

Towards 2000: Marine Monitoring in the 1990s



The 5th Report of the UK
Marine Pollution
Monitoring Management
Group



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MARINE MONITORING IN THE 1990s**

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Marine Pollution Monitoring
Management Group**

1998

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1. INTRODUCTION

The world is very conscious of pollution, and the notion of the sea as a general repository for harmful wastes and contaminants provides one of the most obvious focuses for environmental concern. There is thus a continuing need for monitoring of the marine environment to determine what pollution is there, what is changing, and what are the risks to human health, ecology and man's uses of the seas. The implications are highly practical, for they influence the technical and policy aspects of pollution control and remediation, as well as helping to inform public opinion. It is therefore essential that the monitoring carried out is soundly based in science, is well targeted to obtain the most from limited resources, and is responsive to new needs and priorities as they arise. The Marine Pollution Monitoring Management Group (MPMMG) set up in 1974 by the Department of the Environment (DoE) constantly seeks to achieve these ends through its activities.

Since the production of the fourth report of MPMMG in 1990, which covered the years from 1985 to 1989, the Group has been actively involved in a broad range of issues. Progress is outlined in the following eight sections of this report. These texts are written to provide a brief overview, which in most cases can be followed up through the separate, detailed papers that have been published on each aspect.

The membership of the MPMMG and its various sub-groups during the period 1990-1995 is given in Appendix 1. During the production of this report, the National Rivers Authority (NRA) and the River Purification Boards (RPB) have been incorporated into the new Environment Agency and Scottish Environment Protection Agency respectively, and the Scottish Office Agriculture and Fisheries Department (SOAFD) has become the Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD).

1.1 National Monitoring Plan/ Programme

One of the main goals of the last five years has been the development of a National Monitoring Plan for the UK, in recognition of the previous patchy co-ordination between numerous independent monitoring exercises. The planning has now come to fruition, in the form of an agreed National Monitoring Programme (NMP), based on consistent procedures for the collection and analysis of samples from a network of estuary, intermediate and offshore sites dispersed around the coast. The details of the design, and the balance between spatial surveys and trend monitoring, are described in Section 2. Since marine science in general, and assessment of contaminants in particular, is an international business, it is important for the UK to have the capability to provide

consistent information for the varied purposes required by international conventions and assessment exercises. The NMP will greatly facilitate this responsibility.

1.2 Quality Control

The quality of the data is at the heart of the NMP, as it is for any monitoring scheme. One of the problems revealed by reviewing previous arrangements was the variability in methods and the quality standards achieved under different schemes. MPMMG has tackled this through the establishment of National Marine Chemical and Biological Analytical Quality Control Schemes (Sections 3 and 4), which address the ability of laboratories to provide comparable data of the quality required for the NMP. The schemes have been highly successful, both in exposing shortcomings and in improving performance. They have proven the value of a rigorous, formal approach towards quality control, and as a result have attracted participation from laboratories unconnected to the NMP.

1.3 Sea disposal monitoring

The deliberate disposal of material such as sewage sludge and dredgings requires a major investment in monitoring, to identify appropriate sites and to check that the effects of disposal are acceptable. This task is overseen by a sub-group of MPMMG, the Group Co-ordinating Sea Disposal Monitoring (Section 5). In the last few years, this group has set out an objective scientific basis for monitoring and assessing the acceptability of sewage sludge disposal. It has examined how this may need to be modified to be applicable to the disposal of dredged material, and has begun to also consider the monitoring and assessment of pipeline discharges. These activities are of crucial importance for ensuring the protection of operations that introduce contamination into the sea non-accidentally.

1.4 Effects of marine fish farming

Expansion of the fish-farming industry, and the associated burgeoning of sea cages for salmon in some parts of the UK, raised a need for a review of the environmental impacts of this practice. MPMMG set up a sub-group which has looked into potential effects on sediments and benthic communities, water quality, microbial communities and fish populations, arising from nutrient enrichment and the use of toxic chemicals. This has helped to establish how the acceptability or otherwise of the effects due to a fish-farming enterprise might be judged, and has clarified the nature of the monitoring that might be carried out to detect impacts. It has also identified where research would be required, to fill gaps in knowledge.

1.5 Radioactivity in the Irish Sea

In response to concerns about the implications of discharging radioactive waste into the sea, there has been long-term monitoring of radionuclides in UK coastal waters. MPMMG commissioned a review of the information relating to the Irish Sea, in order to identify and place into context the principal issues of concern, relating to the transport and ultimate fate of radionuclides, and the associated risks. This was published in 1992, as a Ministry of Agriculture, Fisheries and Food (MAFF) report (Kershaw *et al.*, 1992), which will be instrumental in guiding further investigations of issues such as the possible resuspension of sediments in which radioactive material has gathered.

1.6 Nutrient studies

The Joint Nutrient Study (JONUS) research project has been underway since 1990. Its objective was to improve understanding of how the amounts of nutrients entering rivers may be modified by various geochemical and biological processes before they reach coastal waters where they potentially may cause eutrophication problems. This research, which has focused to date on the Humber, Wash and Thames estuaries, is important for two reasons: first, it helps to demonstrate the complexity of mechanisms determining nutrient fluxes in different river/estuary systems, and hence the problems involved in prediction. Secondly, it provides information to counter over-simplified assumptions about risks of eutrophication, which can have major consequences for nutrient reduction policies and their ensuing costs.

The Southampton Water Nutrients Study (SONUS) commenced in 1995 with the main objectives of determining a quantitative nutrient budget for the Southampton Water system and to establish the nutrient fluxes from this system to the English Channel.

Work on nutrient cycling is also being undertaken in Strangford and Belfast Loughs in Northern Ireland, designed to produce a budget estimating net nutrient exports to the open Irish Sea. In Scotland, nutrient modelling is being carried out in Loch Linnhe to assess the impact of nutrient enrichment from fish farming; additional work is being undertaken in the Scottish North Sea Coastal Zone and in the Ythan Estuary.

1.7 Inputs

In 1988, the Paris Commission decided to initiate comprehensive annual surveys of inputs of selected pollutants to Convention waters. The first survey in the UK was carried out in 1990; the results of the 1993 survey (the fourth in the series) are covered by this report and compared with earlier data when appropriate. Generally there has been an overall downward trend.

2. THE NATIONAL MONITORING PROGRAMME

2.1 Introduction

When the MPMMG reviewed the monitoring carried out in UK estuaries and coastal waters, (MPMMG, 1991), it concluded that there would be considerable merit in regular sampling at a network of monitoring stations. These stations should include some that are not expected to be significantly contaminated, to serve as reference stations for comparison with more heavily contaminated sites around the coast and in estuaries. Offshore sites would also provide data on the natural variability of the marine environment, which could be used to give a clearer definition of contamination trends in affected areas.

In its formal response to the MPMMG review (DoE, 1991), the Government accepted the need for a core programme of marine monitoring to national standards for all UK waters. As a result the National Monitoring Plan (NMP - subsequently termed the National Monitoring Programme) was devised. The rest of this Section outlines the main features of the NMP, which is described in detail in MPMMG, 1994.

The programme is not intended as a substitute for more intensive sampling programmes to assess sources of contamination and control measures taken in some estuaries. The national programme is primarily aimed at producing a co-ordinated and reliable data set on nationally significant contaminants in inshore and coastal waters. It provides a framework for assessing the need for, and the effects of, national measures and provides a focus for improving standards in all marine contaminant monitoring.

2.2 Objectives

The objectives of the National Monitoring Programme are:

- (a) to establish as precisely as practicable the spatial distribution of contaminants in UK waters and to identify their biological impact, thus identifying any areas of specific concern;
- (b) to detect trends in contaminant concentrations and biological well-being in those areas identified as being of concern;
- (c) to measure long-term natural trends in physical, biological and chemical parameters in selected areas.

2.3 Strategy

To achieve these objectives, it is necessary to establish a central computerised database for important contaminants in biota, sediment and water and for biological effects, in the UK marine environment. This database will permit comparison of environmental levels between sites, will indicate trends over time and will allow assessment against criteria relating to human and environmental health. It should also be able to identify the effects of changes in inputs, for example as a result of Government policy to reduce inputs.

The strategy is to conduct an initial spatial study of contaminants in water, sediments and biota, including a review of existing information collected to NMP standards. This study will identify areas of concern and estimate the inherent variability of the data. In the light of the results of the spatial study, particular determinands of concern will be included in future annual programmes to establish trends of selected contaminants and biological effects at selected sites.

For benthos monitoring, there may be difficulties in interpreting spatial trends along transects from inshore to offshore sites, since natural habitat variability may be so great that it masks any anthropogenic effects. The spatial study will nevertheless assist in the design of an annual monitoring programme for benthic macrofauna.

The assessment of long-term trends requires additional knowledge of other relevant causes of variation, such as deposition and mixing rates for sediments, the hydrography and climate.

2.4 Network of monitoring sites

Figure 1 shows the locations of estuarine, intermediate and offshore sites in the UK National Monitoring Programme.

Three principles were adopted in choosing the network of monitoring sites:

- (a) the inshore sites correspond as far as possible to the previously established Oslo and Paris Commissions (OSPARCOM) Joint Monitoring Group (JMG) sites;
- (b) where practical there is a salinity gradient from estuarine sites through intermediate sites (the interface between the estuarine plume and the open sea) to the offshore sites;
- (c) the offshore sites in the North Sea and the English Channel correspond to those previously selected as North Sea Task Force stations.

Within estuaries there are three fixed sampling sites, approximately representative of salinity regimes 0-10,

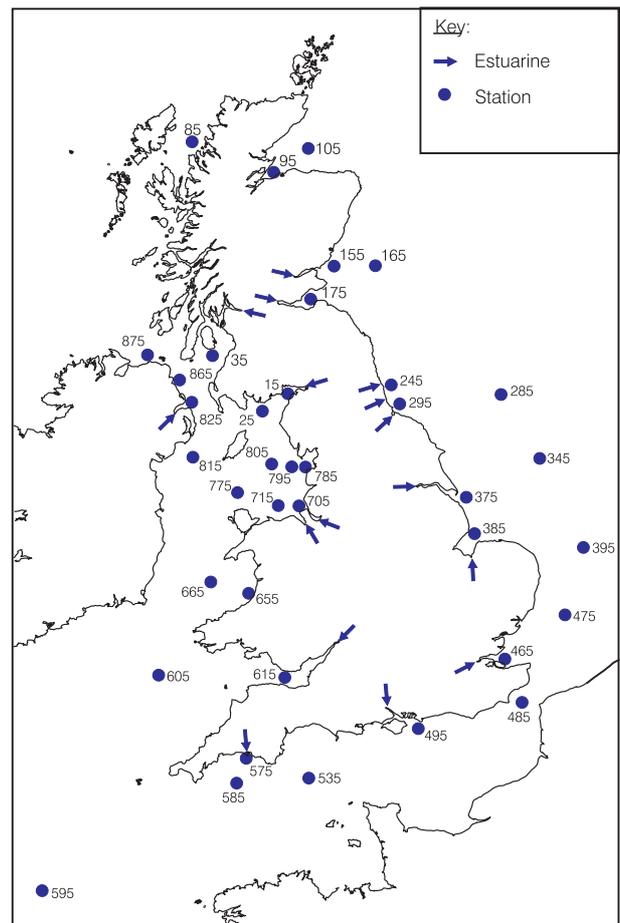


Figure 1. NMP sampling station positions

10-20, and 20-30 at high water under normal flow conditions. The sites are chosen to provide a good geographical coverage of the estuary and to equate, in general terms, to the upper, middle and lower reaches.

The estuarine sites are monitored by the NRA, RPBs or the Department of the Environment, Northern Ireland (DoE(NI)) as appropriate. The responsibilities for sampling and analysis of intermediate sites are as agreed between the NRA, RPBs, DoE(NI) and the Fisheries Departments on a local basis, whilst the offshore sites are the responsibility of the Government Departments (MAFF, SOAEFD and the Department of Agriculture for Northern Ireland (DANI)).

2.5 Variables to be measured at each station

Water

Water column samples are being collected in accordance with JMG guidelines, from a depth of 1 m below the surface and at, or near, high water for estuarine sites. Unfiltered samples are analysed for organic compounds (essentially pesticide residues), dissolved oxygen,

suspended solids and chlorophyll a. Filtered samples are analysed for metals (Hg, Cd, Cu, Pb, Ni, Zn, Cr) and nutrients.

Biological effects monitoring is also being carried out using the oyster embryo bioassay technique; biannually at estuarine sites and annually at intermediate and offshore sites. This is performed in accordance with the guidelines specified by the International Council for the Exploration of the Sea (ICES).

Sediments

Sediment samples are being taken in accordance with ICES guidelines, by means of a suitable grab or corer, such that disturbance of the surface layer is minimised. The top centimetre of the sediment is sampled for chemical determinands which include metals (Al, Hg, Cd, Cu, Pb, Ni, Zn, As, Cr), polychlorinated biphenyls (PCBs), and other organic compounds. All sediment analyses are accompanied by an estimation of organic carbon content and particle size analysis.

For biological effects monitoring, samples of sediment are being collected between February and May for the analysis of benthic macrofauna. Sediments from intermediate and offshore sites are sieved to 1 mm; from estuarine sites, samples are sieved to 0.5 mm.

A sediment bioassay should be carried out at all sites. (Whole sediment bioassays are now replacing the use of the oyster embryo bioassay tested on sediment elutriates.)

Fish/shellfish

The first choice fish species for residue level assessment is dab (*Limanda limanda*). Flounder (*Platichthys flesus*) may be used as the second choice, but no other species are acceptable to the NMP. The shellfish species of choice is the mussel (*Mytilus edulis*), *Modiolus* may be used at offshore sites, but no other shellfish species are acceptable. Fish muscle is analysed for mercury and arsenic; fish liver for cadmium, lead and some organic compounds. Whole shellfish tissue is analysed for mercury, cadmium, lead, zinc, and organic compounds.

Additional biological effects monitoring by Government Departments

Fish disease studies, dogwhelk imposex studies and mixed function oxidase tests (EROD), are to be carried out by Government Departments as deemed appropriate.

Special surveys of additional determinands

It is planned that Government Departments will undertake more restricted surveys of additional determinands in order to assess whether to include them in wider scale studies under the NMP. Contaminants

under consideration include: polybrominated biphenyls and diphenyl ethers; dioxins and furans; chlordanes; toxaphene; tributyltin (TBT) and polycyclic aromatic hydrocarbons (PAHs).

Timing

The initial survey, studying the spatial variation in contaminant concentrations in UK waters, was essentially completed in mid-1996. Results are being assessed to identify any areas of concern on which future monitoring work will be concentrated.

To assist in this process, DoE agreed to establish the centralised NMP database, to be operated by the Environment Agency and this was duly set up in 1996.

3. NATIONAL MARINE CHEMICAL ANALYTICAL QUALITY CONTROL SCHEME

3.1 Introduction

It is clearly necessary that analytical results should be of sufficient accuracy and precision for their intended application. In recent years, collaborative work to establish the quality of marine chemical and biological measurements, both nationally and internationally, has taken place on a voluntary basis co-ordinated mainly through ICES, the Marine Chemistry Working Groups and other *ad hoc* initiatives. These exercises often demonstrated that laboratories were producing analytical results that could not usefully be compared. Furthermore, possible improvements in laboratories' procedures were not addressed, and there was no follow-up assessment of performance.

Action to provide a national co-ordinated programme for quality assurance (QA) and analytical quality control (AQC) was stimulated in 1991 by the move to develop a UK National Monitoring Programme (NMP). MPMMG formally accepted this need, and endorsed a proposal to set up an independently run and funded UK programme of AQC for participating laboratories. The scheme was planned to focus initially on the determinands in the NMP, and invitations to participate concentrated on contributors of data to the plan.

