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REPORT OF THE SEVENTH SESSION

LONDON, 24 – 30 APRIL 1975

INTER-GOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION

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JOINT GROUP OF EXPERTS ON THE SCIENTIFIC ASPECTS OF MARINE POLLUTION

(GESAMP)

REPORT OF THE SEVENTH SESSION

held at

IMCO Headquarters, London

24 - 30 April 1975

NOTES

1. GESAMP is an advisory body consisting of specialized experts nominated by the Sponsoring Agencies (IMCO, FAO, UNESCO, WMO, WHO, IAEA, UN). Its principal task is to provide scientific advice on marine pollution problems to the Sponsoring Agencies and to the Inter-governmental Oceanographic Commission (IOC).

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ACRONYMS

AAPG	American Association of Petroleum Geologists
ACMRR (of FAO)	Advisory Committee on Marine Resources Research
ACOMR	Advisory Committee on Oceanic Meteorological Research
ASFIS	Aquatic Sciences and Fisheries Information System
CARPAS	Regional Fisheries Advisory Commission for the Southwest Atlantic
CCOP (EA)	Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas
CCOP/SOPAC	Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas
CICAR	Co-operative Investigations of the Caribbean and Adjacent Regions
CIESM (See ICSEM)	
CIM	Co-operative Investigations in the Mediterranean
CINCWIO	Co-operative Investigation in the North and Central Western Indian Ocean
CMG (of IUGS)	Commission for Marine Geology
CMM (of WMO)	Commission for Marine Meteorology
COFI (of FAO)	Committee on Fisheries
CSK	Co-operative Study of the Kuroshio and Adjacent Regions
ECOR	Engineering Committee on Oceanic Resources
EIFAC (of FAO)	European Inland Fisheries Advisory Commission
EPA	Environmental Protection Agency (of USA)
FAO	Food and Agriculture Organization

GEBCO	General Bathymetric Chart of the Oceans
GELTSPAP	IOC Group of Experts on Long Term Scientific Policy and Planning
GEMS	Global Environmental Monitoring System
GFCM (of FAO)	General Fisheries Council for the Mediterranean
GIPME	Global Investigation of Pollution in the Marine Environment
IABO (of IUBS)	International Association for Biological Oceanography
IAEA	International Atomic Energy Agency
IAPSO (of IUGG)	International Association for the Physical Sciences of the Ocean
IAWPR	International Association on Water Pollution Research
IBP	International Biological Programme
ICES	International Council for the Exploration of the Sea
ICGs	International Co-ordination Groups
ICITA	International Co-operative Investigations of the Tropical Atlantic
ICNAF	International Commission for the Northwest Atlantic Fisheries
ICSPRO	Inter-Secretariat Committee on Scientific Programmes Relating to Oceanography
ICSEM	International Commission for Scientific Exploration of the Mediterranean
ICSU	International Council of Scientific Unions
IDOE	International Decade of Ocean Exploration
IGOSS	Integrated Global Ocean Station System
IGU	International Geographical Union
IHO	International Hydrographic Organization
IIOE	International Indian Ocean Expedition

IMCO	Inter-Governmental Maritime Consultative Organization
IOC	Inter-Governmental Oceanographic Commission
IODE	IOC Working Committee on International Oceanographic Data Exchange
IOFC	Indian Ocean Fisheries Commission (of FAO)
IPLAN	Joint IOC/WMO Planning Group for IGOSS
IPFC	Indo-Pacific Fisheries Council (of FAO)
IRES	IOC Group of Experts on Oceanographic Research as it Relates to the Integrated Global Ocean Station System (IGOSS)
ITECH (IOC/WMO)	Joint Group of Experts on IGOSS Technical Systems Design and Development and Service Requirements
IUBS (of ICSU)	International Union of Biological Sciences
IUGG (of ICSU)	International Union of Geodesy and Geophysics
IUGS (of ICSU)	International Union of Geological Sciences
MAOA	WMO Executive Committee Panel on Meteorological Aspects of Ocean Affairs
MEDI	Marine Environmental Data and Information Referral System
MEPC (of IMCO)	Marine Environment Protection Committee
NAT	Joint IOC/ICES/ICNAF Co-ordinating Group for the North Atlantic
NOAA	National Oceanic and Atmospheric Administration (of USA)
ODAS	Ocean Data Acquisition System, Aids and Devices
OECD	Organization for Economic Co-operation and Development
POOL	Ad Hoc Group of Experts on Pollution of the Ocean Originating on Land
SCAR (of ICSU)	Scientific Committee on Antarctic Research

SCOR (of ICSU)	Scientific Committee on Oceanic Research
SOC	ICG for the Southern Oceans
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
WHO	World Health Organization
WMO	World Meteorological Organization

IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN
JOINT GROUP OF EXPERTS ON THE SCIENTIFIC
ASPECTS OF MARINE POLLUTION

Report of the Seventh Session

(IMCO Headquarters, London, 24-30 April 1975)

OPENING OF THE MEETING

1. The Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) held its seventh session at IMCO Headquarters, London, from 24-30 April 1975. The Chairman of GESAMP, Dr. G. Berge, opened the session.

2. Mr. Y. Sasamura, Director of the Marine Environment Division of IMCO and Administrative Secretary of GESAMP, on behalf of the Secretary-General of IMCO, welcomed the experts, the representatives of the sponsoring agencies and the observers from other organizations attending the session.

3. The agenda of the seventh session, as adopted by the Group, is attached as Annex I. A list of the documents considered by the Group under each agenda item is shown at Annex II. This also includes a list of information papers summarizing the recent activities of the sponsoring agencies in the field of marine pollution, or relating to matters under discussion.

4. A list of participants, comprising the experts, the representatives of the sponsoring agencies and observers from other organizations, is shown at Annex III. Owing to unforeseen circumstances, Mr. R. Gerard was obliged to retire from the session on 25 April 1975 and was replaced by Mr. M.J. Cruikshank.

HARMFUL SUBSTANCES IN THE MARINE ENVIRONMENT

(a) Review of harmful substances

5. The Group was informed of events occurring since the last meeting on the Review of Harmful Substances (GESAMP VI/10/Supp.1) which led to the reopening of discussion on certain aspects of this paper. The Chairman characterized as unfortunate, the situation in which an agreed decision of the GESAMP experts was subsequently rejected by an agency thus causing a long delay in the issuing of the GESAMP report and a continued delay in the publishing of the approved Review of Harmful Substances.

6. It had been agreed during the inter-sessional period that, although the Review had been approved by GESAMP at its sixth session, in order to enable certain specific questions relating to the effect of metals on human health to be resolved, this particular section of the Review would be reconsidered at the current session. A working paper was presented by WHO as a basis for this re-examination and an ad hoc working group was organized to consider the new material presented and to amend statements on human health aspects which had been considered by consultants to WHO in the inter-sessional period as inaccurate or misleading.

7. The ad hoc working group presented the results of its deliberations which included a series of amendments to GESAMP VI/10/Supp.1. The Group expressed its appreciation to the working group for having reached a successful compromise. Further comments of both a detailed and a general nature were submitted and were considered. Some of these were included in the amendments and the remainder, which were of a more general nature, were remitted to the Chairman of the Working Group on the Evaluation of Hazards of Harmful Substances in the Marine Environment for further consideration in the course of the continued updating of the Review. The Group approved amendments to GESAMP VI/10/Supp.1 as shown at Annex IV and agreed that the Review should be published by UN as a GESAMP Study as soon as possible, in accordance with the decision taken at the sixth session (GESAMP VI/10, paragraph 7).

(b) Evaluation of the hazards of harmful substances

8. The Group took note of the decisions made by the IMCO Marine Environment Protection Committee (MEPC) at its second session (18-22 November 1974), with regard to arrangements for continuing the task of evaluating the hazards of harmful substances carried by ships. In particular, the Committee, having noted the establishment and terms of reference of the Working Group on Evaluation of the Hazards of Harmful Substances in the Marine Environment, agreed that the Group's principal function would be to assess information received from various sources and to advise IMCO as to what particular data would be appropriate for evaluating substances in accordance with the established rationale (GESAMP IV/19/Supp.1).

9. The Group noted and approved the Report, introduced by the Chairman (Dr. Jeffery), of the first session of the Working Group on Evaluation of the Hazards of Harmful Substances in the Marine Environment (GESAMP VII/2/1) which was held at IMCO Headquarters on 14 and 15 November 1974. As one of its principal tasks the working group had prepared advice for IMCO on the hazard evaluation of substances considered for inclusion in the Annex to the Protocol Relating to Intervention on the High Seas in Cases of Marine Pollution by Substances Other than Oil. The Group approved of the action taken by the working group including certain views which it had expressed regarding the method of selecting substances for inclusion in the Annex to the Protocol. It was noted that all this information had been taken into account by MEPC which had expressed its appreciation to all concerned with the completion of the list within the required deadline (30 November 1974).

10. The Group was further informed of the work being carried out by the IMCO Sub-Committee on the Carriage of Dangerous Goods with a view to formulating measures for the prevention of pollution by harmful substances carried by sea in packaged forms or in freight containers, portable tanks or road and rail tank wagons. The Group noted that, at its twenty-third session (17-21 June 1974), the Sub-Committee had requested advice from GESAMP concerning the feasibility of identifying certain quantities of pollutants below which it could be regarded as unnecessary to apply pollution prevention measures, and the basic criteria or other limiting factors which should be considered if such an approach was adopted.

11. The Group agreed that this enquiry fell within the terms of reference of the Working Group on Evaluation of the Hazards of Harmful Substances in the Marine Environment which, at its first session, had suggested a possible approach to the problem. This information had been noted by the IMCO Sub-Committee at its twenty-fourth session (28 January - 4 February 1975) when it requested GESAMP to continue its study of the problem and to calculate the critical quantities involved in respect of those substances listed in GESAMP IV/19/Supp.1 for which the relevant data are readily available. The Group agreed that the working group should continue to develop this approach to the problem, including the calculation of the critical quantities involved for a number of substances, to illustrate the use of this approach. This task is to be undertaken in liaison with the IMCO Sub-Committee and/or MEPC so that any views which may be expressed by those bodies can be taken into account as and when appropriate.

12. At its sixth session, GESAMP had noted that, for many substances, considerable time and resources were required to produce the authoritative data necessary for evaluating the hazards of substances in accordance with the rationale (GESAMP IV/19/Supp.1). This difficulty was particularly evident where laboratory work was necessary to assess such factors as toxicity effects on marine organisms. At that time GESAMP had also noted that the 1973 Conference had invited governments to pursue studies on the environmental hazards of harmful substances and to provide IMCO with available information, and suggested that the use of governmental experts or consultants might well be the most effective means of obtaining the necessary data.

13. It was noted that MEPC had specifically invited governments to supply data on substances carried by ships, drawing their attention to Resolution 14 of the 1973 Conference. However, it was further noted that even by the date of the seventh session of GESAMP, no Member Government had supplied data to IMCO that would enable this work to progress.

14. The Group expressed concern that this work of assessing the hazards of harmful substances carried in ships was proceeding so slowly and it is understood that a similar concern has been expressed by certain IMCO Member Governments. The Group considered that this criticism arose from the lack of data, and that no progress could be made or expected by the GESAMP working group or by any other body that might consider the hazards of substances carried at sea until the required data had been extracted from government archives or the necessary further experimental work had been undertaken.

15. The Group gave further consideration to the problem of how such experimental work could be undertaken and concluded that there were two possible mechanisms for this, namely by direct commissioning from an international body such as IMCO to a marine laboratory or laboratories to undertake this work, or by direct commissioning from Member Governments of IMCO to a marine laboratory or laboratories capable of undertaking this work in accordance with accepted scientific practices in this field.

16. It was considered that before such work was commissioned, the working group should examine the list of substances for which data were required, to determine if priorities could be assigned to particular substances or groups of substances. The working group should also attempt to group the substances for which data are required in such a way as to facilitate the experimental work required.

17. It was further noted that difficulties were being experienced in making a chemical identification of a number of substances known to be carried in bulk by ships and known only by trade names. It was agreed that the list of these substances should be reported to IMCO, with a view to seeking assistance from Member Governments in resolving this difficulty. The working group should also continue its efforts to make the identification of these substances.

18. The Group suggested that a circular be sent to governments by IMCO seeking:

(a) Identification of trade materials on a list to be supplied by the working group;

(b) toxicity data on substances for which the working group has attempted to evaluate the hazard but been unable to locate toxicity and other data;

(c) any new data available on materials that have already been evaluated to enable any necessary revision to be made.

19. The Group suggested that one of the reasons for the lack of response to earlier requests for toxicity data could have been that the circulars sent out by IMCO had not reached the appropriate departments of the governments concerned. It stressed the importance of ensuring, in future, that such requests are referred to the authorities most likely to have the required information available, e.g., health authorities, fisheries departments, etc.

20. The Group further pointed out that the most likely source of information regarding the identification of trade materials would be the manufacturers of the substances concerned. The Group recommended therefore that IMCO should consider possible ways and means of obtaining the requisite information from such sources.

21. It was proposed to set a time limit on the receipt of this information, and the 3-4 month period from the third to the fourth sessions of MEPC was suggested. Following this, the GESAMP working group would ask for a further circular to be submitted to Member Governments requesting that fundamental work be commissioned on those substances for which it had not been possible to obtain data. Ideally this work should be undertaken and the assessments completed by the working group in the Spring of 1976 before the fifth session of MEPC and the IMCO Technical Symposium in Mexico. If required, the working group would be prepared to advise on how these fundamental data could be obtained.

22. In the past and at present, GESAMP has endeavoured, not only to evaluate, but also to gather appropriate data for the development of hazard profiles. This effort must now be reinforced by IMCO and/or governments as the data availability becomes more limited and in many cases non-existent. If the most effective use is to be made of GESAMP's limited resources, then the co-operative efforts of IMCO, governments and GESAMP are needed to ensure that the needs of IMCO for adequate and comprehensive hazard profiling for noxious substances carried by ships will be met.

23. In respect of its long-term role in the assessment of the hazard profiles of harmful substances, the Group confirmed that the principal function of the working group was to assess the information received from IMCO, governmental and other sources and to advise IMCO as to which particular data would be appropriate for evaluating the environmental hazards of each of the substances in accordance with the GESAMP rationale.

24. In order to expedite action to obtain the necessary data, it was agreed that IMCO should be asked to arrange for the early distribution to Member Governments of these comments by the Group, in order to draw the attention of Member Governments to the urgency with which the Group viewed this problem, and to provide notice prior to the third session of MEPC of the need for experimental work to be undertaken.

SCIENTIFIC BASIS FOR THE DISPOSAL OF WASTE INTO THE SEA BY DUMPING

25. The Working Group on the Scientific Basis for Disposal of Waste into the Sea submitted its final report which was prepared at its second meeting from 5-11 October 1974 at the WHO Regional Office for Europe, Copenhagen.

26. The Chairman of the working group, Dr. Kullenberg, introduced the paper and informed the Group that both the discussions about the preliminary report of the working group, which took place at the sixth session of GESAMP, and the written comments received from a selected number of scientists from various disciplines were taken into account by the working group for the preparation of the final report.

27. The Chairman also pointed out that the working group had reconsidered the title of its report in the light of the debate at the sixth session of GESAMP, and agreed that the title should read "Scientific Criteria for the Selection of Sites for Dumping of Wastes into the Sea". It was felt that this would indicate more clearly, than was expressed in the present title of the working group, that its main task was to discuss the factors which must be considered in the selection of sites for issuing a permit for the disposal of waste into the sea.

28. The Group commended Dr. Kullenberg and the working group for a thorough and useful report, particularly with reference to the implementation of the London and Oslo Conventions on ocean dumping. After adoption of several amendments, the Group agreed that, besides including the report as an Annex to the report of this Session (Annex V), the report should also be published separately by FAO as a GESAMP study. The Group requested the Administrative Secretary to make copies of the report available to the depositaries of the London, Oslo and Baltic Conventions.

IMPACT OF OIL ON THE MARINE ENVIRONMENT

29. The Working Group on the Impact of Oil on the Marine Environment held its first session from 28 October - 1 November 1974 at FAO Headquarters, Rome, and its report was introduced by its Chairman, Dr. Thompson. As part of its Work Programme, approved by the sixth session of GESAMP (GESAMP VI/10, Annex IV), and as a basis for discussion on topics of specific concern, a number of working papers were submitted to the working group (see Annex VI).

30. The Group was informed that, after detailed discussion of the working papers, the working group had agreed upon their substances in general, and had decided to develop a common format for their presentation in the final report. An extract from the report of the working group is given in Annex VI.

31. The Group considered the proposed content of the report and the detailed outlines of the various chapters submitted by the working group in document GESAMP VII/4. A number of suggestions were made for amendments or changes which will be taken into consideration by the working group at its second session scheduled to be held in Rome in September 1975.

32. Some members of the Group expressed concern about the broad scope of the paper and, in particular, about the relative importance of the various topics. However, the Group felt, especially in view of the need for advice to governments of developing countries, that the work programme of the working group would not necessarily be changed. Further comments expressed by members were noted by the Chairman of the working group and will be taken into account in the further work to be done on this subject. With regard to offshore production and distribution of petroleum, special attention should be given to the papers prepared by the Working Group on the Scientific Aspects of Pollution Arising from the Exploration and Exploitation of the Sea-Bed. The working group should reconsider the list of topics at its next session.

33. The Group was informed that, owing to other commitments, two of the members of the working group (Prof. Johannes and Dr. Erhardt) had been obliged to resign. Furthermore, Dr. Okubo, who was proposed as a working group member, could not accept this invitation. The Group strongly suggested that a marine biologist (ecologist) should be included when replacing these members of the working group.

SCIENTIFIC BASES FOR THE DETERMINATION OF CONCENTRATIONS AND EFFECTS OF MARINE POLLUTANTS

34. The report of the Working Group on the Scientific Bases for the Determination of Concentrations and Effects of Marine Pollutants, which met at Dubrovnik, Yugoslavia (14-18 October 1974), was presented to the Group by the Chairman (Dr. Goldberg) for consideration and approval. The Group felt that the report should include a preamble giving the background and the purpose. These were indicated to the plenary by the Technical Secretary for UNESCO: the report is intended to provide guidance to the IOC and WMO for the development of the Joint IOC/WMO IGOSS Pilot Project on Marine Pollution Monitoring, and to the IOC's ICG for GIPME to enable it to identify research needs for inclusion in its Comprehensive Plan. It was also mentioned that GEMS might benefit from the report.

35. The Group considered that the title of the report did not reflect the contents accurately, and that there was some lack of coherence between the two main sections on levels and effects and the introduction. The report limited itself to defining a global open-ocean marine pollution monitoring system.

36. The Group emphasized the need to state clearly why a global system is necessary. Some reasons given during the discussion were: a need to know the background levels and any accumulation of potential pollutants; the consequences of undetected yet irreversible damage to the open-ocean; the role of the open-ocean in understanding the dynamics of marine pollution in any part of the sea.

37. It was pointed out that a global monitoring system had two aspects:

(i) scientific
(ii) organizational

and that the report before the Group really dealt only with (i). The organizational aspect was the connexion to be established between such an open-ocean system and the national and regional systems.

38. The Group felt that the term monitoring was given a range of meanings in the report: from measurements related to a specific risk assessment, to merely repetitive measurements. The proposal that the system should measure present levels and temporal trends was thought to require additional consideration, both from the organizational and economic points of view.

39. The choice of pollutants to be monitored was based on a clear and definable threat; some doubt was expressed that this criterion had been firmly established for each of the pollutant groups chosen, especially litter. The report indicated some difficulties in measuring pollution by some of the proposed pollutants, litter and oil, for example; it was pointed out that adequate measurements were required to define the threat so the report was to some extent self-contradicting. However the Chairman of the working group gave several examples of these threats.

40. The Group believed that mass-balance models on which the proposed monitoring system was based, should be related to the time scales involved in the various zones of the ocean (e.g. upper mixed layer, deep water).

41. There were several other technical and scientific objections or queries, and these, as well as the comments outlined above, were considered in the revision of the report which was undertaken by an ad hoc drafting group appointed during the session. Some members of the Group felt that the report would benefit from the inclusion of key references but it was emphasized that no hard and fast rule in this regard should be established for GESAMP working group reports. The Group reviewed the revised report and approved it in the form shown at Annex VI.

INTERCHANGE OF POLLUTANTS BETWEEN THE ATMOSPHERE AND THE OCEANS

42. The Group was informed that the WMO Executive Committee at its twenty-sixth session had endorsed the proposal of GESAMP at its sixth session for the establishment of an ad hoc group on interchange of pollutants between the atmosphere and the oceans. This ad hoc group consists of two meteorological experts and two oceanographers nominated by WMO and IOC respectively. Such composition was considered to be satisfactory at this stage. When the working group on this subject is established by GESAMP a wider representation of experts would be desirable.

43. The following subject areas that might be used by the ad hoc group in developing its scope of studies have been discussed:

(1) Selection of air pollutants which can enter the oceans in significant quantities on a regional and global scale;

(2) Preliminary assessment of the budget of selected pollutants;

(3) Selection of ocean-originated pollutants which can enter the atmosphere in significant quantities on a regional and global scale;

(4) The life-cycle in the atmosphere of ocean-originated pollutants. Particular attention should be given to the fate of contamination exposed to such effects as ultra-violet radiation;

(5) Selection of ocean contaminants which might directly or indirectly affect atmospheric processes over oceans;

(6) A survey of currently available methods of measurements and projected developments related to measurement of selected pollutants in the atmosphere and the oceans on a global scale;

(7) Meteorological and oceanographic factors governing the transport of pollutants from the land to the sea; washout and fallout of pollutants;

(8) The mechanisms governing the interchange of pollutants between the atmosphere and the oceans at the interface and their possible mathematical description;

(9) The mechanisms governing the atmospheric transport of marine pollutants on a regional and global scale and their possible mathematical description;

(10) Development of a guideline for a monitoring programme for the atmospheric transport of pollutants from the land to the sea.

44. The Group felt that, in spite of the restrictions imposed by the present state of methodology, the breakdown of organic materials in the atmosphere over the ocean should be considered by the future working group.

45. The Group, in discussing this question, pointed out the importance of the problem of interchange of pollutants as well as its complexity and connected difficulties. Careful identification of pollutants of terrestrial origin entering the ocean through the atmosphere in significant quantities was considered to be essential. The atmosphere is also a major pathway for pollutants entering the sea on a regional and local scale.

46. It was agreed that WMO should be asked to maintain the present ad hoc working group on interchange of pollutants for the next inter-sessional period. The main task of the group, at this stage, would be to identify the scope of the studies and to develop a working paper outlining and summarizing the content of the studies. This working paper should be presented at the next session of GESAMP.

PRINCIPLES FOR DEVELOPING COASTAL WATER QUALITY CRITERIA

47. The Working Group on Principles for Developing Coastal Water Quality Criteria, which was established at the fifth session of GESAMP, held its first session from 25-29 November 1974 at FAO Headquarters, Rome. A report was submitted to this session of the Group for discussion (GESAMP VII/7).

48. The Chairman of the working group, Dr. Waldichuk, introduced the paper and pointed out that the report was based on the deliberations of an ad hoc working group at the fifth session of the Group (GESAMP V/10, Annex VI) and the discussions held at the sixth session (GESAMP VI/10, paragraphs 50-52). He emphasized that this report from the first meeting was a preliminary one (See Annex VIII).

49. The Group discussed the report at length, taking note of its preliminary character, and made a number of comments which were appreciated by the Chairman of the working group. He assured the Group that these comments would be duly taken into consideration when the working group meets for its second session in October 1975 in order to finalize its report for approval by the eighth session of GESAMP.

50. The Technical Secretary for WHO, on request from the Special Secretary of the Environment (Ministry of Interior of the State of Guanabara, Brazil), brought to the attention of the participants the new legislation enacted in the State of Guanabara in regard to the quality of water required for bathing in that State.

SCIENTIFIC ASPECTS OF POLLUTION ARISING FROM THE EXPLORATION AND EXPLOITATION OF THE SEA-BED

51. The Working Group on the Scientific Aspects of Pollution arising from the Exploration and Exploitation of the Sea-bed, which had been formed at the sixth session of the Group, was Chaired by Dr. Cole, who presented the results of two inter-sessional meetings in the form of a report with three appendices. The terms of reference were reviewed and the Group was reminded that this was a first report and much work remained to be done.

52. The priority items in the terms of reference: petroleum, manganese nodules, dredging and offshore construction had been selected in part with the intention of presenting an approved report to the UN Conference on the Law of the Sea. The schedule of this Conference being changed, much of the pressure to approve a report on certain priority items had disappeared.

53. The aspects of the working group's task dealing with petroleum had led to some overlap with the Working Group on the Impact of Oil on the Marine Environment. Steps were taken during the inter-sessional period to avoid unnecessary duplication of effort and to confine the work on oil within this working group strictly to an assessment of the pollution hazards arising directly from offshore exploration and exploitation.

54. As a consequence of the change in the need to send the report to the UN Conference on the Law of the Sea and noting that the Working Group on the Impact of Oil on the Marine Environment would present a final report at the next session of GESAMP, the Chairman of the working group suggested, and the Group agreed, that neither the conclusions nor the Appendix on Petroleum be discussed at the present session. The Group further agreed that the conclusions on the pollution implications of exploration and exploitation of petroleum from the sea-bed presented by the working group, together with the Appendix, be remitted to the Working Group on the Impact of Oil on the Marine Environment for serious consideration during the inter-sessional period and for full discussion at the next session of GESAMP.

55. It was decided, however, that certain matters related to petroleum exploitation, but outside the terms of reference of the other working group (such as prevention and control measures and production material effects, e.g. drilling muds and heat exchange media), would be abstracted from the Petroleum paper and be considered in future work by reference to drilling activities in general (see also paragraph 32 above).

56. A number of subjects brought out in the plenary discussion and requiring further attention by the working group were accepted on behalf of the working group by its Chairman. These will be added to the work programme and reported upon at the next session of GESAMP.

57. The first report of the working group containing major sections on Manganese Nodule Mining and the Dispersion of Fine-grained Materials was discussed and accepted by the Group as shown at Annex IX. A lengthy discussion was held on the ways and means of incorporating the longer papers on these subjects which had been commented on and amended by the working group but not by the Group in plenary sessions. It was agreed to annex the report (Annex IX) and attach these two papers as Appendices on condition that the original author's name would be included together with a statement that they had not been examined by the Group. The importance of not creating a precedent for the consistent inclusion of working papers was stressed.

58. The Group agreed that the working group should continue its work in the inter-sessional period and accepted the view of the working group Chairman that a complete report based upon the present terms of reference could be presented to the eighth session of GESAMP. This report would include consideration of those additional matters mentioned in paragraph 56 above. In addition, the UN Technical Secretary had requested the working group to take note of Resolution 1802(LV) of the Economic and Social Council concerning coastal area development. As a consequence, the working group had given particular attention to pollution arising from activities in coastal areas and will include this subject in its final report.

OTHER MATTERS

Support from UNEP

59. The Group expressed appreciation for the financial support given by UNEP during the inter-sessional period for meetings of GESAMP working groups on the following subjects:

(1) Principles for developing coastal water quality criteria;

(2) Scientific bases for the determination of concentrations and effects of marine pollutants;

(3) Scientific basis for the disposal of waste into the sea;

(4) Impact of oil on the marine environment;

(5) Scientific aspects of pollution arising from the exploration and exploitation of the sea-bed.

World Register of Rivers discharging into the Oceans

60. The progress of the UNESCO Group of Experts on the World Register of Rivers Discharging into the Oceans was reported to the Group. It was explained that, although the parameters were limited to the river above the tidal reach, and although many significant processes were known to take place in the estuary and possibly to alter the river derived polluting load discharged into the sea, the Register was of interest to GESAMP inasmuch as it had been proposed to measure several potential marine pollutants in the rivers to be included in the Register.

IGOSS Pilot Project on Monitoring (Petroleum)

61. The Technical Secretary for WMO informed the Group that the development of the IGOSS pilot project has been considered by the fourth Joint Session of the IOC Working Committee for IGOSS and the WMO Executive Committee Panel on Meteorological Aspects of Ocean Affairs held from 4-12 February 1975 in Paris. Considering the extension of the pilot project, that meeting had invited the ICG for GIPME, in consultation with the WMO EC Panel on Environmental Pollution and GESAMP, to consider the need for inclusion in the pilot project, at a later stage, of pollutants other than oil.

62. The Group was further informed that the WMO EC Panel on Environmental Pollution, at its first session held in Geneva from 1-5 April, had agreed that, if the pilot project is extended, consideration should be given to the inclusion of:

(a) heavy metals (e.g. lead, mercury)
(b) halogenated hydrocarbons (e.g. PCB's, DDT)
(c) detergents
(d) CO_2

FUTURE WORK PROGRAMME

63. At the conclusion of the session, the Group expressed appreciation to all the Chairmen and members of its working groups, both from within and outside GESAMP, who had contributed to the preparatory work during the inter-sessional period. This had considerably facilitated the completion of the substantial items during the session.

64. The Group noted that the Working Groups on the Scientific Basis for the Disposal of Waste into the Sea and on the Scientific Bases for the Determination of Concentrations and Effects of Marine Pollutants had now completed their current work. It was therefore agreed that these two working groups should be disbanded at the conclusion of the seventh session.

65. With regard to its future work the Group requested the following working groups to continue to deal with the tasks allocated to them as set out in Annex VI to the Report of the sixth session (GESAMP VI/10):

(1) Evaluation of the Hazards of Harmful Substances in the Marine Environment;

(2) Principles for Developing Coastal Water Quality Criteria;

(3) Impact of Oil on the Marine Environment;

(4) Scientific Aspects of Pollution Arising from the Exploration and Exploitation of the Sea-bed.

66. The Group agreed to consider, at its next session, the need for establishing a new Working Group on Interchange of Pollutants between the Atmosphere and the Oceans (see paragraph 42 above).

DATE AND PLACE OF NEXT SESSION

67. The Group was informed that UN would act as host agency for the eighth session of GESAMP which was tentatively scheduled to be held in New York from 22-26 March 1976. Since the date would conflict with the IMCO Symposium on Prevention of Marine Pollution from Ships (Acapulco, 22-31 March 1976), the UN Technical Secretary was requested to consult his Organization with a view to changing the dates of the session, or to explore alternative means of avoiding this conflict.

ELECTION OF CHAIRMAN AND VICE-CHAIRMAN FOR THE NEXT INTER-SESSIONAL PERIOD AND FOR THE EIGHTH SESSION

68. The Group unanimously elected Dr. G. Kullenberg as Chairman and Dr. C.H. Thompson, as Vice-Chairman for the next inter-sessional period and for the eighth session of GESAMP. In taking this decision, the Group expressed its sincere appreciation to the retiring Chairman, Dr. G. Berge, and the retiring Vice-Chairman, Prof. A.I. Simonov, for the efficient way in which they had carried out their responsibilities during their terms in office.

CONSIDERATION AND APPROVAL OF THE REPORT

69. The present Report of the seventh session of GESAMP (GESAMP VII/9) was considered and approved by the Group on the last day of the session.

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ANNEX I

AGENDA

Opening of the Meeting

1. Adoption of the Agenda
2. Evaluation of the hazards of harmful substances in the marine environment
3. Scientific basis for the disposal of waste into the sea by dumping
4. Impact of oil on the marine environment
5. Scientific bases for the determination of concentrations and effects of marine pollutants
6. Interchange of pollutants between atmosphere and oceans
7. Principles for developing coastal water quality criteria
8. Scientific aspects of pollution arising from the exploration and exploitation of the sea-bed
9. Date and place of next session
10. Other matters
11. Election of Chairman and Vice-Chairman for the next inter-sessional period and for the eighth session
12. Consideration and approval of the Report of the Session

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ANNEX II

LIST OF DOCUMENTS

No.	Agenda item	Author	Title
GESAMP VII/1	1	-	Provisional Agenda
" VII/2	2	IMCO	Evaluation of the hazards of harmful substances in the marine environment
" VII/2/1	2	Working Group	Report of Ad Hoc Working Group on the Evaluation of Harmful Substances in the Marine Environment
" VII/2/2	2	WHO Consultants	Comments of consultants on Supplement to the Report of the Sixth Session
" VII/3	3	Working Group	Report of Working Group on the Scientific Basis for Disposal of Waste into the Sea
" VII/4	4	Working Group	Report of Working Group on the Impact of Oil on the Marine Environment
" VII/5/Rev.1	5	Working Group	Report of Working Group on the Scientific Bases for the Determination of Concentrations and Effects of Marine Pollutants
" VII/6	6	WMO	Interchange of Pollutants between the Atmosphere and the Oceans
" VII/7	7	Working Group	Report of Working Group on the Principles for Developing Coastal Water Quality Criteria
" VII/8	8	Working Group	Report of Working Group on the Scientific Aspects of Pollution Arising from the Exploration and Exploitation of the Sea-bed
" VII/9	12	-	Report of the Seventh Session of GESAMP
" VII/INF.1		IMCO	Recent Activities of IMCO in the field of marine pollution

No.	Agenda item	Author	Title
GESAMP VII/INF.2		FAO	Summary Report of Activities of FAO in the field of marine pollution
" VII/INF.3		UNESCO	Report of the work of UNESCO in relation to marine pollution since the sixth session of GESAMP
" VII/INF.4		WMO	Recent activities of WMO in the field of marine pollution
" VII/INF.5		WHO	Recent activities of WHO in the field of marine pollution
" VII/INF.6		IAEA	Activities related to aquatic environments
" VII/INF.7		UN	Recent activities of the UN in marine affairs
" VII/INF.8		IAEA	Convention on the prevention of Marine Pollution by Dumping of Wastes and Other Matter
" VII/WP.1	2	Working Group	Report of the Ad Hoc Working Group
" VII/WP.2	3	Drafting Group	Report of the Drafting Group
" VII/WP.3	2	Working Group	Report of the Ad Hoc Working Group
" VII/WP.4	5	Drafting Group	Report of the Drafting Group
" VII/WP.5	12		Draft report of the seventh session of GESAMP

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ANNEX III

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ANNEX IV

EVALUATION OF THE HAZARDS OF HARMFUL SUBSTANCES
IN THE MARINE ENVIRONMENT

Amendments to the Review of Harmful Substances
(GESAMP VI/10/Supp.1)

As a result of certain questions relating to the effects of metals on human health, the Group, in the inter-sessional period, agreed to reconsider the particular section at their session. On the basis of a paper prepared by Dr. Falk (GESAMP VII/2/2), additions and changes were made, as recorded below, and refer to GESAMP VI/10/Supp.1).

