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REPORT OF THE ICES WORKING GROUP ON POLLUTION OF THE NORTH SEA

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International Council for the Exploration of the Sea
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FOREWORD

There is growing concern regarding the possibility of lasting damage being done by pollution to the marine environment and its living resources. An essential preliminary to the development of rational protective or ameliorative action is the assembly of factual information regarding pollutants and their effects. The International Council for the Exploration of the Sea decided in 1967 to begin this task by setting up, under my Chairmanship, a Working Group to cover the North Sea and adjacent waters; the results of our efforts are to be seen in this report, which we believe provides a sound basis for an appreciation of the situation and for the development of the necessary additional research programmes. The selected bibliography is likely to prove of lasting value.

I wish to place on record my appreciation of the great efforts made by my colleagues to assemble factual information from national sources. As Editor of the Report I have taken care to ensure, so far as possible, the accuracy of the data given, but final responsibility must rest with the national sources from which they were derived.

The greater part of the work of compiling the Report fell upon Dr. J. E. Portmann, the Secretary to the Committee, and we are very much in his debt.

The Report was presented to the 1968 Statutory Meeting of the Council and the resolutions passed on that occasion are reproduced below.

H. A. Cole

The Council, noting the Report of the Working Group on North Sea Pollution, decided that:

1 member countries be urged to intensify their programmes of marine pollution research with special reference to the examination of ecological effects, the measurement of toxicity of pollutants to all stages in the life-cycle, including combined effects of several substances, and the assessment of the effects of sub-lethal concentrations on the physiology, behaviour, growth and breeding of marine life (C. Res. 1968/5:4);

2 in view of the scattered nature of pollution research, member countries be asked to supply the names and addresses of their principal research workers in this field, with brief notes on the nature of the work being undertaken (C. Res. 1968/5:5);

3 recognizing the importance of an understanding of water movements and dispersion in relation to pollution studies, the Hydrography Committee be invited to initiate further studies of:
   (a) coastal hydrography with special reference to water movements,
   (b) theoretical and experimental studies of diffusion processes,
   (c) the development of mathematical models describing the relationship between environmental factors and the spread of polluting substances (C. Res. 1968/5:6);

4 in view of the present and potentially serious effects of pollution in the sea member countries should when possible undertake research into the effects of pollutants of all kinds on planktonic organisms (C. Res. 1968/5:15).

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Report of the ICES Working Group on Pollution of the North Sea

INTRODUCTION

Following the Helgoland Symposium on Pollution of the North Sea and the ICES meeting of 1967 the Council established a Working Group of the Fisheries Improvement Committee "for the purpose of assembling factual data regarding substances harmful or potentially harmful to fisheries being discharged or likely to be discharged into the North Sea and adjacent seas". The Working Group was to consist of "one expert in the field of pollution from each member country concerned, assisted by two experts nominated by the Hydrography Committee".

The Working Group, under the chairmanship of Dr. H. A. Cole (UK), held its first meeting in London on 6-8 February 1968, when the following representatives attended:

Dr. Ir. W. Deschacht	Belgium	
Dr. J. Boëtius	Denmark	
Prof. Dr. H. Mann	Federal Republic of Germany	
Prof. Dr. P. Korringa	Netherlands	
Mr. G. Berge	Norway	
Mr. B. I. Dybern	Sweden	
Mr. A. C. Simpson	United Kingdom	) Observers
Mr. R. E. Craig	United Kingdom (Scotland)	)
Dr. J. E. Portmann (Secretary)	United Kingdom	
Mr. L. Otto	Netherlands	) Representatives) of Hydrography
Dr. G. Weichart	Federal Republic of Germany	) Committee

Mr. Craig was replaced by Dr. R. Johnston for the meetings on 7 and 8 February.

The various representatives put forward factual information on the following aspects of pollution in their own countries:

(1) legislation controlling pollution of the sea;
(2) sewage pollution;
(3) pollution by industrial wastes;
(4) pollution by pesticides;
(5) pollution by oil, including oil-removing chemicals;
(6) toxicity studies, methods and results;
(7) dispersion studies.

Although radioactive wastes could be considered to fall within the terms of reference of the Working Group this type of pollution was not discussed, since other more highly qualified groups, e.g. the European Nuclear Energy Agency, were already working on this topic.

A second meeting of the Working Group was held in IJmuiden on 24-25 June, in order to discuss the first draft of this report. With the exception of Dr. Boëtius the representatives who attended the first meeting were again present and Dr. Roskam (Netherlands) also attended as an observer.

France was invited to send a representative to both meetings but did not do so. However, a reply was received to a special questionnaire which was sent to France and the information given in the reply has been included in this report.

The information put forward at the two meetings has been summarized under the topic headings listed above. In order to keep the report as concise as possible, in many instances it has been necessary to quote references to published data and merely to give the more important or relevant facts in this summary. The references given are all listed in the bibliography following the report. The bibliography includes, in addition to those works referred to in the report, a number of other important publications which are relevant to the general theme of North Sea pollution. Maps illustrating, for example, the distribution of industry discharging wastes to the North Sea and the quantities of effluent discharged were produced by some member countries for the Working Group's meetings, and these have been included in Appendix 1 at the end of the report.

Appendix 2 contains the toxicity data as put forward by the United Kingdom at the first meeting and brought up to date in August 1968.

Appendix 3 contains the amended draft of an agreement by the European representatives at a conference on methods of cooperation in fighting oil pollution of the North Sea held in June 1968.

(1) LEGISLATION CONTROLLING POLLUTION OF THE SEA

(i) Belgium

Pollution of both inland and territorial waters is controlled by the basic law of 11 March 1950 (Moniteur Belge 1950). This law has been modified on various occasions but essentially it prohibits the discharge of waste material to public waters unless consent has been given for that discharge by the Ministry of Public Health. Before consent is given various authorities must be consulted, among them the agency which might subsequently use the water to which discharge is to be made, and the authority dealing with waste water treatment. When permission is given conditions are laid down which define the quality of the discharge. Public waters were classified by the Royal Decree of December 1953 (Moniteur Belge 1954) into three main classes according to pH, oxygen content, suspended solids content, temperature, toxicity and bacterial quality. Subsequently a fourth, poor quality, water class was added with the addition of a methylene blue test requirement. In practice the law is enforced by the Ministry of Public Health which concentrates on the bacterial aspects of pollution. There are no other inspecting organizations, and control over other aspects of pollution is rather loose.

Special laws govern the disposal of wastes from sugar factories (10 December 1954, Moniteur Belge 1955), paper mills (2 August 1956, Moniteur Belge 1956a), and the steel industry (12 September 1956, Moniteur Belge 1956b). Belgium has ratified the London Oil Pollution Convention 1954 (H. M. S. O., 1958), and oil disposal is controlled. There is, however, no control of disposal of other pollutants outside territorial waters, although in the one known case of dumping outside territorial waters the Government was consulted and the dumping was in an agreed area of no fishing importance.

(ii) Denmark

Pollution of rivers, lakes and marine waters is governed by the Watercourse Act of 11 April 1949 (Denmark 1949) and subsequent amendments to this Act in 1963 (Denmark 1963), and an ordinance of 1945 (Denmark 1945) which relates to measures for purifying watercourses. Under this Act no material such as earth, sand, stones, etc. may be deposited near a watercourse so as to create a risk of being washed into it. This also applies to solids or liquids, such as pesticides, which may pollute the water. Section 5 of the Act states that waste waters from towns and factories must not be discharged to a watercourse, including the sea, in such a way that "considerable pollution" arises. The decision as to what constitutes "considerable pollution" is left to the Water Courts.

The Water Courts are constituted on a local basis and there are about one hundred of them. Each case of pollution is considered separately by the Water Court concerned and the various interests involved are taken into consideration. Experts can be called if the court feels this to be necessary but the Water Court must in any event notify the Ministry of Fisheries of the case. After considering all the facts the court can impose limits if they feel this to be necessary. The decision of the Water Court is open to appeal but in practice this course is rarely taken.

In general all sewage and other waste waters should be treated prior to discharge to the sea. In the case of fjords and other such waters the Ministry of Agriculture, after consulting the Ministry of Fisheries and the Ministry of the Interior, may prohibit the discharge of untreated or insufficiently treated wastes. Responsibility for the supervision of the provisions concerning effluent quality rests with the Police and Fishery Control, whe:··as supervision of the watercourses is by the Ministry of Agriculture. Failure to comply with the provisions of the Watercourse Act, or rulings by the Ministry of Agriculture or Water Courts is punishable by fines.

There is no control of dumping of wastes outside territorial waters, but up to the present no such disposals of wastes are known to have occurred. There have been a few proposals and these are now being considered by the Ministry of Fisheries which, however, can only advise. Denmark has signed the London Convention and oil pollution is controlled.

(iii) Federal Republic of Germany

The Federal Republic of Germany passed a law in 1957 (Bundesgesetzblatt 1957, Part I, p. 1110) controlling the pollution of inland waterways. This was modified on 15 August 1967 (Bundesgesetzblatt 1967, Part I, p. 909) so as to bring coastal waters under the same legislation. The section relating to pollution of coastal waters became operative on 1 January 1968. Under the new law it is only possible to discharge solids or liquids to coastal waters with the permission of the authorities. If there is any likelihood of dangerous effects the authorities can withhold their permission or impose certain conditions. The authorities have the additional right to withdraw or modify their consent if damage becomes apparent at a later date. It is also forbidden to store dangerous materials near waterways in such a way that the waters may become contaminated. Failure to comply with these regulations means that the person or persons responsible for the pollution may be liable to heavy penalties. There are special rules and regulations to the Federal Water Law which apply in the various States of the Federal Republic (published in: A. Wüsthoff, Handbuch des Deutschen Wasserrechts, Erich Schmidt - Verlag, Berlin, 1958).

The rules relating to pollution of coastal waters apply only to territorial waters. Disposal of waste - except oil - beyond this zone is not controlled by law, but in practice anybody wishing to dump waste in the open sea asks the Federal Ministery of Transport for permission. The Ministry of Transport may then consult the German Hydrographic Institute (Deutsches Hydrographisches Institut, Hamburg (D. H. I.)), the Federal Research Board for Hydrology (Bundesanstalt für Gewässerkunde, Koblenz), the Federal Research Board for Fisheries (Bundesforschungsanstalt für Fischerei, Hamburg) and the Biological Station Helgoland (Biologische Anstalt Helgoland, Hamburg). Each proposal is considered according to a standard set of criteria; for example, is it possible to treat the material on land?; if it must be disposed of at sea, where is a suitable area?; and what containers should be used? If the material is to be disposed of at sea then it is given a danger classification and must be disposed of accordingly (Weichart 1968).

The Federal Republic is a signatory of the London Oil Pollution Convention.

(iv) France

France has four laws which give control of pollution of the sea and sea water. Two of these (France 1958, 1964a) were designed to limit, and prevent, respectively, the pollution of the sea by oil. The other two govern (a) the aquatic regime, methods of assessment of the waters and measures to be taken against their pollution (France 1964b), and (b) the limits of protection to be established near, or in some instances, some distance away from, places where surface waters are extracted (France 1967).

In addition to these laws there are a number of ministerial Circulars or Instructions which supplement or explain the laws and the way in which they are to be enforced. All the regulations apply to the marine environment.

The laws giving powers of control are all fairly new, and because the scale of the pollution is very large and the organizations of enforcement are new the process of putting the laws into effect is rather slow; however, considerable progress has been and is being made. In the case of a factory or town wishing to discharge effluent to the sea permission must be obtained from the Prefecture of the area concerned. A public enquiry is held and then, according to the merits of the application, the Prefecture either authorizes the discharge or imposes conditions.

(v) Netherlands

A new law concerning pollution is in the course of being adopted. This law (Nederlandse Staatsdrukkerij 1968) will rigidly control pollution of inland waterways and coastal waters and no discharge will then be permitted without prior consent from the government. The Ministry concerned will be that for Public Works but will consult the Ministries for Agriculture and Fisheries, of Public Health, Economic Affairs and of Recreation, i.e. it will be a joint decision. In addition to controlling the pollution of coastal waters the new law will also control the disposal of waste outside territorial waters; this will include the disposal of wastes by other countries where the waste is transported through the Netherlands.

One of the difficulties arising in the new law is how to control discharges to inland waters prior to their passage through the Netherlands. The main river involved is the Rhine, and an International Rhine Commission has been set up to look into the general reduction of the Rhine pollution. This Commission is made up of representatives of all the interested countries, i.e. Switzerland, Federal Republic of Germany, France, Luxembourg and the Netherlands. Analyses of Rhine waters are regularly made and studied. Attempts are made to improve the pollution situation. Fisheries representatives can attend the meetings of the Commission as observers.

So far there are not many discharges to the sea but the tendency is for them to increase. Although no powers of control existed over these discharges before the new law was passed the Ministry of Public Works was usually consulted and in turn asked the Ministry of Fisheries before granting permission.

Offshore mining and mineral exploitation is controlled in that the explosives which may be used are specified; an inspector of fisheries accompanies each exploration vessel to enforce this. No inspector is present on drilling platforms but the operators are not allowed to dispose of drilling "mud" into the sea. In common with other countries the Netherlands has ratified the London Oil Pollution Convention.

(vi) Norway

Control of pollution of the sea is at present afforded by two laws: the Salt Water Fisheries Law of 17 June 1955 (Norsk Lovtidend 1955) and the Lakes and Rivers Law of 15 March 1940 (Norsk Lovtidend 1940). Under the Salt Water Fisheries Law it is forbidden to dispose of materials in the sea or on the sea bed in such a way that fishing activities are impeded. This law also provides the means by which industrial pollution of the sea can be regulated, or forbidden, in cases where the advantages so gained are sufficiently important to justify the disadvantages which may be caused by the ban or regulation. Under the Lakes and Rivers Law it is possible to control pollution of the sea as a result of the dumping of wastes in lakes or rivers. Pollution of harbour waters by shipping is prohibited by the port authorities and a vessel must not discharge any wastes, and this includes dredgings, until it is outside harbours, shallow waters and narrow seaways (Norsk Lovtidend 1933). Dumping can therefore take place within territorial waters, provided that these are open seas.

Exemption from any ban on pollution may be given by the Ministry of Industry on the recommendation of the Norwegian Lakes, Rivers and Electricity Administration. Usually the health authorities are consulted, as is the Ministry of Fisheries when there is a possibility of pollution of the sea. In cases where exemption is given efforts are made to minimize harmful effects by insisting on some form of filtration or purification.

As a result of increasing sea pollution a Committee was set up in 1960 to study the existing laws and to propose steps to limit pollution; its report has now been submitted and a new law is expected to be introduced which will prohibit all pollution of the rivers, lakes and sea. Permission to discharge wastes will then only be granted by a special committee which will consult sea fisheries interests where applicable. As a result of the new law most towns will have to treat their sewage, although some small coastal communities may be exempt. The new law will only cover pollution from ships where the waste has been taken aboard specifically for disposal at sea. It will not include other, more general, pollution from ships but this will continue to be controlled by existing legislation, e.g. the Salt Water Fisheries Law.

Norway recognizes the London Oil Pollution Convention and oil pollution is controlled.

(vii) Sweden

There are several laws governing water pollution in Sweden and the main one of these is the Water Law (Stockholm 1918) which has been amended several times. This states that anyone who discharges or intends to discharge sewage to rivers, lakes or other waters is responsible for any eventual damage and must, to a reasonable extent, take the necessary steps to prevent pollution of the receiving water. This in effect means that, for all communities of 200 or more persons, primary treatment of sewage is compulsory; further treatment may be required where the use of the water, for example for drinking purposes, makes this necessary. In practice there have been many exceptions, but pressure is now being exerted and a big improvement is in progress. All new discharges will have to be notified to the National Nature Conservancy Office, which controls all important outlets of sewage and industrial waste waters.

Industrial wastes may not be discharged in such a way that considerable inconvenience is caused. For most industries this means at least a limited form of treatment. Certain types of industry, such as pulp and paper, butcheries, dairies, bone-meal, oil-refineries and some chemical industries, must obtain a permit from a Water Court. The permit will detail the measures which must be taken to avoid pollution of the receiving waters. Under certain conditions, for instance where the industry is essential to the national economy, the government may disregard the ruling of the Water Court. In almost every case new discharges are now thoroughly discussed before they take place, and the body responsible for the pollution must always provide all the necessary material for the investigation. On occasions where a detrimental effect is produced by an effluent the industry concerned must pay a "fishery charge" of up to 10 000 SW Crowns/year. Much of this money is then allocated for various forms of water research.

At the regional level, questions of water conservation are the province of the County and Municipal Councils in their capacity as Boards of Health, etc. They have at their disposal experts in various fields who exercise a certain controlling power.

Silage seepage and the washings and waste from cattle sheds must not be allowed to enter waters, but in practice this cannot always be avoided. Disposal of material in the sea is controlled only within territorial waters. In cases involving dumping outside territorial waters, fishery organizations are sometimes consulted. However, there has not been much dumping of this type in recent years, largely due to past objections by the fisheries organizations.

A new law will shortly be introduced which will help to strengthen the existing laws. Its main effect, however, will be that in future all pollution problems will be discussed as a whole, e.g. water pollution will be discussed in relation to any air or other pollution which may arise. The Water Courts will no longer handle these matters, which will be transferred to a central licence authority and 24 special courts, one in each province of Sweden.

Oil pollution is controlled as laid down by the London Oil Pollution Convention.

(viii) United Kingdom

(a) The control of pollution around the coasts of England and Wales is vested in the River Authorities under the Clean Rivers (Estuaries and Tidal Waters) Act 1960 (H.M.S.O. 1960), and in the

Sea Fisheries Committees under the Sea Fisheries Regulation Act of 1966 (H. M. S. O. 1966) which repealed and re-enacted a number of previous enactments. These authorities are organized roughly on a county basis and there are 13 River Authorities and 8 Sea Fisheries Committees along the North Sea and English Channel coasts. In general the River Authorities control the rivers and estuaries and the Sea Fisheries Committees the waters off the open coasts. The River Authorities have full powers of control over all new discharges or ones which are appreciably changing. The powers of the River Authorities are somewhat stronger than those of the Sea Fisheries Committees, since all new effluents must be made known to them; the Sea Fisheries Committees have no such powers but may object if sea fisheries are likely to be affected. The River Authorities can impose conditions regarding the treatment, composition and quality of effluents before they grant permission for the discharge to a river or estuary. In addition they can inspect the effluents and receiving waters in order to ensure that these conditions are observed. Their powers in these two respects are stronger than those of the Sea Fisheries Committees which can only prohibit "the deposit or discharge of any solid or liquid substance detrimental to sea fish or sea-fishing".

