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Report of the twenty-seventh session of GESAMP

Nairobi, Kenya, 14 - 18 April 1997

IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)

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Notes

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Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)

REPORT OF THE TWENTY-SEVENTH SESSION
Nairobi, Kenya, 14-18 April 1997

UNITED NATIONS ENVIRONMENT PROGRAMME
Nairobi, Kenya; July 1997

Contents

Executive Summary

I. Evaluation of the hazards of harmful substances carried by ships (Working Group 1)

More hazardous chemicals are being listed and evaluated

- GESAMP has revised its evaluation criteria for hazardous chemicals.
- Copies of the next edition of the International Maritime Organization's Composite List, containing 2,500 hazard profiles of substances transported at sea, will be made available to member States of UNEP's Regional Seas Programme.

II. Environmental impacts of coastal aquaculture (Working Group 31)

As the aquaculture industry grows, so too does the use of chemicals

- Some of the chemicals used in coastal aquaculture include: antibacterial agents, feed additives, hormones, pesticides, soil and water treatments.
- Chemicals originally developed for use on food crops and in livestock production are now being used in aquaculture.
- An overview on chemical usage was prepared, with the goal of protecting coastal environments and their living resources, human health and the sustainability of the aquaculture sector.
- Although intended to enhance coastal aquaculture, chemical usage may actually cause problems. Examples include: difficulties of effluent treatment; trade difficulties arising from drug residue monitoring and enforcement programmes; potential loss of efficacy because of prophylactic use of antibacterials; and lack of alternatives to chemotherapy use.
- Evaluating and quantifying the risks associated with aquacultural chemicals is complicated by a lack of quantitative data on chemical use as well as lack of field data. Available data relates primarily to temperate regions with little information on tropical areas.
- Most countries have little or no data on the amount of chemicals used in aquaculture within their borders; further, the information from temperate regions may not be applicable in lower latitudes.
- Because some chemicals are essential for aquaculture activities, regulatory mechanisms must be put in place and monitoring must be undertaken. Governments, the scientific community and pharmaceutical companies all have a role to play in these efforts.

III. Storage of carbon dioxide in the deep sea

The equilibrium between the atmosphere and the oceans may be sensitive to CO_2 emissions from anthropogenic sources.

Can fossil fuel CO_2 be injected into deep oceans as a means of counteracting the effects of global warming? To address this possibility, the following factors must be considered:

- The feasibility of capturing a large proportion of future carbon dioxide emissions from fossil-fuelled electrical generation and the disposal of such in the deep ocean.
- The scientific and technical limitations.
- The legal impediments.
- The social and political concerns.
- The total benefits *vs* the total costs (economic and environmental).

IV. Review of the state of the marine environment (Working Group 26)

Periodical assessments of the state of coastal and marine environments are being made. Emphasis is on the effects of, and threats by, humans to coastal and marine waters

- An initial activity is a report on Land-based Sources and Activities Affecting the Quality and Uses of the Marine, Coastal and Associated Freshwater Environment, to be ready in 1999. This report will contribute to the implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, for which the United Nations Environment Programme is the Secretariat.

- GESAMP will prepare "State of the Marine Environment" reports every decade.

- A comprehensive, integrated global international waters assessment (GIWA), encompassing the problems of freshwater basins, their associated coastal systems, and the global oceans, is being prepared. Collaborative possibilities between the GESAMP and GIWA assessments are being explored and a joint GESAMP/GIWA task force is being developed.

V. Significant matters regarding degradation of the marine environment

- Technological developments now allow for much deeper drilling for oil and gas in oceans than was the case in the past. As a result, contamination and pollution from such activities can affect large offshore areas and their ecosystems.

- Changes to the London Convention and the management of wastes. The ban on dumping of many wastes at sea from ships and barges may have in unforeseen repercussions. An example is increases in wastes through pipelines and rivers, thereby adversely affecting coastal areas. There may also be more land-based pollution.

- Serious fisheries issues include overfishing and biomass removal, the physical impacts of fishing, by-catches of other species, new fisheries and their impact on ecosystem integrity. There clearly is a need to improve the science for monitoring of fisheries.

- Contaminated marine sediments. Remedial options include capping of contaminated sediments with a layer of clean material, and removal and isolation elsewhere. Guidance is needed on appropriateness of the remediation, and on evaluation criteria such as effectiveness and overall costs/benefits (including the best net benefit for environmental protection).

- A critical appraisal of the Large Marine Ecosystem (LME) concept is needed, including a review of the scientific foundation of LME's and their use as a management tool.

1. INTRODUCTION

1.1 The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) held its twenty-seventh session at the Headquarters of the United Nations Environment Programme (UNEP) in Nairobi, Kenya, under the Chair of Ms. H. Yap. Mr. P. Wells was Vice-Chairperson.