1. Page 2

Paragraph 5, after last line, add the following new sentence: "Similarly, more extended and detailed reviews of the hazards associated with radioactivity are available from IAEA."

2. Page 2

Add a new section after the Introduction and before the metals are discussed: "General Notes on the Review

A general problem that arises in connexion with the toxicity of certain metals is that the interaction between them is not well understood, although it has clearly been demonstrated that in the presence of one element, the anticipated toxic effect of another may not be fully observed. Cadmium and zinc, lead and calcium may react in this way. The interaction of mercury and selenium is noted below.

It should be noted that bioaccumulation of some heavy metals is a reversible process and that with many organisms, the increased metal levels that occur following an acute exposure will fall once the source of pollution is removed.

It is stressed that the toxicity effects of metals can only be considered in relation to the valency state(s), solubility, stability of complexes and many other factors. This is particularly true of the short-term effects. Consideration of longer term effects must take into account the forms to which the metals and other materials are converted in the marine environment.

The completed review reflects the state of knowledge available to the experts at the time of its compilation. Scientific knowledge is continually changing and developing, and as it does so, changes will be required in this review. For this reason, this document will be updated regularly. It is strongly recommended that the most up-to-date version of it should be used wherever possible."

3. Page 3

Paragraph 4, second line: Changed to read "There are certain similarities to arsenic but unlike arsenic it shows no tendency to be stored in tissues and also shows difference in toxicity."

4. Page 4

Paragraph 3, first line: Changed to read "Certain inorganic compounds are known to be carcinogenic and are highly toxic to man on acute or long-term administration, ...".

5. Page 5

Paragraph 3, after the last line add the following new sentence: "However, data are limited and caution is necessary."

6. Page 7

Paragraph 7, third line: Change "could" to "are known to".

7. Page 8

Paragraph 8, first line: Change "man, being a component" to "man: it is also a component". Delete that part of the sentence after the semi-colon: "the amount ... week". Also delete the final three words of this paragraph, "is extremely small".

8. Page 10

Paragraph 3, fourth line: Delete "roughly twice ...... requirement."

Paragraph 7, sixth line: Change "is declining" to "can be expected to decline".

9. Page 13

Paragraph 1, fourth line: Delete "who requires 3-9 mg. each day."

Paragraph 1, last line: Insert "at the present time" between the words "do not" and "present".

Paragraph 6, second line: Changed to read "The role of leaching of the metal into the sea is uncertain, since it has ... sediment."

Paragraph 6, last line: Add the following new sentence "Under these conditions some conversion to alkyl mercury may still occur."

10. Page 16

Paragraph 2, fourth line: Add the following section after "... hazard.", "And at the present time, with the present levels of nickel in the marine environment, the consumption of seafood is unlikely to be harmful."

Paragraph 2, last line: Add the following new sentence: "A hazard could arise if increasing amounts are to be discharged into the sea."

11. Page 17

Paragraph 3, fifth line: Delete "from polluted areas".

Paragraph 3, last line. Add the following new sentence: "Nevertheless, concern could arise where the discharge of selenium compounds occurs,".

12. Page 20

Paragraph 1, last line: Add the phrase "than in fresh water animals" after "... lower".

Paragraph 4, third line: Change "highly polluted" to "contaminated".

Paragraph 4, fourth line: Insert "since" after "... compounds".

Paragraph 4, last line: Insert "present day" before "seafoods".

13. Page 21

After paragraph 1, add a new paragraph to the Radioactivity section: "There are three different types of radioactive substances, namely those that give rise to α (alpha), β (beta) or γ (gamma) emissions (or mixtures of these). Each of these activities has a characteristic energy. Different isotopes have different half-lives and pathways in the marine environment and these, together with the different types of emissions lead to different degrees of hazard. For more complete and detailed information see, e.g. IAEA Information Circular 205/Add.1, 10 January 1975. (Convention on the prevention of marine pollution by dumping of wastes and other matter)."

14. Page 22

Under "ETHYLENE DIBROMIDE", paragraph 5, second line, add: ", and the material is known to be both carcinogenic and mutagenic" after "bioaccumulation".

15. Page 23

Paragraph 6, third line: Insert "(20-30 mg./litre)" before "injury through contact".

16. Page 24

Table 1, title changed to read: "Degree of Importance as Pollutants According to the Major Categories of Marine Pollution Recognized by GESAMP".

Below this heading add the following Note: "The ratings in this table refer to knowledge of the state of marine pollution at the present time. As such they can be considered to provide guidance on future levels of pollution, provided existing controls are maintained or strengthened."

As a Footnote to the table add: "It should be noted that, especially in relation to many of the metals, WHO has much more detailed information on the hazard to man that these pose under a variety of environmental and other exposure situations. This WHO documentation should be consulted whenever a fuller appreciation of these hazards to man is required."

Table 1

Under Column 2, "Hazards to human health":

For Lead change	"(+)"	to	"+"
Arsenic change	"?"	to	"(+)"
Selenium change	"–"	to	"(+)"
Beryllium change	"–"	to	"(+)"
Allyl alcohol	"+"	to	"–"

17. Page 25

Table 2

Add the same note as below the heading for Table 1:

"The ratings ... strengthened".

Add the same footnote as for Table 1: "It should be noted ... required".

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ANNEX V

REPORT ON THE SECOND SESSION OF GESAMP WORKING GROUP ON THE SCIENTIFIC BASIS FOR DISPOSAL OF WASTE INTO THE SEA

Second Session

(Copenhagen, 5-11 October 1974)

The Fifth Session of GESAMP (Vienna, 18-23 June 1973) decided to establish a Working Group on the Scientific Basis for Disposal of Waste into the Sea with the following terms of reference:

"With reference to Annex III of the London Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter:

(1) To carry out a critical review of our present knowledge of those aspects of dispersion and physical, chemical and biological processes relevant to the selection of sites for discontinuous injection of wastes into the marine environment in both deep and shallow waters;

(2) to identify gaps in our present knowledge, focus attention on urgent research needs, and suggest research priorities.".

The working group held its First Session at FAO Headquarters, Rome, from 4-8 February 1974, and prepared a preliminary report for discussion at the Sixth Session of GESAMP (Geneva, 22-28 March 1974). A second meeting of the working group took place at the WHO Regional Office for Europe, Copenhagen, during 5-11 October 1974.

The members of the working group participating in these sessions were: Dr. G. Kullenberg (Chairman), Dr. E.K. Duursma, Dr. B. Ketchum (Second Session only), Dr. S.A. Malmberg, Dr. J.E. Portmann, Dr. M. Waldichuk, Dr. G.F. Weichart. Unfortunately, Prof. A.I. Simonov, who was nominated as a member of the working group, was unable to attend the meetings. Dr. G. Tomczak (FAO) provided secretariat assistance (see Appendix I).

At the Second Session, the working group was welcomed, on behalf of the host agency, by Dr. M.J. Suess, who also participated part-time, together with Dr. A.H. Wahba from the Regional Office for Europe, in the discussions and in the drafting of this report.

The working group took note of the discussions on its Summary Report of the First Session held at the Sixth Session of GESAMP, and of the written comments on this report sent to the Chairman by various reviewers, and discussed what amendments should be made to its report so as to take account of these comments.

It was agreed that, although not specifically stated in the title of the working group, its main task was to discuss the factors which must be considered in the selection of sites for disposal of wastes into the sea, and that this should be clearly indicated in the title of the final report.

In the following, therefore, the title has correspondingly been changed, and the working group suggests that, in the future, reference to its work should be made by using the title "Scientific criteria for the selection of sites for dumping of wastes into the sea".

SCIENTIFIC CRITERIA FOR THE SELECTION OF SITES FOR DUMPING OF WASTES INTO THE SEA

CONTENTS

SCIENTIFIC CRITERIA FOR THE SELECTION OF SITES FOR DUMPING OF WASTES INTO THE SEA

ABSTRACT

The main concerns with dumping of wastes at sea are their possible adverse effects on living resources. Effects on human uses are mainly associated with bioaccumulation of substances by marine organisms, tainting of sea food and reduction of amenities arising from discolouration, turbidity and floating materials. The wastes of greatest concern are those which are toxic to marine organisms or accumulate within organisms to a concentration substantially greater than that in the environment, and which reach the sea in large amounts or persist there for long periods of time. For liquid waste disposal, a principal objective is rapid and widespread dispersion.

Dumping of those materials permitted under the London Convention should be done in such a way as to avoid, or minimize, undesirable effects by: (1) ensuring maximum initial dilution through an appropriate means of disposal; (2) selecting areas where dispersive processes (transport and mixing) are active and (3) avoiding particularly sensitive areas.

Sewage sludge and dredge spoils constitute about 90 per cent of the total materials presently being dumped. Both can contain heavy metals, petroleum hydrocarbons, animal and vegetable fats and oils and chlorinated hydrocarbons. They may also introduce into the sea micro-organisms which require special attention, particularly the pathogenic bacteria and viruses.

Wastes are sometimes containerized. An overall density of at least 1.2 g/cm^3 is recommended to ensure that containers of wastes sink to the bottom and remain there. Since containerized materials and bulky solids interfere with bottom trawling, they should be dumped only in selected areas in the deep ocean.

Biological observations might be expected to include: fisheries resources, primary productivity, zooplankton and benthic populations, as well as turbidity, dissolved oxygen and the nature of the sediments. Chemical measurements in water, benthos and sediments might include organochlorine substances, petroleum hydrocarbons, nutrients and such metals as mercury and cadmium. Physical observations should be mainly directed to evaluating dispersion processes. Wind and wave features, vertical density distribution, including mixed-layer depth, and data on currents and bottom conditions would be desirable.

A number of research priorities have been identified which, if met, would greatly improve our predictive ability.

1. INTRODUCTION

The dumping* of wastes into the sea is only one method of disposal of a material and should be carried out only after other alternative methods of dealing with the waste have been fully considered. Ideally, the only ultimate method of eliminating waste disposal of conservative substances is recovery and reutilization of the materials presently considered to be wastes; other disposal operations merely move material from one part of our environment to another. The decision to consider a substance a "waste" rather than a potential "natural resource" is based on economic rather than on scientific principles, because the technology to recover the material in useful form is either not available, or is more costly than the value of the recovered product.

For certain wastes, and under particular circumstances, the cost of disposal at sea may be less than that of recycling or of disposal on land, but the cost must be assessed against the risk and cost of damage to marine resources. Thus, low operating costs may have to be set against costs of damage to the environment which may be quite high. It must be recognized, however, that the environment is not divisible into neat compartments and that the cost and risk of effect of waste disposal in a variety of alternative ways, must be examined. In the event it may be necessary to select one method, even though some damage does occur, simply because it provides the safest long-term solution; financial considerations may or may not help justify such a course of action.

However, the GESAMP Working Group on the Scientific Basis for Disposal of Waste into the Sea has not considered cost benefit analysis, which is involved in waste disposal as currently practised, nor did the working group discuss alternative disposal methods, but agreed that these will always have to be taken into account when choosing the best procedure. The purpose of this report, according to the terms of reference of the working group (see Appendix II), is to consider how the effects of waste disposal can be assessed and reduced to a minimum, and in particular, what scientific principles are involved in the selection of sites for dumping.

The working group agreed that the disposal of waste at sea can be scientifically discussed without taking into account consideration of the justification of waste disposal. The sea has a capacity for receiving a finite amount of waste. This is often largely related to its great volume. The self-purification and buffering capacity of the water is limited, while the sea-bed as a sink will not be effective for all materials.

The working group did not discuss the disposal of radioactive waste into the sea, as this is being covered by a specialized working group (IAEA, 1974,1975). Dumping in relation to specific marine geological features was considered at the fourth session of GESAMP by an ad hoc Working Group on the Consequences of the Human Perturbation of the Deep-Sea Floor (GESAMP IV/19, Annex VII).

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* The definition of dumping used by the working group is that given by the London Convention on the Dumping of Wastes at Sea (UN, 1972).

In preparing this report, the working group was aware that considerable experience could be drawn upon in relation to the effects of marine dumping. Some examples have been cited from the members' own experience; such examples should not be assumed to mean that disposal of those particular wastes is safe under all conditions. The reader should therefore pay due attention to the particular conditions existing in any proposed area of dumping, before making a decision for any new situation.

The assessment of the probable effects of waste disposal at sea involves several disciplines, namely, physical oceanography, chemistry, sedimentology and marine biology, all of which are interdependent and none of which can be considered in isolation. In a report of this scope it has been necessary to concentrate on an identification of those matters of primary importance in order to predict the behaviour and effect of materials when dumped at sea. Having done this, an attempt has been made to identify those subject areas where knowledge is reasonably precise and also those in which knowledge is lacking.

Detrimental effects of pollution of the sea include harm to marine organisms, hazards to human health, hindrance to maritime activities and reduction of amenities. Of the various uses of the sea likely to be affected by the disposal of wastes by dumping, the working group considered that attention should be focussed particularly on the living resources of the sea and their exploitation. This was interpreted as including those species which are, or may be exploited commercially, and the food organisms on which they directly or indirectly depend, plus the need to avoid interference with fishing activity. It should be noted that, in many cases, the young stages are particularly vulnerable. Certain areas of the marine environment, although not at present supporting commercial resources, have potential value in this respect and should be protected. The working group also realized that human health aspects must be considered, especially in respect of possible contamination of food resources.

Possible concerns which may be important in special circumstances include aquaculture, recreation, preservation of endangered species and exploitation of mineral resources on or under the sea-bed.

In making an assessment of the most sensitive species or use to be protected, it is worth noting the merit of the critical pathway approach which has been used with success in the field of radioactive waste disposal. The problems involved in adapting this approach to non-radioactive waste disposal are complex owing to the greater variability of the sensitive species or use to be considered, plus the different types of waste and different modes of action. Nevertheless, the system should be applicable and has considerable merit since, once the decision has been made as to what has to be protected, all other interests are subjugated (Preston, 1974).

The report deals with the various properties of the waste which should be known in order to understand the way it will behave in the marine environment, and considers how these may be affected according to the method of disposal used. The methods of disposal considered include the discharge from hopper barges, discharges into the wake of a vessel and disposal of containerized or other bulky wastes. Attention should be drawn to the need to ensure that conditions of licences are observed, especially in relation to site and method of disposal.

The working group wishes to stress that this report is not intended to replace Annex III of either Dumping Convention (Norway, 1972; UN 1972), of which note must always be taken. Rather, it is hoped that the report will serve to amplify and clarify the items listed in the Annex III of the two Conventions. In attempting to satisfy its terms of reference the working group has prepared its report in the following sequence:

(i) What are the biological, physical and chemical characteristics of the waste and possible effects of the waste in the marine environment?

(ii) How can the effects be minimized by appropriate selection of the method of disposal?

(iii) How can the effects be minimized by appropriate selection of the site for disposal?

Rather than considering various zones of the oceans, such as shallow coastal waters, fjords and the deep sea, the working group preferred to work on a more general basis, giving specific examples as illustrations. Finally, in accordance with its terms of reference, the working group prepared a section on research needs, whereby an attempt has been made to identify those requiring the most urgent attention.

2. CHARACTERISTICS AND POSSIBLE EFFECTS OF WASTES

The characteristics of a waste fall into three categories of properties: physical, chemical and biological. All three have a bearing on their effects on the marine environment. Different criteria might be applicable, e.g. for degradable and non-degradable substances, and also the degree of toxicity of the substances and turbidity might influence the selection of dumping sites.

2.1 Biological characteristics and effects

The wastes of greatest concern relative to marine life include those materials which are toxic to marine organisms and/or are accumulated within organisms to a concentration substantially greater than that in the environment, or which reach the environment in large amounts, and/or which persist in the environment for long periods of time. Some substances are generally recognized as being of a particularly hazardous nature to the marine environment or its resources; these are listed in Annex I of the Dumping Conventions, and their deliberate disposal by dumping is not permitted.

Less hazardous wastes, e.g. sewage sludges and polluted dredge spoils, may also introduce into the sea micro-organisms and as such may still require special attention. Of principal concern are the pathogenic bacteria and viruses. Amoebae, parasites, yeasts and fungi, which can cause human diseases may also be present. The principal concern when dumping such contaminated waste is to avoid the possibility of their encroachment on beaches or the return to man via his food, especially shellfish which may be eaten raw, or without sterilization by adequate cooking. Harvesting of shellfish in the vicinity of sludge or spoil dumps, and their marketing, may need to be prohibited or at least be subjected to systematic, hygienic control, in order to protect human health. However, shellfish growth or reproduction may not necessarily be adversely affected.

In order to cause human disease, pathogenic agents must be taken in at certain minimal infecting dose levels. For micro-chemical hazards, certain harmful levels are also needed. Some enteropathogenic micro-organisms are quite resistant to the various effects of sea water. It is clear that micro-biological research should be conducted on the problems associated with sewage sludge.

The acute toxicity of waste materials to marine organisms must be evaluated in order to specify the degree of dilution and dispersion needed to render the waste harmless. The customary method is to conduct a bioassay test, generally for 96 hours, to determine the concentration which will kill half of the population of test organisms in that period of time. Ideally, the test organism should be either the most sensitive, locally important in the proposed dumping area, or an organism critical to the maintenance of the ecosystem of the area. This is not always possible, since the first type may be difficult to keep alive even under the best of laboratory conditions; equally, it is often not possible to maintain the most sensitive life stages; finally, the critical organisms may not be known. Thus, the results of bioassays are applied with application factors, of one to three orders of magnitude.

Another complexity of applying bioassay test results to dumping of wastes, where dispersion and dilution is the objective, rests in the fact that the organisms in the sea are not exposed to a fixed concentration, but rather to a constantly decreasing concentration as natural mixing and dilution with uncontaminated sea water follows the disposal. Bioassays which simulate this natural dilution in the laboratory would be useful, but at present probably unrealistically difficult to achieve and control. Therefore, it is suggested that as a general rule the concentration found to be toxic in a 96-hour bioassay might be stipulated as a maximum allowable concentration at the disposal site one hour after discharge. The further natural mixing and dilution would be expected to give additional factors of safety during the next four days. Further safety factors might be necessary for wastes which accumulate either biologically or physically, or if the discharge is made under quiescent conditions.

The possibility of sub-lethal, chronic, toxic effects must also be evaluated. These longer term effects may interfere with behavioural activities of marine organisms such as feeding, breeding and migrations. There is also the possibility that exposure to sub-lethal concentrations of some pollutants may render the organism more susceptible to disease or to other environmental stress. However, if the waste is dispersed in an area of rapid circulation these sub-lethal effects may not be of great importance. Some waste disposal operations may produce local concentrations of the pollutants on the bottom, such as the disposal of sewage sludge or dredging spoils. In such cases the chronic effects need to be evaluated.

Living organisms can accumulate some pollutants within their tissues to a concentration greater than that found in the environment. For example, heavy metals can combine with proteins, and petroleum and chlorinated hydrocarbons are concentrated in the lipid components. This bio-accumulation results from an imbalance between the rate of assimilation and the rate of excretion. The concentration factor (the ratio of the concentration within the organism to that in the water) may reach several orders of magnitude. When these organisms are eaten, the predator is, in turn, ingesting larger quantities of the pollutant than it would be exposed to otherwise. Although substances such as mercury and DDT and its breakdown products are recognized as being potentially harmful to marine organisms or to man, it should not be assumed that bio-accumulation per se is harmful, since bio-accumulation may also represent a mechanism by which the organism counteracts the toxic effect.

Another indirect effect of dumping might be the change of habitat characteristics. This would be most critical with wastes which accumulate on the bottom. Sessile benthio organisms can be smothered if the waste accumulates to a depth of a few centimetres, and the characteristics of the bottom might be changed so that it is no longer suitable for the life style of the natural benthic biota and organisms feeding thereon. Characteristically, such modified bottoms will be invaded by opportunistic species (such as the worm Capitella) which breed rapidly and are tolerant of polluted conditions. Although in some circumstances they may be replaced by other exploitable species, previously present species of value to man, such as molluscan shellfish, lobsters and crabs, may be excluded from these modified bottoms. As mentioned above, if microbial contamination is also present, harvesting may have to be prohibited even in adjacent areas where the organisms survive, in order to prevent the danger of return of pathogens to man.

2.2 Chemical characteristics and effects

It is possible to obtain some clues, but not a full chemical characterization of a waste, from a knowledge of the raw materials and the production process used. A standard, full-scale analysis for an extensive list of chemical elements or compounds is not necessary; rather, analysis should be tailored to the needs for each waste. However, certain general guidelines can be given. For example, analysis for total solids, total particulates, organic matter and specific gravity will generally be applicable. Analysis for several trace metals, pesticide compounds and PCBs will provide useful information on persistent substances; these are likely to be present in many wastes.

Sea water has a considerable buffering capacity for acids and alkalis. For example, the acid-iron waste from the production of titanium dioxide using the sulphuric acid process is rapidly neutralized on release into the sea. Following neutralization, the original ferrous sulphate is oxidized to the ferric state, thus exerting a chemical oxygen demand, and is precipitated as ferric hydroxide.

Under stagnant conditions, wastes with a high chemical oxygen demand (COD) and/or bio-chemical oxygen demand (BOD) can lead to deoxygenation of the water or the sediment (examples are sewage sludge, pulp-mill wastes and food processing wastes). This decomposition of organic matter can lead to release of large amounts of nutrients such as phosphate and available nitrogen which, if not adequately dispersed, can cause local enrichment of the water and changes in species composition. In such circumstances, blooms of algae, including those associated with red-tides, may occur and ultimately, on death and decay, cause deoxygenation and odour problems.

Certain chemicals, of which the chlorophenols are probably the best known example can, even at very low concentrations, cause tainting of fish and shellfish, rendering them unacceptable for human consumption. It is important, therefore, to avoid disposal of such wastes to the sea.

Other chemicals (e.g. cyanide, free chlorine, organophosphorus compounds) are acutely toxic to marine life. In many cases, they are rather rapidly rendered harmless by chemical or biological processes. Cyanides, which are present in some heat treatment salts used in the case-hardening of steels, are hydrolysed to formic acid and ammonia. Barium, which may also be present in some heat treatment salt mixtures, is precipitated by the sulphate of the sea water as insoluble barium sulphate. Chlorine is reduced to chloride, which is a major constituent of sea water. The highly toxic organophosphorus compounds are hydrolysed in sea water, with a half-life ranging from a few days to several months. However, colloidal elemental phosphorus is only very slowly oxidized in sea water and has been known to cause damage to marine resources (Jangaard, 1972).

Many heavy metals are accumulated by marine organisms. The special risks posed to human health by mercury and cadmium are recognized by total prohibition of disposal (except as trace contaminants) under both Dumping Conventions. Investigations have shown that, in the aquatic environment, mercury is transformed into organic mercury compounds, e.g. methyl mercury, which are far more toxic than inorganic or metallic mercury (Jernelöv, 1969).

Wastes containing other metals or elements such as lead, zinc, copper and arsenic, can be dumped but require special attention. A local build-up of any of these compounds or elements is likely to be undesirable. Again, the chemical state is important; in insoluble form, and in some cases also in complexed form, the acute toxicity of lead, zinc and copper is much reduced. In anoxic areas of the sea, where hydrogen sulphide occurs, many heavy metals can be eliminated from the sea water by formation of very insoluble metal sulphides. One exception is iron, which as ferrous sulphide is more soluble in sea water than in the form of ferric hydroxide which is the normal form under oxygenated conditions. In some cases, the precipitation of heavy metals as sulphides can be prevented by complexing agents present in sea water which form soluble metal complexes. It should be noted that it has been found that under anoxic conditions, mercury sulphide is more soluble in sea water than would be expected from its solubility product (IAEA, 1971).

It should be pointed out that certain metals and organic substances are readily and strongly adsorbed on to and/or absorbed into, particulate matter, such as clay or metal hydroxides. There is some evidence that in this form they are much less readily available to marine organisms, i.e. the risk of bio-accumulation or toxic effects is reduced. Similar effects may also be created by the formation of organic complexes, but this would be largely dependent upon the stability of that complex. It should be noted that the valency state of an element is of importance when its effects on marine organisms are to be predicted, e.g. arsenic is less toxic in the pentavalent form than the trivalent form, but hexavalent chromium is more toxic than trivalent chromium.

The incineration at sea of chlorinated hydrocarbons results in the formation of large amounts of gaseous hydrochloric acid and water vapour. These combine and condense to form droplets, which precipitate usually within a relatively short distance of the incineration vessel. The acid is readily neutralized by the sea water.

2.3 Physical characteristics and effects

It is necessary to know whether the waste is a liquid or solid, or a solid in suspension, and the density of the waste as a whole and of any solids it may contain, since these properties will influence both initial dilution, and subsequent dispersion and settlement. Settling velocity will be influenced by the shape, size and density of the particles, and aggregated matter will settle more rapidly than individual particles of the same density. Under stratified conditions, particulate matter may be retained or have its vertical dispersion suppressed in a pycnocline layer.

Particulate material can influence the marine environment in several ways. If it settles in large amounts in a confined area, the benthic flora and fauna will probably be adversely affected. If the solids are organic, anoxic conditions could become established. Although in some sea areas the natural suspended particle load is high, addition of suspended matter will increase turbidity and may cause discolouration of the water with possible adverse effects on fisheries and recreational interests. Certain forms of particulate waste may clog gill surfaces of marine fish, crustacea and bivalve shellfish. If a waste is practically insoluble and positively buoyant, it will float and shipping or amenity interests may be adversely affected.

2.4 Organic matter

In spite of the fact that natural dissolved organic substances decompose under favourable conditions (Duursma, 1965), they have a residence time of some thousands of years in the deep water of the open ocean (Williams, 1969). This means that an introduction of more stable artificial organic compounds into the deep sea could lead to an even longer residence time. The conditions close to land are more favourable for decomposition since, owing to the presence of solid matter, lower pressure and generally higher temperatures, the bacterial activities are much higher; as a result a rapid turnover of dissolved organic materials is commonly observed (Jannasch, 1969; Jannasch et al, 1971). It should be noted that the rates of such processes are substantially reduced at low temperatures, e.g. in high latitudes.

This does not imply that dissolved organic materials should preferably be dumped in coastal areas. It is clear that aspects other than degradation are important. In particular, some toxic compounds are resistant to degradation. For certain materials, disposal in areas far from land may be preferable to dilution and degradation in near-coastal waters. For artificial organic wastes it is usually safest to neglect degradation (which may be very slow), and to base the evaluation of limits on the concentration achieved by physical dispersion.

2.5 Sewage sludge and dredge spoils

On the basis of United States and European figures, the largest bulk of materials dumped into the sea is dredge spoils (about 80 per cent) and sewage sludge (about 10 per cent). For this reason, special attention is given to these wastes. Both can be contaminated with metals, bacteria and viruses, polynuclear aromatic hydrocarbons, petroleum hydrocarbons and organohalogens.

Dredge spoils consist of a heterogeneous aggregation of materials, very often anoxic, in a broad spectrum of sizes, ranging from submicron clay particles to stones of many centimetres in diameter, with often a large proportion of organic material. Sewage sludge is a more uniform mixture of finer organic and inorganic substances.

The principal ecological problems arising from the disposal of dredge spoils and sewage sludges are the large oxygen demand and deposition on the bottom to considerable thickness. Both may also have associated human health implications. Decomposition of the organic content of dredge spoils or of sewage sludge, particularly undigested sludge, can deoxygenate both the sediments and the overlying water and lead to the formation of highly toxic hydrogen sulphide.

The health hazard posed by pathogenic bacteria in sewage sludge can be diminished by digestion. Only dilution will decrease residual hazards of the viruses. In order to cause human diseases, pathogenic agents must be ingested at certain minimum infecting doses. For these reasons the dumping of sewage sludges must always be carefully operated according to the local oceanographic conditions.

2.6 Bulky and containerized wastes

The deliberate placing on the sea-bed of bulky objects, such as old cars and car tyres, has been advocated by numerous interested parties and has been carried out on an experimental basis in a few countries. The artificial reefs so formed are usually reported to provide good settling surfaces for a variety of sessile organisms, and havens for creatures such as lobsters; they also appear to be attractive to a variety of species of interest to sport fishermen. Baled municipal wastes may provide similar havens, but buoyant materials, e.g. plastic, must either be packed so that they do not return to the surface, or be pretreated in an appropriate way. In many of the continental shelf areas trawl fishing is so intensive that great care would be necessary in order to avoid interference with fishing activities.

Particular care is required in relation to areas of fishing activity when dumping waste in containers. The recovery of such containers in the course of fishing operations could be hazardous to the crew of the fishing vessel, especially as the container is likely to be seriously weakened by corrosion. Under the terms of the Oslo Convention, disposal of bulky and containerized wastes is prohibited except in deep water.

It is considered necessary when dumping a containerized waste in the sea to ensure that disposal avoids known deep-sea cables, in case these might be damaged by the impact of a container on the cable. In several instances wastes are containerized to avoid release of the waste in the upper or middle layers of the ocean. Occasionally the waste may be in a container merely because this provides a convenient means of handling. However, most wastes disposed of in containers are toxic to man. Of the examples known to the members of the working group, most wastes dumped in containers are solids and also toxic to marine organisms. But since they are also solids in most cases they will dissolve only slowly into the deep water layers and the area likely to be affected by toxic action can be shown to be relatively small. (National Academy of Sciences - National Research Council, 1962). In some cases, wastes dumped in containers are either mixed with concrete or the container is encapsulated in concrete; in both cases the rate of release of the waste to the water is likely to be much reduced. Nevertheless, any marine organisms in the immediate area of a container of waste on the deep sea floor may be at risk.

The areas of interest from a commercial fisheries point of view now extend to the continental slope regions down to at least 1,000 m. Therefore, if such wastes are to be disposed of in deep water, they should be dumped well away from the continental slopes. Similarly the higher regions of deep sea ridges should be avoided. It should be noted that, although no definition is given in the London Convention, for the purpose of the Oslo Convention, deep water dumping areas are defined as being at least: 2,000 m deep and 150 nautical miles from land; additionally, it has been agreed that dumping should not take place within 20 nautical miles of any known cables. However, these criteria alone are not sufficient, and care should be taken to avoid ecologically sensitive areas.

3. METHOD OF DISPOSAL

Dumping is defined by the terms of the London Convention on the Dumping of Wastes at Sea as an intermittent injection of waste materials into the sea, and it is pertinent to distinguish between the dumping of:

(i) Waste confined in containers, or in the form of compacted bales, and/or bulky scrap materials; and

(ii) uncontained waste in a bulk cargo.

3.1 Confined wastes

Wastes of a heterogeneous type can be handled much more readily in contained form than in bulk, unincorporated state. Municipal solid wastes can, by high pressure compaction, be transformed into stable bales suitable for transportation.

The primary requirements for the containers and bales are that they meet the appropriate transport regulations and retain their contents during the descent to the sea-bed, or some pre-determined intermediate depth. In a situation where prolonged confinement is required, the containers should not break owing to the increased pressure. Their overall density should exceed 1.2 g/cm^3.

Depending on the shape, size, integrity and weight of containers of waste, and the character of the sea bottom where the containers are dropped, there are a number of ways in which the containers may behave:

(i) sink intact into the bottom ooze without disintegration;

(ii) sink into the bottom ooze and disintegrate;

(iii) remain intact and sealed indefinitely on the bottom without significant penetration;

(iv) rupture on impact accidentally, or deliberately charged to do so, spewing their contents onto the ocean floor and into the overlying water;

(v) implode under the high pressure, or gradually disintegrate on the bottom, releasing their contents to the surroundings.