In July 1992 a contract was let, establishing the National Marine Analytical Quality Control (NMAQC) scheme. Funding for the scheme came through a consortium of participants comprising DoE, NRA regions, Scottish RPBs, MAFF, SOAFD, DoE(NI), DANI and the British Geological Survey (BGS), the scheme being managed and administered by the Forth River Purification Board. The Water Research Centre (WRc) was awarded the contract to implement the first 4 year's work.

3.2 Objectives of the scheme

The overall aim of the scheme is to improve and maintain the quality of data submitted to the NMP and data collected for other purposes. In the first instance the scheme was designed to:

- monitor (and provide a demonstration of) the standard of accuracy achieved in laboratories which contribute data to NMP;
- assist participating laboratories in achieving improvements in performance where accuracy falls short of that required.

3.3 Scheme operation

The scheme concentrates on quality control for chemical determinands, based on the Manual on Analytical Quality Control produced for the Water Industry in 1989. In its idealised form (Figure 2) there is an in-house cycle and an external inter-laboratory cycle, both of which are monitored by the National Co-ordinating Committee (NCC).

Because of the urgent requirement to establish actual laboratory performance against specific targets of accuracy and precision, arising chiefly from the NMP, it was not feasible to follow this idealised approach in full. Circulation of standards to check for bias, and the need to establish control of within-laboratory precision would have been far too time-consuming. Consequently, in the first year of operation the scheme concentrated on establishing performance levels using four inter-laboratory distributions of aqueous and sedimentary matrices and one distribution of a biological matrix. In addition, there were one-off investigations into the stability of mercury in sea water and mixed nutrient standards.

In the first year the national scheme had 21 participating laboratories, and encompassed about 80% of the determinands in the NMP (Table 1). The performance targets for marine analyses have been set at 20% for metals and nutrients and 50% for trace organics. Maximum allowable errors in concentration terms for low level determinations were also set. These were updated in 1995 and are shown in Table 2. Currently the scheme covers greater than 90% of the chemical determinands in the NMP and the scheme has sixteen participating laboratories (see Table 3) including all the contributors to the NMP.

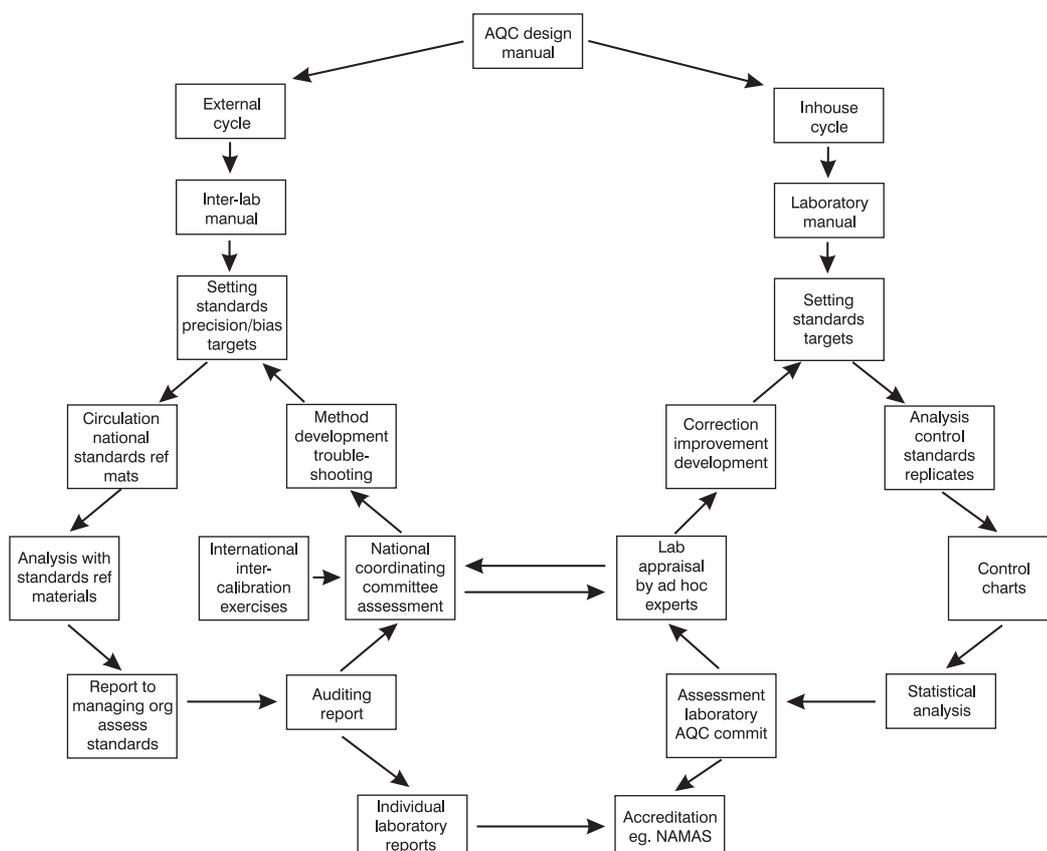


Figure 2. NMAQC Scheme operation (idealised approach)

Table 1. Analytical requirements

Determinand	Code	Matrix and Units					
		UW	FW	SS	SF	FM	FL
Metals							
Al (Aluminium)	AL	-	-	mg/kg	-	-	-
Hg (Mercury)	HG	-	ng/l	µg/kg	mg/kg	mg/kg	-
Cd (Cadmium)	CD	-	ng/l	µg/kg	mg/kg	-	mg/kg
Cu (Copper)	CU	-	µg/l	mg/kg	-	-	-
Pb (Lead)	PB	-	µg/l	mg/kg	mg/kg	-	mg/kg
Ni (Nickel)	NI	-	µg/l	mg/kg	-	-	-
Zn (Zinc)	ZN	-	µg/l	mg/kg	mg/kg	-	-
As (Arsenic)	AS	-	-	mg/kg	-	mg/kg	-
Cr (Chromium)	CR	-	µg/l	mg/kg	-	-	-
TBT (Tributyl tin) [in conjunction with Dogwhelk survey]	TBTIN	ng/l	-	µg/l	mg/kg	-	-
Organic Compounds							
PCB (Polychlorinated biphenyls) (congeners: 28,52,101,105,118,128,138,153,156,170,180) ¹	CB28, CB52, etc	-	-	µg/kg	µg/kg	-	µg/kg
a-HCH (Alpha-hexachlorocyclohexane)	HCHA	ng/l	-	-	µg/kg	-	-
b-HCH (Beta-hexachlorocyclohexane) [estuarine sites only]	HCHB	ng/l	-	-	-	-	-
γHCH (Gamma-hexachlorocyclohexane: Lindane) (Unfiltered Water: estuarine sites only)	HCHG	ng/l	-	-	µg/kg	-	-
Dieldrin	DIELD	ng/l	-	µg/kg	µg/kg	-	µg/kg
Aldrin (estuarine sites only)	ALD	ng/l	-	µg/kg	µg/kg	-	µg/kg
Endrin (estuarine sites only)	END	ng/l	-	µg/kg	µg/kg	-	µg/kg
Isodrin (estuarine sites only)	ISOD	ng/l	-	-	-	-	-
HCB (Hexachlorobenzene)	HCB	ng/l	-	µg/kg	µg/kg	-	-
PCP (Pentachlorophenol)	PCP	ng/l	-	-	µg/kg	-	-
DDT (Dichlorodiphenyltrichloroethane) [pp TDE, pp DDE, pp DDT]	TDEPP, DDEPP DDTPP	-	-	µg/kg	µg/kg	-	µg/kg
op DDT [estuarine sites only]	DDTOP	ng/l	-	-	-	-	-
HCBD (Hexachlorobutadiene) [estuarine sites only]	HCBD	ng/l	-	-	µg/kg	-	-
[Priority Hazardous Substances to be analysed on Unfiltered Water samples at estuarine sites only]		µg/l	-	-	-	-	-
PAHs (Polycyclic aromatic hydrocarbons) [Part of Special Survey of Additional Determinands]		-	-	µg/kg	µg/kg	µg/kg	-
Nutrients etc							
NH ₄ - N (Ammonium)	AMON	-	mg/l*	-	-	-	-
NO ₃ - N (Nitrate)	NTRA	-	mg/l*	-	-	-	-
NO ₂ - N (Nitrite)	NTRI	-	mg/l*	-	-	-	-
PO ₄ - P (Orthophosphate)	PHOS	-	mg/l*	-	-	-	-
SiO ₄ - Si (Silicate)	SLCA	-	mg/l*	-	-	-	-
Dissolved Oxygen	DOXY	mg/l†	-	-	-	-	-
Suspended solids	SUSP	mg/l	-	-	-	-	-
Chlorophyll a	CPHL	µg/l	-	-	-	-	-
Physical Measurements							
Secchi depth or other appropriate measurement	SECCI	m	-	-	-	-	-
Salinity		‰	-	-	-	-	-
Temperature	TEMP	°C	-	-	-	-	-
Oyster Embryo Bioassay							
Percent net response ²	PNR	%	-	%	-	-	-

¹ Also Congeners 77, 126 and 169 if possible

² $PNR = \frac{\% \text{ test abnormality} - \% \text{ control abnormality} \times 100}{100 - \% \text{ control abnormality}}$

Alternative units: Chemical measurements can alternatively be given as required by ICES,
i.e. as g/l (*=moles/l; †=1/l) or g/g I scientific notation expressed in the form: x.xxxExxx.

Code: ICES Parameter/Contaminant Code, to be used as determined identifier when recording data

UW: Unfiltered water

FW: Filtered water - pore size 0.45 microns

SS: Total Surficial Sediment - Total analysis of <2 mm fraction of sediment; dry weight

SF: Shellfish - wet weight (plus % solid and % lipid)

FL: Fish Liver - wet weight (plus % solid and % lipid)

Table 2. NMAQC Scheme determinands, error thresholds and lowest levels of interest

	Lowest level of interest	Thresholds	
		Absolute	%
AQUEOUS SAMPLES			
Group 1 - Seawater Nutrients			
Ammonia	5 µM	0.50 µM	20
TOxN	5 µM	0.50 µM	20
Nitrite	0.5 µM	0.05 µM	20
Orthophosphate	0.5 µM	0.05 µM	20
Silicate	5 µM	0.50 µM	20
Group 2 - Estuarine Nutrients			
Ammonia	20 µM	2.00 µM	20
TOxN	15 µM	1.50 µM	20
Nitrite	2 µM	0.20 µM	20
Orthophosphate	5 µM	0.50 µM	20
Silicate	20 µM	2.00 µM	20
Group 3 - Trace Metals (A and B)			
Cadmium	100 ng/l	10 ng/l	20
Copper	0.5 µg/l	0.05 µg/l	20
Lead	0.2 µg/l	0.02 µg/l	20
Nickel	0.5 µg/l	0.05 µg/l	20
Zinc	2 µg/l	0.20 µg/l	20
Chromium	2 µg/l	0.20 µg/l	20
Group 4 - Mercury (A and B)			
Total Mercury	5 ng/l	0.50 ng/l	20
Group 5 - Organochlorines (A and B)			
α-HCH	2 ng/l	0.2 ng/l	50
γ-HCH	2 ng/l	0.2 ng/l	50
HCB	2.5 ng/l	0.25 ng/l	50
HCBD	2.5 ng/l	0.25 ng/l	50
β-HCH	2 ng/l	0.2 ng/l	50
Dieldrin	5 ng/l	0.5 ng/l	50
Aldrin	5 ng/l	0.5 ng/l	50
Endrin	5 ng/l	0.5 ng/l	50
Isodrin	5 ng/l	0.5 ng/l	50
pp' DDT	3 ng/l	0.3 ng/l	50
pp' DDE	3 ng/l	0.3 ng/l	50
pp' DDD	3 ng/l	0.3 ng/l	50
op' DDT	3 ng/l	0.3 ng/l	50
Trifluralin	5 ng/l	0.5 ng/l	50
Total Endosulphan	10 ng/l	1 ng/l	50
1,2,4 TCB	6 ng/l	0.6 ng/l	50
1,3,5 TCB	6 ng/l	0.6 ng/l	50
1,2,3 TCB	6 ng/l	0.6 ng/l	50
Group 6 - Volatiles (A and B)			
Chloroform	1 µg/l	0.1 µg/l	50
Carbon tetrachloride	1 µg/l	0.1 µg/l	50
Trichloroethane	1 µg/l	0.1 µg/l	50
1,2 Dichloroethane	10 µg/l	1 µg/l	50
Trichloroethane	1 µg/l	0.1 µg/l	50
Tetrachloroethene	1 µg/l	0.1 µg/l	50
Group 7 - Pentachlorophenol (A and B)			
PCP	1000 ng/l	100 ng/l	50
Group 8 - Triazines			
Simazine	100 ng/l	10 ng/l	50
Atrazine	100 ng/l	10 ng/l	50
Group 9 - Organophosphorus Compounds			
Azinphos-methyl	200 ng/l	20 ng/l	50
Azinphos-ethyl	200 ng/l	20 ng/l	50
Fenthion	100 ng/l	10 ng/l	50
Malathion	150 ng/l	15 ng/l	50
Parathion	100 ng/l	10 ng/l	50
Parathion-methyl	150 ng/l	15 ng/l	50
Fenitrothion	100 ng/l	10 ng/l	50
Dichlorvos	200 ng/l	20 ng/l	50

Table 2. continued

	Thresholds	
	Absolute	%
SEDIMENTS		
Group 1		
Copper	1.00 mg/kg	20
Lead	2.00 mg/kg	20
Cadmium	0.05 mg/kg	20
Zinc	2.50 mg/kg	20
Nickel	1.00 mg/kg	20
Chromium	1.00 mg/kg	20
Mercury	0.005 mg/kg	20
Arsenic	1.00 mg/kg	20
Aluminium	0.5%	20
Group 2		
HCB	0.01 µg/kg	50
PCBs	0.01 µg/kg	50
Aldrin	0.01 µg/kg	50
Endrin	0.01 µg/kg	50
Dieldrin	0.01 µg/kg	50
Isodrin	0.01 µg/kg	50
pp'DDT	0.02 µg/kg	50
pp'DDE	0.02 µg/kg	50
pp'DDD	0.02 µg/kg	50
op'DDT	0.02 µg/kg	50
BIOTA		
Group 1		
Lead	0.20 mg/kg	20
Cadmium	0.05 mg/kg	20
Zinc	1.00 mg/kg	20
Mercury	0.01 mg/kg	20
Arsenic	0.30 mg/kg	20
Group 2		
Organochlorine cpds	0.50 µg/kg	50
PCBs	0.50 µg/kg	50
Group 3		
PCP	0.5 µg/kg	50

Table 3. Laboratories participating in the scheme (Year 3)

British Geological Survey, Keyworth
Clyde Regional Purification Board
Department of Agriculture, Northern Ireland, Aquatic Sciences Group
Forth Regional Purification Board
Industrial Science Centre, Industrial Research and Technology Unit
Ministry of Agriculture, Fisheries and Food, Burnham
Ministry of Agriculture, Fisheries and Food, Lowestoft
National Rivers Authority, Nottingham
National Rivers Authority, Waterlooville
National Rivers Authority, Exeter
National Rivers Authority, Fobney Mead, Reading
National Rivers Authority, Llanelli
National Rivers Authority, Leeds
Scottish Office Agriculture, Environment and Fisheries Department
Tay Regional Purification Board
University of East Anglia

The strategy adopted for the operation of the first year of the scheme has been continued through Years two and three of the scheme, with three activities contributing to the achievement of the aims of the scheme. These are:

(a) **Routine proficiency tests**

They provide a continuing check on comparability for the full suite, as far as practicable, of determinands and matrices required for the NMP.