Opening of the Session

1.2 The Chairperson called the twenty-seventh session of GESAMP to order at 0930 h.

1.3 Mr. J.E. Illueca, UNEP Assistant Executive Director, welcomed the participants on behalf of the UNEP Executive Director. He noted the importance of the work of the GESAMP Working Group on Marine Environmental Assessments (MEA), particularly as it related to the implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, for which UNEP serves as Secretariat.

Adoption of the Agenda

1.4 The participants adopted the provisional agenda as agenda for the session, as shown in annex I. A list of documents considered during the session under each agenda item is given in annex II, and the list of participants is shown in annex III.

2. REPORT OF THE ADMINISTRATIVE SECRETARY

2.1 The GESAMP Administrative Secretary drew particular attention to requests made by countries that the UNEP Executive Director should consider, in cooperation with the heads of the other GESAMP sponsoring organizations, how GESAMP might most effectively contribute to the task of carrying out the next periodic review of the state of the marine environment. The Administrative Secretary also expressed his concern that the financial resources of GESAMP's sponsoring organizations are being continually reduced, thereby seriously affecting the work of GESAMP.

2.2 In response to requests that GESAMP's sponsoring organizations review the Group's *modus operandi*, with a view to providing opportunities for dialogues with intergovernmental bodies, the GESAMP Administrative Secretary noted that sponsoring organizations should present GESAMP's results and studies at meetings of their committees. Equally, representation by Governments regarding GESAMP activities should be addressed and dealt with by GESAMP sponsoring organizations. From this perspective, there appeared to be no need to change GESAMP's rules of procedures.

3. EVALUATION OF THE HAZARDS OF HARMFUL SUBSTANCES CARRIED BY SHIPS (EHS) (Working Group 1)

3.1 Following a brief introduction by the IMO Technical Secretary of GESAMP, Mr. P. Wells (chair of the Working Group) presented a report on progress achieved during the 32nd and 33rd sessions of the Working Group, noting the continuing number of chemicals which had been evaluated or reviewed at the request of industry and Governments. He reported on the review of the GESAMP hazard evaluation procedure, which is now complete. The new scheme is based on an expanded set of criteria, ordered into columns, with the goal of providing easily readable data to IMO and other bodies (see annex IV for the revised hazard evaluation procedures).

3.2 It was stressed that, after 25 years of operation, IMO requested a revision in order to consider modern insights in environmental science (e.g., biodegradation). It also realized that, under Chapter 19 of Agenda 21, the Organization for Economic Cooperation and Development (OECD) established a clearing-house for the global harmonization of chemicals classification systems, including "substances dangerous to the environment", and that close cooperation with OECD should be supported.

3.3 Following a series of OECD Working Group meetings, considerable progress has recently been made towards developing a core classification scheme, and a final proposal is expected by early 1998. Realizing the importance of global harmonization, the Working Group tried to consider as many of the OECD criteria as possible in designing the revised hazard evaluation procedures. All the environmental criteria (acute and chronic toxicity, biodegradation and bioconcentration) are similar to those proposed by GESAMP for its new hazard evaluation scheme. However, some unavoidable differences exist between the schemes with regard to structure and cut-off points:

(i) The OECD scheme is a combined hazard evaluation and classification scheme, with labelling forming a separate downstream activity. The GESAMP profiles are restricted to hazard evaluation only and "classification" into pollution categories, plus "labelling" in the form of assignment of carriage conditions is the remit of IMO;

(ii) The GESAMP Working Group maintains a published, peer reviewed list of a relatively small number of high volume chemicals (2500 chemicals as of 1997), whereas OECD is designing a "self classification" system for use by industry with no mechanism of peer review, except for that provided by individual administrations (e.g., European Union, United

States of America and Japan) for selected groups of chemicals; and

(iii) Many of the acute toxicity cut-off points required by IMO in the categorization of bulk liquids have not been included in the OECD scheme because these were transport-mode specific.

3.4 GESAMP requested the Working Group to monitor progress, although it also was recognized that resolving potential conflicts between the OECD and GESAMP hazard schemes was outside its terms of reference. Some members expressed their concern at the use of transport mode-specific (road and rail) criteria, such as load size in a global OECD scheme, and the effect that this might have on shipping.

3.5 With regard to implementation of the proposed GESAMP revised hazard evaluation procedures, IMO recently noted that the above activities will have "an effect on its guidelines for the categorization of noxious liquid substances described in Appendix I to MARPOL 73/78, Annex II". An international project was underway to determine the potential impact of these and other changes on marine transport in general.

3.6 One member asked whether a period of overlap was envisaged between the old and new hazard profiles. He was informed that an overlap of several years at least was envisaged in order to facilitate the introduction of new regulations and guidelines for IMO and other current users of the hazard profiles.

3.7 Several members queried whether the new hazard evaluation procedures could be used more broadly (e.g., for implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, and other UNEP or FAO programmes). The IMO Technical Secretary of GESAMP responded that the existing hazard profiles are being expanded and clarified greatly to allow such wider usage.

