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JOINT GROUP OF EXPERTS ON THE SCIENTIFIC ASPECTS OF MARINE POLLUTION

(GESAMP)

REPORT OF THE FOURTH SESSION

held at
WMO Headquarters, Geneva
18-23 September 1972

N O T E S

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 Intergovernmental Oceanographic Commission (IOC).

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10 December 1972

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

(GESAMP)

Report of the Fourth Session

Annex IV, page 7, second paragraph, 7th line, replace "paternal" by "potential"

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

Report of the fourth session

(WMO Headquarters, Geneva, 18 - 23 September 1972)

OPENING OF THE MEETING

1. The Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) held its fourth session at WMO Headquarters, Geneva, 18-23 September 1972. The Chairman, Dr. M. Waldichuk, opened the session with a welcome to the experts, to the representatives of the sponsoring agencies, and the observer from IAMS.

2. On behalf of the Secretary-General of WMO, Dr. D.A. Davies, his representative, Mr. N.L. Veranneman, welcomed the participants. He briefly recalled the history of GESAMP, originally established between IMCO, FAO, UNESCO and WMO, later joined by WHO, IAEA and the United Nations itself. In so doing, he thought it useful to re-emphasize the special character of GESAMP which had been established for the sole purpose of facilitating the inter-disciplinary work required to deal effectively with the many aspects of marine pollution, whether it occurs in coastal waters or on the high seas. The Governments represented at the UN Conference on the Human Environment in Stockholm reiterated the views which they had already expressed in the governing bodies of other organizations concerned, and unequivocally stressed the need for an inter-disciplinary approach to marine pollution problems. This approach, however, has raised problems such as the size and diversity of the agenda of GESAMP sessions which, in turn, increased the difficulties of conducting successful intersessional work. These problems must be resolved in the near future if GESAMP is to fulfil its proper role. The solution may well have to be looked for in much more intersessional preparatory work by small inter-disciplinary task teams which would enable successive GESAMP sessions to concentrate on the discussion of specific and hopefully comprehensive proposals. Mr. Veranneman concluded by wishing the session successful deliberations.

3. The agenda of the fourth session, as adopted by the Group, is attached as Annex I and a list of documents is shown as Annex II. Information papers summarizing the recent activities of the sponsoring agencies in the field of marine pollution were available to members of the Group for reference during the session. These documents are also listed in Annex II. A full list of participants comprising experts, representatives, observers and members of the Secretariat, is attached as Annex III.

IDENTIFICATION OF POLLUTANTS OF INTERNATIONAL SIGNIFICANCE

Review of Harmful Chemical Substances

4. The Group noted, with interest and appreciation, Recommendation 88 of the Human Environment Conference which calls on GESAMP to "re-examine annually, and revise as required, its Review of Harmful Chemical Substances with a view to elaborating further its assessment of sources, pathways and resulting risks of marine pollutants..." It was agreed that a considerable number of additions could be made to the present Tables as contained in Annex IV of the Third Session report

and that the explanatory text could be supplemented not only by information on any further substances added to the table, but also by more detailed information on the industrial sources of many pollutants, including production statistics where these can be obtained, in order to illustrate the scale of the problem. The IMCO List of noxious and hazardous cargoes (Ref. GESAMP IV/2 and Supplement 1 to this report) would be particularly useful in many respects.

5. As an on-going activity, the Group would also supplement the Review with relevant technical information on waste disposal and treatment methods and gradually develop broad assessments of the levels of treatment and methods of disposal desirable for harmful substances under particular circumstances (Ref. Agenda Item 7; Annex VI). In the course of work on Annex VI, "Management of Waste Disposal", the working group in question produced new information on the effects of certain substances. This information was incorporated in Annex IV, but will be transferred to the Review in the intersessional period. Special note was made of the need for information on biodegradability, transformation into more basic compounds, and synergism, which were particularly covered under Agenda Item 4.

6. The elaboration of the Review and the regular re-examination of its content was felt to be basic to much of GESAMP's work and therefore merited additional support particularly for intersessional work.

7. The following programme was suggested for intersessional work in 1972/73:

(a) Further elaboration of Table 2 of the Review with respect to organic substances and preparation of explanatory notes. It was agreed at the third session that this was the main task for the Group. Funds were provided for Dr. Cole to meet with a small group of industrial chemists from the United Kingdom to initiate this work. Suitable chemists were located and cooperation was promised but in the meanwhile, at the request of IMCO, a new and urgent task of constructing hazard profiles in respect of substances transported by ships was begun and is to continue later this year. The substances evaluated include nearly 100 organic chemicals, many of which are produced in very large amounts and appear in industrial wastes. Although the hazard profiles produced for use by IMCO cannot be converted directly into ratings in Table 1 of the Review, the amount of work needed to provide such ratings and the appropriate markings in Table 2 has been very much reduced. The task of providing explanatory notes on these additional organic substances has also been eased. Moreover, the hazard profiles prepared contain some additional material which can be used to expand slightly the other major categories of pollutants listed in Table 1.

(b) Examination of IMCO report (GESAMP IV/2) and material collected in preparing that report for possible incorporation in the Review. It will be necessary to consider the rationale used to assess hazards arising from the discharge of harmful substances carried in ships (e.g. climatic factors) in order to ensure a consistent approach in both projects. Also, shipping statistics supplied for some of the substances identified in the IMCO report should be studied as a guide to the production of those substances.

(c) Expansion of the notes on radioactive wastes by reference to the IAEA report "Principles for Limiting the Introduction of Radioactive Wastes into the Sea" (GESAMP IV/9).

(d) Examination of a paper prepared by Japan (A/CONF.48/IWGMP 2/Inf. 10) for the Intergovernmental Working Group on Marine Pollution, Ottawa, 1971. This paper relates wastes to specific industrial processes and may be helpful in expanding the notes to the Review.

8. It is therefore recommended that the agreed preparatory meeting with industrial chemists takes place in early 1973 in London with Dr. Cole as Chairman and Dr. J.E. Portmann and Dr. P. Jeffery assisting, if possible, and that additional provision be made for a subsequent meeting of a selected working group of GESAMP to further elaborate the Review in accordance with the intersessional work programme suggested above. This latter meeting was estimated to need 3 working days.

Hazard Evaluation of Noxious Substances Transported by Ships

9. The IMCO Sub-Committee on Marine Pollution, in preparing for an International Conference on Marine Pollution to be convened by IMCO in 1973, noted certain difficulties in utilizing the categories of noxious substances identified by GESAMP at its third session (GESAMP III/19, Annex V) for the development of control measures for operational discharges and for the construction and equipment of ships carrying dangerous chemicals in bulk. In response to the Sub-Committee's urgent request for further information from GESAMP, a special Panel of IMCO and GESAMP Experts had been set up to review the environmental hazards of substances other than oil transported by ships. This Panel met at IMCO Headquarters from 21 to 25 February 1972 and from 26 to 28 June 1972, under the Chairmanship of Dr. H.A. Cole, in order to carry out this task. The report of the Panel, which was submitted to the Group for approval (GESAMP IV/2), indicated that the Panel had developed a rationale for evaluating the hazards of noxious substances which it subsequently utilized in constructing hazard profiles for some 200 selected substances. This work will be continued at a further session of the Panel to be held later this year. A method of evaluating potential discharges had also been developed to demonstrate the relationship between the hazard rating of a substance, the quantity discharged, and the properties of aquatic systems which may be receiving the material.

10. The Group concurred with the views of a working group which, during the session, considered the Panel's report in detail. It was noted that, since the report had been prepared in response to a specific enquiry from IMCO, it contained basic data which were being used in the formulation of technical provisions for inclusion in a draft international convention for the prevention of pollution from ships. The Group agreed that the report was an accurate and scientifically based document which would be particularly useful for the purposes of the 1973 IMCO Conference on Marine Pollution. The Group recognized and approved that, in the absence of sufficient data on threshold concentrations, it had been necessary to use LC_{50} values. It was stressed, however, that, as indicated in the review of bio-assay methods (see paragraph 3.1.1 of Annex IV), there is limited biological significance in such values and that evaluation of threshold concentrations is preferable and should be encouraged.

11. The Group agreed that the rationale, which had been carefully established and was well described, would considerably facilitate the future hazard rating of additional substances on a comparable basis. Subject to two small amendments, the Group endorsed this rationale but realized that there was a real possibility that the hazard ratings would be used for purposes other than those specified in the IMCO enquiry. The Group agreed that a similar approach might well be used in preparing hazard ratings for a variety of pollutants from other sources, the need for which was becoming increasingly apparent. Nevertheless, it was felt that before the present rationale and its table of ratings could be used for other purposes, it would be necessary to include additional or more detailed information particularly with respect to physical properties, bio-accumulation characteristics, persistency in the marine environment, long-term effects on the balance of the

eco-system and the transformation reactions of certain substances.

12. The Group noted that IMCO was using the information contained in the Report as a basis for assigning the substances into appropriate categories for the purposes of the draft convention. Some views were expressed with regard to the interpretation of hazard ratings of substances which bio-accumulate and which might be repeatedly discharged in a given area. These views will be brought to the attention of the experts concerned.

13. Subject to the foregoing considerations, the Group approved the Panel's report which will be issued as a supplement to this report (GESAMP IV/19/Supp. 1)* and used as a reference document for the IMCO Conference in 1973. The Group well understood the need to establish a mechanism for continually updating the list of substances, as recognized by the IMCO Subcommittee on Marine Pollution. It was suggested that GESAMP continue to offer its assistance.

BIO-ASSAYS AND OTHER TECHNIQUES FOR EVALUATION OF LETHAL AND SUB-LETHAL EFFECTS OF POLLUTANTS ON MARINE ORGANISMS

14. A report (GESAMP IV/3) which had been prepared in the intersessional period was presented. This report provided a summary of the present bio-assay techniques and the Group discussed the problem of interpretation of the results of such tests. In the light of Agenda Items 2.2, 5.1 and 9, which are closely related to the subject of interpretation, it was agreed that a working group should be established to discuss in detail the limitations of bio-assay techniques and their role in establishing water quality criteria for the protection of marine organisms.

15. The Working Group met under the Chairmanship of Dr. Berge and was given the following terms of reference:

(a) Definition of the term bio-assay;

(b) Identification of the problems to be answered by bio-assays;

(c) Critical review of the tests available and their limitations;

(d) Discussion of the utilization of bio-assays and other pollution parameters in the definition of water quality criteria (standards); and

(e) Consideration of the report GESAMP IV/2.

16. For the purposes of its deliberations, the Working Group adopted the following definition. Bio-assay is an experiment using aquatic organisms or their individual organs to examine the response (usually detrimental though not necessarily so) to substances or energy added to or subtracted from the water. Also considered to be bio-assays are those experiments where organisms are fed or injected with the substance.

17. The working group found that it was unable to give an adequate consideration to all the problems raised by its 4th term of reference but, in considering this, identified several related problems of a toxicological nature. The working group's report is attached as Annex IV and contains the following main conclusions and recommendations.

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* Copies of this supplement, in English and French only, may be obtained on request from the IMCO Secretariat, London.

18. Although bio-assays appear unlikely to be suitable, in isolation, for the establishment of Water Quality Criteria to protect all uses of the marine environment, they will continue to provide vital information for such purposes. The Group therefore recommends that:

(1) Attention be given to the further development and use of bio-assay procedures, particularly in the fields of pathological, biochemical and physiological effects;

(2) Where it is necessary for various reasons to conduct acute toxicity tests, the continuation of the tests to evaluate threshold concentrations, in addition to the TL values for stated time periods, should be encouraged;

(3) Where possible, analyses should be carried out on the animals killed or surviving bio-assay tests, particularly where bio-accumulation is suspected;

(4) Further use be made of experiments both in the laboratory and in the field to ensure the detection and assessment of synergistic effects of pollutants;

(5) Encouragement be given to an early conclusion to discussions within fisheries organizations such as EIFAC, preferably in collaboration with terrestrial and medical fields of interest, with a view to the production of an internationally agreed terminology for toxicological bio-assay procedures;

(6) Further attention be given by GESAMP to the relative importance of bio-assay results and other pollution parameters for the evaluation of water quality standards to protect different kinds of water use,

(7) The continuation of bio-assay tests to establish the dose-effect relationship for given radionuclides and marine organisms should be encouraged;

(8) Investigations should be made to determine the extent of carry-over of pollutants during the course of desalination;

(9) In relation to the incidence of biotoxin formation, the following studies should be encouraged:

(a) Determination of the ecological factors which might be contributory causes of biotoxin formation;

(b) Standardization of the methods of evaluating the presence of biotoxins; and

(c) Forecasting the occurrence of biotoxin formation.

MARINE ENVIRONMENTAL TOXICOLOGICAL PROBLEMS WITH PARTICULAR REFERENCE TO HEALTH ASPECTS

19. Owing to insufficient time, Agenda Item 4 was not adequately discussed. This was most regrettable because the Group recognized the extreme importance of the toxicological aspects of marine pollutants. It was further suggested that intersessional work would be needed by a group of experts capable of dealing with the broad aspects of toxicology, including carcinogenesis and other long-term effects.

ADVICE ON FURTHER PLANNING AND IMPLEMENTATION OF GIPME AND RELATED SCIENTIFIC SERVICES (cf. Annex IV)

20. In order to promote the international exchange of information on research into the survival and fate of pathogenic bacteria and viruses in the marine environment, the following actions are recommended:

a) The establishment of a directory of laboratories in such research; and

b) The preparation and dissemination of a bibliography of publications dealing with the survival of pathogenic organisms in the marine environment.

Transformation and Degradation of Pollutants by Microbial Activities

21. A working paper (GESAMP IV/5) by Dr. Floodgate illustrated the importance of micro-organisms in the marine biosphere both in terms of biomass, productivity and bio-degradation activity. In discussing related marine microbiological patterns it was indicated that both damage to micro-organisms and their ability to degrade pollutants depend on a large number of variables. These were illustrated by reference to some specific pollutants. The effect of marine bacteria on those introduced in sewage was also mentioned, particularly as regards antibiotic production. As these problems have not yet been adequately covered in the Long-term and Expanded Programme of Oceanic Research (LEPOR), the Group suggested that in the further work in relation to GIPME the role of marine microorganisms should be examined in regard to persistence and transformation of pollutants introduced into the sea.

TRANSPORT AND DILUTION OF POLLUTANTS AND MARINE POLLUTION MONITORING

22. The report of the Working Group on this topic was prepared on the basis of some written and oral presentations on the transport and dilution of pollutants in the atmosphere, in the ocean and across the ocean boundary layer (cf. Annex V).

Pollution of the sea through the atmosphere

23. Information available at present on concentration, fluxes and mechanisms governing pollution of the sea through the atmosphere is largely of an indirect nature (GESAMP-IV/6) and there is urgent need to correlate calculated airborne pollution data with observed quantities at coastlines and over the ocean. Since direct measurements are difficult and may easily lead to errors if not executed with extreme precautions against contaminating the samples on board ship, it was suggested to intensify efforts to gain experience with such measurements on research vessels, preferably on those working on related problems. It was noted that this approach is being followed already in a few cases. It seems important that measurements of individual pollutants should be accompanied, where feasible, by the measurement of relevant parameters such as wind intensity and be combined with comparable measurements of gas exchange and evaporation.

Specification of parameters to be monitored in an evolving marine pollution monitoring system

24. The Group was requested to provide advice to the Joint IOC/WMO Planning Group for IGOSS, and to assist certain research aspects under review by the IOC Working Group on Research as Related to IGOSS. In view of the long-term nature and complexity of this work, the Group proposed to deal with this matter in three phases:

(i) During the current session the Group would identify and advise on the components which could be included immediately in the first phase of IGOSS, because of the availability of methodology and the nature of physical and chemical data.

(ii) When information becomes available on monitoring programmes executed by Governments or developed on a regional basis, the Group would advise on areas where a pilot experiment on IGOSS monitoring could be initiated on the basis of existing national and other systems.

(iii) Progress made under GIPME in biological monitoring (concentrations of contaminants in living organisms, effects on species and aquatic communities would be reviewed and advice given to the Joint IOC/WMO Planning Group for IGOSS on new parameters to be progressively included in IGOSS.

25. The experts agreed with the evaluation of the present state of knowledge and the remaining scientific gaps regarding the physical processes involved as given in the report. Doubts were, however, expressed concerning the specification of parameters to be monitored in an evolving marine pollution monitoring system. It was felt that the main emphasis should be placed on the preparation, for the next session of GESAMP, of a report on the needs for monitoring physical and chemical parameters with special regard to their effect on the distribution of the basic pollutants. The Group's advice on parameters to be immediately included in the IGOSS system would need some further consideration.

Dispersion and movement of pollutants in the sea by natural physical process

26. The interim report, GESAMP IV/7 by Mr. L. Otto, discusses problems relating to the spreading and movement of oil spills on the water surface under the influence of meteorological and oceanographic agents. The Group was informed that a final report will be prepared by the author for a future session of GESAMP, taking into account relevant comments from the sixth session of the WMO Commission for Marine Meteorology.

27. The second paper submitted to the Group (GESAMP IV/17) related to the physical processes responsible for the dispersal of pollutants in the sea in a very broad sense. The Group noted with interest the progress made in the theoretical approach including modelling in the field of experimental meteorology. Particular attention was drawn to the experiments on the movement and dilution processes at very great depths, using dye techniques.

28. The Group came to the conclusion that further studies were needed and that priority should be given to the following problems: study of vertical mixing processes; and correlation of data on transport and dilution of pollutants in the sea with the results obtained by modelling. The need for a report on physical factors governing transport and dilution of pollutants was also indicated; this report would be prepared during the intersessional period.

REVIEW OF METHODS OF SEWAGE AND INDUSTRIAL WASTE TREATMENT AND DISPOSAL

29. At its Third Session, GESAMP decided to begin the task of collecting information on methods of treatment and disposal of sewage and industrial wastes with a view to expanding the scope of "The Review of Harmful Chemical Substances". Two papers were consequently prepared for consideration at the session: GESAMP IV/7.1 "Collation of information on methods of preventing the release to the marine environment of certain potentially harmful chemicals" (WHO Secretariat); and GESAMP IV/16 "Domestic and Industrial Waste" (Dr. E. Føyn). These papers were referred to the Working Group established to undertake this project under the chairmanship of Dr. H. Thompson.