The powers of the River Authorities and Sea Fisheries Committees apply only to territorial waters; beyond this there are no legal powers of control. However, dumping outside territorial waters is normally done according to the advice of the Ministry of Agriculture, Fisheries and Food (Fisheries Department). Specified areas are set aside for dumping of various materials, and according to the nature of the material dumping may be requested in one of these areas or in very deep water beyond the edge of the continental shelf. A suitable form of container is usually prescribed. A copy of an extract from the ship's log recording the deep-water disposal of the wastes is normally required by the authorities.

(b) In Scotland there are no Sea Fisheries Committees, and powers to control pollution, both of inland streams and of tidal waters, rest entirely with the 21 river purification authorities. These include 9 River Purification Boards, established under the Rivers (Prevention of Pollution) (Scotland) Act 1951 (H. M. S. O. 1951), each with power to control the pollution of a whole river or group of rivers from source to sea in the more highly industrialized areas in Scotland, and 12 local authorities who control the pollution of rivers in the more sparsely populated areas.

Under the Rivers (Prevention of Pollution) (Scotland) Act 1951 (H. M. S. O. 1951), the river purification authorities have powers, similar to those of river authorities in England and Wales, to control all new discharges of effluent to non-tidal streams in their areas and to prohibit the use of such streams for the disposal of polluting matter. The Rivers (Prevention of Pollution) (Scotland) Act 1965 (H. M. S. O. 1965), extended these powers and gave the river purification authorities power to control, in addition, all discharges to non-tidal streams which pre-dated the coming into effect of the 1951 Act. The 1965 Act also gave river purification authorities power to control new discharges of effluent into certain "controlled" tidal waters as defined in Schedule 2 of that Act. These cover all the coastal areas where pollution is most likely to occur.

Where it is shown that stricter control of tidal waters in an area is required, the Secretary of State for Scotland may, by order, extend the full powers of both Acts to any of the tidal waters around the Scottish coastline.

Dumping outside territorial waters is administered in Scotland in much the same way as for England and Wales.

Oil pollution around the United Kingdom is controlled under the London Oil Pollution Convention provisions. Possible pollution from oil or gas exploration and exploitation is controlled under the Petroleum (Production) (Continental Shelf and Territorial Seas) Regulations 1964 (H. M. S. O. 1964a). These stipulate that harmful effects as a result of gas or oil escapes must be avoided during drilling or other operations. Failure to observe this clause can lead to the revocation of the licence for exploitation.

Summary of the various control powers

Pollution of coastal waters is controlled at present (December 1968) in all the countries represented on the Working Group except the Netherlands, where a new law controlling pollution is in 1969 in the course of being adopted. However, the mechanisms and degree of control exercised vary considerably from country to country, as does the amount of purification of effluents required by law.

All the member countries represented in the Working Group, with the exception of Norway, either do, or will, legally control the dumping of wastes from ships within territorial waters, i. e. within three miles. In the case of Norway the territorial limit is four miles, but provided a vessel is in open waters it may dump wastes (see part vi of this section). The control of disposal of wastes outside territorial waters is generally on a persuasive basis and all the member countries effectively operate some such system. The new pollution law of the Netherlands will, however, give legal powers of control over <u>all</u> sea dumping, including that by other countries of wastes carried through the Netherlands. Sweden has discussed the eventual possibility of controlling offshore dumping under existing export legislation. All the member countries control oil pollution according to the London Oil Pollution Convention agreement.

(2) SEWAGE POLLUTION

A summary of the situation in each member country

(i) Belgium

Largely untreated sewage is carried by all the main rivers and discharged from the big towns direct to the sea. There are large seasonal variations at coastal holiday resorts, e. g. Ostend, where the discharge rate is 8 000 m^3/day in winter but rises to 15 000 m^3/day in summer. The total quantity of sewage discharged directly to sea is estimated at 23 x 10^5 m^3/day. Some of this receives partial treatment and no figure is available for the polluting load.

(ii) Denmark

In general all sewage must be treated although exemption can be granted in certain cases, e. g. small towns. The total quantity of sewage discharged directly to sea is estimated at 1 x 10^4 m^3/day. No figures are available for the pollution load which this represents, but some of the sewage is partly treated.

(iii) Federal Republic of Germany

All sewage must be treated; very large quantities of treated wastes are carried by the main river systems. The total quantity of sewage discharged directly to sea is very small and is insignificant compared with that carried by the rivers. No figures are available for the polluting load carried by the rivers.

(iv) France

Treatment of waste water is now a matter undertaken by all communities wherever possible. At present approximately 85 000 m^3/day of sewage is discharged from France directly to North Sea or English Channel waters. About 48 per cent of this receives some form of treatment prior to discharge.

(v) Netherlands

There are not many discharges direct to sea but the tendency is for the number to increase. There is a trend towards long sea outfalls with little or no treatment of the wastes. The sewage discharged directly to sea comes from a population of about 3 million and imposes a pollution load of 10 tons/day phosphorus, 100 tons/day nitrogen and 1 500 tons/day BOD. The polluting load carried by the Rhine is much greater and the 2 x 10^8 m^3/day flow carries 60 tons/day phosphorus, 1 000 tons/day nitrogen and 2 x 10^3 tons/day BOD.

(vi) Norway

Under a new pollution control law expected in 1968 large towns will in future have to give at least primary treatment to their sewage. Many do not do so at present. The total quantity of sewage discharged directly to the sea is estimated at 3.8×10^5 m^3/day. No figures are available for the quantity of nitrogen or phosphorus pollution.

(vii) Sweden

There are many untreated wastes at present, but a programme of construction of treatment plants is in progress and there is a rapid move towards treatment of wastes. No figures are available for the total quantity of sewage discharged directly to sea or for the polluting load.

(viii) United Kingdom

(a) England and Wales. Much untreated sewage is discharged directly to the sea, and a tendency for long pipelines to be used is increasingly evident. Treatment is adopted at some holiday resorts and also for many estuarine discharges. In some shellfish-producing areas treatment of sewage is required by local legislation. Large seasonal variations occur in areas where tourism is important. The total quantity of sewage discharged directly to the sea is estimated at 25×10^5 m^3/day and this imposes a pollution load of about 23 tons/day phosphorus, 100 tons/day nitrogen and 550 tons/day BOD.

(b) Scotland. Sewage is mainly untreated although the present tendency is for primary treatment plants to be built. The total quantity of sewage discharged directly to the sea is estimated at 13×10^5 m^3/day and this imposes a pollution load of about 12 tons/day phosphorus, 52 tons/day nitrogen and 290 tons/day BOD.

Note: In many instances it has been extremely difficult to obtain figures for the quantity of sewage discharged directly to the sea. The figures quoted for volumes are not strictly comparable since water consumption *per capita* varies tremendously with the different countries, for instance 400 l/capita in Norway and 100 l/capita in France.

Effects of sewage pollution

Sewage pollution can influence marine waters in any of the following ways:
(i) the addition of nutrients such as phosphate and nitrate may lead to eutrophication; (ii) pathogenic micro-organisms in the sewage, including viruses, may be transported from one place to another, or be concentrated by shellfish, with risk to public health; (iii) the addition of organic material may cause de-oxygenation of the receiving waters. The bacterial contamination and organic loading aspects can, to a large extent, be overcome during the course of sewage treatment, but the nutrients will still remain in the effluent waters; indeed their initial concentration will be higher as a result of the decomposition of organic material. Some methods are available which will remove the nutrients (Rohlich 1964; Shapiro *et al.* 1967; Føyn 1964), but these are often relatively costly and are used only in special instances.

(i) Nutrients

Few of the members of the Working Group were aware of any major problems arising as the result of nutrients in sewage discharged to the sea, but in Oslofjord eutrophication creates considerable difficulties (Anon. 1968a). The fact that phosphate and nitrate come in appreciable quantities from the land can be seen to some extent in the Serial Atlas of the Marine Environment (Johnston and Jones 1965), which shows clearly that the phosphate and nitrate concentrations are highest near the coasts. There does not appear to have been much detailed work done on the tracing of nutrients close inshore, although Krey (1956) has shown that the effect of river systems can be followed well out to sea by tracing the changes in nutrient levels and plankton composition. A similar situation has been reported for the Thames and Elbe by Kalle (1953, 1956), who followed phosphate and phytoplankton tongues offshore.

Studies particularly concerned with tracing nutrients are in progress in three countries. In the Netherlands the programme involves sampling a network of densely-spaced stations inshore in order to map the phosphate concentrations in the coastal waters. A study of the nutrient levels in Oslofjord has been in progress since 1936 and the evidence shows a gradually extending enriched zone moving out along the fjord. In the United Kingdom a study of nutrients and suspended solids in the inshore waters off the north-east coast of England is under way in connection with an investigation of the possible effects of pollutants on marine flora and fauna in that area.

Most of the delegates knew of blooms of phytoplankton which had either caused the death of fish or shellfish indirectly by de-oxygenation of the water or had had direct toxic effects on fish or shellfish (Rae, Johnston and Adams 1965). In some instances these had also been observed in man and birds (Ingham, Mason and Wood 1968). The effects of these blooms are usually confined to individual fjords or estuaries, but a few have been very widespread and two recent ones off Norway and the United Kingdom have extended over several hundred kilometres (Brongersma-Sanders 1957; Ingham, Mason and Wood 1968). It was generally agreed that nutrient upwelling was of prime importance as a causative agent in the blooming of phytoplankton. However, other factors such as sunlight, temperature, stability of the water column and addition of nutrients from sewage discharges, or even from large colonies of wild-life, have also been suggested as possible causes of plankton blooms.

Typical blooms due to nutrient enrichment occur regularly in Oslofjord, different species of flagellates being involved. Such blooms may be widespread, as, for example, in 1966 when *Gyrodinium aureolum* bloomed sporadically along the coast from outer Oslofjord in the east to north of Bergen in the west. Although in this area the prime cause of plankton blooms is thought to be nutrient upwelling this particular organism was not reported prior to the fjord becoming polluted by sewage. However, *Gyrodinium aureolum* is a fragile organism and is not easily preserved; it is therefore possible that it was missed in earlier investigations. Among other cases discussed was a recent bloom of *Prorocentrum micans*? off the Netherlands coast which was stated to be unique in Netherlands' records.

Although many of these plankton blooms have been reported, and in some instances nutrient enrichment as a result of man's activities has been suspected as the causative agent, in no case has there been any conclusive evidence to prove that this was so.

(ii) Bacteria

The risks of bacterial contamination from sewage pollution have long been recognized in connection with illnesses arising as a result of consumption of infected shellfish, particularly oysters and mussels (Bulstrode 1896, 1911; Dodgson 1928). It was pointed out that escallops (*Pecten maximus*) which had previously been considered safe might well become infected as a result of the growing move towards the adoption of long sea outfalls discharging in deep water.

The anaerobic bacterium *Clostridium botulinum* type E may under certain conditions render fish products toxic for man, causing botulism. The organism, being present in sewage and soil, is carried into the bottom deposit of certain coastal regions of the northern hemisphere, i.e. Japan, Canada, USSR and western Europe (Johannsen, 1963). In Europe, it is widely distributed along the coasts of Scandinavia, Greenland, France and Germany, but not of Britain (Cann *et al.* 1968). The organism produces a highly potent toxin when contaminated fish are stored incorrectly. In Europe the greatest danger is associated with raw or partially cooked herrings taken from regions where type E organisms are present in the deposits (Cann *et al.* 1966), although canned and smoked salmon, pickled herring and canned sprats have also been vehicles of infection (Pedersen 1955).

The possible connection between sea-bathing and contraction of diseases by man was discussed at some length. Various workers have reported on this subject, e.g. Brisou (1955, 1962) who concluded that sea bathers do run some risk of contracting various minor diseases and hepatitis and that water skiers are in particular danger by way of water forced up their nasal passages. Brisou's work refers particularly to crowded and polluted beaches on the Mediterranean coast. The report of the Moore Committee (Moore 1959) in the United Kingdom was also discussed. This Committee was unable to find any direct correlation between sea-bathing and illnesses such as poliomyelitis and hepatitis, and concluded that unless the sea was so heavily polluted by sewage that bathing became aesthetically objectionable there was no risk to sea bathers. Melbye (1967) also concluded that the contraction of serious diseases could not be directly linked with sea-bathing.

It was concluded that bacteria introduced to the sea via sewage were unlikely to be dangerous to sea bathers except in certain very heavily-polluted areas, since they have a comparatively short life in sea water. The evidence as regards diseases caused by viruses is conflicting, with some workers claiming a correlation between sea-bathing and, for example, hepatitis infection, and others refuting it. Although standards of pollution are not applied to North Sea beaches it should perhaps be mentioned that in the United States varying but rigorous standards based on numbers of *E. coli*/100 ml are applied by each State.

Outbreaks of disease in fish might on occasion be attributable to bacteria carried in sewage or, alternatively, to poor water quality giving the conditions conducive to the rapid spread of disease. An outbreak of a disease in coalfish (*Pollachius virens*) in Norway, possibly caused by *Vibrio anguillarum*, was discussed in some detail. The outbreak had been very widespread, the larger part of young coalfish being affected. Bacterial infection of cod eggs in Oslofjord has been reported by Oppenheimer (1955) and Shelbourne has noted reduced viability of plaice eggs under hatchery conditions and attributed this to the same cause (Shelbourne 1963).

(iii) Organic loading

Where the discharge of effluent, such as town sewage, which has a relatively high organic content, is involved, some effect on the dissolved oxygen levels can occasionally be discerned. These problems are usually local in nature; however, commercially exploitable fish may be driven away, or the passage of migratory fish prevented by the lack of oxygen.

In the United States, particularly off California, a great deal of work has been done which is relevant to the effect of organic wastes on marine fauna (e. g. Pearson *et al.* 1960). The general conclusions of this work are that locally the effect is to increase the quantities of lower forms of life, often with a reduction in the number of species. A study in the Firth of Forth, Scotland, of the fauna of a polluted shore had shown that *Polydora ciliata* was abundant almost to the extent of excluding other organisms (Smythe 1968). Similar work was carried out by Swedmark (1966), in the harbour and outside it, at Göteborg. He found that *Capitella capitata* was very common in polluted, but not heavily-polluted, waters. In exceptional circumstances, however, even local effects could be important, for example if a fish nursery area was affected. A joint Swedish-Danish study had been carried out in the Øresund (Bonde 1967) to study the effects of sewage pollution on fisheries, and the conclusion was that there were no detectable effects except perhaps with herring, the fishery for which has declined.

Complete de-oxygenation of marine waters over extensive areas was not a problem except in certain special cases such as fjords, for instance Oslofjord (Anon. 1968a) where the rate of exchange was very slow. However, a Swedish study (Fonselius 1968) demonstrates that there is no cause for complacency. The oxygen concentration at a number of stations in the Baltic Sea has been studied for the past sixty years. At one of these stations, F75, 100 km east of Gottland, the oxygen level in the water at 100 m had decreased from over 3 ml/l in 1904 to less than 0. 4 ml/l in 1967. Some scientists believe that this is at least partly due to the breakdown of organic matter carried out from the coasts. This breakdown would cause the consumption of oxygen in the deep water which, due to the salinity conditions and pronounced halocline, is rather stagnant.

Summary

Sewage pollution may have detrimental effects as a result of its oxygen demand, its nutrient content (either actual or potential) and its bacterial content. The effect of oxygen demand is usually local only and is not considered to be significant in terms of the North Sea as a whole, although it may be important in restricted areas, for example fjords. There is some evidence that increased nutrient levels as a result of sewage pollution may be associated with blooms of algae and that these may be important in coastal waters, particularly in shellfish-producing areas in the case of a bloom of a toxic alga. There was no evidence brought forward that bacteria caused more than local problems.

The overall conclusion was that the situation as regards sewage must be watched, but at present the effects are believed to be local.

(3) INDUSTRIAL POLLUTION

(i) Belgium

A large number of industrial wastes are discharged to the rivers and although some work is in progress on the effects of these wastes on fisheries very little is at present known either about their effects or even their composition. The Schelde Estuary is affected by industrial pollution from higher up the river and from Antwerp, but this river's contribution to North Sea pollution is only 10 per cent of that of the Rhine.

Only one major industrial waste is known by the authorities to be discharged directly to the sea. This waste is produced by a factory making titanium dioxide and is a typical iron-containing acidic effluent. After consultation with the Belgian and Netherlands authorities, permission was given for the waste to be dumped outside territorial waters. The waste has been dumped daily by barge in an agreed area since 1960. It contains on average 10 per cent sulphuric acid and 2-3 per cent iron sulphate; exceptionally these concentrations can rise to 15 per cent H_2SO_4 and 9 per cent $FeSO_4$. Discharge from the barge is via two 20 cm hoses, 1 metre below the water surface while the barge steams counter current. The area (radius 1 mile, centre 51°50'N and 3°10'E) is one of rapid water movement and little fishing importance: to date no ill effects on fishing interests have been reported, although some discoloration of the water has been observed.

(ii) Denmark

There is very little heavy industry in Denmark and there is therefore very little direct pollution of the sea from industrial sources. Previously there had been local problems caused by fish oils at fish-processing plants but these are no longer a problem since the factories have installed purification plants.

The only major problem encountered was at a factory producing weed-killers which used phenols and cresols as raw materials. Some phenols and cresols were being discharged to the sea and some fish, particularly eels, cod and flounders, were affected by tainting. A paper by Boëtius (1954) sets out the levels of phenols which can cause tainting. These levels are very low; for instance, 1 part in 10^{10} of solution can cause tainting of oysters, since these animals can concentrate the pollutant above the human taste threshold of about 1 part in 10^8. It was pointed out that only one or two tainted fish are needed to seriously affect the whole fish market. Thus even if the taint problem is a local one a much wider area may be affected. This problem with phenols has been eliminated, since the factory now purifies its waste prior to discharge.