3.8 Another member enquired about the origin of the definitions for carcinogen and suspected carcinogen. He was informed that correct International Agency for Research on Cancer (IARC) definitions and references would be retained in the final editing.

3.9 Clarification was requested by several GESAMP members on the use of the log Pow scale. It was noted that the log Pow was an essential scale for determining environmental hazard, particularly in the absence of measured data. The use of an upper log Pow cut off point (*ca.* 7-8), at which organic substances can be classified as not hazardous in terms of significant bioconcentration, was discussed. It was suggested that this limit was not high enough to cover polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins (PCDDs) safely, as these may still show significant accumulation at log Pow's in this range. In reply to this suggestion, the chairman of the Working Group stated that, for the majority of non-persistent organic compounds this was not the case. Rapid metabolism generally leads to far lower levels of bioconcentration in any case than predicted on the basis of the log Pow. However, the point was accepted as an important contribution, and it was agreed that highly persistent organic compounds [e.g., PCBs, PCDDs and polychlorinated dibenzo furans (PCDFs)] should be treated as special cases, with no upper limit on the log Pow scale. The Group advised to reconsider the definition of bioconcentration in the glossary, to better reflect "tissue bioconcentration" as opposed to the presence of particulate material (e.g., in the gut).

3.10 One member suggested that the methods associated with the determination of chemical oxygen demand (COD) should be altered to reflect the preferred use of potassium permanganate instead of potassium dichromate. This matter would be re-examined in the final editing.

3.11 The relationship between acute and chronic aquatic toxicity, as well as definitions of chronic toxicity endpoints, was raised by several members. The chairman of the Working Group stated that a factor of 10 between both columns was adequate to cover the acute-chronic ratios of majority of narcotic substances without a specific mechanism of toxicity. Consistent with separating all properties into discrete columns, it had been decided to use different ratings for acute and chronic toxicity. The appropriateness of "no observed effect concentration" (NOEC), as opposed to "effective concentration 50%" (EC50) values for the ratings in chronic tests was also queried. The Group, however, noted with satisfaction that the NOEC has been chosen as the most conservative, experimentally-derived value of the toxicity threshold concentration.

3.12 Arising from requests that a broader usage of the hazard profiles should be promoted, a small drafting group was formed to consider this matter. It recognized that the scheme is based on selected intrinsic properties reflecting potential harm to the aquatic environment and, although the parameters were specifically intended for the management of chemicals at sea, they could also be used individually or collectively in many fields of water management and pollution control:

(i) GESAMP hazard profiles already have some use in providing guidance and data for the evaluation of oilfield chemicals. Few regional

organizations have developed specific regulatory schemes of its own with a wide selection of narrowly prescribed tests intended for risk analysis;

(ii) Regarding the aquaculture industry, many common chemicals are contained in the GESAMP hazard profiles, and it was felt that the new scheme, which will contain biodegradation data, as well as the acute aquatic toxicity and bioconcentration properties of the current scheme, could be useful. It was further noted that there were few, if any, pharmaceuticals in the current profiles and that efficacy was outside their scope;

(iii) It was felt that the existing and new hazard profiles could be very useful for developing countries where decisions have to be made as to the disposal of old chemical stocks. The GESAMP Chemical Composite List contains reliable profiles on many "older" chemicals; and

(iv) Until such time as the OECD scheme and "self classification" were instituted in the global setting adopted, the GESAMP hazard profiles might have some use under the Basel Convention by providing basic environmental data on high volume chemicals.

3.13 GESAMP approved the revised hazard evaluation scheme in principle. It thanked the Working Group for completing the proposals on schedule, and also requested the Working Group to finalize the scheme. The IMO Technical Secretary of GESAMP undertook to make copies of the next edition of the GESAMP Chemical Composite List containing 2500 hazard profiles of substances transported at sea, available for distribution to member States of UNEP's Regional Seas Programme.

4. ENVIRONMENTAL IMPACTS OF COASTAL AQUACULTURE (Working Group 31)

4.1 The FAO Technical Secretary of GESAMP reported that the Working Group met in Iloilo, the Philippines, from 23-28 May 1996. The Working Group prepared the document "Towards safe and effective use of chemicals in coastal aquaculture" (GESAMP XXVII/4, XXVII/4/1 and XXVII/4/2), proposed for approval and publication.

4.2 In introducing the document, Mr. D. Weston (chair, Working Group) explained that the report provides information on over 50 chemicals used in coastal aquaculture, and highlights issues of concern related to their use and eventual discharge to the marine environment, as well as to the presence of residues in the tissues of cultured organisms. The report further offers a number of recommendations on the safe and effective use of chemicals in coastal aquaculture.