(b) **Special exercises for important or 'problem' determinands**

These are a series of inter-laboratory tests which are intended to assist in the development of laboratories' systems and in achieving an improvement in performance where accuracy falls short of that required.

(c) Training workshops

Training workshops are organised to exchange information concerning best analytical practices. The workshops are co-ordinated with the programme of special exercises.

To date, special exercises have been carried out for aqueous mercury, trace metals, organochlorines, ammonia and total oxidised nitrogen (TOxN) in aqueous samples and trace metals in sediments. Workshops for mercury and trace metals in aqueous media, organochlorine analysis and sediments have been held.

The NCC recognises the need to establish links with and stimulate collaboration in international quality assurance schemes. This has been done through QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring in Europe), a project sponsored by the Community Bureau of Reference (BCR) and NMAQC has made use of materials derived from QUASIMEME. Timetables for workshops have been set in order to receive feedback from this international scheme.

Although it is presumed that participating laboratories will have their own in-house AQC, the scheme has produced a policy and procedures document, in order to encourage a co-ordinated UK approach. In-house AQC data from the participating laboratories have been collated, summarised and presented in the scheme's third annual report.

3.4 Laboratory performance

The major conclusions arising from the results of the routine proficiency tests, workshops and special exercises are described here. However it is clear from the performance data of the best laboratories that, in general, it is possible to produce data of the accuracy required for the NMP.

Analysis of aqueous samples in external distributions

A majority of laboratories achieved the required standard of accuracy for the determination of nutrients over the range of concentrations and sample types distributed. Initially the highest incidences of important error were for ammonia in both marine and estuarine waters; performance improved significantly in Years 2 and 3 for these determinands (see Figure 3).

Determination of trace metals in water for Year 1 distributions was often poor, largely due to insufficiently low limits of detection (LoD). In particular, improved methodology appears to be required for lead, mercury and chromium. In Years 2 and 3, significant improvements were made for mercury including more participating laboratories and lower LoDs.

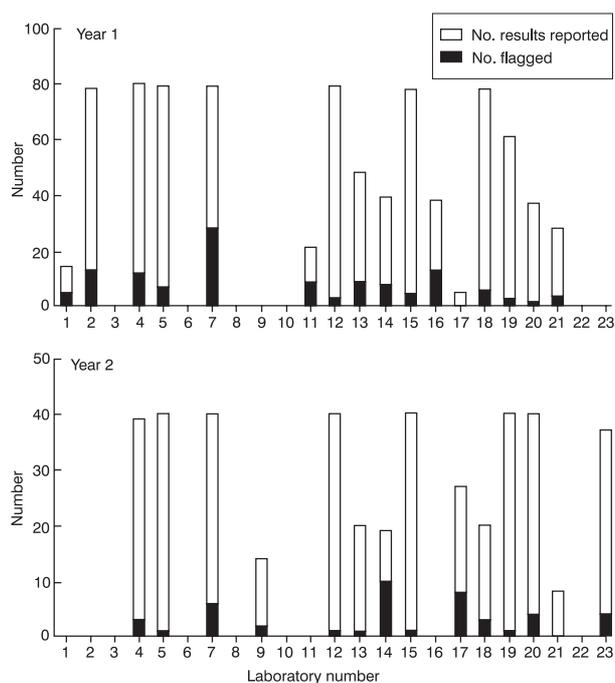


Figure 3. Performance in proficiency tests for aqueous nutrients, Years 1 and 2

In Year 1, laboratories fell into three roughly equal groups with respect to their determination of organics in water. Some reported a nearly full set of results with very few important errors. Others tended to produce results of satisfactory accuracy, but failed to report results for all determinands. The third group were subject to large errors, with inadequate limits of detection and intermittent reporting. In Year 2 there was a clear improvement in performance in routine proficiency tests. Laboratories' LoDs were improved and some new determinands were introduced which presented few problems. These improvements have been consolidated in Year 3.

Analysis of sediments in external distributions

The results of the routine proficiency tests indicate that relatively good comparability can be achieved for the determination of metals in marine sediments. Effecting further improvements appeared to depend on variations in the approach to sample digestion being ironed out. The NMP requires sediments of <2000 μm to be analysed for a total metal concentration using a digestion procedure involving hydrofluoric acid (HF). A special exercise for sediment trace metal digestions demonstrated that for the sediments under test the precision of extractions, using strong acids, carried out in a given laboratory appears to be relatively consistent across the group of laboratories. A typical value for within laboratory/digestion relative standard deviation was between 3.5% and 4.5% (including the within-batch analytical variation). This level of precision is considered quite adequate for NMP purposes.

The proportion of the metal content extracted by the different digestion methods varied from one metal to another. It appears that strong acid extraction methods and HF digestions were equivalent for copper and zinc. It is clear that for chromium and lead both the HF digestions and those based on strong acids are subject to significant negative bias with respect to the X-ray fluorescence (XRF) results for samples in this exercise. Although the methods based on HF digestion tend to solubilise a greater proportion of these two metals than strong acid methods, a true total value is not obtained.

There was good agreement between XRF and HF digestion for nickel. The strong acid digestions released approximately 90% of the metal from both sediments. Comparison of data between HF and strong acid digestions for cadmium indicates that a proportion of the metal may not be solubilised by strong acid attack.

XRF gives better recoveries than HF for some metals e.g. Cr and Ni. However since this technique is not widely available, MPMMG recommend the use of HF digestion.

Tight control of digestion procedures will be required to ensure comparability of data both between laboratories and between batches within a laboratory.

Whilst all three procedures, strong acid digest, HF digestion and XRF gave similar recoveries for some metals, use of HF digestion or XRF is required for aluminium. Determination of aluminium is required by the NMP to allow normalisation procedures to be applied to the data.

The determination of metals in sediments has shown an improvement in comparability of results in Year 2 compared with Year 1. A small number of laboratories have good control over the accuracy of results; others

showed evidence of problems. Many laboratories were inconsistent in their frequency of reporting results.

For organics in sediments the frequency for reporting of results has improved. The number of results failing to meet performance standards was reduced in Year 2 compared with Year 1.

Analysis of biota in the external distributions

Some improvements in performance for the analysis of trace metals in biota were evident between Year 1 and Year 2, with participation increasing for organic determinations. Further assessments have been made via the QUASIMEME scheme.

Summary of performance

The routine proficiency exercises indicated that overall performance was good compared to that achieved in similar inter-laboratory water analysis exercises, especially for the low concentrations that are of particular interest. There was overall similarity in performance between NRA, RPB and Government laboratories.

The required standard of accuracy for nutrient determinations was met by a large proportion of participants. However, improved accuracy appears to be required in some instances for trace metals in water and in some laboratories for organic determinands.

Overall performance is shown in Table 4. Acceptably high standards of performance might be regarded as those which combine reported data for a high proportion of determinands (>60%), with a low incidence of important error (>80% pass rate). During Year 3, 7 out of 15 participating laboratories, achieved this level of performance, compared with 3 in Year 2. Participation levels had also increased for the better performing laboratories.

Table 4. Overall Laboratory performance in Year 1, 2 and 3 for all matrices (aqueous, sediment, biota)

Laboratory No.	No. Reported Data Year 3	No. Flagged Data Year 3	% Returns			% Passes		
			Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
3	23	5	38.2	35.5	7.6	78.5	74.6	78.3
4	234	25	67.2	75.6	77.8	74.2	79.7	89.7
5	36	9	24.9	12.0	12.0	91.1	97.5	75.0
7	220	28	59.3	66.0	73.1	69.7	84.9	87.3
8	4	2	21.5	19.9	1.3	67.7	80.3	50.0
9	220	54	17.0	27.7	73.1	66.7	81.5	75.6
11	236	20	42.3	63.6	78.4	75.4	87.2	91.5
12	301	29	88.6	84.0	100.0	80.8	79.6	90.4
14	75	41	38.5	17.1	13.3	75.4	54.4	45.3
15	246	12	61.5	60.2	81.7	81.5	95.5	95.1
17	144	42	29.0	30.4	47.8	69.9	79.2	70.8
19	185	23	65.9	45.5	61.5	90.0	94.7	87.6
20	36	10	11.7	12.0	12.0	94.6	90.0	72.2
21	187	26	45.1	47.0	62.1	79.7	78.2	86.1
23	64	13	-	46.1	21.3	-	77.8	80.0

Maximum returns possible in Year 3 = 301

Data from distributions 7, 8, 9, 9(special) and 10 are included in Year 3 returns

There is evidence that quality systems are important in achieving consistently good analytical results. It is clear from the results of the NMAQC that analytical methods exist which will produce adequate data for the NMP. These methods have been adapted to work with success using a variety of equipment. However, these same chemistries were also used by some laboratories who failed to achieve the required standards. This confirms that the use of a standard method alone does not give adequate data - this will only be achieved if the method is applied as part of a system operated under quality assured conditions. The laboratories which had the highest levels of participation and the greatest accuracy are those with formalised quality systems subject to scrutiny by external assessors. The NCC is committed to guiding the participating laboratories towards National Measurement Accreditation Service (NAMAS) accreditation, which is recognised within the European Community (EC) and is equivalent to EN 45000 and ISO 9000 standards.

3.5 The future

The scheme has been planned to continue into Years 4 and 5, operating a similar strategy to that employed currently. This will allow a continued assessment of laboratories' performance, and offer a mechanism to laboratories to achieve performance improvements through special exercises and workshops.

The success of these exercises is reflected, not only by the standards of accuracy achieved, but also by the level of participation. Inter-laboratory tests can only provide a demonstration of proficiency if laboratories continue to report data for as wide a range of determinands as possible. For all determinands and matrices, continued attention to the application of routine AQC, involving the development and use of realistic control materials, is essential.

The preliminary stages of gathering and reporting on in-house AQC have indicated that there is scope for making operational improvements in this area. The more widespread participation of laboratories in accreditation schemes such as NAMAS is to be encouraged.

To promote the fullest possible participation in the scheme, data provided for NMP purposes will be checked to ensure that they have been subject to the rigours of the Marine Chemical AQC scheme. All data not subject to the scheme will be flagged. In due course, data failing to meet the specified quality performance standards will be identified by a separate flag. Indeed the principle should apply to all marine data.

4. NATIONAL MARINE BIOLOGICAL ANALYTICAL QUALITY CONTROL

4.1 Introduction

Following the establishment of the National Marine Chemical AQC Scheme in 1992, it became clear that the biological components of the National Monitoring Programme would not be covered by the scope of that scheme. The National Co-ordinating Committee however, recognised the need for a suitable biological AQC programme and recommended to the MPMMG that a separately funded and co-ordinated biological AQC scheme be developed. This recommendation was endorsed by the MPMMG in April 1993 and in September 1993 the Co-ordinating Committee for the National Biological AQC Scheme met for the first time. The Committee was formed from members of the Group Co-ordinating Sea Disposal Monitoring (GCSDM) Biological Task Team (see Section 5) and built upon the experience of intercalibration exercises undertaken by that group. The Scheme was designed initially to target the benthic ecology component of the NMP.

All Laboratories submitting data to the NMP agreed to participate, as well as a number of other organisations and in March 1994, a contract was awarded to UNICOMARINE to carry out the programme for 1 year, with the Scheme being administered by the Clyde River Purification Board.

4.2 Year 1

During Year 1, the Scheme was designed to test laboratories' taxonomic proficiency and sample processing techniques through inter-laboratory testing using ring tests and the circulation of 'real' grab samples. The programme also included particle size analysis and biomass determination within its list of determinands. A recommendation made to the MPMMG that the chemical AQC group be requested to include the determination of sediment organic carbon and chlorophyll a in water in its programme was taken up.

The first distribution of material took place in April 1994 and the first year's programme was completed in March 1995.

Fewer than half of the participating laboratories met the standards laid down by the Co-ordinating Committee. Many laboratories performed well in individual components of the scheme although some laboratories

exhibited a generally poor performance. The Co-ordinating Committee expressed the view that no laboratories should have their data 'flagged' as unsuitable for the NMP database until Year 2 of the scheme was completed. This was due to the difficulty in relating laboratory performance in the scheme to the analysis of real samples. The Co-ordinating Committee also recognised that many biology laboratories were new to the concept of AQC schemes and through the National Marine Biological Analytical Quality Control (NMBAQC) scheme now had suitable information to allow them to improve their performance and develop good procedures.

4.3 Year 2

Following the response to a questionnaire distributed to participants the scheme was modified to include analysis of a participants routine macrobenthic sample. A number of special projects were undertaken by the contractor including:

- (a) the development of a standard list of taxonomic references based on information obtained from ring test returns and macrobenthic exercises;
- (b) identification of problem taxa;
- (c) investigate the possibility of having twinned sediment samples analysed perhaps using different analytical techniques to allow comparison of methods.

During the second year of the scheme participation levels remained high although the level of returns decreased slightly.

The Co-ordinating Committee spent a great deal of time during the year debating the problem of standards. Eventually after taking into account feedback from the participants, two standards were proposed, one relating specifically to the NMP which is based on the returns from user supplied samples applying the following separate standards.

Total Taxa Target -
± 10% or 2 taxa whichever is greater. Based on comparison between laboratory and contractor value.

Total Abundance Target -
± 10% or 2 individuals whichever is greater. Based on comparison between laboratory and contractor value. A more relaxed standard of ± 20% may be applied to samples requiring subsampling.

Total Biomass Target -
± 20%. Based on comparison between laboratory and contractor value.

Bray-Curtis Similarity Target -
± 90%. Based on comparison between laboratory and contractor value.

Taxa Correctly Identified Target -
± 5% or 2 taxa whichever is greater. Based on a comparison between laboratory and contractor value.

The same standards will be applied for contractor supplied samples. For ring tests a suggested achievable standard 90% correct over the year. Laboratories will be assigned to quartiles using a simple numerical ranking system for each determinand.

The interpretation of returns from particle size analysis exercises has been problematic and the Co-ordinating Committee is seeking to co-opt outside expertise to offer advice. In the interim a provisional standard has been based set on the determination of the <63 µm fraction to ± 10% total weight of sediment. For both the ring tests and the contractor supplied benthos samples.

For those labs participating in the NMP the only meaningful assessment of their capabilities with respect to their NMP samples is an assessment of their actual performance on those (or very similar) samples, and not on someone else's samples. Relevant user supplied samples should therefore be the sole basis for QA of NMP data.

As a benthic sample consists of an assessment of a number of quasi-determinands (i.e. total taxa, total abundance, etc.), any assessment of a laboratory's performance should be made on the basis of these individual determinands. If these determinands were combined into some overall assessment, valuable information would be lost. Recognising that the Biological AQC has wider significance outside of the NMP a proforma has been produced (Table 5) which deals both specifically with an assessment for the NMP laboratories (the boxed section) and also deals with other elements of the scheme. The standards are generally consistent with what a majority of laboratories achieved in macrobenthos exercises.