30. The Working Group recognized that there was much published information on the various unit operations and unit processes that may be selected for any given treatment or disposal system and it would not be useful to reproduce such material. Rather, the group would identify the main treatment systems and develop the rationale for determining the applications of various unit operations and unit processes. Therefore, the preliminary paper attached as Annex VI is designed as a basis on which to develop the Review of Harmful Chemical Substances so that it can come to serve as a reliable and comprehensive guideline to the prevention and control of marine pollution. The paper is organized according to the major categories of effects and substances in the Review. It is intended that the economic aspects of this exercise will be considered at a later stage. The Group emphasized that Annex VI should be considered as no more than an introduction to the subject; the report would be used as a working document for substantial intersessional work.

31. Obviously a considerable amount of work will be required, particularly on the relationships between effects and methods of treatment and waste disposal. It is recommended that for the next intersessional period Dr. H. Thompson should continue to develop the section of Annex VI dealing with systems of waste treatment, and should seek the co-operation of other members of GESAMP in the development of the sections dealing with chosen categories of pollutants.

IAEA REPORT ON PRINCIPLES FOR LIMITING THE INTRODUCTION OF RADIOACTIVE WASTE INTO THE SEA

32. The report (GESAMP IV/9) was submitted by Mr. Klimov at a plenary session and discussed in detail in the Working Group 4 (cf. Annex VII)

33. The comments given might be summarized as follows:

(a) The report was thought to be a useful example of an approach to the establishment of limits of disposal not only for radioactive wastes but also for other pollutants disposed of in the sea. Research programmes, as recommended in item 6.1 of the IAEA report, might well be applicable to non-radioactive pollutants. In order to economize in labour and money, research programmes need to be co-ordination by the Organization concerned.

(b) It was noted that the report was developed on the basis of the ICRP recommendations on the effects of ionizing radiation on the human body. It was suggested that future GESAMP activity might follow the ICRP example in working out basic recommendations suitable for non-radioactive substances.

(c) It was felt that careful considerations should be given by GESAMP or other bodies to the impact of ionizing radiation on marine organisms and ecosystems. While this has been done fairly well for assessing the impact of ionizing radiation on man, comparatively little attention has been paid to the marine environmental aspects of the problem. In considering these situations the possible use of bio-assays was explained in Annex IV (WG-1, p.8)

(d) Concerning the register of radioactive waste discharged into the sea there was a suggestion to identify sources of radioactivity released into the water for inclusion in item 5.3 of the IAEA report. Item 5.3 needs to be re-examined and clearly stated.

(e) The opinion was also expressed that the general principles, set out in the paper, should be used as bases for sorting out a definite policy of disposal of radioactive waste into the sea, with specification as to the kind of radioactive wastes which are not suitable for ocean dumping.

Principles for developing coastal water criteria

34. Public health criteria for water quality in connexion with recreation are generally based on E. coli counts. E. coli merely serves as an indicator of the presence of mammalian faecal matter that may be correlated with the occurrence of pathogenic organisms in the water.

35. Some epidemiological studies that have been performed in temperate areas have failed to demonstrate any obvious correlation between E. coli counts in recreational water and the occurrence of diseases among bathers. The situation, however, may be quite different in warmer climates, where the stay in the water and corresponding exposure are much longer.

36. Another important factor that has to be taken into account is that tourists may be more sensitive than local people to the exposure, through bathing water, to certain pathogenic organisms to which they have not developed resistance.

37. For the development of water quality criteria for public health use, carefully planned and executed epidemiological studies on the correlation between bathing water quality and public health are urgently required. At the same time, environmental parameters other than the quality of water should be considered.

38. A working group recently convened in Ostend, Belgium, by WHO considered in this connexion "pH, bathing water clarity, freedom from toxic substances, taste, odour and colour, the absence of settleable solids or visible oil, an adequate level of dissolved oxygen and radioactivity". In the U.S.S.R. and some other countries, the methodology for the development of maximum permissible concentrations of harmful substances in water includes experimental studies to ascertain the degree of harmfulness based on 3 criteria of harmfulness with effects on:

i) the organoleptic properties of water;

ii) the general sanitary régime of water bodies; and

iii) health of the population.

39. When a multiple use of the water occurs, the standard of the area has to be strict enough to protect the most sensitive use. The common experience and opinion of the participants was that when fish and shellfish are to be caught in a recreational area, the standards required to protect fish, and especially shellfish, are much stricter than those needed for bathing purposes.

40. GESAMP called attention to the necessity for increased research on combined actions of harmful substances and the effects that these might have on a wide range of public health concerns.

41. The Group also discussed the idea of a specially planned designation of areas for special purposes. The required water quality standards would then be set in relation to the specific use. This approach was found to have both advantages and drawbacks that could not be evaluated in quantitative terms during the session. It was recommended that the idea of designated uses of certain areas should be explored in some detail, either as an intersessional activity of GESAMP, or by some other appropriate body.

42. Through a recommendation directed to GESAMP by the ACMRR/SCOR/ACOMR/GESAMP Joint Working party on GIPME, the Group had been requested to consider initial criteria to be met from the point of view of effects on marine organisms and ecosystems when establishing test programmes for evaluation of toxicity of industrial pollutants.

43. The Group felt that for each pollutant the ultimate objective must be the establishment of a maximum permissible level for receiving waters related to particular situations. Although this could not be achieved by bio-assays alone, this approach provides important information for the overall assessment of water, quality. The Group recommended that bio-assay techniques should be further developed to satisfy the needs for biological monitoring of pollution, and protection of living resources. It also recommended that results from other working groups known to be considering bio-assay techniques in detail be made available to GESAMP for consideration at its next session.

INFORMATION SERVICE RELATING TO MARINE POLLUTION AND ITS EFFECTS WITH PARTICULAR REFERENCE TO DATA EXCHANGE

44. The Group noted with appreciation the "Progress Report on the Development of an Aquatic Sciences Information System and on Exchange of Data on Contaminants in Aquatic Organisms "prepared by FAO (GESAMP-IV/12). The paper showed that considerable progress has been made in the development of an integrated aquatic sciences information system, along the lines previously reported to GESAMP (GESAMP III/19).

45. The new publication "Aquatic Sciences and Fisheries Abstracts" (ASFA), announced at the Third Session of GESAMP, had been started in July 1971. About 1000 items per month, taken from over 2000 core and fringe journals, are being abstracted and/or catalogued and will be produced by a computer-oriented technique from January 1973 on.

46. The Group discussed and endorsed action taken by FAO in this regard as well as steps towards the establishment of an inventory containing information data on contaminants in aquatic organisms.

47. The Group was informed that a similar information system on medical effects of pollutants is available with WHO, and it was noted that, initiated by the IOC Working Group on International Oceanographic Data Exchange, a Task Team on Interdisciplinary and Interorganizational Data and Information Management and Referral has been set up.

48. The Group urged that all efforts be made to ensure input from governmental agencies concerned with information exchange in this field.

49. Further, the Group discussed the proposed inclusion of non-conventional sources of information in the system, such as drawings, maps, training manuals, and others. Whilst this would be valuable for many users of the information system, the Group felt that special consideration should be given to the risk of uncritical quoting of information of a preliminary and unreliable nature that would be made available.

50. Similarly, while recognizing that the Data Inventory offers a means of access to data which, although perhaps accurate, may never be published, the Group felt that it might be advisable, in order to ensure an acceptable standard of information on data to be referred to in the Inventory, that a central national authority screens such information before submission to the FAO Data Centre.

Advice on Matters Relating to the United Nations Sea-Bed Committee

51. The Group noted the recent steps taken by Sub-Committee III of the United Nations Sea-Bed Committee to prepare draft treaty articles on marine pollution for the Law of the Sea Conference. A working group has now been formed to begin the actual drafting work at the Committee's next session in 1973 and Governments have been requested to submit materials for the use of this group. In view of these recent developments, GESAMP felt that it would be useful to examine some of the consequences of human perturbation of the deep-sea environment.

52. While there is very little knowledge and experience to draw upon in this exercise, it was agreed that the special character of the deep-sea environment would have implications for the Committee's work inasmuch as the scale of effects would vary considerably from that in coastal and shallower waters.

53. In a paper presented by Professor K.K. Turekian (GESAMP IV/14), this variation was well-illustrated with recent data collected on the growth rate of benthic abyssal clams. It was demonstrated by radioactive dating that this deep-sea organism took 200 years to reach maturity and inferred that the recovery rate for such organisms in the deep ocean would be many times slower than rates for coastal organisms.

54. The Group decided to form a small working group, under the chairmanship of Dr. Turekian, which prepared a brief but comprehensive survey of the kinds of effects that might follow perturbation of the deep-sea environment, comparing these with analogous natural processes. The Group's preliminary paper is contained in Annex VII.

55. It was recommended that this working group, led by Professor Turekian, should continue to develop this project intersessionally. As with other working groups, any new information relevant to the further elaboration of the "Review of Harmful Chemical Substances", will be brought to the attention of the other experts involved.

Outcome of the United Nations Conference on the Human Environment

56. The report of the Human Environment Conference was distributed to the Group with a reference to those decisions taken by the Conference which relate to marine pollution and to GESAMP itself (ref. GESAMP IV/15). The recommendations of the Conference concerning GESAMP deal with subject areas which relate to work currently underway, particularly under agenda item 2. Mr. Peter Thacher of the Secretariat of the Conference, in his statement to the Group, stressed the value of GESAMP's work in preparing for the Conference and the important role that GESAMP will play in the future.

57. It was understood that special consideration would be given to ways in which GESAMP could be given the proper support necessary to meet the increased demands which will be made for scientific advice on marine pollution problems.

58. Related information on the preparation of an international ocean-dumping convention (GESAMP IV/15 Add. 1) was presented with special reference to the forthcoming intergovernmental meeting to be convened by the United Kingdom Government on 30 October-10 November 1972. Some scientific considerations pertinent to ocean dumping were discussed in the course of work under agenda items 6 and 11 in particular.

DATE AND PLACE OF THE NEXT SESSION

59. The Group was informed that IAEA would act as host agency for the fifth session which was tentatively scheduled to be held in Vienna from 9 to 14 April 1973.

OTHER MATTERS

60. The Group encountered some difficulty in meeting the long and varied work programme outlined in the Agenda and were, in some cases, dissatisfied with the quality of the work they were able to accomplish in the limited time at their disposal. It was also felt that many items on the agenda had not been developed sufficiently during the intersessional period. The remarks of Mr. Veranneman at the opening meeting were thought to be extremely pertinent in this respect. It was hoped that the sponsoring organizations would provide for much more intersessional preparatory work, through the use of small groups, leaving the annual sessions to concentrate on the major problem areas as identified during the intersessional periods.

ELECTION OF THE CHAIRMAN AND VICE-CHAIRMAN FOR NEXT INTERSESSIONAL PERIOD AND FOR THE FIFTH SESSION

61. The Group unanimously re-elected Dr. M. Waldichuk as Chairman and Dr. H.A. Cole as Vice-Chairman for the next intersessional period and for the fifth session.

CONSIDERATION AND APPROVAL OF THE REPORT

62. The report of the fourth session of the IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP IV/19) was approved as it is.

Annex I

AGENDA

Opening of the Meeting

1. Adoption of the Agenda

2. Identification of pollutants of international significance:

    2.1 Further elaboration of review of harmful chemical substances

    2.2 Hazard evaluation of noxious substances transported by ships (GESAMP IV/2)

3. Bio-assay and other techniques for evaluating lethal and sub-lethal effects of pollutants on marine organisms. (GESAMP IV/3)

4. Marine environmental toxicological problems with particular reference to health aspects. (GESAMP IV/4.1)

5. Marine pollution section of LEPOR

    5.1 Advice on further planning and implementation of GIPME and related scientific services

    5.2 Transformation and degradation of pollutants by microbial activity (GESAMP IV/5)

    5.3 Pollution of the sea through the atmosphere (GESAMP IV/6)

    5.4 Specification of parameters to be monitored in an evolving marine pollution monitoring system

6. Dispersion and movement of pollutants in the sea by natural physical processes (GESAMP IV/7)

7. Review of methods of sewage and industrial waste treatment and disposal (GESAMP IV/7.1; IV/16)

8. IAEA Report on Principles for Limiting the Introduction of Radioactive Waste into the Sea (GESAMP IV/9)

9. Principles for developing coastal water quality criteria (GESAMP IV/10 and 11)

10. Information service relating to marine pollution and its effects with particular reference to data exchange (GESAMP IV/12)

11. Advice on matters relating to the UN Sea-Bed Committee (GESAMP IV/14)

12. Outcome of the United Nations Conference on the Human Environment (GESAMP IV/15)

13. Date and place of next session

14. Other matters

15. Election of Chairman and Vice-Chairman for next intersessional period and for the fifth session

16. Consideration and approval of the report.

Annex II

LIST OF DOCUMENTS

No.	Agenda item	Author	Title
GESAMP IV/1 Rev. 1			Provisional Agenda
GESAMP IV/1 Add. 1			Draft Annotated Agenda
GESAMP IV/2	2.2	GESAMP Panel	Identification of Noxious and Hazardous Cargoes - Report of an Ad Hoc Panel of GESAMP Experts to Review the Environmental Hazards of Substances other than Oil Transported by Ships
GESAMP IV/2 Add. 1	2.2	Technical Secretariat of IMCO	Identification of Pollutants of International Significance - Hazard Evaluation of Noxious Substances Transported by Ships
GESAMP IV/3	3	R. Lloyd/ J.E. Portmann/ K.W. Wilson	Evaluation of Lethal and Sub-lethal effects of Pollutants on Marine Organisms
GESAMP IV/4.1	4	B.W. Halstead	A working paper on Surveillance of Biotoxins in Marine Food Products
GESAMP IV/4.2	4	B.W. Halstead	Concepts of Toxicity Indicator Profiles
GESAMP IV/5	5.2	G.D. Floodgate	Marine Pollution and Micro-Organisms
GESAMP IV/6	5.3	K.O. Münnich	Pollution of the Sea through the Atmosphere
GESAMP IV/7	6	L. Otto	Dispersion and Movement of Pollutants in the Sea by Natural Physical Processes Environmental Support for Operations to Combat Oil Spills

No.	Agenda Item	Author	Title
GESAMP IV/7.1	7	Water Pollution Research Laboratory, Stevenage, U.K. WHO Secretariat	Collation of Information on Methods of Preventing the Release to the Marine Environment of Certain Potentially Harmful Chemicals
GESAMP IV/9	8	IAEA Panel's report	Principles for Limiting the Introduction of Radioactive Wastes into the Sea
GESAMP IV/9.1		J. Brisou	Critères de qualité des eaux littorales
GESAMP IV/10	9	WHO Secretariat	Health Criteria for the Quality of recreational Waters with Special Reference to Coastal Waters and Beaches (Report on meeting at Ostend, Belgium, 13-17 March 1972)
GESAMP IV/11		Professor L. Mendia	Principles for the Development of Standards for the Quality of Coastal Waters
GESAMP IV/12	10	FAO Secretariat	Progress Report on the Development of an Aquatic Sciences Information System and on Exchange of Data on Contaminants in Aquatic Organisms
GESAMP IV/14	11	K.K. Turekian	Can Exploitation of the Deep-Ocean Floors Significantly Perturb the Environment?
GESAMP IV/15	12	UN Secretariat	Decisions of the Human Environment Conference Relating to Marine Pollution
GESAMP IV/15 Add. 1		UN Secretariat	Additional Background Material relating to the Recommendations of the Conference on the Human Environment

No.	Agenda Item	Author	Title
GESAMP IV/16	7	E. Føyn	Domestic and Industrial Waste
GESAMP IV/17	6	ICES Secretariat	Report of the Symposium on the Physical Processes Responsible for the Dispersal of Pollutants in the Sea with Special Reference to the Nearshore Zones, Aarhus, 4-7 July 1972
GESAMP IV/18	5.4	WMO/IOC Secretariat	Joint IOC/WMO Planning Group for IGOSS Paris, 26-30 June 1972
GESAMP IV/19	16		Report of the Fourth Session of GESAMP
GESAMP IV/INF. 1		Technical Secretariat of IMCO	Recent Activities of IMCO in the Field of Marine Pollution
GESAMP IV/INF. 2		Technical Secretariat of FAO	Summary Report of Activities of FAO in the Field of Marine Pollution
GESAMP IV/INF. 3		Technical Secretariat of UNESCO	Recent Activities of the IOC and UNESCO in the Field of Marine Pollution
GESAMP IV/INF. 4		Technical Secretariat of WMO	Recent Activities of the WMO in the Field of Marine Pollution
GESAMP IV/INF. 5		Technical Secretariat of WHO	Summary of WHO Activities in the Field of Coastal Pollution and its control - 1972
GESAMP IV/INF. 6		Technical Secretariat of IAEA	IAEA Relevant Activities during the Period March 1971 - August 1972
GESAMP IV/INF. 7		Technical Secretariat of UN	Activities of the United Nations in the Field of Marine Pollution

Annex III

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Annex IV

BIO-ASSAYS IN RELATION TO WATER QUALITY CRITERIA

(Working Group 1 - Agenda Items 3, 2.2, 5.1 & 9)

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CONTENTS OF REPORT

1. INTRODUCTION

In considering the usefulness of bio-assays, the Group adopted the following definition for its purposes. A bio-assay is an experiment using aquatic organisms or their individual organs to examine the response (usually detrimental though not necessarily so) to substances or energy added to or subtracted from the water. Also considered to be bio-assays are those experiments where the organisms are fed or injected with the substance.

For the particular purpose of their deliberations of the agenda item 3 referred to it, the Group restricted its considerations to the assessment of lethal and sub-lethal effects and to a large extent therefore ignored whole ecosystem effects.

2. IDENTIFICATION OF THE PROBLEMS TO BE ANSWERED BY BIO-ASSAYS

The Group concluded that bio-assay techniques had been used up to now mainly as an instrument in attempts to protect economically important living resources and that less attention had been paid to the possibility that other species which might be more sensitive, on which they may depend, were not protected.

The Group considered that, in the future, bio-assays would be used in addition as one of the tools in attempts to protect the aquatic environment as a whole and also as a means of ensuring the acceptability of marine resources as food or for other usage by man.

The Group recognized that there is a risk of confusion in the definition and terms used in the various fields of toxicology. However, the Group were aware that several groups of specialists, e.g. in fishery bodies such as EIFAC, were expected to produce detailed definitions of the terminology used in aquatic bio-assays in the near future. The Group considered that every encouragement be given to an urgent conclusion of such discussions, which are expected to result in an international glossary, preferably with collaboration between the aquatic, terrestrial and medical fields of interest.