4.3 The chair of the Working Group pointed out that, in spite of relatively little information available from Latin America and Africa, the Working Group was able to prepare a thorough compilation of coastal aquaculture chemicals in current use worldwide. The Working Group considered that most aquaculture chemicals, if used properly, were beneficial, and should have no adverse environmental and or human health implications. However, concern was raised over the use and mis-application of certain chemicals for which marine hazard profiles were not available. Another concern was the apparent lack of availability of quantitative data on drug usage.

4.4 In the ensuing discussion, GESAMP offered numerous technical comments and suggestions for inclusion in the report. In particular, it was proposed to make efforts to draw upon information available in a few countries on quantities of chemicals used, to give a general impression of the magnitude of possible impacts. More information on chemicals (e.g., toxicity data when available) also should be given. Reference to already-existing guidelines for the proper management of chemicals should be made. Projections on whether or not the trend towards intensification of aquaculture would lead to increasing risk from use of chemicals would also be useful.

4.5 It was noted that the structure of the report generally needed improvement. Statements made in the report regarding the low probability of eutrophication from coastal aquaculture are not applicable in all cases, and tropical reef environments may be particularly vulnerable. Some concern also was raised with regard to the overall tone of the report, which appeared to be overly optimistic as to the dangers inherent in the use of chemicals in aquaculture. It was particularly noted that it would be necessary in the report to indicate concern over the use of chemical compounds that were neither designed for use in the aquatic environment, nor tested to that end. The report also should mention the need for collection of quantitative data on use of chemicals and information on their potential environmental effects, as well as stress the need for adequate regulatory mechanisms addressing the use of chemicals in coastal aquaculture.

4.6 The chair of the Working Group undertook to incorporate into the document the comments received, and resubmitted it later during the present session. Further amendments are to be provided by GESAMP members by 15 May 1997. A final version will then be circulated for approval and publication as GESAMP Reports and Studies No. 65. A summary

of work of the Working Group and the list of participants is attached as Annex V.

4.7 GESAMP invited the Working Group to address, during the next intersessional period, its third (final) term of reference; namely, the review of concepts and experiences related to the integration of aquaculture into coastal area management schemes. In this context, the Working Group should pay particular attention to the requirements for ensuring that coastal aquaculture development is conducted in a sustainable manner compatible with other legitimate uses of the coastal zone. This may require consideration of criteria or indicators for judging successes or failures in meeting such aspirations.

5. STORAGE OF CO_2 IN THE DEEP SEA

5.1 The IMO Technical Secretary of GESAMP introduced document GESAMP XXVII/5 ("Storage of CO_2 at deep sea"), in referring to the formation of the Correspondence Group on this topic at GESAMP XXVI, co-sponsored by UNESCO-IOC and IMO. Mr. J.M. Bewers (chair, Correspondence Group) outlined the content of the document stressing that it dealt largely with scientific and technical matters relevant to the terms of reference of the Working Group, as follows:

(i) Describe proposals for CO_2 storage in the ocean;

(ii) Evaluate the current state of knowledge regarding the consequences and effects of such storage;

(iii) Identify the major scientific unknowns and uncertainties regarding the assessment of consequences; and

(iv) Make recommendations for any further GESAMP action on this matter.

5.2 There also are elements of a social, economic and legal nature in the document that provide a broader appreciation of the topic.

5.3 In the ensuing discussion, there was general appreciation of the content of the document. A number of questions, however, were raised about details and terminology used in the document. Some suggestions for additions to the paper also were made, including more representation of the contemporary rates of fossil-fuel CO_2 production globally to provide a more illustrative representation of the scale of the problem. There were some errors in the document that need to be rectified.

5.4 GESAMP agreed to annex the document, in revised form and accompanied by an executive summary, to the report of its XXVII session (Annex VI). However, because of the level of technical detail in the document, it was suggested there would be a need to prepare the executive summary in simpler, more direct language, in order to convey the major points and findings of the paper to a more general, non-technical audience.

6. REVIEW OF THE STATE OF THE MARINE ENVIRONMENT (Working Group 26)

6.1 Mr. O. Osibanjo [Co-chair, Working Group on Marine Environmental Assessments (MEA)] introduced document GESAMP XXVII/6, a report of the first meeting of the Working Group on Marine Environmental Assessments (Geneva, 17-18 May 1996). He stated that Annex V ("State of the marine environment report: a possible structure/approach") and Annex VII ("Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment") of the report needed GESAMP's particular attention.