The Co-ordinating Committee has also been given the task of advising the NMP Working Group on the archiving and analysis of the biological data generated from the NMP. This has included advice on how taxonomic lists should be classified and the committee has begun to make progress in linking the US National Oceanographic Data Centre (NODC) codes to the

Table 5. NMBAQC proforma

NMBAQC PERFORMANCE REPORT FOR NMP LAB

LAB CODE:

Lab Supplied Sample	Sample Ref	Sample Ref	Sample Ref	Average	NMP Flag
Total Taxa Target (abs % diff)					P/F
Total Abund. Target (abs % diff)					P/F
Total Biomass Target (abs % diff)					P/F
Bray Curtis Similarity (% diff)					P/F

Particle Size Analysis	Sample Ref	Sample Ref	Sample Ref	Average	
% material <63 µm (% difference from mean)					P/F

Ring Test Score (out of 75):

Contractor supplied benthos sample	Sample Ref	Sample Ref	Sample Ref	Average
Total Taxa Target (abs % diff)				
Total Abundance Target (abs % diff)				
Total Biomass Target (abs % diff)				
Bray Curtis Similarity (% diff)				

Lab supplied samples quartile:	1	2	3	4
Particle size samples quartile:	1	2	3	4
Ring Test quartile:	1	2	3	4
Contractor supplied benthos samples quartile:	1	2	3	4
Comments:				

Marine Conservation Society Species Directory taxonomic lists. In order to facilitate the production of the new edition of the species directory it has been agreed that the AQC scheme will provide an element of financial support.

4.4 The future

As the scheme moves into its third year it is anticipated that more effort will be channelled into the incorporation of user supplied or 'real samples' into the planned circulations. It can be anticipated that a substantial amount of effort will be devoted to the holding of specialised workshops dealing with such topics as so called 'problem taxa' and problems of field AQC and sample processing.

5. CO-ORDINATION OF THE MONITORING OF SEA DISPOSAL ACTIVITIES

5.1 Introduction

Before the period covered by this report, a sub-group of MPMMG carried out a review of monitoring at sewage sludge disposal sites. This concluded that much of the monitoring did not follow any recognisable pattern, and in most cases, both the objectives of the monitoring and the details of how results were assessed were unclear. The MPMMG accepted these conclusions and in 1987 established a Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites.

From the outset it was recognised that there are similarities between the requirements for monitoring sewage-sludge disposal sites and the sites used for the disposal of other materials. However, attention was focused initially on sewage sludge, and by mid-1991 that mission had largely been accomplished. MPMMG then agreed that attention should also be turned to monitoring the impact of dredged material disposal and perhaps pipeline discharges. In recognition of these extended terms of reference, the Group's name was changed to the Group Co-ordinating Sea Disposal Monitoring (GCSDM). Its membership was enlarged to include a member from the NRA and two representatives of dredging interests, one from industry and one with expertise in the field of impact assessment. The current membership is given in Appendix 2.

The Group advises MPMMG and its parent Government Departments on policy and on the extent to which the advice is implemented by the licensing authorities and licensees. Much of its detailed work is carried out by specialist Task Teams, (Appendix 2) allowing input from a wide range of organisations with relevant expertise, although the membership of GCSDM itself is kept small.

The GCSDM has published reports each year (GCSDM, 1992; 1993; 1994(a)), describing the activities of the Group and its Task Teams. Each report provides a summary of monitoring at each disposal site in the immediately preceding year, and includes a detailed analysis of monitoring conducted the year before that. Particular attention is paid to how closely monitoring complies with the guidelines laid down by GCSDM, and the extent to which the results demonstrate compliance with the environmental quality objectives and standards established by the Group. It is pleasing to note that there has been a marked improvement in both respects since the Group was established.

5.2 Environmental Quality Objectives

One of the first tasks undertaken was to define a set of environmental quality objectives which would protect key uses of the marine environment. These are:

- maintenance of basic amenity use,
- maintenance of fish and shellfish of a quality suitable for harvesting for human consumption,
- protection of commercially exploited species,
- general ecosystem conservation,
- preservation of the natural environment.

For each of these uses, criteria were laid down so that compliance could be judged, and the standards were quantified wherever possible.

5.3 Improvement of methods

It was also apparent at the outset that the different organisations involved in monitoring used different procedures and that it was uncertain how comparable their results would be. In order to resolve this situation, three specialist Task Teams were established to advise on: (1) the methods to be used for conducting benthic sampling and assessment of the benthos; (2) sampling and analysis of metals in sediments; and (3) sampling and analysis for organic contaminants in sediments.

Once these tasks were completed, intercomparison exercises were carried out to ensure that the organisations involved were capable of producing comparable results. Finally, the Task Teams undertook work to establish a full set of quantifiable standards against which compliance with the defined environmental quality objectives can be judged. In 1989, a second biology Task Team was set up to advise on the extent to which existing biological effects techniques (i.e. those involving sub-lethal responses) are applicable to sewage sludge disposal monitoring. Its report was included in the second report of the Group (GCSDM, 1991). A further biological effects Task Team was established in 1993 to advise on a suitable technique

for use in assessing the toxicity of sediments to animals living in them. The GCSDM also successfully promoted the development of an Infaunal Trophic Index as a means of defining the biological well-being of an area.

5.4 Dredged material disposal

In addition to the uses of the marine environment that may be affected by sewage sludge disposal, the following requirements should be added in order to ensure protection from the effects of dredged material disposal:

- coastal zone management (i.e. there should be no effect on coastal erosion unless it is a deliberate goal, as in beach nourishment),
- navigational uses should not be affected by the disposal operation or by settled material,
- fishing activities should not be adversely affected by the disposal operation.

It is accepted that the standards set for dredged material sites may be different to those set for sewage-sludge disposal sites. As most standards are expressed in terms of divergence from a norm, this should not be a problem in extending the guidance to cover both. Also, the numerical limits set for contaminants are related to organic content, and therefore they are site specific. At present, they should be regarded as tentative guideline values rather than strict standards.

5.5 Sewage sludge disposal

The UK Government has recognised the strength of opinions overseas against the disposal of sewage sludge at sea and has accepted that alternative means of disposal are available. Accordingly, it was announced early in 1990 that the disposal of sewage sludge at sea would cease by the end of 1998. However, there remains an international obligation to monitor the continuing impact of sewage-sludge disposal operations. Also, although no major impacts have been observed at most sites, in many cases the monitoring programmes were initiated long after disposal operations started. Thus, when disposal ceases, it is possible that subtle, previously unnoticed changes might be reversed. Monitoring to establish whether this actually occurs will be useful in a number of respects. This would be particularly important should it prove necessary in the future to foreclose on presently accepted disposal practices, such as incineration or use on agricultural land, and reconsider the sea disposal option.

MPMMG has therefore endorsed the GCSDM recommendation that monitoring should continue at all sites for the first year after disposal ceases. Also, recognising that all the major sites (i.e. Forth, Clyde, North Channel, Liverpool Bay, Thames and Tyne) are

different, monitoring should continue at these sites at a reduced level every two years, for up to ten years, or until it is clear no change is occurring, whichever is sooner. At the other sites, a single further survey should be conducted six years after disposal ceases. In the first year, monitoring will be carried out by the licensee as well as the licensing authority, but thereafter, monitoring would be the sole responsibility of the licensing authority. This extended monitoring will be less intensive than that previously undertaken, in the numbers of determinands and stations sampled.

5.6 Pipeline discharges

Up to the end of 1993, the questions of what uses need to be protected from the adverse effects of pipeline discharges, and how compliance with present standards should be assessed, had not been examined. In England and Wales, the NRA was responsible for the regulation of pipeline discharges, a role taken by the River Purification Authorities in Scotland, and DoE(NI) in Northern Ireland. However, in 1992 the DoE asked the GCSDM to provide advice on the type of comprehensive studies that would be required to demonstrate that an area to which sewage is or may be discharged can be identified as 'less sensitive' under the terms of the EC Urban Waste Water Treatment Directive. This was an important task, because the outcomes of the studies have major implications for the level of sewage treatment, and therefore expenditure, applied by sewage disposal authorities throughout the UK.

Following previous practice, a new Task Team was established to produce appropriate advice. A report was produced, accepted by GCSDM and MPMMG and, following DoE approval, published early in 1994 (GCSDM, 1994(b)). The GCSDM has been asked to review how useful the guidelines have proved, and to identify any changes that are needed. This task was undertaken in 1995 and some minor clarification of certain guidelines will be issued.

5.7 Conclusions

The GCSDM has achieved considerable success in introducing a much more co-ordinated approach to monitoring of sea disposal sites and a readily understandable set of common guidelines and standards is now in place. Unfortunately, not all parties have accepted that quality assurance is an essential prerequisite of good monitoring, and some licensees still supply data which, due to lack of QA or inappropriate detection limits, are of no value. Nevertheless, there have been marked improvements in compliance with the standard based on the principle of 'no sewage derived litter on disposal grounds'. Most monitoring is now conducted according to the guidelines, and the results demonstrate that uses of the sea are not being prejudiced by sewage disposal to sea.

6. THE ENVIRONMENTAL IMPACT OF MARINE FISH FARMING

6.1 Introduction

Rapid expansion of the salmon farming industry during the 1980s resulted in the establishment of large numbers of sea cages in sea lochs in western Scotland and Ireland. Public concern over the potential impact on the marine environment focused on the degradation of benthic communities around sea cages due to deposition of organic matter, the use of chemicals and their release to coastal waters, and the potential eutrophication of sea lochs and coastal areas caused by nitrogen and phosphorus from fish cages. To address this, a sub-group on marine fish farming was set up following a submission by SOAFD to MPMMG in January 1989. At the time, River Purification Authorities, NRA regions with salmon farms in their areas, and DoE(NI) were each considering means for the measurement, monitoring and control of biological and chemical impacts. There was a need for co-ordination of the strategies being developed in different areas.

The sub-group was asked to address the following remit:

- to examine all aspects of pollution as a result of the use of chemicals and the by-products of fish farms with a view to advising on possible problems and their scale,
- to examine the control measures in use and advise on the most appropriate measures for common adoption.

The sub-group met five times between September 1989 and December 1990, and presented its final report to MPMMG in 1991, after which it was published as a SOAFD Scottish Fisheries Working Paper (MPMMG, 1992).

Membership of the sub-group was drawn from departments and organisations with a specific interest or experience in managing the environmental impact of marine aquaculture. Cross-membership with other technical working groups included GCSDM, the ICES working group on environmental impact of mariculture, the Association of Directors and River Inspectors of Scotland (ADRS) technical working group on monitoring of caged fish farms, and the DANI/DoE(NI) Aquaculture Committee. This ensured rapid assimilation of relevant ideas from as many sources as possible.

6.2 Legislation

The sub-group examined legislative means available in the UK for setting environmental quality and discharge

standards, monitoring compliance, and enforcement. In all regions, the management of environmental effects is based on legal requirements that discharges to water be consented by a regulatory authority, since discharges from fish farms are considered as trade effluents under the 1989 Water Act in England and Wales, the 1974 Control of Pollution Act in Scotland, and the Water Act (Northern Ireland) 1972. The conditions imposed on fish farmers in various regions in order for consent to be granted were discussed in relation to the potential and practicality of establishing a common approach between regions.

6.3 Impacts of marine fish farming

With reference to published papers and other available data, the sub-group reviewed documented cases of environmental impacts caused by caged salmon farms at sea, in the following areas:

- effects on sediments and the benthic environment,
- effects on water quality, including nutrient enrichment and effects of chemical treatments,
- effects on microbial communities and fish populations.

With the exception of effects of organic waste on sediments and the benthic environment, it was clear that specific adverse effects have not been demonstrated in UK waters for many potential pollutants released from fish farms. However, this does not necessarily mean that there is no potential for adverse effects, and there is a need for work on particular aspects, such as nutrient enrichment. SOAFD studies on the toxicity of releases of dichlorvos were noted as a demonstration of the potential for some direct short-term toxicity to zooplankton coming into contact with water released from cages after the use of this pesticide as a de-lousing treatment.

6.4 Environmental Quality Objectives and Standards

The sub-group produced proposals for managing and controlling fish farm impacts by means of Environmental Quality Objectives (EQOs) and Standards (EQSs). This is in line with UK and European Community practice, and takes account of the intended adoption of statutory water quality objectives in the UK. In proposing this approach, the organisations represented on the sub-group were able to draw on their experience of monitoring practices which have proved workable.

There will always be an area around a sea cage operation where environmental quality standards set for the protection of pristine environments cannot be met.

However limited this 'mixing zone', there are implications for monitoring strategies. Also, even within the immediate area surrounding fish farms there is a need to limit certain potential effects. These aspects were built into a set of detailed proposals for consideration by the authorities responsible for monitoring impacts. EQSs were recommended where there was sufficient information available on which to base a standard. If this was not possible, the need for further work on the chemicals and determinands concerned was highlighted.

One of the remaining problems is how to detect statistically the point at which chemical contamination or biological change becomes unacceptable. This requires further study. There is potential to use hydrodynamic and dispersion models as an aid to defining 'mixing zones', although plugs of effluent present a potential problem.

The sub-group considered that although the most desirable standards or limits would ideally be set on a statistical basis, in reality the imposition of annual 95 percentile standards analogous to those set for freshwater monitoring would present an unacceptable sampling burden.

6.5 Conclusions and recommendations

The concluding section of the published report lists specific recommendations for action on monitoring and control of fish farming operations. Where there is insufficient information, long- and short-term research needs have been identified. Key gaps in current knowledge include the lack of marine biotic pollution indices based on benthic community structure, and inadequate understanding of the mechanisms linking nutrient availability to algal growth in coastal waters receiving fish farm wastes. The effects of releases of antibiotics to the environment is also an area where research is required. Some work is currently under way on these aspects, and will help to reduce the information gaps.

7. RADIOACTIVITY IN THE IRISH SEA

7.1 Introduction

The following is a brief summary of a 65 page report prepared for MPMG by staff of the then Aquatic Environment Protection Division of the Directorate of Fisheries Research (DFR) (Kershaw *et al.*, 1992). Data are presented using the Système Internationale (SI) radiological units. These are summarised in Appendix 4.

The principle sources of radioactive waste discharges to the Irish Sea are related to power generation and the nuclear fuel cycle; these are dominated by those from the Sellafield nuclear reprocessing plant, situated on the Cumbrian coast. Low-level radioactive liquid wastes from Sellafield, resulting from the reprocessing of irradiated fuel and the conditioning and storage of nuclear material and radioactive wastes are discharged, under authorisation, into the eastern Irish Sea.

The quantities of radionuclides discharged have changed markedly with time (Figure 4). The quantities of some of the shorter-lived fission product nuclides in the effluent, such as ^{95}Zr and ^{106}Ru have steadily declined since the early 1970s, whilst discharges of ^{134}Cs and the longer-lived ^{137}Cs reached peak values from 1974 to 1978 and then declined. Discharges of the major transuranium nuclides have also fluctuated, with peak values of ^{241}Am from 1971 to 1975 and of ^{241}Pu from 1970 to 1980.

Discharges of Pu and Am were reduced further from 1994 onwards, with the commissioning of the Enhanced Actinide Removal Plant (EARP). Conversely, the quantities of ^{99}Tc , ^{129}I , ^{60}Co and ^{14}C increased as a result of both the processing of the medium-level radioactive liquors (stored on site) and the starting-up of the Thermal Oxide Reprocessing Plant (THORP).

7.2 Radionuclides in sea water

In recent years the distribution of ^{137}Cs in the Irish Sea and certain adjacent waters has been determined annually. The considerable reduction in Cs discharges since the mid-1970s has resulted in a decrease in Cs concentrations in the water. Figure 5 compares the distribution in 1977 with that in 1988.

There is evidence to suggest that since the early 1980s, concentrations of ^{137}Cs in near-shore waters have not decreased as quickly as the reduction in the discharge would have implied. This suggests that there is re-mobilisation of ^{137}Cs from the subtidal sediments as the system re-equilibrates - an hypothesis which is supported by model calculations and some limited experimental work (Kershaw *et al.*, 1990)

The overall decline in Cs concentrations in the Irish Sea and other UK waters was interrupted in April 1986 following the Chernobyl reactor accident. The signal from this could be detected in increases in the concentrations of ^{134}Cs , ^{137}Cs and other radionuclides. However, levels decreased rapidly in near-shore waters of the Irish Sea, the effects being more marked and longer lasting in the North Sea.