If the container and contents sink into the bottom ooze without disintegration, they will, in effect, be permanently interred in bottom sediments. Provided the bottom is not disturbed later by mining or deep dredging activities, the effect on the bottom water and sediment will be minimal. Disintegration after penetrating the sediments would lead to local sediment contamination. If the container explodes or implodes, because of pressure, impact or explosive, the contents will be suddenly released to the water and sediments.

3.2 Bulk cargo wastes: Release techniques

In this case the wastes are discharged from barges in bulk. Usually two types of barges are used, self-propelled or towed, discharging either by pumping or by gravitation. In small dredging operations bottom release (bottom dump) may be used, whereas automated tank barges are used for sewage and industrial sludges and liquids.

The size of the barges varies from 300 to 8,000 tons, and the discharge is usually about 5 metres below the surface through pipes which can have diameters in the range 10-60 cm. The release is usually carried out at speeds of 6-10 knots, at a discharge rate of 4-250 tons/minute. Sewage sludge is usually discharged from a hopper barge at a rate of 100-200 tons/minute, using gravity alone or in combination with low pressure air (EPA, 1971).

The incineration at sea of combustible waste materials can result in the formation of large amounts of gases. In most cases, these will be transferred back to the sea by the precipitation. The subsequent spreading of the remains, mainly in the surface layer, can be expected to be fairly rapid in most cases.

3.3 <u>Bulk cargo wastes: Dispersion</u>

The release technique has a considerable influence on the initial dilution and consequently the long-term physical dispersion in the marine environment.

Physical dispersion is defined as the combined action of (a) mixing on release followed by the turbulent mixing in the sea, and (b) the transport by currents. An effective dispersion requires good mixing conditions and a high rate of exchange between the dumping area and the surrounding sea, so that the waste becomes diluted by a large volume of water. It is primarily by means of the physical dispersion that the impact of the waste on the marine environment can be controlled. However, as noted earlier, there are a number of other processes acting in the same direction and these help to minimize the impact.

Two stages of the dispersion phase are considered, namely, the initial phase covering the initial dilution, and the subsequent dispersion.

(i) The mixing on release will depend both upon the characteristics of the waste and the technique of release. The important physical characteristics of the waste in this connexion are the density distribution, the content of solids and their size distribution. The initial dilution is mainly controlled by the rate of release and the speed of the vessel during release.

In areas where there is some degree of density stratification, the waste material can be dispersed so as to retain it temporarily in the surface layer by releasing it into the wake of the steaming ship. An initial dilution of the order of 1:1000 of the waste shortly after release will reduce the density of the mixture to an acceptable level under most stratified marine conditions. This dilution is usually reached about 500 m astern of the ship, in its wake, at speeds of 6-8 knots (Abraham <u>et al</u>, 1972). When the water column is homogeneous, the contaminated water will sink or remain at the surface, depending upon whether the density of the waste is greater than, less than, or the same as that of sea water.

Wastes with an average density higher than sea water dumped from an almost stationary vessel, or in great amounts over a short period of time (order of one hour), will sink due to their initial excess density and momentum. Two phases of the initial dispersion can be defined (EPA, 1971).

(a) Convective descent - due to initial excess density and momentum;

(b) collapse in a pycnocline layer where the falling waste cloud can be trapped.

The initial dilution appears in this case to be of the order 1:100-1:500, but this is based on relatively few observations (Crickmore, 1972; Kullenberg, 1974). Models have been constructed for predicting the depth of penetration (i.e. maximum depth) of the waste and the vertical concentration distribution in the contaminated water column, but they suffer from many simplifying assumptions and approximations (EPA, 1971).

(ii) The subsequent environmental dispersion is due to the turbulent mixing and the transport by currents in the water. The rate of dispersion can be very slow and will depend primarily on several physical environmental factors to be discussed in Section 5 on site selection. However, the dispersion can be influenced considerably by the initial concentration distribution of the waste immediately after the dumping has been completed. This will depend upon the method of disposal, the characteristics of the waste and the density stratification of the disposal area. Spreading over a large vertical distance will in practically all cases favour a rapid subsequent dispersion. Accumulation of waste at density interfaces will always suppress the rate of the subsequent dispersion. Such accumulation can occur by trapping of the falling cloud of waste in the pycnocline layer, or by trapping of buoyant waste material at the surface. Trapping of kraft-mill effluent from a submarine diffuser outfall has been demonstrated by Waldichuk (1964).

It can be concluded that in all cases when a rapid dilution is required, the method of disposal should be in the wake of a steaming ship. In general, an initial dilution as high as feasible should be secured; reasonable values which can be achieved under normal conditions are in the range 1:200-1:2000 (Weichart, 1972; Crickmore, 1972; Abraham et al, 1972; EPA, 1971).

Since both the disposal technique and the waste characteristics can be adjusted, at least to a certain extent, an initial dilution can usually be obtained which will meet requirements for minimum impact on the environment. Generally, trapping or collapse in pycnocline layers should be avoided.

The dumping frequency should be adjusted according to the capacity and dispersion characteristics in the dumping area: in areas of rapid mixing and transport, the frequency of disposal can be higher than in areas of less vigorous dispersion. A build-up of waste materials in the water column should be avoided. As a useful generalization, the dumping locations and frequency should be adjusted so that individual waste clouds do not overlap. This will be relatively easy in the open sea but may be impossible in an estuary. A preliminary assessment can be made on the basis of the current conditions in the area, such as tidal, wind-generated, and residual currents.

4. OTHER USES

Uses of the marine environment other than for ocean-dumping are manifold, they include fishing, transportation, recreation, including sport fishing, mining including chemical extraction, aquaculture. In addition, sea water is used as process water and cables are laid on the ocean floor. Many of these uses can be adversely affected by marine pollution, but for the purposes of this report, only the relationships between the other uses and ocean dumping are considered.

Fishing: Fishing is one of man's major activities in the marine environment. The world fisheries (including all marine organisms) exceeded 65×10^6 metric tons in 1973 (FAO, 1974). It has been estimated that the maximum sustainable yield of world fisheries may be about twice this figure.

Transportation: Shipping and transportation is another of the major uses of the sea, and continually increases. Ocean dumping operations might interfere with the shipping directly by interference with navigation as well as by such effects as blockage of cooling systems and fouling of propellers.

Recreation: Outdoor recreation increases continually and sea shore recreation ranks as one of the most important, economically and socially; it is therefore important to avoid the stranding of aesthetically undesirable material such as grease, plastic and other slowly degradable organic matter.

Mining: Ocean mining on the bottom of the sea and extraction of chemicals from sea water may be affected by impurities or physical obstructions introduced by dumping.

Aquaculture: Aquaculture practices in marine and fresh water contribute, at present, 5-6 million metric tons to the world food supply of which about 85 per cent is produced in Asia and the Far East region (Rabanal, 1974). The potential is great but economic factors currently confine the practice to high quality fish, invertebrates and seaweed.

Submarine cables and pipelines: Submarine cables and pipelines may be affected by ocean dumping, chemically as well as physically. Besides this possible direct effect of dumping on submarine cables and pipelines, submarine slides triggered by dumping could be a potential threat to them.

Scientific research: Geophysical exploration, meteorological-oceanographical measurements, for instance by means of moored buoys, or even studies on variations in fish stocks due to natural causes, may interfere with or be disturbed by dumping activities.

5. SITE SELECTION

The selection of dumping sites must be made in such a way as to minimize the influence on present and potential other uses of the sea.

5.1 Biological characteristics

An evaluation of the biological sensitivity of a potential dumping area should always be made. Disposal sites should, obviously, be selected to avoid areas of high biological productivity, intensive fishing, breeding or nursery grounds, and migrating routes of important fish resources. Some of these activities, such as breeding and migration, may be seasonal and dumping at other times of the year may be acceptable, provided no substantial mobilization of toxic material occurs after dumping. Dumping in active fishing areas may not only affect the living resources of the sea, but the operation may interfere with fishing vessels, and some kinds of wastes may damage or foul the nets or the fishing gear. The marine environment and its living resources are sensitive to natural changes and they have to be carefully guarded against artificial changes.

Food production is one of the major uses of the sea. Many areas are already over-exploited, whereas others are more or less untouched (FAO, 1972). The present world catch is largely restricted to the coastal zones and continental slopes where input of pollutants from all sources is likely to be highest. In recent years, fishing for new species has extended to much greater depths on the continental slopes than previously. It should be noted also that significant pelagic fisheries exist in some open ocean areas, e.g. the equatorial zones.

In relation to waste disposal at sea, it should be noted that the highly productive areas in the oceans are often related to such physical features as cyclonic gyres, upwelling, lateral boundary currents, ocean fronts, i.e. all areas of divergence. All these conditions are more or less conducive to high nutrient supplies and primary production and zooplankton concentrations, on which fish stocks and other marine life depend.

Conversely the ocean circulation gives rise to convergence such as the Sargasso Sea, equatorial convergences and coastal convergences. Although productivity is generally low in such areas, waste matter may accumulate there, especially if it is resistant to degradation.

The natural stress to which organisms are subjected varies in magnitude and frequency. For example, seasonal variations in temperature are extreme at high latitudes when compared with the tropics. A high degree of seasonal variability can also occur along ocean fronts. It is always cold and dark in the deep water of the open ocean, while salinity, light, and temperature can change rapidly in estuaries, on tidal, daily, and seasonal time scales. The organisms living in such highly stressed environments have evolved to withstand these changes, but may not be well adapted to artificial stress. Similarly, pollution might affect their capacity to adapt to natural changes.

Special attention must be paid to animal migration. Migrating species use their acute sense as a guide in homing on their native region. Interference with the natural characteristics of these waters by introduction of foreign materials can disrupt fish's detection processes. Dumped materials could conceivably mask natural characteristics of the sea water or of tributary streams. This might confuse migrating fish, possibly to the extent that they become lost and go unspawned or fail to find food.

Closely connected to these aspects are spawning, nursery and feeding processes of marine organisms. Critical species, vertical and horizontal biological transports, bio-accumulation, bio-transformation, and taint should also be considered.

Depending upon the characteristics of the waste material, certain general precautions should be observed in planning the disposal operations. If the waste contains toxic materials, the dilution achieved during disposal and the subsequent mixing of the waste with sea water should ensure that the concentrations are not sufficient to damage the marine biota. For substances that settle to the bottom, areas of little or no benthic productivity should be selected, or, if not possible, the sacrifice of a part of the benthic population should be assessed as part of the "cost" of the disposal.

5.2 Sediment characteristics

Sediments of the sea bed of the major ocean basins have a potential sorption capacity for all kinds of metals and organic substances. However, material originating from dumping of wastes may be dispersed in the water column rather than sorbed to the sea-bed/sea water interface. In the presence of high turbidity, there is a scavenging effect by solid materials of substances from solution.

When the materials reach the sea bottom, a high affinity of the sediments for the waste material leads to a large total uptake by the sea bed. However, this uptake is primarily in a thin surface layer of the sediment, and penetration deeper into the sea-bed is slow. Therefore, if resuspension or erosion occurs, the material might be recycled to the water and to the benthic epiflora and epifauna. Thus the sea-bed will not always be the ultimate sink for dumped wastes.

Wastes submerged in the sea-bed would in principle be removed from the water system. Migration to the supernatant sea water takes a long time when the wastes are buried under several centimetres of sediment. However, burying of wastes inside the sea-bed is technically difficult to achieve.

For liquid or dissolved wastes, unless sediments are stirred up, little material will be bound by the sea-bed. In a dumping site, most of the dissolved substances will become so dispersed within the water system that sorption by the sea-bed will be extremely limited. However, with respect to repeated dumping, especially of materials which are not rapidly degradable, the area will accumulate more and more material in the sediments. This will apply particularly to certain heavy metals for which a phenomenon of immobilization exists via absorption inside crystal lattices of sedimentary particles (Ros-Vicent et al., in press).

5.3 Dispersion characteristics

The turbulent mixing in an area, and the rate of exchange with the surrounding sea, should both be studied in order to assess the dispersion characteristics of a potential dumping site. In studying the physical dispersion characteristics of an area, the following generalizations should be borne in mind.

A. Mixing rate

The turbulent mixing in the sea is determined by such physical factors as wind, waves, mixed layer thickness, density stratification, currents including their temporal and spatial variations (Okubo, 1971; Weidemann and Sendner, 1972). In many shallow water areas, the tidal currents are the dominating mixing agents. In conditions of stable stratification, the mixing is suppressed, and very markedly so in pycnocline layers. There the rate of dilution is slow and varies very much with time, i.e. the mixing is intermittent. For contaminants which do not affect the flow, dilution rates of less than 1:10 in 24 hours have been observed in enclosed areas (Kullenberg, 1974a). Similarly suppressed mixing is likely to occur in strongly stratified open sea areas. Under those conditions, particulate matter settles due to gravity, although near-neutrally buoyant material may remain in suspension. The settling velocity of the waste particles will vary, although a rate of 1 m/hour appears to be representative for the flocculated state (Crickmore, 1972). Trapping of almost neutrally buoyant material can occur in pycnocline layers.

In the wind-mixed layer the dilution rate is considerably higher; a dilution in the range 1:10-1:50 over a period of 1-5 hours can be expected under light wind conditions. During strong winds, the rate of dilution increases approximately with the square of the wind speed (Bowden et al., 1974; Kullenberg, 1971).

Close to the bottom, there will often be a turbulent boundary layer, the thickness of which will depend upon the bottom roughness and current velocity. An indication of the transport conditions along the bottom can often be obtained from the type of sediments at the interface. Fine-grained material normally suggests weak transport and a favourable settling environment, whereas coarse materials suggest resuspension and erosion. However, care should be taken in applying this concept, and it should be noted that conditions often vary seasonally.

In estuaries and river mouths, the compensation current transports material along the bottom towards the shore. This can also occur in shallow waters with horizontal density differences, eddies or wind-induced coastal upwelling. The oscillating (tidal) currents in many areas will cause resuspension and fractionation due to differential settling. This implies that the fine-grained fraction of a waste, which can serve as a carrier for pathogenic organisms and other pollutants, may be selectively transported inshore.

Available information on deep sea, near-bottom currents suggests that resuspension will not take place except in certain areas. These are mainly located at the lateral boundaries and are related, in part, to topographic features such as slopes, canyons and ridges.

B. Mixing mechanisms

In the wind-mixed layer, the vertical mixing down to the primary interface is quite rapid. Thus, the thickness of the wind-mixed layer is significant in determining the mixing characteristics. An important dispersion mechanism for scales in the range 1-10 km is the vertical shear effect, i.e. the combined effect of vertical mixing and vertical current shear in generating horizontal dispersion. For an initially thick contaminated volume, the stretching due to the vertical shear is also important. In this connexion, the time-dependent and, in particular, the oscillatory components of the current are important in determining the spreading.

In the surface layer, the vertical mixing depends upon the wind, the shear and the stratification. In internal stratified layers the vertical mixing is suppressed, and is inversely proportional to the stratification. Dominant features of the internal motion in the sea are internal waves which only give rise to mixing when breaking.

At larger scales, above about 10 km or several days, the large-scale horizontal variations of the currents will dominate the mixing.

C. Exchange rate

When considering the dispersion characteristics of an area, it is necessary to take into account the rate of exchange with the connected open sea area. A useful indicator of the rate of exchange is the residence time for a particular element, which can be estimated by means of a natural tracer. This holds true in particular for enclosed or semi-enclosed areas like fjords, marginal seas and the land-locked seas. The residence time will also give a measure of the build-up of a persistent material in the area.

From the point of view of dispersion, the following three categories of areas may be defined:

(i) Areas of great turbulence

Areas of tidal activity are often characterized by a high degree of turbulence; and such areas offer great possibilities for natural dispersion. Care is necessary, however, to avoid conflict with local interests, especially aesthetic and recreational, and also in order to predict where particulate matter in the waste might ultimately be deposited.

(ii) Confined basins

Confined basins (e.g. Baltic or Black Seas) will, in many cases, periodically approach anoxic conditions and be subject to periodic turnover. Such areas might sometimes be considered for the disposal of inert wastes, and perhaps also biodegradable ones. However, persistent and potentially bio-accumulatable substances should be avoided, since ultimately they might be returned to the productive surface waters. It should be pointed out that, as in all other cases, local considerations must be taken into account.

(iii) Other areas of minimal turbulence or "quiescent" conditions

These areas are characterized by a distinctly limited capacity to receive wastes, since transport out of the area and renewal of oxygen supplies etc., are all limited. The all-important consideration in waste disposal in such areas is therefore how to achieve maximum possible initial dilution. The scale of the operation will also have to be controlled. The more inert a substance, in general, the greater the acceptable scale of dumping, but in this context the local existing or potential marine resources must be considered.

D. Methods of prediction

Predictive modelling of the dispersion of various wastes following a dumping operation is of great interest, but suffers as yet from several deficiencies. Nevertheless, simple models have been used with satisfactory results in predicting the dispersion of radioactive wastes. Attempts have been made to model both the initial and the subsequent dispersion (EPA, 1971; Koh and Chang, 1973). However, the results must be regarded with great caution since a number of very limiting assumptions are made, such as treating the contaminants as passive. The lack of relevant observational information is at present the most severe hindrance to further development of the predictive models.

6. OBSERVATIONS AT THE SITE

Once a preliminary selection of the site for disposal has been made on the basis of existing knowledge of conditions in the area, a series of observations of the physical, chemical and biological characteristics should be made. Ideally, these should extend over a period of at least one year in order to take account of variations which will occur with seasonal changes. It should be noted that long-term variations arise as a result of purely natural causes and at present it is often extremely difficult to distinguish these from artificially induced changes.

Observations of turbidity and chemical and biological characteristics should be continued after dumping commences to ensure that no detrimental changes occur. All observations should be made at and around the selected site, and it should be recognized that in the light of the pre-dumping, or even post-dumping observations, a new site may have to be selected.

6.1 Biological observations

Prior to approval of a disposal site, biological observations to characterize the site are usually essential. If repeated disposals at the same location are expected, these observations should be made at all seasons of the year and repeated more frequently at critical times of the year, both to monitor the biological effects and to account for year-to-year variations. For a single dump, which is not expected to be repeated, a single assessment prior to the dump should be acceptable, but observations following the dump would be desirable to evaluate the effect and to form the basis for future decisions concerning similar operations.

Desirable observations might be expected to include:

(i) Fisheries resources. Data on this subject are probably already available in the appropriate agencies or ministries for most coastal regions.

(ii) Primary (plant) productivity as related to light intensity and nutrients. This is especially important if decomposable organic matter is included in the waste, and if its decomposition would release nutrients stimulating plant growth, sometimes with undesirable effects such as modification of species composition.

(iii) Natural turbidity of the water, and the changes in turbidity which may be produced by the waste disposal. Turbidity influences the amount of light reaching various depths in the sea, and a persistent increase would be expected to reduce plant productivity. However, if rapid dispersion (or sinking) of the waste is achieved, and if the circulation in the area is such that the turbidity increase is transitory, little effect on productivity from a non-toxic waste would be expected. Phytoplankton reproduce at such a high rate that recovery from a decrease in photo-synthesis is likely to be rapid.

(iv) Zooplankton populations and their vertical diurnal migrations. These organisms might transport elements from one level in the water column to another, through absorption, feeding and excretion.

(v) The oxygen content of the water and its natural variability. This will help to evaluate whether or not a waste with an oxygen demand may reduce the oxygen content to levels which will be detrimental to marine organisms.

(vi) Structures of normal benthic populations, whether or not they are of commercial importance. This is especially important whenever the waste may reach or accumulate on the bottom of the disposal site. Since benthic animals remain in a fixed location (in contrast to fishes and plankton), they reflect the integrated effect of chronic exposure to the pollutant and can provide early warning of potential damage.

(vii) Microbiological indices with respect to water quality for protection of human health.

6.2 Chemical observations

The design of the chemical observations, unlike those of a biological or physical nature, can be tailored to the chemical characteristics of the waste. For example, if the waste to be dumped contains no nutrients, there is little point in carrying out an exhaustive survey of nutrient levels in the area selected for disposal.

It is difficult to provide a comprehensive list of substances which should be measured in the area, but depending upon the composition of the waste, the following substances might be worthy of attention: organochlorine pesticide residues, PCBs, petroleum hydrocarbons and metals such as mercury and cadmium - these are all prohibited under the terms of Annex I of the Dumping Conventions, but they are known to be present in wastes such as sewage sludge and dredge spoils and may be found in a variety of industrial wastes. The Working Group noted that such substances are permitted to be present in trace amounts, regardless of the volume of the waste, and this raised the question in the minds of the members of the Working Group, that perhaps a prohibition as currently prescribed in the Dumping Conventions was debatable. The point highlights the need for the continuous reappraisal of the Annexes of the Dumping Conventions and their definitions.

A number of other elements, e.g. zinc, copper, lead and arsenic, may also be accumulated and should be measured. The highest concentrations of most of the substances listed above are likely to be found in sediments and benthic animals. It will in general be undesirable that the organic content of the sediments be unduly increased; as a measure of this, loss on ignition, or more preferably total organic carbon content, should be measured. If the waste contains substantial quantities of nutrients such as phosphate, nitrate, nitrite or ammonia, these should be measured in the water column.

It is perhaps worth pointing out that substances considered to be harmful in the freshwater environment may be less so in the marine environment, e.g. cyanide due to complexation with metal ions, and ammonia due to the buffering effect of sea water, or even virtually harmless, e.g. chloride, sulphate or barium (the former are present naturally in sea water at high concentrations, and the latter will precipitate as barium sulphate). Subject to such fairly obvious exceptions, in general, if a substance is known to be present in waste in high concentration, its presence should be expected in the dumping area and appropriate measurements should be made.

6.3 Physical observations

From the point of view of dispersion, the physical conditions at the dumping site should be observed, and a general assessment of the exchange rates between the waters in the dumping area, near-by-areas and the open ocean should be made.

Observations of the physical conditions might be expected to include:

(i) wind and wave features;

(ii) vertical density distributions during different weather conditions, including the mixed-layer depth on a seasonal basis, water temperature and its seasonal variations;

(iii) current conditions, including the vertical current distribution, velocity ranges and directions, time-dependence, oscillations and residual currents;

(iv) bottom conditions and geological characteristics, such as the nature of the sediment and topographic features (e.g. flat bottom, trenches, ridges).

Useful tools in such observations include dye diffusion experiments, the use of radioactive tracers, wave gauges, grab and core samples of the sediments.

7. SUBJECTS REQUIRING FURTHER RESEARCH

In the course of preparing its report, the working group has identified a number of areas where basic information is either imprecise or lacking. In particular, it considered that the predictive ability in a relatively unstudied area is inadequate. It is considered that research in the following subjects would be most productive in providing information relevant to the selection of dumping sites.

7.1 Biological and chemical aspects

Basic acute bioassay techniques are reasonably well established. Further attention is required in relation to the selection and culture of the most appropriate test organism for a particular set of site conditions. This should take into account possible food chain accumulation and the most appropriate life stage.

In order to be able to have a better appreciation of the appropriate factors and time effects, long-term (one or more generations) "flow-through" tests are required to evaluate potential sub-lethal or chronic effects.

It is recognized that combinations of two or more wastes may be more, or less, toxic than each waste separately. At present, there is little information on how the effects of such combinations can be predicted for conditions in the marine environment.

Much more detailed information is required on the mode of action of particular chemicals, especially in relation to uptake and availability from a toxic action standpoint. In this context information is also required on the various forms of a chemical substance which may be present in the sea, e.g. valency state of ionic species, metallo-organic complexes, adsorbed metal or organic compounds.

Similarly, and especially in relation to human health implications, studies are required of the form and toxicity of the compound once it has been accumulated by a marine organism, e.g. the forms of mercury, cadmium and arsenic in marine organisms and the way these may be altered. In this connexion, studies are required to provide more detailed information on the mechanisms of bio-accumulation within a single organism and transfers in a food chain.

Many inorganic and organic compounds find their way to the sediments. The rate of such transport, the residence times of substances in the sediments, and their subsequent mobilization, are generally not well understood. For deep-sea disposal, research is required to improve and modify the methodologies and measuring techniques.

The persistence of organic chemicals, especially petroleum and chlorinated hydrocarbons is a matter of concern. The rates of decomposition under various environmental conditions, such as tropical, temperate and arctic conditions, need to be established. Information is required on the dependence of marine bacteria on threshold concentrations of the organic substrate, and inorganic nutrients. The extent to which microbial activity takes place under deep-sea and mid-depth pressure and temperature conditions, requires detailed investigation.

In order to be able to assess the impact of a waste in the marine environment, some estimate of existing levels of waste constituents and their sources is required. River or pipeline inputs can be determined fairly readily but the influence of aerial transport, including that on breakdown and production of pollutants, is unknown for most substances, although it is now generally recognized as being of great importance.

It is known that a number of entero-pathogenic micro-organisms are quite resistant in sea water (Gameson, 1975). Further work is required in the study of the behaviour and fate of micro-organisms associated with wastes such as sewage sludge, especially the influence of such factors as temperature, light, salinity and sedimentation.

7.2 Physical aspects

Carefully designed field experients are required in order to obtain information for developing and testing models for predicting the depth of penetration and possible collapse of a falling cloud of waste. Measurements should provide information on the concentration distribution during descent, turbidity generation, settling velocity and subsequent dispersion in relation to physical conditions. Such experiments would need to be carried out under a variety of environmental conditions, ranging from quiescent to near-storm conditions and in both deep and shallow, stratified and unstratified waters. Particular attention should be paid to those conditions likely to give the least initial dilution and/or subsequent dispersion.

Due to the difficulty of covering all conditions occurring in nature, careful attention should be given to the selection of environmental conditions for field experiments, so that expensive field experiments can be backed by appropriate laboratory experiments. In many instances, large-scale dumping experiments can give required information more rapidly, on both physical and chemical behaviour of wastes in the sea.

There is a severe lack of information about the influence of the waste on the mixing processes, as well as about the possible physical interactions between various types of materials. At present, it is not possible to take into account properly the multiphase character of a waste when predicting its physical fate.

In relation to disposal in deep waters, there is an urgent need for studies of deep water and near-bottom dispersion processes, including the development of new techniques, e.g. for measurements of currents and turbulent diffisuion.

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Appendix I

GESAMP Working Group on the Scientific Basis for Disposal of Waste into the Sea

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Appendix II

GESAMP Working Group on the Scientific Basis for Disposal of Waste into the Sea

Terms of reference:

as agreed upon by the Fifth Session of GESAMP, Vienna, 18-23 June 1973 (GESAMP V/10, paragraph 40):

"With reference to Annex III of the London Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter,

(1) to carry out a critical review of our present knowledge of those aspects of dispersion and physical, chemical and biological processes relevant to the selection of sites for discontinuous injection of wastes into the marine environment in both deep and shallow waters; and

(2) to identify gaps in our present knowledge, focus attention on urgent research needs, and suggest research priorities."

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ANNEX VI

IMPACT OF OIL ON THE MARINE ENVIRONMENT

(Excerpt from PROGRESS REPORT submitted by the Working Group on the Impact of Oil on the Marine Environment to the Seventh Session of GESAMP - Documentation: GESAMP VII/4)

CONTENTS

VI. MICROBIAL POPULATIONS - EFFECTS RELEVANT TO OIL DISCHARGES
(Thompson, lead expert; Mironov)

1. Microbial Attack of Oils
2. Oil Effects on Micro-organism Populations

VII. HIGHER MARINE LIFE FORMS - LETHAL AND SUBLETHAL EFFECTS FROM OIL DISCHARGES
(Levy, lead expert)

VIII. HUMAN EFFECTS FROM OIL DISCHARGES
(Blackman, lead expert; Palmork)

1. Loss of Marine Food
2. Health Effects

2. Manner of Study

At a first preliminary meeting of the GESAMP members of the working group (Geneva, 20-21 March 1974), the group took note of Resolution 6 of the International Conference on Marine Pollution, convened by IMCO in 1973, recommending that the Organization take appropriate steps, at an early date, to review, on a comprehensive basis, the environmental problems created by the discharge of all petroleum-derived oils into the marine environment, with particular reference to the problems associated with the discharge of light refined oils. The working group was also informed that, with a view to implementing the above recommendation, the Marine Environment Protection Committee of IMCO had requested GESAMP to accelerate its work on this subject. The working group used as the basis for its study the work programme agreed at its preliminary meeting, and adopted at GESAMP VI (GESAMP VI/10, Annex IV). At that preliminary meeting "Lead Experts" were appointed with the task of identifying specific references, reviews, symposia and other material from which the data base would be constructed for each topic of concern, as identified. This work had been undertaken intersessionally, and working papers were presented describing this intersessional activity for most of the topics listed.

With this information in mind, the working group recognized that its deliberations should be extended to a discussion on certain physical and chemical effects which have a considerable influence on the biological effects. The Group also found it appropriate, for the purposes of this Report, to limit the scope of its work to consideration of the oils falling within the definition of "oil" as set out in Annex I of the International Convention for the Prevention of Pollution from Ships, 1973, i.e. "petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than petrochemicals which are subject to the provisions of Annex II of the present Convention) and, without limiting the generality of the foregoing, includes the substances listed in Appendix I to this Annex" (see Table 1: List of Oils). It is the understanding of the working group that this definition includes weathered petroleum products.

3. Background Information

As a basis for discussions at the First Session of the working group (Rome, 28 October - 1 November 1974) the following Working Papers were prepared:

K.H. Palmork:	Tainting
P.G. Jeffery:	Effect of oil pollution on oxygen transfer
R.A.A. Blackman:	Carcinogens
E.M. Levy:	The effects of oil on marine organisms
M.G. Ehrhardt:	Oil in the sea; routes into and within biosystems
R.R. Cowell and J.D. Walker:	Impact of petroleum hydrocarbons on micro-organisms in the marine environment

TABLE 1: LIST OF OILS*

Asphalt solutions

Blending Stocks
Roofers Flux
Straight Run Residue

Oils

Clarified
Crude Oil
Mixtures containing crude oil
Diesel Oil
Fuel Oil No. 4
Fuel Oil No. 5
Fuel Oil No. 6
Residual Fuel Oil
Road Oil
Transformer Oil
Aromatic Oil (excluding vegetable oil)
Lubricating Oils and Blending Stocks
Mineral Oil
Motor Oil
Penetrating Oil
Spindle Oil
Turbine Oil

Distillates

Straight Run
Flashed Feed Stocks

Gas Oil

Cracked

Gasolene Blending Stocks

Alkylates - fuel
Reformates
Polymer - fuel

Gasolenes

Casinghead (natural)
Automotive
Aviation
Straight Run
Fuel Oil No. 1 (Kerosene)
Fuel Oil No. 1-D
Fuel Oil No. 2
Fuel Oil No. 2-D

Jet Fuels

JP-1 (Kerosene)
JP-3
JP-4
JP-5 (Kerosene, Heavy)
Turbo Fuel
Kerosene
Mineral Spirit

Naphtha

Solvent
Petroleum
Heartcut Distillate Oil

From: International Convention for the Prevention of Pollution from Ships, 1973, (Annex I, Appendix I)(IMCO).

*This list of oils shall not necessarily be considered as comprehensive

It was noted that certain additional topics of concern will be considered including

Heating effects - effects on marine organisms and substrata due to elevated temperature produced by absorption of solar radiation by oil films

Absorption of pesticides such as DDT and metals by oil films and layers on the sea surface and the effects that this might have on marine resources

Each working paper (see paragraph 29 of the main body of the report) was presented to the working group and extensively discussed in order to identify the significant data and assumptions, to examine the shortcomings and gaps existing in the present studies as well as in present state of knowledge.

In addition, the Chairman made available two bibliographies on the "Effect of light refined oils and petroleum hydrocarbons on the marine environment", one of them containing a complete set of the references given in the working papers, the other giving annotations of 153 additional articles submitted by over 70 organizations throughout the world involved in petroleum hydrocarbon research.

4. Format of Study

It was agreed that the studies on each topic of concern should be further developed intersessionally, but that a common outline or format should be used as follows:

Definitions - a statement of the topics of concern. These were identified at the preliminary meeting of the working group and amplified at GESAMP VI

Problems - including a statement of the controversy (if it can be identified) that exists concerning each topic.

Background - the context in which the controversy has arisen and the necessary background information to enable the controversy to be considered

Data - the scientific evidence relative to both the problem and the background to it

Comments - in particular the extent to which the data can be validated, the existence of gaps in the data base and opinions expressed about the data

Conclusions - initially a resolution of the controversy in qualitative terms, but developed whenever possible into a quantitative assessment

Recommendations - these should highlight those gaps in the existing knowledge that have prevented a full assessment of the problems, and comment on how these gaps may be filled.