6.2 Mr. Osibanjo noted that the Working Group identified a number of significant points fundamental to achieving its goals, including:

(i) Preparation of the state of the marine environment (SOME 2002) and land-based activities (LBA) reports are the main tasks of the MEA Working Group, and should proceed without delay. The need for adequate financial resources for preparing the reports also was stressed;

(ii) All GESAMP sponsoring agencies should effectively support the MEA Working Group substantially and financially, and consider it as a joint Working Group. If the MEA Working Group was to succeed in its goals, the support of all agencies (not UNEP alone as the lead agency) was needed;

(iii) GESAMP sponsoring agencies were invited to reconsider the priority and resources they had assigned to preparation of both the SOME and LBA reports, and also to mobilize additional financial resources from other potential sources [e.g., the Global Environment Facility (GEF), European Union, and individual Governments]; and

(iv) Collaboration with relevant programmes and organizations to prepare the SOME and LBA reports was required.

6.3 The UNEP Technical Secretary of GESAMP introduced document GESAMP XXVII/6/1 ("GESAMP Working Group on marine environmental assessments: a progress report"), noting that progress in the agreed tentative activities and workplan for the LBA and SOME reports has been hampered to date, primarily because of financial constraints.

6.4 Nevertheless, limited progress has been achieved in some areas since the first meeting of the MEA Working Group, particularly through the activities dealing with implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, for which UNEP is the Secretariat. These activities include the preparation of overviews of land-based activities affecting the marine, coastal and associated freshwater environment in regions of the UNEP Regional Seas Programme. The UNEP Technical Secretary of GESAMP also noted the potential linkages between the objectives of the SOME and LBA reports and the Global International Waters Assessment (GIWA) project (i.e., preparation of global assessments, based on a series of regional assessments; see below). These two activities are further detailed in GESAMP XXVII/INF.1-4.

6.5 Mr. J. Pernetta (UNEP/GEF Unit, and chair, GIWA Steering Group), who attended this GESAMP session as observer, gave an overview of the GIWA project (GESAMP XXVII/INF.4), and how it might relate to the MEA Working Group activities. He emphasized the following points:

(i) GEF interventions in the Biodiversity, Climate Change and Ozone focal areas focus on single country interventions, while those of the International Waters portfolio emphasize multi-country interventions;

(ii) GEF does not function as the financial mechanism for any single global convention relating to International Waters; hence, guidance on the nature of GEF interventions is provided through Chapter 4 of the GEF Operational Strategy and Operational Programmes 8 (Waterbody), 9 (Integrated land-water multiple focal area), and 10 (Contaminants);

(iii) GEF has approved a UNEP Project Development Facility (PDF) Block B Grant proposal to prepare a Global International Waters Assessment that would encompass areas of interest to GESAMP, the International Council of Scientific Unions (ICSU)/Scientific Committee on Problems of the Environment (SCOPE) and a variety of other agencies and organizations; and

(iv) The preparatory activities for GIWA are underway and include two expert meetings to examine the issue-related and regional-related frameworks for such an assessment. A number of GESAMP experts have been invited to participate in these activities.

6.6 It was indicated by the UNEP/GEF Unit observer that, while the GEF would not finance an independent GESAMP assessment, GESAMP activities that represented a substantial intellectual contribution to the GIWA process could be eligible for GEF support. In view of the mutual benefits that might be derived from collaboration of GESAMP with the proposed GIWA project, GESAMP agreed to examine possible modalities of cooperation and collaboration, as recommended by its Joint Intersecretariat, and further that the UNEP Technical Secretary of GESAMP should represent GESAMP at the first GIWA experts meeting (Geneva, 21-25 April 1997), and transmit to it the outcome of its present discussions.

6.7 GESAMP agreed to review the terms of reference of the MEA Working Group. In this context, it was suggested that it might be most useful to consider preparation of (i) more frequent and concise biennial reports; and (ii) long-term, comprehensive major reports. After some discussion, GESAMP generally agreed to this suggested change of its reporting modalities. It was noted that a change in the types of reports produced might also require consideration of a different audience for various reports. As an example, it was suggested that the short reports could target Governments, while the long-term report would address the needs of a wider audience. It also was suggested that every GESAMP meeting should prepare a report for public consumption. A further suggestion was that the first short biennial report could focus on land-based activities. GESAMP generally agreed with this suggestion.

6.8 The UNEP/GEF Unit observer, however, noted that the GIWA effort might be most compatible with the SOME assessment. He further provided information on the nature of the GEF International Waters portfolio. Among the items highlighted were (i) GEF International Waters works with groups of countries, rather than individual nations, in contrast to the other GEF focal areas; (ii) nevertheless, GEF must have government and regional commitments for international waters projects; (iii) GEF's policy generally is not to fund strictly assessment activities; and (iv) the GIWA Steering Group identified five major issue clusters, including freshwater scarcity, pollution, habitat/community maintenance, excessive use of resources, and global change. The UNEP/GEF Unit observer also reminded GESAMP that the main goal of the GIWA project was to help GEF decide on

priorities, and that, at the same time, GESAMP interests could be accommodated within this goal. Finally, he noted that the intention was that the GIWA project document would be submitted to the GEF Council in July 1997, and that the resultant funds (if approved) would be available in the last quarter of 1997.