In common with other Scandinavian countries Denmark is concerned about mercury pollution, and although this does not at present seem to be as serious as in Sweden (see part vii of this section) the situation is being examined to see what may need to be done.

(iii) Federal Republic of Germany

The Federal Republic has very little industry near the coast and there are no important industrial discharges directly to the sea. The main industries of the Federal Republic at present discharge their effluents to inland waterways, but under the new laws for pollution control much of the present pollution will have to stop. As a result many industries are turning to sea disposal as an alternative. Since coastal water pollution is now also controlled this sometimes means dumping beyond coastal waters.

A number of applications for permission to carry out disposal of waste at sea have been received by the authorities. The materials to be disposed of cover a wide range, but they include regular dumpings of sulphuric acid (375 tons/day), iron sulphate (750 tons/day), gypsum (200 000 tons/year), chlorohydrocarbons (40 tons/month), and polyethylene (40-50 tons/month). Single dumpings are also common and proposals for such things as creosote, pyrites cinders (600 m^3), calcium arsenate (350 tons), arsenic residues (10 tons) and spoilt lecithin (300 tons) have been received and dealt with.

These proposals for sea disposal are dealt with as described by Weichart (1968) (see section 1, part iii) and according to the danger class to which they are assigned, permission to dump may or may not be granted. Most proposals are granted and very often the area designated for disposal is the North Atlantic beyond the continental shelf; examples of wastes disposed of in that way would be arsenic, the chlorohydrocarbons and gypsum (since it contains some U^{235}). The proposal to dump polyethylene was turned down since it does not decay and will float. If a waste is to be disposed of in drums then the drums must be completely filled and weighted so as to sink. The disposal of some solids in very strong paper sacks is proposed. Both drums and sacks must be disposed of at depths greater than 1000 m.

(iv) France

Industrial pollution of the North Sea proper, i. e. from the French coast east of the Pas de Calais, comes primarily from an oil refinery at Dunkirk, a factory treating titanium minerals, a paper mill and a small distillery at Calais. There are a number of smaller factories and cooling water effluents but these do not have any marked effect on the environment. West of the Pas de Calais the main industrial centre is Le Havre which has bunkering facilities, oil refineries, a petrochemical plant and a factory treating titanium minerals.

All industrial effluents must satisfy the provisions of an Instruction of 6 June 1963. Where the main industrial effluents do discharge to the sea their outlet points are all several dozen metres from the shore, and it is felt that any effect they may have on the environment must be very limited.

No discharges of wastes are made from ships within North Sea or English Channel waters.

(v) Netherlands

The major source of industrial pollution in the Netherlands is that which is carried by the River Rhine. This river, as well as carrying effluents discharged to it in the Netherlands, also carries the effluents discharged in the other countries through which it passes. As was mentioned in section 1, part v, an International Rhine Commission is working towards improving this situation. The extensive industrial area west of Rotterdam also discharges wastes to the same sea area as the Rhine. The second most important source of pollution is the River Schelde and Antwerp, although this is considerably less than that of the Rhine. There are also a number of smaller discharges which are of little importance other than locally. These include the iron and steel industry at IJmuiden which are of little importance such as zinc, in its waste waters. The third pollution source of importance is international shipping which contributes a variety of wastes, of which oil is the most important, to the general pollution load.

Disposal of wastes directly to the sea by long pipe-lines or by ships is growing in importance, with some firms specializing in disposal of wastes at sea. In addition to these two direct methods there is also some dumping from the North Pier, Hook of Holland. The principal discharges from the pier at present are 1 500 tons/year of nitric acid and lower fatty acids, and a total of 1 700 tons/year of pickling bath wastes from three sources (main one 1 500 tons/year) which contain a variety of metals, such as aluminium, iron, chromic chromium, together with sulphuric acid, hydrochloric acid and cyanide.

The trend towards discharge of waste materials at sea from ships outside territorial waters is increasing. Among the wastes at present being discharged are 1 200 tons/year of mixed salt and sulphates, 3 600 tons/year of sulphuric acid containing aromatic sulphur compounds, and 750 000 tons/year of titanium dioxide wastes containing 20 per cent sulphuric acid and 5 per cent iron sulphate. The number of new proposals for disposal by this method is steadily increasing and they include proposals to dump 700 000 tons/year of gypsum wastes, 60 000 tons/year iron sulphate, 700 tons/year pickling wastes containing cyanide and 10 per cent metals, 4 000 tons/day sewage sludge, an unspecified quantity of 6-chlorocresol, etc. Many of these new proposals came from other countries, for example the Federal Republic of Germany, as a result of new pollution control measures in these countries.

There has been no evidence of large-scale and lasting harm to fish or shellfish as a result of industrial pollution, but there have been a number of incidents at pesticide manufacturing plants (see section 4, part v) which have resulted in fairly extensive fish mortalities. A case of pollution by copper sulphate in coastal waters caused locally extensive fish mortalities (Roskam 1965, 1966).

(vi) Norway

Industrial pollution in Norway has not yet reached levels of very great importance but the growth rate of industry is very rapid and pollution is on the increase. Pollution caused by the timber and paper pulp industries has caused a minor reduction in home fisheries, particularly in the fjords. Among the first species to be affected are sea trout and salmon. Mussels may be affected up to 100 metres from the pulp mills by the blanketing of fibres. The fish-processing side of the fishing industry gives rise to effluents which cause local complaints but these are frequently on aesthetic grounds. Preservation of fish in formalin prior to curing results in the discharge of wastes containing 18 000 tons of 40 per cent formalin solution per year, about half of which is discharged to the sea, often in the upper reaches of fjords. Over half of the formalin is used during the summer months; it does not appear to affect fisheries. In addition to the formalin waste the fish-curing industry gives rise to wastes containing fish oils and soluble material; these can create pollution problems up to several kilometres from the release site. Improved methods for the regeneration of oil and organic solubles are however under development and an improvement is expected.

Mining activities, chiefly in southern Norway, for iron, copper, sulphur and niobium cause some local problems. These are most serious in the sulphur mining areas, but as most of the mines are situated inland their effects on the marine environment are negligible and no complaints are received from marine fisheries interests.

Of the newer industries aluminium is one of the most important. Most of the factories are situated on the west coast and many of them use imported bauxite. The wastes from these factories include some aluminium oxide, hydrofluoric and sulphuric acids and large quantities of "red mud". The effects on fisheries are noticeable but local, and usually areas of about five square miles are involved. Some fish kills have been reported from the sea area off the mouth of the River Nidelva and these were attributed to poisonous wastes dumped from industrial plants along the river.

The fishing industry is the cause of some local trouble to traffic due to discarded or lost fishing gear. The situation has been aggravated by the introduction of synthetic fibre netting which does not decay. Recently a ban was introduced by the Director of Fisheries on the dumping of ropes, nets and drums, etc., since on several occasions these have proved to be dangerous and have caused shipwrecks and fatal casualties. Lost purse-seine catches have proved to be harmful to local fisheries, and on one occasion the rotting dead fish so polluted the bottom water of a fjord that the fish caught there became tainted.

As in Denmark and Sweden (see this section, parts ii and vii), mercury pollution is a problem although perhaps on a lesser scale. Mercury compounds are chiefly used in fungicide preparations of paper and pulp. In 1968 a total of 8 000 kg/year was used.

(vii) Sweden

The principal industry in Sweden causing marine pollution is the forest industry which, taken as a whole, imposes a BOD load of 620 000 tons/year on the waters to which it discharges its wastes. By comparison sewage from Sweden has a total BOD loading of only 50 000 tons/year and the total contribution from other Swedish industry is 25 000 tons/year. Most of the discharges are, however, to the Baltic Sea.

There are several problems directly produced by the forest industry and one of the worst is the fibre problem; each year approximately 200 000 tons are discharged to the rivers and sea and most of these eventually reach the Baltic Sea. A typical factory would use 100 000 m^3 of water/day and discharge 6 tons of fibres; ultimately these decompose and as they do so tend to reduce the oxygen concentration in the water. Trouble is also caused by the wood sugars, lignin acids, resins, sulphate and sulphite waste liquors which darken the water and limit primary productivity. The pollution problems arising as a result of the forest industry are much worse in Sweden than in Norway and fishing has been seriously affected in many coastal areas. In some areas acid wastes from the pulp factories appear to be responsible for the very thin shells which are found on molluscs. In general, the sulphite process is preferred from a pollution point of view because it gives rise to a less toxic waste liquor. However, other types of paper are required and it is impossible to change over entirely to one manufacturing process.

Many factories are now attempting to remove fibres and other substances prior to discharge of the wastes. Under a new law, which will take air pollution into account, it may not be possible to dispose of the wastes by burning, and the pulp industry may be faced with another problem.

Pollution by mercury compounds is very serious in Sweden. Although the usage of mercury has been curtailed it will remain in the environment for a long time to come. The main use of mercury compounds was in the forestry industry as fungicides but they were also used in agriculture and in some other industries. The problem has now reached the stage where commercial fishing has had to be prohibited in certain lakes and some coastal areas, although exceptions may be made for some migratory fish (see Appendix 1, Figures 3 and 4). In some of the restricted areas the level of mercury found in fish tissue reaches 3-4 mg/kg wet weight, which is far above the recommended safe consumption level set by FAO, i.e. 0.02-0.05 mg/kg. The safe level at present in Sweden is set at 1.0 mg/kg, but there is an official recommendation that such fish should only be eaten once a week. Mercury is a cumulative poison and the uptake and transformation into dangerous compounds by the organism is now being thoroughly studied by several scientists (see, e.g. Noren and Westöö 1967; Hannerz 1968; Jernelöv 1968). Boëtius (1960) has reported on the levels of mercury, both inorganic and organic, which are known to be harmful to fish.

Although the usage of mercury and its compounds has now been restricted within Sweden, air-borne mercury from industrial sources in Europe will still be rained out over Swedish territory and thus mercury pollution may continue to be a problem. A further air-borne source of pollution is sulphur dioxide from European and Swedish industry, e.g. nylon and titanium dioxide production. This is also rained out and although it has not yet caused trouble in the sea some fish kills have been experienced in lakes as a result of lowered pH.

Other industries such as metallurgy, engineering, food and chemicals are situated primarily in southern Sweden and some of the biggest factories are in coastal areas. Generally their wastes are controlled and only local trouble may be caused. A number of accidents do occur and in some areas these have caused mortality of marine flora and fauna. One such example is a copper refinery where some of the marine animals are affected from time to time. Until recently arsenic was dumped in the sea as a waste but this is now being reclaimed.

Some dumping of wastes in the sea is carried out from ships: the materials dumped range from harbour dredgings to chemicals in drums and paper mill fibre sludges, which interfere with fishing and cause tainting of fish.

Hot water wastes from power stations are increasing both in volume and number and these may cause alteration in the flora and fauna and thus affect fishing activities. No problems exist at present but large new stations, for example 2 000 MW nuclear plants, are being built, some of them rather close together. Their combined heated effluent flows will be similar to the flows of some of Sweden's larger rivers.

(viii) United Kingdom

(a) England and Wales. Inland industrial wastes are disposed of on land or via rivers, usually after treatment at the factory or at a sewage works. The main industrial areas causing pollution on the North Sea coast are on or adjacent to the estuaries of the Tyne, Tees, Humber, Thames, Medway and Swale, and on the south coast around Southampton.

The types of industry in England are varied and it is impossible to select any one as being the most important from the pollution standpoint, although the largest volume of any one type of waste arises from chemical factories. The north-east coastal area around the estuaries of the Rivers Tyne, Wear and Tees is heavily polluted by a variety of wastes of which chemicals are by far the most important, as in the River Tees where out of 1.4×10^6 m^3/day of effluent over 90 per cent is waste from the chemical industry complex which discharges a wide variety of chemicals including sulphuric acid, metals, cyanide, ammonia and phenol. None of these three estuaries supports any fishing, but within a $\frac{1}{2}$ km of the estuary mouth fishing is relatively good. Just north of Teesmouth a factory which extracts magnesium from sea water discharges 2.3×10^5 m^3/day of spent sea water containing about 35 tons of suspended solids, chiefly calcium hydroxide, but there is no evidence that this affects fishing. Coal washings and coal wastes dumped directly on the shore line amount to 1.8×10^4 m^3/day and 4 million tons/year respectively. Their effect is local, some loss of crab and lobster ground resulting.

The Humber Estuary is affected from a fishing point of view by pollution; it is difficult to determine how serious this is, but 1.4×10^6 m^3/day of trade wastes are discharged. These effluents carry with them 1 000 tons/day of sulphuric acid, 250 tons/day of iron sulphate, 2 500 tons/day of gypsum, 7.2 tons of zinc and 3.0 tons of phenols, plus many other chemicals.

The Thames Estuary, with 2.8×10^6 m^3/day of mixed trade waste and sewage, is very seriously polluted and until very recently was devoid of oxygen along a five mile length at certain times of the year (H.M.S.O. 1964b). This situation is slowly being rectified by sewage purification and treatment of trade wastes, but at present fishing is still seriously affected. South of the Thames the Medway and Swale are affected by wastes from the paper industry which is concentrated in that area. Fishing has been adversely affected, particularly the oyster industry which has been almost completely wiped out in the estuaries. The nearby Whitstable native oyster fishery has also declined, probably as a result of the loss of parent stock in the Swale.

Southampton Water on the English Channel coast receives about 1×10^6 m^3/day of trade wastes, part of which is power station cooling waters. However, between one-third and one-half of the total is effluent from chemical factories and oil refineries. Fishing is affected locally, chiefly by tainting by oil of both fish and shellfish. On the south-west coast china-clay wastes are the major problem. These are at present carried by the river waters and a total of about 1.4 million tons/year is discharged into Mevagissey and St. Austell Bays and the Fal Estuary. Approximately 0.3 million tons/year are also discharged into the Plym Estuary. Fishing is affected but it is not known to what extent; a survey in 1968 attempted to assess the situation.

In addition to the discharge of trade wastes direct from the shore some wastes are disposed of in deeper water offshore by barges. The materials are dumped in recognized areas around the coast and range from harbour dredgings and sewage sludge to gas-works liquors. Apart from harbour dredgings the amounts involved are generally not very great except off the north-east coast, where 1 million tons of power station ash and 2 million tons of colliery wastes are dumped in the sea each year. The effect on fisheries of these materials, which are not toxic but increase the suspended matter in the water, appears to be slight. Further investigations are to be made.

(b) Scotland. The industries in Scotland which give rise to the majority of the industrial wastes are iron and steel manufacture, coal-mining, pulp and paper or board production, and whisky distilling. The iron and steel and coal industries do not appear to affect fishing interests and no problems arise from that source.

Paper and board production in Scotland give rise to about 2.4 x 10^3 m^3/day of effluent but most of the mills treat their wastes and discharge them to inland waters and so do not affect marine fisheries. The only pulp mill in Scotland has been in operation for only three years. The effluent carries up to 30 tons of suspended material and has a BOD load of up to 40 tons of oxygen each day.

The production of whisky in Scotland now runs at 80 000 000 proof gallons/year (approximately 6 x 10^6 m^3 by volume) and together with the beer-brewing industry uses over 3 million tons of barley annually. The fermentation of barley to make whisky is not efficient and 80 per cent of the dry weight of grain is discharged as waste. In the Moray Firth alone over 4 450 m^3/week of "spent ale" are discharged, with a BOD equivalent of 112.5 tons of oxygen. This is one-fourteenth of the sewage BOD for the whole of Scotland. Whisky wastes undoubtedly affect fishing, although only locally. In some areas road tankers dump hot spent liquors directly into the sea from harbour jetties. This practice can cause the death of lobsters held in cages near the point of discharge, and the effects on the oxygen level in the water can be followed for about 100 metres. Whisky wastes have also been blamed for mortalities of salmon held in bag nets.

Dumping of solid wastes in Scottish waters is confined mainly to the Firths of Forth and Clyde. Approximately $\frac{1}{4}$ million tons of fly ash are dumped annually in the Clyde and explosives are dumped both in the Clyde and Forth. The current rate of explosives dumping in the Firth of Forth is about 38 tons/year, but immediately after the last war much larger quantities were dumped. In the Clyde the present dumping rate is about 300 tons/year, but at the end of the last war it was much greater, e.g. 10 000 tons in 1946. These explosives are claimed to cause tainting or colouring of fish. Typical cases have been plaice from the Firth of Forth which had an almond-like odour, and *Nephrops norvegicus* from the Firth of Clyde which had a yellow colour. However, no direct link with explosives could be established either by chemical analysis or other means.

Most of the pollution effects on fisheries are local and are confined to areas of 100-200 metres radius around the outfalls. The only large areas seriously affected are the Firth of Clyde - which receives about half of all Scottish effluents - and the Firth of Forth - which receives about one-quarter of all Scottish effluents. The Firth of Clyde is not recognized as a fishing area within about 20 km of Glasgow. Fishing is still practised in the Firth of Forth, but it is claimed (without any precise evidence, however) that the loss of the oyster fishery during the last fifty years was due to sewage and industrial pollution.

Summary

(i) Belgium

There is very little industrial waste known to be discharged directly to the sea, but the one known case takes place in an agreed area outside territorial waters.

(ii) Denmark

There is not a great deal of industry to give rise to wastes. There have been one or two local problems in the past but these are now controlled.

(iii) Federal Republic of Germany

Since most industry is inland there is very little direct industrial pollution of the sea. However, as a result of new anti-pollution laws concerning inland waters the trend is towards disposal of wastes at sea, often in the deep water of the Atlantic by special vessels.

(iv) France

There is not a great deal of industrial pollution from the French coast and there are only three towns which cause any real degree of pollution. All industrial wastes discharged to the sea must satisfy certain conditions. The effects of industrial wastes are thought to be extremely local in nature.

(v) Netherlands

The major source of pollution is the Rhine, which also carries pollution from outside the Netherlands. Rapid expansion of industry is resulting in increased pollution in the Netherlands, but apart from a few isolated cases the effects are local. There is a marked move towards the disposal of wastes beyond territorial waters as a result of anti-pollution measures in force in the Netherlands and other countries along the Rhine.

(vi) Norway

There is not much industrial pollution at present although it is increasing. The main sources are pulp and timber, electrochemicals and fish processing. Mainly it is the fjords which are affected, particularly Oslofjord; these, as well as the coastal waters, are becoming increasingly affected by drifting plastic articles and discarded fishing gear. The latter problem has been shown to be seriously affecting shipping traffic and has definitely hampered local fishing activity.