3. CRITICAL REVIEW OF THE TESTS AVAILABLE AND THEIR LIMITATIONS

In reviewing the bio-assay procedures presently available, the Group based its discussions on the preparatory paper GESAMP IV/3 by Lloyd, Portmann and Wilson. Much of the information on which the conclusions and recommendations are based is derived from freshwater studies, mainly because the literature and experience in this field is greater than that in marine research. However, the basic principles involved in bio-assay are common to both marine and freshwater research.

The Group considered the information which can be obtained from acute and chronic toxicity tests, sub-lethal tests and field observations, and the extent to which the data obtained can be used in the preparation of water quality criteria for marine animals (excluding birds and mammals).

3.1 Acute toxicity tests

The various technical procedures used for toxicity tests are well known and will not be described here, except to point out that, if results of such tests are to be of any value, the concentration of pollutant used must be firmly established and be constant. Although for many poisons similar results can be obtained from static and continuous flow tests, the latter are to be preferred for those toxic substances which are either volatile, biodegradable or absorbed/adsorbed by the test animals or apparatus. A satisfactory compromise can often be achieved without recourse to complex continuous flow apparatus, if the solutions are completely changed at intervals of 12 to 24 hours.

The most frequently recorded response of the organisms in a toxicity test is mortality; in many cases this is a clearly defined "end point" although for some organisms the stage of morbidity taken as mortality needs to be clearly described. Less commonly recorded is loss of equilibrium (overturning time) which may be of importance for those poisons which have an anaesthetic effect at concentrations well below those found to be lethal and which, in the presence of a less sensitive predator, could result in mortality in the natural environment. On the other hand, immobilized animals may be carried by water currents or sink by gravity away from the polluted zone and subsequently recover.

It is usual in aquatic animal bio-assay tests to expose animals to a given concentration of a chemical and to define results in terms of that concentration. This is in direct contrast to tests with mammalian or avian species where frequently the test animal is fed, or injected with, a stated amount or dose of a chemical. There is considerable value in obtaining the concentration/response curve for the poison under the specific test conditions, which requires that observations of the test apparatus should be made at frequent intervals to record the individual survival times so that for each concentration the median survival time can be calculated.

Somewhat less information can be obtained from an inspection for mortalities at infrequent fixed intervals from which LC_{50} values for these times can be derived, i.e. at 6, 12, 24, 48, 96 hours. Ideally, the test should be continued until a threshold concentration (where the concentration/response curve becomes parallel to the time axis) is established; this may be after a few hours or may take several days, or, in exceptional circumstances, may not be obtained even after several weeks. There is no special biological significance in the fixed time intervals of 48 or 96 hours which have been commonly used. The range of resistance within the test population can be established, e.g. by evaluation of LC_5 and LC_{95}.

3.1.1 Value of toxicity tests

The shape of the concentration/response curve can give some indication of the reaction of the test organism to the poison; for example, if a threshold concentration can be obtained in an experiment lasting a few hours such as found for ammonia and freshwater fish, or acids and marine animals, it is possible that the organism has adapted physiologically to the imposed stress. A threshold LC_{50} arrived at after a few days implies the presence of a detoxification mechanism which is overloaded at higher levels, e.g., phenols and marine animals, whereas the absence of a threshold concentration suggests that a detoxification mechanism is almost or completely lacking and the poison slowly accumulates in the tissues until a toxic level is reached.

Toxicity tests can also be used to provide data on the effect of various environmental variables on the toxicity of poisons and the resistance of the test organisms to them. For example, some toxic substances dissociate in water into an ionized and an un-ionized fraction, of which only one form may be toxic and the requisite toxicity information can only be obtained by performing a series of tests at different pH values and temperatures and comparing the threshold LC_{50} values obtained. The chemical form the toxin takes has an important influence on its toxicity, particularly in sea water where it may be altered by the presence of other ions.

Effects of temperature on the resistance of animals to poisons can be determined in the same way; generally, survival times are shorter at higher temperatures although there are exceptions. Also, although threshold LC_{50} values for a poison may be similar for a range of higher temperatures, some species of freshwater fish, for instance, are more susceptible to some poisons at temperatures below 5°C.

Similar data can be obtained for the effects of dissolved oxygen concentrations and different salinities.

Acute toxicity tests have been used to measure the effect of mixtures of poisons; for freshwater fish it has been found that, using equitoxic concentrations of 2 or 3 poisons, a threshold LC_{50} for a mixture is obtained when the sum of fractions of the individual threshold LC_{50} equals unity. This additive principle has been used with success in predicting the toxicity of effluents from their chemical analysis, where good agreement was obtained with the observed toxicity. Toxicity tests can usefully be used for comparison of a group of very similar substances, e.g. oil dispersants; the results of toxicity tests with widely different chemicals, e.g. an acid and DDT, should not be compared too closely. Finally, toxicity tests can be used to measure the difference in the resistance of various species to poisons, and the susceptibility of different stages in the life cycle of each species. Here again, although one species or development stage may be more resistant than another in the short term to acutely lethal levels, it may have an equal or greater sensitivity over a longer period of exposure.

So far only the steady concentration of toxic substance in solution has been considered. Information on residue concentrations in the animal is also important, particularly where death is suspected to be the result of a long-term accumulation of a chemical. This is especially important for persistent chemicals such as organochlorine pesticides which may enter the environment by a variety of routes and which can be taken up by aquatic life, either directly from solution or through the food chain. There is little information on the toxicity of fluctuating concentrations of poisons on aquatic animals.

It is essential that, in reporting the results of toxicity tests, information should be given on the temperature, pH value, dissolved oxygen concentration and salinity, the developmental stage of the species used, the LC_{50} values for several time intervals up to the threshold LC_{50} value and, if possible, the tissue concentration associated with mortality at selected time intervals. This information will enable a better comparison to be made of the data obtained from different research laboratories. However, it should be remembered that there is no simple factor which can be applied to any stated set of LC_{50} values to define a "safe" concentration since the "application factor" will vary according to the selection of test animals, the chemical involved, the area of release and the particular resource or animals it is desired to protect. Furthermore, there is no common ratio between the threshold LC_{50} for poisons and the level of no effect for any given species.

3.2 Sub-lethal tests

In recent years there has been a considerable upsurge of effort in measuring the responses other than the lethal effects of poisons, but so far no single test has been shown to be of itself capable of giving information on which water quality criteria can be based, and frequently the meaning of the demonstrated response in ecological terms is either unknown or doubtful.

The Group considered the following sub-lethal tests:-

3.2.1 Biochemical studies

Most common of these are studies on enzyme induction and inhibition; such experiments are useful if they shed light on the nature of the toxic action which may then provide a wider understanding of effect of the poison on the animal and lead to the prediction of important side-effects. But too often the significance of the results in terms of effect on the viability of the animal or species is not given, nor can it be readily obtained.

3.2.2 Studies of pathological effects

Prepared sections of tissues and organs from animals exposed to lethal and sub-lethal levels of toxic substances can give an indication of the site of toxic action, particularly where the tissue damage is severe for example, the destruction of the gill epithelial tissue of fish exposed to acutely lethal levels of heavy metal salts. It becomes more difficult to assess the significance of slight tissue aberrations in that these may be the result of adaptation by the organisms to the stress imposed by the pollutant. Any such tests should show both the existence of a graded response and the concentration of poison which represents a level of no effect. Techniques are now available to allow the quantification of such histological effects and these should become more widely used, e.g. electron microscopy in providing early warning of possible carcinogenic, mutagenic and teratogenic effects.

Histochemical studies could be useful if the target organ of the poison is either small or cannot readily be excised for chemical analysis, and such data, coupled with other sub-lethal tests, could be useful in monitoring programmes.

Haematological parameters have been measured to assess a sub-lethal response and such studies may increase in value with more experience in the interpretation of the results.

3.2.3 Physiological effects

Under this heading come tests on the effect of poisons on the ability of organisms to osmoregulate, to adapt to temperature changes, and changes in heart and respiration rates which may be brought about by changes in nervous potential as a result of changes in water quality. Again it is important to demonstrate that the reaction being studied is of vital importance to the individual specimen and that a graded response exists and that the level of no effect is obtained.

However, such tests are normally of short duration and the possibility remains that longer exposure to sub-lethal levels may affect a different system to a deleterious extent.

3.2.4 Growth rate

Measurements of changes in growth rate have much to commend them, since an organism growing at a normal rate can be presumed to be healthy and it is an important factor for species of commercial importance (many such tests have been carried out using oysters to evaluate the effects, e.g. of pesticides).

For tests with persistent poisons the organism should be first allowed to accumulate them to a predetermined level, otherwise growth rate is measured during a period when the toxic substance rises from zero to a low level in the tissues and the toxic effect may not be immediately apparent. Both food supply and its presentation should be as natural as possible.

3.2.5 Behaviour

Mobile species may actively avoid areas of pollution, and laboratory tests have been made to measure the reaction of an animal to a choice of clean or polluted water. Such tests are normally made in a small apparatus with a clear interface between the two conditions. It is often assumed that animals will avoid a pollutant whereas in many instances, e.g. Crangon crangon with DDT, the animal cannot detect concentrations several orders of magnitude greater than those which are potentially lethal. There may even be an attraction effect as was noted with Crangon and mercury or zinc and roach with trinitrophenol. It is difficult to extrapolate from such data to field conditions, where a sharp interface between clean and polluted water is lacking, and where other stimuli, such as territorial, migratory or feeding behaviour patterns may have an overriding effect.

Other aspects of behaviour, such as learning or physical reaction to stimuli, have also been tested in the presence of poisons. Those in which the species are exposed to a poison for a short period of time and their behaviour pattern then tested may be of doubtful value if the ecological significance of the altered behaviour pattern is difficult to ascertain. Poisons which act on the sensory mechanism of animals may affect the behaviour pattern such as feeding, mating and migration, and may also influence their response to other poisons.

3.2.6 Activity

It has been shown that an increase in activity in fish makes them more susceptible to poisons, but the increase in sensitivity is small. Also, swimming speeds were affected by concentrations only slightly lower than the lethal levels.

3.2.7 Uptake and loss experiments

Where possible, tests should be made on the rate at which toxic substances are taken up from sub-lethal solutions, the equilibrium concentration reached and the rate of loss in clean water. This provides information on the accumulative nature of the poison and on the possible effects of an intermittent exposure to it. Biological magnification can also be studied by means of small artificially established food chains. Such tests can be combined with those made to determine the tissue level associated with mortality. Because of the lack of suitable analytical methods for many poisons, this type of test is at present of limited application, but it represents an ideal to be aimed for. It should be pointed out that certain accumulated substances, e.g. phenol may produce undesirable tainting of fish flesh at concentrations well below the lethal level.

3.2.8 Photosynthetic activity tests

Photosynthetic activity of phytoplankton constitutes the base for the organic life in the marine ecosystem. Inhibition of photosynthetic activity of planktonic algae can be studied with cultures (of single or mixed algae) incubated in bottles, or in the field, using e.g. C^{14} techniques.

This technique gives information on the immediate effect of a pollutant; however, the tests are essentially short-term and give no information as to the long-term effects. Nevertheless, an effect on the rate of photosynthesis should be regarded as a warning, although it should be recognized that the long-term damaging effect could be a change in species composition of phytoplankton rather than a permanent reduction of primary production.

3.2.9 Viability of eggs or larvae

Experience with a number of pollutants has shown that among the most sensitive stages of aquatic animals are some of the early stages of reproduction e.g. survival of planktonic larvae or the hatchability of eggs. These have already been used in bio-assays with economically important fish species, e.g. salmon and herring.

3.2.10 Life cycle tests

These tests are probably more illuminating than any other type, and quite unsuspected effects of poison can be discovered, as in the case of low level of copper and zinc inhibiting the breeding success of at least one North American species of freshwater fish. Not only can fecundity be measured, but also growth rate and resistance to disease. Their drawback is that the number of species that can be investigated in this way is limited and, because of the length of time taken, only a few poisons under a limited range of environmental conditions can be investigated unless considerable experimental facilities are available. Also, the test species are normally exposed to a constant level of poison, whereas this is unlikely to occur in the natural ecosystem.

3.3 Field observations

Studies of the effects of an intermittent or continuous discharge of an effluent can be made by means of ecological surveys or by experiments using caged organisms.

Animals may be killed by a high, transient, concentration of a poison, as from an accidental spillage. In such instances, satisfactory water samples are usually unavailable and it is then necessary to determine the concentration of poison in the tissues of the killed animals. Unless some clues, as to the likely identity of the poison, are available and there is a suitable analytical method, the necessary analysis may be virtually impossible. The results of the analyses of tissues from the dead organisms can sometimes be correlated successfully with similar data obtained from toxicity tests. However, in many instances, particularly in the marine field, such information is not currently available and it must be concluded that in the marine context it is very difficult to attribute any mortalities to a transient discharge, except in exceptional cases.

There are a few cases where an ecological survey of a polluted area can readily provide more accurate and detailed information on the effect of a pollutant than the whole range of laboratory tests. Surveys clearly show the changes brought about in the ecosystem and allow an assessment of their possible deleterious character. The effects of discharges of simple effluents, such as acid wastes to an estuary, can be measured in terms of the status of sessile organisms around the outfall, and, together with the chemical data, correlated with the results of laboratory experiments. However, pollutants rarely occur singly; most effluents contain a complex mixture of poisons, and the contribution of each to the total effect has to be determined, both for effective pollution control, and to provide data on the effects of each poison to reinforce laboratory findings. Also, there is a possibility that the animals in the polluted zone may have undergone considerable adaptation to the poison present.

Experiments carried out in the field provide the best opportunity of ensuring that additive or synergistic effects are not underestimated. For this reason, the use of caged organisms exposed under field conditions should be encouraged. Indicator species and modification of species diversity may also provide useful information on changes which may be taking place in the aquatic environment, either by decrease or increase in populations. Special attention should be paid to the paternal use of coral reef organisms. The coral reefs in tropical waters are an important ecological link in the production of food fishes in the reef areas.

4. UTILIZATION OF BIO-ASSAYS AND OTHER POLLUTION PARAMETERS IN THE DEFINITION OF WATER QUALITY CRITERIA

The Group considered that for each pollutant the ultimate objective must be a maximum permissible concentration for the receiving water, such that the various uses of the marine environment would be completely safeguarded. The most important uses of the sea were considered to be transport; use of water for industrial purposes; use for recreational purposes; use after desalination for drinking water; and use for fishing and aquaculture; it was also recognized that the quality of marine food products should be safeguarded in order to protect human health.

It was agreed that bio-assays could play no part in the evaluation of standards to protect transport interests or the use of sea water for industrial purposes.

The Group were aware that there was considerable interest in many parts of the world in desalination of sea water to produce drinking water. They were also aware that certain substances might not be removed by the process of desalination and that these would have to be analyzed by chemical means. They did not consider that bio-assays would be of much value. Nevertheless, after a discussion of the problem, the Group recognized that there was a need for investigations into the carry over of pollutants in desalination processes, and recommended that attention be given to such investigations.

The Group did not consider that bio-assays could be used to replace any of the tests already applied to maintain the standard of the marine environment for recreational purposes. In their opinion, measures to determine the quality of sea water from a chemical standpoint for the protection of bathers, etc, could most easily be achieved by chemical analyses. It was however pointed out that the effect of certain chemicals, even in trace amounts, might affect skin, eyes, etc, and that this matter had received little attention to date.

They considered that at present bio-assays provided no improvement on existing methods used in microbiology and were aware from the reports presented to them (GESAMP-IV/10 and 11) that there were already standards for the microbiological quality of sea water for recreational purposes which had been discussed by suitably qualified expert panels.

The Group considered that although microbiological standards, e.g. for shellfish, already exist, bio-assays could play a role in protecting the health of man from the effects of contaminants in food products. In particular, they had in mind that bio-assays might indicate the accumulation of a particular substance by the test organism, although they concluded that in many cases precise medical knowledge as to the significance of this in relation to the health of the consumer might well be lacking. They also agreed that although there was at present no proven link between the incidence of cancerous lesions in fish and cancer in man, such changes in fish gave a warning and should be carefully considered.

The Group was aware that the incidence of marine biotoxication was a matter of serious public health concern. There is evidence that in some instances marine biotoxin cycles may be triggered off by chemical pollutants. This can result in a valuable food resource becoming unfit for human consumption. The Group therefore recommends that the following studies be encouraged:-

1. Determination of these ecological factors which might be contributary causes of biotoxin formation;
2. Standardizing the evaluation methods; and
3. Forecasting such a phenomenon.

The Group agreed that bio-assays were most useful in developing standards for the protection of marine organisms regardless of their economic importance. They recognized, however, that even the evaluation of a threshold concentration for a given organism and particular pollutant did not answer the problem of what was a safe concentration, since there may be more sensitive organisms or stages in the life cycle. In addition, there might be bio-accumulation along the food chain. These factors, among others, entail the use of some application or safety factor based on the threshold concentration observed. The use of caged organism experiments was considered one of the best means of establishing whether the application factor used was adequate. In this context, it was pointed out that certain pollutants have been shown to lower the resistance of marine organisms to disease and that the true significance of such findings might well be underestimated.

The Group recommended that bio-assay techniques using micro-organisms and algae should be further developed to satisfy needs for biological monitoring of pollution and for protection of living marine resources.

The Group considered the question of bio-assays in relation to tests with radionuclides and could see no special difficulties. It was agreed that such tests provided a most valuable method of determining the dose effect relationships for a given radionuclide and marine organism.

The Group concluded that the evaluation of a maximum permissible concentration, in order to safeguard all uses of the sea, could not be achieved at the present time by the use of bio-assays alone. Moreover, the Group considered it was unlikely that bio-assays alone could ever be used to produce such a value. However, they considered that bio-assays provide important information in the overall assessment of water quality standards and will continue to do so.

The Group recognized that regulatory authorities urgently need to be able to establish maximum permissible concentrations and recommends that GESAMP at its next session should be given further time to discuss the relative importance of bio-assay results and other pollution parameters presently available. In this respect, the Group were aware that an ACMRR/SCOR Working party was expected to discuss this subject in detail during the intersessional period and expressed the wish to be kept informed of the result.

5. HAZARD EVALUATION OF NOXIOUS SUBSTANCES

The Working Group considered the Report of the *Ad-Hoc* Panel of GESAMP Experts (GESAMP IV/2), which had been prepared in response to a specific enquiry from IMCO and contained basic data to be used in the formulation of technical provisions for inclusion in an international convention for the prevention of pollution from ships. The Group agreed that the Report was an accurate and scientifically based document which would be particularly useful for the purposes of the 1973 Conference on Marine Pollution. The Group recognized and approved that, in the absence of sufficient data on threshold concentration, it had been necessary to use LC_{50} values. They wish to stress however that, as indicated in their review of bio-assay methods, there is limited biological significance in such values and that evaluation of threshold concentrations is preferable and should be encouraged.