ANNEX VII

REPORT OF THE GESAMP WORKING GROUP ON THE SCIENTIFIC BASES FOR THE DETERMINATION OF CONCENTRATIONS AND AND EFFECTS OF MARINE POLLUTANTS

Dubrovnik, Yugoslavia

14-18 October 1974

Guidelines for an open ocean monitoring system

PREFACE

At its third session GESAMP was asked by the IOC to review a paper by the IOC's Group of Experts on Long-Term Scientific Policy and Planning (GELTSPAP 1/17) on marine pollution in the framework of the Long-term and Expanded Programme of Ocean Research of which the Global Investigation of Pollution in the Marine Environment (GIPME) is an important element. Two small sessional working groups were established to study the above-mentioned document. One of these working groups dealt with the scientific bases on which a system of marine pollution monitoring could be found. The system envisaged at that time was regional and was intended to include the recording of deliberate or accidental discharge into the marine environment. Three 'type' regions were proposed, (Baltic Sea, North Sea and Puget Sound, USA). Five groups of potential pollutants were proposed: halogenated hydrocarbons, petroleum, heavy metals, radionuclides and nutrients, as well as certain environmental parameters. The report of this sessional working group was approved by GESAMP at its third session and remitted to the IOC. This Working Group's report was clearly a policy proposal.

At its fourth session GESAMP, in dealing with the subject of Transport and Dilution of Pollutants and Marine Pollution Monitoring, was asked to provide advice to the Joint IOC/WMO Planning Group for IGOSS (IPLAN) and contribute to a review of research aspects being carried out by the IOC Working Group on Research as Related to IGOSS (IRES). GESAMP decided to identify, at the fourth session, the components which could be included immediately in the first phase of IGOSS. This referred to physical and chemical parameters. GESAMP agreed on the physical oceanographic parameters proposed, but felt that the strictly marine pollution parameters could not, at that time, and given the state of knowledge, be adequately specified.

At the fifth session, in view of the continuing concern to specify these parameters, a sessional working group was established to develop this subject. GESAMP was not able, at that time, to agree with some of the proposals in the working group's report. After much discussion GESAMP agreed that no global marine pollution monitoring system should be limited to physical and chemical parameters, but should include biological ones. The report of the working group was not accepted by GESAMP and the group was asked to address itself to these problems inter-sessionally.

At the sixth session of GESAMP the Chairman of the working group reported that in the present state of the art of biological monitoring, it was not feasible to specify biological parameters satisfactorily. Correspondingly, the working group was expanded to include biologists and was given revised terms of reference; this expansion involved a change from the apparently simple specification of parameters to the scientific bases for a global marine pollution monitoring system. It was agreed that the working group should be established with two panels, one to specify parameters relating to concentrations, and one to specify those relating to effects (GESAMP VI/10, p.5). Professor Goldberg was nominated to chair the panel on concentrations, and Dr. Kečkeš the panel on effects. The terms of reference for the two panels were approved as given in GESAMP VI/10, Annex I.

The expanded working group met in Dubrovnik, Yugoslavia, in October 1974 to revise and expand the report tabled by the working group at the fifth session. The working group decided that it should propose an open ocean monitoring project as an international venture, recognizing that this could eventually be co-ordinated with regional and national monitoring programmes.

The main purposes of the present report are to advise the IOC and WMO on the monitoring that can now be undertaken, particularly within the framework of the IGOSS Pilot Project on Marine Pollution Monitoring, and to indicate to the ICG for GIPME the subject areas in which research requires to be promoted. The Governing Council of UNEP has already approved the GEMS programme, which contains a marine monitoring component, and it is interested in the views of experts on this subject. FAO, also, has a considerable interest in knowing what biological parameters could now be monitored, and is following this work closely, especially its relevance to the work of its own ACMRR Working Parties on bioaccumulation, ecological indices and effects of pollutants on marine organisms.

1. Introduction

The main purpose of a global marine pollution monitoring programme is to provide a basis for the management of those materials that can jeopardize human health, the stability of marine ecosystems, or the amenities of the environment. The proposed monitoring programme will consist of systematic measurements of changes in marine ecosystems and pollutant concentrations in oceanic waters, airs, sediments and organisms, as well as in their terrestrial counterparts where deemed necessary. These measurements would need to be repeated on a temporal basis, the time-scale of which would be indicated by the levels found initially. The oceanic pollutant levels can be compared with "acceptable levels", defined as those which society is willing to accept on the basis of a pre-determined risk assessment, to provide a rational basis for applying controls on the release of materials to the environment. National and regional programmes of this type have been formulated for the controls upon releases of mercury and artificial radioactivities to the marine environment.

The proposed global marine monitoring programme is designed to determine the pollutant levels and any effects they might have upon living systems in the open ocean as opposed to the coastal ocean and marginal and enclosed seas, the monitoring of which is usually carried out through national programmes. Coastal waters may be defined as those whose chemical and physical properties are significantly influenced by their contacts with the continents or the sea floor. In general, such waters extend over the continental shelf. An effective global marine monitoring programme must be co-ordinated with national and regional water monitoring programmes.

It should be recognized at the outset that the time and space scales of a global marine monitoring programme are substantially greater than those for coastal zones and most marginal and semi-enclosed seas. Whereas in general distances of tens of kilometres may define a coastal area, and distances of 100 to 1000 km are characteristic lengths of marginal and semi-enclosed seas, open-ocean water masses can extend over thousands of kilometres. Flushing of coastal waters normally takes place over periods of a year or less. In the open ocean, surface waters mix with those from greater depths over periods of tens of years, while for the deeper layers time scales from centuries to millenia are involved.

Herein lies the rationale for a global monitoring programme. Our concern is with the irreversible loss of open-ocean resources because of the extremely slow build-up of persistent pollutants originating from many sources. The problem is to prevent the titration of the open-ocean system with a pollutant for which the endpoint would be either an irreversible loss of a major ocean resources or the severe contamination of open-ocean waters which were previously available for the dilution of the already polluted coastal waters through mixing. In coastal regions we have depended upon the scientific community or upon catastrophes to initiate the formulation of policies concerning the release of pollutants to the marine environment. For example, the injections of artificial radioactive nuclides from reactors are regulated by some nations upon the basis of their potential build-up in commercial food products or the degree of human exposure by other routes, e.g. on beaches. With conditions of high public interest and concern, regulatory programmes may result within a year, but normally situations of grave danger must be clearly indicated from monitoring programmes otherwise there may be a significant delay in controlling the discharge. For example, it took a decade to institute the regulation of mercury releases to Minamata Bay waters following recognition of their impact upon human health. The first inputs of mercury wastes took place in 1939; the first victims were recognized in the 1950s; and the first regulation of releases was in the 1960s. The lower levels of pollutants in the open ocean and the perhaps less obvious effects expected upon living systems underline the difficulties in initiating monitoring programmes.

2. Pollutants to be monitored

At the present time, five groups of substances have so far been recognized as potentially serious pollutants in open-ocean waters - artificial radioactive nuclides, petroleum, halogenated hydrocarbons, heavy metals and litter. These groups of materials are found in the surface waters of the open ocean and sometimes at depth following entry from coastal waters, from the atmosphere or from ships. Methods are available or can be envisaged for the analysis of the five groups of pollutants in organisms, sediment, water and air samples.

2.1 Artificial radionuclides. Fission products (^{90}Sr, ^{137}Cs, etc.) induced activities (^{55}Fe, ^{65}Zn, etc.) and the transuranic elements ($^{239, 240}Pu$, ^{241}Am, etc.) are being produced in ever increasing amounts and their environmental concentrations are expected to increase. The present levels in the open ocean are a consequence of fallout following their introduction into the atmosphere during nuclear weapons tests. The compounds of the transuranic elements, produced in nuclear reactors and weapons are among the most toxic substances known, on the basis of their chemistries and of their radioactivities. Baseline measurements upon the open-ocean burdens of plutonium and americium isotopes should be initiated as soon as possible to gain an estimation of their present fluxes to the open ocean and to allow predictions of future fluxes on the basis of increased uses of nuclear energy.

2.2 Petroleum. Of the two billion tons of petroleum annually produced, about 6 million tons are estimated to enter the oceans directly. This figure is merely a fraction of the estimated natural hydrocarbon input into the oceans originating from the release of biosynthesized hydrocarbons, the decay of organic matter and natural seepage. It has to be made quite clear, however, that the composition of petroleum differs markedly from the composition of biogenic hydrocarbons produced in the marine environment. Petroleum has substantial quantities of aromatic hydrocarbons of known carcinogenicity. Pelagic marine organisms carry body burdens of petroleum; any effects upon life processes have yet to be demonstrated for presently observed levels. The chemicals contained within petroleum, in combination with such synthetic organic chemicals as the halogenated hydrocarbons, may stress living organisms. Some beaches of the world, as well as the waters in open-ocean shipping lanes, are soiled with tar balls and oil slicks. Some scientists are concerned about the effects upon human health through the transfer of carcinogenic petroleum compounds found in fish and shellfish. There is a need to reduce losses to the oceans as far as practicable, and to ascertain the effects of improved handling through a monitoring programme.

2.3 Halogenated hydrocarbons. The two most ubiquitous groups of synthetic organic chemicals in the oceans are the polychlorinated biphenyls (PCBs) and DDT and its metabolites (DDT). Both have been implicated in deaths or reproductive failures of marine birds. There is evidence, on the basis of actual use, that the amount of DDT presently being dispersed about the environment is roughly the same as it has been over the past decade, about 100,000 tons per year. On the other hand, there are now decreasing rates of production of PCBs. Yet both groups of compounds are still being transferred from the continents to the oceans in measurable amounts. Marine organisms today carry parts per million (wet weight) levels of these collectives of chemicals. Present concerns involve their interference in hormone production in higher organisms and possible impacts upon the photosynthetic processes in some algae. The PCBs, if ingested in sufficient amount by man, may cause a chloracne type of disease (YUSHO).

Other synthetic halogenated carbon compounds are measurable in surface waters of the open ocean: the chlorofluorocarbons used as aerosol propellants; dry-cleaning fluids and solvents such as trichloroethylene, perchloroethylene and trichloroethane; aliphatic chlorinated hydrocarbons, such as the constituents of the EDC tars and waste products involved in polyvinyl chloride production; and hexachlorobenzene, an agricultural fungicide and a waste product from the manufacture of halogenated compounds. Some of these materials are resistant to breakdown and are toxic to marine organisms at higher levels than now presently observed. Their manufacture and use is expected to increase.

2.4 Heavy metals. Two metals, of established toxicity to man in elemental forms and in their compounds, are entering the oceans in amounts that may affect life processes. These are lead and mercury. Although increases in marine levels have so far been associated with coastal areas, nonetheless their continuing use in industrial activities indicates a possible rise in their open-ocean concentrations. Perhaps cadmium falls in this category, although there are no definitive reports on its increases in coastal waters.

2.5 Marine litter. On beaches, surface waters and the sea floor there is a multitude of society's discards that are not rapidly decomposed: plastic-ware, plastic bags, glass-ware, metal objects, etc. The flux appears to be about 6 million tons per year. Many of these artifacts are used as containers or wrappings of substances and goods used by society. Some, such as polystyrene spheres and discs, are discards from manufacturing processes. A substantial proportion of the litter appears to come from ships, but measures are being taken to control this (International Convention for the Prevention of Pollution from Ships, 1973). Statistically valid sampling techniques are urgently needed to evaluate amounts of litter in surface waters and on the sea floor. The effects of litter upon components of the ocean system can only be hypothesized. Perhaps they provide new econiches for organisms, and hence alter the structure of marine communities. The accumulation of solid wastes on the sea floor may decrease the exchange of chemicals between water and sediments, and perhaps affect the activities of benthic organisms.

3. Descriptive and Predictive Models - the Mass-Balance Approach

In order to describe present dispersion of a pollutant about the environment and its open ocean concentrations, and to predict future values, models must be developed to relate quantitatively the source functions, environmental levels, fluxes between reservoirs, and sinks. Such models attempt to balance inputs and outputs and are known as "mass-balance models". They can be developed for the steady state situation or for the transient case in the following generalized form for the open sea:

$$\Delta C = (C_b + C_m + C_B + C_g + C_a) - (C_B' + C_{px} + C_{pb} + C_g' + C_a')$$

where

ΔC is the change in the pollutant content of the open ocean in a given interval of time;

C_b is the contribution from rivers or coastal outfalls;

C_m is the contribution by dumping into the sea from ships;

C_B is the outflow caused by water exchange;

C'_B is the inflow caused by water exchange;

C_ε is the flux to the sediments from the open ocean;

C_a is the flux from the atmosphere to the open ocean;

C'_a is the flux from the open ocean to the atmosphere;

C'_ε is the flux from the sediments to the water of the open ocean;

C_{px} is the loss of pollutant by chemical or radioactive disintegration; and

C_{pb} is the loss of pollutant by biochemical degradation.

It must be emphasized that the above model is only an illustration of a possible approach and cannot be applied to the ocean in general in short time-scales of the order of a year or years. It can be applied to the surface layer, i.e. to the upper mixed layer, for time scales of the order of 10 years. This implies that a monitoring programme must be of sufficient duration to allow the dynamics of the ocean-atmosphere system to achieve equilibrium. It must be recalled that the mixing and transport processes in the ocean are much slower than in the atmosphere.

These models and their included mass balances are an integral part of a monitoring programme. The pollutant levels and fluxes are combined with the physical parameters to describe mixing and transport processes. On a global basis, the validity of the model depends upon the availability of reliable production and use data which up to the present time have often been difficult to obtain. In the cases of all pollutants considered in this report, there is an urgent need to assemble such data now. To formulate these models, the rates of mixing and advection must be sought from empirical and theoretical information in the literature of physical oceanography. At present, the available information is not adequate for highly precise calculations; nonetheless, the models developed so far have been successful in describing pollutant dispersions.

4. General Strategies for Determining Pollutant Levels in an Open-Ocean Monitoring Programme

An open-ocean monitoring programme should be developed with the following characteristics:

1. Sample numbers. The smallest number of samples, consistent with ensuring the statistical validity of the mass-balance model in which they are used, should be sought. Ideally, sampling locations should be related to the salinity/temperature field, and not arranged only geometrically.

2. Sample collection. Since the risk of contamination is usually great for those pollutants whose concentrations are extremely low, sample collections should only be made by qualified personnel aware of these difficulties.

3. Laboratories. A small number of laboratories should be involved in the analytical work. Most of the pollutants have very low concentrations in environmental samples and require highly sophisticated equipment for analyses. Competent analysts are few in number. For example, there are fewer than ten laboratories in the world currently measuring either DDT and PCBs or the transuranic elements in sea water, because of the great difficulties involved in the analytical techniques.

   The laboratories should prepare reference samples for inter-comparison with each other and should attempt to relate their results to those of coastal monitoring programmes.

   The procedures of analyses should be made available to other laboratories for evaluation and use.

5. Sampling for Environmental Levels

5.1 Sampling procedures. A long-term global monitoring programme should first determine absolute levels of pollutants in the marine environment and then as necessary temporal trends of those levels. Such a programme will need a methods handbook describing sampling methods, sampling equipment, sample handling and sample storage. There are precautions to be taken with regard to contamination of samples because of the very low levels of those pollutants in the samples. The handbook should describe in detail the precise procedures to be followed. Such action has already been initiated in certain regional programmes (e.g. ICES, OECD and NOAA (USA)).

5.2 Sampling types. To formulate mass-balance models and to understand the processes of pollutant transfer and storage and mechanisms, it is important that the following components of the environment be sampled and analyzed:

(a) The particulate and gaseous phases of the atmosphere.

(b) The particulate and the dissolved fractions of rain-water.

(c) The particulate and dissolved fractions of the surface microlayer (upper few mm) the surface waters, and the deeper water masses of the sea.

(d) Several species of organisms which concentrate specific pollutants.

(At the present time, except for such fish as the tuna, there is little information on the bioaccumulation of pollutants by pelagic organisms in the open ocean and hence a research programme to identify appropriate species is urgently needed. Organisms or substrates artificially introduced to a given area might be used to monitor pollutant levels.)

5.3 Sample frequency. The wealth of existing open-ocean oceanographic data suggests that the chemical composition of open-ocean areas is rather constant over short periods of time. Changes in major wind systems and current patterns are seasonal in nature; thus, changes in pollutant level due to changes in atmospheric input and water-mass movements need not be sampled more than two or four times per year. Boundary or coastal stations may need to be occupied more often than open-ocean stations, because of the variability due to runoff, storms and variations resulting from local input patterns. It should be noted also that the deep-water sphere should be sampled over decades and not merely over seasons to note significant changes.

5.4 Sampling sites. Two types of sampling site have been considered: "open-ocean stations" and "boundary stations". The former category should meet the objectives mentioned below; the latter category should provide the data to calculate the fluxes into the ocean from the coastal areas and marginal seas, and should preferably be part of existing or future national or regional monitoring schemes. The working group considered that the often used terms "baseline station", "regional station" and "impact station" are less appropriate for the scheme presented here.

For the "open-ocean stations" the following objectives were defined:

1. To document the levels of pollutants and their long-term changes.

2. To provide background information for the evaluation of data obtained in regional or local monitoring schemes.

3. To develop mass-balance models of pollutants on oceanic and global scales, and to test their validity.

It was recognized that many marine pollutants reach the ocean in significant quantities via the atmosphere, and that for some materials this is the principal pathway. Therefore, for the development of mass-balance models, the monitoring schemes for the oceans and for the atmosphere should be interconnected, and, in particular, monitoring of atmospheric and oceanic pollution should, where possible, be done at the same stations.

With regard to specific requirements of the sampling sites for "open-ocean stations" the working group felt that:

1. Both the ocean circulation patterns and the general circulation of the atmosphere should be taken into account.

2. The monitoring should preferably be done at fixed points in the oceans where the oceanographic and meteorological conditions are well known or where a long time-series of observations of these conditions can be made. The weather ship stations, or areas where repeated observations are being made or are planned, could play an important role in this context.

3. The siting should be closely co-ordinated with the network for monitoring background environmental pollution over the land.

4. Available information should be used and preliminary surveys should be organized prior to the establishment of such stations.

It has been recognized that only a limited number of such stations can be established because most pollutants of concern have very low concentrations in the open ocean, and require special sampling procedures and highly sophisticated equipment for analysis.

Although it is premature to formulate concrete proposals for oceanic sampling sites, ten stations for each ocean is considered a reasonable maximum number.

The "boundary stations" being preferably part of national or regional monitoring schemes have to be located on the basis of regional considerations. In the context of a global monitoring scheme the setting up of national or regional schemes should be encouraged, with the provision of technical assistance, training and financial support where needed. Special emphasis should be given to the intercomparability of the data, and laboratories charged with the global monitoring should, where needed, organize standardization programmes (intercalibration exercises).

As an example, a rational network of sampling sites for the Atlantic Ocean is suggested in the Appendix.

5.5 <u>Additional parameters to be included in the levels programme</u>. A proper and full interpretation of the measurements of pollutants requires the observation of additional parameters (physical, chemical and biological). Only when the sampling procedures for the pollutants have been developed will it be possible to give a critical listing of these parameters. The following paragraphs only give indications of what may be necessary.

Physical parameters

1. In situ temperature and salinity of the water sample, together with an STD record, in order to assess the composition of the water mass as a mixture of various water types, and to show the degree of vertical homogeneity of the water column and the depth of the mixed layer.

2. The total amount of particulate matter in the water column being sampled, in order to relate it to the concentration of the pollutant in particulate form.

3. The parameters describing air and sea state, in order to relate the sampling conditions to the normal conditions.

Chemical parameters

1. Dissolved oxygen, in order to distinguish deep water masses.

2. Concentrations of nutrients in surface waters, in order to assess the potential biological productivity of the water mass. On a local or regional scale these parameters may be considered as indicators of pollution, but their inclusion in this global scheme is not based upon this aspect.

As indicated in section 3, on models and mass balances, our knowledge of the transport process taking place is not enough to allow us to calculate the fluxes of pollutants accurately. Therefore, further investigations of these processes are needed which may involve monitoring of physical parameters on a wider scale than mentioned here. It is suggested that the term "pollution monitoring" be restricted to the measurements mentioned in this section. Other measurements might also be made to facilitate mass balance studies. For example, it would be desirable to include long-term observations of currents and temperature (possibly salinity also) by means of moored recording instruments.

6. Monitoring the Effects of Pollutants on Marine Communities and Ecosystems

6.1 Introduction. Although changes in the structure of marine communities and ecosystems under the influence of pollutants are evident in many coastal areas, the majority of these result from gross pollution by sewage or other wastes with a high oxygen demand, and similar changes could occur in the open oceans if the pollutant concentrations reach a critical level. Structural and functional changes in open-ocean communities and ecosystems may be used as indications of the overall pollution effects. It was recognized, however, that it will be difficult to define a clear cause/effect relationship between the existing concentration of a single pollutant and the observed changes, without additional experimental (laboratory and in situ) investigations. The primary role of these investigations is to link the body burden of single pollutants and the levels of pollutants in ambient water, particularly those that may impair the behaviour of the organisms, to any measurable effects of pollutants on individual marine organisms or their populations, or on artificial ecosystems.

The synergistic or antagonistic effect of different pollutants is virtually an unexplored field. Additional data are also required on the effects of environmental conditions such as dissolved oxygen concentrations, salinity, and temperature.

The results of laboratory investigations will assist in providing an understanding of the changes observed *in situ*, but the difficulties in extrapolating from laboratory experiments to conditions in the sea are generally recognized. Correlation should be sought between the response of the marine community and the observed body burden.

6.2 *Laboratory studies*. *In situ* studies to determine the effects of pollutants on open-ocean species and communities are necessarily long-term, but often it is critically important to identify effects before such studies are complete. This can sometimes be accomplished by obtaining information on the body burdens of pollutants that occur in ocean organisms and utilizing this information in laboratory evaluations.

It is difficult and often impossible to demonstrate effects of pollutants on certain ocean organisms *in situ* or in the laboratory, primarily because of the difficulties in retaining them *in situ* or culturing them in the laboratory. It may be possible, however, to conduct meaningful tests on other sensitive marine species that are compatible with a laboratory testing programme and to make reasonable extrapolations of the results to the ocean environment. Methods are available for selecting sensitive laboratory organisms and for conducting laboratory tests to determine the effects of pollutants on them. Sensitive organisms in this sense mean those organisms that are especially susceptible to a particular pollutant; for example, crustaceans react adversely to part per billion levels of halogenated hydrocarbons and some metals, and can be considered sensitive "indicator" organisms for effects of these chemicals.

Laboratory tests should include indicator organisms and experimental ecosystems, and criteria for effects on behavioural responses, growth, reproduction, physiological processes and species diversity should be established. The laboratory experiments should in no case be limited to individual organisms, but ideally should cover populations, where subtle changes in behavioural patterns could serve as early warning signs and lead to the possibility of predicting the moment at which the organisms will be harmed at the population level.

Experiments also can be conducted in the laboratory to determine rates of accumulation and loss of pollutants and concentration factors (ratio of the amount of pollutant in an organism to amount in the water per unit volume) for various organisms. Knowledge of concentration factors for a specific pollutant in laboratory organisms and its concentration in related indigenous organisms permits estimation of levels of the pollutant occurring in the environment from which the indigenous organisms were taken. Furthermore, these experiments lead to an estimate of the expected body burden, where the body burden of the pollutant is in equilibrium with the pollutant concentration in the environment and might in particular circumstances be used for the assessment of the expected changes in indigenous marine communities.

6.3 Non-indigenous organisms, populations and ecosystems. The low population densities of pelagic plankton and fish communities in the open ocean make meaningful assessment of pollutant impacts upon their structures and functions difficult. Alternatively, it may be possible to employ non-indigenous organisms cultured on small islands, buoys, platforms or weather-ships. Pollutant bioaccumulating organisms hopefully can be imported and cultured in situ. The bioaccumulating organisms which can survive in pelagic areas following transport from their normal habitats have not yet been identified. Initially, mussels and barnacles might be used for such a role. In combination with laboratory experiments, it may be possible to relate their body burdens of pollutants and changes in their functioning to environmental levels.

Fouling plates with indigenous communities may provide a basis for relating structural and functional changes to the changes in pollutant levels.

6.4 Monitoring of marine communities and ecosystems. To obtain meaningful in situ baseline data and to observe long-term changes of parameters characterizing a certain open-ocean community, the structure and functional state of such a community should be monitored simultaneously with the physical and chemical parameters that may be related to such changes. Due to intrinsic difficulties, inadequately developed monitoring techniques, and the lack of a commonly accepted methodology, it is recommended that the monitoring should be restricted only to a few selected areas representing typical open-ocean waters and should be carried out by frequent sampling. Because of large natural variations in populations, only long-term studies can reveal meaningful changes, and therefore, it is recommended that whenever possible the monitoring exercises should be launched in areas where relevant long-term series of biological observations, such as plankton or fish-egg surveys, already exist. Even so, the linking of such changes with pollution as effect and cause will be extremely difficult.

In developing the monitoring strategies, use should be made of the various documents dealing with this matter, such as the Report of the SCOR-ACMRR-UNESCO-IBP/BM Working Group 29. (See also ICES Coop. Res. Rept. 39.)

The Group recommended the following monitoring exercises:

Monitoring of phytoplankton communities

The selection of an ecological sub-system for monitoring purposes in the open-ocean is beset by practical difficulties. At the present time, the best choice appears to be open-ocean phytoplankton, but care will be required in interpretation of the results. The most useful groups of parameters to be studied are:

- Community structure (species diversity and abundance); it does not bear directly on productivity but structural indices characterize the community and might reflect the impact of pollutants;

- Functional indices (primary productivity, primary production, metabolism). Carbon assimilation integrated over the euphotic zone, i.e. values per unit area of sea surface, chlorophyll measurements, particularly the measurement of chlorophyll a as an index of standing crop, and ATP determinations, probably yield the most significant information on the functional state of a phytoplankton community;

- Body burden of pollutants in the standing crop, as an indicator of the accumulated level of the pollutants and for use in the assessment of the possible transfer of pollutants to higher trophic levels;

- Level of pollutants in sea water, simultaneously with the biological parameters, to detect their variations over short time periods. Physical and chemical properties (irradiation, light attenuation, temperature, salinity, oxygen and nutrients), simultaneously, to obtain background data for a better understanding of the monitored community.

Monitoring of fish populations

The presently used methods for stock assessment could perhaps be adopted for use in monitoring changes in fish populations. It will be difficult to correlate the observed changes with the level of pollutants in the sea water and with the measured body burden of pollutants, inasmuch as natural variations in a population and the effects of fishing make the interpretation of results difficult.

In most studies to date the determination of long-term trends in pollutant levels in the environment have been hampered by the lack of adequate base-line data. For this reason, it is recommended that monitoring of the body-burden of economically important ocean-living species, such as tuna, swordfish and whales, should be commenced.

Migratory species which during their life cycle enter coastal and fresh water (eels, salmon) pose special problems because they accumulate substantial amounts of pollutants from non-open ocean sources. For such species monitoring of the body burden should be done in both fresh waters and coastal waters.

The working group noted that there have been a number of reports on teratogenic effects in fish from contaminated coastal waters, and recommended that an assessment of these effects be made for possible inclusion in an open-ocean programme. The most practicable approach seems to be a simultaneous monitoring of morphological changes and body burdens.

Open-ocean island ecosystems

Marine ecosystems around remote islands which are free from coastal pollution were considered as very good monitoring zones. Volcanic islands or ones with large bird colonies or a seal colony might have significant "natural" inputs of "pollutants". In such ecosystems various sub-components should be monitored, particularly the functional and structural changes in their benthic communities.

Fish-eating birds or other organisms at high trophic levels

Such populations are often of great importance in studying cumulative pollutants, since effects are often worst in such animals, and accordingly noticeable earlier. For fish-eating birds which nest in colonies on islands, there is also the enormous advantage of being able to obtain accurate standardized counts of populations, breeding success, etc.

Open-ocean bacteria

The diversity and abundance of the indigenous marine bacterial flora seen to be dependent on the quality of seawater. Therefore, the group considered that the monitoring of open-ocean bacteria is feasible, although it was recognized that further research is needed before such a monitoring exercise can be firmly recommended.

Microlayer studies

The boundary layer between the atmosphere and the ocean is in many respects a unique zone, whose biological components could be especially susceptible to pollution. For example, relatively high levels of halogenated hydrocarbons occur in surface slicks that are rich in microbes. Future research should include efforts to better characterize this layer biologically and to develop techniques for assessing pollution effects on it.

Genetic effects

The *in situ* monitoring of the genetic effects of pollutants on marine ecosystems does not seem feasible at present, and such studies should be restricted to laboratory experiments and observations.

Appendix I

GESAMP WORKING GROUP ON THE SCIENTIFIC BASES FOR THE DETERMINATION OF CONCENTRATIONS AND EFFECTS OF MARINE POLLUTANTS

Terms of Reference

The terms of reference for the two panels approved by GESAMP VI are as follows:

1. For the panel on levels:

   (a) chemical and microbiological pollutants to be monitored;

   (b) associated chemical, biological and physical parameters of the system to be measured, including those necessary to permit an assessment of the chemical modifications of the marine environment;

   (c) sampling sites, including waters, airs, sediments and organisms;

   (d) sampling and storage procedures;

   (e) sampling frequency;

   (f) the formulation of scientific methods, models and mass balances;

   (g) interlaboratory comparisons and preparation of standards.

2. For the panel on effects:

   (a) effects on physical and chemical processes and properties;

   (b) effects on marine communities feasible for monitoring;

   (c) effects on biological resources;

   (d) suitable organisms which can be used as pollution indicators or indicators of ecosystem changes;

   (e) sites, sampling and storage procedures, frequency of monitoring and effects;

   (f) formulation of scientific methods (models).

Appendix II

GESAMP WORKING GROUP ON THE SCIENTIFIC BASES FOR THE DETERMINATION OF CONCENTRATIONS AND EFFECTS OF MARINE POLLUTANTS

Dubrovnik, 14-18 October 1974

LIST OF PARTICIPANTS

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Secretary of the Working Group

Miss Z. Tonišić

NOTE:

Dr. A.I. Simonov was unable to attend owing to illness.

Dr. E.E. Geldreich was obliged to withdraw from the group for professional reasons.

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* Dr. Schneider replaced Dr. C.S. Hogre.

** Dr. Duke is a biologist who was in Dubrovnik during the last two and a half days of the meeting and who was invited by the Chairman to sit in on the group's sessions.

Appendix III

PROPOSED OCEANIC SAMPLING SITES FOR POLLUTANT CONCENTRATIONS IN THE ATLANTIC OCEAN (the numbers refer to attached map)

1. Surface water flowing into the Polar Seas; and the deep water, as one of the sources of the North Atlantic Deep Water. (Oceanographic and meteorological conditions are well-known because of Ocean Weather Ship "Mike" and connexion with regional air pollution data from Faroes and Shetlands is possible.)

2. Surface waters of North Atlantic Drift. (OWS "India" and "Julliet" provide good background information on meteorological and oceanographic conditions.)

3. Deep waters close to the major sources of North Atlantic Deep Water. (Influence of atmospheric transport from North America can be monitored, and oceanographic data from former Ocean Weather Ships and International Ice Patrol are available.)

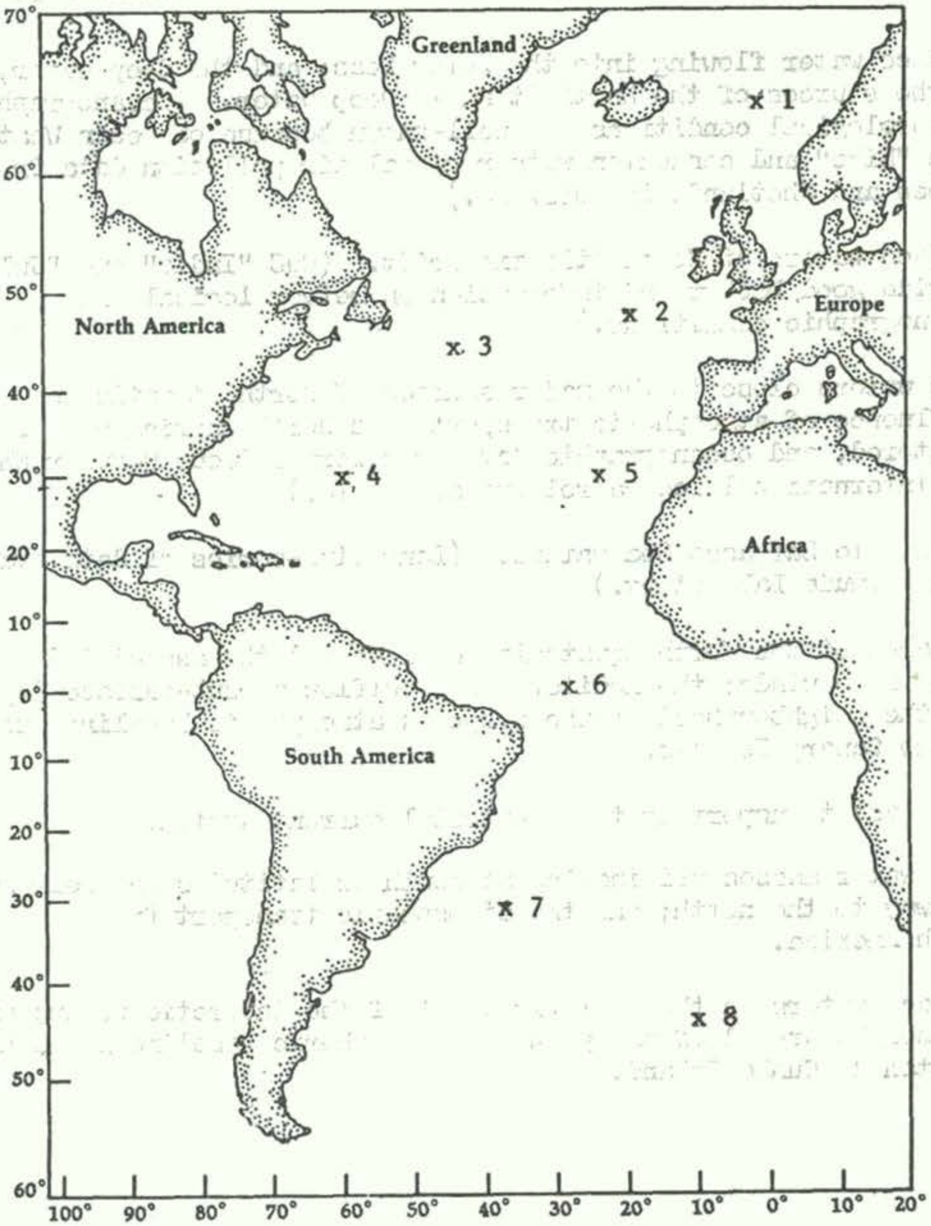
4. The stable Sargasso Sea waters. (Long time-series of data available from Bermuda Laboratory.)