(vii) Sweden

Large areas of the coastal waters are polluted and fishing is affected. The main sources of pollution are the forest products industries but minor problems arise as new industries, such as chemicals, expand. Mercury pollution of Swedish waters is also a major problem and many inland and some coastal waters have been declared prohibited fishing areas. The topographical and hydrographical conditions of Sweden assist in preventing pollution being dispersed to the open sea.

(viii) United Kingdom

Diverse industrial effluents are discharged to the sea and these do cause some problems which are, however, local in nature. Generally only estuaries are affected (e.g. Tyne, Tees, Humber, Thames, etc.), and even though these are affected to a greater or lesser degree, fishing within 1 km of the mouths of the estuaries does not appear to be reduced. In Scotland a pulp mill and distillery wastes are the main problems, but even these are local in their effects. There are some areas offshore where dumping of wastes is permitted, and in Scotland the dumping of explosives is claimed to cause fish tainting or colouring.

(4) PESTICIDES

(i) Belgium

Very little is at present known about pesticides and their effects on fishing or fish in Belgian waters, either inland or marine. Although there are no immediate plans for studies on this topic it is likely that some work will be started within the next two to three years.

(ii) Denmark

In the marine field there is at present very little pesticide research in progress, and there are no plans for such work in the immediate future. A few experiments have been carried out to examine the toxicity of some herbicides to fish, and some troubles of a local nature were experienced at a parathion-formulating factory and at a factory producing weed-killers from phenols (see section 3, part ii). A small government laboratory carries out analyses for pesticides but these are primarily for food control purposes. However, there are no statutory tolerance levels for pesticides in food laid down at present. As far as is known no analyses have been carried out either of sea fish or sea water. There have been some fish kills in rivers, usually as a result of washing of spraying equipment, but no marine fish kills attributable to pesticides have been reported.

(iii) Federal Republic of Germany

Some work on pesticides is being done in the Federal Republic, but it is at present chiefly confined to the effects on man of pesticides in food. A system of tolerance limits came into force in 1968 (Bundesgesetzblatt 1966) and the use on crops of many pesticides including aldrin, dieldrin, endrin, heptachlor and arsenic, selenium and mercury compounds has been banned. (Local laws in certain States of the Republic may permit usage of these materials in special circumstances.). As new pesticides are developed they are tested for efficiency in their intended role and for toxicity to fish, and a working agreement is then drawn up between the manufacturer and the land and fisheries ministries on the uses to which the new product can be put. It is compulsory to label containers, where appropriate, with warnings as to danger to fish.

Some fish kills have been experienced in inland waterways and one case of tainting of carp in a fish-farm by "gammexane" at a distance of 50 km downstream of its source has been reported. There is at present little or no work being done on pesticides in the marine field but work will shortly start on this topic at the Institute of Inland and Coastal Fisheries, at the Helgoland Biological Station and at other establishments. Most of the German work to date is summarized by Bauer (1961), but much of the information given refers to the freshwater environment.

(iv) France

Research is carried out at a number of laboratories in France on the subject of pollution by pesticides. Some measurements have been made with marine animals but no results have been published; however, the pesticide contents were described as being "extremely low".

Some fish kills have occurred as a result of accidental spillages of herbicides in estuarine waters. A fish kill was observed some years ago in Mediterranean salt ponds after spraying as an anti-mosquito measure. As a result subsequent treatments have been confined to biological measures.

Usage of pesticides is governed by the following legislation: the Law of 2 November 1943, which was ratified by the Ordinance of 13 April 1945 and later modified by the Law of 30 July 1963. All pesticide formulations must be approved before they can be sold. No maximum permissible pesticide content has been fixed for foods but the matter is being considered. The European Economic Community is at present preparing regulations to this effect.

(v) Netherlands

The Netherlands operates a system of pesticide residue tolerances as published in a Pesticide Residues Order of 1965 (Nederlandse Staatscourant 1965). This Order defines the maximum quantities of a large number of pesticides which can be permitted in foodstuffs. On the general subject of pesticides there is a moderate amount of work in progress and some of this is directly related to the marine environment. All new compounds must be thoroughly tested for their toxicity before they can be used, but marine fish are not included in this scheme. Only approved pesticides can be used in agriculture. At the Institute of Fisheries Investigations, IJmuiden some work is carried out on the toxicity to fish of pesticide formulations, in particular herbicides, but most of this work is related to problems in the canal system. In the last few years analyses of shrimps for organo-chlorine pesticides have revealed a gradual increase in the concentrations of pesticide found in these animals and this trend is causing concern.

Accidents at the large pesticide manufacturing plant in Rotterdam have caused at least two major fish kills. The first of these involved a release of endrin which resulted in a kill of all fish in an extensive system of inland waters. The second incident was not discovered until the colony of sandwich terns at the Isle of Griend showed an alarming decrease in the number of birds nesting. The incident was finally attributed to an accidental release of telodrin at a works in Rotterdam (Koeman et al. 1967).

Some work is planned which will be directly concerned with pesticides in the marine environment. It is intended that both seawater samples and marine organisms will be analysed, in particular for organo-chlorine pesticides and possibly for organo-mercury compounds. The marine animals to be analysed will include shrimps and mussels. Some food-chain and accumulation studies will be made, both in laboratory tanks and in the field.

(vi) Norway

As part of an OECD programme, the Institute of Zoology at the Norwegian High School of Agriculture, in cooperation with the High School of Veterinarians, is carrying out work on levels of pesticides in the environment; recently analyses of DDT in marine fish have been included in the programme. The quantities of pesticides which may be used in agriculture are defined by licence. Some pesticide analyses of sea fish are being considered by the Fisheries Institute but the main concern at present is for the rivers and freshwater fish.

(vii) Sweden

Some work on the effects and levels of pesticides on freshwater fish is in progress, but only very little is being done on marine fish. It is planned to continue the present research programme and it is also intended to include some marine species. A special council is working on the question of banning the use of some pesticides completely and limiting usage to those materials which are comparatively short-lived. Since 1966 a system of tolerance levels in some food-stuffs has been in force regarding aldrin, dieldrin, DDT and -BHC (Kommerskollegii Forfattningssamling 1966).

(viii) United Kingdom

An extensive programme of pesticide studies is in progress at a number of laboratories. Rather more work has been done which can be directly applied to the freshwater environment than to the marine environment. It has now been established that very little organo-chlorine pesticide material is washed out of the soil into the river systems. The main supply routes to the marine environment are via rain water and rivers which carry pesticides that have been discharged as a result of industrial usage or accidents, or from the cleaning of agricultural spraying equipment and the disposal of sheep dips.

At present (December 1968) voluntary schemes for agricultural chemicals approval and pesticide safety precautions are operated in the UK. Under the first of these schemes recommendations for the correct usage of the various chemicals are made and the use of unsatisfactory chemicals is discouraged. Under the provisions of the second scheme, new chemicals, or formulations, are not released for general use until recommendations for their safe usage have been agreed by the various government departments concerned. Only pesticides which have been approved should be used and all containers should carry warnings of toxicity to fish or other animals where such warnings are needed.

It has recently been announced that this voluntary system is to be replaced by legislation. The proposed new Law will be called the "Pesticides Bill" and under it a Licensing Authority will be set up. The Authority will consist of the Minister of Agriculture, Fisheries and Food, the Secretary of State for Scotland, the Minister for Health and Social Security, and the appropriate Ministers for Northern Ireland or the Home Secretary on their behalf. A licence, which could be revoked, will be issued by the Authority for a "pesticide product" and this term will include fertilizers with pesticide additives. Conditions attached to the licence will, for example, stipulate the proportion of active ingredient permitted, the uses to which the product may be put, and the directions regarding safe usage etc. which must be included on the label.

Under the new law it will be an offence to buy, sell, or import any pesticide product for use in agriculture in its broadest possible sense, in the home or garden or in food storage, which has not been licensed or which does not fulfil the conditions of that licence. It will also be an offence to use a pesticide product in a way that contravenes the instructions of its licence, for example by deliberately overdosing a crop or foodstuff in store, or by continuing to use a pesticide for a purpose publicly announced as no longer allowed.

There are no tolerance limits for residues of pesticides in food in operation in the United Kingdom, but a general limit of 0.1 ppm for aldrin and dieldrin in all foods, with special exceptions such as 1 ppm in mutton fat and 0.003 ppm in milk, has been proposed (Egan 1967). A clause in the new law will provide the necessary powers to impose residue limits on any crop or foodstuff to ensure good agricultural practice, irrespective of any danger to the consumer.

Marine organisms are being analysed at two Government establishments, the Freshwater Fisheries Laboratory, Pitlochry, Scotland (DAFS) and the Fisheries Laboratory, Burnham-on-Crouch, England (MAFF).

At Pitlochry, analyses for chlorinated hydrocarbons have been made, using several organs and tissues of a variety of marine fish. The species used have not been confined to those of commercial interest and have included cod, whiting and other gadoids, mackerel, sand eels, dabs, flounders, herring and sea trout. Analyses have also been made of mussels (in connection with the OECD cooperative study, see end of this section), of marine zooplankton and of seals and porpoises.

Most of the fish came from inshore waters or from estuaries and though there were wide variations among individuals, all presented evidence of significant and undesirable contamination of these parts of the marine environment. In general, the pesticide concentrations were highest in the liver; for instance, codling from the Firth of Clyde had up to 0.5 ppm total chlorinated hydrocarbon in muscle tissue, but the concentration in the liver ranged from 2.6 to 12.0 ppm.

Zooplankton samples were found to contain measurable, but low, levels of pesticides. Residues of dieldrin, pp'-DDE and pp'-DDT were detected in all the examples examined but, with few exceptions, the levels of individual substances were less than 0.01 ppm.

The highest levels of contamination in the marine environment have occurred in the blubber of seals and porpoises caught on the Scottish coasts. The total residue concentration (dieldrin + DDT complex) in the blubber of seals ranged from 2.9 ppm to 38.9 ppm, and the total residue concentration in one of the two porpoises examined was as high as 73.3 ppm. Although there is no clear distinction between the levels of contamination of seals from different areas of the Scottish coast, the highest contamination occurs on the east coast south of Aberdeen and the lowest in seals from Harris, off the west coast. Seals from Canada, which have also been examined, were generally less contaminated than seals from Scotland (Holden and Marsden 1967).

Fish analysed at Burnham-on-Crouch come from fishing ports all round the coasts of England

and Wales. Analyses are made of the fish muscle and liver for organo-chlorine pesticides. In general the livers are found to contain the highest concentrations of pesticides, and the highest concentration so far recorded was 19 ppm; generally, however, the level is about 1 ppm. Muscle tissue concentrations are generally lower by a factor of 10 or more, and the flesh of oily fish, such as herrings, contains the highest concentrations (Portmann 1967).

In addition to the coastal water samples fish are also sent from deepwater fishing areas off Norway, Iceland and Newfoundland. These fish usually contain less pesticide material than the specimens caught around England and Wales, and the relative proportions of pesticide are usually different. Some analyses are also made of shellfish and the main emphasis to date has been on the analysis of oysters, which are examined at fortnightly intervals. Some analyses have, however, been carried out on shrimps and cockles (Portmann 1967) and others are planned for mussels and lobsters.

Only a very few analyses of sea water have been made so far and the pesticide concentrations found have been very low, ranging between 9 and 24 parts per million million.

Toxicity tests based on the standard 48 hour LC_{50} test described by Portmann (1968) are being conducted and some of the pesticides tested have proved extremely toxic, for example an LC_{50} of 0.0003 ppm for azinphos-methyl to brown shrimps (Portmann and Connor 1968) (see Appendix 2). Experiments are also in progress to study the effects of the time-scale factor but these are not yet complete. No information is available at present on the concentrations of pesticide in the animals killed in toxicity experiments, but it is hoped to include this kind of work in the programme.

Since 1963, the Nature Conservancy has been analysing the eggs and flesh of coastal species of marine birds. The level of pesticides found in the eggs of a number of different species of seabirds varied, but were generally within the range 0.2-8.9 ppm (Moore 1965). Analyses of the breast muscle, liver, and egg contents combined have been carried out on two groups of seabirds, those feeding on plankton and those feeding on fish etc. The levels found in the plankton-eating birds were generally lower than those found in the fish-eating birds, with only one out of twelve specimens containing a total pesticide residue within the range 2-10 ppm, compared with twenty-three out of seventy-nine specimens in the fish-eating group (Moore 1966).

Summary

(i) Belgium

No work is in progress on pesticides in the marine environment and there is none planned at the present time.

(ii) Denmark

Very little work is being done on pesticides in the marine environment and there are no plans for any in the immediate future. Some troubles have occurred at pesticide formulation factories on the coast, chiefly from raw materials causing tainting of fish.

(iii) Federal Republic of Germany

There is little or no work at present in progress applicable to the marine field. An extensive programme of analysis and toxicity testing was planned to start in 1968 at several institutes on the coast.

(iv) France

Some work has been done at a number of laboratories and marine animals have been analysed for their pesticide content. Extremely low concentrations were found. A few fish kills have been reported in marine waters as a result of accidental spillages of herbicides.

(v) Netherlands

Little or no work is at present in progress which is applicable to the marine field. A programme of analysis and toxicity studies on pesticides is planned to start soon. Some bird kills in marine waters have been experienced as a result of accidental releases of pesticides at manufacturing plants.

(vi) Norway

There is some work at present in progress on pesticides in the marine environment. Analyses of sea fish are included but with emphasis on freshwater fish, birds and land animals.

(vii) Sweden

Very little work on pesticides in the marine environment is at present in progress.

(viii) United Kingdom

An extensive programme of research into the levels of pesticides found in fish from coastal and deep-water fishing grounds, and in shellfish, seabirds, seals and porpoises is in progress. A great deal of information has now been assembled on the concentrations of organo-chlorine pesticides in fresh-water fish. Toxicity studies with marine fish and shellfish are also being carried out.

Usage, manufacture, transport and disposal of pesticides

In many countries the principal use of pesticides is in agriculture, horticulture or forestry, but in several countries there is also considerable usage for moth-proofing woollen goods. There is some use of pesticide formulations in Scandinavian countries for wood preservation purposes. In the United Kingdom industrial usage of pesticide materials, particularly for moth-proofing woollen garments and carpets etc., is an important outlet for the pesticide manufacturers; it probably accounts for one-third to one-half of the pesticides discharged to the sea via rivers.

Manufacture of pesticide materials and/or formulation takes place in most of the member countries, but the Federal Republic of Germany, the Netherlands and the United Kingdom are probably the main producers. Of the United Kingdom production of pesticides a high proportion is exported. The manufacture of pesticides inevitably leads to the need for disposal both of contaminated wastes and of surplus or superseded stock. The most commonly used method of disposal is sea dumping in deep water in sealed drums.

Considerable quantities of pesticides are transported by sea every year and must be considered to be among the most hazardous of cargoes from a fishing point of view. If a vessel carrying pesticides in its cargo were to be wrecked in the North Sea the effects on marine life could be disastrous. A government committee is at present working in the United Kingdom on methods of reducing the risk of such a catastrophe taking place; for example, pesticides might be carried in strong corrosion-resistant, clearly labelled containers stowed in a readily accessible position to facilitate ease of salvage etc.

Treatment of pesticide materials so as to render them harmless is not an easy problem. Some of the compounds involved, such as phenol-based herbicides, may be treatable with hypochlorite which causes splitting of the ring structure and inactivation. Many others are more or less intractable and incineration is often the only satisfactory method of treatment. This method of disposal/destruction can pose problems if not carefully supervised, for instance through explosion and corrosion. A method of treating waste waters which could possibly be useful is filtration through activated carbon.

Monitoring

Only one country, the United Kingdom, is at present operating a monitoring programme, although the Netherlands and the Federal Republic of Germany both have plans along these lines. At present the UK programme involves the analysis of fish and some shellfish at fairly regular intervals from a number of coastal and deep-water fishing grounds; seabird eggs are also being examined. Various animals were suggested as being suitable for inclusion in a monitoring programme and it was felt that non-migratory animals were most satisfactory for this purpose. It has been shown by Butler (1966) in the United States that oysters are good indicator organisms for organo-chlorine pollution, since not only can they readily concentrate these materials but they can also excrete them once the polluted waters have passed. It is generally agreed that the higher the trophic level the higher the concentration of pesticide that may be expected (see Woodwell et al. 1967). The whelk (Buccinum undatum) was mentioned as being possibly a suitable animal since it is a non-migratory carnivore, but no member of the Working Group knew of any analyses of these animals.

Under a programme sponsored by the OECD the analysis of a number of widely dispersed common animals has been arranged. The marine representatives chosen are the mussel and the dogfish. Many laboratories in different countries are submitting results of such analyses to the programme co-ordinator (Mr. Holden, DAFS, Pitlochry, Scotland) in order that the world-wide distribution of pesticides in these species can be determined. As a check against variations in analytical techniques standard mixtures of known content are also being analysed.

(5) OIL AND DETERGENTS

(i) Belgium

Belgium has had little experience in dealing either with oil on beaches or with oil-spills and there is no information available on the effects of oil on fisheries. Where oil has polluted beaches these have been flat and sandy and the oil has been buried or cleared by bulldozers. Solvent-emulsifiers would normally be used on floating oil before it reaches the beaches. One oil-spill occurred in a closed dock system in Antwerp and solvent-emulsifiers were used on this with success.

(ii) Denmark

Oil pollution is a permanent but minor problem in Danish waters. Only one major incident has been experienced and that was when a vessel was wrecked in the Kattegat. Solvent-emulsifiers were used on this occasion and would probably be used in the future. Until recently oil sinkers were used but it is now strongly suspected that this practice can lead to fouling of fishing gear and fish tainting. Some experiments with oil sinkers and oil in glass tanks have confirmed the view that oil is released from many oilsinking materials.

Oil alone is not thought to be very toxic and experience with one small oil-spill in a harbour confirmed this theory. On that occasion an oil hose broke and between 10 and 100 tons of oil were spilt into the harbour, covering the entire water surface. Live cod and plaice were being stored in the harbour at the time and although these became tainted no physical ill-effects were noticed.