The report contained a carefully established and well-described rationale which would facilitate the future hazard rating of additional substances on a comparable basis. Subject to two small amendments, the Group endorsed this rationale but realized that there was a real possibility that the hazard ratings would be used for purposes other than those specified in the IMCO enquiry. The Group agreed that a similar approach might well be used in preparing hazard ratings for a variety of pollutants from other sources, the need for which was becoming increasingly apparent. Nevertheless, it was felt that, before the present rationale and its table of ratings could be used for other purposes, it would be necessary to include additional or more detailed information, particularly with respect to physical properties, bio-accumulation characteristics, persistency in the marine environment, long-term effects on the balance of the ecosystem and the transformation reactions of certain substances.

The Group discussed the problem of interpretation of the hazard ratings at some length and concluded that even after a most careful interpretation, to ensure an acceptable level in the water, there might still be a risk to marine organisms or man under certain special circumstances, e.g. in an area where tank washings of a bio-accumulated substance were repeatedly discharged.

Annex V

TRANSPORT AND DILUTION OF POLLUTANTS AND MARINE POLLUTION MONITORING

(Working Group 2 - Agenda Items 5.3, 5.4 and 6)

Members of the Working Group:

Dr. P.G. Jeffery
Dr. G.N. Kostjanoj (Technical Secretary)
Professor K.O. Münnich (Chairman)
Mr. L. Otto
Professor A.J. Simonov
Dr. G. Tomczak
Mr. N.L. Veranneman
Dr. G.F. Weichart

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1. INTRODUCTION

The group agreed on the following terms of reference:

(i) to review the processes and extent to which pollutants are exchanged between the atmosphere and the marine environment;

(ii) to review the nature of physical processes in the marine environment that are responsible for dispersion and movement which are important in relation to the ultimate fate of pollutants;

(iii) to consider and if possible to define the parameters which are important in the evolution of a monitoring system.

2. POLLUTION OF THE SEA THROUGH THE ATMOSPHERE

Dr. Münnich presented verbally a report outlining the complex problems involved in assessing the exchange of pollutants between the atmosphere and the marine environment. Some progress had been made since his earlier report, summarized in the report of the 3rd session of GESAMP (GESAMP III/19, p.4), and in particular, it was now well recognized that for some pollutants, this route to the marine environment was the principal pathway involved, in terms of total contribution.

In considering this and the following items, the group also took into account the relevant recommendations of GIPME (FAO Fisheries report No. 112).

The knowledge of pollutant aerosol production coupled with measurements of the deposition velocity, enables pollutant life times to be calculated, but there is an urgent need to correlate pollutant data obtained in this way with experimentally-determined quantities.

It was also noted that further work is required on the scavenging efficiency of rain water in the transport of gases, vapours (especially those of low vapour pressure such as pesticides) from the atmosphere to the marine environment.

The role of airborne material in the form of small particles of, for example, clay minerals was discussed in relation to the ability of such matter to carry adsorbed pollutants into the marine environment. In addition, reference was made to the use of talc as a carrier for pesticides.

The pollutant transfer through the air/ocean interface is in principle determined by thin quasi-stagnant boundary layers adjacent to both sides of the interface. It was noted that on account of low concentration levels and the difficulty of assessing mass transfer across the interface, the ability to measure the contribution to marine pollution by direct transport from the atmosphere is still limited. Further work in this field is indicated, and in particular in respect of methodology, for simultaneous monitoring across the ocean-atmosphere boundary layer.

The group considered the recommendations of the third session (GESAMP III/19 §19). The group was informed of the ongoing activities under the GEOSECS Programme designed to provide better global data on ocean chemistry and environmental radioactivity (GESAMP IV/6). A few cruises under

GEOSECS /METEOR cruises No. 23 (1971) and 32 (1973/ also include an air chemistry programme (aerosols, trace gases) primarily directed to natural substances and only gradually including pollutants.

The group endorsed the GIPME recommendation that when suitable methods have been developed, their use should be encouraged, first on individual vessels, and later on multiship programmes, such as the GARP Atlantic Tropical Experiment (GATE) scheduled for 1974. A goal for the study of atmospheric transport of pollutants could be to perfect the methods and design an observational programme for incorporation in GATE in 1974.

3. DISPERSION AND MOVEMENT OF POLLUTANTS IN THE SEA BY NATURAL PHYSICAL PROCESSES

The group took note of the following papers:

Doc. GESAMP IV/7:	L. Otto	Dispersion and movement of Pollutants in the Sea by Natural Physical Processes; Environmental support for Operations to Combat Oil Spills
Doc. GESAMP IV/17:	ICES	Report of the Symposium on the Physical processes responsible for the Dispersal of Pollutants in the Sea with Special Reference to the Nearshore Zones, Aarhus 4-7 July 1972

and of oral presentations concerning these papers. In addition, Dr Simonov gave an oral presentation on various aspects of the transport and dilution of marine pollutants by physical processes.

The group noted with interest Doc. GESAMP IV/7. It was informed that this constituted an interim report and that the final report would be prepared for submission to a future session of GESAMP when answers had been received to some of the questions raised in it. For the latter purpose it was understood that the interim report would also be considered by the 6th session of the WMO Commission for Marine Meteorology.

It was noted that the papers presented at the Aarhus Symposium which, to a great extent, related to processes in the nearshore zone, showed that certain progress has been made both in experimental methodology and in the theoretical approach including modelling. It appears, however, that there are still some gaps in knowledge, especially a need for further studies of vertical mixing processes and for a closer comparison of the results of modelling with those obtained experimentally.

The role of sorption, reaction and sedimentation processes in depositing pollutants in estuaries and in the nearshore zone deserves special attention, and further investigation is required.

It was further noted that new techniques for studying estuarine and open ocean conditions by dye dispersal measurement are emerging, as was shown at the Symposium where results of experiments made in 1000 m depth were presented. It was felt that attempts should be made for further investigations in this field, if necessary, on the basis of international co-operation.

The group noted that further studies will be needed, in particular the following:

(a) the development of transport and dilution models for the release of pollutants at different depths in respect of the various zones of the marine environment including the off-shore coastal zone, shallow seas and estuaries, continental shelf and the deep water zone; and

(b) the development of experimental studies on vertical exchange, taking into account the physical factors arising from chemical and biological processes.

The group felt that a review of the present state of knowledge on the transport and dilution of pollutants (of neutral, positive and negative buoyancy) by physical processes should be prepared for the 5th session of GESAMP, taking into account all recent work and in particular the full text of papers from the Aarhus symposium. It was suggested that a small group of not more than three experts in the relevant fields be appointed to accomplish this task, if necessary by an intersessional meeting.

4. SPECIFICATION OF PARAMETERS TO BE MONITORED IN AN EVOLVING MARINE POLLUTION MONITORING SYSTEM

The Working Group noted the Joint IOC/WMO Circular Letter No. 5 of 25 August 1972 (GESAMP-IV/18): Development of an IGOSS Marine Pollution Monitoring Pilot Project, in particular recommendation No. 3 contained in Appendix 2, page 7 of that paper.

The Working Group considered in detail the suggestions made in the above document for the acquisition of data on marine pollution and the physical and chemical parameters suggested for inclusion in an integrated monitoring system. It was agreed that all these parameters were of concern in respect of a broad spectrum of pollutants, but that some were of greater interest and concern than others.

After some discussion which, unfortunately, was limited by the shortness of time available during the session, the group came to the following conclusions regarding the physical and chemical parameters listed on p. 5 of Appendix 2 GESAMP-IV/18:

(a) sea temperature

(b) salinity

(c) ocean currents

(d) sea level

(e) mixed layer depth

(f) wind

(g) waves

(i) precipitation

These physical parameters, which can at present be relatively easily included in an IGOSS scheme, are relevant to marine pollution problems.

A number of chemicals and other parameters as indicated in the above-mentioned document were felt to be of significance. As regards the significance of the parameters (l) pH, (m) nitrates, (n) phosphates, (o) silicates, this is largely determined by the area and the subject under investigation. Also the relevant methodology appears at present not yet sufficiently developed for use in an extended monitoring system. The other parameters, viz. (h) low-level temperature profiles (atmosphere) and (j) turbulence (ocean internal) may possibly be introduced at a later stage.

In discussing the further possibilities of a marine pollution monitoring scheme, either in connexion with IGOSS or otherwise organized, the Group felt that for some pollutants there is a need to conduct reconnaissance surveys. National and international research expeditions could be used for this purpose. The use of ocean weather ships may also be envisaged.

However, a few types of pollutants might easily be monitored at this stage already, namely oil in different states (oil slicks, oil clusters and suspended oil) and floating debris are examples. The impact of the presence of oil slicks existing on the surface of the sea upon the distribution of lipid-soluble substances, such as DDT was recognized. The Group therefore recommended that work should be stimulated to develop suitable methods for sampling these surface films and to establish their role in the distribution of the pollutants.

With further regard to marine monitoring, and especially to a pilot project, the Group felt that GESAMP advice can only be given when more information is available on monitoring programmes executed by Governments or being developed on a regional basis. It was understood that such information is being collected jointly through the Secretariats of IOC and WMO.

The Working Group recognized the provisional character of the recommendations in the previous paragraphs, and considered the following action appropriate:

> Preparation of a report on the needs for monitoring physical and chemical parameters with special regard to their effect on the distribution of the basic pollutants. The report should especially take into consideration results of studies on the regional distribution of these pollutants.

5. CONCLUSIONS

(a) There is an urgent need to correlate calculated airborne pollution data with experimentally-determined quantities over the ocean.

(b) Further work is indicated in the measurement of low concentrations of marine pollutants in the atmosphere and the mass transfer across the air/sea interface, in particular in respect of methodology for simultaneous monitoring of the ocean/atmosphere boundary.

(c) There is a need to study vertical mixing processes in greater detail, and also to correlate data on transport and dilution of pollutants in the sea with results obtained by modelling.

(d) Attempts should be made to develop the use of new techniques for the study of dispersal of pollutants at great depths.

(e) The need was indicated for intersessional work on:

(i) physical factors governing transport and dilution of pollutants; and

(ii) physical and chemical parameters needed for monitoring the most important pollutants of the various basic categories.

Annex VI

MANAGEMENT OF WASTE DISPOSAL*

(Preliminary, subject to revision)

(Working Group 3 - Agenda Items 7 & 9; Annexes IV & VI of GESAMP III/19)

Members of the Working Group:

Dr. C.H. Thompson (Chairman)
Dr. H.A. Cole,
Dr. G.D. Floodgate,
Dr. L. Mendia,
Mr. J. Ui,
Dr. F. Valdez-Zamudio,
Miss G. Matthews and Mr. H. Bonne (Technical Secretaries)

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* This document was prepared during the fourth session of GESAMP and is intended for the use of the working group in developing a technically correct and comprehensive report. It was not possible to review the report in any detail; technical and administrative use of the document in its present form is therefore inadvisable.

1. INTRODUCTION

This report reviews the major reasons for treatment and disposal of sewage and industrial waste as well as the several alternative systems that are available. A preliminary evaluation of the treatment and effectiveness of treatment is given for the twelve general categories of waste listed in Table I of the "Review of Harmful Chemical Substances"(Report of the Third Session of GESAMP - GESAMP III/Annex IV, p.19). Future steps and recommendations are provided. In general, the wastes discussed here are assumed to be water borne and collected to a central point for treatment or disposal.

The basic principle governing waste disposal to estuaries and the sea is to prevent avoidable harm to living resources, hazard to human health, hindrance to maritime activities and reduction of amenities, while making sensible use of the sea's capacity to assimilate certain wastes and render them harmless. In seeking to achieve these objectives, information is required not only on the amount, nature and effects of the wastes to be discharged but also on the characteristics of the receiving locality, the nature, distribution and importance of the living resources, the proximity of amenity areas and the extent and nature of other legitimate uses of the area. An adequate assessment of what it is desired to protect and of the ways in which damage from wastes may arise is the only satisfactory basis for decisions regarding the kind of treatment needed and the disposal conditions that should be satisfied. It is appreciated that this is the statement of an ideal and that such scientific assessments may later be modified by economic or political factors. Although the latter have no place in a report of a scientific group, some assessments of comparative costs of different treatment and disposal practices are made below, and this is a subject to which the working group proposes to give further attention.

Annex III of the Oslo Convention 1972 sets out in detail the considerations which should be applied in reaching decisions regarding the disposal of waste by dumping. The greater part of this Annex is equally applicable to waste disposal to estuaries and coastal waters and is reproduced here as Add. I. It is necessary to bear in mind that rates of chemical and biological breakdown of pollutants and the extent of their effects, being temperature-dependent, will vary according to latitude and that practices developed for temperate areas are not necessarily equally applicable in the tropics or the Arctic. Salinity and the presence of suspended material may also be very important modifying factors but all geographic and oceanographic considerations need to be taken into account.

The choice of treatment systems and disposal practices is much wider than is often imagined. Beginning with no treatment at all one may proceed to more complex systems of combined physical and chemical treatment and biological breakdown.

Disposal methods include discharge by coastal and submarine outfalls of varying length, with or without special jets and other structures to achieve rapid initial dilution; dumping by ships or barges (with varying discharge techniques) and incineration on ships at sea. A more detailed discussion of these methods is given below but is to be regarded as an introduction to the subject rather than a comprehensive account. This is followed by some consideration of the ways in which treatment and disposal practices can be related to the four principal effects of marine pollution, and separate notes on the treatment and disposal of substances in the 12 major categories of marine pollutants set out in Table 1 of the "Review of Harmful Chemical Substances"

1.1 REVIEW OF METHODS OF TREATMENT AND DISPOSAL

It was noted by the group that additional detailed information should be provided on the technical and economic aspects of methods of treatment and disposal of sewage and industrial wastes. It was recognized that there is much published information on the various unit operations and unit processes that may be selected for any given treatment or system. Therefore, it was decided that as an interim statement the following brief notes on methods of treatment and disposal would be compiled with the understanding that a more complete and referenced description of the alternative methods would be undertaken in the near future. This future description should contain at least the schematic diagrams of the alternative available and short narratives on the advantages and limitations of each alternative. The capital and operating costs, the operator training required and the necessary laboratory support would be included.

Systems for treatment or disposal of sewage and industrial waste include, but are not limited to, the following:

(1) Screening or Mechanical separation is accomplished using coarse screens or bar screens which remove large objects from the waste stream.

(2) Grit removal is obtained by slowing the velocity of the waste stream in a special chamber so that the sand and other materials of high specific gravity are collected.

(3) Sedimentation is used in the primary stage and later stages of treatment and is simply a continuous flow decanting operation in which materials are allowed to settle or float and are then scraped or skimmed from the waste stream - these materials are then considered as the sludge of the waste stream to be disposed of or further treated. These operations may be conducted using a variety of tank size and arrangements including upflow or slurry blanket clarification and down flow clarification in conjunction with digestion tanks.

(4) Flotation is caused by the natural particle buoyancy or is induced by turbulent conditions caused by flow régimes or compressed air being forced into the waste stream and suspended particles are swept to the surface and skimmed off. Foam fractionation is used where the background of detergent is great enough to reduce the surface tension and allow the flotation chamber to froth and therein hold the particles swept from the waste stream.

(5) Filtration is carried out using several media such as sand, microstrainers, membranes and mixed beds of materials of different specific gravity to remove the particles in the waste stream. The systems used are selected based upon attainable throughput flow rates, ease of maintenance, etc. Typical uses of filtration are microscreening a clarified waste stream, slow sand filtration, taking additional advantage of biological degradation, sand filtration for sludge dewatering and drying, vacuum filtration for sludge dewatering, and filter pressing which squeezes the water from sludge.

(6) Centrifugation is regarded as one of the more expensive capital investments for waste treatment and is used primarily for sludge dewatering or for waste stream concentration and consists usually of continuous throughput steam or electrically-operated machines that require careful maintenance.

(7) Comminution and maceration are used to physically degrade or grind materials into smaller particles, which can be more efficiently treated by other processes, such as biological treatment, or for better dispersion if disposal at sea is to be used.

(8) Evaporation and distillation may be used to accomplish the same result for a vastly different capital investment. Evaporation is normally used in semi-arid parts of the world to allow solar energy to separate the water from the contaminated, suspended and dissolved materials, and takes place usually in simple ponds or basins and sometimes directly on the soil. Distillation, however, requires elaborate and costly installations to vaporize and condense the water and thereby separate out the contaminating suspended and dissolved materials. It should be noted that volatile materials may not be separated using this technique unless additional chemical or physical treatment steps are incorporated, such as oxidation or sorption of carry-over contaminants.

(9) Biological filtration as commonly used is a misnomer in that filtration plays a minor role in the processes' efficiency. These processes employ several coarse media made of a variety of materials such as stone, ceramic, plastic, wood, metals, etc. The concept is to distribute the waste stream over a thin bioslime layer which develops on the media. These systems are designed so that ventilation is encouraged, and therefore, aerobic metabolism of pollutants in the waste stream occurs. There are dozens of modifications of this process which offer varying degrees of treatment and efficiency. High and low rate, single and multiple stage systems are currently widely used around the world with the most reliance being demonstrated in temporate climates. The bioslime on the media is produced by the mixed microbial population in the waste stream plus any that may be deposited from the air being used for ventilation. The biomass developed sloughs periodically from the medium and is collected in a sedimentation basin which follows the biofilter process.

(10) Activated sludge: This process also uses the mixed microbial populations found in the waste stream plus airborne organisms, in which the opportunity for a preconditioned (acclimated) mixed microbial culture may be used, circulating the biological mass (sludge) which is produced from this process. There are many variations of flow rates, aeration periods, circulation patterns, means of aeration, concentrations of microbial populations, stages of treatment, and combinations with other processes such as the biological filters. The sludge produced from this process is usually collected in a sedimentation basin which follows the aeration basin and the sludge is then further processed or disposed.

(11) Lagoons are in the simplest sense ponds which have been designed to have an aerobic and anaerobic zone of treatment. The retention times are much longer than in either the biofilter or the activated sludge and therefore require large areas of land. Sedimentation takes place in the lagoons and often forced aeration is employed to maintain adequate oxygen for waste stabilization. Maintenance becomes more of a housekeeping and grounds-keeping nature than mechanical repair which is required in the biofilter and the activated sludge processes. Lagoons are often used for a final polishing of the waste stream before release when used in conjunction with the treatment systems. The sludge build-up in the lagoon treatment facility is slow and clean out is required very infrequently.