5. The area of the North Equatorial current and the associated North East trade winds; the Mediterranean outflow at sub-surface depths; and the neighbourhood of the proposed atmospheric baseline station in the Canary Islands.

6. West-East transport by the equatorial current system.

7. Deep water masses originating at southern latitudes on their major pathway to the north; and the atmospheric transport from South America.

8. Surface waters in the westerly drift of the Antarctic Ocean; and the neighbourhood of the proposed atmospheric baseline station at Tristan da Cunha Island.


Greenland
North America
Europe
Africa
South America
x 1
x 2
x 3
x 4
x 5
x 6
x 7
x 8
70°
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
60°
100°
90°
80°
70°
60°
50°
40°
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ANNEX VIII

REPORT OF THE GESAMP WORKING GROUP ON THE PRINCIPLES FOR DEVELOPING COASTAL WATER QUALITY CRITERIA

First Session

(FAO, Rome, 25-29 November 1974)

Some members of the working group (Appendix I) met briefly on 28 March 1974 during the sixth session of GESAMP in Geneva and decided to consider aspects of water quality criteria related to human health as well as those of marine resources.

The first session of the working group took place at FAO Headquarters, Rome, from 25-29 November 1974, under the Chairmanship of Dr. M. Waldichuk. The Agenda is attached as Appendix II. The meeting was attended by Mr. J.S. Alabaster (acting as Rapporteur), Dr. A.L. Downing, and Dr. C.S. Hegre. Prof. A. La Fontaine was represented by Mrs. S. de Maeyer from his institute. Drs. S. Kečkeš and J.B. Sprague were unable to attend. The working group was welcomed by Dr. H. Kasahara, Director, FAO Fishery Resources and Environment Division. Dr. G. Tomczak (FAO) provided secretariat assistance to the group. Mr. R. Pavanello (WHO) attended the meeting part-time.

The group took account of instructions given to it as a result of deliberations during a sessional working group meeting on principles for developing coastal water quality criteria and during discussions in plenary session at the fifth session of GESAMP. It further noted the urgency of its task for IMCO, as expressed at the sixth session of GESAMP, arising out of Resolution 12 of the International Conference on Marine Pollution, 1973.

A list of background papers prepared by members of the working group on specific aspects of the coastal marine environment are given in Appendix III. Other pertinent literature was noted as further background information, in particular, "Water Quality Criteria, 1972" (Report of the Committee on Water Quality Criteria, National Academy of Sciences, Washington, D.C., 1972).

WORKING GROUP ON THE PRINCIPLES FOR DEVELOPING COASTAL WATER QUALITY CRITERIA

CONTENTS

1. INTRODUCTION

Following a recommendation of the report of GESAMP V/10 (paragraph 20) the working group defined "criteria" as the required scientific information on which a decision or judgement may be based concerning the suitability of the environment to support a desired use, recognizing that the health of man is paramount and that the latter can be affected either directly or indirectly. The working group considered that criteria for the marine environment should include consideration of all aquatic compartments rather than water alone. It defined "coastal waters" as the coastal region containing waters having a salinity of more than 0.5 parts per thousand and extending to the edge of the continental shelf, or, in the case of islands comparable areas. Considering the request in the same paragraph, the working group concluded that its report and recommendations, as well as any criteria that might be formulated therefrom, might be for the benefit of international and national groups of scientists and interested persons.

The "format of the criteria", which the working group was specifically asked to suggest, was discussed and interpreted to mean the mode of expression of the criteria. It was agreed that expressions of cause-effect relationships should describe response to either concentration of constituents or mass inputs to the system in relation to time.

The working group considered that the "critical path" method outlined by Preston[1] was consistent with the above, since it could be viewed as a series of interacting dose-response relationships, in some of which the dose would be amenable to expression as aqueous concentration for a given purpose, and in others as mass flow. For example, it would be possible to express criteria related to human health in terms of concentrations of material in an edible fish product, without excluding the possibility of also expressing them in terms of the concentration of the same material in the water or other media, given the necessary data relating the two. Also, it would be possible for criteria regarding a particular waste to be expressed in a number of other ways, the choice being dependent on the target or use to be protected.

The working group reconsidered its terms of reference, namely:

(i) to evaluate the nature and extent of problem areas in order to establish an order of priority of coastal water quality characteristics which should be considered for the formulation of coastal water quality criteria;

(ii) to consider past and current work and to identify gaps in our knowledge; and

(iii) to formulate tentative coastal water quality criteria.

1/ Preston, A., 1974: The application of critical path analysis techniques to the assessment of environmental capacity and the control of environmental waste disposal (pp. 573-583). In: "Comparative Studies of Food and Environmental Contamination". Proceedings IAEA Symposium, Helsinki, August 1973. International Atomic Energy Agency, Vienna, Austria.

The working group agreed that, while it might be desirable to proceed rapidly with all items, the last item in particular was a task well beyond its present resources. In order to tackle item (i), the working group recognized that it would be necessary to collect and analyse appropriate data from national and international bodies. Useful data are regarded as summary statistics on the incidence and severity of observed pollution incidents, their probable causes and projections of potential problems based on the expected growth of water use. It noted that much relevant information is available in the literature and that additional data may be forthcoming as a result of the activities of marine workshops, such as those being conducted by international agencies for the Mediterranean, Indo-Pacific area and Caribbean. The working group considered that such information alone would probably not be sufficient to describe the situation adequately and that, in the long term, comprehensive field studies in clean and polluted areas would be essential. The working group envisaged that the main problems are likely to be found in estuaries, inshore coastal waters and those seas having little exchange with the open ocean.

The working group felt that, as an essential first step, it would start by considering the principles to be taken into account in formulating coastal water quality criteria and make recommendations. Subject areas singled out for consideration were:

(1) Ecosystems

(2) Human health

 (a) Fish and Shellfish

 (b) Bathing waters

 (c) Aesthetics

(3) Living resources

 (a) Fisheries

 (b) Fishing Activity

 (c) Aquaculture

However, the group recognized that other uses, such as desalination, transportation and waste disposal are also important and might warrant attention in the future.

2. RECOMMENDATIONS

The following preliminary list of recommended principles for the development and application of water quality criteria should not be used or taken out of context without a careful study of the document as a whole. The succeeding sections from which these recommendations arise provide definitions and insight valuable in applying them to unforeseen circumstances. Furthermore, sections on specific uses contain guidelines as to the meaning and value of environmental data relative to those uses, and often suggest appropriate formats or useful forms of expression of criteria in relation to a specific use. A procedure which might be used in establishing criteria has been given in some detail in Appendix IV.

(1) The health of man is a paramount consideration (p. 3, paragraph 1), and can be influenced either directly or indirectly by changes in water quality.

(2) Studies of real field situations, whether or not damage has been noted, are an essential element in establishing whether or not a problem really exists and in developing valid criteria (p. 7, paragraph 5; p. 8, paragraph 2; p. 9, paragraph 6; p. 12, paragraphs 1 and 7; p. 14, paragraphs 1 and 2). In each case, these should take full advantage of the critical path approach (p. 3, paragraph 3; p. 8, paragraph 1).

(3) In developing criteria to protect a particular water use, effort should be made to identify the critical factors on which this use depends. Priority should be given to establishing the exposure-effect relationships for these factors (Appendix IV).

(4) Criteria should be expressed in such terms as are likely to be most useful in the establishment and enforcement of control measures, including standards.

(5) As a general principle, it is important to establish the reliability and relevance of criteria in order that the desired degree of protection of the waters' use can be accomplished with confidence at minimum cost. This is particularly applicable where it is necessary to rely heavily on responses observed under laboratory conditions (p. 13, paragraph 2).

(6) The most effective criteria will be those that take into account, to the greatest degree, differences in local circumstances such as population susceptibility and environmental factors (p. 7, paragraphs 4 and 5; p. 8, paragraphs 1 and 2; p. 12, paragraphs 2 and 3).

(7) The great uncertainty concerning the accuracy of available data on exposure/response relationships may be sufficient justification for adoption of regulatory standards based on the lowest exposures found to cause an undesirable effect.

(8) It should be recognized that, for practical reasons, there may be justification for using standards for which no exposure-effect relationship has been established. This might apply, for example, where costs of control measures are small relative to those involved in establishing criteria (p. 13, paragraph 5). In such a case it is assumed in effect that no exposure is acceptable (p. 7, paragraph 1; p. 15, paragraph 6; p. 20, paragraph 6(b)), and that there has been general acceptance of the desirability of some control measure which could obviate the need for a criterion (p. 14, paragraph 7).

(9) Where water quality problems extend over the area of jurisdiction of more than one control authority, every effort should be made to further the use of criteria derived according to a common methodology agreed upon by the authorities involved.

(10) Criteria for the protection of a given use should first be established independently of other uses which may or may not be made of the area of concern, and then on the assumption that the eventual standards will be based on the most restrictive criteria.

(11) In development of criteria to protect aesthetic satisfaction it is considered that, pending further information on the nature and extent of the problems, priority should be given to development of exposure-effect relationships for turbidity, colour slicks and odours derived from sewage and other wastes (p. 13, paragraphs 4 and 5; p. 14, paragraph 1).

(12) For the preservation of ecosystems for scientific study, the criterion would be the virtual exclusion of man-made changes (p. 7, paragraph 1).

(13) For some substances that cannot be reasonably quantified and that constitute a hazard, e.g. driftwood, plastics and drums of waste, the only reasonable criterion is virtual absence of the substances (p. 15, paragraph 6).

(14) The validity of criteria should be reviewed in the light of new knowledge (p. 12, paragraph 5).

3. ECOSYSTEMS

It has been held that the protection of any living marine resources can be most certainly accomplished by protection of the integrity and balance of the greater or smaller ecosystem of which it is a part. While this can be accepted as basically true, many characteristics of such systems act to make this a most difficult task. Only by considering individuals in greatly restricted groupings of interdependent organisms and in simple environments or (in the opposite extreme), by considering as an entity the whole system rather than each component has any progress been made in predictive modelling.

In the first case, biological input and output terms of the model are each predicted or observed values, resulting from the activities of individual species within the aggregations of organisms. The importance of the contribution of each included component to these terms must be known. In the second "black box" case, individual species disappear entirely and results are thus not easily used to predict the response of desirable species. Difficulties in modelling are especially critical in marine waters, where the systems of interest and inter-actions within them have often not been adequately described. For example, many life cycles are still unknown. This, of course, limits the success of attempts at quantitative descriptions of inter-actions. The situation is further complicated in regard to criteria by the fact that, especially in temperate waters, the components of a local system change with season, the various ecological niches being filled by species of varying sensitivity at different times.

In consideration of the foregoing, aside from a recommendation for more research, the guiding principle for protection of natural ecosystems for scientific study must be total non-intervention. It must be recognized, however, that even if this is possible, the system being "preserved" is subject to natural change.

Ecological principles do, however, offer qualitative if not quantitative guidance in the development of criteria, whether the approach used is inductive or deductive. Although a change induced in one component will result in changes in other components, this will not necessarily disrupt the ecosystem, but may rather result in a new series of oscillations (e.g. fluctuating population density ratios). These are gradually dampened but never disappear entirely. The system and each organism within it are constantly adjusting to variations in stress, whether these be environmental factors or population pressure. This elastic or plastic nature of ecosystems allows for a certain capacity to absorb stress and to tolerate management. Thus, if preservation of one species, or a fishery, is to be an objective, criteria which fall short of non-intervention will usually be effective. This consideration applies most forcibly where the interests and well-being of man are concerned. The quality of human life is enhanced by co-existence with a wide range of species. The protection of human health obviously demands intervention, but further consequences of alternative courses of action need to be carefully weighed.

Not all systems are equally robust. Many scientists consider that arctic systems are particularly fragile because fewer species are available to fill vacated niches. Even in species with many systems, the complexity of inter-actions among components provides some stability and is also responsible for the fact that alterations in one portion of the system can cause desirable or undesirable effects in seemingly unrelated portions of the system. For example, bioaccumulation of toxic substances may produce a hazard to consumers, including man.

3.1 Impact of ecological considerations on the development of principles

Discussions of the effects of pollution on, for example, plankton in relation to fisheries, as well as to amenities, public health and shellfish quality, illustrates the difficulties encountered and thus the difficulty in formulating criteria, and is therefore of value in clarifying the principles operative in arriving at criteria. Various marine organisms, by virtue of occupying different ecological niches, have different relationships to various types and modes of introduction of pollutants. These determine the nature of their exposure.

The essential differences involve varying time scales for exposure (constant, intermittent or cyclical stress), alterations of the pollutant before or during exposure, and the route of administration to the target organism (i.e. via water, suspended sediment or food particles, detritus, etc.). Consideration of these differences has led to the formulation of basic procedural requirements for obtaining data on which well-founded defensible criteria should be based. Observance of one or all of these requirements is essential to criteria development, dependent on the resource for which a specific criterion is to be set and the importance of those characteristics in limiting its use. Not surprisingly, generation of completely adequate information on which to base criteria requires, in almost all cases, satisfaction of all requirements listed in Appendix IV.

Most of these requirements are also recognized by EIFAC[1] and, taken as a whole, embody the principles underlying the formalized "critical path" technique referred to earlier. The working group gave some thought to classifying the various known stresses, according to the applicability of the various requirements in the establishment of criteria, but agreed that this approach would offer them little real help, because it is unlikely that consideration of various uses would result in similar groupings of requirements. Also, even within a reasonably inclusive group such as inorganics, extreme variations are known to occur in duration of biological effect as a result of recycling pathways, bioaccumulation and physical or chemical alteration. The same may be assumed for groups of chemicals not yet considered or even synthesized. Furthermore, the pattern of fluctuation in concentration with time within a class or for a single compound, is extremely variable between points of introduction where criteria may be of value. This is also true for major environmental variables (oxygen, temperature, salinity, etc.). In general, the greater the temporal variation, the greater the obligation to test using a multi-factorial approach approximating the extreme limits of local variation of each factor as well as the observed local rates of fluctuation. It should be borne in mind that the most common appearance of most contaminants is as a component of a mixture, the total effect of which is of concern. Consideration of the components of the mixture is likely to indicate the complexity of procedures required for developing criteria.

4. HUMAN HEALTH

In the introductory part of this report, a definition of coastal water quality criteria has been given in the most general terms acceptable to the group. Criteria for coastal waters in regard to human health should ideally be sets of quantitative exposure-response relationships between environmental exposure factors and effects on the population groups exposed. When dealing with human subjects, it is often difficult to establish even a basic cause-effect relationship, and even more difficult to obtain a graded response.

Acute effects of exposure to high levels of chemicals or pathogens are more easily linked to human response, than are effects of chronic exposure to the low levels so often typical of the environment. At the lower end of the response spectrum, sub-clinical changes in behaviour or enzyme activity (the biological significance of which is difficult to assess) have been detected down to the "no-effect level", i.e. below the exposure level at which no gross pathological, physiological or metabolic impairment has been detected.

The observed no-effect level is of course related to the choice of the indicator(s) of response and the sensitivity of the methods available or adopted for its measurement. The same can be said for the identification and measurement of the exposure. Unless evidence is available that such sub-clinical changes

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1/ European Inland Fisheries Advisory Commission has a Working Party on Water Quality Criteria for European Freshwater Fish which documents background information and from time to time publishes this in international journals, e.g., EIFAC, Water quality criteria for European freshwater fish. Report on Finely Divided Solids and Inland Fisheries. EIFAC Tech.Pap., (1):21 p. (1964).

are simply adaptive, and do not prejudice survival, reproduction or quality of life, they must be assumed to be detrimental. There are, however, well established principles, such as those enunciated by Bedford Hill (1965)[1/], which should be used for testing the significance of cause-effect relationships derived from epidemiological data.

4.1 Fish and Shellfish

This report deals principally with criteria for water quality, but in the case of hygienic quality of fishery products, other factors may influence microbiological and hygienic qualities of the shellfish. Catching, handling, processing, storage, marketing and the way the product is prepared may affect the transmission of disease by fish products, and occasionally falsely indicate inferior water quality. These factors should not influence the role of criteria for quality of the water where fish and shellfish are grown.

The influence of the physical, chemical and biological quality of fish and shellfish growing waters may extend beyond effects on marine organisms themselves. Effects on consumers include: bacterial infections and intoxications; parasitic diseases; intoxications due to accumulated chemical poisons or biotoxins; allergic reactions; responses of undetermined etiology; and offensive flavour causing nausea or more acute illness due to tainting of the product. Effects on non-consumers include: occupational diseases such as secondary bacterial skin infections, bites, stings, and allergic reactions due to contact with shellfish or gear.

Table 1, derived from Tables 1 and 2 of WHO (1974)[2/], summarizes the principal bacterial, parasitic and viral diseases in man which are transmitted by fishery products.

The adequacy of the basis for criteria should be taken into account when contemplating control action, which could involve, for example, the closure of fishing grounds, requirements for the reduction of input of pollutants and the restriction of consumption of contaminated fishery products. Such actions can also be supported by sanitary surveys.

4.2 Bathing Waters

Seawaters near some beaches are becoming increasingly polluted chemically and microbiologically and may be a health hazard for man. One of the scientific approaches to demonstrating the relationship between water quality and disease is the epidemiological survey.

1/ Bedford Hill, A., 1965: Proc.Roy.Soc.Med., 58:295

2/ WHO, 1974: Fish and Shellfish Hygiene. Report of a WHO Expert Committee convened in co-operation with FAO. World Health Organization, Geneva, Techn.Report Series 550, 62 pp.

TABLE 1. CHARACTERISTICS OF PRINCIPAL BACTERIAL AND VIRAL FISH- AND SHELLFISH-BORNE DISEASES IN MAN

	Etiological Agent	Principal aquatic food animals involved as source of infection	Sources of infection for aquatic food animal	Pathogenicity for aquatic food animal	Mode of transmission to man	Disease in man and most common manifestations
Bacterial infection	*Salmonella* spp. a) *S. typhi*, *S. paratyphi* b) other species (e.g., *S. typhimurium*, *S. enteritidis*)	fish or shellfish secondarily contaminated through polluted waters or through improper handling	a) human faeces and waters contaminated by human faeces b) human and animal faeces, polluted waters	nonpathogenic	ingestion of raw or insufficiently cooked contaminated fish or shellfish	a) typhoid and paratyphoid fever, septicaemia b) salmonellosis: gastroenteritis
	Vibrio parahaemolyticus	marine fish and shellfish	organism occurs naturally in the marine environment	may cause death of shrimps and crabs; experimentally pathogenic for fish	usually through consumption of raw or inadequately cooked fish or shellfish that has not been properly refrigerated	diarrhoea, abdominal pain
Bacterial intoxication	*Clostridium botulinum*	fermented, salted, and smoked fish	sediment, water, animal faeces	toxin can kill fish	ingestion of improperly processed fish or shellfish	botulism: neurological symptoms with high case-fatality rate
	Staphylococcus aureus	fish or shellfish secondarily contaminated through improper handling	man—nose and throat discharges, skin lesions	nonpathogenic	ingestion of fish or shellfish cross-contaminated after cooking	staphylococcal intoxication: nausea, vomiting, abdominal pain, prostration
Bacterial intravital intoxication 1)	*Clostridium perfringens*	fish or shellfish secondarily contaminated through polluted waters or through improper handling	polluted waters, human and animal faeces, sediment	nonpathogenic	ingestion of cooked fish or shellfish that has not been properly refrigerated	diarrhoea, abdominal pain
Bacterial skin infection	*Erysipelothrix insidiosa*	fish, particularly spiny ones (e.g., searobins, redfish) — organism is present in fish slime and meat		nonpathogenic	through skin lesions—usually an occupational disease	erysipeloid—severe inflammation of superficial cutaneous wounds
Viral infection	virus of infectious hepatitis	shellfish	human faeces and water polluted by human faeces	nonpathogenic	ingestion of raw or inadequately cooked contaminated shellfish	infectious hepatitis

1) *Intoxication by toxin produced in the body by bacteria present in heavily contaminated foods*

TABLE 1 (cont'd) CHARACTERISTICS OF PRINCIPAL PARASITIC FISH- AND SHELLFISH-BORNE DISEASES IN MAN

	Etiological agent	Principal aquatic food animals involved as source of infection	Life cycle of parasite	Pathogenicity for aquatic food animal	Mode of transmission to man	Disease in man and most common manifestations
Parasitic infection — trematodes	*Clonorchis sinensis* (Chinese liver fluke)	freshwater fish—Cyprinidae family (e.g., carp, roach, dace)	1st intermediate host: snail 2nd intermediate host: fish Definitive host: man, dog, cat, other fish-eating mammals	muscle cyst infection	ingestion of raw or insufficiently cooked, infected fish (dried, salted or pickled fish may be involved)	clonorchiasis: signs and symptoms related to liver damage
	Opisthorchis felineus *O. viverrini*	freshwater fish—Cyprinidae family (e.g., whitefish, carp, tench, bream, barbel)	1st int. host: snail 2nd int. host: fish Def. host: man, dog, fox, cat, other fish-eating mammals	muscle and subcutaneous cyst infection	ingestion of raw or insufficiently cooked, infected fish	opisthorchiasis: cirrhosis of the liver
	Heterophyes heterophyes	freshwater or brackish-water fish	1st int. host: snail 2nd int. host: fish Def. host: man, dog, cat, other fish-eating mammals, fish-eating birds	encyst in muscles and skin	ingestion of raw or insufficiently cooked, infected fish (frequently salted or dried fish)	heterophyiasis: abdominal pain, mucous diarrhoea; eggs may be carried to the brain, heart, etc., causing atypical signs
	Metagonimus yokogawai	freshwater fish (e.g., trout, sweetfish, dace, whitebait)	1st int. host: snail 2nd int. host: fish Def. host: man, dog, pig, cat, fish-eating birds	encyst in gills, fin or tail	ingestion of raw or insufficiently cooked, infected fish	metagonimiasis: usually mild diarrhoea
	Paragonismus westermani *P. ringeri* (Oriental lung fluke)	freshwater crab and crayfish	1st int. host: snail 2nd int. host: crab, crayfish Def. host: man, dog, pig, wild carnivores	encyst in gills, muscle, heart, liver	ingestion of raw or insufficiently cooked, infected crabs or crayfish, or ingestion of water contaminated by metacercariae that have escaped from a crab or crayfish	paragonimiasis: usually chronic cough and haemoptysis from flukes localized in the lungs; flukes may invade other organs
— cestodes	*Diphyllobothrium latum*	freshwater fish (e.g., pike, trout, turbot)	1st int. host: copepod 2nd int. host: fish Def. host: man, dog, cat, pig, fox, polar bear, other fish-eating mammals	plerocercoid larvae infection of muscles and other organs	ingestion of raw or insufficiently cooked, fish (frequently inadequately pickled fish)	diphyllobothriasis: disease may be mild or inapparent; may see signs of gastro-enteritis, anaemia, weakness
— nematodes	*Anisakis marina*	marine fish (e.g., cod, herring, mackerel)		internal larvae infection	usually from ingestion of raw or partially-cooked, pickled or smoked herring	anisakiasis: eosinophilic enteritis
	Angiostrongylus cantonensis	freshwater shrimp, land crab, possibly certain marine fish	1st int. host: slug, land snail Def. host: rat Paratenic hosts: shrimp, land crab		ingestion of raw or inadequately cooked shrimp or crabs (sometimes pickled)	eosinophilic meningitis

For waterborne diseases, such as typhoid fever, cholera and viral hepatitis, the link between disease and drinking water, or between disease and shellfish eating, has been firmly established, whereas, for diseases occurring at the seaside, the link with bathing is more difficult to establish. Monitoring of water quality is one of the means of assessing the potential risk. However, the recovery of pathogens from bathing waters does not necessarily indicate a substantive health danger.

In practice, the routine monitoring for pathogens presents various difficulties. Recovery of pathogens from bathing water is not normally done for routine surveillance as to bacteriological quality. Enteric diseases can originate from drinking water contaminated by excreta from infected humans or animals. It therefore seems important to use, as indicators of water quality, faecal organisms.

Although there is no demonstrable correlation between faecal indicators and pathogens, except for Salmonella, several countries have introduced norms of bacteriological quality based upon the faecal coli index. After a long discussion about the linking of faecal indicators with the presence of pathogens and about the dose-response relationship for pathogens occurring in seawater, the working group wished to emphasize that criteria for bathing, like those for other uses such as fisheries, should ideally be based upon well-founded dose-response relationships. Nevertheless, at the present state of knowledge and under certain circumstances, an indicator organism characteristic of the contamination by sewage of human or animal origin may be used to indicate a potential hazard to human health, because of the possible presence of human pathogens. It should be borne in mind, however, that the dose-response relationship will vary as the susceptibility of the population changes.

Microbial water quality criteria are one of the more important considerations in the derivation of standards applicable to local circumstances.

The principle of reviewing the validity of criteria, in the light of experience and the acquisition of new knowledge, applies to health criteria as much as it does to the others considered here.

4.3 Aesthetics

The enjoyment of amenities is heavily dependent, not merely on the availability of an activity, but on the aesthetic satisfaction which it affords. Aesthetic satisfaction can be a very positive force in promoting public health and well-being. It is experienced through the senses of sight, smell, taste and touch.

In seeking criteria to protect aesthetic quality, one requires ideally, a knowledge of the relationships between water quality, its detectability by the senses, and the degree of associated adverse or favourable reaction. In attempting to derive such information it is obviously necessary to ensure that the population, whose reaction is to be assessed, is reasonably representative of those whose interests the criteria adopted are intended to protect. In many coastal areas, this may involve obtaining a proper balance of reactions of residents and non-residents whose requirements and sensitivity may differ.

Determination of the association between aesthetic reactions and water quality presents considerable difficulties, because it is rarely possible to expose people in a controlled manner to a range of conditions in coastal waters themselves, though some guidance can be obtained from assessment of experience at different sites, where differing conditions exist, or at the same site, before and after a change in conditions. Because of these difficulties, such information will in practice need to be supplemented by assessments of the reaction of people to water quality conditions created artificially in the laboratory. Such laboratory assessments would probably be most relevant in the case of taste, which is unlikely to be greatly affected by the circumstances in which people are exposed, and perhaps least relevant in the case of reactions to certain visible manifestations of pollution, such as the appearance of a slick, which is difficult to simulate realistically in the laboratory.

As a general principle, it will be important to make every effort to establish the reliability and relevance of the criteria in order that the desired degree of protection of the waters' use can be accomplished with confidence at minimum cost. This is especially important where it is necessary to rely heavily on reactions observed under laboratory conditions.

There is also a problem in deciding on adequate measures of aesthetic satisfaction and in standardization of their use so that reliable data can be attained. Among measures that might be applicable in different situations, the following come immediately to mind: verbal or written expressions of opinion in graded categories as determined by interview or questionnaire, trends in the ratio of numbers of visitors to a site, and the accommodation available, trends in the price of property, or expressed willingness to pay for measures designed to reduce effects. These matters require further study.

The problems encountered would be simplified if it were to be accepted that one usual and proper objective of designers of disposal schemes is to prevent any unwelcome aesthetic effects. In developing aesthetic criteria, it is then mainly necessary to assess the levels of contamination at which such effects just become detectable. It is considered that attention should be initially concentrated on the limited objective of obtaining such information. This, combined with our more fragmentary knowledge of the detailed response of people to the degree of contamination, might well be adequate for most decisions. The visible effects, whose thresholds of detection are required, principally include appearance of floating or suspended debris, turbidity, foams, slicks and colour.

Determination of thresholds of sensibility presents a variety of difficulties. In certain instances, these could be obviated by taking into account that assessment of detectability in a comprehensive scientific manner would be expensive, and that it might be possible, in cases where material causing offence can be easily and cheaply eliminated, to make a pragmatic decision that no material of this kind should be released. It seems, however, quite feasible to develop meaningful relationships between amounts of substances present and sensory perception of turbidity, due to suspended matter released in waste-waters, or recognition of colour, foams, and slicks. Some progress towards this end has already been reported. Developing such criteria for turbidity, resulting from the growth of organisms induced by polluting discharges, also seems feasible in principle, though more difficult in practice.

Development of criteria for odour presents the difficulty of establishing a relevant test. There is no problem in determining the level of dilution of a polluting discharge, or one of its constituents which, when allowed to establish equilibrium with a standard volume of air, can just be detected by smell. More work is required, however, to establish the way in which results of such a test could be related to the degree of offence, which would actually occur in open coastal areas, owing to the presence of polluting matter at the minimum detectable level so obtained.

5. LIVING RESOURCES

5.1 Fisheries

The sections dealing with ecosystem and impact of the ecological concepts on the development of principles for water quality criteria are pertinent to criteria for fishery resources. A fishery is a managed system in a state of dynamic equilibrium; disturbance caused by altered chemical, physical and biological factors is not necessarily incompatible with the full use of its resources.

The criteria should permit all stages in the life cycles of the fish and their food organisms to be successfully completed, and should not produce conditions which would cause fish to avoid a region where they would otherwise be present, congregate in a region where imminent danger exists, taint the flesh of fish, or give rise to accumulation of substances to levels which are harmful to the fish or to the consumer.

The criteria should, if necessary, include separate consideration of commercial and sport fisheries, of species and races of different susceptibility and of regional differences of habitat. They should make allowance for times when vulnerable stages of organisms are found, and for the effects of season, temperature and water quality.

Ideally the criteria should relate all these factors to the probable impact on the fishery of impairment of each part of the life cycle. This, however, as already discussed, is difficult because of our lack of knowledge and understanding. Criteria may be expressed in physical, chemical and biological terms.

Difficulties arise, however, in their formulation because of the widely different patterns of fluctuations in environmental quality and the dearth of laboratory experiments simulating these conditions. Furthermore, field data are generally inadequate in that either the fish populations present, or the régime of environmental quality, are poorly described.

Scientifically-based criteria should not be influenced by factors such as the feasibility and cost of remedial action, e.g. depuration. However, the availability of treatment processes may create circumstances which obviate the need for regulatory standards. For example, in cases where product criteria are effective in protecting the use, there may be no need for environmental criteria for this particular product. On the other hand, where the remedial measures are likely to fail, environmental quality criteria must be invoked to provide a second line of defence.

5.2 Fishing activities

Commercial and recreational fishing can be affected by physical conditions in the water and on the bottom. Floatables, ranging from logs to fragments of plastic, may interfere with use of nets and of hook and line. Large floating objects, such as submerged logs just below the water surface, present a collision hazard to fishing vessels, while plastic sheets can get sucked into seawater cooling systems and pose at least a nuisance, if not causing outright damage to an engine. Floating oil is a nuisance in fishing activities, because of its tendency to foul fishing gear and vessels. Moreover, the lighter refined petroleum products, such as gasoline and kerosene, can be a serious fire hazard to fishermen.

Turbidity and discolouration can modify fishing effectiveness with hook and line because of the reduction of underwater visibility. For recreational spear fishing with SCUBA, reduced visibility is a definite problem. However, it should be noted that many estuarine regions are already highly turbid as a result of inflow of silty, muddy river water, which can be aggravated by bad agricultural practices and other land activities.

At least two types of pollutants (sewage and radioactive waste) have a psychological impact on fishermen, even though there is usually no physical harm to the fishermen, his gear or his catch.

The character of the bottom may be modified to such an extent by dumped solid wastes, both containerized and in bulk, that commercial bottom trawling is seriously affected. Indeed, recreational fishing with hook and line, could also be adversely affected, but such materials are usually dumped in deep water far enough from shore as to be out of the range of most sports fishermen.

Containerized wastes of various kinds have been recovered by trawl fishermen, and these can damage fishing gear, as well as pose a hazard to fishermen when brought on deck. Such wastes can include noxious chemicals, radioactive substances of low and intermediate level, and military materials, including nerve gases, all of which have been dumped in the sea. Water-logged wood, sometimes escaping from booms of logs towed in coastal waters, presents occasional but not serious problems in some local areas.