(iii) Federal Republic of Germany

Oil pollution affects the Federal Republic, particularly in the navigable rivers, and one major oil-spill has occurred in the German Bight. Oil-spill removers are generally toxic to fish, whereas the oil is in many cases not thought to be so toxic. Wherever possible oil-sinking agents are used, and absorbent floating materials such as "Ekopell" (Mann 1966) and peat have been used successfully in harbours and rivers without harming fish. Attempts are being made to find a material which is equally effective at sea.

Some work has been carried out on the toxicity of oil and oil-emulsifier mixtures with the larvae of Clupea harengus and Agonus cataphractus (Rosenthal and Gunkel 1967). This showed that, although oil alone did not damage the larvae over a four-day period, concentrations as low as 0.5 mg/l of solvent-emulsifier, mixed with 2 mg/l of oil, did. Fourteen different solvent-emulsifiers were examined by Kühl and Mann (1967) for their toxicity to sea and freshwater animals; lethal limits of between 0.001 and 0.1 ml/l were found. Although very little attention has been paid to the toxicity of oil alone to marine animals a report on the toxicity of oil to freshwater fish showed that oil could be harmful at 200 ppm and that motor fuels were toxic at between 40 and 200 ppm, depending on the boiling point (Zahner 1962).

At a meeting held in Helgoland in September 1967 a Working Group discussed various aspects of oil pollution and its removal. The main proceedings of that Working Group have been published in the Helgoländer Journal (Anon. 1967a) and some of the papers are referred to individually below. For example, Wallhauser (1967) reported on investigations into the role of naturally occurring bacteria in the normal breakdown of oil on the sea or on the shore, and suggested that cultures of these bacteria might be used to deal with oil-spills in some cases. Wallhauser (1967) has also developed a method of isolating these bacteria which can break down oil, and Gunkel and Trekel (1967) have worked out a quantitative determination technique.

Work by Hellmann, Klein and Knöpp (1966) at Koblenz has suggested that although solvent-emulsifiers are effective in emulsifying oil the emulsion breaks down again in a few hours. However, since dispersion will probably have occurred by then this need not necessarily be important. Work by Gunkel (1967) in Helgoland has shown that the degradation of oil by bacteria is inhibited by the use of solvent-emulsifiers.

(iv) France

Oil pollution of the North Sea coast is caused by passing ships and to some extent by the Dunkirk refinery. Pollution due to oil refineries has caused some damage to marine life and certain inshore areas are no longer exploited, but these are not extensive.

Considerable experience was gained in the treatment of oil pollution and its effects on marine life at the time of the TORREY CANYON disaster. It was found that on beaches which were entirely. covered by oil the gastropods were killed. Crustaceans such as crabs and shrimps disappeared immediately, but soon returned. Rock lobsters which had been only briefly in contact with the oil survived if placed in clean water, and bivalves survived for several hours in water with oil floating on it. The detergents used to treat the oil were toxic to marine fauna but their toxicity varied with the animal species as well as with the detergent used.

The means available for dealing with oil pollution, especially after an accident, are being studied and are expected to be published in an Inter-ministerial Instruction which will specify which bodies will organize operations and the methods to be used.

In the event of a disaster at sea the Ministry of Defence will co-ordinate and direct operations at sea. It will be assisted by the merchant fleet in such matters as the supply of materials. Stocks of anti-petroleum products have now been built up at certain ports.

(v) Netherlands

Oil pollution of coastal waters and beaches is an ever-present problem in the Netherlands. A committee has been studying the problem of pollution of beaches by oil for a number of years and receives reports from all coastal towns. Although some communities are not as efficient as others in sending in reports it is clear that there has been very little change in the situation during the period of study. Reports have also been gathered from aircraft, shipping and lightvessels over the past 4-5 years and again very little change has been indicated.

From a fisheries point of view it is considered better to leave the oil alone, but beach amenity interests often conflict with this. Once the oil is on the beaches, which are generally sandy, bulldozing is the usual practice and although solvent-emulsifiers are being considered it is unlikely that their usage will become widespread. The Ministry of Fisheries is opposed to the use of oil-sinking materials and solvent-emulsifiers which are known to be toxic.

Under the auspices of the Ministry of Public Works work is in progress to find the best methods of dealing with oil. It has been suggested that harrowing of oil-polluted beaches aids degradation of the oil by bacteria. Methods of recovery of oil from the sea by the use of materials such as absorbent plastic foam, possibly in conveyor belt form with a roller to squeeze out oil, have shown promise for use in sheltered waters.

(vi) Norway

Three oil refineries are in production (two) or being built (one), but so far no spills have occurred and stringent measures are taken to prevent them. Some experience has been gained, however, in dealing with accidental oil-spills and an official "Oil Pollution Commission" advises on means and techniques for the treatment of oil-spills. Mechanical recapture followed by cleaning of beaches using emulsifiers has been employed, for example, after the stranding of a tanker on the west coast of Norway in spring 1968 which caused an oil-spill of several hundred tons. Only a minor part of this was recovered and the cleaning of beaches using solvent-emulsifiers was still in progress in August 1968 in a few places, by which time approximately 30 000 litres of detergent had been used.

(vii) Sweden

As in other countries, oil pollution as a result of accidental oil-spillages does occur. No definite procedures have been devised for treating oil-spills, but where oil is on the sea it is usually dispersed or collected by various means, e.g. peat, because of dangers to bird life and recreation areas.

(viii) United Kingdom

Oil pollution is quite an important problem in the United Kingdom although Scottish waters are less seriously affected. Release of oil accidentally at oil terminals, or for one reason or another from ships at sea, results in about 50 000 tons of oil contaminating the coast and coastal waters of the United Kingdom each year. This figure was exceeded in 1967 when the wreck of the TORREY CANYON alone resulted in approximately 100 000 tons of oil polluting the waters off the south-west coast, and of this about 20 000 tons actually reached the coast of Cornwall, causing serious pollution of beaches, cliffs and harbours.

The general practice in the United Kingdom is to treat oil on beaches with oil-spill removers, provided that these beaches are not in estuaries or near other important shellfish areas. The toxic nature of solvent-emulsifiers is recognized but it is accepted that, in many instances, in the interests of beach amenities and of seabirds, steps must be taken to clear the oil. Each large oil-spill is considered on its merits before permission is given to use solvent-emulsifiers; in minor incidents the local authority - or at an oil terminal the company concerned - usually deals with the problem. A report by the Warren Spring Laboratory of the Ministry of Technology (1968) advises on the various methods of dealing with oil pollution and at the same time draws attention to the toxicity of solvent-emulsifiers. Bulldozing, raking and harrowing were suggested and all are used on occasions on suitable beaches.

Following the wreck of the TORREY CANYON about 3 million gallons (13.6×10^3 m^3) of solvent-emulsifiers were used at sea and on the Cornish coasts. In this area the beaches shelve very rapidly and water movements are comparatively rapid, and, although the beach flora and fauna suffered considerably, the effects of the solvent-emulsifiers were barely perceptible immediately offshore. Some crabs and lobsters were killed and a few incidents of lobster tainting were reported, but damage to commercial fish offshore seems to have been very slight (Simpson 1968).

It is accepted that the results of such large-scale use of solvent-emulsifiers would probably have been very different and unacceptable in a different area, for instance the eastern English Channel or the outer Thames Estuary. It is for this reason that a variety of alternative methods of dealing with oil pollution are being examined. Progress is being made with foam scavengers, methods of recovery of oil by pumping it off the water surface, and oil-sinking agents. Attempts are also being made to develop less toxic and more effective solvent-emulsifiers. One oil company claims to have developed such a material.

A considerable amount of work has been done in the United Kingdom on the toxicity of solvent-emulsifiers to marine life, both before (Warren Spring Laborabory 1961) and after the TORREY CANYON disaster (Corner, Southward and Southward 1968; Portmann and Connor 1968; Wilson 1968a and b; Smith 1968). The general conclusions of these workers were that the solvent-emulsifiers were highly toxic to marine animals and particularly to their larvae, but that their toxic effects were largely due to the solvent fraction which rapidly evaporated, with a resultant decrease in toxicity. In the case of larvae, however, the initial damage caused by exposure to fresh solvent-emulsifier was often sufficient to prevent further development, even though the larvae appeared to recover and behaved normally for 4-6 weeks (Wilson 1968a).

Some attention has also been given to the natural fate of oil in the sea, and an article by Pilpel (1968) summarizes the known means by which oil is naturally lost from the sea. In this paper figures are given for the rate of bacterial degradation of oil; this process is temperature-dependent and in the tropics the rate of breakdown can be as high as several hundred grammes of oil per cubic metre of sea water per year.

Although oil-sinking agents are not generally acceptable from a fisheries point of view, since the sunken oil can contaminate fishing gear, it has been claimed by Cooper (1968) that the rate of bacterial decomposition of oil is enhanced when materials such as chalk are used. On the matter of bacterial decomposition, observations after the TORREY CANYON incident indicated that although the numbers of bacteria were initially reduced by the solvent-emulsifiers they rapidly recovered and attacked the oil.

Summary

(i) Belgium

Belgium has had only limited experience with oil pollution, which has been dealt with chiefly by bulldozing it on beaches or by solvent-emulsifiers.

(ii) Denmark

Until recently oil-sinking agents were used to deal with pollution by oil, but these are now suspected of causing tainting of fish and contamination of fishing gear and are no longer used.

(iii) Federal Republic of Germany

The main problems arise in estuaries and rivers and since solvent-emulsifiers are recognized as being toxic, sinking and floating absorbent agents are preferred, although owing to the difficulties involved in using these materials solvent-emulsifiers are frequently used. Research work is in progress on various methods for dealing with oil and of oil-degrading bacteria. In 1967 a committee was set up to deal with oil accidents on the sea.

(iv) France

Oil pollution is a recurrent problem on the French coast. Considerable experience was gained in both the effects of oil pollution on marine life and the ways of combating it, at the time of the TORREY CANYON disaster. Standard procedures are now being worked out which will lay down the organizing body and methods to be used in the event of oil pollution occurring again.

(v) Netherlands

Oil pollution presents a recurrent problem on beaches and bulldozing has been the method used for dealing with serious oil pollution. Solvent-emulsifiers are being considered but there is a reluctance to use them because of their toxicity. A committee receives regular reports from coastal towns on the state of the beaches and also from lightvessels etc. on floating oil patches.

(vi) Norway

Complaints of oil-spills have occasionally been received. Oil in Oslofjord and from accidental losses on the coast are the main causes of complaints. There is no generally accepted method for dealing with oil pollution, but some progress is being made on a method of removing floating oil by pumping it off the water surface.

(vii) Sweden

The pollution of coastal waters and coasts by oil is a minor problem along the entire Swedish coastline. There is no recognized single procedure for dealing with the pollution but in most cases some action is taken because of the risk to seabirds and recreation areas.

(viii) United Kingdom

The quantity of oil causing pollution of British coastal waters is approximately 50 000 tons/year. The general method of treatment is by the use of mechanical methods of removal and solvent-emulsifiers, but the latter are not recommended for use in areas of important shellfish beds or areas of importance for nature conservation. Oil-sinking agents are not generally recommended because of the risk of contaminating fishing gear and tainting the catch. Experience after the TORREY CANYON disaster, when 3 million gallons of solvent-emulsifier were used at sea and on the Cornish coast, showed that although much of the intertidal life was destroyed, very little damage was caused to fishing interests - largely due to the hydrographic conditions in the area. Development work is in progress on new and improved methods of dealing with oil-spills, and the toxicity to marine life of solvent-emulsifiers and oil and solvent-emulsifier mixtures has been examined.

General

All the member countries recognize the Convention on the Prevention of the Pollution of the Sea by Oil (H. M. S. O. 1958), and pollution of the sea by their own vessels is controlled by domestic legislation.

At a recent meeting of delegates of each of the countries represented on this Working Group and France, agreement was reached on procedures which should be adopted in the event of a major oil-spill in the North Sea (see Appendix 3). It now only remains for the agreement to be ratified by each country for it to come into effect.

Among the agreed procedures for cooperation are: the interchange of information on dealing with oil pollution, prompt reporting of accidental spills from a vessel of a member country or seen by a vessel or aircraft of a member country, the supply of information about the movements of an oil-spill, and the supply of man-power and equipment by neighbouring countries in the event of difficulties being experienced by a member country in dealing with a large amount of oil pollution either at sea or on the coast.

It was also envisaged that these procedures should apply in the event of a discharge of any other noxious substance in the North Sea. In both cases the North Sea has been defined as being that area south of latitude $61^{\circ}N$, including the Skagerrak, as far as a line in the English Channel, the exact position of which has now been fixed.

Domestic detergents

Household detergents were briefly discussed under this heading and it was concluded that there is very little chance of these materials being damaging to marine life, particularly now that many countries are using biologically "soft" detergents. In Germany, where the river system carries large volumes of sewage effluent, the sale of "hard" detergents is forbidden by law. In the United Kingdom "hard" detergents have been almost completely replaced by "soft" materials on a voluntary basis.

(6) TOXICITY STUDIES, METHODS AND RESULTS

Information on the topic of toxicity experimentation was rather scattered and has been collected together under sub-topic headings rather than by national contributions as in other sections. Brief notes are, however, included concerning the work being done in the various countries which were members of the Working Group.

Type of test

Only one country, the United Kingdom, had toxicity-testing apparatus actually in continuous operation, with two laboratories - one run by Imperial Chemical Industries (ICI) in Devon and the other by MAFF - carrying out tests on a routine basis. Both of these laboratories conduct short-term (5 days or less) toxicity experiments as routine, with the object of determining lethal concentrations to 50 per cent of the test organism. The apparatus used by MAFF has been fully described by Portmann (1968) and that used by ICI is similar (Carter 1963), the main difference being one of scale; ICI uses a larger arrangement. The drawback to static water systems, such as these, is that toxin may be lost from the water by one means or another during the course of the experiment. This loss naturally becomes more serious the longer the experimental period. To overcome this difficulty continuous flow methods must be devised, and although a number of these have been used in the freshwater field such methods do not yet appear to have been widely used in the field of marine toxicity testing.

There are many advantages in studying lethal doses over a relatively short period, among them that feeding is unnecessary and that complications arising as a result of a "normal" death rate are negligible. However, such experiments give no information about sub-lethal effects and frequently do not even give information on the threshold lethal concentrations. The classical methods for obtaining threshold concentrations have been described by Wuhrmann (1952) and Wuhrmann and Woker (1948, 1950). If the logarithm of the survival time is plotted against the logarithm of the concentration then a curve should be produced which is asymptotic to the concentration axis and to a line parallel to the other axis which cuts the concentration axis at a point giving the threshold concentration. Frequently, however, instead of a curve, a straight line is obtained which cuts both axes and this is typical of the results obtained with heavy metals. Other exceptions encountered are neither the classic curve nor the straight line, but a combination of the two.

The majority of symptoms which can be used to give a measure of the effects of different sorts of pollution involve long-term studies, for example effects on reproduction, growth, etc. Recently, however, Butler (1966) has described a technique for shellfish, applicable at least to American oysters, in which the shell-edge is filed off and the rate of regrowth in five days is sufficiently large for any reduction due to pollution to be measurable. One factor which can readily be used over a short period is oxygen uptake. This method has been used successfully by a number of workers for marine organisms and even for fish eggs (see e. g. Kühl and Mann 1967). A variation of this method has been used by Carter (1962) to determine approximate LC_{50} values. Here the oxygen content of water in sealed vessels containing fish is noted at the time at which the fish die, both for the controls and polluted waters. By graphical comparison of the two sets of figures a rough estimate of LC_{50} can be produced.

The behaviour of fish submitted to electrical fields is altered by the addition of some toxins and this can be used as a measure of pollution (Halsband 1966). Over a period of 2-4 weeks changes can also be detected in the number and type of blood cells in the blood of fish subjected to certain types of pollution, and this method has been used by Halsband (1963) with small guppies, trout, etc. The rate of development of juvenile stages of some marine animals is reasonably rapid and this has been used in recent work on solvent-emulsifiers intended for use on oil-spills (see e.g. Corner, Southward and Southward 1968; Wilson 1968a and b).

Which organism should be used?

There was no general agreement as to which organisms should be used for toxicity testing, but it was agreed that those organisms which are easily maintained under laboratory conditions do not necessarily make the best test species. Among the suggestions for suitable test organisms were: cod, herrings, plaice, dabs, black gobies, sticklebacks, guppies, shrimps, oysters, cockles, Tubifex and phytoplankton cultures.

Various stages in the life cycle of the different test organisms have been used in experiments, e.g. the eggs of herrings (Kinne and Rosenthal 1967), shrimp and crab larvae (Portmann and Connor 1968), and barnacle larvae (Corner, Southward and Southward 1968), but most experiments have been carried out on the adults of the species. It was generally agreed that larvae are more sensitive than adults to a particular toxin (see e.g. Portmann and Connor 1968). Similar results have been experienced with young shrimps (Portmann 1968) and with fish (Boëtius 1960), where the size measured by body weight was related to metabolic rate by a fixed power of between 2/3 and 1 and this in turn was related to death rate.

Although no definite conclusions were drawn, there was a general feeling that any meaningful toxicity testing should be carried out with representatives of the different groups of marine life, e.g. fish, crustacea, mollusca, flagellates, etc., and that care should be taken to avoid using the more resistant members of each group. It was also felt to be undesirable to base all conclusions on tests with very sensitive species. Tests with various stages in the life cycle of the test organism were generally felt to be important, with different member countries emphasizing different stages.

Factors affecting susceptibility

A number of factors were mentioned as affecting susceptibility of the test animal, and work by Boëtius (1960) and Portmann (1968) has already been mentioned in the section above. In the same paper Portmann gives details of the effect of starvation and found that it increases susceptibility. Details are also given of experiments carried out at various temperatures, and although different responses were noted with different organisms there was a general pattern of increased susceptibility with rise in temperature. The influence of feeding conditions on the uptake of radionuclides by cod has been noted by Berge (1964). Sundnes (1957) discussed the acclimation time of cod and noticed that small changes in the environment might affect the oxygen uptake. Thus, for example, a change in observer caused an immediate rise in the oxygen uptake by cod (Sundnes, unpublished work).