6.9 An informal Working Group met to discuss the MEA Working Group activities, including (i) its terms of reference; (ii) the biennial assessment reports; (iii) the LBA Report; (iv) the comprehensive assessment report; (v) schedule of work; and (vi) logistic arrangements. These items, as endorsed by GESAMP, are summarized below:

6.9.1 The terms of reference are modified as follows:

(1) To undertake:

(a) Short, general biennial assessments, including highlights of major current and emerging issues;

(b) Assessment of land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment; and

(c) Periodic comprehensive assessments of the condition of the marine environment (SOME reports), with emphasis on the effects of, and threats posed by, anthropogenic activities.

(2) To develop scientific approaches:

(a) For improving the reliability, comprehensiveness and utility of assessments; and

(b) To meet expectations of the international community for a more balanced geographic coverage of assessments, including, *inter alia*:

* New concerns and perspectives;

* Improved insight regarding trends; and

* The social and economic consequences of impacts on the marine environment, its resources and amenities, and *vice versa*.

(3) To identify actions, including adoption of new scientific and innovative approaches for sustainable protection and development of the marine environment, its resources and amenities within the context of existing and planned international and regional agreements.

(4) To promote and keep under review the conduct of regional assessments, and to provide scientific and technical guidance to facilitate improved global assessments.

(5) To identify, recommend and apply better indices of environmental conditions to assess environmental changes and trends.

The outlines of the SOME and LBA assessment reports mentioned in item (1) above are attached as annexes to this report (Annexes VII and VIII). The outline for the biennial assessment reports is give below.

6.9.2 *Biennial ("short") assessment reports*

The reports [see item 1(a) of the Working Group's terms of reference] should be structured in the following way:

ABSTRACT/EXECUTIVE SUMMARY
1. INTRODUCTION
2. OVERALL ASSESSMENT
   - coastal/shelf
   - open ocean
3. CURRENT MAJOR ISSUES AND EMERGING PROBLEMS
4. IMPLICATIONS FOR SCIENCE, MANAGEMENT AND POLICY
5. RECOMMENDATIONS
6. BIBLIOGRAPHY

The assessment report will be short [no more than 25 pages (A4) of published text, including tables and figures, consistent with the standard format of GESAMP reports]. Heading 3 above would constitute the bulk of the report. Land-based activities will be the major topic of the first "short" assessment report (i.e., the current "major issue").

6.9.3 *Land-based activities (LBA) report*

The LBA Report agreed to at GESAMP XXVI should be prepared as a separate report, based on the outline in Annex VII of GESAMP XXVII/6, taking into account the annotations provided for the individual sections and sub-sections of the report (see Annex VII of the present report). A section should be added to the outline to deal with the enhancement of environmental conditions, restoration of damaged systems, and beneficial effects, if any.

The assigned responsibilities for preparation of the report's individual sections indicated in Annex VII of GESAMP XXVII/6 should be reconsidered in the light of planned reconstitution of the MEA Working Group.

It was noted that present expertise available among the GESAMP members is inadequate to evaluate (and approve) the LBA Report as a GESAMP report. Thus, the Joint Intersecretariat was invited to consider the need to broaden the current spectrum of expertise of GESAMP to include experts familiar with, *inter alia,* political and social sciences, environmental and industrial economics, land-use planning and coastal zone management, freshwater issues, civil engineering, hydrology, and international maritime law.

6.9.4 *Comprehensive ("long-term") assessment report*

The next comprehensive report on the state of the marine environment ["SOME 2002": item 1 (c) of the Working Group's terms of reference] should be structured on the basis of the outline in Annex V of GESAMP XXVII/6 (i.e., Annex VIII of the present report).

The assigned responsibilities for preparation of the individual sections of the report indicated in Annex V of GESAMP XXVII/6 should be reconsidered in the light of planned reconstitution of the MEA Working Group.

Recognizing that the ultimate use of the report is for management purposes (e.g., pollution control measures, regulation of fisheries activities, and coastal zone management), the regional subdivisions in the report should be based on areas selected on the basis of the following criteria (given in priority order):

(i) Areas covered by existing or planned regional (including bilateral) agreements/conventions;

(ii) Areas covered by existing or planned regional programmes; and

(iii) Areas displaying continuity of major physical, chemical and biological features and processes (the Large Marine Ecosystem concept should be applied with caution).

The number of regions to be considered for the comprehensive report should not exceed 20.

6.9.5 The establishment of cooperative arrangements between GIWA and GESAMP on all scientific and technical issues relevant to preparation of the GIWA and GESAMP long-term assessments was recognized as highly desirable. Establishment of joint task forces for preparation of regional reports and issue-related reports was advocated in all cases where GIWA's and GESAMP's objectives and interests coincide. This would facilitate the mutual benefits of GIWA and GESAMP building a common data- and information-base, and rational use of financial and human resources. As an example, with the exception of item 1 (Freshwater Scarcity; Table 1a, GESAMP XXVII/INF.4), all other items are of high relevance for preparation of the GESAMP long-term assessments. It was also noted that GESAMP would benefit from collaboration with GIWA, in terms of social, economic, political, legal and similar aspects of the assessments.

