	<5	<30	<5	<40	<5	<10	47	<25	<10	<10	<10
38	Central Channel/Perintis 7	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
39	Plymouth Sound (anchor)	<25	<30	<10	<5	<30	<5	<40	<5	<10	82	<25	<10	<10	<10
40	Tamar (South Tamar buoy)	<25	<30	<10	<5	<30	<5	<40	<5	<10	31	<25	<10	<10	<10
41	Tamar (Hamoaze)	<25	<30	<10	<5	<30	<5	<40	<5	<10	33	<25	<10	<10	<10
42	Off Plymouth Sound (MBA														
	station E1)/Perintis 8	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
46	Western Approaches	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	41
47	Celtic Deep	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	28
56	Severn (Nash Point)	<25	<30	<10	<5	<30	<5	<40	<5	<10	16	<25	<10	<10	<10
57	New Quay	<25	<30	<10	<5	<30	<5	<40	<5	<10	19	<25	<10	<10	<10
58	Cardigan Bay	<25	<30	<10	<5	<30	<5	<40	<5	<10	38	<25	<10	<10	<10
59	Off Cardigan Bay	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
60	Burbo Bight	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	17
61	Mersey (CI buoy)	1163	119	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
62	Mersey (Seacombe Ferry)	1198	181	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10

Appendix 12. continued

Station	Location	cfm	111-t	edc	ctet	tric	bdcm	tol	dbcm	perc	bfm	benz	ebenz	o-xyl	1,2,4-tmb
CIROLANA 6/93															
63	Mersey (Tranmere oil terminal)	1283	193	<10	<5	<30	<5	<40	15	<10	<10	<25	<10	<10	<10
64	Mersey (Eastham Lock)	519	126	1064	38	160	32	<40	40	439	53	<25	<10	<10	<10
68	Dee (HE2 buoy/Hilbre Swash)	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
71	River Lune (no. 1 buoy)	26	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
72	Off Lune/Wyre (Fairway no. 1 buoy)	31	<30	<10	<5	<30	<5	<40	<5	<10	90	<25	<10	<10	<10
77	Off Morecambe Bay	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
78	SE Isle of Man	<25	49	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
80	AEP3 mooring	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
93	Off Tees	335	93	58	<5	<30	<5	<40	<5	<10	38	<25	<10	<10	<10
94	River Tees: No. 8 buoy	3007	35	2548	<5	<30	37	<40	26	97	141	<25	<10	<10	<10
95	River Tees: Redcar jetty	39080	308	3970	<5	50	802	<40	66	365	60	<25	<10	<10	<10
96	River Tees: ICI No. 4 buoy	1454	88	1203	<5	<30	26	<40	11	323	48	<25	<10	<10	<10
97	River Tees: No. 25 buoy	1237	99	941	<5	31	24	<40	<5	491	47	<25	<10	<10	<10
98	Off Tees	960	54	448	<5	<30	<5	<40	<5	21	81	<25	<10	<10	<10
99	River Tees: No. 8 buoy	4887	50	1709	<5	<30	59	<40	27	159	109	<25	<10	<10	<10
100	River Tees: Redcar jetty	118300	497	5800	<5	85	1528	<40	134	269	63	636	1037	10000	3800
101	River Tees: ICI No. 4 buoy	1185	110	801	<5	<30	22	<40	<5	299	46	<25	<10	<10	<10
102	River Tees: No. 25 buoy	1537	223	705	<5	<30	<5	<40	<5	316	53	<25	<10	<10	<10
S1	Wash (Ouse, Stowe Bridge)	<25	453	<10	<5	53	<5	<40	<5	120	<10	<25	<10	<10	<10
S2	Wash (Ouse, Freebridge, Kings Lynn)	<25	43	<10	<5	89	<5	<40	<5	23	<10	<25	<10	<10	<10
S3	Wash (Ouse, The Point, Kings Lynn)	31	40	<10	<5	<30	<5	<40	<5	15	<10	<25	<10	<10	<10
S4	Humber (Spurn Head)	<25	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
S5	Humber (North Killingholme)	26	<30	<10	<5	<30	<5	<40	<5	118	43	<25	<10	<10	<10
S6	Thames (West Thurrock)	97	68	20	<5	84	<5	<40	<5	211	<10	<25	<10	<10	<10
S7	Thames (Mucking)	<25	<30	<10	<5	<30	<5	<40	<5	17	69	<25	<10	<10	<10
S8	Southampton Water (Dock Head)	<25	<30	<10	<5	<30	<5	<40	<5	11	51	<25	<10	<10	<10
S9	Southampton Water (E. Bramble buoy)	<25	<30	<10	<5	<30	<5	<40	<5	<10	26	<25	<10	<10	<10
S10	Southampton Water (Hook buoy)	<25	<30	<10	<5	<30	<5	<40	<5	<10	30	<25	<10	<10	<10
CORYSTES 10/93															
29	Tees	64	<30	<10	<5	<30	<5	<40	<5	<10	<10	<25	<10	<10	<10
30	Tees	4019	3362	<10	<5	704	<5	<40	<5	587	<10	353	1512	2612	13582
31	Tees	435	148	<10	18.90	<30	17	<40	<5	13	<10	<25	<10	<10	<10
32	Tees	333	128	<10	<5	<30	24	<40	<5	22	<10	<25	<10	<10	<10
33	Tees	11435	359	875	<5	<30	217	<40	<5	92	<10	<25	<10	15	<10
34	Tees	9709	1125	806	<5	98	288	3301	27	150	39	740	960	5531	<10