Criteria for sea water quality and bottom characteristics, as they affect fishing activities, cannot be developed in the way normally followed for other uses, but rather, must result in total prohibition or disposal into deep water out of range of fishing. Disposal of floatables, including plastics and wood debris, should be similarly treated. Guidelines for control of dumping of solids and containerized wastes are dealt with in recent international conventions, e.g. the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, 1972, and the Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, 1972. The scientific aspects of the disposal of wastes at sea have been considered in the GESAMP working group on that subject.

5.3 Aquaculture

There is increasing production of seafood through marine aquaculture, particularly in developing countries. The practice is carried out on either an intensive (high density, closely-controlled) or extensive (low density, semi-natural) scale. Water quality for intensive aquaculture must be high to compensate for the stresses from crowding, unbalanced diets, increased waste products and general confinement. Food used in such culture must meet the same high standard, although it is recognized that sewage effluent is successfully used for carp ponds in parts of Europe and pig and poultry manure are put into fish ponds in Hong Kong and China. The threat of disease is ever present, and it must be recognized that latent fish pathogens can be stimulated into active disease outbreaks by the stress of inferior water quality which lowers the fish's resistance.

Extensive aquaculture, being less confined than the intensive form, has fewer risks from diseases and poor water quality. However, the practice is highly dependent on the coastal marine environment, and is, therefore, vulnerable to infusion of polluted water from great distances. Being dependent for food on the influx of planktonic organisms with the seawater, it can also suffer from extreme fluctuations in food supply that may be related to water quality.

It is clear that superior water quality is required for aquaculture, but this can vary with species. For example, salmon require a much higher water quality than mullet. It must also be noted that cultured organisms are essentially captive and cannot escape a toxic water mass. While the bioaccumulation of certain substances, such as metals and organochlorine compounds, can be controlled through use of prepared food, it is known that some of these substances can enter fish directly from the water through the gills or across digestive membranes.

Development of criteria for aquaculture which have much in common with those for fisheries should include consideration of: environmental stability; continuous control of those factors desirable for healthy and vigorous stocks of organisms; prevention of deleterious chemical, physical and biological conditions; avoidance of introduction of parasites and diseases; and prevention of environmental conditions favourable for development of diseases.

6. OTHER ASPECTS

The working group recognized that environmental quality criteria have to be developed for other uses of the coastal zones. These range from underwater marine parks and preserves for which maximum environmental protection is required, to sea-bed mining and transportation requiring minimal environmental quality. However, the working group felt that it lacked expertise in its present make-up to deal with any of these other uses in any detail.

Appendix I

GESAMP Working Group on the Principles for Developing Coastal Water Quality Criteria

List of Participants

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Appendix II

GESAMP Working Group on the Principles for Developing Coastal Water Quality Criteria
(First Session, Rome, 25-29 November 1974)

AGENDA

1. Opening of the Meeting
2. Adoption of the Agenda
3. Review of background papers
4. Alternative approaches to development of coastal water quality criteria
   (a) General
   (b) Specific
5. Preparation of Report
6. Future work
7. Other matters

Appendix III

GESAMP Working Group on the Principles for Developing Coastal Water Quality Criteria

List of Working Papers

J.S. Alabaster	- The Development of Water Quality Criteria for Marine Fisheries
E.E. Geldreich	- Principles for Developing Criteria for Coastal Bathing Waters
C.S. Hegre	- Plankton Ecology in Relation to Establishment of Coastal Water Quality Criteria
S. Kečkeš	- Manual on Beach Sanitation (Guides and Criteria for Recreational Quality of Beaches and Coastal Waters)
M. Waldichuk	- Coastal Water Criteria for Fishing Activities
A.L. Downing	- Criteria for Protection of Amenities
E.E. Geldreich	- Guidelines to Microbiological Quality of Shellfish Waters

Appendix IV

GESAMP Working Group on the Principles for Developing Coastal Water Quality Criteria

Suggested Procedure for Establishing Criteria
(Applicable mainly to criteria for protection of living marine resources)

1. Determine physical, chemical and biological characteristics which influence the desired use or property of the environment. This can be partially achieved by preliminary field observations and laboratory experiments and will limit the number of variables to be considered.

2. Establish the relative importance of each characteristic - usually to within an order of magnitude. This again can be achieved in both the field and laboratory and will further limit the number of variables to be considered.

3. Determine the amount of stress being applied to the water mass to be protected (or chosen for study). This should be expressed in appropriate units, (e.g. concentration, mass, volume, btu, number of organisms). This will help define the magnitude of the problem.

4. Determine the chemical and physical fate and distribution of the stress in the system taking into account any time factors. This will require chemical and/or microbiological analyses of various compartments in the system as well as hydrological data.

5. Determine the portion of the population or use in the area to be protected (or chosen for study) which is subject to several intermediate degrees of risk. This information will be needed when deriving standards from criteria, and requires estimation of the rates of input to defined portions of the system.

6. Determine the exposure-response relationship which holds for the local system in question. This is a fundamental and nearly universally applicable procedure and will involve:

   (a) Determination of the most vulnerable point in the system (e.g. top predator, man, fish, life stage, required food organism, enzyme system, physiological process).

   (b) Experimental exposures in laboratory and/or field to establish a family of exposure-response curves reflecting the effects of expected variations in conditions and pollutant input on observed response. An attempt should be made to cover the full range from stimulatory to toxic levels, particularly for biologically essential substances. It is expected that variations introduced will cover the range of ambient conditions encountered in the region and that the test systems chosen will approximate the expected or actual nature of the actual encounter of the target with the stress. Factors affecting this encounter include chemical alterations of the toxicant, intermittent exposure, route of administration, etc. It is expected that as far as possible the parameters being measured will reflect response at the most vulnerable level of the target. This level may not be the same in all degrees of duration of exposure. This will provide one of the bases for selecting a particular exposure or response as a criterion in formulating a standard.

7. Determine the range of natural variations occurring locally in both the density and condition of the target population and in the response parameter being measured. This will provide a perspective or framework within which to view the dose-response relationships.

8. Estimate the effects of several degrees of target response on trophic levels immediately above and below the target. This will provide a first estimate of the probability of remote effects in the ecosystem and requires consideration of patterns of biomagnification.

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ANNEX IX

FIRST REPORT OF THE GESAMP WORKING GROUP ON THE SCIENTIFIC ASPECTS OF POLLUTION ARISING FROM THE EXPLOITATION AND EXPLORATION OF THE SEA-BED

Meetings held at IMCO Headquarters, London
6-9 January 1975 and 21-23 April 1975

INTRODUCTION

1. Two meetings of the working group have been held at IMCO Headquarters, 101-104 Piccadilly, London, from 6-9 January 1975 and from 21-23 April 1975.

2. The following experts participated:

Dr. H.A. Cole (Chairman)
Dr. G. Kullenberg
Professor F. Valdez-Zamudio
Dr. R. Gerard
Ir. E.J. de Boer (first meeting only)
Mr. M.J. Cruickshank (second meeting only)
Mr. J.A. Nichols (second meeting only)
Dr. L.D. Neuman, Technical Secretary, UN (second meeting only)

Dr. R.G.J. Shelton was unable to attend.

At the first session, because Dr. Neuman was unable to attend, Secretariat duties were undertaken by members of the Marine Environment Division of IMCO.

3. The terms of reference of the working group as set out in the Report of the Sixth Session (GESAMP VI/10, Annex VI, page 43) are:

(a) To identify the sources of information relevant to the scientific aspects of pollution arising from present and future activities related to the exploration and exploitation of the sea-bed. The suggested priorities for initial action are:

(i) Petroleum (including natural gas)

(ii) Manganese nodules

(iii) Dredging for both mineral resources and construction projects, but excluding dredge spoil disposal

(iv) Offshore construction (including platforms, artificial islands and reefs).

(b) To collate and evaluate, where possible, all such existing information within time to present an assessment to the seventh session of GESAMP of current and potential marine pollution hazards from these activities, and conflicts with other uses of the sea which may arise, with the intention of obtaining approval for its submission to the Third United Nations Conference on the Law of the Sea at its third session projected for June 1975.

(c) To assess the feasibility of extending this information to meet future needs, such as measures to prevent and control marine pollution from these activities and to make proposals on the future action of GESAMP concerning this area.

4. In planning its programme of work the working group took note of the objectives as set out by GESAMP at its sixth session (GESAMP VI/10, paragraph 56); these are, in relation to the environmental aspects of the exploration and exploitation of sea-bed resources:

(a) to determine the possible range of effects of certain activities in different regions, such as the Arctic and the tropics, and to assess the hazards to marine living resources, human health, amenities and the environment; and

(b) to determine the measures required to prevent and control pollution from such activities.

5. At the request of the United Nations Technical Secretary, the working group also took note of Resolution 1802 (LV) of the Economic and Social Council which, <u>inter alia</u>, called upon the United Nations to undertake an inter-disciplinary study of the problems and opportunities for coastal area development. In carrying out its tasks, as stated in the terms of reference, therefore, the working group gave particular consideration to the problems of pollution arising from exploration and exploitation of the sea-bed in coastal areas, including the effects of dredging for construction and similar activities. The working group also approved a suggestion from the Chairman that he should prepare an additional statement on the problems of coastal area development as viewed from the pollution standpoint and this has been circulated. A further memorandum by Prof. Valdez-Zamudio was also made available to the UN Technical Secretary.

6. In addition to the priority tasks described above, the working group reviewed and revised the list of other sea-bed activities to be considered as given in the Report of the Sixth Session (GESAMP VI/10, paragraph 57, page 9). These cover the exploitation of:

(a) Consolidated sedimentary deposits:

(i) sulphur

(ii) salt

(iii) potash

(iv) coal.

(b) Unconsolidated superficial deposits:

(i) placer deposits of heavy metals and diamonds
(ii) sand and gravel
(iii) limestone shells and calcareous algae
(iv) metalliferous muds.

(c) Crystalline rock metallic deposits exploited for:

(i) copper
(ii) lead
(iii) zinc
(iv) nickel
(v) gold
(vi) silver
(vii) tin
(viii) mercury
(ix) beryllium.

(d) Other deposits:

(i) phosphorite
(ii) glauconite
(iii) fresh water (sub-seabed deposits).

(e) Materials not mentioned above (e.g. metalliferous brines).

7. For the purpose of its studies, the working group agreed that the term "Sea-bed" should be regarded as including all benthic areas from the highwater line to the deep ocean floor.

8. The working group took note of previous papers and reports in this field, particularly those prepared by GESAMP as set out in the Reference Documents listed in Appendix III.

Liaison with other GESAMP working groups

9. Dr. P.G. Jeffery, Chairman of the Working Group on Evaluation of the Hazards of Harmful Substances in the Marine Environment, and a member of the Working Group on the Impact of Oil on the Marine Environment was present at part of the first meeting of this working group. Dr. C.H. Thompson, Chairman of the Working Group on the Impact of Oil on the Marine Environment and Dr. Jeffery also attended at the last session of our second meeting. As noted above, Dr. G. Kullenberg, Chairman of the Working Group on the Scientific Basis for the Disposal of Waste into the Sea is also a member of this working group. Many opportunities were therefore available for co-ordination of the activities of these various groups.

10. All types of exploration and exploitation activities on the sea-bed result in changes but these are often of a local and temporary character. Although they fall within the definition of pollution adopted by GESAMP at its first session* it is desirable to assess the significance of such pollution in relation to local circumstances and the extent of the damage likely to result. The killing of ten or twenty fish, although it may seem to those on the spot to be a substantial act of pollution, is without significant effect on the stocks of which these fish form a part: the passage of a single large trawler will result in the incidental destruction of a great many more small fish of both commercial and non-commercial species. Nevertheless it is necessary to examine and evaluate the effects of each and every type of sea-bed exploration and exploitation so as to be able to recognize those which, because of their scale, frequency, widespread distribution, persistence or the harmful nature of the by-products they release, may constitute significant pollution.

11. The principal methods by which sea-bed resources may be exploited are through drill holes (e.g. for oil and gas), by surface excavation (e.g. dredging for tin, sand or gravel and manganese nodules) or by underground mining (e.g. for metallic ores). These may require a variety of structures to be placed on the sea-bed for the purpose of drilling, dredging of unconsolidated sedimentary deposits and excavation of bed-rock deposits. Explosives may be required.

12. Such activities may extend from highwater to the deep ocean floor, but almost all of the current activity takes place in shallow water near the shore or on the exposed beach. Most construction work involving sea-bed disturbance extends out from the shore, but there is increasing interest in the development of structures offshore for ship-mooring and unloading, for oil storage, for waste disposal (including incineration), for the siting of power stations, for mineral processing, as air terminals and for a variety of recreational purposes. The effects of building such works appear in the main to be quite local and confined to within a few miles of the site, but the activities which take place subsequently on them (e.g. mineral processing or the operation of a nuclear power station) could have a much wider effect. The presence of the structures may cause local but permanent changes in the marine environment.

(a) <u>Drilling and fluid extraction through drill holes.</u> The principal pollution risks arise from the uncontrolled release of the products which are being sought, e.g. oil, gas or sulphur. Supplementary hazards arise from the accidental or deliberate release of substances employed in drilling, e.g. to lubricate the drilling head, or to prevent the escape of the product, or materials used in other supplementary activities e.g. bactericides or algicides, anti-corrosive treatments, power production, etc. Quite apart from legislative control imposed for environmental protection by the country on whose shelf drilling takes place, Industry takes the view that the value of the product being sought provides

* This definition is as follows:
"Introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazard to human-health, hindrance to marine activities including fishing, impairing of quality for use of sea water and reduction of amenities."

a strong brake on accidental losses. Similarly supplementary materials, such as the "muds" used in deephole drilling, are usually costly and their loss or wastage imposes delay so providing a marked disincentive to careless use or disposal. The situation is, however, quite the reverse in respect of waste materials generated on drilling rigs and offshore platforms and in consequence directives to ensure the return to the shore and the safe disposal of such waste may be ignored with local fouling of the sea bottom and possible obstruction to fisheries. In many countries near approach to drilling rigs and similar structures for purposes unconnected with the operation of rigs, etc. is forbidden by law, but it still remains possible for solid rubbish from the rigs to be dropped on the sea-bed away from the immediate vicinity of the structures by the vessels servicing the rigs and removing these wastes.

It has been established that drilling rigs and other large structures placed on the sea-bed, or moored for a substantial period, attract fish, probably because of shelter provided or growth of attached animals and plants. This usually represents a local re-distribution and concentration of existing fish and not an addition to the stock unless breeding and/or escape from predators is facilitated.

(b) Dredging and beach mining. Dredging involves the removal of unconsolidated material from the sea-bed, usually from a ship or floating platform, but beach mining may involve the use of shore-based equipment working within the littoral zone or standard earth-moving equipment working behind protective dams. The immediate effects are alteration of the contours of the bottom or the beach, the release of fine material which is likely to be carried away from the operating site by tides and currents, and increased turbidity. Secondary effects generated, especially if the exploitation is on a large scale or pursued over a substantial period, may include local alteration of sediment-transport and even current regimes, disturbance of banks, beach erosion or enrichment, blanketing of the bottom locally by fine deposit, interference with bottom-fishing activities, particularly trawling, and local de-oxygenation due to deposition of organic material (e.g. drifting seaweed) in the holes made on the sea bottom. In addition anoxic or even toxic material may be released from sub-seabed levels.

Very commonly fine sand and silt is washed out of dredged material during its passage from the bottom to the hold of the dredger and this spreads the effects more widely since surface currents are often stronger than those near the bottom. However, a recent careful study of the action of the three major types of dredging plant (cutting head pipeline dredgers, grapple dredgers and trailing suction hopper dredgers) used in the San Francisco Bay area showed physical effects of dredging operations to be minor when compared to turbidity and suspended solids increases caused by natural events such as high run-off from overland or wind and wave action.

Dredging can, however, produce serious effects if it materially damages or destroys discrete spawning or nursery grounds for young fish which are of critical importance in maintaining the stock. Local effects may also arise from alterations in behaviour induced by turbidity clouds or disturbance of the bottom.

These would be changes in distribution patterns rather than losses of stock but might reduce fishing success by preventing concentration of fish or by presenting local fishermen with an unfamiliar distribution of their target species. Local effects on shellfish, particularly sedentary species, can be profound by rendering the habitat unsuitable or by smothering with fine material. Other local effects can arise from alterations in bottom-topography, currents, sediment transport and shore exposure arising from removal of bottom material. There is, however, a possibility of adventitious beneficial effects from the same causes.

(c) Underground mining. Mining of sea-bed rock is at present rarely practised; this statement excludes operations extending under the sea-bed from the land. Perhaps the best known examples of true sea-bed mining are the extraction of barytes from solid rock on the sea-bed in Alaska and the winning of sulphur. The latter is, however, obtained by drilling and *in situ* liquefaction and so is included in the preceding section on drilling.

Although in theory many valuable minerals could be mined from sub-sea rocks, in practice offshore mining generally gives rise to higher production costs than exploitation on land. It has been forecast that land supplies will meet even greatly increased needs for minerals over the next 30 years and offshore minerals will be exploited only when they can be marketed competitively with those derived from land sources. Advances in mining and processing technology are likely to benefit land-mining as much, if not more, than sea-mining, so that the prospects for a major extension of the latter in the immediate future are not high. Nevertheless, exploitation of otherwise uneconomic deposits of some minerals might be subsidized for strategic reasons or to achieve national self-sufficiency. The pollution implications of such mining must therefore be considered.

Pollution could arise in three ways, firstly by the disturbance and incidental release of unwanted materials, including surface fine deposits, during the opening up and working of the mine; secondly by the loss of the material during mining, bringing to the surface and transport to a processing site, and, thirdly, by the discharge of waste materials during the processing operation, if this is conducted at sea on ships or on a special structure such as a platform or artificial island placed in the sea or on the shore. Most of these effects would be quite local and comparable to those produced by dredging but if the exploited material was a metal ore, or a metalloid, then some potentially dangerous fine material might accumulate in the bottom deposits and be subsequently released, and some soluble material might enter the water column directly. The importance of such pollution would be related directly to the amount, solubility, toxicity and persistence of the material concerned, with mercury at the head of the list.

If explosives were used extensively in establishing an undersea mine then additional local damage could be done.

(d) Construction work associated with placing of structures on the sea-bed. To place structures on the sea-bed it may be necessary to drill, excavate, use explosives, drive piles, deposit foundation or protective material, possibly in very large quantities and sometimes derived from adjacent areas of the sea-bed (e.g. sand or gravel banks), and engage in all the processes normally associated with, say, dock construction. Clearly this may entail small losses of a wide variety of the materials used in construction. Harmful effects of construction will, however, be local and damage to living resources will be insignificant except in so far as the construction actually occupies a site of critical importance in the population dynamics of exploited species or so alters the current and sediment transport régimes as to affect, in a substantial way, such a critical site. An important fish spawning ground could be destroyed or major damage done to a highly productive shellfish ground; otherwise effects are likely to be minor and of local importance only.

Marine construction work can be considered under two categories: offshore and shore-connected. Among the former are constructions related to petroleum exploitation activities: drilling rigs, production platforms, well-heads, pipelines and storage tanks. Other works in this category include offshore terminals, towers, semi-submersible platforms (e.g. sea thermal power plants) and artificial islands and reefs.

Among the shore-connected construction consideration must be given to tunnels, bridges and causeways, port installations, breakwaters and wave-damping structures, and pipes for discharge or intake. Although the presence of new structures may result in long-term changes in the marine environment, in nearly all cases the significant pollution aspects of these constructions are of short duration, limited to the actual construction-installation activities.

Although no serious pollution aspects appear to be associated with marine construction, it is recommended that careful environmental impact studies be carried out for each major construction on an individual basis prior to, and following the completion of, each installation. The permanent alterations in the marine environment arising from the presence of artificial structures need to be assessed. The more serious potentials for pollution associated with these structures, however, generally arise from their use rather than their presence in the marine environment.

Petroleum (including natural gas)

Introduction

13. (a) The working group was asked, inter alia, to assess the marine pollution implications of the exploration and exploitation of the sea-bed for oil and gas as a first priority task. It was recognized that there was some overlap between this part of the group's terms of reference and those assigned to the Working Group on the Impact of Oil on the Marine Environment under the chairmanship of Dr. C.H. Thompson. It was understood however that Dr. Thompson's working group would be concerned mainly with the resolution of evident areas of controversy between scientists regarding the biological effects and ultimate fate of petroleum hydrocarbons. As noted above steps were taken to facilitate co-ordination between these two working groups and with two other relevant working groups of GESAMP.

(b) Following correspondence between the Chairman of the working group, the UN Technical Secretary, Dr. C.H. Thompson and Dr. P.G. Jeffery, it was decided that this working group would confine its work on oil strictly to an assessment of the pollution hazards arising directly from offshore exploration and exploitation, setting aside, for the time being at least, any additional risks arising from ship transport and refining although these subjects had been mentioned in its terms of reference. Pollution risks arising from storage at the production site, loading of tankers at production platforms and pipeline transmission to shore would, however, be considered.

(c) The discussions of the working group were based on a working paper prepared by Dr. R.G.J. Shelton and Mr. J.A. Nichols; it was agreed that a revised and edited version of this paper, together with a summary of the working group's findings, should be remitted to the Working Group on the Impact of Oil on the Marine Environment for their consideration.

Manganese Nodules

14. The working paper on this topic is attached as Appendix I. This paper addresses aspects of pollution arising from exploration and exploitation of manganese nodule deposits, excluding exploitation activities other than mining.

15. Although detailed understanding of the distribution of manganese nodules on the ocean floor is incomplete, broad regional patterns have been mapped, and major deposits appear to have been delineated.

16. No single theory adequately explains the origin and distribution of manganese nodules, nor the mechanism or mechanisms which concentrate economically valuable metals within them. Despite these outstanding questions, enough is already known about the ore value of deposits in specific areas to stimulate commercial interests. Deposits having the greatest economic potential lie in deep ocean basins; those considered most favourable for initial exploitation are found in the eastern equatorial North Pacific.

17. Two methods for mining manganese nodules in 5000 metre depths are in an advanced state of development. Both methods will, in varying degree, have potential pollution effects in the surface and bottom ocean environments. Plumes of suspended sediment will be created in both zones (depending upon the mining method) which may have adverse effects upon benthic or pelagic life. In addition, the discharge of nutrient-rich mining effluent (bottom water) at the surface may have either positive or negative impact upon pelagic communities.

18. Present information regarding mining disturbances is derived from small-scale tests and laboratory studies, and is inadequate to predict the nature and scale of potential pollution expected from full-scale mining. Preliminary results, however, suggest that it will be minimal. Comparison between the estimated magnitude of the mining perturbations and analogous large-scale natural phenomena supports the view that no serious pollution will arise from manganese nodule mining activities. In reaching this conclusion attention was given to the Report of the Fifth Session of GESAMP which examined the possible effects of disturbance of the sea-bed on the specialized ecosystems present on the floor of the deep ocean.

19. The evidence required to predict confidently the pollution effects of nodule mining can only be obtained through careful monitoring of full-scale mining operations. Recommendations for monitoring of certain important parameters are given in Appendix I. Such investigations will be aided by baseline studies currently in progress by the United States National Oceanic and Atmospheric Administration at selected Pacific mining sites which appear to represent a timely and orderly pre-mining environmental inventory.

20. Manganese nodule deposits of the ocean floor are, in certain areas, rapidly being reclassified as proved reserves rather than unquantified resources. Active mining operations are expected to begin in the Pacific area before 1980.

21. A unique opportunity exists to establish international agreement on regulations which would promote orderly development of these reserves and insure against adverse environmental effects arising from their exploration and exploitation prior to the advent of large-scale mining activities.

<u>Dispersion of fine-grained material</u>

22. In Appendix II aspects related to the transport and mixing (i.e. dispersion) of fine-grained material in relation to dredging and mining operations are considered, dealing separately with beach dredging and excavation, offshore suction dredging, and deep sea-bed mining. Although in all cases the present theoretical understanding of the processes occurring is limited and the available experimental data are few, an assessment of the possible range of physical effects of the operations can be made.

23. In the nearshore zone it can be shown that the increase of turbidity may be considerable, and fine-grained material can be carried over large distances, both alongshore and offshore. The possible implications of dredging for the material budget of the beach zone should always be considered. Dredging can change the topographic conditions and consequently the on-offshore material transport pattern. In the nearshore region dispersion is primarily governed by the wave conditions and to a lesser extent by currents. The most effective dispersion occurs in the breaking wave zone.

24. In the offshore dredging case the transport by currents and the mixing conditions normally can be expected to be effective enough to reduce the discrete concentration of waste material to insignificant levels over time periods of 5-10 hours. This conclusion is based on commonly observed dilution factors in the wake of a ship releasing waste material and on known subsequent dilution factors in the surface layers. Present experience in Europe and North America supports this conclusion. The small-scale topographic disturbances on the sea floor, however, appear to be very persistent. It should also be noted that internal layers of suspended matter in regions of increased density stratification can be very persistent.

25. In the case of deep sea-bed mining no full-scale case study is available. Small-scale experiments have been carried out but there is considerable danger in extrapolating the results of these to the full-scale case. The initial distribution of resuspended material in the water column will depend very much on the mining technique used (compare Appendix I). Taking the manganese nodule mining as an example, and assuming that as much sedimentary material as the amount of nodules is brought to the surface and released with the mining effluent into the surface layer, an estimate of the turbidity increase in a single 24 hours operation suggests that the initial concentration will be of the order of 100-1000 times the natural (ambient) concentration in the top 50-100 metres. Over a period of 10 hours this concentration will normally decrease by at least a factor of 100.

26. In connexion with all the operations mentioned, environmental observations should include physical parameters in addition to biological and chemical ones in order to make a reasonably reliable prediction of the possible consequences.

27. Other physical aspects are briefly considered. It is not possible to make useful general statements, only to state that every case of nearshore construction must be investigated carefully on its merit.

Future work programme

28. After reviewing its future work programme the working group concluded that it would need to meet for 3-5 days in the Autumn. A meeting in London during November 1975 was considered to be most convenient.

29. The need for inter-sessional work to prepare for such a meeting was considered in relation to those parts of the working group's terms of reference which had not been covered during the first and second meetings and an appropriate division of responsibility was agreed.

Appendix I

REPORT ON POLLUTION ARISING FROM EXPLORATION AND EXPLOITATION OF MANGANESE NODULES

Note: 1. This Appendix has not been examined or accepted by GESAMP.

2. The original draft for this Appendix was prepared by Robert D. Gerard.

3. The working group examined and amended this report during the inter-sessional period and had approved its presentation to GESAMP.

INTRODUCTION

The winning of mineral resources from the ocean floor involves three basic tasks: ore body location and delineation, mining, and transport to land. The first of these may be termed exploration; the remaining tasks are part of exploitation. A fourth activity, processing at sea, may also be considered under exploitation. The purpose of this report is to examine the nature of possible pollution effects arising from exploration and mining activities in connexion with the acquisition of manganese nodules from the ocean floor. Pollution aspects of the other exploitation activities are not considered in this report. Processing of manganese nodules at sea appears to be unlikely within the next 10 years.

BACKGROUND

Manganese nodules on the deep ocean floor were first discovered one hundred years ago on the world-wide CHALLENGER Expedition (1873-1876). In the CHALLENGER report on Deep-Sea Deposits Murray and Renard (1891) wrote: "In some regions of the ocean the CHALLENGER discovered ferro-manganic concretions in great abundance, the minute grains giving a dark chocolate colour to the deposit, while the dredges and trawls yielded immense numbers of more or less circular nodules or botryoidal masses of these oxides of large dimensions". As recently as 1970 new analyses were still being published on nodules collected by the CHALLENGER expedition in the Central Pacific (Stevenson and Stevenson 1970).

At the turn of the century, extensive collections of nodules were dredged by Alexander Agassiz (1906) aboard the United States Fish Commission Steamer ALBATROSS in the Equatorial Pacific while collecting specimens of benthic organisms. It is ironic that Agassiz, who made his fortune in copper mining, did not foresee the metal resource potential of manganese nodules.

Until the mid 20th century research on manganese deposits from the ocean floor was sporadic and sample collection was, in general, incidental to other oceanographic work. In the late 1950's extensive surveys and collections of nodules were made in the Central Pacific under the aegis of the International Geophysical Year. These new data together with earlier observations suggested a broad and dense distribution of manganese nodules in certain deep ocean basin regions and were interpreted by Mero (1965) as a potential economic resource by virtue of their metal content of nickel, copper and cobalt.

By the early 1970's commercial mining interests in the United States, West Germany, Japan and France had made considerable investment toward developing the capability to explore, recover, refine and market deep sea manganese nodules and their metals. Present predictions indicate that these efforts will reach the exploitation stage before 1980 (Rothstein and Kaufman, 1973).

Distribution of Manganese Nodules

Ferromanganese slowly accumulates on the surfaces of all current-swept rock outcrops which occur on the deep sea floor. It also accumulates on sediment covered bottoms (except where sedimentation rates are significantly higher than the norm of 1-3 mm per 1000 years) in the form of nodules and these too are found in areas of bottom ocean currents.

Although some writers have made the mistaken assumption that manganese nodules are a renewable resource, radiochemists have determined that manganese accumulates very slowly on crusts and nodules at rates of 2-15 millimetres per million years (Ku and Broecker 1969, Heye and Beiersdorf 1973).

The United States Inter-University Program of Research on Ferromanganese Deposits of the Ocean Floor (1973) cites three general hypotheses, either singly or combined, which have been proposed to explain the origin and distribution of ferromanganese accumulations on the sea floor. These are:

(1) the supply of elements directly from the water column;

(2) the supply of elements by emanations from igneous rocks below; and

(3) the mobilization of elements naturally occurring within the sediment column and the redisposition of these elements at particular sites.

Studies are continuing to evaluate the significance of these processes in the formation of manganese nodules and to elucidate the mechanism or mechanisms which concentrate economically valuable metals within the nodules.

Recent interest in the resource aspects of ferromanganese deposits has stimulated a number of reports which have brought together existing data on the distribution, concentration (population density) and metal content of manganese nodules on the ocean floor:

- Ewing et al (1971) have plotted the world distribution of deep ocean manganese nodules based on 50,000 bottom photographs obtained from 28 oceanographic cruises.

- Horn et al (1972a) have shown the major provinces of ferromanganese deposits based on data from 6000 deep sea cores throughout the world ocean.

- Horn _et al_ (1972b) discuss world patterns of ferromanganese nodules and encrustations based upon piston core and dredge samples.

- Horn _et al_ (1972c) plot and describe the distribution and composition of manganese nodules in the North Pacific in relation to bottom sediment distribution. A correlation is shown between a relatively high nickel-copper content of nodules in the eastern equatorial North Pacific and the siliceous sediment substrate found in this zone.

- Frazer and Arrhenius (1972) published computer-drawn charts showing the distribution of manganese nodules in the world ocean together with the weight percent of cobalt, nickel and copper and the ratio of Co+Ni+Cu:Mn+fe. These charts are based on approximately 800 nodule analyses.

- Horn _et al_ (1973a) have compiled data on metal contents of manganese nodules and crusts from cores and dredges in the major ocean basins (North Pacific, North Atlantic and Northern Indian Oceans, South Pacific and Southern Indian Oceans and South Atlantic). Maps showing the distribution of samples and metal contents for copper, nickel, cobalt and manganese are also given.