The labelling of sea water by Cs radionuclides from Sellafield has provided excellent opportunities to study the hydrography of the area as a whole and of adjacent

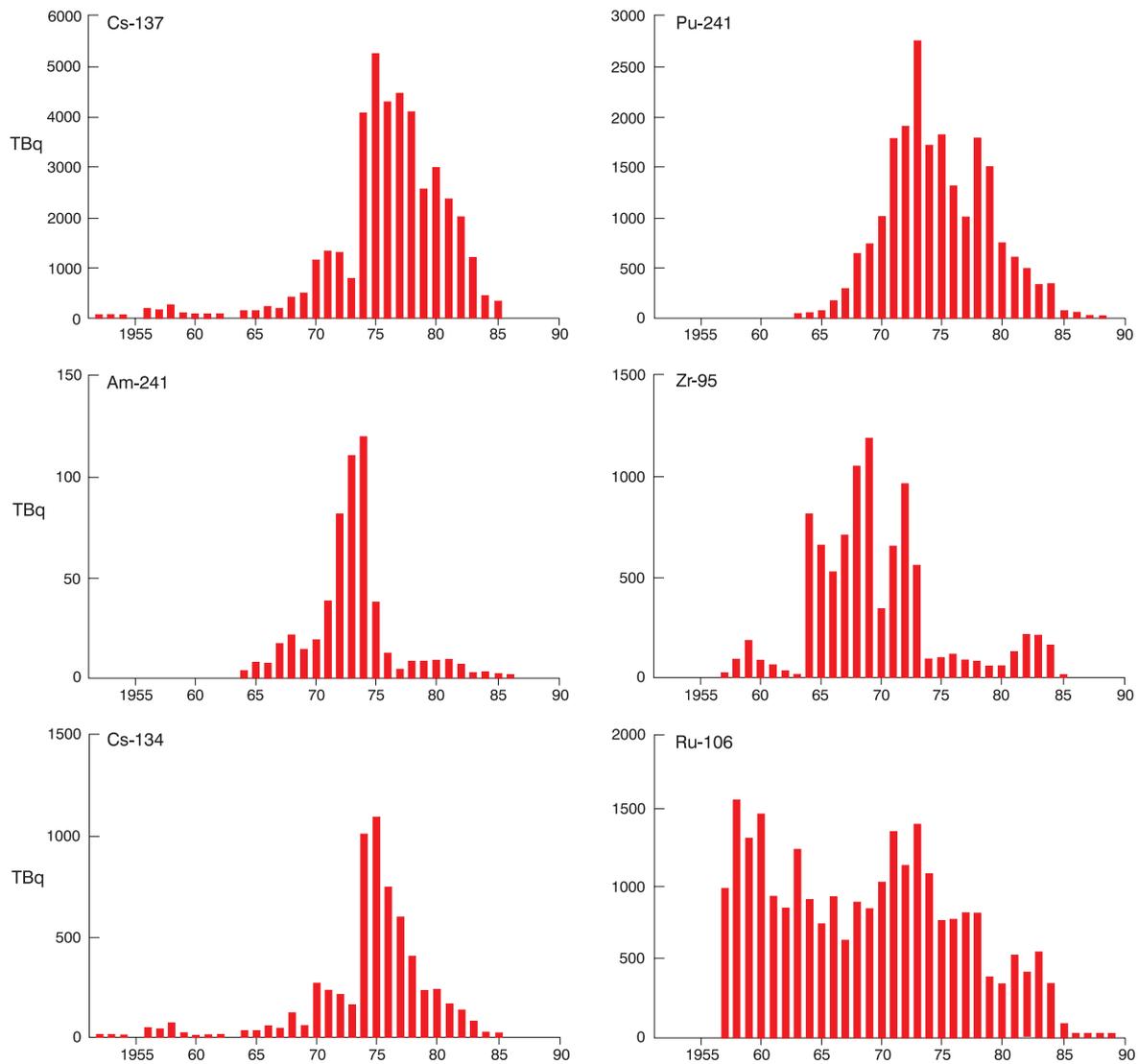


Figure 4. Annual discharges to sea from BNFL Sellafield

waters. The waters leaving the Irish Sea pass through the Clyde Sea and using ^{137}Cs data, the rate of exchange of the water, has been estimated to be approximately 4.5 months.

The increased discharge of ^{99}Tc from Sellafield, resulting from the commissioning of the EARP and THORP plants in 1994, has provided an opportunity to use this tracer to study water movements and validate transport models within the Irish Sea, and exchange in the North Channel, Malin Shelf and along the Scottish coastal current.

7.3 Radionuclides in sediments

The seabed sediments of the north-eastern Irish Sea represent a significant sink for many of the radionuclides discharged from Sellafield. Their distributions are strongly influenced by distance from the source, the time dependant variations in the quantities discharged and the nature of the sediments.

The detailed distribution of gamma-emitting radionuclides in sub-tidal sediments has been described by Jones *et al.* (1988). The distributions of ^{137}Cs , ^{106}Ru and $^{95}\text{Zr} + ^{95}\text{Nb}$ were similar, with contours of equal activity running parallel to the coast, displaced north of the outfall (Figure 6). A recent re-interpretation of existing, extensive DFR data from samples collected between 1968 and 1988, has confirmed the existence of the 'northerly foot'.

Recent hydrodynamic modelling has indicated that persistent northerly flows of bottom water are set up parallel to the Cumbrian coast during strong northerly and westerly gales, because of topographic constraints on the wind-driven flow (Davies and Jones, 1992). Westerly gales will also result in the greatest wave induced resuspension. It is evident that a mechanism exists which could result in the episodic movement northwards of particle-associated radionuclides, away from the vicinity of Sellafield. Model developments are

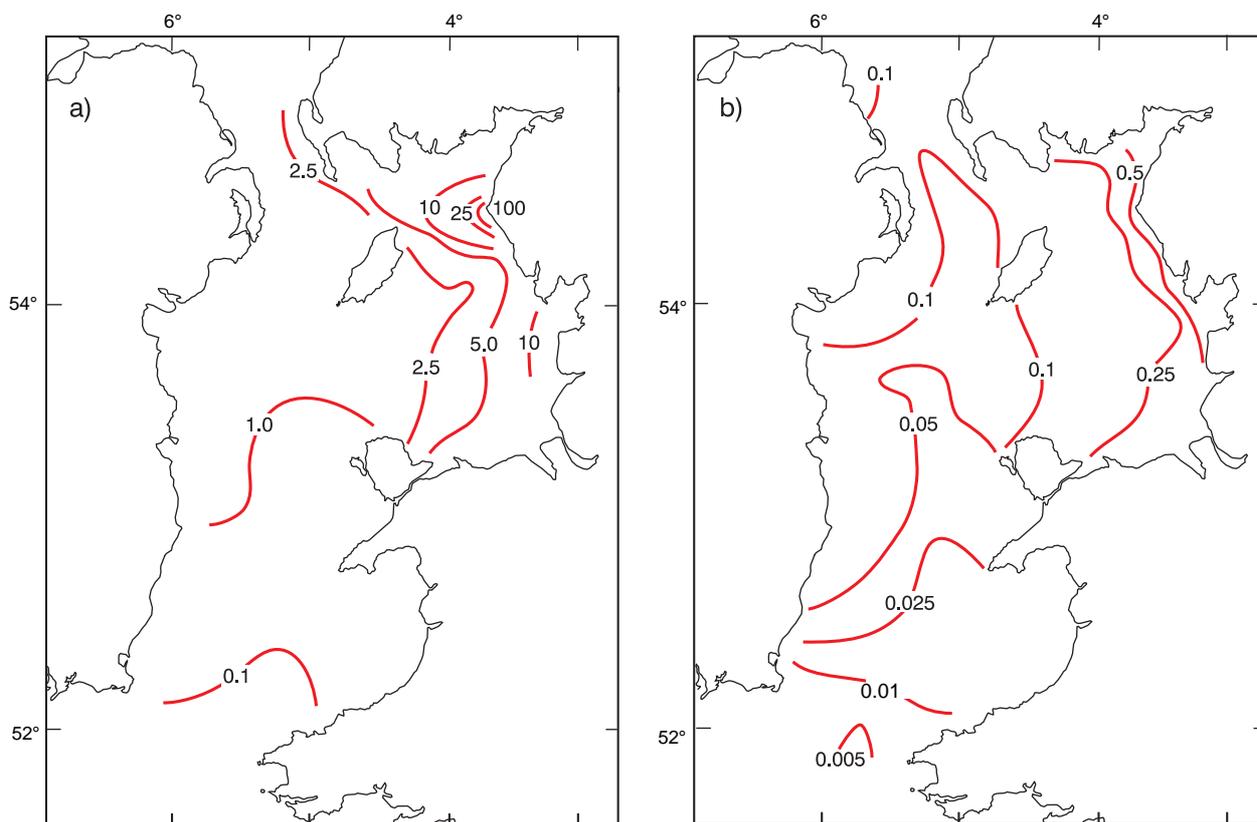


Figure 5. Distribution of ^{137}Cs (Bq kg^{-1}) in filtered sea water in the Irish Sea for the years (a) 1977 and (b) 1988 (from: Hunt, 1979, 1989)

being linked to a major field programme addressing the problem of cohesive sediment dynamics (COSED).

The interest in the contaminated offshore area is primarily because of its potential to act as a significant long-term sink, or continuing source, of long-lived nuclides in the future. Contaminated estuaries and the shore-line in general, are important areas because of the public's direct contact with them.

The intertidal zone, when exposed to wave activity, is dominated by sandy deposits. Consequently radionuclide concentrations are relatively low but the dynamic nature of this environment results in a large volume of sediment becoming contaminated, with uniform mixing of beach sands to the base of the wave activity being common.

Details of the contamination of a number of estuaries and intertidal areas are given in the report.

7.4 Accumulation of radionuclides by biota

From the earliest commissioning of the Sellafield plant, samples of marine biota in the area were analysed for their radionuclide content. One of the first important

observations was that benthic algae concentrated ^{106}Ru , significant because one species, *Porphyra umbilicalis*, was harvested for human consumption. Estimated concentration factors for a range of biota are given in Table 6 (Preston and Jefferies, 1969(a)). The accumulation of Cs nuclides by fish was also considered of importance because of the quantities of fish caught in the area for human consumption; a considerable amount of data on this is given in the full report.

A detailed laboratory study was carried out by Jefferies and Hewett (1971), on the accumulation of ^{134}Cs from sea water by plaice (*Pleuronectes platessa*), with comparative studies on the thornback ray (*Raja clavata*). They concluded that, at least 50% of the environmental body burden of Cs in plaice, and 80% in rays, was due to absorption from food rather than the uptake from sea water. An assessment of other gamma emitting fission product nuclides in the diet of plaice conclude that apart from ^{137}Cs and to some extent ^{106}Ru , other fission products are not accumulated by fish muscle. This was in contrast to, for example, crabs (*Cancer pagurus*) which have readily detectable concentrations of ^{144}Ce , $^{95}\text{Zr}/^{95}\text{Nb}$ as well as ^{106}Ru and ^{137}Cs in hepatopancreas and muscle tissue. From studies on transuranium nuclides it was generally concluded that neither Pu nor Am was highly accumulated by benthic or pelagic fish.

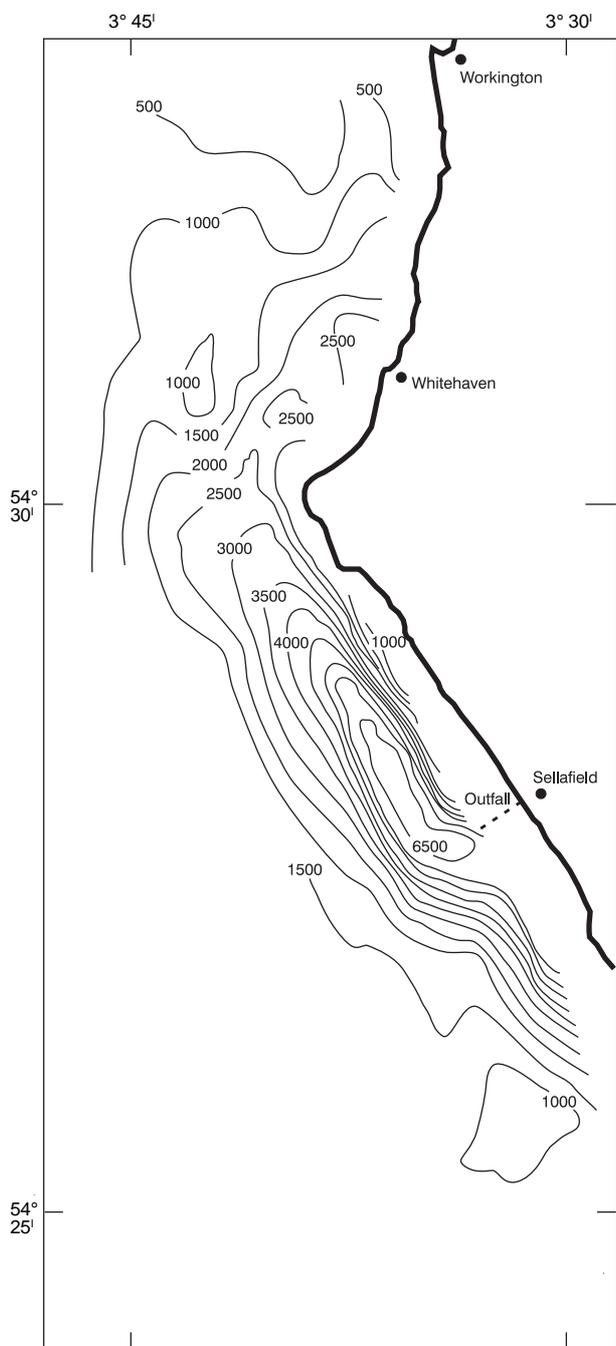


Figure 6. Distribution of ^{137}Cs (Bq kg^{-1}) in seabed sediments in the eastern Irish Sea for the year 1982 (from: Jones et al., 1988)

7.5 Assessment of radiation exposure to the public

The discharges from nuclear sites, including those from Sellafield, are subject to strict authorisation and environmental surveillance by UK Government departments. These measurements are implemented in order to safeguard the public, based on the recommendations of the International Commission on Radiological Protection (ICRP) and the advice of national bodies on radiological protection, a role played in the UK since 1970 by the National Radiological Protection Board (NRPB).

Table 6. Estimates of concentration factors for several fission product nuclides (from: Preston and Jefferies, 1969(a))

Sample	^{106}Ru	$^{95}\text{Zr}/^{95}\text{Nb}$	^{137}Cs	^{90}Sr
<i>Fucus vesiculosus</i>	330	1700	100	6
<i>Porphyra</i>	1800	420		1
Mussels	2000	950	15	8
Winkles	2000	1000	100	17
Limpets	1200	750	70	15
Lobster	25	10	25	
Shrimps	600	200	100	
Plaice	10		45	0.3
Skate	1		25	0.3

The changes in the nature and relative importance of particular exposure pathways during the past four decades are summarised below.

Dose limits for exposure of individuals and critical groups, and the assumptions made in calculating these limits, have been subject to review. MAFF (1992), provides a summary of the changes which have been made, or are contemplated. The ICRP dose limitation system includes the requirement that 'all exposures shall be kept as low as reasonably achievable..' (ALARA). This applies both to individual and collective doses in radiological control procedures.