Note: cfm=chloroform; 111-t=111-trichloroethane; edc=1,2-dichloroethane; ctet=carbon tetrachloride; tric=trichloroethylene; bdcm=bromodichloromethane; dbcm=dibromochloromethane; perc=tetrachloroethylene; bfm=bromoform; benz=benzene; ebenz=ethylbenzene; o-xyl=o-xylene; tol=toluene;1,2,4-tmb=1,2,4-trimethylbenzene

See Appendix 8 for station details

Appendix 13. Compounds tentatively identified by GC/MS spectral library matching in samples from the River Tees (Redcar jetty)

Scan number	Compound	CAS Registry number
250	1,2-dimethyl benzene	95-47-6
251	ethyl benzene	100-41-4
262	1,3-dimethyl benzene	108-38-3
292	1,3-dimethyl benzene	108-38-3
391	1,2,3-trimethyl benzene	526-73-8
400	1,2,3-trimethyl benzene	526-73-8
411	1,1-dimethyl-N,N'-diphenyl silanediamine	13435-09-1
488	1,2,3-trimethyl benzene	526-73-8
511	1-ethenyl-2-methyl benzene	611-15-4
525	1H-indene	95-13-6
710	1-methyl-1H-indene	767-59-9
720	1-methyl-1H-indene	767-59-9
734	1-methyl-1H-indene	767-59-9
736	1,1a,6,6a-tetrahydrocycloprop[*a*]indene	15677-15-3
771	naphthalene	91-20-3
788	a,a-4-trimethyl-3-cyclohexene-1-methanol	10482-56-1
822	trichloroeicosylsilane	18733-57-8
860	decanedioic acid, didecyl ester	2432-89-5
947	[1,1'-bicyclopentyl]-2-one	4884-24-6
962	2-methyl naphthalene	91-57-6
990	1-ethylidene-1H-indene	2471-83-2
991	benzocycloheptatriene	264-09-5
997	trichloroeicosylsilane	18733-57-8
1020	trichloroeicosylsilane	18733-57-8
1029	trichloroeicosylsilane	18733-57-8
1102	1,1'-biphenyl	92-52-4
1143	1,1'-oxybis-benzene	101-84-8
1167	1,8-dimethyl naphthalene	569-41-5
1168	1,2-dimethyl naphthalene	573-98-8
1172	1,5-dimethyl naphthalene	571-61-9
1187	2-methyl-1,1'-biphenyl	643-58-3
1254	7-tetradecene	10374-74-0
1267	acenaphthene	83-32-9
1346	(E)-3-eicosene	74685-33-9
1353	1-methyl-4-(phenylmethyl)-benzene	620-83-7
1414	9H-fluorene	86-73-7
1471	1,1'-methylenebis[4-methyl]-benzene	4957-14-6
1491	1,1'-methylenebis[4-methyl]-benzene	4957-14-6
1504	4,6-di(1,1-dimethylethyl)-2-methyl phenol	616-55-7
1594	4-(2,2,4-trimethylpentyl) phenol	
1611	nonylphenol	25154-52-3
1616	4-(2,2,4-trimethylpentyl) phenol	
1632	4-(2,2,4-trimethylpentyl) phenol	
1635	nonylphenol	25154-52-3
1644	nonylphenol	25154-52-3
1658	4-(2,2,4-trimethylpentyl) phenol	
1669	nonylphenol	25154-52-3
1689	phenanthrene	85-01-8
1794	4-(1-methyl-1-phenylethyl) phenol	
1804	1,2-benzenedicarboxylic acid, butyl octyl ester	84-78-6
1820	17-pentatriacontane	6971-40-0
1909	4-amino-2-cyclopentyl-5,6-trimethylene pyrimidine	