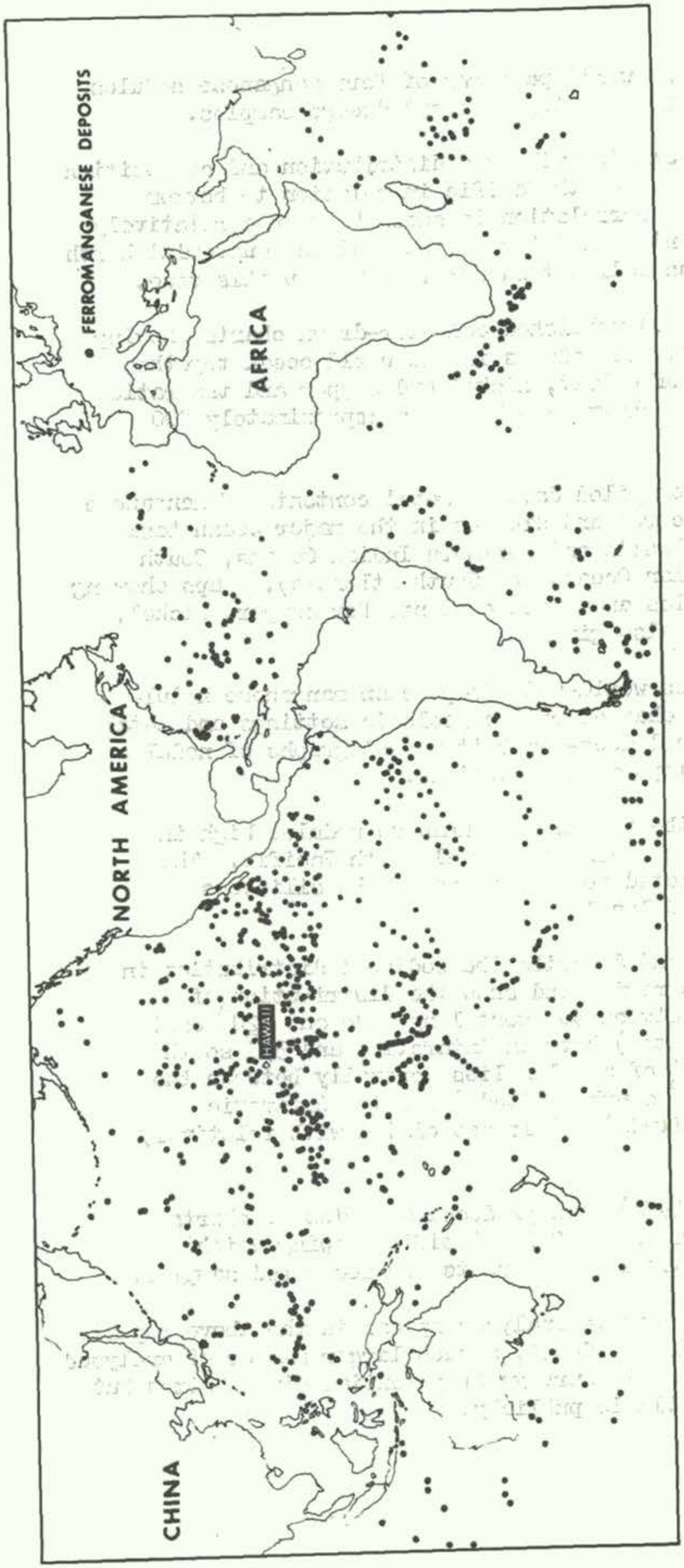
- Horn _et al_ (1973b) discuss world-wide deep ocean manganese nodule provinces and show their characteristic geologic settings and metal values of nodules. Typical deep-sea bottom photographs of nodules are shown together with topographic sections.

- Horn _et al_ (1973c) describe a zone of manganese nodules high in nickel and copper in the eastern equatorial North Pacific. The high metal values are related to properties of the siliceous sediments on which the nodules lie.

- Goodell _et al_ (1973) map and describe the sediment distribution in the Circumpolar Antarctic region and show the distribution of ferromanganese deposits between 30° west longitude and 120° east longitude (the Pacific sector) between Antarctica and 35° south latitude. The medial belt of nodules lies generally between the Antarctic Convergence (55° south latitude) and the Antarctic Divergence (65° south latitude) and is associated with relatively strong bottom currents.

- Glasby, and P. Lawrence (1974) have produced a series of charts showing manganese deposits of the South Pacific showing weight percentages of the major metal constituents for recovered samples.

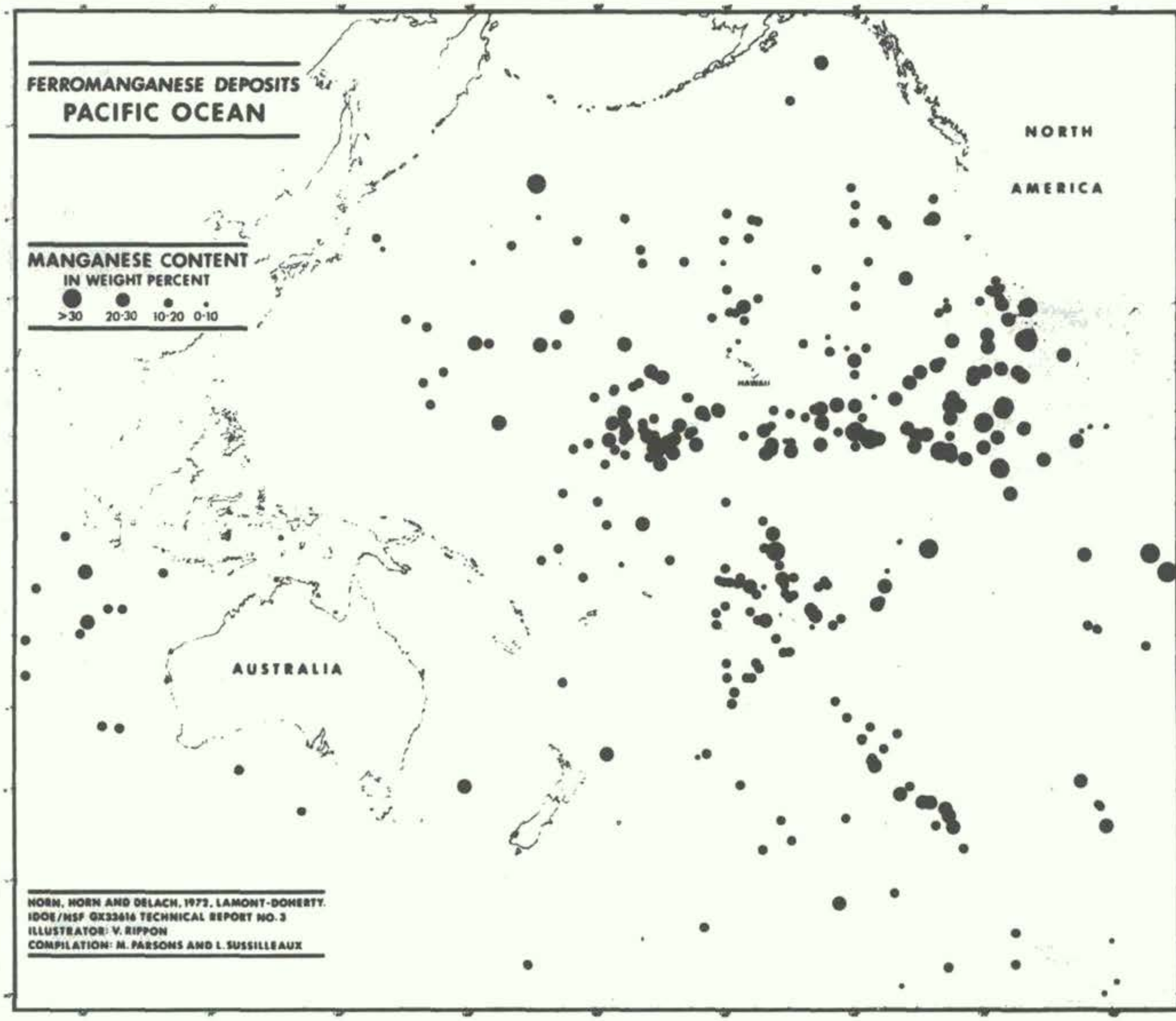
In all, about 1500 manganese nodule analyses appear in the above reports which have been widely circulated. No doubt, a much larger number of analyses have been made by companies engaged in surveys of potential mining sites but these data have not been made available publicly.



Worldwide distribution of surficial ferromanganese deposits on the ocean floor based on core and dredge data. The great majority of occurrences are in the North Pacific south of Hawaii.

FIGURE 1

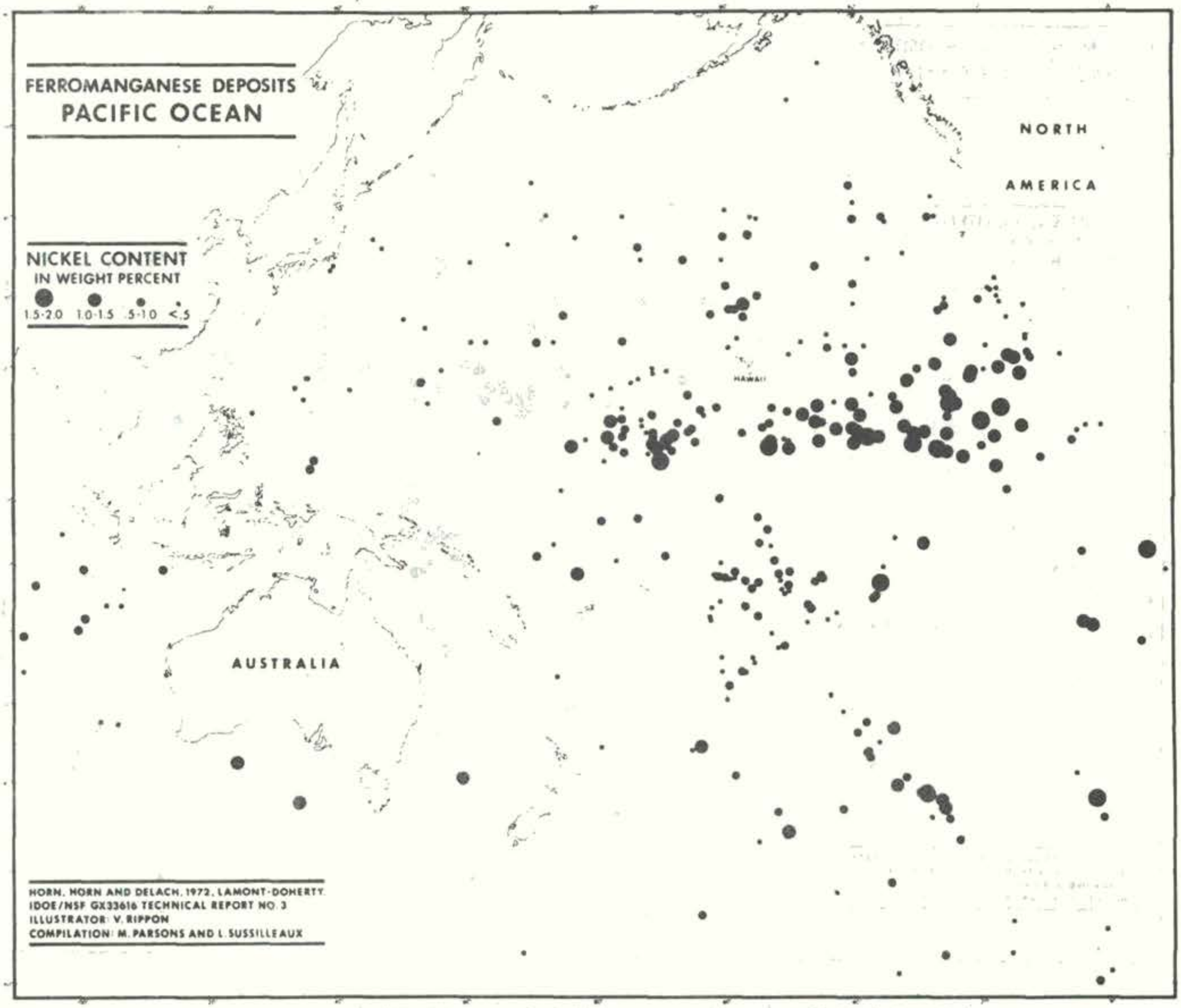
(from Horn et al, 1972d)



Manganese content of ferromanganese deposits of the Pacific Ocean.

FIGURE 2

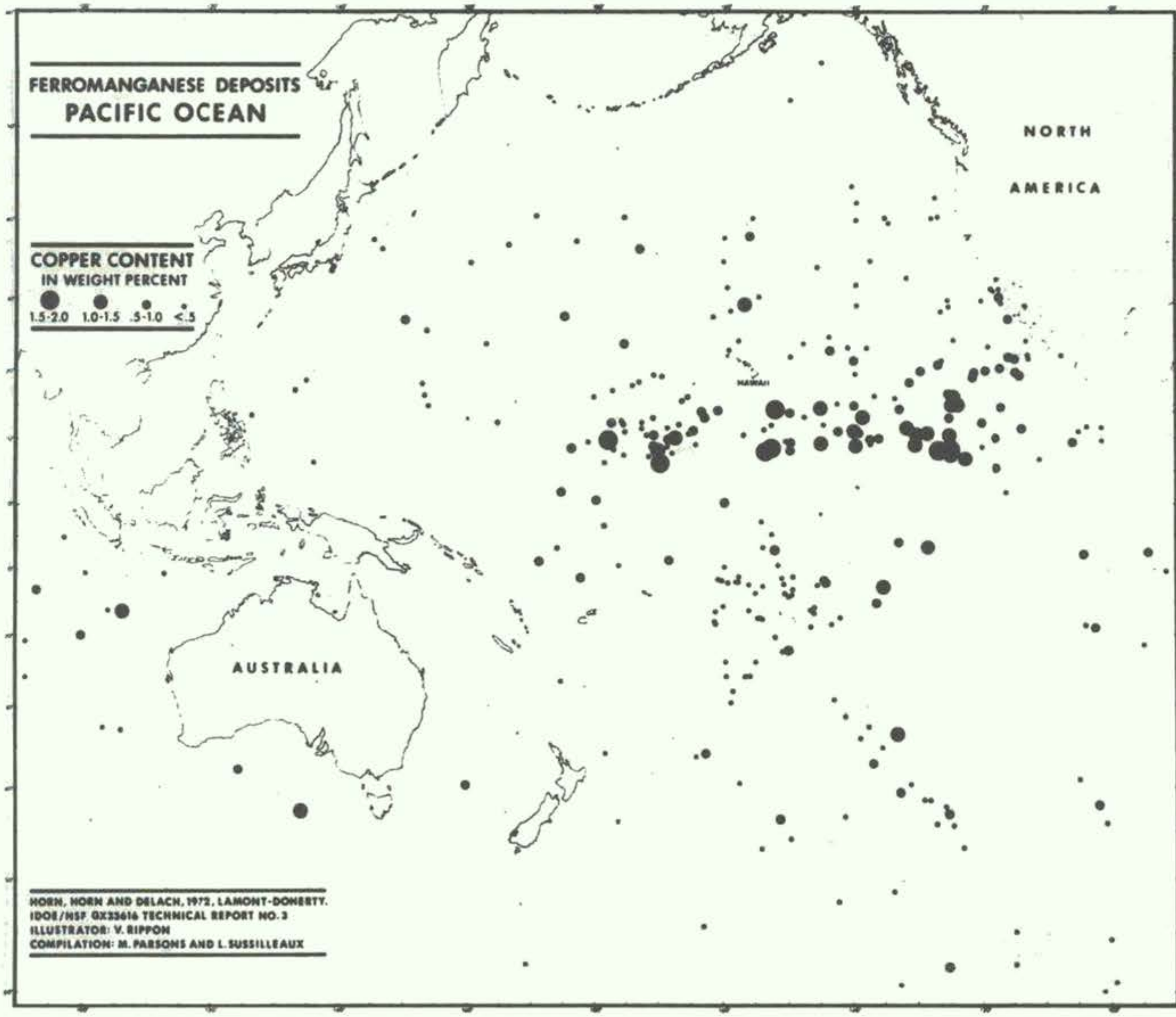
(from Horn et al, 1972d)



Nickel content of ferromanganese deposits of the Pacific Ocean. Nodules rich in nickel are widespread southeast and southwest of Hawaii.

FIGURE 3

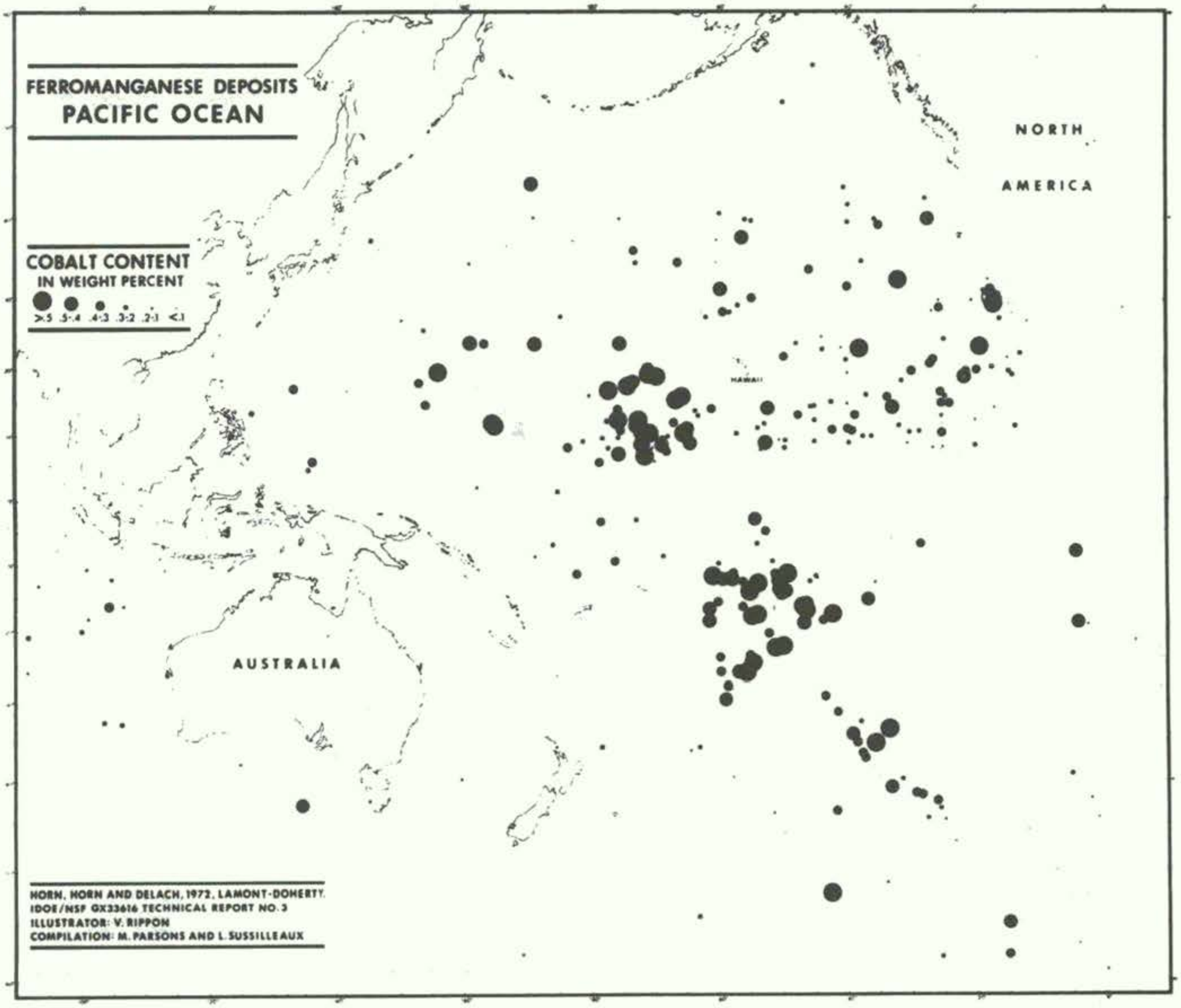
(from Horn et al, 1972d)



Copper cont-nt of ferromanganese deposits of the Pacific Ocean. Chemical analyses reveal a broad band of nodules rich in copper south of the Hawaiian Islands.

FIGURE 4

(from Horn et al, 1972d)



Cobalt content of ferromanganese deposits of the Pacific Ocean. High values of cobalt are obtained from samples of deposits which occur on crests and flanks of submarine topographic highs. The circular grouping of high cobalt values southwest of Hawaii reflects the summits of a ring of submarine mountains encrusted with ferromanganese. High cobalt values in the South Pacific are also characteristic of relatively shallow water regions of the Manihiki Plateau and Tuamoto Archipelago.

FIGURE 5

(from Horn et al, 1972d)

From the published data it is possible to observe general regional trends in nodule abundance and patterns of metal enrichment. For the following summary of manganese nodule regions of the world oceans the reader is referred to Figures 1 through 5, taken from Horn et al (1972d).

In the North Atlantic, an area of relatively rapid sedimentation, nodule occurrences are generally associated with steep topographic features (seamounts and ridges) which make them unattractive from the standpoint of mining. One area off the southeastern United States shows significant deposits on a broad, level 1000 metre-deep platform (the Blake Plateau) but the metal values are low (Ni 0.52%, Cu 0.08%) according to Horn et al (1973b).

The nodule deposits in the South Atlantic and Indian Ocean are similar to the North Atlantic in that these areas too are affected by relatively rapid sedimentation. As a consequence the areas favouring nodule development are restricted to isolated basins and topographic highs. The average metal contents for the two oceans are: Ni 0.54%, Cu 0.20%, Mn 16.28%, Co 0.26% (Horn et al, 1973a). These relatively low metal values combined with topographically unfavourable mining sites are considered poor prospects for mining at the present time.

Owing to low sedimentation rates, the South Pacific has broad areas of nodule deposits. Notable among these are the Manihiki Plateau, Tuamotu Archipelago and the Peru Basin (Glasby and Lawrence, 1974). While the cobalt content of nodules on submarine elevations are relatively high (Co 0.78%) the average metal contents of South Pacific nodules are too low to be of commercial interest (Horn et al, 1973b).

Based on available data the most abundant and widespread deposits of manganese nodules occur in the deep basins of the North Pacific Ocean. Furthermore the eastern North Pacific nodules contain the highest known concentrations of copper and nickel (Cronan, 1972).

Various estimates are given as to what metal percentages in nodules constitute acceptable ore grades. Dubs (1973) suggests 1 to 1.6% nickel, 0.75 to 1.5% copper and 0.2 to 0.3% cobalt. Ratiner (1973) lists economically feasible nodule ores as having: 1.25% nickel, 1% copper and 0.22% cobalt. To be of economic interest a deposit should have a population (bottom coverage) of 30-35%, and a concentration of 5 kilograms (wet weight) per square metre (Dubs, 1973). The eastern equatorial North Pacific nodule zone (from 6°30' to 20° north latitude and 110° to 180° west longitude) is the only area which meets these requirements. Specifically, the nodule deposits east of 150° west longitude associated with siliceous sediments have the richest metal concentrations. Horn (1973a) gives averages for Ni of 1.28%, Cu 1.16%, and Co 0.23%.

Perhaps the most convincing indication that this area best meets the requirements of deep sea mining is a recent Notice of Discovery and Claim of Exclusive Mining Rights filed by Deep Sea Ventures, Inc. with the United States Department of State (Tenneco Inc., 1974). Their proposed claim indicates a 60,000 square kilometre area (to be reduced later to 30,000 square kilometres), centered at 15° north latitude and 126° west longitude in water depths of about 5000 metres. The company claims to have conducted surveys in the area since 1969 and describes the deposit as follows:

Average assay (% dry weight)	Manganese	29.0
	Nickel	1.28
	Copper	1.07
	Cobalt	0.25
	Iron	6.3
Average population (aerial percentage of sediment surface occupied by visible nodules)		30-40%
Average concentration (Wet-weight per unit area)		9.7 (wet) kg/metre²

The company plans to mine the deposit for up to 40 years and to produce nickel, copper, cobalt and manganese.

Exploration

The objectives of deep ocean nodule exploration are to locate large deposits of the ore grade material in desirable environments and to verify the deposit in terms of economic value. The evaluation must lead to a development plan and a production plan that is economically viable for a definable period of time. Kaufman and Siapno (1972) have outlined an ideal exploration programme in four distinct phases. Phase 1 involves the location of nodule deposits of potential commercial interest. Such activity would involve bottom topographic mapping using conventional ship-mounted echo sounders. Acceptable mine sites are those which have a minimum of rough terrain and acceptable depth variation within a given local area of less than 100 metres with slopes not exceeding 10°. Studies of bottom coverage and concentration of nodules will also be made using deep-sea photographic methods and underwater television for continuous transects. A sampling of small quantities of nodules is also made in this phase in order to assay the metal content of the deposit. A large number of small samples from representative locations throughout the mine site is necessary to permit statistical analysis of the distribution of ore tenor and concentration. Preliminary assays are made aboard the survey ship and preliminary assessment is made by reference to pre-established cut-off grades based upon economic mining system models.

The Second Phase would continue the First Phase activities and incorporate additional work including large quantity nodule sampling (5 tons to 10,000 tons) required for beneficiation and processing research, pilot plant design and engineering tests of mining equipment. Seafloor sediment properties (physical properties) must be studied carefully in order to set the design for successful dredging systems. Sampling is commonly done on large box core samples which are brought to the surface. Environmental data, including seasonal weather, sea and current conditions, require careful assessment during this phase of exploration. Ecological data also need to be collected to determine dispersion and mixing rates of deep water and sediment discharge at the surface and the effects on the marine environment.

Phases 3 and 4 include the same types of measurements as the first two Phases, but these are carried out in much greater detail based upon the results of earlier work. Additional activities would include microtopography studies using narrow beam echo sounders and deep-towed side scan sonar systems. Using the generalized and the detailed topographic/bathymetric data detailed maps would be constructed in order to develop the most effective dredging plans with regard to the terrain characteristics and the delineated obstructions.

Judging from such a typical exploration plan the only activity which could result in pollution would appear to be the tonnage sampling using large dredges. Typical bulk dredging would expectably recover 5-10 tons of nodules per day (Isaacs, 1973). The dredge is likely to disturb the sediment to a depth of 1/2 metre and remain on bottom for less than one half hour at each station.

The scale of such operations (a few thousand tons of nodules recovered) is unlikely to cause discernible environmental damage. It is encouraging to note that the commercial companies acknowledge the need for ecological data in the exploratory phases. However, it is important that meaningful programmes be established for the collection of ecological and environmental impact data so that a realistic assessment can be made of pollution hazards in specific areas.

Mining

The mining of manganese nodules in ocean depths of 5000 metres in a productive manner presents major engineering and economic problems. At the present time two systems are under development and have been tested in the deep sea.

The continuous-line bucket dredge (Mero, 1972) consists of a loop of line which extends from a surface ship to the ocean floor. Open mesh metal dredge buckets are attached to the line every 20 to 50 metres. A traction machine on the ship moves the line so that empty buckets descend on one limb of the loop, contact the ocean floor collecting nodules, and are hauled up on the ascending limb of the loop to discharge their content of nodules on shipboard. As the ship (and the dredge system) move slowly, each successive bucket is exposed to a fresh strip of the ocean floor to collect nodules. Figure 6 from McCauley (1974) illustrates this system. Deep ocean tests have been successfully accomplished with the CLB system in the Pacific in 1970 and in 1972. Masuda (1972) estimates that the CLB system is capable of recovering 500 to 1000 tons of nodules per day in depths of 5000 metres.

A second method under development for nodule mining is described as the airlift hydraulic system (Garland and Hagerty, 1972). This system employs a ship fitted-out with equipment similar to that of a deep sea drilling vessel. A pipe extends from the ship to sea floor at the bottom of which is a truss assembly and a dredge head fitted with jets, harrow blades, and rake-like appendages optimized for gathering nodules of a prescribed size. The system is shown in Figure 7 taken from McCauley (1974). Transport of nodules from the sea floor to the mining vessel through the pipe is achieved by entrainment in a high velocity water flow. The flow is maintained by injection of high pressure air at locations along the pipe causing reduction of density of the fluid inside

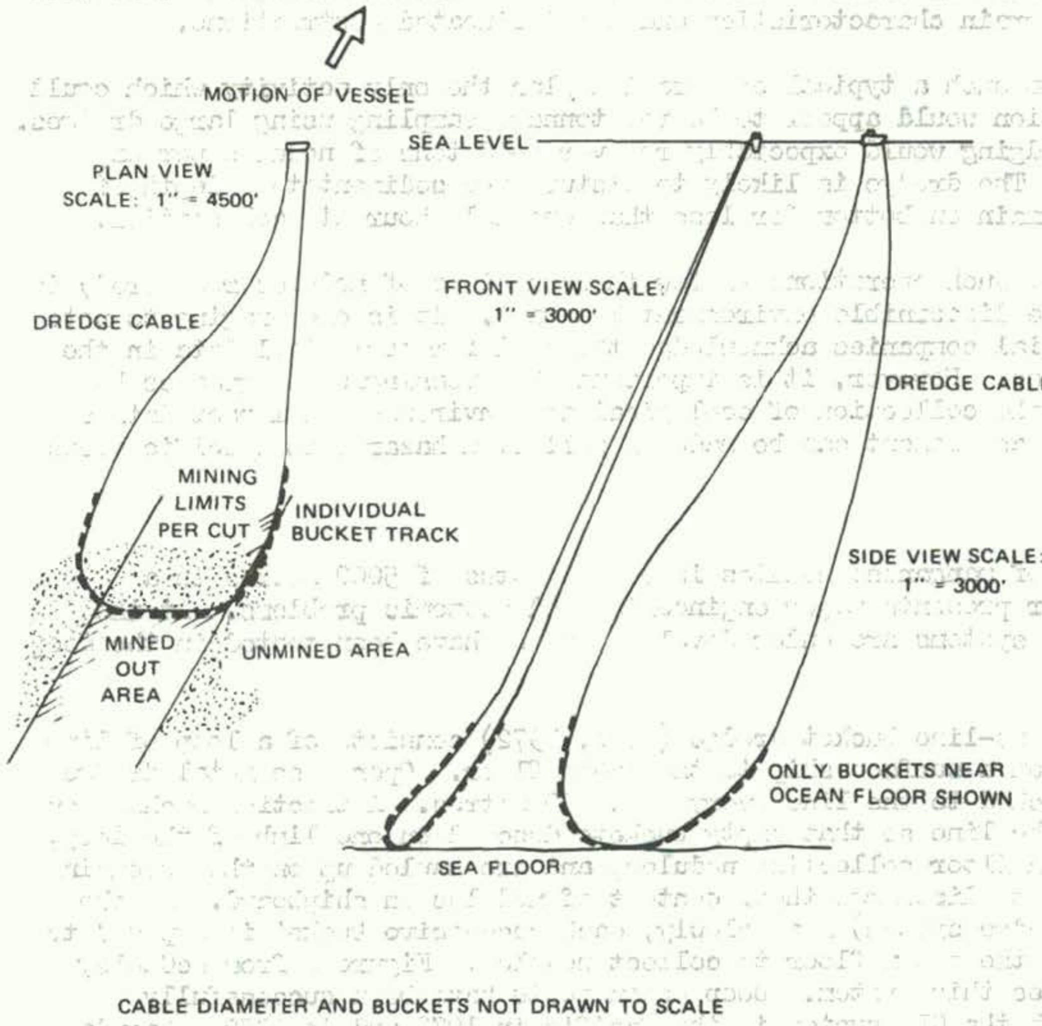
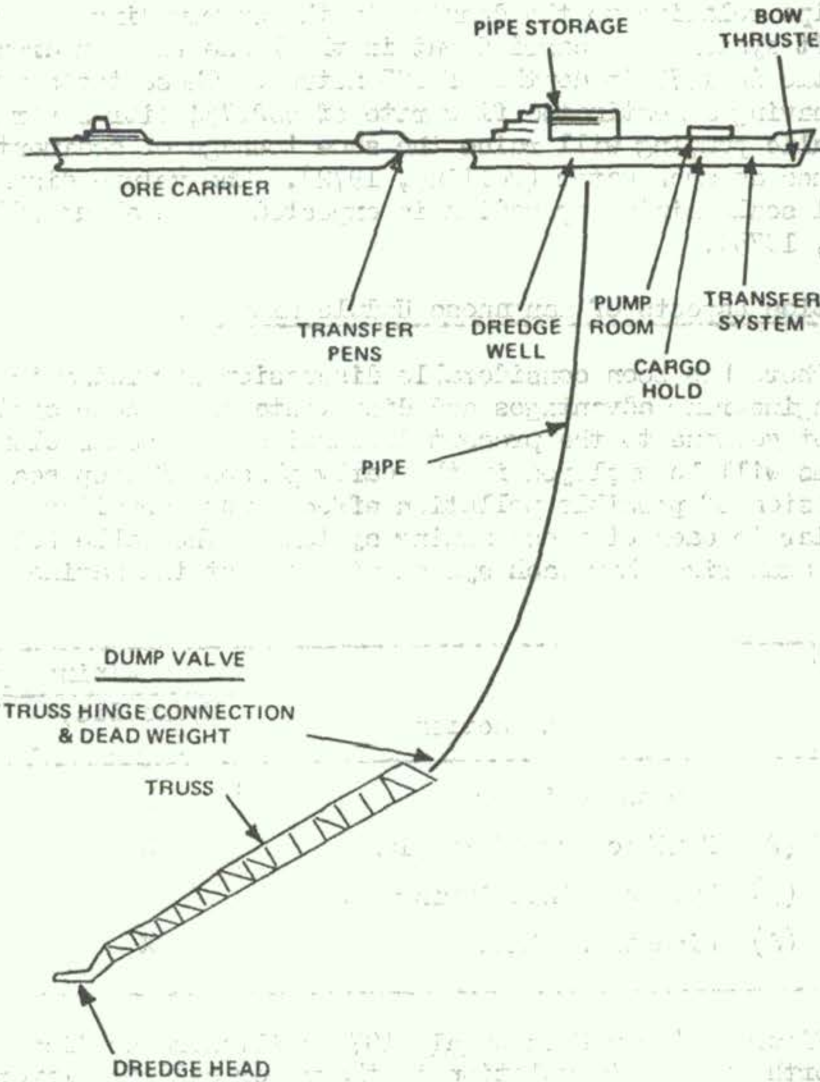


FIGURE 6

Continuous Bucket Line System of Manganese Nodule Recovery

(from McCauley, 1974)



AIR LIFT PUMP SYSTEM

FIGURE 7

(from McCauley, 1974)

the pipe relative to the density in the surrounding water column. Tests of the airlift system were carried out in the Blake Plateau area of the western North Atlantic in 1970 in depths of 800 metres. These tests utilized a 23 cm diameter pipe having an estimated flow rate of 562,754 litres per hour (Amos et al, 1972a). Hydraulic pumping will raise the same tonnage of sediment as nodules and 10 to 20 times as much water (Welling, 1972). The volume discharge of effluent from a full scale mining operation is expected to be about 260 x 10^3 metres^3 per day (NOAA, 1975).