In the early 1960s, the critical exposure pathway was the consumption of laverbread, which is produced from the alga *Porphyra*, particularly in the Swansea area of south Wales; much of the *Porphyra* used was collected from the coast near Sellafield. A detailed survey, (Preston and Jefferies, 1969(b)), estimated that the critical group had a median consumption rate of 160 g day^{-1} , resulting in doses of 4 to 7 mSv year^{-1} to the lower large intestine of adults, during the period 1962 to 1967.

Although contaminated sediments in the Esk Estuary and concentrations of Cs in fish were identified as secondary and tertiary exposure pathways, *Porphyra* consumption remained the dominant pathway until 1972, when the harvesting of *Porphyra* from the coast near Sellafield ceased. Routine monitoring of both laverbread and *Porphyra* from the Sellafield coast has, however, continued since they remain potential sources of exposure, though decreased discharges since the mid-1970s have reduced the potential importance of this pathway. By 1974 the consumption of fish and shellfish had become the dominant pathway due to the increasing discharges of ^{134}Cs and ^{137}Cs . The estimated percentages of the ICRP dose limit for members of the public during the period 1970-76 are given in Table 7. The concentrations of transuranium nuclides in fish flesh is low, but they are accumulated in molluscan shellfish.

Their importance in the critical pathway increased in the 1980s, due to the increased consumption of local shellfish; the importance of ^{137}Cs decreased at this time, the quantities discharged having been substantially reduced. By the late 1980s, the external exposure pathway was perceived to be the critical pathway, resulting from activities such as angling, living on houseboats, small boat maintenance, beach walking, fishing, farming, policing of nature reserves and inhalation. The most significant doses result from boat occupancy, with critical groups in the Wyre and the Ribble estuaries receiving a mean dose of 0.14 mSv and 0.17 mSv per year respectively in 1989. (The ICRP recommended dose limit had been reduced to 1 mSv per year by this time.)

Table 7. Maximum exposure, as a percentage of ICRP-9 limits for members of the public (5 mSv year⁻¹) resulting from Sellafield discharges from 1970 to 1976

Year	Porphyra/ laverbread (Critical group)	External exposure (Ravenglass)	Fish consumption (Critical group)
1970	5	12	1
1971	33	11	3
1972/3	2	7	3
1974	<0.2	7	14
1975	<0.2	9	34
1976	0.2	8	44

7.6 Impact on the environment

The assessments of the impact of discharges from Sellafield have always taken the irradiation of the local marine fauna and flora into consideration. Initial calculations had estimated that, at the maximum permissible discharge rate, the maximum possible dose rate would be about 0.45 mSv hour⁻¹, over a relatively small area. It was concluded that such a dose rate would be unlikely to have any significant effect on the marine ecosystem (Dunster *et al.*, 1964).

It must be assumed that any exposure to radiation carries some degree of risk of harm. For marine organisms, however, if the damage to individuals does not manifest itself at the population level and does not damage the overall reproductive capacity of the population, the effect may be regarded as being of little significance. In a comprehensive review of radiation effects, particularly on teleosts, it was concluded that the lowest dose rate at which minor radiation-induced disturbances of physiology or metabolism might be detectable was ~400 mSv hour⁻¹. The dose rates around Sellafield are

at least an order of magnitude below those which would be expected to elicit any effect under controlled laboratory conditions and about two orders of magnitude below those which might be expected to have an effect at the population level during the period of maximum discharges.

7.7 Concluding remarks

It should be apparent that a considerable body of knowledge exists on the behaviour of radionuclides in the Irish Sea and the transfer processes responsible for their redistribution. Many of these have arisen because of a need to assess the radiological consequences of the principal discharge source, BNFL Sellafield (formerly referred to as Windscale). Other studies have used the opportunity provided by the elevated concentrations of artificial radionuclides to investigate their fundamental chemical properties and post-depositional behaviour. This is information which has a much wider applicability in other actual or potential waste disposal or accidental release events. A third category has made use of the time- and space-dependent distribution of artificial radionuclides to elucidate the nature of transfer processes within the Irish Sea and beyond over much of the NW European continental shelf.

The subtidal sediments of the eastern Irish Sea represent a significant potential source of long-lived radionuclides. There is evidence that Cs has been remobilised from the seabed since the early 1980s. The estuaries of the coasts of NW England and SW Scotland appear to be acting as continuing sinks for Sellafield-derived nuclides. It is not yet possible to predict with complete confidence what the longer term consequences of sediment redistribution will be, particularly in response to infrequent storm events, on radionuclide distributions. However, it is unlikely that the dose consequences will approach the levels experienced in the late 1970s to early 1980s in view of the sustained decrease in Sellafield discharges and the effect of dispersion. The 'ultimate sink(s)' is unknown, although it is conceivable that the area of muddy sediments between Ireland and the Isle of Man, in deep, relatively quiescent conditions, will play an increasingly important role, albeit over a very long time-scale.

Studies are in progress, or are planned, to attempt to address some of the unknowns detailed above. For example, the response of sediments to waves and tidal currents will be linked to a fine resolution hydrodynamic model in a study conducted by a number of university departments and research institutions. A second example is utilisation of the increases in Tc discharges in 1994 to improve estimates of water transport times, exchanges through the North Channel and to validate existing transport models.

8. NUTRIENT STUDIES

8.1 JONUS

The Joint Nutrient Study (JONUS) was set up in 1990, in response to international pressures to limit the risks of pollution due to excess nutrients entering the North Sea. Adverse effects of nutrients in coastal waters cannot be predicted merely by monitoring the inputs of nutrients to rivers. Additional information is required on the fate and behaviour of nutrients as they are carried through the estuaries.

The JONUS approach, was to establish, over a period of time, realistic budgets for the throughput of the principle nutrient species (N, P and Si) in the main estuaries opening into the southern North Sea namely, the Humber, Wash and Thames and to determine and quantify the key processes by which each estuary modifies its nutrient load and establish their time-dependence. This approach was subsequently endorsed in the 1993 North Sea Quality Status Report.

The starting point for the programme was to understand the factors controlling inputs from rivers, not only in terms of quantity and concentration but also in terms of N:P ratio, since this may induce toxicity in certain marine dinoflagellates. Both waste-water treatment and climatic changes can affect the quantity and ratio of nutrients entering a river. During times of flood for instance, phosphorous inputs from waste-water are diluted while nitrogen, leaching from farmland, is increased. One of the aims of JONUS was to establish whether such a direct climatic effect controls nutrient concentrations and hence N:P ratios in the Great Ouse. The results over two years show an inverse correlation between phosphate and nitrate concentrations, with flow rate. Establishing the precise form of the relationship was an important result for JONUS, in aiding the understanding and management of the nutrient balance in this river and coastal water system.

The next step was to look at the transport and modification of nutrients in the estuaries themselves. It was assumed that biogeochemical processes here, were likely to be complex and estuary-specific. For this reason, the three river-estuary systems on which the JONUS programme was based, have widely contrasting catchment areas; the Humber, mixed-industrial, and agricultural, the Wash, agricultural and the Thames, urban.

Comparative studies of the Humber and the Wash have pinpointed essential differences in the two systems. The main difference is the much higher suspended solid loads of the Humber (up to 1500 mg l⁻¹) compared with the Great Ouse (up to 350 mg l⁻¹). This has two major effects. In winter time, whilst nitrate and silicate show, in general, a steady linear decrease with increasing

salinity in both systems, abiological removal of dissolved phosphate, which has a high affinity for particles, is therefore almost completely removed to the sediment in the upper reaches of the Humber. In the Ouse, the reduction is 40% of the initial concentration, but the process occurs much more gradually downstream. Secondly, in other seasons of the year (especially spring), the extreme turbidity of the Humber inhibits both phytoplankton growth and the biological uptake of all the main nutrient species. This clearly indicates that the flux of phosphate through the Humber is linked not only to water flow-rates, but to the more complex issue of what controls the flux of sediment through the system.

Although this example shows that the factors controlling the throughflux of nutrients in a given estuary is complex, it also reinforces the idea that they may be sufficiently recognisable, to be assimilated in to realistic models for use as a valuable diagnostic tool for management.

The primary goal of JONUS was to provide a budget of the nutrient flux to the sea through the river estuary system. Table 8 shows estimates of total flux (in kilotonnes) of total oxidised nitrogen (TOxN), silicon (Si) and phosphorous (P) to the sea for the Great Ouse in 1992 and 1993, together with a preliminary budget for the Humber in 1991-1993.

The differences in the two catchments are reflected in the differing amounts and ratios of these inputs.

Table 8. Estimates of total flux (kilotonnes) of TOxN, Si and P to the sea for the Great Ouse in 1992 and 1993, together with a preliminary budget for the Humber in 1991-93

	1991	1992	1993
Ouse TOxN		9.1	8.1* (14.6)
Ouse Si		4.4	2.2* (6.2)
Ouse P		0.4	0.2* (0.3)
Humber TOxN	57.3	58.2	57.4 [§]
Humber Si	16.4	22.2	30.8 [§]
Humber P	0.4	0.7	0.9 [§]

Note: * - January to August fluxes

() - full year fluxes

[§] - figures calculated using mean monthly flows; final daily means not yet available

The JONUS programme has been the first to attempt to sustain an intensive and complex field and modelling effort over a period of years, but the justification for such an approach is evident in the above calculations. The time period over which the work was carried out included both drought and flood conditions, which provided a broader range of values for establishing a firmer relationship between river-flow and nutrient flux

and also provided some of the clearest direct evidence of riverine change feeding through the estuaries into coastal waters. An intimate relationship has been identified between inter-annual changes in Ouse river-flow, nutrient load and surface nutrient concentration in the Wash.

The nitrogen cycle in estuarine sediments is complex with many options for nitrate conversion, including its assimilation into organisms and subsequent burial and organic degradation. The exposure of intertidal mud flats in the Wash was found to support a denitrification pathway of particular local importance, but probably the most important JONUS finding to date, is the remote control of Wash denitrification by its feeder streams. The flux of nitrate from the water to the sediment (which drives the denitrification process) is itself driven by the concentration-gradient between the two, which is maintained by the 'fresh-nitrate rich water' of incoming rivers. The time series on nitrate flux to sediment in the Wash, plotted against the mean flow of the Ouse showed a correlation coefficient of 0.9 between the two variables (Figure 7). Whilst this is not a newly discovered process, the ability of JONUS to demonstrate it in the field is further justification of the JONUS approach.

Understanding of the key processes in the Humber is less advanced than in the Wash, but sufficient knowledge has been accumulated thus far, to anticipate what the essential differences might be in comparison with the Great Ouse, though this will only be confirmed by further analysis.

Another, less well developed, element of JONUS is the biological component. One notable achievement has been to demonstrate the unexpected significance of algal blooms in the turbid upper estuaries of the Wash system. In April 1993, a diatom bloom in the Great Ouse was shown to be responsible for an almost total removal of dissolved silicate in the upper reaches of the Ouse. Such an example illustrates the ability of plankton to 'mop up' the dissolved nutrient load, but it tells us little about the net effect of such temporary and localised blooms on the throughput of nutrients to sea. JONUS anticipates that a significant net effect of primary production on the nutrient budget may occur through the mitigating effect of benthic algae on benthic geochemical processes and this will be a topic of future work.

An offshore survey component was included in the JONUS programme to ascertain whether long-term trends in the nutrient concentrations of coastal waters could provide any indication of their nutrient status. It remains evident however, that in order to identify any inter-annual trend in these offshore data with any confidence, appropriate action must be taken to remove the higher frequency variability (including the complex seasonal signal). An estimate of analytical error and its likely time-dependence will also be required before the significance of any trend can be assessed.

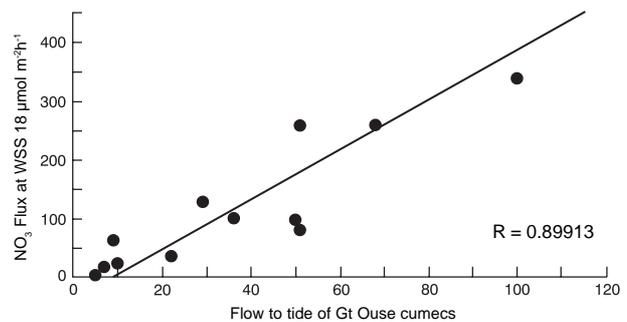


Figure 7. Correlation between sediment-water flux rate in the south-eastern Wash and river flow in the Great Ouse

Another approach by JONUS, was to measure denitrification rates at a range of offshore sites. The results showed that the equivalent of approximately 12% of the anthropogenic input to the whole North Sea is removed by denitrification and that with increasing distance from the coast, an increasing percentage of denitrification is derived from nitrate production *in situ*.

The advances made by JONUS have significantly enhanced understanding of the processes which control the flow of nutrients to sea. However, the estuary dependence of these results implies a continuing need for further study of other target systems.

8.2 SONUS

The main objective of SONUS is to determine a quantitative nutrient budget for the Southampton Water system and to establish nutrient fluxes from this system to the Channel. It comprises two projects. Firstly, a database of historic and current data on nutrients which has been assembled by Plymouth Marine Laboratory, and secondly a field programme that is operated by the Southampton Oceanography Centre. The project is funded by the Department of the Environment.

The database contains historic and current data on nutrients, in MS-Access format, and uses standard British Oceanographic Data Centre (BODC) formats for data extraction. Data from the Marine Biological Association (MBA), surveys undertaken by Southampton University in the Channel, FluxManche data, and some French data from the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) are included, plus NRA catchment data.

Surveys in Southampton Water started in January 1995 and have since been maintained on a monthly basis, subsequently covering the Test, Itchen and Southampton Water. Additional surveys have been completed by the NRA around the Isle of Wight and by FluxManche further out into the Channel to give background farfield data. The surveys measure nitrate, nitrite, ammonia, urea, dissolved organic nitrogen and total particulate

nitrogen, phosphorus, organic phosphorus and total particulate phosphorus, and dissolved silicon. Additional parameters measured are temperature, salinity, transmission, chlorophyll fluorescence, and dissolved oxygen. The Hamble is surveyed on a regular basis. Parallel surveys of phytoplankton are being undertaken.

Associated studies funded by the EC are being undertaken in Langstone Harbour by the University of Portsmouth, on the population dynamics of *Ulva* and by MAFF under contract to the NRA to examine bacterial degradation in sediments and pore water fluxes of nitrogen and phosphorus.

Nutrient samples from rivers are being taken on a regular daily basis from the Itchen and in 1996 will be taken from the Test. The NRA is providing additional data via its riverine database.

Joint SONUS/JONUS modelling work is being funded by the DoE

8.3 Nutrient-related studies in Northern Ireland and Scotland

In Northern Ireland, DANI/DoE(NI) and Queens University are conducting studies on nutrient cycling in two coastal embayments, Strangford Lough and Belfast Lough. Although primarily driven by the need to classify these coastal waters in relation to the EC Urban Waste Water Treatment and Nitrate Directives, these studies have been designed to produce a budget estimating net nutrient exports to the open Irish Sea, thus linking directly with other studies on nutrient cycling in the Irish Sea.

The studies have been designed to obtain good quality loading data and to relate this to the cycling of nutrients in the water column and sediments in the Loughs. Early indications are that much of the nitrogen entering these systems from the land may be taken up in the inner reaches of these Loughs through a combination of factors which include denitrification and burial. There is also evidence to suggest that Strangford Lough may act as a sink for nitrogen entering from the open sea.