(12) Anaerobic digestion is a process normally used to further degrade the sludge collected from the other waste-treatment systems and is required to biologically reduce materials such as cellulose. The processes use the facultative aerobic and anaerobic organisms found in the sludge plus a starter seed culture kept in the digester which carry out their functions in an atmosphere of no oxygen. Volatile acids and gases are produced from this process and the digested sludge released to the drying beds or to other dewatering systems is similar to humus or peat. The supernatant liquor as well as the digested sludge are oxygen consuming and odoriferous.

(13) Composting is a process of combined sewage and refuse treatment on land in which aerobic and anaerobic decomposition is slow, requiring careful mixing, temperature dependent, and is of use primarily for very small operations handling sludge. The mixing may be done by hand, by earth-moving equipment or even by a rotating kiln-type system. The practice is useful for garbage and refuse degradation if local conditions allow the time, space and manpower requirements.

(14) Spray irrigation is a system of using minimal plant treatment of the waste followed by transporting the waste to farm lands where normal irrigation is carried out. The public health considerations must always be carefully monitored, but some success has been demonstrated using this technique. Non-food crops are especially suitable for irrigation by this highly nutriated water to minimize health concerns. Care must be exercised not to over irrigate and therefore large acreage is usually required. The capital investment is mainly in the pipeline, distribution system and any preliminary treatment required.

(15) Incineration is a technique for ultimate disposal of the dewatered sludges, certain concentrated waste streams and solid refuse. The temperatures of combustion must be maintained in the 1000° C range to minimize the potential of incomplete combustion. Certain air pollution control devices will be required because of local conditions of population density and need to prevent any toxic fumes which may be produced if the combustion is incomplete. Usually, the incineration is carried out on land at a large facility, but there are applications of small units on land, and of ship-borne units operating at sea. The ash produced from this system is normally regarded as safe and inert and can be disposed of on land or at sea, or it may be used as a component of a building material.

(16) Disinfection is a process whereby chemical or radiation treatment of the waste stream will severely reduce the potential for disease transfer. Chlorine and ozone among other materials, are used in concentrations and contact times sufficient to oxidize and chemically interfere with the microbial life forms present in the waste stream. Other reactants may participate in the reaction such as amines and hydrocarbons, but the advantage of minimizing disease transfer has been viewed as outweighing any of these potential disadvantages. Gamma radiation has been used in place of chemical disinfection, but requires the additional safeguards against any radiation damage to workmen in the immediate vicinity.

(17) Chemical treatment other than disinfection is commonly employed to assist coagulation-flocculation-sedimentation, neutralization of acidior basic wastes, oxidation or reduction of difficult-to-treat materials, and nutrient and metal precipitation. The process requires high capital investment in facilities, well-trained personnel and has high operating expenses. However, it is employed because there are usually very few other options that will adequately treat the waste. Normally, the more concentrated the waste, the more efficient is the process.

(18) Wet oxidation is a process used for treatment of dissolved and suspended organic matter, whereby at high pressure and a slight increase in temperature, oxidation is stimulated and the energy released is exchanged back into the system to maintain the elevated temperature and pressure for oxidation of additional waste material. The system requires well trained personnel and a high capital investment. Maintenance can be a problem, but there is little odour and the system is compact and has a high volume throughput.

(19) Activated carbon is used to absorb waste materials from the polluted stream, using several schemes for contacting the water and the carbon. Powdered and granular carbon systems are normally used to handle low concentrations of highly toxic organic materials. The carbon capacity can be exhausted; the regeneration process can be as expensive, or more so, to build and operate as the carbon absorption system is itself. Care must be exercised during regeneration to avoid serious air and water pollution.

(20) Reverse osmosis and electrodialysis are processes which employ membranes to provide a separation between the polluted and treated water. After some preliminary treatment to remove suspended solids these processes may be employed to remove large molecules and dissolved solids. The reverse osmosis operates at high pressure and allows the differential osmotic pressure of the contaminant and water to promote the movement of the purified water which is collected. The electrodialysis technique employs an electric charge across a membrane, which allows the pollutant to migrate in the direction of the charge, thereby separating the contaminant from the water. These systems are compact but expensive, and are limited, at present, to rather minimally-polluted waters. The quality of the water produced can be extremely high.

(21) Aquaculture, utilizing warm nutrient-rich wastes, could be to the ocean environment as the spray irrigation is to the land. It is anticipated that my managing polluted water discharges beneficial to plants, fish and animal life could be supported and sustained to the benefit of man and the environment. The typical example would be the use of elevated temperature in conjunction with a highly-nutriated discharge to create an abundant alga/growth upon which fish would be fel and on up the food chain. The technique is only practised under limited conditions or by accident at present.

(22) Ultra-violet degradation is used to take advantage of the principle of molecular disturbance of certain complex organic materials by exposure to UV light. The workmen must be protected and the depth of light penetration is small, but for some wastes the technique may be useful. Some pesticides have been shown to be significantly destroyed by this technique. For large-scale operations and low concentrations of contaminants, it would be expected that a high capital investment would be required.

(23) Ion exchange is a process whereby resins with anionic and cationic charges are placed in contact with the waste stream and the oppositely charged pollutant is removed. The resins can be regenerated, but this must be done with care to avoid concentrated pollution from this operation. The regeneration is usually a chemical one to restore the exchange capacity of the resin. Operator training must be high.

(24) Electrochemical treatment is a process which uses the principle of electrolysis of a sewage-sea water mixture which is followed by an upflow clarifier or a slurry blanket type unit. The process has been regarded as accomplishing clarification, disinfection and phosphate reduction. The process does require a moderate capital investment and some degree of operator training. The optimum pH for electrolysis is about ten.

(25) Extraction is a process which uses the selective solubility of pollutants relative to water and thereby reduces the volume of pollutant to be treated. This process is very seldom used and only in the most extreme cases. High capital investment is required as well as operator training and is normally only available economically within an industrial facility. A typical application of this technique would be to concentrate a combustible pollutant to the point that it could be economically incinerated.

(26) Marketable products can be created from many waste treatment plant operations. Several cities in the U.S.A. have developed considerable revenue by preparing the sludge to be used as a lawn fertilizer or soil conditioner. In addition, the sludge has been examined for use as a building material, road repair and finishing material, as a chicken or animal feed supplement and for several other uses. Each of the uses is very dependent upon the local conditions of the market and resources available to the waste treatment plant personnel.

(27) In-plant process modification is usually required for very old industrial facilities and simply means stopping the materials that are being wasted at the source. There is a strong trend toward more and more closed-system industrial process design. The implication is that industry would rather invest in tighter control at the process and save product loss than invest in elaborate and expensive industrial waste treatment plants.

(28) Ocean disposal is used widely for a variety of sewage and industrial wastes. The alternative presented here is one composed of many factors to be considered, such as should the waste be dumped from ships or barges; should an ocean outfall be designed and built, should pre-treatment be given to the waste; should the discharge be to coastal water, or continental shelf waters, or to deep-sea trenches? As described for several of the specific wastes which follow, a careful evaluation of the waste, the area for discharge and the intended beneficial uses of the sea must be part of the process of evaluating this alternative method. It should be recognized that the short-term economics may be misleading in indicating ocean disposal for areas of rapid industrial growth. Also, it should be recognized that with proper design and operation of ocean disposal systems, certain wastes can be discharged at sea, with the chemical and biochemical capacity of the sea being utilized to render these materials harmless.

(29) Deepwell injection is an alternative process which is quite controversial in several parts of the world. The technique is used with limited pretreatment to simply pump the waste into a well. These wells are usually exhausted or non-producing oil wells. The wells must eventually be lined and be at least 5000 feet deep to prevent groundwater contamination. Concern has been expressed over possible seismic disturbances using this technique. Limited capital investment is required, but highly trained and experiences personnel are needed. The land-areal requirements are minimal, but problems have been experienced by allowing the injection in highly urbanized areas. Some success has been achieved in the use of waste-injection wells in coastal lands, to keep the salt water intrusion from destroying the ground water aquifers.

(30) Land filling and reclamation is a system whereby certain liquid and solid wastes can be mixed together with soil and compacted into eroded areas or into excavations resulting from mineral exploitation. These wastes are degraded by soil microbes at a very slow rate. It can be expected that the degradation of some wastes will require of the order of 25 years to become stable. Additional reclamation can be obtained by using the liquid wastes with or without pretreatment irrigation water as noted earlier. Groundwater contamination is a serious limitation to this system of disposal. Operator training and capital investment are relatively low, assuming that suitable inexpensive land is available.

(31) Containerization is a system whereby wastes are concentrated and then sealed in steel, concrete or other types of vaults. Often steel drums are used. These containers are thus either dumped at sea or are stored on land. Certain military wastes have been handled in this manner with reported minimal impact on the ocean environment. The weakness in the approach is that the containers deteriorate both at sea and on land, if stored, for example, in abandoned coal mines. This situation then becomes one where highly concentrated wastes in sizeable quantities enter an environment of reported slow biological activity. The use of ocean dumping as an alternative to other methods on disposal must be based upon careful evaluation of relative hazards to man and the environment. Old ships have repeatedly been sunk with cargoes of containerized wastes. The results of these operations are difficult to assess, but reports have indicated minimal ocean impact.

(32) Matrix encapsulation is a more complicated containerization which takes the waste material such as radioactivity and incorporates it into a material such as glass. Studies have indicated the leaching rates to be quite slow and the problem of the container deteriorating is minimized since the waste is actually part of the container. The process is expensive, requires very skilled personnel and is therefore normally applicable only to wastes which are extremely difficult to handle

1.2 RELATION OF TREATMENT AND DISPOSAL PRACTICES TO EFFECTS OF POLLUTANTS

1.2.1 Harm to living resources

The term "living resources" is sometimes interpreted as meaning only fish and shellfish marketed for human consumption. This definition is too narrow in that not only other invertebrates in great variety (e.g. sea urchins and barnacles, but also seeweeds, mammals and seabirds may be eaten. Resources may also be exploited for production of meal and oil, or for skins (seals) or other products. However, the living resources depend upon the maintenance of primary and secondary production, so that wastes which damage the plankton or benthos may indirectly affect these resources.

In making a choice of method of treatment and disposal to be adopted in respect of a particular waste, it should be remembered that local populations of fish may migrate seasonally to another area, and it is the cumulative effect of exposure during the whole life cycle that needs to be assessed. Young stages of both fish and shellfish are generally substantially more sensitive to pollution damage than adults and may also occupy different areas. Fish and shrimp nursery areas, in particular, are often in shallow estuarine or coastal areas where pollution exerts its major effects. Although fish are frequently able to swim away from polluted areas, their very young stages are planktonic and drift only with tides and currents. Fish spawning and nursery areas are more or less fixed in position, and if seriously affected by pollution, the stock may be severely damaged. Crustacea have a limited capacity for moving out of polluted areas, but molluscs and other exploited invertebrates, and especially edible seaweeds, are static and may require special conditions for their cultivation which, if altered by pollution, cannot be provided easily on alternative sites. Thus, the existence of systems of artificial farming for fish, shellfish or seaweeds must be given special weight in deciding disposal areas for harmful wastes. The existence of colonies of conserved marine mammals or seabirds is also an important consideration.

In more detail, the main objectives of waste disposal in relation to protection of living resources are the avoidance of:

(a) concentrations likely to be directly toxic to any stage in the life cycle;

(b) long-term exposure to lower levels of pollution likely to cause behavioural effects or physiological damage;

(c) bio-accumulation leading eventually to direct toxicity or loss of quality as seafood;

(d) tainting;

(e) reduction of growth either directly or by impoverishment of food supply, e.g. by excessive turbidity;

(f) eutrophication;

(g) alteration of environment e.g. by deposition of sediments, or ecosystem imbalance; and

(h) accumulation of surface films.

These requirements can be related directly to the treatment processes available and the composition of the waste and to the choice of means and site for disposal. Treatment may be aimed specifically at reducing or eliminating particularly undesirable substances from the waste, e.g. those with a capacity to taint fish or shellfish, whereas disposal is concerned mainly with removing the discharge point from the vicinity of important resources, effective utilization of the dispersal characteristics of the available sites or in achieving a high initial dilution by special outfall works. The removal of nutrient substances may require special attention in areas where hydrographical characteristics lead to risks of eutrophication; in others they may give a valuable boost to production.

1.2.2 Hazards to human health

These may arise from

(a) direct skin contact with or swallowing of polluted water or contact with contaminated beaches, e.g. when bathing;

(b) by the consumption of seafood carrying infective material (e.g. from sewage); or

(c) accumulated toxic materials (such as persistent organochlorine compounds or metals).

The avoidance of effects under (a) above, arising from sewage contamination, depends upon the adoption of effective treatment procedures to produce an effluent of the required standard or the siting and construction of outfall works in such a way as to prevent the effluent from reaching areas used by human populations for recreational and other purposes (entailing direct contact with water or beaches). The removal of an outfall from an open beach and the substitution of a fully or partially treated discharge into a backwater or estuary may be effective, as also may be the adoption of a lengthened submarine outfall without recourse to treatment beyond screening or maceration where hydrographic conditions are suitable. The gathering together of several local discharges into a main trunk sewer and discharge at a selected point with favourable hydrographic characteristics away from important recreational beaches or living resources is another device which has frequently been employed. Disinfection may be employed if treatment works and outfalls cannot be moved at reasonable expense; it may also be adopted in respect of effluents from particular establishments, e.g. hospitals dealing with infectious diseases.

The avoidance of adverse hygienic or health effects (skin or eye damage or irritation) by direct contact with chemical wastes depends upon adequate knowledge of the composition of wastes, the properties of particular substances, and the dilution and dispersal characteristics of the receiving waters. The relation between water movements and climatic factors, particularly wind, may be important, since several corrosive or otherwise objectionable substances may be carried in surface waters.

The transmission of disease by shellfish (b) above, has been extensively studied. Reliable methods of purification exist for eliminating the risk of typhoid and can be adapted to the needs of special situations (e.g. inland markets where artificial seawater may be used) and a variety of species of molluscs. Less assurance can be given regarding the removal of viruses by existing purification techniques, but all cases so far recorded of infectious hepatitis contracted by eating shellfish have been associated with grossly polluted conditions. Nevertheless, certain obscure non-specific illnesses of a fairly mild character may occasionally follow the consumption of shellfish, even those purified to an acceptable standard. It is highly desirable, therefore, to avoid the pollution of important shellfish-producing areas by the adoption of suitable régimes of sewage treatment and disposal.

The principal substances which may be accumulated in fish and shellfish are now fairly generally known. Methods have been developed both for analysis and for the assessment of the hazard these substances may present, when considered in relation to the total dietary intake and exposure from other sources, e.g. aerial transport. Avoidance of harm depends upon adequate knowledge of sources of a particular substance and an evaluation of the relative importance of different pathways to the marine environment and hence to seafood. Surveys for the presence of particular substances in seafood need to cover a full range of exploited species, since marked differences occur in the extent of accumulation. Distribution within an animal needs to be related to the edible portions and seasonal variations, which may be considerable, also need to be taken into account. Since the principal substances causing concern are known (e.g. mercury, cadmium, lead, chlorinated hydrocarbon pesticides, PCBs, etc), specific treatment processes can be developed to reduce their discharge to the marine environment. Where treatment is not practicable or is ineffective, the possibility of replacement by less harmful substances should receive close attention.

1.2.3 Hindrance to maritime activities

An alternative expression to the above heading which is often used, is "interference with other legitimate uses of the sea". Some of the more important of these are shipping, fishing operations (including the operation of fish processing plants) oil and gas exploitation, undersea mining including gravel extraction, power station operation, industrial activities dependent upon sea water, desalination, scientific research, laying and maintenance of cables, and numerous aspects of coastal development. Certain of these, such as power station operation, desalination and also most forms of mariculture, require particular standards of pollution control which must be kept firmly in mind in making a choice of treatment and disposal methods. Certain scientific purposes, e.g. nature reserves, wildlife conservation (especially of sea mammals and seabirds) and marine parks, may be critically dependent upon freedom from pollution damage, and their presence may influence waste disposal policy beyond their immediate vicinity. The development of the concept of "designated use" in respect of particular coastal areas could be of value in meeting such special needs.

1.2.4 Reduction of amenities

Amenities in this context include both recreational uses and scenic values. The objectives should be the maintenance or improvement of the existing situation. Oil is the most widespread problem, but other effects of importance are the presence of floating and stranded wastes, scums, odour, discolouration and turbidity. Considerable difficulty may be experienced in locating the source of the problem, as with oil, but when identified, the specific treatment needed can usually be stated with some confidence, although its application may be limited or prevented altogether by economic considerations. Very frequently, the offending materials may be discharged by rivers sometimes passing through several countries. The deposition of garbage from ships, which is certainly a factor in reducing coastal amenities, is receiving attention by IMCO at its International Conference on Marine Pollution to be held in 1973, and suitable regulations to control its disposal are being developed. Dumping of wastes from ships and the discharge of tank washings from chemical tankers and bulk carriers may also lead to amenity problems. The former will be covered by the projected global dumping convention, and the latter is under consideration by IMCO as part of the preparations for its 1973 Conference.

2. EVALUATION OF METHODS AVAILABLE TO TREAT OR DISPOSE OF 12 GENERAL CATEGORIES OF WASTE

The following discussion of more detailed methods of treatment and reasons for treatment is arranged to follow Table 1 of Annex IV of the GESAMP III report.

2.1 DOMESTIC SEWAGE

In accordance with current terminology, domestic sewage means waste water coming from houses and small communities, as well as the waste waters from cities (urban sewage). In effect, urban sewage is a mixture of sewage, storm waters and wastewaters from workshops and industrial activities; therefore, the disposal of town sewage involves a much broader spectrum of problems than domestic wastewaters alone.

2.1.1 First alternative

The direct disposal of sewage by submarine outfalls is generally considered as the most convenient one. However, it is most important that this technique should be considered in the light of the following points:

(a) hydrographic, meteorological and geological conditions of the coast and the sea bottom;

(b) length of pipe necessary for an adequate submarine outfall;

(c) characteristics of wastes to be disposed; and

(d) optimum use of coastal waters.

In those instances in which the above-mentioned conditions contra-indicate the use of a direct disposal of the sewage, preliminary treatment processes should be considered. The number and the sequence of the operations depend upon the type and nature of local situations that it is desirable to protect.