The period of exposure to a toxin is clearly important, particularly where lethal concentrations are in question, and this subject was briefly discussed above under the heading of "Type of test", when work by Wuhrmann and Woker (1948, see also 1953) was mentioned as having shown that many chemicals do have threshold concentrations.

Important environmental effects are not confined solely to the higher marine life. Measurements of photosynthesis in phytoplankton have demonstrated that such organisms are sensitive to the quality of the bottles as well as to the techniques applied in washing them.

Results of toxicity experiments

Many results of toxicity experiments are never published, particularly where the experiments are done by private laboratories or industry. Often the reason is simply that they have been conducted in order to answer specific pollution questions and do not merit publication on their own. There is, however, a limited literature on marine toxicity tests and most of the more important papers have already been mentioned. A few others are, however, included in the bibliography which follows this report.

Work in the member countries

(i) Belgium

At present no experiments have been done or are in progress which can be directly related to the marine environment.

(ii) Denmark

Some work is done at the Danish Institute of Fisheries Research in connection with fish kills. Almost all the experiments are made using fish and are designed to find thresold concentrations.

(iii) Federal Republic of Germany

Some experiments have been done using fish, fish eggs and larvae. Studies of sub-lethal effects by measuring the rate of oxygen uptake are included in the present programme, and toxicity experiments with algae are in preparation.

(iv) France

Some work on the toxicity of various chemicals to marine animals is carried out at the Institut Scientifique et Technique des Pêches Maritimes, Roscoff, Côtes du Nord. Most of the experiments are conducted on bivalves.

(v) Netherlands

Only limited work with marine species has been done at present, but a programme is planned which will involve long-term chronic toxicity studies using large outdoor tanks with a variety of "standard" organisms.

(vi) Norway

Some limited experiments with fish have been made. Some experiments with algae using carefully controlled conditions have also been done, where the effect of the pollutant was measured by monitoring productivity. A study of the effects of pollution on primary productivity in Oslofjord is now planned.

(vii) Sweden

At present only a little work is being done which is relevant to the marine environment. Concerning mercury pollution, methods for investigating the mercury content of fish have been worked out (see e.g. Christell et al. 1965; Westöö 1966, 1967a and b). Routine toxicity tests are made. Some tests with caged fish to study their susceptibility to certain pollutants, especially those from the pulp and paper industry, have been conducted (Hasselrot 1964).

(viii) United Kingdom

Two main laboratories are carrying out routine toxicity testing. Most experiments at present are based on lethal concentrations. Some experiments, however, are intended to measure sub-lethal effects, and work is in progress on the development of methods of studying such factors as oxygen uptake, growth rates and possible avoidance behaviour. A variety of marine organisms is used which includes representatives of several biological groups, for example fish, molluscs, crustacea and algae.

(7) REVIEW OF TRANSPORT AND DIFFUSION MECHANISMS WITH RESPECT TO THE POLLUTION OF THE NORTH SEA

The polluting substances can be divided into three groups:

(1) dissolved substances and substances forming a stable suspension;
(2) substances floating at the surface (for instance, oil);
(3) substances temporarily in suspension which are slowly sinking to the bottom.

Under certain conditions substances from one group may pass into another, for instance, if dissolved substances are adsorbed on sediment particles, they change from group (1) into group (3). The processes of transport and dilution of the polluting substances may be different for the different groups. This report will deal mainly with substances of group (1).

We may consider the following processes:

(1) initial dilution (determined by the method by which the polluting substance is discharged into the sea);
(2) turbulent diffusion: (a) vertical;
(b) horizontal;
(3) advective transport.

It is important to point out that in many cases people are concerned not so much about average processes of diffusion and transport, but rather more about the chance that certain extreme conditions may occur that are thought to be critical. The probability of such an occurrence in similar situations is usually estimated directly from a statistical analysis of a long time series of values of the relevant variable. However, no long series of observations of rates of diffusion has been made and the limited number of long series of current observations is insufficient for most transport problems. In this case we can only make an indirect assessment by considering the influence on diffusion and transport of such better documented factors as wind field and river outflow.

Initial dilution

The purpose of initial dilution of polluting substances is two-fold:

(1) lowering of the concentration below a critical (e.g. toxic) level at a short distance from the outfall;
(2) reducing possible density differences to such an extent that further natural diffusion and transport in the sea is not unfavourably affected by stratification.

Initial dilution is likely to be important only very close to an outfall, since at moderate to large distances it is likely to have only a very marginal effect on the overall dilution achieved.

Initial dilution may be achieved for coastal outfalls by discharging the pollutant through some kind of diffuser or, for discharge from a ship, by mixing in the wake.

In the first case the critical circumstances occur when the current at the place of discharge is weak, e.g. in tidal areas at slack water. A study of the dilution that can be attained under different conditions has been made by Abraham (1963). Some practical considerations are given by Abraham (1966).

A study of the mixing that may be achieved by discharge of pollutants in the wake of a ship has been made by Abraham and Hilberts (1967). Previous investigations have been reported by Hood (1964).

Turbulent diffusion

The turbulent movement, causing the diffusion of pollutants, draws its energy from the tidal motion, from non-tidal currents and from the wind. Thus rates of diffusion may depend on tidal and wind conditions and this should be kept in mind when considering the values found at different places and on different occasions.

Vertical diffusion

Vertical diffusion may be of importance in pollution studies, both from the contribution it may make to the dilution of a pollutant, and also because, as a method of vertical transport, it may move pollutants towards particularly critical regions, for instance from the bottom to the euphotic layer. A combination of vertical diffusion and current shear can also contribute appreciably to the horizontal mixing process (Bowden 1965; Okubo 1967).

The vertical diffusion varies with wind force, wave conditions, current velocity, depth, bottom roughness and vertical stability of the water column. Some of these factors are locally determined, others are subject to regular or irregular variations.

Joseph (1954) has estimated the vertical diffusion coefficient K_z due to the tidal current at a station off Texel. A review of values of K_z and of the coefficient of eddy viscosity N_z, which is of the same order of magnitude as K_z, has been given by Bowden (1964).

From the practical point of view we may divide the North Sea, apart from the near-coastal waters where salinity stratification occurs, into three main regions: the region with vertical homogeneous water during the whole year, the region with a summer thermocline, and the region with a permanent salinity stratification along the Swedish and Norwegian coasts (Dietrich 1950; Laevastu 1963). The conditions for which a thermocline develops have been described by Dietrich (1954). An atlas showing the monthly average depth and intensity of the thermocline from July till September is given by Tomczak and Goedecke (1964). A review of these investigations may be found in the publication of Sager (1965).

In the shallow areas of the southern North Sea where no stratification occurs the values of the vertical diffusion coefficient are determined by turbulence generated by the tidal currents. Some variation of the diffusion coefficient from one area to another is therefore to be expected, according to the strength of the tidal flow. In the bottom layer of the region, with a temporal or permanent stratification, tidal or other currents (together with the bottom roughness) determine the value of K_z, while in the upper layer above a thermocline the wind will usually be the determining factor. In the latter case the diffusion coefficient may show irregular variations with time. Diffusion through the thermocline will be slow and is often negligible.

Horizontal transport by diffusive and advective processes

No sharp distinction is possible between processes to be classified under the headings "turbulent diffusion" and those that are considered as transport. A small-scale view may regard as transport those processes which, on a larger-scale view, would more reasonably be regarded as diffusion. Usually the nature of the problem under consideration will determine where the boundary between the two methods of description has to be drawn.

Thus, for a few days following a point source release the tidal currents may be regarded as producing mainly advective transport. However, at later times, or when considering a continuous discharge, they may be considered as a system of large-scale turbulent eddies. Therefore, in most cases it will be necessary to investigate the hydrographic conditions in the area under consideration, and especially the circulation patterns of different scales. The publications that are relevant to such a study can be found for the years prior to 1961 in the bibliography prepared by Model (1966).

As an example of a local circulation pattern, causing an effective mixing, the circulation described by Dietrich (1953) for the sea area near the island of Texel may be cited.

Horizontal diffusion

Various mathematical approaches to the problem of turbulent diffusion have been considered. In all cases the complexity of the problem has necessitated some simplifying assumptions; the main difference between the various approaches lies in the assumed dependence of the diffusion coefficient on the scale of the diffusing system. A detailed discussion on this subject is given by Okubo (1962). For a shorter review see Bowden (1964).

Apart from a scale effect on the value of the diffusion coefficient we must also take into account persistent current shear which can lead to considerably increased rates of diffusion in the direction of the current.

Estimates of the horizontal diffusion have been made from the salt balance of various North Sea areas (Visser 1966; Schott 1966) and of a number of estuaries, as well as from the diffusion of a water mass marked by turbidity as a natural tracer (Joseph and Sendner 1958).

However, most of the information available comes from experiments with artificial tracers. Rhodamine was used by Joseph, Sendner and Weidemann (1964), van Dam (1965, 1966), van Dam and Davids (1966) and during the ICES experiment RHENO[x]. Radioactive ammonium bromide-82 as a tracer has been used by Harremoës (1964). Similar studies have been made in the Channel in connection with the discharge of radioactive effluent (Whipple 1964; Ausset and Cantel 1966). A review of recent work in the North Sea is given in the reports of the ICES Working Group on Diffusion Processes in the Sea, CM 1967/C:29 (revised) and CM 1968/C:45. Recent theoretical and experimental work of general interest was presented during the symposium on diffusion (Convener J. Joseph), held during the 14th General Assembly of the IUGG (IAPO) in Berne, 25 September - 7 October 1967.

The concentrations of a pollutant in the case of a discontinuous release principally depend on the diffusion. For practical use we can distinguish two different cases:

(1) the waste is released into the open North Sea in a relatively short time, and the area of release is very small so that it can be approximated as a point.

In this case the theoretical treatments predict a decrease of the maximum concentration (C) with time (t) according to an equation of the form:

$$C = \text{constant} \times t^{-n},$$

where n is a constant between 1 and 3 depending on the particular theoretical approach being considered. Experimental results have provided some confirmation of the above equation, although various values of n have been indicated within the range stated.

The area of significant pollution, that is the area in which the concentration exceeds some critical value, changes with time in the following manner. At first this area will increase rapidly; then, after reaching a maximum value, it will decrease again until it finally reaches zero. The time taken to reach the maximum area of significant pollution will depend upon the rates of diffusion, the quantity of substance released and the critical concentration. Formulae and diagrams for this process are given in the publication of Joseph and Sendner (1958).

(2) The waste is released into the open North Sea in a relatively short time in the form of a straight line.

Although there are clearly practical differences between a release along a line and a point release, most of the comments above will be found to apply in both cases. However, the value of n in the formula quoted for the decrease of the maximum concentration with time is unlikely to exceed 2.

The concentrations of a pollutant in the case of a continuous release are dependent on the transport as well as on the diffusion. In this case the general practical rule cannot be given, because the prevailing conditions and the local situation are decisive.

Transport

Transport of pollutants by tidal currents can be evaluated using tidal current atlases as published by different authorities.

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x) The results of this experiment will be published by ICES in its Rapports et Procès-Verbaux.

For a study of the transport by residual currents the variability of the current pattern for different conditions of stratification, river run-off and wind field has to be taken into account. Apart from the fact that charts of esidual currents are often based upon rather scanty field data, these charts do not in any case give predictions for extreme critical situations. An impression of the influence of these factors may be obtained from the investigations of long series of current observations. Up till now this means the observations made from lightvessels. In this connection may be mentioned the work of Carruthers, Lawford and Veley (1950a and b), Lawford and Veley (1955), Mandelbaum (1956), and Veley (1959) in which the relation between the residual current and the local wind is studied. A study of the effect of the local wind on the current near the Netherlands lightvessels is in preparation by the Royal Netherlands Meteorological Institute, and publication of similar results for a number of German lightvessels is envisaged by Mandelbaum (personal communication). It can be expected that more information on this subject will become available in future, since the use of automatic recording current meters is increasing. However, this kind of data at least in the near future will be insufficient.

It should be emphasized that such studies cover only the average relation between wind and current at a certain place and depth. General relations between wind and current should be used with caution. In particular the net onshore or offshore components of water transport near the coast are very close to zero. Thus any offshore movement of the upper layers must normally be compensated by onshore movement of the lower layers or sometimes at other places. The possibility of recycling of polluted water must, therefore, be kept in mind. A review of the present knowledge of the residual current system and the wind influence is given by Lee and Ramster (1968).

Hydrodynamical-numerical methods can be helpful. These methods are used for describing and predicting tides, storm surges and current patterns. A review of these methods as used by a team working in the University of Hamburg is given by Hansen (1966). Leendertse (1967) has given a method that may be especially useful for detailed studies.

Water masses

The concept of water masses (see e.g. Laevastu 1963) may perhaps be helpful in certain cases, giving a general impression of the areas which may be affected by a particular case of pollution. However, in such cases the water masses should be defined on the basis of the concentration of some conservative or quasi-conservative substances in the water, and not on the thermal regime of the area or on biological considerations. It is thought that instead of giving maps with more or less arbitrary demarcation lines between certain water masses (or water types), suggesting rather rigid boundaries, it would be better to give maps with isolines of the contribution (in %) of the different defined water types of the water mass in a certain region.

Special cases

Some special cases have to be considered separately. In the first place the discharge of pollutant in the surf zone has to be mentioned. Here the mixing by wave action, especially by breakers, and the transport by longshore currents and by local rip currents is important. From the coastal engineering angle some of these problems have been studied in detail, but no studies from the point of view of water pollution are known about the North Sea. A South African study of this problem was published by Harris *et al.* (1964).

In the case of pollutants floating at the sea surface (e.g. oil), the wind effect on the transport is of special importance. Here the work of Tomczak (1964), further extended by Neumann (1966), must be mentioned. According to the latter author transport appears to take place with a velocity of about 4.2 per cent of the wind speed in the same direction as the wind. This transport is superimposed on the general movement of the water. However, Smith (1968) gives a velocity of about 3.4 per cent of the wind speed, superimposed on the general water movement.

If, on the other hand, the pollutant is in a particulate form or becomes adsorbed on particles, sedimentation must be considered. In that case the variation of the current with depth has to be taken into account, and in the presence of tidal currents the settling lag, as well as the effect of high seas, stirring up bottom material. This problem is very complex and an adequate review falls beyond the scope of this report.

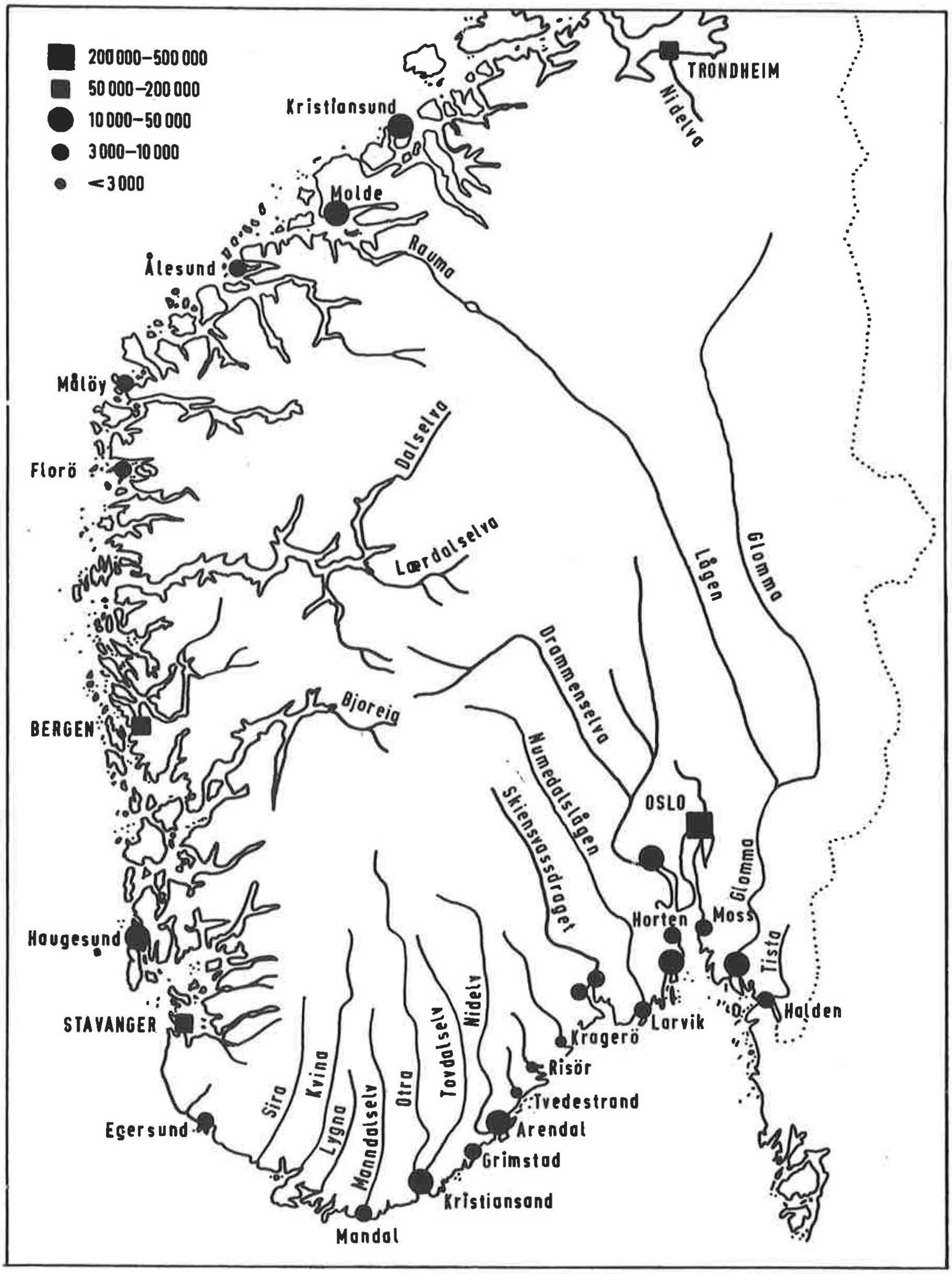

Figure 1. The principal cities and the larger rivers of southern Norway.