There are several nutrient-related projects underway in Scotland:-

8.4 Loch Linnhe Project

During 1990, the Marine Laboratory Aberdeen collaborated with the University of Strathclyde in the development of an ecosystem model for Scottish sea lochs. The objective was to provide a means of assessing the impact of nutrient enrichments from fish farming operations or land runoff on the coastal environment. In particular the model was intended to determine the relationship between nutrient input and enhancement of

phytoplankton production. Results from the model indicated that in most cases, taking the sea loch as a whole, exchange with the open sea and water turbidity are such that nutrient concentrations are not limiting phytoplankton growth, even with no additional inputs.

Few data could be found in the scientific literature to compare with the results of the model, particularly with respect to the interaction between phytoplankton and zooplankton in sea loch systems. Therefore, during 1991 the Marine Laboratory undertook a sampling programme in Loch Linnhe between Oban and Fort William on the west coast of Scotland. Sampling was carried out from the research vessel *LOUGH FOYLE* which visited Loch Linnhe for one week cruises at monthly intervals throughout the year. In addition, instruments were moored in the Loch for the whole year, to collect data on hydrographic conditions, nitrate and phytoplankton concentrations, and sedimentation rates at times when the ship could not be present.

To date modelling effort has been targeted at phytoplankton and zooplankton dynamics. Nutrient modelling is now in progress however. A major objective of this modelling is to conserve all forms of nitrogen in the ecosystem.

8.5 Coastal Zone Project

The Scottish North Sea Coastal Zone (SNSCZ) is the 5-10 mile wide strip of water adjacent to the Scottish coast, extending from the Moray Firth in the north, to the south of the Firth of Forth. It receives all of the east coast fresh water discharge, including nutrients from land drainage and discharges. The fresh water itself modifies the dynamics of the coastal zone, forming a front which may act as a barrier to offshore transport, concentrating nutrients in the coastal strip. The coastal zone is therefore the most vulnerable area of Scottish North Sea waters, while it also represents one of the most important areas of usage by man for leisure, domestic and industrial purposes, including important fin and shellfish fisheries. It is a vital nursery area for many North Sea commercial fish species.

The Coastal Zone project commenced in 1991 to:

- (a) Quantify the riverine and oceanic contributions to coastal nutrient levels.
- (b) Describe the annual changes that occur in the physical structure and circulation of the SNSCZ.
- (c) Describe the seasonal cycle of inorganic nutrients within the SNSCZ.
- (d) Quantify at selected sites the along-shore and across-shore transport of salt and dissolved nutrients.

Estuarine surveys identified the Tay as the dominant source of nutrients to the SNSCZ. Fieldwork was subsequently targeted at the area off Dundee/Fife Ness. Cruises were completed and moorings maintained over a 12 month period. A hydrographic model of this area has been developed, the nutrient data will be interpreted within the framework of this model.

8.6 Ythan estuary

Under the terms of the EC Nitrates Directive the catchment of the River Ythan has been considered for possible designation as a Nitrate Vulnerable Zone. Collaborative work between the North East River Purification Board, Macaulay Land Use Research Institute and the Marine Laboratory has been proceeding, partly funded by the Scottish Office Agriculture, Environment and Fisheries Department. This work has examined historical nutrient inputs to the estuary. The work has demonstrated that the 3-4 fold increase in nitrate concentrations since the 1960s in the River Ythan have been mirrored in the estuary itself. Current work includes a collaborative hydrographic survey of the estuary between Aberdeen University and the Marine Laboratory, and physiological studies of *Enteromorpha*, which occupies substantial areas of the Ythan and many other estuary mudflats, by the University of Dundee, this work is funded by the Scottish Office Agriculture Environment and Fisheries Department. Early in 1996, the decision was taken not to designate the catchment of the River Ythan as a Nitrate Vulnerable Zone. Under the terms of the EC Nitrates Directive, this decision is due for review in December 1997, by which time the results of the SOAEFD sponsored research should be available.

9. REPORT ON INPUTS OF CONTAMINANTS TO UK WATERS IN 1993

9.1 Introduction

At its meeting in Lisbon on 15-17 June 1988, the Paris Commission decided to initiate comprehensive annual surveys of inputs of selected pollutants to Convention waters. The first survey in the UK was carried out during the calendar year 1990. The results of the fourth survey, carried out in 1993, are covered by this report, with appropriate comments on how the data compare to those for previous years.

The parameters to be monitored on a mandatory basis were five metals (mercury, cadmium, copper, zinc and lead), five nutrients (ammonia, nitrates, orthophosphate, total nitrogen and total phosphorus), one pesticide (gamma HCH) and two general parameters (suspended particulate matter and, where appropriate, salinity). PCBs were to be monitored on a voluntary basis for seven congeners (IUPAC numbers 28, 52, 101, 118, 138, 153 and 180).

The objective of each survey was to monitor 90% of the input of each selected contaminant. As an aid to achieving this the Commission published a document 'Principles of the Comprehensive Study on Riverine Inputs' giving details of the methodology to be followed.

9.2 Procedure

Within England and Wales, the NRA executed the Survey work, and in Scotland the seven River Purification Boards were the statutory bodies charged with the work. DoE(NI) undertook the survey work in Northern Ireland.

All the main river systems were sampled approximately monthly at a sampling point close to, but upstream of the tidal limit, (i.e. the point at which the unidirectional fresh water flow ceases). In addition, all significant direct discharges of industrial or sewage treatment works effluent entering downstream of that sampling point were also sampled, as were all significant coastal discharges.

The river sampling regime was designed generally to cover the whole flow cycle but with a bias towards periods of expected high flow.

No storm water overflows were sampled as part of the survey. It is considered that the contribution of storm water to the total inputs load will have been small. Furthermore, most storm water overflows to inland river systems will be picked up by the tidal limit sampling.

9.3 Results

The results are presented in Table 9 as summary statistics for each of five principal sea areas namely North Sea (UK East Coast), North Sea (Channel), Celtic Sea, Irish Sea and Atlantic (Figure 8). Inputs are recorded as Direct, (Sewage and Industrial inputs downstream of the riverine input monitoring sites) and as Total (Direct plus Riverine inputs).

In the full report to the Paris Commission, each of the five sea areas was sub-divided into a number of sampling regions (Figure 8) and information on inputs given separately for each.

Two sets of annual input estimates are supplied, a lower estimate and an upper estimate. The first set treats results recorded as less than the limit of detection as having a true concentration of zero. The second set treats such results as having a true concentration of the limit of detection.

Inputs of PCBs are reported as the sum of the seven recommended congeners (IPUAC numbers 28, 52, 101, 118, 138, 153 and 180).

Table 9(a). Direct inputs (Sewage plus Industrial) to Paris Convention waters in 1993 by the United Kingdom

Sea area	Cd t	Hg t	Cu t	Pb t	Zn t	∑HCH kg	PCBs kg	NH ₄ -N kt	NO ₃ -N kt	PO ₄ -P kt	Total N kt	Total P kt	SPM kt
North Sea (UK East Coast) upper	1.58 2.36	0.20 0.33	123.3 124.7	42.9 46.2	794 794	95.8 96.8	0.6 61.5	35.9 35.9	12.9 13.1	7.1 7.1	55.6 55.8	8.1 8.1	454 454
North Sea (UK Channel) upper	0.07 0.09	0.00 0.00	24.7 24.8	5.5 5.7	22 22	13.6 13.9	0.0 0.2	9.2 9.2	1.0 1.1	2.0 2.0	10.3 10.4	2.0 2.0	10 10
Total North Sea upper	1.65 2.45	0.20 0.34	148.0 149.5	48.4 51.9	816 816	109.5 110.7	0.6 61.8	45.1 45.1	13.9 14.1	9.1 9.1	66.0 66.2	10.1 10.1	464 464
Celtic Sea upper	2.40 2.66	0.04 0.05	22.5 26.0	10.7 19.3	159 159	6.1 17.0	26.7 82.7	7.3 7.3	1.5 1.5	1.2 1.2	9.0 9.0	1.2 1.2	61 61
Irish Sea upper	5.22 5.65	0.80 0.87	13.7 14.3	57.0 57.8	138 138	17.3 18.7	0.0 8.2	3.3 3.3	1.1 1.1	1.9 1.9	5.6 5.6	2.1 2.1	59 59
Atlantic upper	0.12 0.86	0.03 0.06	24.2 25.6	13.2 14.5	36 36	9.5 10.1	0.0 8.9	4.6 4.6	3.3 3.3	0.7 0.7	7.8 7.9	1.1 1.1	55 55
Total Non North Sea upper	7.74 9.16	0.87 0.98	60.4 65.9	80.9 91.6	333 334	32.9 45.7	26.7 99.8	15.2 15.2	5.9 5.9	3.8 3.8	22.4 22.5	4.5 4.5	175 175
Total UK (Direct) upper	9.4 11.6	1.1 1.3	208 215	129 144	1149 1150	142 156	27 162	60 60	20 20	13 13	88 89	15 15	639 639

Table 9(b). Total inputs (Direct plus Riverine) to Paris Convention waters in 1993 by the United Kingdom

Sea area	Cd t	Hg t	Cu t	Pb t	Zn t	∑HCH kg	PCBs kg	NH ₄ -N kt	NO ₃ -N kt	PO ₄ -P kt	Total N kt	Total P kt	SPM kt
North Sea (UK East Coast) upper	5.66 15.81	0.97 3.68	316.6 327.2	350.2 375.8	1724 1747	328.6 383.1	13.9 749.3	43.2 43.4	124.1 131.3	15.4 15.4	197.6 197.9	16.9 17.0	1159 1164
North Sea (UK Channel) upper	0.80 0.89	0.07 0.11	74.7 74.8	26.5 27.2	288 289	25.4 25.8	0.0 22.4	9.7 9.8	25.2 25.3	3.1 3.1	35.3 35.4	3.1 3.1	222 223
Total North Sea upper	6.45 16.70	1.04 3.79	391.3 402.0	376.6 403.0	2013 2035	353.9 408.9	13.9 771.6	53.0 53.1	149.3 156.6	18.4 18.5	232.9 233.3	20.0 20.1	1381 1387
Celtic Sea upper	3.43 5.81	0.84 1.28	81.1 91.6	57.3 76.1	449 450	29.4 128.5	34.8 626.7	9.2 9.2	41.8 41.9	3.6 3.7	51.4 51.6	3.6 3.7	699 700
Irish Sea upper	8.14 10.67	2.10 2.91	124.2 133.8	105.6 123.5	485 491	50.3 133.9	88.1 1041.5	8.1 8.2	30.6 30.6	4.4 4.5	44.1 44.8	4.8 4.9	361 365
Atlantic upper	0.87 6.53	0.21 0.91	65.7 76.9	56.0 64.7	219 227	41.2 57.5	0.6 256.9	7.2 7.2	15.6 15.6	2.0 2.1	29.9 40.0	4.6 4.6	416 418
Total Non North Sea upper	12.44 23.00	3.15 5.11	271.0 302.2	218.8 264.2	1153 1168	120.9 319.9	123.5 1925.1	24.5 24.6	88.0 88.2	10.1 10.3	125.4 136.4	13.1 13.3	1476 1483
Total UK (Direct) upper	18.9 39.7	4.2 8.9	662 704	595 667	3166 3203	475 729	137 2697	77 78	237 245	29 29	358 370	33 33	2857 2870

The overall UK inputs in each of the four years 1990-1993 are summarised in Table 10, information again being given on Direct Inputs (Sewage and Industrial inputs downstream of the riverine input monitoring sites) and Total Inputs (Direct plus Riverine).

9.4 Discussion

Total (Direct plus Riverine) inputs for 1993 are lower than the inputs for 1992, except for those of mercury, lead, gamma HCH and PCB. Exceptional inputs of lead, from sampling Region E7a, caused by the rain water flooding of old lead mine workings within the catchment of the River Ouse were the main reason for the increased lead inputs. Substantial reductions of inputs of gamma HCH and PCBs were noted in the 1992 report. Consequently increases in 1993 probably represent a move back closer to the underlying (downward) trends for these two substances. The drop in the input of zinc in 1993 was substantial (order 700 tonnes). However, this reflects the exceptional increase (of the order of 600 tonnes) reported for 1992 due to the escape of water from an abandoned Cornish tin mine. The absolute quantities of gamma HCH and PCB inputs remain very low.

For the 1993 inputs, upper estimate totals for Cd and Hg are of the order of 100% higher than the respective lower estimate totals. The corresponding differences for Cu, Pb and Zn are less than 15%, for gamma HCH 50%,

and for PCBs 1900%. Upper estimate totals for nitrate, nitrogen and phosphorous were only marginally higher than the lower estimate totals. Experience shows that where, as for Cd, Hg and especially PCBs, there is a wide range, the true input is probably much closer to the lower estimate than the upper estimate.

Consideration of the data on total inputs for the four years 1990-1993 shows that generally there has been an overall downward trend. This is most marked in the inputs of Cd and Hg which show a reduction of 30-40%. The major departure from this trend is found with inputs of N which show increases in the order 20% over the period.

Rainfall in the period 1988 to 1992 (and in particular the winters of those years) was significantly less than the long term average. Thus fresh water river flow to sea in those years was also lower than normal. This will be reflected in the loads of river borne contaminants reaching the sea during that period. Nutrient substances such as nitrogen, where a substantial proportion of the river load is derived from rainfall run off from agricultural land, will show this effect with loads for the early 1990s likely to be less than in later years.

Large annual variations in the inputs from some of the 40 sampling zones into which the UK coastline is divided have been noted. This would indicate that it is imprudent to draw any firm conclusions from the data for any one year.