2.1.2 Second alternative

The disposal of sewage into sea water used for amenities should comply with the following requirements: absence of coarse floating and settling solids, high turbidity and discoularation, unpleasant odours and septic phenomena. To reach this goal, it is recommended that wastewaters be submitted some or all of the following treatment processes:

(a) screening;

(b) flotation;

(c) sedimentation; and

(d) final disposal of the product removed by (a), (b) and (c).

In order to reach a better quality when the water is used for bathing and recreation and to improve aesthetic conditions, it is advisable to add a coagulation process before the above step (c).

Public health implications of the disposal of sewage are relative to the use of sea water by human populations for different purposes. The choice of site for the sewage outfall must be carefully established in relation to the allocation for existing or future public and private beaches, shellfish areas and aquaculture activities. It is recommended that, when the situation demands, the treatment system foreseen for amenities preservation should be improved by an efficient disinfection step. Particular care should be taken in the case of outfalls of sewer systems carrying waste waters from industrial activities, characterized by pollutant substances which tend to accumulate in filter feeder species (shellfish).

2.1.3 Third alternative

When, to protect the marine coastal environment, a higher standard of the effluents is required: i.e. in connection with the local geographic conditions, the highly developed tourist industry, or with the daily flow or the characteristics of the sewage, it is worthwhile considering the opportunity of submitting the effluents from the above-mentioned primary treatment to other additional processes of an oxidative, biochemical nature. The mineralization of organic matter can be accomplished using the following technical processes:

(a) oxidative lagoons;

(b) trickling filters; and

(c) activated sludge plants.

The processes (b) and (c) require a successive sedimentation. The disposal of the sludges of the secondary sedimentation should follow the lines described for the sludges of primary sedimentation. In particular situations, a disinfection of oxidized effluents can be recommended.

The protection of living resources from domestic sewage is basically obtained by the elimination of nutrients, hydrocarbons, organic matter and other substances incuding high turbidity or colour.

In the case of industrial pollutants particularly deleterious to the marine environment, i.e. heavy metals, discharged in a mixture with domestic effluents, it is recommended that pretreatment processes be developed at the industrial site to treat the wastes before their introduction to the urban sewer system. This policy, in some cases, also avoids damage to the sewer system and treatment plant.

Domestic sewage may cause hindrance to marine activities by the introduction of solid or floatable objects (plastic material) into the sea. The latter may become wrapped around ship propellers or block water intakes. Hydrocarbons and fats that float on the sea surface may cause damage to nets and ships. In enclosed sea areas, high BOD may lead to the production of H_2S that makes sea waters highly corrosive, causing harmful effects to metal vessels. A screening process, followed by sedimentation is usually sufficient to avoid hindrance to maritime activities.

2.2 PESTICIDES

The effect of pesticides in the marine environment is mainly damage to living resources and, to some extent, hazard to human health. There is at the moment no known adverse effect on maritime activities or amenities. Some pesticides are so persistent that there is no known method of destroying them, nor of removing them from the marine environment. In such cases, the only way to solve the problem is to stop the use of such compounds or to restrict their use to limited fields of application which give no possibility of polluting the marine environment. Some compounds are more or less bio-degradable, and could be removed by ordinary biological treatment processes as well as by natural decomposition, although there is still the possibility of marine pollution by the decomposition products. The concentration of pesticides to be handled varies widely from the considerably high levels in the waste water from some manufacturing processes to the relatively low levels in the surface runoff from pesticide-treated land. Generally, the various effective methods can be applied only to the high concentration of pesticides in wastes, and there are practically no methods available for low concentration such as those in surface runoff.

2.2.1 Organo-chlorine compounds

Most of these compounds are known to be highly persistent in the environment as in the classic case of DDT. Some of them are highly toxic such as dieldrin, while they have a general tendency to accumulate in the marine biomass. Some other compounds may disappear from treated soil, but the mechanism of their decomposition is not known. A few cases of bio-degradable compounds are cited where these compounds can be removed successfully from water by ordinary biological treatment. Some compounds can be removed from water by the activated sludge process, but the accumulation of them in the sludge produces another difficult problem. Generally speaking, the strictly controlled use for limited purposes, giving no possibility of marine pollution, is the only solution for this group of compounds.

Recently it was discovered that high energy radiation can decompose most of these compounds even in moderately low concentration in water. This method may have some use for the treatment of waste water from the manufacturing process if the required engineering arrangements are made, but this method is still in an early stage of development and its economic value is unknown.

2.2.2 Organophosphorus compounds

It is generally accepted that these are less persistent and more easily degradable than organo-chlorine compounds, but some intermediate decomposition products have been found to be quite toxic to living resources. Effluents with high concentration of organophosphorus compounds from the manufacturing process are generally treated by chemical decomposition processes using alkali and oxidative agents. However, this method is not useful for low concentrations. Biological treatment has been tried at times, but the results vary from success to failure, possibly with the conditions of the acclimation and other properties of the sludge. So-called less persistent and less toxic compounds have been invented every year in this field, but their degradation in a conventional treatment plant has not been fully investigated. At the present stage, caution is necessary before introducing these compounds into existing treatment systems. Small amounts of organophosphorus compounds inevitably occur in domestic sewage, but their effect on biological treatment processes is not fully known.

When these compounds are applied by aerial spray, coastal pollution by drifting can occur, and careful control of such application is required.

2.2.3 Carbamate compounds

This group can be treated and removed from water by chemical decomposition if the concentration is sufficiently high. Such treatment is used, in most cases, for wastewater manufacturing. Again, chemical treatment is not useful for low concentration, but the decomposition rate under natural conditions is rather high, and few cases of damage by this group have been reported. The extent of application, however, is increasing because this group is replacing more persistent organo-chlorine compounds, so it is necessary to investigate their effects in low concentration in the natural environment. There is no available literature on the treatment of carbamates by biological processes, but there seems to be no difficulty in acclimating micro-organisms to carbamates, if the concentration is not too high and it is stable.

Apart from their use in pesticides, carbamates have been used widely for a long time in the rubber processing industry. Some occupational health problems are known to occur in the latter. The discharge of carbamates with wastes from the rubber industry is to be expected but treatment, although necessary, is frequently neglected. Carbamates are used generally in powdered form for rubber processing and occasionally cause some air pollution. Washing of air by water and subsequent chemical decomposition are commonly used for removal of these substances in a plant with large-scale production.

2.2.4 Herbicides

Various groups of organic compounds are in use as herbicides and their biodegradability varies widely. Organo-chlorine compounds, such as pentachlorophenol and 2,4-D, 2,4,5-T, are used widely in large amounts for this purpose and their marked effects on living resources are frequently reported. Pentachlorophenol is considered to be quite persistent in common treatment processes, as well as under natural conditions, and there is no report of successful biological degradation at present. 2,4-D is generally considered less persistent in soil, as well as in common biological treatment processes, but there are few reliable reports of its behaviour in an actual treatment plant. 2,4,5-T is considered more persistent than 2,4-D, but it is reported to be degradable in low concentrations in biological treatment processes. Nothing is known about treatment in the manufacture of these compounds, but it generally believed that chemical decomposition is less effective.

The information regarding biodegradability of other compounds, such as urea derivatives and dipyridyl derivatives, is practically nil. From their chemical structure and limited persistence in treated soil, they might be considered more susceptible to biological degradation, at least more so than organochlorine compounds.

As for organo-chlorine herbicides, high energy radiation can decompose even the most persistent ones to some extent, but the technical developments for this process are still in early stages.

2.2.5 Mercurial compounds

With the realization of the persistent toxicity of mercury compounds, the use of mercury in agriculture has decreased considerably. However, a considerable amount of organic mercury compounds is still used in various agricultural applications such as seed dressings, disinfection of bulbs, and so on. In the manufacturing process of these compounds, oxidation by free chloring and subsequent precipitation by sulfide give successful results in a proper engineering scheme. Spent disinfectant solution may be treated by the same method, if the concentration of mercury is high enough. Recent investigation in Japan disclosed that, to some extent, inorganic mercury may pass through an ordinary biological sewage treatment plant into the effluent, but the greater part goes into the air by incineration of sludge. Mercury compounds exhibit high toxicity to biological treatment processes, so that the introduction of mercury-containing waste into a municipal sewage system should be avoided.

The absorption and combination of mercury with soil is quite strong and seepage through surface runoff is very slow. For this reason, the possibility of marine pollution by seed dressings is considered to be negligible; but in some countries, such as Japan, a large amount of mercury compounds applied to rice paddies brought another difficult new problem of stable discharge of mercury. There is no technical solution for such pollution from mercury already applied, and other countries should learn from such experience.

Three successive accidents from eating disinfected seed in Iraq show that present management systems for mercury compounds in agricultural use urgently need improvement, and a reduction of marine pollution should be one of the results of such improvements.

2.2.6 Miscellaneous metal-containing compounds used as pesticides

Few reports are available on the effect on living resources of these substances or on their chemical character in relation to the marine pollution problems. Some metal compounds, such as organo-tin compounds, could be decomposed successfully by chemical treatment, and this method is used for treatment of wastewater from the manufacturing process. Biological decomposition in normal sewage treatment plants seems to have less possibility of success. Perhaps controlled application may be the only way of avoiding marine pollution by these compounds.

2.2.7 PCB

Remarkable pollution by PCB in coastal and open sea areas has been reported in the last few years and this seems to present a serious hazard to human health. The concentration of BCB in the body fat of coastal fishermen in Japan has reached the lowest level recorded in the notorious PCB poisoning case known as the Kanemi rice oil case. There is no technical solution at present for such accumulation of PCB in the human body. The retention time of these compounds is very difficult to estimate, but it is believed to be very long. The effect of PCB on living resources is less visible and persistent, so the detection of pollution is quite difficult. This condition makes it more difficult to solve the PCB marine pollution problem. Analysis of food is quite lengthy and needs care, so that the whole picture of PCB pollution is very difficult.

Several countries have already prohibited the use of PCB in some open-system applications such as copying paper and paint. The use in closed systems, such as transformers and capacitors, has also decreased markedly following the news of PCB accumulation in the biosphere. But to substitute PCB by other compounds which might also be persistent and less detectable, has created another new problem in marine pollution. There is no reliable information on the toxicity of such PCB-substitutes or on their biodegradability. There is sufficient reason from their chemical composition to suspect that such PCB-substitutes may be accumulated. Efforts should be directed to the evaluation of these characteristics. Substitution is only a partial solution for the PCB problem.

At present, high temperature incineration is the only available technology to destroy PCB. Incomplete combustion may produce highly toxic by products and the control of the incineration furnace is rather difficult. This method is applicable only to pure PCB and is of no use for PCBs in paper, paint, and other structures. The development of new technology to decompose such PCBs in the combined state seems quite difficult but is urgently needed.

Recently, it was discovered that PCB in alcoholic solution can be decomposed by radiation from high-energy gamma rays, as well as by ultraviolet rays, to unknown chlorine-free compounds and chloride ions. To apply this method on the industrial scale, however, needs much effort and time, because the investigation is still at an early stage and no economic evaluation has yet been made. Also, it was reported that certain strains of soil bacteria could decompose PCB but the pathway and the end products are not yet known. The possibility of using this strain of bacteria in a biological treatment process if far more speculative. Simple introduction of PCB into a conventional biological treatment plan causes the accumulation of PCB in the sludge and subsequent air pollution through combustion of sludge or leads to persistent soil pollution by the application of sludge to agricultural land. There is a case of accumulation of PCB in rice grown on polluted rice paddies. The careless introduction of PCB into sewer systems should be strictly avoided.

In short, the use of PCB should be restricted to controllable applications and any release into the environment should be minimized as far as possible. There is no technical solution for pollution by PCB one it is released into the environment.

2.3 INORGANIC WASTES

In recent years, many industries have changed their processes because of problems in waste disposal; and the nature of industrial waste has changed considerably in the direction of less volume and easier handling. But in spite of this effort, there is still much dumping and many discharges of inorganic waste into the marine environment. In most cases, the first step for the control of pollution is not treatment, but the proper management of water use on the production site. The next step is the modification of the production process itself, such as separation of waste systems, recycling of water, varying the choice of reacting conditions and raw materials, etc. Only after such steps have been taken can the treatment process be properly planned and designed. Generally speaking, waste treatment at the production site with a smaller volume of waste is an improvement from the viewpoint of efficiency as well as economies. Such at-the-source treatment should be more powerfully advocated.

2.3.1 Acids and alkalis

Although sea water has considerable buffer capacity, some recent examples of damage to marine resources and even to navigation activities show the value in certain areas of neutralization before discharging such waste to the coastal zone. Sometimes the neutralization process may bring new problems of sludge disposal if the quantity is very large. In high concentration and with smaller volume, neutralization is easy and more efficient, as well as leading to easy handling of products. The choice of neutralizing agent should be considered carefully from the viewpoint of the overall process. For instance, although hydrochloric acid is more expensive than sulphuric acid, the handling of neutralization is generally easier, and the overall cost is sometimes smaller than with sulphuric acid. Weaker acids and alkalis are generally more convenient for achieving a particular pH range after neutralization and have considerable merit as neutralizing agents. especially in an automated neutralization plant. Alkaline wastes with moderate concentrations of organic matter generally do not need neutralization before biological treatment, if the biological step is properly designed and maintained.

Discharge of alkaline waste into the immediate coastal zone may cause secondary precipitation of voluminous magnesium hydroxide, and can produce damage to living resources in shallow seas. This experience also supports the necessity for consideration of neutralization of waste water before discharge, even if the waste is proven to be non toxic in other ways. Sudden discharge of acidic waste into a highly polluted zone may also cause the formation of highly toxic hydrogen sulphide, H_2S, so in such cases some degree of neutralization is desirable.

Although neutralization is the fastest chemical reaction known, the actual reaction is generally dependent upon efficient mixing and the design of a process with enough mixing is essential. If sludge-like by products are formed, the importance of mixing increases. Caution should be exercised because of the potential for difficult-to-handle precipitates being created, such as occurs during the handling of TiO_2 wastes.

2.3.2 Nutrients

Eutrophication and the production of toxic algal blooms (red-tides) are becoming more frequent, especially in shallow closed regions such as the Oslo fiord, Baltic, Adriatic and the Seto Inland Sea in Japan. More attention should be paid to this special problem. Although there is no agreement on the triggering mechanism for such blooms, nutrients clearly play an important part, and increasing pollution may be the cause in some areas.

The sources of nutrients from the viewpoint of marine pollution are many and, in most cases, very difficult to control. From human excreta and detergents through domestic sewage a large amount of nutrients reaches the marine environment. Erosion of cultivated land also contributes some nutrients to the sea, but proper management of soil can reduce considerably this runoff loss. Partially anaerobic conditions in shallow water bodies, such as lagoons, lakes and estuaries, can lead to the discharge of a large amount of phosphate ion into the receiving coastal zone. In addition to these sources, industrial wastes have a considerable nutrient input into the sea. In some areas, nutrients are intentionally applied as fertilizer for aquaculture.

Nitrogenous nutrients can be removed, if they are not in too low concentration, by denitrification combined with organic waste removal, and ammonia can be removed by extended aeration after nitrification. Such conditions exist in nature in lagoons and rice paddies, but some skill is necessary to maintain them in the ordinary biological treatment plant. Phosphate can be removed by chemical precipitation with aluminium or ferric ions, followed by coagulating agents, but efficiency depends upon the concentration of phosphate and other factors.

Elemental phosphorus has caused some serious problems in the past, and it should be considered as a rather persistent pollutant with high toxicity. The source of discharge is limited to a special branch of industry, and the removal is rather easy at the source in the factory.

2.3.3 Cyanide

The main sources of cyanide waste are plating and other metal-processing industries, as well as the steel manufacturing industry, where cyanide is combined with heavy metal ions. For such waste water, alkaline oxidation and chemical decomposition by free chlorine or hypochlorite has been successfully applied for a long time, followed by heavy metal removal by precipitation. Again the efficiency and performance depends largely upon concentration of cyanide, co-existing ions and design and maintenance of the plant. Especially in small plating industries, the maintenance of the process is of vital importance. Generally biodegradation is not suitable for this kind of waste because of the heavy metal toxicity.

Another important source of cyanide waste is coke ovens, gas works and refineries, where cyanide and other toxic organic materials are contained in liquid waste. Most organic compounds in this type of waste can be decomposed by properly designed and acclimated biological treatment processes, and cyanide is decomposed to CO_2 and NH_3 rather easily. Acclimation of micro-organisms and their maintenance needs some skill.

2.3.4 Sulphite

Sulfite is not a persistent pollutant and is easily oxidized to sulphate under normal conditions. Generally, oxidation in air is the simplest method of treatment. The reaction is rather slow and dependent on the co-existent ions, so the operation of the treatment plant needs some skill, in spite of the simplicity of the reaction. Its initial toxicity to micro-organisms in the biological treatment plant should be considered, if such waste is introduced into the sewer system.

2.3.5 Mercury

Because of its persistency and its ability to convert to the highly toxic methyl mercury compounds, every discharge or dumping of mercury and its compounds should be minimized and strictly controlled. The largest source is the chlor-alkali industry where inorganic mercury occurs in low concentration in a large volume of calcium and magnesium sludge. For the moment, there is no suitable method to recover or to remove mercury from this sludge. For this reason, steps have been taken in many countries to convert the chlor-alkali production process to the once-abandoned diaphragm method.

Some mercury is still used as a catalyst in the synthesis of acetaldehyde and vinyl chloride monomer. Mercury compounds in the waste water from these processes are easily removed by suitable chemical reactions, if the quantity of waste water is controlled by good water management. This is a typical case of treatment at the source with more than 90% success.

Other mercury sources of importance are mercury mines, sulphite smelting industry, pharmaceuticals, and the paint industry. Most of the waste waters from these sources can be treated by the same method as in chemical industry.

Mercury is also used in many applications in the electric and electronic industries, and this gives rise to new problems in marine pollution control. Some waste from such applications, e.g. electric cells, switches and relays, may find its way into the sea for final disposal and can cause gradual increase of mercury levels in bottom sediment. Although the effect of this disposal has not been investigated, it should be controlled as soon as possible.

2.3.6 Lead

The largest input of lead into the marine environment arises from the combustion of anti-knock agents in gasoline and subsequent transport through the atmosphere. There is no technical solution to this problem other than the control of the use of lead for this purpose, and such measures have been taken gradually in recent years. Lead is also discharged from various sources such as mining operations, the chemical industry, the pigment and paint industry, and the plastics industry. If the concentration of lead is sufficiently high and does not fluctuate markedly, lead can be removed from the waste water by chemical precipitation with sulphide and the flocculates with the help of a flocculating agent. Organic lead waste from tetraethyl lead manufacture is successfully treated by the combination of ion exchange and chemical decomposition, followed by precipitation and flocculation.