Further, if GIWA could accommodate the criteria given above for the geographic scope of regional reports, establishment of joint regional task forces was advisable. GESAMP members participating in meetings dealing with development of GIWA should work to ensure that GESAMP's views consistent with GIWA were adequately and accurately presented at these meetings.

6.9.6 *Schedule of work*

The outlines or early drafts of the first biennial and the LBA reports should be reviewed by GESAMP XXVIII (1998), and submitted as final versions for adoption by GESAMP XXIX (1999). Given the time constraints associated with preparation of these reports, it was suggested that GESAMP XXIX should be scheduled for the second half of 1999.

The schedule and modalities for preparation of the SOME Report will depend in part on the expected approval of the GIWA project in late 1997, and the cooperation which may be eventually established with GIWA.

6.9.7 *Logistical arrangements*

It was assumed that the GESAMP sponsoring agencies will ensure that the necessary logistic and financial support will be provided for the Working Group activities, keeping in mind that the financial resources required were quite significant (including the resources needed for cooperation with GIWA).

7. MATTERS OF PARTICULAR CONCERN REGARDING DEGRADATION OF THE MARINE ENVIRONMENT

A number of issues were raised by GESAMP members and are presented as discussed.

7.1 *Deeper ocean drilling for petroleum and its impacts*

In past decades, drilling for oil and gas in the marine environment has largely been restricted to relatively shallow, nearshore coastal and continental shelf waters. It was noted that recent technological developments now enable the petroleum industry to undertake exploration for production of oil and gas in

increasingly deeper waters in many regions of the world. Any possible contamination, including from the release of oil and gas, and pollution as a result of these activities could affect large offshore areas of the ocean and their ecosystems. GESAMP was encouraged to monitor the development and the potential for harm to offshore, deeper ocean areas from operational and accidental releases from such petroleum industry activities.

7.2 *Management of wastes - impact on coastal seas of recent changes to the London Convention*

The recently adopted Protocol to the London Convention will ban disposal of most wastes and other matter from ships and barges at sea, except normal dredged materials. This may result in substantial increases in waste disposal through pipelines directly into coastal seas or into rivers that flow to the sea, bringing about significant additional pressure to the coastal zone. It may also result in more pollution on land. It should be emphasized that, from a marine environmental protection viewpoint, the net benefit of these changes in waste management practices must be viewed and estimated holistically, recognizing detriments and enhancements to other sectors and other parts of the environment. In addition, if policy changes are going to lead to alterations in disposal practices, it will be necessary to ensure that monitoring programmes are sufficiently robust and long-term in nature to detect the net benefits, if any, of changed practices.

7.3 *Effects of fishing on the marine environment*

GESAMP reiterated its deep concern with respect to the biological and ecological effects of marine fisheries. This issue was also raised at the GESAMP XXVI session in 1996. There is clearly a fisheries crisis in many parts of the globe. GESAMP members expressed concern not only about the direct effects of overfishing and biomass removal on the marine ecosystems, but also about the physical impacts of fishing (e.g., trawling effects on the bottom, and bycatches of other species) and the effects on ecosystem integrity of new fisheries for so-called underutilized species, including those in intertidal zones and the deep sea. There is a clear need as well for improving the science associated with monitoring the overall effects of fisheries, leading to a better knowledge of both effects and recovery processes. On the policy side, it was felt that sufficient advice and recommendations are already available, and that action largely rests with the coastal States where the majority of fisheries reside.

7.4 *Remediation of contaminated marine sediments - management options*

The vast majority of past research on contaminants in the marine environment has focussed on an assessment of the spatial scale, magnitude and biological effects. In recent years, however, there have been efforts to correct situations of contamination, rather than merely document them. Capping of contaminated sediments with a layer of clean material is probably the most economical option. Removal and isolation elsewhere, either to an inland location or to a specific marine environment site, may provide a more secure disposal option. *In situ* bioremediation is an especially attractive approach, but has not been attempted yet in subtidal environments. Since remediation of contaminated marine sediments is still in its infancy, and recognizing the uniqueness of each disposal situation and site, guidance is urgently needed on (i) Under what circumstances is remediation (*vs.* no action) appropriate? (ii) What approaches are currently feasible, evaluating criteria such as effectiveness and overall costs/benefits, including best net-benefit for environmental protection? and (iii) What follow-up studies are appropriate and necessary to evaluate the success of remediation efforts? Useful general guidance on management options might be provided through an evaluation of individual case studies.