Appendix 14. Polycyclic aromatic hydrocarbons (ng l^{-1}) and total hydrocarbon concentration (µg l^{-1} Ekofisk crude oil equivalents) in sea water

Location	Date sampled	naph	acenap	fluor	phenth	anthrc	fluranth	pyrene	bnz-a-ant
Unfiltered Water									
Off Tweed	10-Jun	<15	<3	<1	<8	<1	<1	<1	<2
Tweed inner	10-Jun	<15	<3	6	<8	1	<1	6	2
Off Blyth	11-Jun	<15	8	14	<8	1	11	<1	6
Blyth inner	11-Jun	<15	6	12	399	4	70	35	12
Off Wear	14-Jun	<15	<3	7	9	1	7	4	3
Wear sandy pt	14-Jun	25	14	21	32	3	35	21	10
Off Plymouth	18-Jun	<15	<3	<1	<8	<1	<1	4	3
Tamar outer	18-Jun	27	<3	7	25	1	18	20	11
Tamar inner	18-Jun	<15	<3	<1	<8	<1	<1	10	6
Liverpool Bay	22-Jun	<50	<3	<1	<8	<1	1	<1	<2
Mersey outer	22-Jun	<50	4	15	21	2	21	23	15
Mersey inner	22-Jun	<50	7	17	27	4	40	51	32
Off Tees	29-Jun	103	13	4	<8	1	<1	2	<2
R.Tees buoy 8	29-Jun	<15	160	88	72	7	45	27	<2
R.Tees RC jetty	29-Jun	2280	761	493	389	81	300	207	78
R.Tees ICI	29-Jun	300	253	125	172	20	57	55	16
R.Tees buoy 25	29-Jun	358	257	100	128	17	61	46	14
Off Tees	30-Jun	<15	93	33	24	3	18	11	<2
R.Tees buoy 8	30-Jun	675	663	294	224	36	111	79	34
R.Tees RC jetty	30-Jun	6850	1300	830	551	157	345	296	89
R.Tees ICI	30-Jun	417	310	121	145	21	59	63	14
R.Tees buoy 8	30-Jun	190	240	92	114	18	46	41	11
Off Thames	16-Jun	<15	<3	<1	<8	<1	2	4	2
Thames Thurrock	16-Jun	114	49	<1	288	107	940	1090	609
Thames Mucking	16-Jun	346	20	<1	304	26	390	373	245
Filtered Water									
Off Tweed	10-Jun	<15	<3	<1	<8	<1	<1	<1	<2
Tweed inner	10-Jun	<15	<3	<1	<8	<1	<1	2	<2
Off Tees	15-Jun	<15	63	10	<8	<1	5	4	<2
R.Tees RC jetty	15-Jun	17300	2220	2540	2130	167	208	186	46
R.Tees Victoria bridge	15-Jun	<15	33	14	17	2	14	15	5
Off Tees	29-Jun	56	9	4	<8	<1	<1	2	<2
R.Tees buoy 8	29-Jun	269	318	117	62	6	66	30	4
R.Tees RC Jetty	29-Jun	4600	1680	910	1030	88	313	205	<2
R.Tees ICI	29-Jun	339	334	137	157	20	83	54	<2
Thames Thurrock	16-Jun	293	16	<1	<8	2	<1	43	<2
Thames Mucking	16-Jun	<15	<3	<1	<8	<1	<1	9	<2