2.3.7 Other metals

From the viewpoint of marine pollution, copper, zinc, cadmium, arsenic, chromium (especially hexavalent), are the most important metals.

Chemical transformation of these metals into an insoluble form (sulphide or hydroxide in most cases), and precipitation is commonly used for the treatment of these metals; in some cases,flocculation is added. The efficiency of treatment depends mainly upon the concentration of metals, and to some extent,upon the presence of organic matter and the solid matter content. For toxic hexavalent chromium, various reducing agents are used to change it into the less toxic trivalent stage, before precipitation.

Some of these metals can be removed from water by various biological treatment, in spite of their rather high toxicity. However, they generally accumulate in the sludges and bring new problems for sludge disposal. Wet oxidation of such sludge might be of some use to concentrate these metals.

2.4 RADIOACTIVE WASTES

The condition under which radioactive materials may be placed into the sea or into the sewage wystem have been extensively studied under IAEA. International agreement has been reached as to maximum permissible levels based upon the recommendations of ICRP. However, there is no international control of radioactive waste discharge into the sea. The introduction of radioactive maeerials into the waste treatment system is usually strictly controlled by national legislation, so that very little finds its way into the waste disposal systems. These small amounts come mostly from hospitals and scientific laboratories. Provided that they are sufficiently diluted so that no hazard arises, the radio chemicals may be treated in the same way as the non-radioactive isotopes of the same chemical species. Where necessary advaiced techniques are available for concentrating the waste and for its subsequent disposal under proper conditions.

2.5 OIL AND OIL DISPERSANTS

Oil, both as crude and as refined products, reaches the marine environment by a variety of routes. These are by aerial transport, from car exhausts, directly from rivers without going through a treatment plant, from refineries and from tanker operation and accidents. The proportion of the total oil burden which arrives by each of these routes is not established and may vary from place to place. Some oil will of course arrive at a treatment plant by way of the sewers. It may be in one of three forms. Firstly, as a film of variable thickness; secondly, as an emulsion and thirdly, as a solution of certain components dissolved in water. It should also be noted that some substances will preferentially dissolve out of the water into the oil.

The subsequent treatment of the oil within the plant will depend upon the form that the oil takes. The floating film may be removed at the primary stage by skimmers with varying degrees of efficiency. Similarly, the emulsions may be broken by suitable methods. The dissolved material will undergo digestion to a degree which will depend upon its chemical structure and the microbiological content of the digesting system. Oil refinery waste poses a number of difficult problems which require sophisticated treatment.

Evidence continues to be gathered on the effect of oil on the living resources of the sea. It has recently been demonstrated that some soluble components, believed to be polyphenolic in nature leak out of oil in prolonged contact with sea water. These substances have been shown to have a chronic toxic effect on porcelain crabs and the larval forms of the sea urchin. In addition, it is also known that degradation by bacteria will depend upon the temperature and the chemical condition of the water, and the degree of dispersion of the oil. Some fractions, in particular the n - alkanes will, under favourable conditions, degrade in a few weeks, while the degradation time of other fractions can be expected to be of the order of years or even decades. There is therefore a danger that in enclosed, or semi-enclosed sea areas, the concentration will rise to an unacceptable level, particularly as the slowly degrading material includes some compounds which have carcinogenic and mutagenic properties. It is important to realize that most, if not all of these compounds are found in the unpolluted environment and arise from natural processes. The critical factor may be the load which the environment is able to assimilate safely.

As far as the effect on amenities is concerned, the use of low-toxicity detergents now available is usually unsatisfactory, where the high amenity of the beach warrants their use. It is essential however that the application be made properly in order that as little as possible of the detergent is used. Creat caution is necessary in the proximity of fish nurseries, fish spawning grounds, areas of scientific interest and other areas which indicate against the use of detergent. It should be borne in mind that not only may the oil itself be toxic, but the detergent may solubilize some components of the oil, thereby releasing toxins into the water. It is equally important that the hydrographical conditions be taken into account, particularly as regards water turbulence and temperature. The surfactants used in the low-level-toxicity detergents are usually biodegradable, a process which, in the laboratory at least, results in oil being released again in globular form. There is as yet no satisfaytory treatment of oil on beaches where detergents are contra-indicated or when the oil loading of the beach is low.

2.6 PETROCHEMICAL AND ORGANIC CHEMICAL PRODUCTION WASTES

These wastes are among the most difficult to treat that are known to man. Each of the chemical groups is unique and there is much information published on the treatment methods. However, as a preliminary comment, the following notes are to be considered for the treatment of organic chemical wastes. The chemical structure, flow rates, temperatures, toxicity, and desirability, as well as many other factors vary widely over time and between industries. There are treatment facilities in Germany, U.K., U.S.A. and Japan, as well as in other countries that employ every conceivable form of unit operation and process to handle these wastes safely and efficiently. The typical industrial waste-treatment plant that would handle these organic chemical wastes would consist of an equalization pond, followed by neutralization and physical treatment to produce the solid-liquid separation. Biological treatment is commonly used next, choosing the optimum forms of treatment including biological filters, activated sludge, lagoons, etc. Often these systems incorporate extended aeration principles to further oxidize the organic materials and reduce the sludge volume.

Several of the chemical plants will use a separate, concentrated, waste stream or a batch-pick-up system by tracks to keep extremely toxic or harmful materials from entering the plant sewer system. These wastes are usually disposed of by high-temperature concentration, deep-well injection, containerization and/or dumping at sea. These materials, therefore, pose the greatest technical and economic challenge to the protection of the marine resources.

2.7 ORGANIC WASTES

Besides the ordinary organic wastes carried by domestic sewage, a large percentage of organic matter is to be found in waste effluents produced by industrial activities such as food processing, pulp and paper mills, slaughterhouses, fish meal and fish-processing plants, dairy plants, pharmaceutical laboratories, tanneries, textile plants and hospital installations.

Generally, the organic wastes from these activities can be disposed of in the same manner as domestic organic wastes. In many towns, the same public sewer system collects both types.

The major characteristic of organic wastes discharged by industrial activities is the high BOD (Biochemical Oxygen Demand). The equivalent population for 1000 litres of milk processed in a cheese plant varies from 250 to 1000 persons. The processing of one cow is equivalent in BOD to the wastes of 70 to 200 persons. The BOD of the sewage from the main fishing port and fishmeal producing town in Peru, was equivalent to the total population of the whole country, 12 million people approximately.

In certain cases, the waste from these industrial plants is so rich in animal oils and protein that it is economic to process the effluent and thereby recover the substances for re-use. Special treatment processes are used before discharging the waste into the municipal system, such as screening, flotation and chemical flocculation. Tests made in one meat processing treatment plant indicated a reduction of protein from 7,000 to 5 mg/l and BOD from 1,800 to 120 mg/l. To partially recover the high amount of proteins contained in the stick water from the fish meal plants specially designed solid recovery units and stick water treatment units are installed in the processing line. Consequently, a better quality fishmeal is obtained, the protein content is raised from 64 to approximately 69 percent and marine waters are duly protected.

An important aspect of the textile industry, besides the acid and oil wastes, is the large amount of cloth that accidentally gets into the sewage pipes, clogging them. Screening at the outlet of every factory should be seriously considered. These wastes are noted to be usually highly alkaline and coloured from the dye operation. Also, the sizing of cloth allows high phosphate discharge to further complicate the waste treatment.

Wastewater from wood processing industries can be classified into two groups: waste from mechanical treatment of the wood; and waste from chemical wood processing. The first can be disposed of by an earlier biological treatment. In case the waste is finely dispersed, flocculating agents should be added. Sea water as a flocculating agent in paper mills located at the sea-shore,could make the process cheaper. The soluble constituents of wood wastes may hinder the biological process,because they lack the necessary nutrient elements. Phosphorus and nitrogen compoundd should be added or the effluent mixed before treatment with nutrient rich domestic sewage.

To produce cellulose from wood,two chemical processes are used, the sulphite and the sulphate processes. From the first a dark brown-coloured liquid with an extremely high organic content mixed with sulphate salts is obtained. Discharged into a body of water, they give rise to a serious oxygen depletion owing to the oxidation of the salts and the digestion of the organic matter. A 500 ton per day plant is equivalent to two million people BOD of the wastes. Up to the present time, no widely accepted method has been developed, although the spent sulphite waste liquor from cellulose digestion is a suitable raw material for many industries, such as production of ethyl alcohol, fatty acids and soaps, chemical processes and others.

In the sulphate process, in reality an alkaline digestion of wood, recovery of the liquor is practised and wash waters are recycled. The wastes suspended and introduced into the liquor give an unpleasant smell causing air pollution. The BOD in this process is relatively small in comparison with the sulphite process. Under certain conditions toxic compounds can be synthesized polluting the environment.

The use of activated carbon or chemical precipitation by means of ferrous sulphate and lime, combined with activitated sludge treatment, are processes that give good results.

It is suggested that organic wastes from industries should be treated prior to disposal into the marine environment by secondary treatment, either at the industry or through the general municipal system's treatment plant. If organic wastes are discharged into enclosed or semi-enclosed marine waters, the oxygen is consumed by the biological process, marine species will die or go away, bad odours caused by the production of hydrogen sulphide (H_2S) will be present, metal vessels and installations will be corroded and public amenities will be seriously reduced.

2.8 MILITARY WASTES

These may contain a very wide range of substances, including some which are highly toxic and persistent,if released into the marine environment. For obvious reasons production figures and details of disposals are rarely available. In most countries,methods of treatment and disposal are closely related to principles and practices applicable to civil establishments. Clearly, it is highly desirable to follow consistent principles in developing waste treatment and disposal policies for all wastes, including those from military establishments and warships.

2.9 HEAT

The main hazard that thermal energy presents in marine waters is its effects on the benthic and non-migratory species, specifically in their life cycle, such as breeding and spawning. In general, thermal pollution is limited to small areas, where outlets from industrial or electric power plants discharge their effluents. The installation of cooling towers in such industrial plants will solve some problems, but other situations present great technical difficulties.

2.10 DETERGENTS

The active substances at the present time in the majority of synthetic detergents consist of a series of alkyl benzene sulphonates (ABS) some of which are resistent to oxidation and treatment. The main hazards in marine waters presented by detergents contained in domestic sewage are the effects on marine species, specially on the larvae, and the increment of phosphates that may produce a process of eutrophication in enclosed areas. In limited cases, the presence of foam can be detected. Effects of detergent films on the surface of the sea have been indicated as a possible mechanism of introducing other pollutants into the sea by improving solubility of atmospheric pollutants.

Until the "soft" biodegradable detergents are generally accepted, the reduction of detergent concentration in sewage can be obtained by foam generation that is removed mechanically before the disposal of the effluent. Partial removal of phosphates can be obtained by means of a carefully controlled secondary treatment, e.g. lagoons.

2.11 SOLID OBJECTS

The principal sources of concern here are the deposition of containers and bulky solid objects, such as old motor cars, in continental shelf waters in such a way as to interfere with navigation and fishing, and the jettisoning of waste from ships, especially virtually indestructible plastic materials, which may subsequently foul propellers or water intakes of ships or be washed ashore and so interfere with amenities and recreational activities. Regional and global action to prohibit such dumping is being developed, with the alternative of disposal in deep water beyond the edge of the continental shelf or destruction ashore. The possibilities of incineration at sea are also being investigated,and deep water deposition of containerized toxic materials at sites established to be infolding areas has also been suggested. The area of choice in the disposal of such objects has already been narrowed and is likely to be further reduced by the projected global convention on marine dumping and action by IMCO in respect of ship-generated garbage. Beneficial effects of artificial reefs established in sport fishing areas are now well documented and the possibility of using selected inert solid materials for this purpose needs to be considered.

2.12 INERT WASTES AND DREDGING SPOIL

The substances in this group are basically inert but arise in very large quantities. They produce their main effects by increasing turbidity and blanketing the sea bottom. They may reduce phytoplankton production by cutting down light penetration and may interfere with filter feeders in the plankton and on the sea bottom (e.g. molluscs). The behaviour and physiology of fish may be affected,e.g. by smothering the gill surfaces. The character of the sea bottom may be so altered as to modify the composition of the ecosystem and its biomass. Not all the effects may be adverse, increases in biomass and availability of fish food having been recorded as soft bottoms replace hard ground. Examples of the inert wastes in this group are fly ash from power stations, coal washings, gypsum, china clay and "red mud" from bauxite reduction. Treatment of these wastes is impracticable because of the quantity in which they are produced,and decisions regarding disposal are therefore mainly related to choice of site. The more important considerations are likely to be degree of dispersal by tides and currents, nature and distribution of living resources, especially crustacea, molluscs, static invertebrates and edible seaweeds, presence of feeding and spawning ground for fish and proximity of amenity areas, particularly bathing beaches. The possibility of beneficial effects should not be overlooked, nor the lessening of harmful effects which might result from a lengthened outfall or the adoption of dumping from ships as an alternative to a coastal pipeline. Whether to adopt sea disposal or dumping on land is likely to depend more upon the availability of suitable land and amenity considerations than upon comparative costs. The choice between a disposal site at sea which, because of water movements, will result in rapid dispersal over a wide area, and one which is likely to lead to local deposition and containment, should be related to the nature of the waste and the particular objectives to be achieved. Drastic local changes in bottom character over a small area may be preferable to a widespread increase in turbidity.

Dredging spoils consist principally of clay, silt, sand gravel and stones, with variable amounts of organic matter, but present special problems because of the presence in many deposits of adsorbed metals and residues of slowly degradable organic materials, including pesticides and PCBs. Oil may also occur in harbour dredgings. Their effects when disposed of at sea are similar to those of the inert wastes described above with the added complication that persistent organic substances and metals may be transferred to the food chain and may eventually reach fish and shellfish used as food.

Treatment of dredging spoils is impracticable and dredging of harbours and navigable channels must be maintained if shipping is not to be hazarded or denied access to particular ports. Moreover, as tankers and bulk carriers have increased in size and number, additional dredging has become necessary and channel and harbour maintenance has been intensified. In addition, in some countries, coastal development projects have been undertaken which have added to the quantity of dumped spoil. Disposal practice must follow the same principles outlined for other inert material with the added need both to determine the average content of metals and persistent organic substances in dredged spoil and to take these into account in selecting a disposal site.

Where substantial quantities of highly objectionable substances, such as mercury and cadmium compounds, occur in harbour or channel dredgings, the possibility of disposing of the most heavily contaminated material on land should be investigated. If impracticable, special attention should be given to the selection of dumping sites to minimize the risk of recycling of these metals through the food web. Needless to say, the possibility of the dumped material being transported by currents and wave action into navigable channels or back to coastal waters should be investigated in respect of all bulky inert materials.

Undersea mining and gravel extraction may also liberate substantial quantities of fine material which may be dispersed by currents and tides and lead to effects similar to those produced by disposal of inert wastes. The creation of almost perpetually-turbid conditions by such submarine mining operations may result in profound local changes in the fauna and flora.

3. FUTURE DEVELOPMENTS

The group is very conscious that, of necessity, a very simple approach has been used in the first attempt to relate the effects of pollutants to the technical methods available for dealing with them. We are aware of the need for a more sophisticated appraisal, but this requires both more time than is available at this meeting and also access to adequate library facilities. We understand that WHO and various governmental agencies in several countries are actively engaged in the review and evaluation of the methods of waste treatment for a large number of industries. Using this and similar data, a working party could develop a document which would clearly indicate, to a non-technical administrator, the various systems available for the treatment of a wide range of effluents, both domestic and industrial. In addition, the working party would indicate the effect on the marine environment of the effluent from each of these treatments, when this effluent enters the sea. We would recommend, therefore, that this task be undertaken during the inter-sessional period.

The group was also conscious that, in practice, economic and technical manpower considerations govern the choice of treatment of waste as much as environmental conditions. We therefore suggest that at a future date, an attempt be made to indicate the relative cost of each alternative treatment. A further advanced development would consist of the preparation of a decision-making manual which could be followed in order to arrive at the optimum treatment for a given waste under specified, hydrographical, chemical and biological, marine conditions when a particular set of economic and manpower conditions apply.

4. REVIEW OF ANNEX VI OF GESAMP-III

The following comments were prepared after the group reviewed the GESAMP-III report. These comments are made as advisory and for agencies to take note for later action. The comments refer to the paragraph numbers.

48 and 49

It was recognized that there is a need for the intercalibration of methods of analysis of marine pollutants. Suitable arrangements for making progress in this field should be considered. In the general field of methodology further efforts should be made to take advantage of what has been learned in the studies of radioactive materials.

57

Further Environmental Studies

It was noted that, for better assessment of the pollution potential of different types and quantities of sewage and industrial wastes discharged at various outfalls, more emphasis should be placed on developing cartographic documentation for coastal zones.

58

Disturbance of ecosystems by construction affecting the coastal zone must be taken into account and environmental impact statements of proposed activities be prepared to provide the basis for well-founded decisions dealing with major hydraulic programmes.

52

Regional Investigations of Marine Pollution

It is considered that, in planning co-operative regional investigations of marine pollution, particular attention should be given to the areas of major importance for fishery production.

New Recommendations

It is strongly encouraged that the techniques for measuring the degree of biodegradability be developed and standardized to assist the overall evaluation of pollution impact on the marine environment, taking advantage of the many indexing techniques that have been attempted from a biochemical standpoint.

Microbiology

It is recommended that, in addition to the projects (a) to (d) described in GESAMP III, Annex VI, further studies be initiated on the fate of human pathogen and parasites in the marine environment under different climatic and hydrographic conditions.

Annex III to the

Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft

Signed at Oslo, Norway, on 15 February 1972

Provisions governing the issue of permits and approvals for the dumping of wastes at sea.

1. Characteristics of the waste

a) Amount and composition;
b) Amount of substances and materials to be deposited per day (per week, per month);
c) Form in which it is presented for dumping, i.e. whether as a solid, sludge or liquid;
d) Physical (especially solubility and specific gravity), chemical, biochemical (oxygen demand, nutrient production) and biological properties (presence of viruses, bacteria, yeasts, parasites, etc.);
e) Toxicity;
f) Persistence;
g) Accumulation in biological materials or sediments;
h) Chemical and physical changes of the waste after release, including possible formation of new compounds;
i) Probability of production of taints reducing marketability of resources (fish, shellfish, etc.)