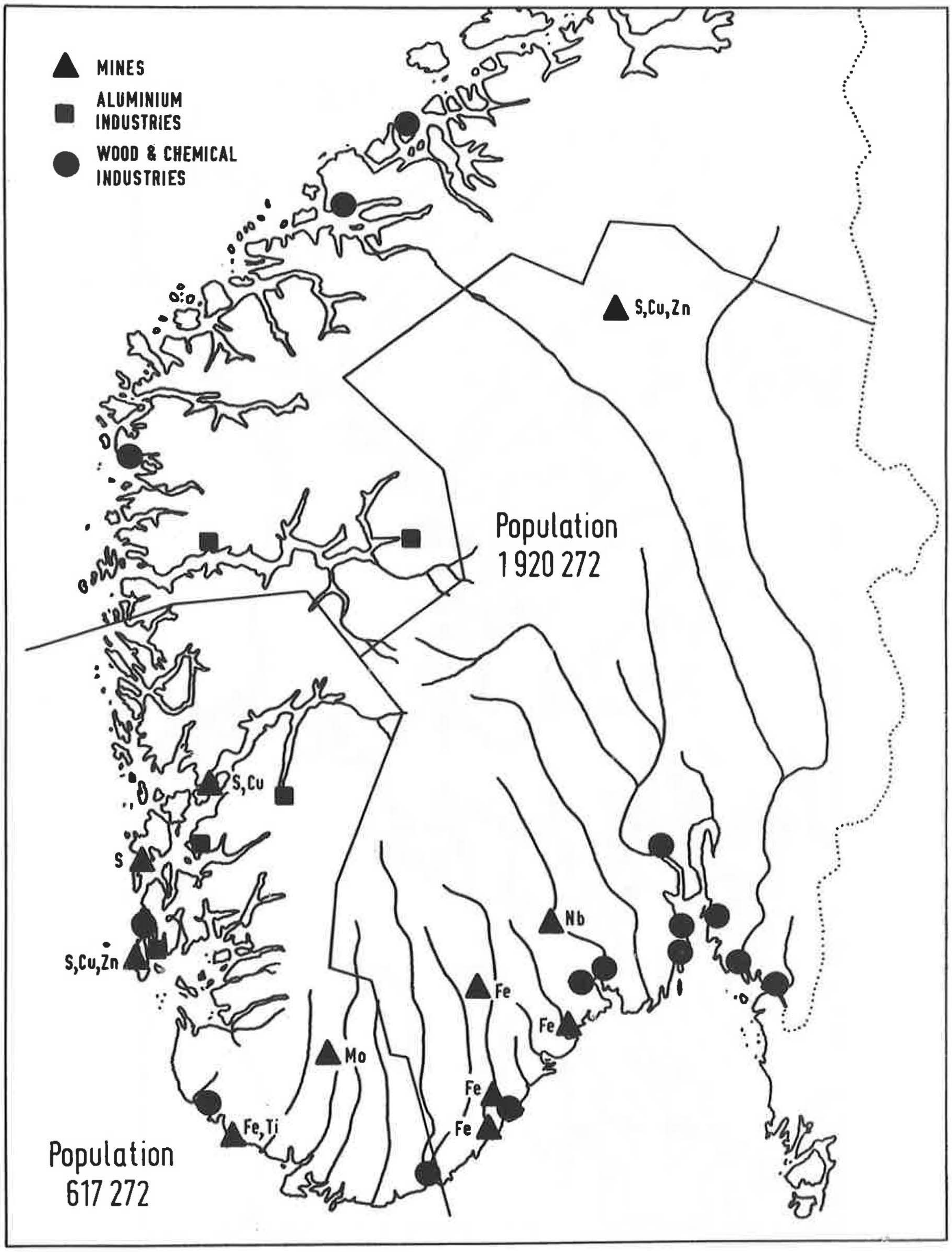

Figure 2. The eastern and western drainage areas, and the location of industries, in southern Norway.

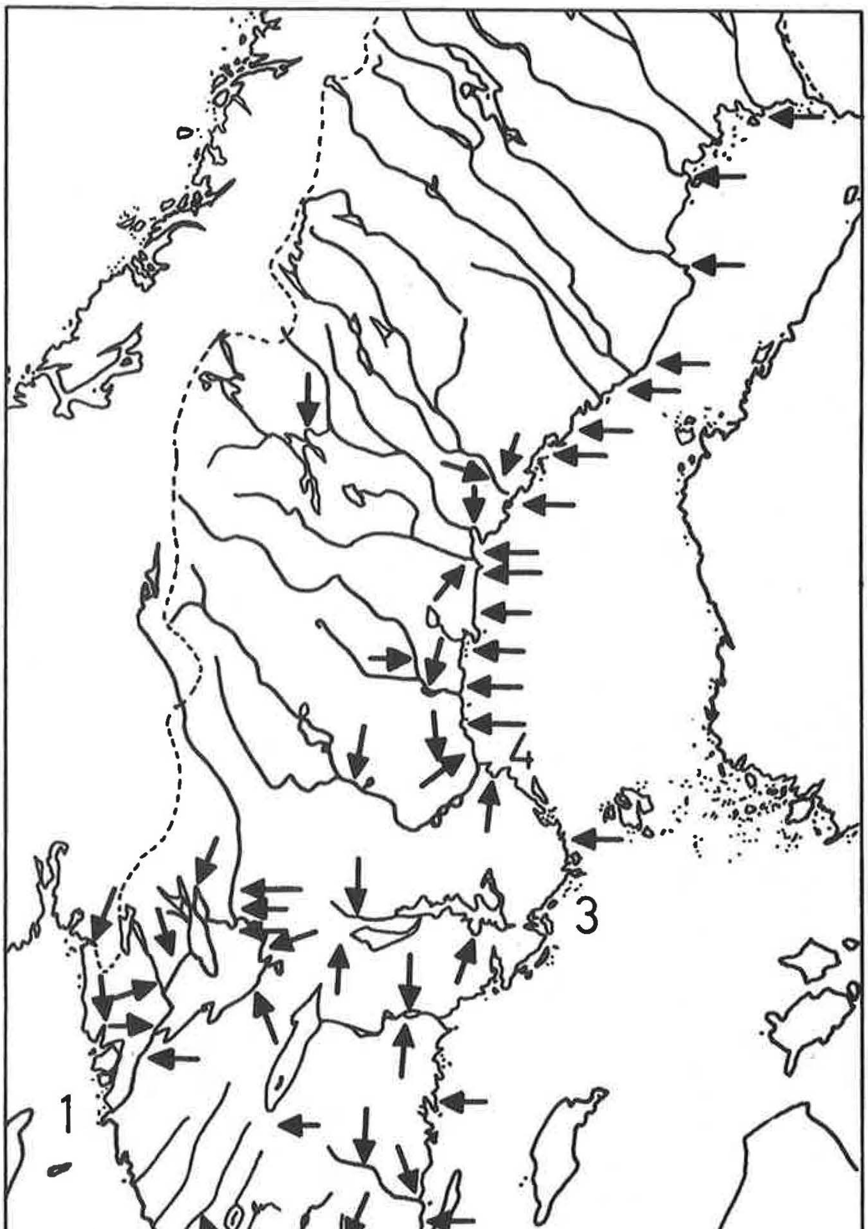

Figure 3. Sweden. The arrows indicate waters polluted from paper and pulp mills. The figures show the worst polluted coastal areas:
1. The Göteborg region, 2. The Öresund, 3. The Stockholm region, 4. The Bay of Gävle. In these areas the pollution is caused both from sewage and industrial waste water.

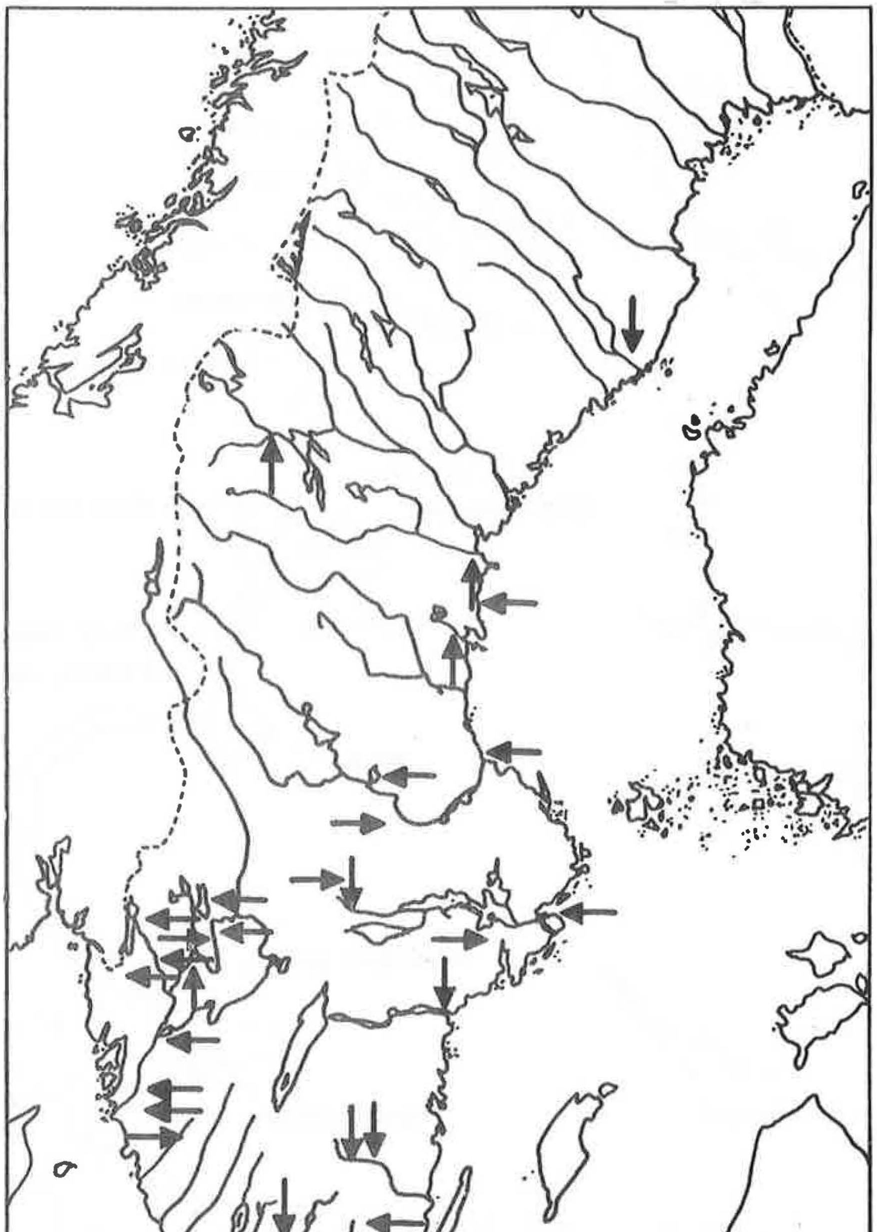

Figure 4. Sweden. Waters heavily polluted with mercury compounds. Fishing is allowed but it is prohibited to sell or give away most kinds of fish. Some of the arrows show more than one locality.

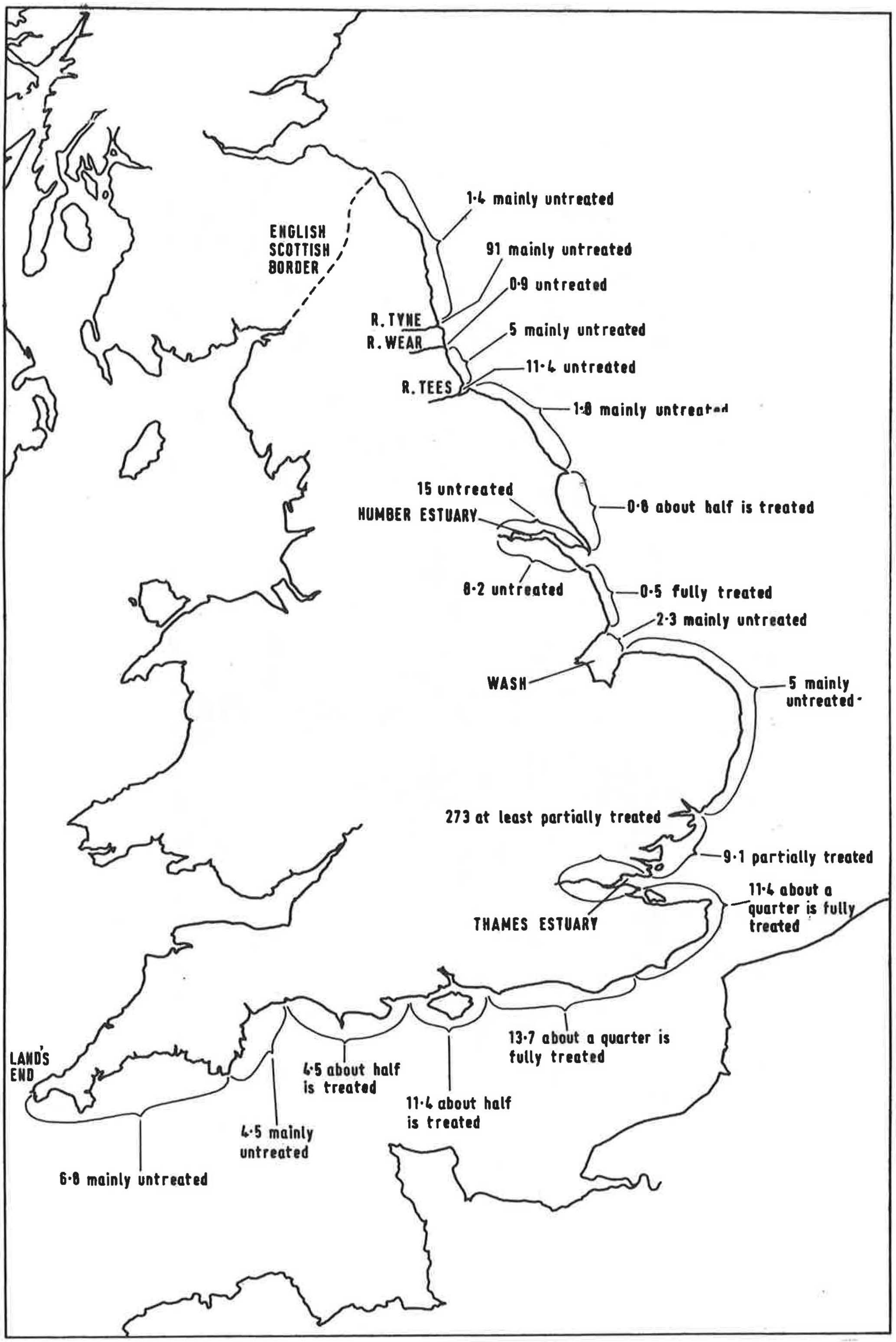

Figure 5. Domestic sewage discharges from the English coast (10^4 m^3 per day).

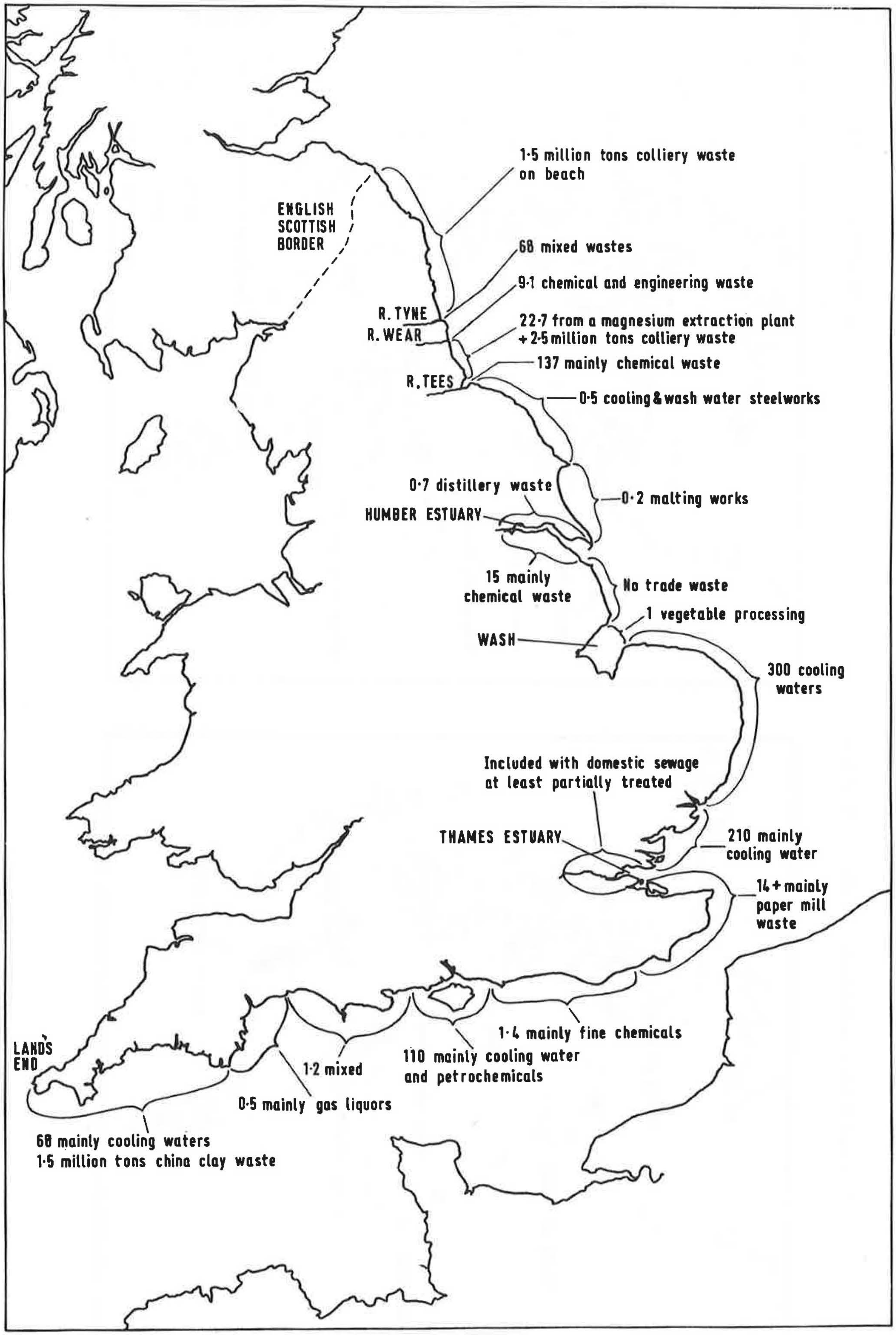

Figure 6. Trade waste discharges from the English coast (10^4 m^3 per day).