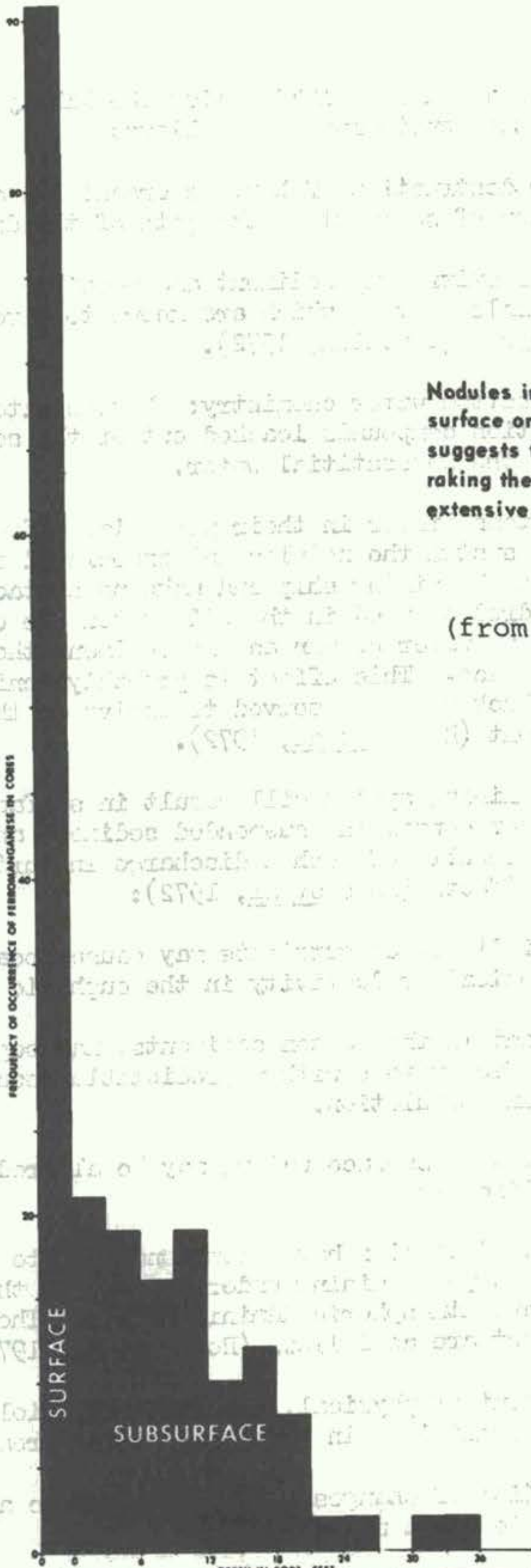
Pollution Aspects of Manganese Nodule Mining

There has been considerable discussion regarding the comparative economic and engineering advantages and disadvantages of each system (Mero, 1972) which are not germane to the present discussion. It seems clear, however, that both systems will be employed in the early phases of deep sea mining and any discussion of possible pollution effects must consider those aspects which are peculiar to each of these mining systems. The table below (adapted from NOAA, 1975) summarizes how each system will affect the marine environment.

Interaction	Mining system	
	Hydraulic, Towed	Mechanical, CLB
(1) Scrape seafloor	X	X
(2) Benthic turbidity plume	X	X
(3) Rain of fines during ascent		X
(4) Discharge plume	X	

Figure 8 (from Horn et al, 1972b) illustrates distribution of nodules in the North Pacific in relation to the upper sediment layers. More than 90% of the nodules lie at the sediment-water interface while most of the small remaining percentage are within the top 1/2 metre of sediment. This type of occurrence reduces the mining techniques to a matter of skimming off this superficial layer of a few centimetres depth. Roels (1974) reports that the CLB system may penetrate the sediment to a depth of 20 centimetres but probably much less. Both the CLB and AL systems have been engineered to separate the nodules from the sediments as well as possible on the ocean floor and to cause the least possible disturbance of the sediment consistent with efficient collection of nodules.

A projected 3 million ton-per-year mining operation will recover 10,000 tons of nodules per day. If the nodule concentration is 10 kilograms per square metre, than 1 square kilometre must be swept clear each day. Considering the inefficiencies of bottom sweep and nodule pick up, probably two or three square kilometres must be mined per day (Flipse et al, 1973). Using a dredge head 15 metres wide, the mining ship would have to sweep a path about 100 km long each day. The disturbance of an operation of this scale on the ocean floor could be a serious environmental concern.



SURFACE AND SUBSURFACE DISTRIBUTION OF FERROMANGANESE DEPOSITS IN CORES FROM THE NORTH PACIFIC

Nodules in the North Pacific occur on the surface or sediment/water interface. This suggests that mining will be confined to raking the seabed and will not include extensive dredging of the substrate.

FIGURE 8

(from Horn et al, 1972b)

Malone et al (1973) and Roels (1974a) list the likely effects of both systems in the ocean bottom environment as follows:

1. Disturbance or destruction of benthic organisms, and mixing and resuspension of sediment in the path of the dredge.

2. Resettlement of stirred up sediment and possible endangerment to benthic animals many of which are known to have a very slow reproductive cycle (Turekian, 1972).

3. Alteration of bottom water chemistry: bottom waters may retain in solution compounds leached out of the sediment or gained from the interstitial water.

The two mining systems differ in their potential effects within the water column. In the airlift system the nodules and associated sea floor materials are delivered by pipe to the mining ship and make no contact with surrounding sea water. The bucket dredges used in the CLB system are expected to add to the turbidity of the ocean water column as the sediment they contain washes out during ascent to the surface. This effect is probably confined to the deeper ocean layers since the buckets are observed to arrive at the surface relatively clean and free of sediment (Roels et al, 1972).

The use of airlift mining system will result in surface discharge of nutrient-rich bottom water containing suspended sediment and fine particles of manganese nodules. The results of such a discharge in surface waters reportedly may have the following effects (Amos et al, 1972):

1. The increase of dissolved nutrients may cause locally increased biological productivity in the euphotic zone.

2. Organisms dormant in the bottom sediments, may begin to grow in the surface waters with unpredictable results upon the existing population.

3. Light penetration of surface waters may be altered due to the turbid discharge.

To date, several field studies have been conducted to investigate environmental impact of deep-sea mining under support of the United States National Oceanographic and Atmospheric Administration. The overall objectives of this continuing project are as follows (Roels et al, 1973):

(a) the establishment of physical, chemical, and biological baseline-environmental conditions in potential mining areas;

(b) the documentation of changes induced in benthic and pelagic ecosystems by deep-sea mining;

(c) the elucidation of the underlying mechanisms and implications in relation to current and potential marine resources;

(d) the formulation of guidelines for future mining operations which will minimize harmful environmental effects while enhancing the development of potentially beneficial byproducts; and

(e) the determination of the properties which should be monitored during deep-sea mining to provide the information needed to evaluate the environmental impact of specific mining methods and to devise mitigating measures, if necessary.

Studies to date under this programme may be summarized as follows:

Baseline environmental conditions in relation to manganese mining impact were studied in the western North Atlantic (Malone et al, 1973, Roels et al, 1973). Observations of benthic biomass in samples and bottom photographs permit an estimate of 9 mg per square metre. Natural surface productivity of phytoplankton was measured and compared with that using various percentages of filtered and unfiltered bottom water. Higher productivity was observed in those samples having higher percentages of bottom water. Both productivity and the standing crop were found to increase a few percent using admixtures which might correspond to the surface ocean layer near a mining ship discharge.

The presence of sediment in the discharge would tend to enhance productivity. Enrichment experiments showed that accumulation of silicate compounds in the surface layer could alter the species composition as could the introduction of dormant organisms from the ocean floor.

Amos et al (1972a, 1972b) studied hydrographic conditions and made diffusion experiments in connexion with a field test of an airlift mining system in the Blake Plateau area of the western North Atlantic. Analysis of hydrographic data at the test site revealed that bottom water raised adiabatically to the surface would be denser at all seasons but if warmed to surface water temperature would be less dense in winter. By using a dye tracer in the effluent it was found that deep water brought to the surface underwent sufficient warming and mixing to remain in the upper layer after discharge.

The growth of phytoplankton was observed in varying mixtures of surface and bottom waters. It was determined that a mixture of at least 10% mining effluent (bottom water) with 90% surface water is necessary to increase significantly phytoplankton growth. It was estimated that full scale mining activities using the airlift pumping system would result in a surface water mixture containing less than 0.3% deep water and would therefore be insignificant in terms of enhancement of surface productivity.

Additional baseline surveys were undertaken in 1972 in the Pacific metal-rich nodule zone in connexion with tests of the continuous line bucket dredge system (Roels et al, 1972, Roels et al, 1973). Hydrographic profiles reveal a salinity and turbidity structure in the bottom few hundred metres indicating a moderately active circulation. Profiles of nutrient concentration, trace elements and particulate carbon and nitrogen were made.

Bottom photographs revealed an epibenthic population density of 0.02 to 0.05 per square metre, values considerably lower than earlier estimates. Attempts were made to observe the effects of the CLB dredging operations, but with the exception of one photograph showing possible striations on the sea floor, none was observed.

Another baseline survey in the potential minesite area of the Pacific was conducted in 1974 (Amos et al, 1975). Intensive physical, chemical and biological sampling was carried out within a small area under precise navigation control. Bottom photography again revealed very low organism density ($0.01/m^2$). Current measurements at 2000, 1000 and 200 metres above bottom over a 14 day period showed increased velocities toward bottom. Current directions were towards east northeast and distinct semidiurnal current peaks averaging 7 cm/sec were observed; the highest peak was 20 cm/sec. Profiles of light scattering showing a slight increase in the bottom 1200 metres are consistent with the current measurements and indicate transport and/or resuspension of bottom sediment.

Enrichment experiments using varying percentages of bottom water and surface water confirmed earlier results: only when mixtures exceeded 33% of bottom water (and contained bottom sediment) did the phytoplankton productivity become significant.

The NOAA Deep Ocean Mining Environmental Study (DOMES) plans to continue baseline investigations in the eastern equatorial North Pacific prior to full scale mining activities (NOAA, 1975). Their main goals are:

1. To identify potential environmental problems with respect to existing regulations.

2. To acquire information which will help establish environmental guidelines for industrial deep ocean mining practices.

Mining Pollution Compared to Natural Models

Environmental baseline information in potential manganese nodule mining areas is an important requirement in assessing possible pollution arising from deep ocean mining but definitive results may not be available for some time. For the present, "order of magnitude" estimates of certain effects can be made from existing information. In some cases, natural phenomena which are analogous to mining disturbances can provide very useful models.

The radiolarian ooze sediments in the nodule-rich Pacific area (Sverdrup et al, 1960) consist of about 50% remains of radiolarians (including entire radiolarians with dimensions of 100-200 microns) and 50% mineral particles (silt to clay size particles less than 50 microns diameter). Once disturbed, sediments in the silt size range and below can be transported by bottom currents as small as 1 cm/sec. The displacement of silt particles (0.06 mm diameter) settling through 100 metres of water in a current of 10 cm/sec will be approximately 3 kilometres (Kuenen, 1960).

Amos et al (1975) have measured near bottom currents in the potential mining area and find (at 200 metres above bottom) average velocities of 1 to 2 cm/sec with peaks up to 20 cm/sec. Broecker (1968) has measured a profile of excess radon and calculated an eddy diffusion value of 15 cm^2/sec in the bottom 50 metres of the ocean at a station near the centre of the high-value Pacific manganese nodule zone. If these measurements represent true averages for horizontal currents and turbulence in this region of the ocean, one would expect the larger silt-size particles to settle within a few kilometres of the mining disturbance while the clay-size particles could be transported much greater distances.

Results of natural processes which introduce large quantities of sediment at the ocean surface and the deep sea floor can be studied to gain an understanding of their environmental impact in comparison to that of mining.

Heezen and Ewing (1952) and Heezen et al (1954) described large scale geologic effects of slump-generated turbidity currents resulting from the Grand Banks earthquake of 1929. This event caused the movement of large quantities of sediment from the Continental Slope near Newfoundland to be spread over a broad area of the North American Basin. Subsequent studies have shown that turbidity currents are a fundamental process in submarine geology and are in fact the chief agent responsible for covering vast areas of ocean basins with turbidite sediments, sometimes thousands of metres thick, making the Abyssal Plains the flattest areas on earth.

An example of the rate of turbidite sediment accumulation is given by Benson et al (1970). Geophysical measurements in the Vema Fracture Zone in the equatorial central Atlantic show a sediment thickness of more than 1000 metres. The section was sampled on Leg IV of the Deep Sea Drilling Project to a depth of 610 metres revealing an average sedimentation rate of 30 centimetres per 250 years. It is noteworthy that this vast quantity of sediment appears to have moved by turbidity current flow across the Demerara Abyssal Plain from a source near the Amazon Cone, more than 800 kilometres to the southwest.

The scale of the Grand Banks turbidity current of 1929 has been estimated by Kuenen (1952). He calculated that a turbidity current moving down the Continental Rise 500 kilometres from the initial slump was probably 3.5 kilometres long, 350 kilometres wide and 100 metres thick. This rapidly moving flow contained 100 cubic kilometres of sediment which settled as a layer 40 to 100 cm thick over more than 100,000 square kilometres of the floor of the North Atlantic Basin. By comparison, it is estimated (NOAA, 1975) that a manganese nodule mining operation raising three million tons per year of nodules might cause resuspension of about 23 million cubic metres of sediment (Welling, 1972 estimates about 1/2 this amount) due to the action of the dredge head. Such a quantity represents 0.023% of the amount of a single documented natural turbidity current. Expressed differently, it would take 40 such mining operations working for 100 years to make a comparable sediment redistribution.

Using submarine geologic evidence and records of sea floor cable breaks, Heezen and Hollister (1971) show that turbidity currents are a frequent and widespread phenomenon. In the area of the mouth of the Congo River, turbidity currents occur intermittently at a rate of 50 per century. Surprisingly, in some respects the areas affected seem to return to normal within a short time. In commenting upon the post-turbidity current conditions in the Congo Submarine Canyon, Heezen and Hollister (1971) write:

> "How long they (bottom organisms) require to track the newly deposited mud is difficult to determine, and is probably highly variable, but the time must be measured in days and weeks, not in years. Photographs taken on the natural levees and in the floor of a distributory channel of the Congo Canyon revealed a muddy, burrowed, and tracked sea floor without obvious evidence of any recent catastrophic event. Although a turbidity current may not have traversed this particular distributory for several years, one might not have observed a very different sea-scape even if this channel had experienced a turbidity current a few weeks before the picture was taken."

To access the recovery rate of benthic communities buried by sediment in a manganese mining operation, abyssal areas affected by recent turbidity current deposition should be studied and compared with comparable areas not similarily affected (e.g. abyssal hills).

Examples of large scale introduction of sedimentary material into surface ocean waters can also be found in nature. The rivers of the world contribute 20 billion tons of suspended sediment annually to the world ocean (Holeman, 1968). While most of this material settles out and deposits near river mouths, significant amounts are carried in the near surface ocean layer to the deep sea.

The Amazon has the largest water discharge of any river in the world ($6,400 \times 10^3$ cfs) and carries 400 million tons of suspended sediment annually into the South Atlantic Ocean (Holeman, 1968). By virtue of its decreased salinity, admixtures of Amazon water and surface ocean water can be traced northward into the Caribbean Sea (Wust, 1964). Jacobs and Ewing (1968) have identified suspended particulate mineral material of Amazon River origin in the near-surface waters of the Caribbean, 3000 kilometres from the river mouth. It would appear that useful analogies could be drawn between the effects of surface discharged mining effluents in open ocean and the effects of suspended particulate materials reaching the deep sea as a result of river discharge. The use of high-quality satellite photography and imagery represents a valuable new method which could be applied toward the selection of sites for such studies.

Monitoring of Mining Activities

Baseline environmental studies of the United States NOAA appear to represent a timely and considered pre-mining inventory. However, the most meaningful studies for pollution assessment must await actual mining operations. When that phase begins, careful monitoring of the disturbances should be carried out. In addition to the more standard measurements, consideration might be given to the following:

1. Sediment traps on the ocean floor to measure sediment redistribution associated with the bottom plume.

2. Direct observation of actual mining operations on the sea floor using a manned submersible vehicle (if safety considerations permit).

3. Measurement of the aerial distribution of the surface plume using aircraft photography techniques.

4. The use of dye tracers (injected into the mining effluent outfall) to measure the 3-dimensional extent of the plume. _In situ_ measurements of rhodamine dye can be made using a continuously recording fluorometer (sensitive to concentrations as small as 10^{-11}).

5. Measurements of a combination of natural tracers to establish separately the patterns of distribution of the effluent particulate content and the water phase. Optical measurements (nephelometer or transmissometer) could establish the distribution of the particulate phase. Radon, dissolved silicate, tritium, C^{14}, O^{18} (or other water tracer) could be measured to distinguish the effluent water distribution by virtue of the differences in the normal concentration of these substances between surface and bottom waters.

Summary and Conclusions

Although detailed understanding of the distribution of manganese nodules on the ocean floor is incomplete, the major deposits appear to have been delineated. Deposits having the greatest economic potential exist in deep ocean basin areas. The manganese nodule deposits considered most favourable for initial exploitation lie in the eastern equatorial North Pacific. Methods for economic exploitation of the resource are in an advanced state of development. Active mining operations are expected to begin in the Pacific area before 1980. Pollution arising from ocean mining might affect both the surface and bottom ocean environment. Scientific baseline surveys are underway in the Pacific as part of a long-range ocean mining environmental impact study. Preliminary results suggest that no serious pollution will arise from manganese nodule mining activities at the scale presently projected. Large-scale natural phenomena analagous to ocean mining pollution can provide useful models for predicting future mining impact. Manganese nodule deposits of the ocean floor are, in certain areas, rapidly changing from the classification of resources to reserves. A unique opportunity exists to establish international regulations which would promote orderly development of these reserves and ensure against adverse environmental effects arising from their exploration and exploitation prior to the advent of large-scale mining activities.

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Appendix II

Dispersion of Fine-Grained Material and Other Physical Aspects

Note: 1. This Appendix has not been examined or accepted by GESAMP.

2. The original draft for this Appendix was prepared by Gunnar Kullenberg.

3. The working group examined and amended this report during the intersessional period and had approved its presentation to GESAMP.

INTRODUCTION

Aspects of the dispersion problem are considered. In doing so some relevant features of circulation, transport and sediment dynamics are discussed without going into details. It should be emphasized that an understanding of relevant physical processes is essential for rational environmental planning and protection. In this note the possible biological effects of variations of turbidity caused by various operations and disturbances on the sea floor have not been considered.

I. DISPERSION OF FINE-GRAINED MATERIAL IN CONJUNCTION WITH DREDGING OPERATIONS

Dispersion is defined as the net effect of turbulent mixing and transport by currents. It is necessary to consider separately dredging in nearshore and offshore waters.

A. Beach dredging and excavation: Dispersion along beaches is primarily governed by the wave conditions and to a lesser extent by currents, e.g. generated by meteorological forcing or tides. The nearshore region is subdivided into swash, surf or breaker and offshore zones (e.g. Hails 1974). The former covers the area where the residual wave motion consists of surges up and down the beach face. The surf zone is the area where the wave energy dissipation essentially takes place. The last zone extends from the breaker line to the depth at which frequent disturbance of bed sediment by wave motion occurs. In relation to this division it is pertinent to consider three aspects of the nearshore dispersion (Bowen and Inman 1974):

(i) Processes occurring seaward of the breaker line (in the offshore zone). In this region the mixing induced by agents other than waves will normally dominate.

(ii) In the surf zone the breaking waves generate strong vertical and horizontal mixing. The transport across the breaker line is considerably more effective than the longshore transport.

(iii) The dispersion due to the nearshore circulation cell, covering the width of the surf and swash zones, and consisting of longshore flow with seaward flow concentrated in rip currents. On a plane beach the spacing between the rip currents is of the order of four times the width of the surf zone. Thus water and suspended matter are transported into the surf zone by the breaking waves, carried alongshore and returned by the rip currents. These are very strong, of the order of 100 cm/s up to 300 m or more from the shore, and consequently have considerable transporting and eroding capacity.

The important aspect of this picture is the limiting of effective dispersion to the surf zone. This is in part due to the less intense turbulence outside the breaker line, but mainly due to the transport (pumping) of offshore water through the breaker line into the nearshore circulation cell. The longshore mixing is less intense than the mixing in the breaker zone and the material is mainly transported with the longshore current, spreading along the beach. Very little spreading occurs upstream of the current. However, the direction of the current is influenced by the direction of the incoming waves, and therefore spreading of material on either side of the dredging site must be expected.

We may estimate the volume in which the released material becomes diluted over a time period of the order of hours. The height (depth) of the surf is H_b, the width of the nearshore circulation cell is B_b and the length of the cell (i.e. spacing between rip currents) is L_b. The observations on straight beaches suggest that:

$$L_b \approx 4\,B_b \text{ and } B_b \approx (10 - 100)\,H_b$$

with $0.2\text{ m} \leq H_b \leq 2\text{ m}$. Thus we have the volume $V \approx H_b \cdot 4 \cdot 50 \cdot 50H_b \cdot H_b$. With $H_b \simeq 1$ m the volume is $10^4\ m^3$. With a dredging of 100 tonnes per hour and a 1% overflow of solid material, this implies a turbidity of the order 100 mg/l. Thus the increase of turbidity is quite significant. The estimate depends, however, very much on how much fine-grained material actually is washed overboard with the overflow. The dredging technique has considerable influence in this context.

Observations suggest that the longshore transport of sand is directly proportional to the longshore component of wave power independent of the grain size. This indicates that the bed load transport is important. It also appears that the finer grain sizes are transported offshore more effectively than coarser grains for the same wave conditions.

Theoretical models for predicting the longshore currents and sediment transport depending upon wave conditions and other parameters are available, but the verification of these models is unsatisfactory due to lack of reliable data (Hails 1974).

On-offshore transport in the breaker zone occurs as both suspended and bed load. Outside this zone, in the offshore zone, the sediment transport is mainly bed load, the energy dissipation being caused mainly by bottom friction.

Different kinds of waves have different transporting properties. Generally short, steep waves generated by onshore winds have a stronger tendency to carry material offshore than onshore (so-called destructive waves). Longer waves on the other hand, generated by distant storms tend to carry material towards the beach (constructive waves). The nature of the wave, its size, the profile and the composition of the beach all influence the action of the wave on the beach.

Normally the waves approach the beach obliquely which results in coastal drifting, i.e. longshore transport of material along the bed. This process can act as a sorting agency separating different grain sizes. It would lead too far to discuss all these processes in detail. Clearly they should be considered in each separate case.

For depths exceeding a few metres the information available on transport by wave action of suspended sediments is limited. Observations show that surges with velocities above 30 cm/sec cause temporary suspension of sand grains (Hails 1974).

For the offshore region, to depths of say 30 m, an important aspect is the presence or absence of sand bars. The formation of these is generally believed to be related to waves, in particular edge waves (i.e. trapped surface waves). In general these sand bars are fairly fixed in relation to water depth and therefore tend not to occur where the tides are appreciable.

Breaking waves often generate sand banks. These are built gradually on the offshore side of the breaker line, and they will have considerable influence on the material budget of the beach, modifying the flow patterns and the transport.

A reasonably safe assessment of the possible effects of nearshore dredging requires information on:

(a) wave (including swell) and current conditions, longshore energy flux and the distribution and dissipation of wave energy,

(b) depth of water and variations of the still water level (e.g. tidal range),

(c) wind and meteorological conditions, particularly occurrence of storms and storm surges,

(d) sediment composition and bulk characteristics,

(e) topographic features, as slope, curvature and plane of beach, occurrence of bars.

Seasonal variations of certain conditions should be taken into account. In this connexion the considerable differences in natural stress in different climates should be observed.

Dredging can change the topographic conditions and thus the wave pattern and the on-offshore material transport. This is a very important aspect (e.g. Jolliffe 1974), although there are few recorded cases of coastal erosion due directly to sand and gravel extraction. This may well be due to the limited research going on in relation to dredging.

Mathematical modelling, using computers, appears to be a very promising tool for forecasting the shape and rate of change of the beach, the longshore sediment transport and areas of increased erosion. Clearly relevant input data must be available for making a reliable prediction.

Turbidity currents and/or sliding can be very effective means of transporting material offshore in areas of some slope, say 2 - 3° or more. The possibility of triggering sliding motion or even small turbidity currents artificially should be borne in mind. This is perhaps in particular true for activities along the shelf break or slope, i.e. in connexion with offshore mining.

B. Suction dredging of offshore sand and gravel: We will now consider the region outside the nearshore zone. Due to the depth limitation of the dredging operation (30 - 60 m at present) this does not imply that wave action will not influence the bottom conditions at the site. It is likely that in areas where dredging of this type takes place the currents are quite strong, implying fairly effective dispersion conditions. Clearly the rate of exchange between the site and adjacent sea areas is also important in this context.

Where hopper dredgers or barges are used for the dredging an overflow of water containing fine-grained material will occur, thus causing a resuspension of sediment and an increase of turbidity. When trailing (i.e. under-way dredging), the overflow is initially spread in the wake of the vessel. Commonly experienced dilution factors are in the range 1:500 - 1:2000 at a distance of a few hundred metres from the vessel. Thus the material will become mixed quite rapidly in the surface layer. The subsequent dispersion depends upon the wind and distributions of current and density in the water. Dilution factors in the range 5 - 20 per hour can be expected in open sea areas under normal wind conditions (5 - 15 m/s). In the case of vertically homogeneous water (in areas of strong wind-induced and tidal mixing) the material will be spread over the whole water column. In areas with a stable stratification, on the other hand, confinement to the surface layer is likely. Nearly neutrally buoyant particles can become concentrated in the pycnocline region, (layer of increased stability) where the mixing is considerably suppressed.

When the dredging vessel is stationary during the operation the initial dilution of the overflow will be less than in the other case. From experience with dumping of sewage sludge one may expect dilution factors in the range 1:100 - 1:500. In areas of homogeneous water a large part of the material will sink directly to the bottom, the rest becoming mixed in the whole water column.

In areas with a marked stratification the sinking rate will be depressed in the pycnocline layer where nearly neutrally buoyant fine-grained material can become trapped at least temporarily. The sinking material will become distributed in a fan-like, layered structure, with considerable concentration variations vertically.

Since the rate of dispersion in these dredging areas generally is expected to be fairly high the increase of turbidity will be limited. An estimate of the increase of turbidity may be obtained as follows. A large dredger may recover say 10^4 m^3 in 5 hours. Assume as a working basis that 1% of the recovered material is lost with the overflow in the form of fine-grained material with a density of 2.5 g/cm^3. Thus we dispose of 50 tonnes per hour in the water, corresponding to 2.5 x 10^4 mg/l overflow.

In the case of dredging by trailing the initial dilution is of the order of 1000 implying a concentration in the water of 25 mg/l a few hundred metres from the vessel. After 5 hours the dilution is another factor of 25 - 100 under normal conditions. The natural suspension in most shelf areas falls in the range 0.3 - 5 mg/l. It may be advisable to adjust the dredging frequency so that the areas of increased particle content do not overlap.

It appears that the dredging operation and frequency can be adjusted so that normally the turbidity increase will have no harmful effects. The maximum concentration in the contaminated areas will decrease roughly proportional to $t^{-2.5}$ for diffusion times of the order of days.

C. Deep-sea mining: Deep-sea mining will generate a local increase of suspended matter in different parts of the water column. The disturbance of the sea floor is obvious. The fate and distribution of the suspended sediments will depend, apart from the technique used, on the type and composition of the sediments, and the physical conditions in the water, especially currents and stratification.

In the wind-influenced surface layer, of the order 100 m thick in the open ocean, the dispersion of the fine-grained material is fairly rapid. It will become more or less evenly distributed in the layer.

An estimate of the concentration of suspended matter can be obtained assuming that the amount of waste sediments brought to the surface is equal to the amount of manganese nodules (taking this as an example of deep-sea mining). Using a figure of recovery of 500 tonnes of nodules / day with a sea floor coverage of 10 kg/m^2 (Mero 1964, p.259), implies that a minimum surface area of 5 x 10^4 m^2, or roughly a square of 220 x 220 m, would be covered in 24 hours. Assume a surface layer current of the order 12 cm/sec or 10^4 m/day, and assume further that the overflow becomes evenly distributed in the top 100 m. Then the dilution volume is of the order 2 x 10^8 m^3, and the concentration of suspended matter (assuming that all goes into suspension) 2.5 mg/l. This is a conservative estimate in the sense that most likely the value is less since not all goes into suspension, the currents can be stronger, etc. After 10 hours the maximum concentration is expected to be in the range 0.05 - 0.01 mg/l.

These values should be compared with the natural concentration of suspended matter in the oceanic surface layer. This is of the order 0.1 - 0.3 mg/l. In a coastal upwelling area (N.W. Africa) the surface layer contains 0.2 - 0.4 mg/l. Very clear ocean water (e.g. Sargasso Sea) generally holds a load of 0.05 mg/l or less.

At present it appears reasonable to expect that the frequency of the operation could be adjusted so that the increase of the surface layer turbidity in the area would be kept at a very low or insignificant level.

However, it is quite conceivable that internal layers of increased particle content will be generated, especially in conjunction with density variation in the water column. Such layers can be relatively persistent in regions of weak turbulent mixing, carrying a substantial load of particles. For this reason the suggested injection of mining effluent into the deeper part of the euphotic layer may be inadvisable.

The dispersion in internal layers of the ocean is not well known. The following statements can be made:

(i) in the main thermocline region the vertical mixing is weak, of the order of 0.1 cm^2/sec against 10 - 1000 cm^2/sec in the surface layer,

(ii) the bottom boundary layer is thin, of the order of metres, and the bottom generated mixing does not penetrate far into the water column except in certain areas where relatively high current velocities persist close to the bottom (e.g. western boundaries).

Since the bottom currents in the abyssal plains generally are weak, the dispersion of the resuspended sediments in the bottom layer will not be very effective (compare estimates on the spreading of leakage material from dumped containers, e.g. NAS/NRC 1962).

A reasonable assessment of the impact of deep-sea mining as far as turbidity increase is concerned requires information on the mining technique, the sediments, the wind conditions, the currents, the density distribution, and the existing content of suspended matter.

II. OTHER PHYSICAL ASPECTS

A. Nearshore (i.e. in the same region as under I.A)

The most serious hazard is effects on the beach material budget. Removal of material by dredging can result in a change of the circulation and the wave pattern. If so, material transport will also be altered. The possible significance of this may be estimated by means of computer model calculations. Similarly a transfer of material from one place to another in relation to construction can result in alterations of the natural transport pattern. These changes and their possible effects should be assessed before any major construction work is initiated. The advance in recent years of computer model calculations makes this quite feasible. It is also advisable to consider what effects removal or alterations of natural bars outside the beach may have on the material supply to the beach. It is clear that these aspects must be considered for each case.

B. Offshore

Dredging will influence the sea-bed topography, creating small-scale disturbances in the sea-bed. The recovery time for these disturbances can apparently be very long, of the order of several years at least (Dickson and Lee 1973). This matter requires further study in other areas.

C. Other constructions

Consideration must always be given to the possible influence of constructions (e.g. piers, harbours, tunnels) on local circulation and wave conditions. Changes in these may result in serious, often unexpected consequences relating to the transport and deposition pattern of sediment material. Again computer simulation techniques are promising tools in this context.

Due regard should also be given to the deposition (dumping) of sedimentary material removed for the purpose of construction, deepening of navigation channels, etc. Reference should be made to the report GESAMP VII/3, by the Working Group on the Scientific Basis for Disposal of Waste into the Sea.

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Appendix III

REFERENCE DOCUMENTS

No.	Author	Title
GESAMP II/11	GESAMP	Report of the Second Session
GESAMP IV/19	GESAMP	Report of the Fourth Session
GESAMP V/10	GESAMP	Report of the Fifth Session
GESAMP V/INF.10	FAO	Possible Adverse Effects of the Exploitation of the Sea-bed beyond National Jurisdiction on Fishery Resources
GESAMP 19	B.W. Halstead	Marine Pollution due to sedimentation
GESAMP 20	J.E. Portmann	Marine Pollution by Mining Operations, with particular reference to Possible Metal-Ore Mining
E/5120	UN Secretary-General	Report on Uses of the Sea
A/AC.138/73	UN Secretary-General	Additional Notes on the Possible Economic Implications of Mineral Production from the International Sea-bed Area
A/AC.138/87	UN Secretary-General	Report on Economic Significance, in terms of Sea-bed Mineral Resources, of the Various Limits Proposed for National Jurisdiction