2. Characteristics of dumping site and method of deposit

a) Geographical position, depth and distance from coast;
b) Location in relation to living resources in adult or juvenile phases;
c) Location in relation to amenity areas;
d) Methods of packing if any;
e) Initial dilution achieved by proposed method of release;
f) Dispersal, horizontal transport and vertical mixing characteristics;
g) Existence and effects of current and previous discharges and dumping in the area (including accumulative effects).

3. General considerations and conditions

a) Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate use of the sea;

b) In applying these principles the practical availability of alternative means of disposal or elimination will be taken into consideration.

Annex VII

THE CONSEQUENCES OF THE HUMAN PERTURBATION OF THE DEEP-SEA FLOOR

(Working Group 4-Agenda Items 8 & 11)

Members of the Working Group:

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CONTENTS OF REPORT

1. INTRODUCTION

The deep ocean floor is being perturbed by man's activities more and more with time. The sunken ships, lost cargoes and weapons deposited on the ocean floor, together with scientific and exploratory drilling and dredging, clearly attest to this. But the extent of such activity is small compared to the area of the ocean bottom. Only the prospect of intensive mining of the ocean bottom for manganese nodules, phosphorite nodules, metal-rich sediments and petroleum, and massive dumping of pollutants there, raise the possibility of serious damage to the oceans.

In this report, we survey the types of perturbation to which the ocean floor may be subjected in the future and make an effort to assess the consequences. The consequences cannot always be expressed in terms of the normal amenities or economic values used for land and coastal water operations; they appear to be a fundamental part of the human enterprise nevertheless.

2. EFFECTS ON THE OCEAN BOTTOM

2.1 Physical effects

In order to assess the importance of man's activities on the ocean floor in causing physical changes, we must compare them to natural processes.

There is now excellent evidence that the ocean bottom is constantly subject to naturally induced physical dislocations. The time scales and intensities vary regionally. Sediments around Antarctica show strong ripple marks, and radioactive dating of sediment cores there indicate dislocations at many one site approximately every thousand years. Slumping on the continental margin and turbidity current transport occur in specific areas at fairly frequent intervals. It is an almost annual event at the mouth of the Magdalena (Columbia) for example, while occurring once every tens of years along susceptible parts of the continental margins of the world. Some regions, although having been active sites of slumping during the low sea stands of glacial times are now quiescent. Presumably they can be activated at a time in the future when sediment instability occurs again. We guess that roughly 0.1% of the ocean bottom - usually the same relatively limited vulnerable areas - are perturbated by slumping and turbidity currents every 100 years.

In areas of strong bottom transport, especially by western boundary currents, high latitude-originating glacial sediments are transported and accumulate in deep basins such as the Argentine basin at rates between 5 to 12 cm/1,000 years, a factor of 10 to 100 times higher than those found in the central parts of ocean basins receiving only eupelagic detritus.

The physical effects of mining, or other artificial perturbing processes, of themselves will probably not be as important as these natural processes. The significance of the human intervention is that an aggressive exploitation of the ocean floor may process, indiscriminately large parts of the ocean basin whereas the natural processes are not uniformly distributed in intensity or frequency. The biological consequences of the latter are known empirically to be capable of accommodation by the deep ocean life, but there is serious concern about the former's effect as discussed in the next section.

2.2 Biological effects

The deep-sea fauna, although having low biomass per unit area (estimated at 10 mg/m^2), is a highly diversified one. Represented there are primitive forms such as the mollusc <u>Neopilina</u> and solitary corals. Although none of these species can be considered either as an economic asset or a critical member of the food chain, their importance lies in the fact that they represent a unique preservation of relict fauna important in the study of evolution. The preservation of bottom fauna is thus a curatorial effort which is one of the hallmarks of civilized man.

Recent evidence presented in GESAMP IV/14 shows that some deep sea organisms require 200 years to reach maturity. A physical dislocation of the deep-sea benthic fauna at a fast enough rate could prevent the opportunity for repopulation of some species. Aggressive sea floor mining, dumping or building could diminish the probability of some species reproducing themselves thus leading to a more rapid extinction rate of this unique fauna.

2.3 Chemical effects

Although the magnitude and complexity of the chemical effects of disturbance of bottom sediments or the supply of alien chemicals to the ocean floor is probably less than those due to natural processes such as submarine volcanism or turbidity current transport, it does locally perturb the chemical and adsorptive equilibrium established between the sediment surface and the water column. Artificial disturbance of this relatively equilibrated interface as well as the interstitial water within the sediment column will cause re-adjustments to take place. The chemical effects of the human intervention can be of several types:-

1) change of oxidation-reduction potential at the sediment-water interface and the associated interstitial water;

2) disturbance of the adsorption equilibria between bottom water and sediment for trace elements and radionuclides; and

3) upsetting the steady-state diffusion process of some elements in the sediments, by the creation of discontinuous concentration gradients.

Although the quantitative estimations of these processes in terms of mass elements adsorbed or desorbed, combined or released, per unit time are hard to make, the re-establishment of new equilibria at the sea bottom requires, at least, several years, possibly a few tens of years. However, the chemical effects due to artificial disturbances will probably remain small considering all the other natural geochemical processes taking place at the ocean bottom.

We can consider two types of metal release at the ocean bottom. One, a surface sediment release of containerized chemical or radioactive waste and the other release of metals from interstitial waters of exposed sediments resulting from scouring.

Recent evidence on the disequilibrium of the Pb^{210}/Ra^{226} daughter-parent pair in deep sea water by Craig, Somayajulu and Krishnaswami of Scripps Institution of Oceanography indicates that effective surfaces exist in the water column to remove lead as it is produced from radium. The efficiency of this process can be stated as equivalent to a mean residence time of less than 50 years for the entire water column. These workers observed that at the very bottom the Pb^{210}/Ra^{226} disequilibrium is even more pronounced. This means that near the ocean bottom, ambient efficient scavenging particles exist for metals behaving like lead but not for radium. A reasonable supposition is that iron and manganese oxides are the agents for sequestering the lead. If this is the case, most metals, radioactive or otherwise, will be subject to capture and retention in the sediments so that although a halo of unknown size will exist for a time around the release site, any unlimited wide dispersion is not envisioned.

In the second case, where deep sediment is exposed by scouring, a similar situation will de obtained. Generally deep-sea sediments below about 30 to 40 cms show some effect of reducing conditions. If sedimentation is rapid enough (say 1 cm/1000 years) sulphate will be reduced and the Mn^{+2}, Fe^{+2} and Ba^{+2} concentrations in interstitial waters will increase. Most metals that form insoluble sulfides will normally not increase in concentration in interstitial waters. The exposure of these reducing sediments to oxygenated deep sea water results in the release and rapid precipitation of manganese and iron as oxides and barium as barium sulphate. The iron and manganese oxides will tend to scavenge any local available metals and barium sulphate will act as a trap for the ambient radium isotopes. The extent of this effect will depend on the speed of bottom currents and the size of the freshly precipitated particles.

2.4 <u>The expected behaviour of alien substances supplied to the sea floor</u>

2.4.1 <u>Oil and hydrocarbon gas seepage</u> : Oil and gas (hydrocarbon dominated by methane) escape from natural seeps in the sea-bed in unknown quantities, but estimates for oil have been as high as 1 million tons per year. Although sophisticated precautions are being taken to avoid oil loss from sea-bed oil drilling and exploitation, it can be expected that some oil will enter the marine environment from such activities. The oil seep at Santa Barbara, California (USA) is an example of escaping oil from an oil extraction operation and it is conceivable that such seeps could occur at depths greater than 1000 m. Even sea-bed mounted oil drilling and pumping equipment can be expected to release oil into the sea as a result of human error, breakdown of equipment and leaks.

Oil which comes into contact with sedimentary materials is expected to become absorbed into particles even in the aqueous environment of the deep sea. Once oil and sediments mix, the oil will deposit on the bottom as an oily sediment, and by analogy with oil spills in Arctic and Subarctic regions, we expect the rates of destruction to be very slow. The depleted viable bacterial population at depth also will not aid in the destruction of the oil. How widespread this would be depends on the topographic characteristics and near-bottom currents. In any case, it is not anticipated that the contamination of the sediments by oil would cover an area exceeding a radius of 500 metres around the drill or pumping rig, except in exceptional cases. However, oil contamination in this confined area could be heavy and continuous.

Gas seeps from the sea-bed are known to be even more prevalent than oil, partly because gas in quantities exists sometimes by itself, such as in the North Sea, and almost always accompanies oil. Moreover, escape of gas is probably more difficult to detect than oil. At the pressures and temperatures prevailing at depths exceeding 1000 m, the gas apparently dissolves in water to form a methyl hydrate clathrate. Some cores brought up by the JOIDES expedition have exploded as they reach the surface temperature and pressure and the gas escapes. The consequences of such material on the bottom and in the sediments are unknown.

The possibility of oil and gas being located beyond the continental slope and rise, at depths greater than 1000 m, appears to be real. The JOIDES expedition penetrated "salt domes", which are good indicators of oil-bearing strata, in deep waters of the Gulf of Mexico during its coring programme and circumstantial evidence off the coast of West Africa indicates the same. Oil-exploitation companies are confident enough in prospects of finding oil that they are now obtaining leases for exploration at depths as great as 2000 m.

Assuming that natural seepage of oil is about 1 million tons per year, (10% of the estimated total oil loss into the sea from all sources), and that oil injected into the marine environment from deep-sea exploration and exploitation eventually approaches this figure, it is of interest to speculate what this added effect would be. The major difference between effects of natural seeps and those arising from exploration and exploitation beyond 1000 m depth would be in their distribution. While natural seeps could be widespread, without major localized effects, the effect of oil on the sea-bed from oil drilling and pumping operations would be concentrated around the drill rigs and pumps. Ecological disturbances could be intensive in these artificially-perturbed areas, whereas some acclimation may have occurred over the long periods of time in regions of natural oil and gas seeps.

2.4.2 Containerized chemical and radioactive wastes : Chemicals of high toxicity or radioactive materials of intermediate-level activity have been containerized for deep-sea disposal. There are possibilities of rupture of these containers on impact, as they strike the bottom, or they may eventually release material because of deterioration or disturbance by other activities. The effect of the released chemical on the bottom would be related to their chemical characteristics as discussed above.

Deep ocean dumping is considered attractive to some for the isolation of radioactive wastes from the biosphere for a long time. The major radionuclides of long-term concern are of two types : the medium-lived fission products (e.g. Sr^{90} and Cs^{137}) and the long-lived actinides (e.g. Pu^{229}). The immediate hazards from the fission products is higher, but it is estimated that after about 700 years they will have decayed to levels which present much lower risks; the actinides are very long-lived and require isolation for several thousands of years.

Packaged radioactive wastes are supposed to be on the sea bottom in such a form that, even after the primary containers have been corroded the rate of radioactive nuclide release will be retarded sufficiently so that it will not result in damage to man or the marine ecosystems. During three ENEA (European Nuclear Energy Agency, now called Nuclear Energy Agency) operations (1967, 1969, 1971) some 67,000 containers of solid radioactive wastes representing about 40,000 curies of beta and gamma emitters and about 1000 curies of alpha emitters were incorporated in concrete and asphalt blocks, placed in metal drums, and dumped into the Atlantic Ocean at a depth of about 5000 metres ENEA hazard assessment has indicated no danger to the marine environment to date.

Even if no direct effects are found over a long time scale by normal attrition at the bottom, there is the risk of recovery of waste containers after disposal by people ignorant of the nature of their content. If this risk can be made negligible by the choice of a suitable designated disposal area, by appropriate design of the containers used, and by strict operational control at all stages of the dumping operation, then it is conceivable that deep ocean dumping may yet prove feasible.

2.4.3 Liquid wastes : Liquid wastes can be dumped into the sea either at the surface or at depth. Aside from the local sea water alteration, the chemicals constituting the waste can be expected to form solids when chemicals precipitate or coagulate, and these will eventually make their way to the sea floor. Surface discharge is a reality today and pipelines for the deep sea have been suggested for the future.

The surface release of liquid wastes is generally accomplished by barge, where the wastes are discharged into the turbulent waters of the wake. Much experience has been obtained in such disposal off the New York Bight, where some studies have been made of dispersion of acid pickling wastes. Some of the precipitating iron is known to settle to the bottom, but the ecological effects are not fully understood. In deep water, the dispersion of these particles would be even greater.

Although it is not expected that pipelines for conveying liquid wastes to the sea will extend to depths greater than 1000 m, the consequences of pipelines even to the continental edge could conceivably be felt at depths beyond. This is a result of seaward transport by currents and spread by lateral diffusion. Again precipitation of dissolved constituents, which exceed their solubility product under conditions present in sea water, could occur. The effects on the bottom would depend on the size of discharge, characteristics of the effluent, location of outfall with respect to the continental edge, and the nature of currents and mixing. Deep liquid dumping could have a more direct effect on the bottom than surface dumping.

2.4.4 Barged loose material : It is common practice for many communities to dump dredge spoils, sludge and debris from excavations into the ocean. To date, these have been dumped on the continental shelf, but concern about pollution in the shelf sediments and overlying waters has elicited the suggestion that dumping be done in the deep water of the continental slope or rise. This is not a desirable practice because the effect on the sparse deep benthic life is likely to be more deleterious than in shallow water environments for the reasons given above.

2.4.5 Material transported down canyons in the continental margin : Some material dumped on the continental shelf adjacent to the beginning of a marine canyon, such as the Hudson Canyon off New York City, may be transported down the canyon as sporadic turbidity currents. The amount of material so transported may be masked by the natural burden, and therefore at the present time, probably does not constitute a major perturbing force for the deep ocean bottom. It is not desirable, however, to use specific channels, such as the Monterey Canyon suggested as an avenue for the transport of San Francisco area sewage, to transport materials whose influence on the bottom fauna is not assessed.

Also there is no value in considering dumping via canyons into deep-sea trenches on the premise that ocean-floor spreading will transport the polluted material into the mantle. The rates of spreading are too slow (less than 5 cm/year), with no guarantee that motion is not sporadic on a 100 year time scale, as it is in tectonism observed on land.

3. EFFECTS AT THE OCEAN SURFACE

3.1 Thermal and chemical effects

The deep water of the ocean everywhere is about 2° to 4° C. If this water should be pumped up together with sediments or manganese nodules during mining as was done by Deep Sea Ventures in a pilot project, it would be discarded in the normally warmer surface layer of the oceans. In an area of 10,000 km^2 a mining rate of 10^6 tons of manganese nodules a year with 20 times that mass of deep water lifted with the nodules, would mean a supply of 2×10^{-4} l/cm^2. If the thickness of the mixed layer is 100 metres this would correspond to 2×10^{-3} l of deep cold water to 1 litre of surface water every year. Such a dilution would not seriously affect any of the thermal or chemical parameters of the surface water.

Although the phospate concentration of deep water may be up to 100 times the concentration of surface water, it is evident that the deep water addition will only increase the phosphate concentration by 10% at most. Nitrate is less affected and trace elements virtually not at all since for most of them the maximum difference between surface and deep waters is about a factor of 2 to 3 enrichment in the deep water over the surface water.

Surface heat exchange of deep water and mixing with surface water will generally result in lateral rather than deep vertical dissipation of the excess water.

3.2 Particles

The most important ocean surface effect of any sort of process lifting a water slurry of material from the ocean floor is that due to the fine grained particles. We can calculate a reasonable estimate of this effect. If the sediment mass is equal to the manganese nodule mass in nodule mining by suction or air-lifting, then assuming an operating area of 10^4 km^2, one million tons of nodules will yield one million tons of surface disposible sediments. If 10% of the sediments is clay size and settles through 100 m in about 5 years then the concentration in the top 100 m will not be greater than 1 mg/l. for five years. Although this is 25 times higher than most deep waters, it is well within the range of coastal waters in which productivity is not hindered. One can conclude therefore that particles of themselves in their transient enrichment in surface waters, as a result of man's activities, will not seriously affect the environment.

3.3 Organisms

The deep-sea is a repository of many forms of life derived from shallower water environments. This ranges from the magafauna which may record the phylogeny of evolving coastal forms as implied in Section 2, to microfauna such as bacteria and such unicellular organisms as diatoms. Dr. O. Roels of Lamont-Doherty Geological Observatory recorded the presence of Nitzchia, a shallow water diatom in deep-sea sediments which became activated on surface exposure Similar results have been reported for bacteria. Ocean-floor mining bringing deep-sea sediments to ocean surface will bring these quiescent forms of life as well. Their fate at the ocean surface will in part be dictated by their successful competition with other forms of food or nutrients. It is difficult to conceive of these forms overwhelming the local population or injecting some detrimental chemical by their growth but clearly some further experiments are required to ascertain the benevolence of these long-passive organisms.

3.4 Oil and other organic components

Oil can enter the upper mixed layer from oil exploration and exploitation operations on the sea-bed. Although oil is lighter than water, and therefore, ascends towards the surface to form a film, some oil may become entrained as small droplets in the water column. Work at the Bedord Institute in Canada showed that Bunker C oil from the tanker ARROW, which broke up on the coast of Nova Scotia in early 1970, was present in significant amounts in the upper mixed layer. This group has noted above-background concentrations of oil in the surface layer of the Gulf of St. Lawrence, with significantly more oil above a sunken barge seeping oil. Studies of zooplankton in the waters near the ARROW wreck have shown that euphausids take up the oil droplets but excrete them virtually unchanged.

It is possible that other dissolved organic compounds, resulting from decomposition of natural or waste materials on the sea-bed, could be released into the surface layer from mining activity. However, the amount of such material would probably be so small as to be inconsequential.

4. CONCLUSIONS

Our major conclusion must be that the natural perturbations of the deep ocean floor are likely to remain greater than those added by man's judicious exploitation.

The greatest potential damage will come about if too aggressive an approach is taken to ocean floor mining. The sparsity of the diverse, ancient fauna of the deep ocean floor and the late pubescence of at least some of the species indicates that ocean floor mining should proceed at a rate metered by the repopulation rate of these species. This may require some regulation especially as the fauna are hidden from common surveillance by 4000 metres of water.

There should not be an automatic rejection of disposal even of radioactive wastes on the ocean floor nor approval of it. Rather, it could be considered as one of the viable alternatives to waste treatment, provided that continued research on waste containments by man-made or natural processes is guaranteed.

The major inputs to the solution of many of these problems will come from a wide spectrum of ocean scientists working in their individual arenas of interest. In that sense, the benefits of basic marine research will far outweigh any monitoring consideration. The proper comprehension of such prophetic concepts as the proper utilization of the deep ocean floor must depend on wisdom gained, commonly, by dedicated marine scientists addressing themselves to scientific questions rather than attempting to obtain specific operational answers with crash programmes.