Location	Date	chrys sampled	bnz-e-py	bnz-b-flr	bnz-k-flr	bnz-a-py	dbn-ah-a	bnz-ghi-p	THC
Unfiltered Water									
Off Tweed	10-Jun	<2	<1	<1	<1	<1	<1	<1	0.6
Tweed inner	10-Jun	3	<1	1	<1	2	<1	3	2.2
Off Blyth	11-Jun	5	<1	1	1	2	<1	4	4.1
Blyth inner	11-Jun	17	28	10	5	13	2	16	11
Off Wear	14-Jun	2	<1	2	<1	1	<1	2	2.1
Wear sandy pt	14-Jun	8	<1	5	2	4	<1	5	15
Off Plymouth	18-Jun	<2	<1	1	<1	1	<1	<1	1.6
Tamar outer	18-Jun	9	5	9	4	11	1	13	9.8
Tamar inner	18-Jun	4	1	3	1	4	<1	5	5.4
Liverpool Bay	22-Jun	<2	<1	<1	<1	<1	<1	<1	1.2
Mersey outer	22-Jun	9	4	10	3	10	2	13	9.1
Mersey inner	22-Jun	17	6	16	6	16	3	19	15
Off Tees	29-Jun	<2	<1	<1	<1	<1	<1	<1	0.7
R.Tees buoy 8	29-Jun	5	<1	6	2	8	<1	5	7.4
R.Tees RC jetty	29-Jun	61	11	39	13	49	<1	32	64
R.Tees ICI	29-Jun	14	4	8	2	7	<1	6	31
R.Tees buoy 25	29-Jun	12	3	8	2	8	<1	7	27
Off Tees	30-Jun	3	1	2	1	2	<1	1	4
R.Tees buoy 8	30-Jun	28	7	18	6	24	<1	15	23
R.Tees RC jetty	30-Jun	62	21	63	21	84	<1	54	63
R.Tees ICI	30-Jun	10	2	4	1	5	<1	4	23
R.Tees buoy 8	30-Jun	10	2	4	1	4	<1	3	25
Off Thames	16-Jun	<2	<1	2	1	2	<1	1	1.1
Thames Thurrock	16-Jun	726	207	621	250	909	126	627	21
Thames Mucking	16-Jun	170	60	170	68	216	33	223	4.9
Filtered Water									
Off Tweed	10-Jun	<2	<1	<1	<1	<1	<1	<1	NR
Tweed inner	10-Jun	<2	<1	<1	<1	<1	<1	<1	NR
Off Tees	15-Jun	<2	<1	<1	<1	<1	<1	<1	NR
R.Tees RC jetty	15-Jun	21	<1	<1	1	3	<1	<1	NR
R.Tees Victoria bridge	15-Jun	4	<1	1	<1	1	<1	2	NR
Off Tees	29-Jun	<2	<1	1	<1	<1	1	<1	NR
R.Tees buoy 8	29-Jun	4	<1	<1	<1	<1	<1	<1	NR
R.Tees RC jetty	29-Jun	<2	<1	<1	<1	<1	<1	<1	NR
R.Tees ICI	29-Jun	<2	<1	<1	<1	<1	<1	<1	NR
Thames Thurrock	16-Jun	20	<1	<1	2	8	<1	7	NR
Thames Mucking	16-Jun	<2	<1	<1	<1	<1	<1	<1	NR

naph=naphthalene, acenap=acenaphthene, fluor=fluorene, phenth=phenanthrene, anthrc=anthracene, fluranth=fluoranthene, bnz-a-ant=benz[a]anthracene, chrys=chrysene, bnz-e-py=benzo[e]pyrene; bnz-b-flr=benzo[b]fluoranthene, bnz-k-flr=benzo[k]fluoranthene,
bnz-a-p=benzo[a]pyrene, dbn-ah-a=dibenzo[a,h]anthracene, bnz-ghi-p=benzo[ghi]perylene, THC=total hydrocarbon concentration, NR=no result
See Appendix 8 for station details