Table 10(a). Direct inputs (Sewage plus Industrial) to Paris Convention waters in 1993 by the United Kingdom

Year		Cd t	Hg t	Cu t	Pb t	Zn t	γ-HCH kg	PCBs kg	NH ₄ -N kt	NO ₃ -N kt	PO ₄ -P kt	Total N k	Total P kt	SPM kt
1990	lower	29.6	3.7	282	112	1700	191	79		20	21	104		1260
	upper	33.8	4.3	297	168	1706	224	300		20	21	105		1260
1991	lower	13.3	3.3	270	134	1670	140	223		19	22	90		1210
	upper	15.3	3.5	279	148	1680	186	424		19	22	91		1220
1992	lower	12.8	2	246	125	1354	144	138	69	24	19	104	21	956
	upper	14.9	2.3	252	141	1356	179	459	69	24	19	105	21	956
1993	lower	9.4	1.1	208	129	1149	142	27	60	20	13	88	15	638
	upper	11.6	1.3	215	144	1150	156	162	60	20	13	89	15	638

Table 10(b). Total inputs (Sewage plus Industrial) to Paris Convention waters in 1993 by the United Kingdom

Year		Cd t	Hg t	Cu t	Pb t	Zn t	γ-HCH kg	PCBs kg	NH ₄ -N kt	NO ₃ -N kt	PO ₄ -P kt	Total N k	Total P kt	SPM kt
1990	lower	36.3	5.7	631	430	3680	394	150		173	36	287		2670
	upper	61.4	11.7	705	577	3690	773	3630		173	36	288		2680
1991	lower	34.9	5.3	612	510	3590	605	236		199	36	321		2570
	upper	63.4	10.6	711	655	3800	910	2140		199	36	322		2630
1992	lower	24.1	3.7	701	465	3840	373	172	88	208	35	384	38	3080
	upper	45.3	8.4	729	539	3870	689	1424	88	217	35	393	39	3090
1993	lower	18.9	4.2	662	595	3166	475	137	78	237	29	358	33	2860
	upper	39.7	8.9	704	667	3203	729	2697	78	245	29	370	33	2870

Note: Part of the input of Cd (for sampling region 22) was inconsistently attributed between Direct and Riverine for the years 1990 and 1991. Consequently, for Cd, the best indication of trends is given by considering Total inputs (Direct plus Riverine)

Research Vessels utilised in UK Monitoring Programmes



Plate 1. *RV FORTH RANGER -
Scottish Environment Protection Agency*



Plate 2. *RV SCOTIA -
Scottish Office Environment, Agriculture
and Fisheries Department*



Plate 3. *RV CIROLANA -
Centre for Environment, Fisheries and
Aquaculture Science*



Plate 4. *RV VIGILANCE -
Environment Agency*



Plate 5. *RV LOCH FOYLE -
Department of Agriculture for Northern
Ireland*

Gear used to collect samples for the National Monitoring Programme



Plate 6. Day grab

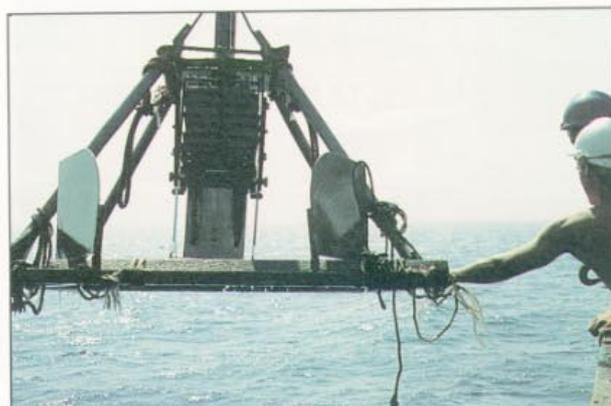


Plate 7. Reineck corer



Plate 8. Surface water sampler (2.5 l)

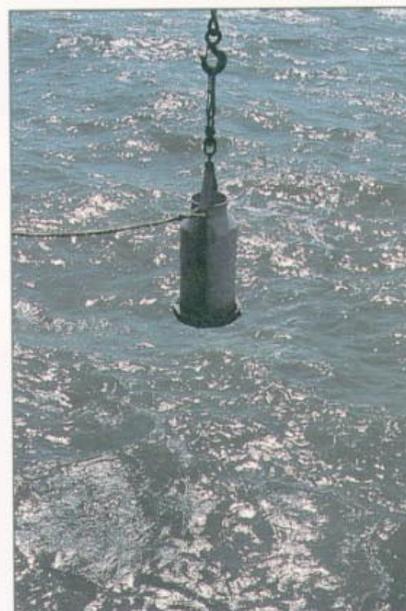


Plate 9. Surface water sampler (40 l churn)

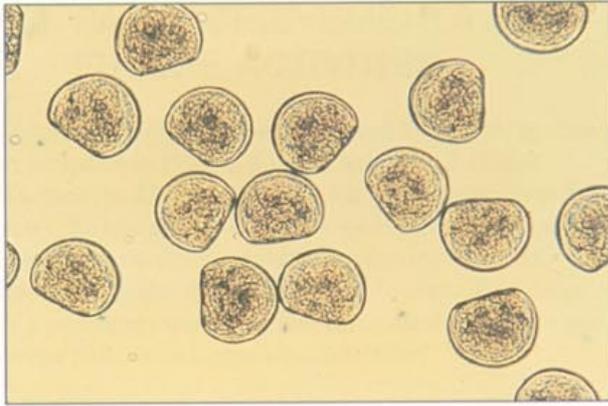


Plate 10. 24 h 'D-shaped' Oyster embryo larvae (*Crassostrea gigas*)



Plate 11. Inductively-coupled plasma/mass spectrometer

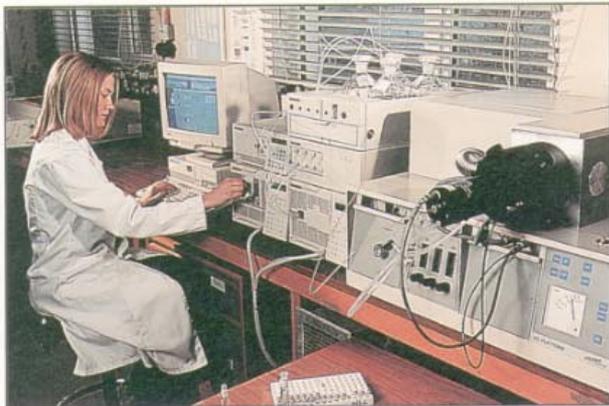


Plate 12. Coupled high-performance liquid chromatograph/mass spectrometer



Plate 13. Identification of Benthos



Plate 14. Dredger showing draghead



Plate 15. Fish farm cages



Plate 16. Deposition of organic matter (food pellets) beneath fish farm cages



Plate 17. Pollack beneath a fish cage showing density of suspended matter in the water

10. PAST ACHIEVEMENTS AND FUTURE ACTIVITIES

The list of published papers produced by MPMMG, since its inception in 1974, is given in Appendix 3. These illustrate the diverse topics tackled by the Group over the years, the end products of which have given a continuous stimulus to the development of monitoring in the UK, through a regular cycle of reviews of existing knowledge of a particular topic, identification of discernible gaps and advice on how such gaps should be filled.

One of the best examples of this is the present National Monitoring Programme (NMP - outlined in Section 2) developed as a result of the identification of deficiencies in existing programmes within the UK by MPMMG in the late 1980s (MPMMG, 1991). Considerable effort has gone into the attainment of a nationwide agreement by Government scientists to monitor a standard set of determinands in agreed matrices. The results from the first stage, a spatial survey, will for the first time be truly comparable throughout the UK and due to the parallel development of the chemical and biological AQC schemes outlined in Sections 3 and 4, will all be of known acceptable quality. The complete resulting NMP dataset will therefore be able to be utilised to help fulfil the UK's national and international monitoring obligations, a considerable step forward. This should go some way to repay the considerable outlay of time and effort by those involved.

A second example where real advances and co-ordination of activities has been achieved stems from the establishment of the GCSDM. Originally set up to co-ordinate approaches to the monitoring of sewage-sludge disposal areas, the group defined harmonised objectives for monitoring and developed common standards by which results can be assessed. Its activities have extended to embrace monitoring of dredged material disposal and the conduct of comprehensive studies required to demonstrate high natural dispersion status in the context of the Urban Waste Water Treatment Directive. In the course of its work, it has published several reports both on how to conduct monitoring and on the comparison of the results of monitoring undertaken and how such monitoring has become more focused over the years.

Other topics covered by MPMMG have ranged from such questions as the possible environmental impact of fish farming to reviewing radioactivity in the Irish Sea.

With regard to its efforts in future, MPMMG will continue to develop and oversee monitoring in the contexts within which it has previously been involved, such as sea disposal of wastes. There are also several new aspects which will be addressed.

Now that the NMP is in place, and its initial spatial survey is nearing completion (see Section 2), MPMMG's priorities will shift towards the interpretation and use of the data that are generated. A sub-group will take charge of the management of the database, and the production of an annual report. The early results will be used to develop a longer-term strategy for further spatial monitoring, and to identify areas that may require trend data for particular contaminants.

The Analytical Quality Control schemes are now fully established for both chemical and biological determinands, and will continue to run. There are many remaining issues to be dealt with, to ensure that the full range of NMP chemical determinands are covered adequately by quality systems. In addition, the early activities of the Biological AQC Scheme on the analysis of benthos samples will be extended to encompass procedures used in collecting samples.

As well as the NMP, there are other monitoring exercises in place, some of which have already generated long-term series of data. MPMMG will be examining the use and value of these data, and the issues connected with continuing to add to long-term databases. This will include assessments of the pros and cons of biological effects measurements compared to chemical residues, and will consider how such data might be used in relation to the more structured approach of the NMP.

A major feature of the remaining years of the century will be the completion of regional assessments of the quality status of the seas around Europe. Following the 1993 North Sea Quality Status report produced by the North Sea Task Force of ICES and the Oslo and Paris Commissions, comparable exercises will be undertaken for several other sea areas. The UK will have a particular interest in the assessment of the Celtic Seas, and MPMMG will contribute towards guiding appropriate use of monitoring and research information in the assessment.

MPMMG has recently set up a Task Team to work on the impact of marine litter. This will report on the scale of the problem and attempt to make recommendations on appropriate action for the control of litter in the marine environment.

In these and other activities that may arise, MPMMG will continue to provide a forum in which the UK's effort in marine monitoring can be reviewed, and directed in the most productive ways, while retaining a high scientific integrity.

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APPENDIX 1. List of Marine Pollution Monitoring Management Group Members 1990-1995

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APPENDIX 3. Publications of the Marine Pollution Monitoring Management Group and its sub-groups

- 1977 MPMMG. Monitoring the Marine Environment of the United Kingdom: The first report of the Marine Pollution Monitoring Management Group 1975-76, DoE.
- 1982 MPMMG. Monitoring of the Marine Environment - Into the Eighties. The third report of the Marine Pollution Monitoring Management Group 1979-1981, DoE.
- 1982 JONES, P. C. W. A review of nutrient salt and trace metal data in UK tidal waters. MAFF Aquatic Environment Monitoring Report No. 7. Update of information provided in Chapter 6 of the 4th MPMMG Report published in 1991 and in Chapter 8 of the 5th MPMMG Report published in 1996.
- 1983 TOPPING, G. Guidelines for the use of biological material in first order pollution assessment and trend monitoring. DAFS Scottish Fisheries Research Report No. 28.
- 1983 NERC. Contaminants in Marine Top Predators NERC Publications Series C No. 23.
- 1987 R. R. DICKSON (ED). Irish Sea Status Report of the Marine Pollution Monitoring Management Group. MAFF Aquatic Environment Monitoring Report No. 17.
- 1989 MPMMG's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites (CGSMD) First Report. MAFF Aquatic Environment Monitoring Report No. 20. Subsequent annual reports 1990 - 1997 (excluding 1996).
- 1990 CGMSD Biological Effects Task Team. Utility of experimental measures of biological effects for monitoring marine sewage sludge disposal sites. MAFF Aquatic Environment Monitoring Report No. 24.
- 1991 MPMMG. Monitoring the Marine Environment - a New Start. The fourth report of the Marine Pollution Management Group 1985-1988, DoE.
- 1991 MPMMG. The Principles and Practice of Monitoring in UK Coastal Waters. A report from the Marine Pollution Management Group, DoE.
- 1992 KERSHAW *ET AL.* A review of radioactivity in the Irish Sea. A report prepared for the Marine Pollution Management Group. MAFF Aquatic Environment Monitoring Report No. 32.
- 1992 MPMMG. Final report of the MPMMG Sub-group on marine fish farming. SOAFD Scottish Fisheries Working Paper No. 3/92.
- 1993 MPMMG's Group Co-ordinating Sea Disposal Monitoring (GCSDM) Fifth Report. MAFF Aquatic environment Monitoring Report No. 39. - Development of a biotic (infaunal trophic) index.
- 1994 MPMMG. MPMMG Monitoring Co-ordination Sub-Group. UK National Monitoring Plan. Her Majesty's Inspectorate of Pollution (HMIP).
- 1994 GCSDM. Comprehensive Studies Task Team. Comprehensive Studies for the purpose of Article 6 of Dir. 91/271/EEC, The Urban Waste Water Treatment Directive. Forth River Purification Board.
- 1996 GCSDM. Benthos Task Team. Monitoring and assessment of the marine benthos at UK dredged material disposal sites. SOAEFD, Scottish Fisheries Information Pamphlet No. 21.
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APPENDIX 4. Glossary of technical terms and acronyms used in the text

(a) ACRONYMS USED IN THE REPORT

ADRS	Association of Directors and River Inspectors of Scotland
ALARA	As low as reasonably achievable
AQC	Analytical Quality Control
BCR	Community Bureau of Reference
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
CGMSD	Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites
COSED	Cohesive Sediment Dynamics
DANI	Department of Agriculture for Northern Ireland
DETR	Department of the Environment, Transport and the Regions (formerly DoE)
DFR	Directorate of Fisheries Research
DoE	Department of the Environment
DoE(NI)	Department of the Environment (Northern Ireland)
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EQO	Environmental Quality Objective
EQS	Environmental Quality Standard
EROD	Ethoxyresorufin-O-deethylase
GCSMD	Group Co-ordinating Sea Disposal Monitoring
HF	Hydrofluoric acid
ICES	International Council for the Exploration of the Sea
ICRP	International Commission on Radiological Protection
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IRTU	Industrial Research and Technology Unit
JMG	Joint Monitoring Group (of the Oslo and Paris Commissions)
JONUS	Joint Nutrient Study
LoD	Limit of detection
MAFF	Ministry of Agriculture, Fisheries and Food
MBA	Marine Biological Association
MPMMG	Marine Pollution Monitoring Management Group
NAMAS	National Measurement Accreditation Service
NCC	National Co-ordinating Committee (of the National Marine Chemistry AQC Scheme)
NERC	National Environment Research Council
NMAQC	National Marine Analytical Quality Control
NMBAQC	National Marine Biological Analytical Quality Control
NMP	National Monitoring Plan/Programme
NODC	National Oceanographic Data Centre
NRA	National Rivers Authority
NRPB	National Radiological Protection Board
OSPARCOM	Oslo and Paris Commissions
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PNR	Percent Net Response (to oyster bioassay test)
QA	Quality Assurance
QUASIMEME	Quality Assurance of Information for Marine Environmental Monitoring in Europe
RPB	Regional Purification Board
SEPA	Scottish Environment Protection Agency
SI	Système Internationale
SNSCZ	Scottish North Sea Coastal Zone
SOAFD	Scottish Office Agriculture and Fisheries Department (now Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD))
SONUS	Southampton Water Nutrients Study
TBT	Tributyltin
THORP	Thermal Oxide Reprocessing Plant
TCB	Trichlorobenzene) Remaining chemical determinands
TOxN	Total Oxidised Nitrogen) named in full in Table 1
WRc	Water Research Centre
XRF	X-ray fluorescence

(b) UNITS USED IN THE REPORT

Weight	kg	1000 grammes	
	g	gramme	
	mg	milligramme	$\frac{(g)}{(1000)}$
	μg	microgramme	$\frac{(mg)}{(1000)}$
	ng	nanogramme	$\frac{(\mu\text{g})}{(1000)}$

Radioactivity

Quantity	New SI unit and symbol	Definition	Old unit and symbol	Definition	Conversion data
Radioactivity	Becquerel (Bq)	Disintegration per second	Curie (Ci)	3.7×10^{10} disintegrations per second	$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$ $1 \text{ Bq} = 2.7 \times 10^{11} \text{ Ci} = 27 \text{ pCi}$
Notes: 1. The terabecquerel (TBq) is used in this report for radioactive discharges:					$1 \text{ TBq} = 10^{12} \text{ Bq} = 27 \text{ Ci}$
2. Radioactivity concentrations are given in becquerels per kilogram (Bq kg^{-1}):					$1 \text{ Bq kg}^{-1} = 1 \text{ mBq g}^{-1} = 27 \text{ pCi kg}^{-1}$ $1 \text{ pCi g}^{-1} = 37 \text{ Bq kg}^{-1}$
Absorbed dose	Gray (Gy)	J kg^{-1} (joule per kilogram)	Rad (rad)	$10^{-2} \text{ J kg}^{-1}$	$1 \text{ rad} = 10^{-2} \text{ Gy}$ $1 \text{ Gy} = 10^2 \text{ rad}$
Dose equivalent	Sievert (Sv)	$\text{J kg}^{-1} \times$ (modifying factors)	Rem (rem)	$10^{-2} \text{ J kg}^{-1} \times$ (modifying factors)	$1 \text{ rem} = 10^{-2} \text{ Sv} = 10 \text{ mSv}$ $1 \text{ Sv} = 10^2 \text{ rem}$



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