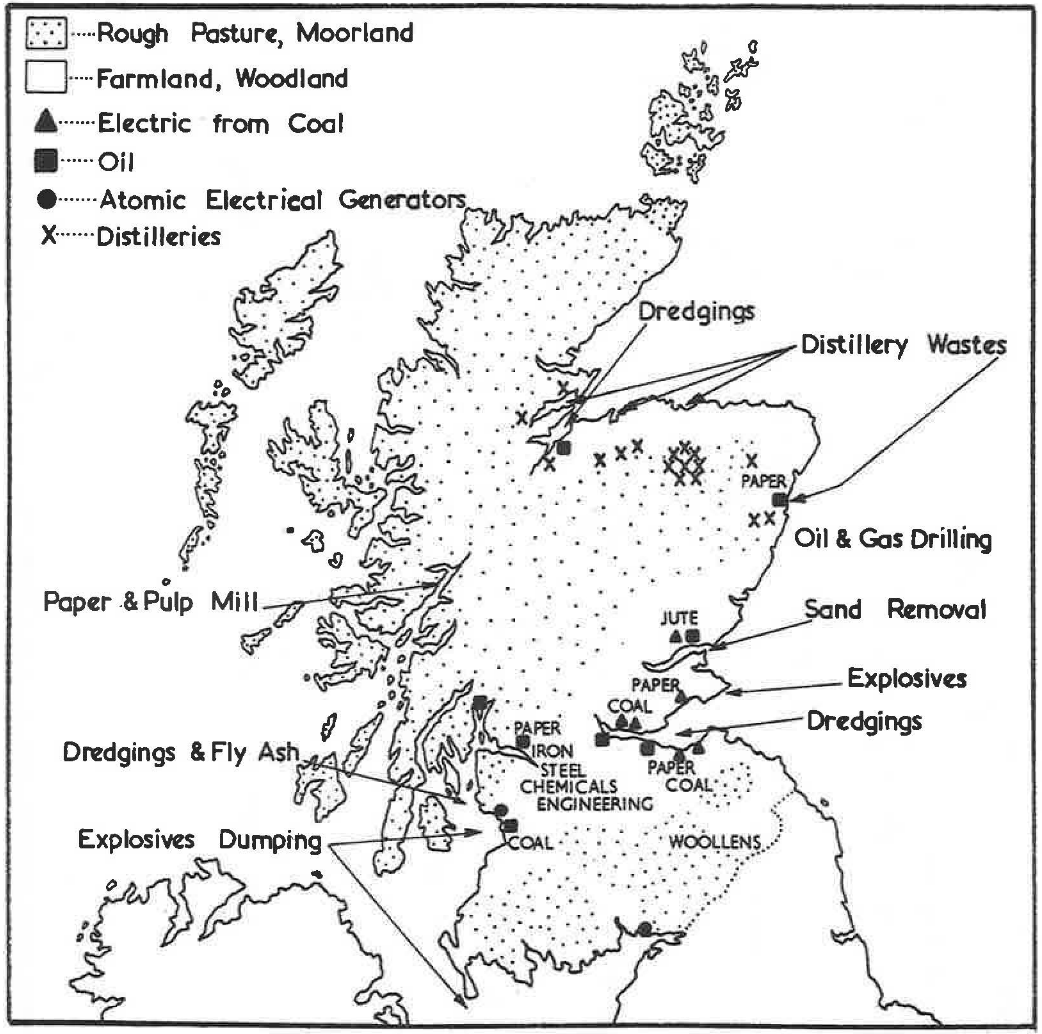

Figure 7. Pollution of Scottish waters.

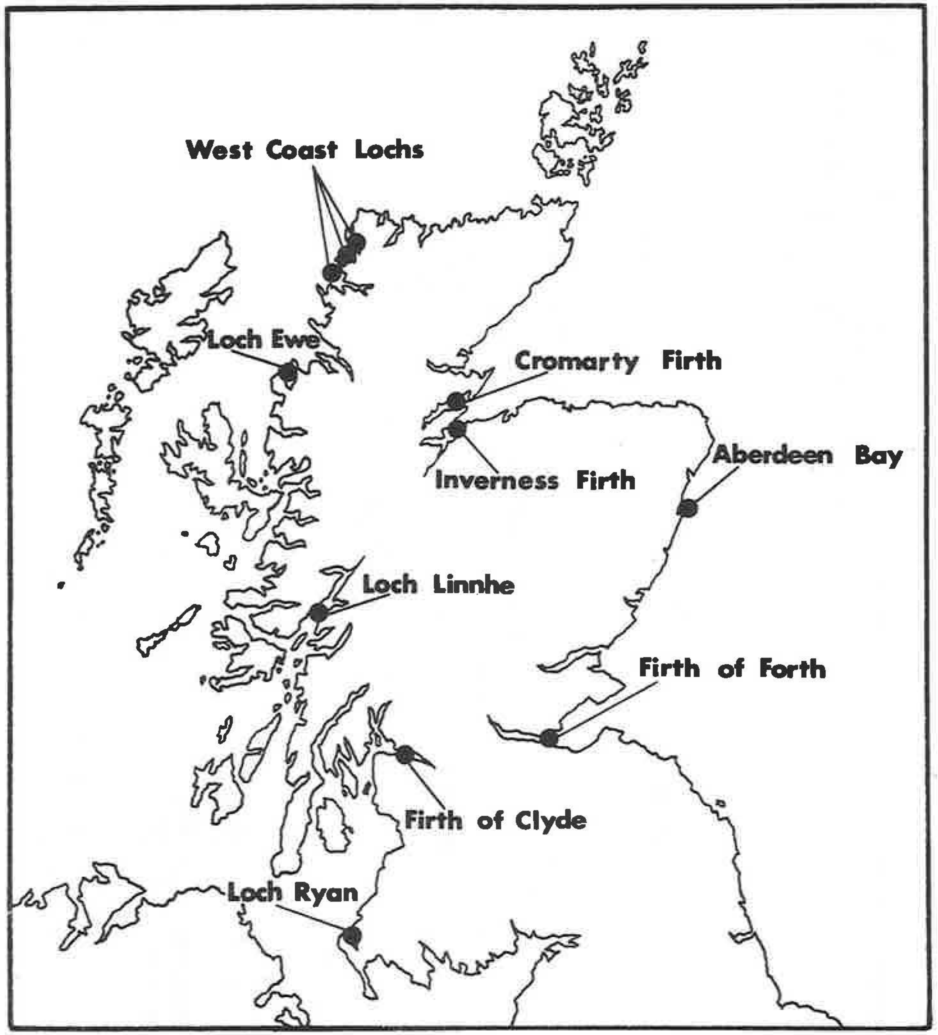

Figure 8. Survey and research sites in Scotland.

APPENDIX 2.

Toxicity test data as supplied by the United Kingdom.

Test material	48-hour LC_{50} expressed in ppm				
	Pandalus montagui	Crangon crangon	Carcinus maenas	Cardium edule	Ostrea edulis (5 days)
Copper as $CuSO_4$	0.14	29.5	109	1.0	>100
Zinc as $ZnSO_4$	9.5	110	14.5	257.5	116.5 (7 days)
Lead as $PbNO_3$	c. 375 mechanical			>500	
Mercury as $HgCl_2$	0.075	5.7	1.2	9.0	(Crassostrea) 4.2 (7 days)
Nickel as $NiSO_4$	139	125	255	>500	100-150
Iron as $FeCl_3$ $6H_2O$	39	56	90-100	190	
Cyanide as KCN	c. 0.25		>5.0	>25.0	
Thiocyanate as NaCNS	>6.2	>500	>500	>500	
Phenol C_6H_5OH	17.5	23.5	56	> 500	
Octyl Phenol 11 Ethylene oxide	10.8	>100	>100	19.6	
Nonyl Phenol 12 Ethylene oxide	19.3	89.5	>100	92.5	>100
Dobs JN	>100	>100	>100	>100	
Dobs 055	>100	>100	>100	34.3	
Lauryl Ether Sulphate 3 Ethylene oxide	>100	>100	>100	24.0	>100
Coco Monoethanolamide		>100		>100	
Coco Monoethanolamide 4½ Ethylene oxide 4/5 Ethoxy Monoethanolamide		>100	>100	>100	
'Toxion'	0.98	6.6	163	27.4	
'Compass'		>100	>100	>100	
'Doxcide'	>500	>500	>500	>500	
'Gamlen O.S.R.'	12.5	8.8	20.4	15.8	15-50
'Polyclens'	8.5	15.7	23.2	70.0	
'Slix'	12.1	114.5	>300	12.7	c. 100
B.P. 1002	5.8	5.8	10-25	81.0	50-100
Cleanosol	32.0	44.0	100-105	19.2	
Essolvene	8.6	9.6	15-20	63.0	50-100
Gamlen 'D'	11.5	9.6		38.8	
Gamlen 'CW'	14.6			69.5	
Atlas 1901	87.2	120	>150	48.5	
Slickgone 1	5.2	6.6	35.0	32.4	
Slickgone 2	4.5	3.5	21.3	30.5	
Dermol	148	156	435	148	
'Cassoron'		6.2	10.4	>100	
Diquat		>10		>10	
Paraquat		>10		>10	
Parathion		0.0033-0.01		3.3-10	
Banner DG01		10-15			
Banner DG02		8-12			
Banner DG03		10-15			

APPENDIX 2 (continued)

Test material	48-hour LC_{50} expressed in ppm				
	Pandalus montagui	Crangon crangon	Carcinus maenas	Cardium edule	Ostrea edulis (5 days)
Banner DG04		15-20			
Basol AD6		10-15			
Cuprinol 106		4-8			
Penetone X		20-30			
Polycomplex A		100-200			
Craine OSR		500-750			
Shamash R1885	1-3.3				
Corexit		7 500-10 000			
Mobilsol		10-33			
D.D.T.		0.0033-0.01		>10	
B.H.C.		0.0033		>10	
Dieldrin		0.01-0.033		>10	
Endosulfan		0.01		>10	
Tetradifon		>10		>10	
Malathion		0.33-1.0		3.3-10	
Azinphos-Methyl		0.0003-0.001		>10	
Sulphuric Acid	42.5	80-90	90	200-500	

Test material	48-hour LC_{50} expressed in ppm				
	Crangon crangon	Agonus cataphractos	Cardium edule	Asterias rubens	Sabella pavelina
Red Mud	>100 000	>100 000	>100 000	>100 000	
Hydrochloric Acid	100-330	100-330	330-1 000	100-330	
Nitric Acid	100-330	100-330	330-1 000	100-330	
Sodium Hydroxide	33-100	33-100	330-1 000	33-100	33-100
Sodium Chloride	10-20 x dilution⊠	10-20 x dilution⊠	< 5x dilution⊠	20-30 x dilution⊠	20-30 x dilution⊠
Pea Waste	>100 000	>100 000	>100 000	>100 000	

⊠ These figures indicate dilutions of a concentration of sodium chloride of 300 parts per thousand with sea water.

APPENDIX 3.

Agreement
for Co-operation in Dealing with Pollution of the North Sea by Oil

The Governments of

the Kingdom og Belgium
the Kingdom of Denmark
the French Republic
the Federal Republic of Germany
the Kingdom of the Netherlands
the Kingdom of Norway
the Kingdom of Sweden
the United Kingdom of Great Britain and Northern Ireland

Recognizing that grave pollution of the sea by oil in the North Sea area involves a danger to the coastal states,

Noting that the Council of the Inter-Governmental Maritime Consultative Organization at its third extraordinary session in May 1967 decided to include among the matters requiring study as a matter of urgency, inter alia,

"procedures whereby States, regionally or interregionally where applicable, can co-operate at short notice to provide manpower, supplies, equipment and scientific advice to deal with discharge of oil or other noxious or hazardous substances including consideration of the possibility of patrols to ascertain the extent of the discharge and the manner of treating it both on sea and land",

Have agreed on the following:

Article 1

This Agreement shall apply whenever the presence or the prospective presence of oil polluting the sea within the North Sea area, as defined in Article 2 of this Agreement, presents a grave and imminent danger to the coast or related interests of one or more Contracting Parties.

Article 2

For the purposes of this Agreement the North Sea area means the North Sea proper southwards of latitude 61° N, together with

(a) the Skagerrak, the southern limit of which is determined by a line joining Skagen and Pater Noster Skären;

(b) the English Channel and its approaches eastwards of a line drawn fifty nautical miles to the west of a line joining the Scilly Isles and Ushant.

Article 3

The Contracting Parties consider that protection against pollution of the kind referred to in Article 1 of this Agreement is a matter which calls for active co-operation between the Contracting Parties.

Article 4

Contracting Parties undertake to inform the other Contracting Parties about

(a) their national organisation for dealing with oil pollution;

(b) the competent authority responsible for receiving reports of oil pollution and for dealing with questions concerning measures of mutual assistance between Contracting Parties;

(c) new ways in which oil pollution may be avoided and about new effective measures to deal with oil pollution.

Article 5

(1) Whenever a Contracting Party is aware of a casualty or the presence of oil slicks in the North Sea area likely to constitute a serious threat to the coast or related interests of any other Contracting Party, it shall inform that other Party without delay through its competent authority.

(2) The Contracting Parties undertake to request the masters of all ships flying their flags and pilots of aircraft registered in their countries to report without delay through the channels which may be most practicable and adequate in the circumstances:

(a) all casualties causing or likely to cause oil pollution of the sea;

(b) the presence, nature and extent of oil slicks on the sea likely to constitute a serious threat to the coast or related interests of one or more Contracting Parties.

Article 6

(1) For the sole purposes of this Agreement the North Sea area is divided into the zones described in the Annex to this Agreement.

(2) The Contracting Party within whose zone a situation of the kind described in Article 1 occurs, shall make the necessary assessments of the nature and extent of any casualty or, as the case may be, of the type and approximate quantity of oil floating on the sea, and the direction and speed of movement of the oil.

(3) The Contracting Party concerned shall immediately inform all the other Contracting Parties through their competent authorities of its assessments and of any action which it has taken to deal with the floating oil and shall keep the oil under observation as long as it is drifting in its zone.

(4) The obligations of the Contracting Parties under the provisions of this Article with respect to the zones of joint responsibility shall be the subject of special technical arrangements to be concluded between the Parties concerned. These arrangements shall be communicated to the other Contracting Parties.

(5) In no case shall the division into zones referred to in this Article be invoked as a precedent or argument in any matter concerning sovereignty or jurisdiction.

Article 7

A Contracting Party requiring assistance to dispose of oil floating on the sea or polluting its coast may call on the help of the other Contracting Parties, starting with those which also seem likely to be affected by the floating oil. Contracting Parties called upon for help in accordance with this Article shall use their best endeavours to bring such assistance as is within their power.

Article 8

Any Contracting Party which has taken action in accordance with Article 7 of this Agreement shall submit a report thereon to the other Contracting Parties and to the Inter-Governmental Maritime Consultative Organization.

Article 9

(1) This Agreement shall be open for signature by the foregoing Governments from the 3rd of March, 1969. Governments may become Party to this Agreement either by signature without reservation

as to ratification or by signature subject to ratification followed by ratification.

(2) Instruments of ratification shall be deposited with the Government of the Federal Republic of Germany.

(3) This Agreement shall enter into force two months after the date on which six Governments have signed the Agreement without reservation as to ratification or have deposited an instrument of ratification. For Governments which subsequently sign the Agreement without reservation as to ratification or ratify, it shall enter into force two months after signature or ratification.

Article 10

(1) After this Agreement has been in force for five years it may be denounced by any Contracting Party.

(2) Denunciation shall be effected by a notification in writing addressed to the Government of the Federal Republic of Germany which shall notify all the other Contracting Parties of any denunciation received and of the date of its receipt.

(3) A denunciation shall take effect one year after its receipt by the Government of the Federal Republic of Germany.

IN WITNESS WHEREOF the undersigned, being duly authorized by their respective Governments, have signed this Agreement.

DONE at Bonn on this third day of March, 1969,
in the English and French languages,

both texts being equally authoritative, in a single copy which shall be deposited in the archives of the Government of the Federal Republic of Germany which shall transmit a duly certified copy to each of the other signatory Governments. This Agreement shall be registered with the United Nations in conformity with Article 102 of the Charter of the United Nations.

For the Government of ....
(Signature)

For the Government of ....
(Signature)

etc.

Annex

Description of the zones referred to in Article 6 of this Agreement

The zones with the exception of the zones of joint responsibility are limited by lines joining following points:

Denmark

55°03' N	8°22' E	
55°10' N	7°30' E	
55°10' N	2°15' E	
57°00' N	1°30' E	
57°00' N	6°40' E	
58°10' N	10°00' E	
57°48' N	10°57' E	
57°44' N	10°38' E	(Skagen)

Germany

53°34' N	6°38' E
54°00' N	5°30' E
54°00' N	2°40' E
55°10' N	2°15' E
55°10' N	7°30' E
55°03' N	8°22' E.

Netherlands

51°32' N	3°18' E
51°32' N	2°06' E
52°30' N	3°10' E
54°00' N	2°40' E
54°00' N	5°30' E
53°34' N	6°38' E

Norway

61°00' N	4°30' E
61°00' N	2°00' E
57°00' N	1°30' E
57°00' N	6°40' E
58°10' N	10°00' E
58°54' N	10°43' E

To be continued along the Norwegian-Swedish border.

Sweden

57°54' N 11°28' E
(Pater Noster lighthouse)
57°48' N 10°57' E
58°10' N 10°00' E
58°54,5'N 10°43' E

To be continued along the Norwegian-Swedish border.

United Kingdom

61°00' N	0°50' W
61°00' N	2°00' E
57°00' N	1°30' E
52°30' N	3°10' E
51°32' N	2°06' E

The zones of joint responsibility are as follows:

(1) Belgium, France and United Kingdom
Sea area between parallels 51°32' N and 51°06' N.

(2) France and United Kingdom
The English Channel south-west of parallel 51°06' N to a line drawn between the points
49°52' N 07°44' W and
48°27' N 06°25' W.

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