Appendix 15. Summary of the rainfall events at ADAS Rosemaund during which the highest mean concentrations of a range of pesticides have been observed by MAFF in the stream and field drain. The concentrations shown are for 'total' pesticide, but with a few exceptions (especially deltamethrin, chlorpyrifos, trifluralin and fenpropimorph), this was approximately equivalent to the dissolved fraction

Pesticide	Rate (kg ha^{-1})	Total applied (kg)	Rainfall date	Rainfall amount (mm)	Stream (S) or drain (D)	Maximum conc. (µg l^{-1})	Mean* conc. (µg l^{-1})	% out
aldicarb+	5.50	23.10	15/4/92	19.0	S	0.9	0.4	<0.001
	5.50	11.77	15/4/92	19.0	D	2.1	1.7	<0.001
atrazine	2.80	14.56	8/1/92	72.5	S	5.7	2.0	0.068
	2.80	5.99	8/1/92	72.5	D	51.3	10.6	0.225
carbofuran	3.00	9.00	8/1/92	72.5	S	26.8	10.4	0.584
	3.00	3.00	25/1/92	9.0	D	58.4	37.2	0.003
chlorpyrifos	0.72	1.54	6/4/93	11.0	D	2.8	1.7	<0.001
2,4-D	1.00	5.18	16/12/87	9.0	S	1.0	0.7	0.002
deltamethrin	0.005	0.023	18/12/92	20.0	S	1.9	0.07	0.687
	0.005	0.011	18/12/92	20.0	D	0.02	0.005	0.009
dicamba	0.40	2.20	16/12/87	9.0	S	0.6	0.4	0.002
dichlorprop	2.60	13.50	19/5/90	12.0	S	1.0	0.3	<0.001
dimethoate	0.30	4.80	25/12/90	10.5	S	3.0	1.2	0.002
	0.30	1.56	8/1/91	15.0	D	0.6	0.2	-
fenpropimorph	0.75	1.60	6/4/93	11.0	D	1.2	0.9	<0.001
isoproturon	1.90	9.88	25/12/90	10.5	S	17.2	10.6	0.009
	1.00	2.14	9/11/89	10.5	D	13.7	6.7	0.007
lindane	0.56	2.91	14/12/89	18.0	S	0.3	0.1	0.005
	0.56	1.20	8/11/89	28.5	D	4.5	1.2	<0.001
MCPA	1.68	26.88	4/3/91	15.5	S	12.4	1.9	<0.001
	1.68	8.75	19/3/91	11.0	D	46.8	14.6	0.008
mecoprop	2.00	11.00	19/11/87	25.0	S	11.7	4.2	0.068
simazine	1.15	6.90	24/2/89	13.5	S	1.8	0.5	0.004
terbutryn	1.00	6.00	15/4/92	19.0	S	0.2	0.06	<0.001
	1.00	2.14	15/4/92	19.0	D	0.2	0.1	<0.001
triclopyr	0.19	1.01	24/2/89	13.5	S	<0.01	<0.01	-
trietazine	1.0	6.00	15/4/92	19.0	S	1.3	0.5	<0.001
	1.0	2.14	15/4/92	19.0	D	3.6	1.9	<0.001
trifluralin	1.1	5.04	11/11/92	10.5	S	0.9	0.6	0.001
	1.1	2.35	11/11/92	10.5	D	3.0	0.5	<0.001

* *flow-weighted mean concentration*

\+ *No unchanged aldicarb was detected. The data shown refer to the sum of the sulphoxide and sulphone degradation products*

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