7.5 *The Large Marine Ecosystem (LME) concept - a critical appraisal*

GESAMP discussed the LME concept, its use in coastal management, and the recognized need for an authoritative, balanced and critical review of its scientific foundation and use as a management tool. GESAMP recognized that IOC recently also discussed the LME concept, with a similar conclusion. No decision for action by GESAMP was taken.

7.6 *Consideration of matters of particular concern for the future*

Taking into account the importance for GESAMP to raise its voice on major current and emerging urgent matters related to threats to the marine environment and needs for environmental protection, and in particular the requirements for the biennial assessment reports, GESAMP decided to keep this agenda item for future sessions. It was also agreed that the GESAMP Chairperson would request GESAMP members to prepare their views and discussion subjects in advance (three months prior to a session), and that GESAMP would hold an informal meeting each year, prior to the formal sessions, to discuss this matter and prepare for formal discussions of matters of concern.

8. FUTURE WORK PROGRAMME

8.1 *Endocrine disrupting substances*

8.1.1 GESAMP welcomed the efforts of the Working Group on the Evaluation of the Hazards of Harmful Substances Carried by Ships in keeping a watching brief on potential ecological effects of endocrine disrupting substances discharged at sea. The Working Group reviewed numerous publications and material made available to it during the intersessional period, and concluded that GESAMP should set up a special task team or working group on this matter. The IMO Technical Secretary of GESAMP proposed that GESAMP consider the proposal, noting the high profile of this area of investigation and the extensive discussion among aquatic toxicologists, wildlife experts, medical scientists and environmental groups in general, as well as the significant political elements in the discussion.

8.1.2 GESAMP was further informed that a number of situations have been described wherein endocrine disruptors have been definite causative agents of adverse reproductive effects (e.g., organotin compounds and imposed in marine snails, pesticides and masculinization of Florida alligators, DDT and egg-shell thinning in gannets). Many localized incidents of endocrine disruptions in fish populations also have been observed. However, cause/effect relationships with respect to human health, and the health of aquatic species, are in most cases uncertain or unproven. It also was recognized that, in general, where endocrine disrupting chemicals have been detected in the sea or in freshwater, their concentrations are below effect levels, based on other health effects endpoints. In addition, while some of the current thinking on endocrine disruption is based on sound investigational approaches, other work in this area is scientifically suspect, and many "short-term" tests developed in an attempt to recognize chemicals with endocrine disrupting properties are not validated, or are flawed by not being based on sound biological, mechanistic or endpoint considerations. As a consequence, the currently available information and conclusions concerning the environmental impacts of endocrine disruptors, and the potential for adverse human health effects, require careful and critical analysis.

8.1.3 GESAMP agreed to establish a Working Group to discuss the issue of endocrine disruptors, and prepare a position paper to meet GESAMP's and IMO's interests and requirements. The Working Group would advise on the reliability of current knowledge on endocrine disrupting chemicals, prepare a perspective of the available information, and draw attention to those areas where discrepancies exist between known facts and extrapolation, and where investigational approaches are flawed. The Working Group should be composed of unbiased experts knowledgeable on the topic from various relevant disciplines and perspectives (scientific, medical, social and regulatory).

8.1.4 The terms of reference proposed for this GESAMP Working Group were as follows:

(i) Prepare a synoptic technical assessment of the consequences to human and marine environmental health of the occurrence of endocrine disruptors in the marine environment, including oestromimetic substances, using credible scientific and medical information;

(ii) Provide an unbiased perspective of the issue, given its recognized complexities and potential for erroneous testing, understanding and response; and

(iii) Recommend appropriate actions on the issue in the marine environment that can be taken immediately by the GESAMP sponsoring agencies.

8.2 *Intersessional work*

Taking into account the above considerations, GESAMP noted the intersessional work planned, as follows:

1. Evaluation of the hazards of harmful substances carried by ships (Working Group 1)

Lead Agency:	IMO
Co-sponsor:	UNEP
Chair:	T. Bowmer
Member:	P. Wells

A meeting of the Working Group will be held in May 1998 to evaluate new substances proposed for transport by ships and to prepare publication of its new procedures.

2. Marine environmental assessments (Working Group 26)[1]

Lead Agency:	UNEP
Co-sponsors:	IMO, FAO, UNESCO-IOC, WMO, WHO, IAEA, UN
Chair:	S. Keckes
Members:	M. Bewers, R. Boelens, S. Charmasson, R. Duce, D. Elder, R. Engler, M. Huber, D. Insull, H. Yap

Meetings to be convened in due course.

[1] Originally called "review of the state of the marine environment" (GESAMP Reports and Studies No. 60: paragraph 8.6.1.4).

3. **Endocrine disrupting substances in the marine environment: impacts on marine life and human health (Working Group 27)**

Lead Agency:	IMO
Co-sponsors:	WHO[2], FAO, UNEP[3]
Chair:	P. Wells
Members:	

A meeting will be arranged in 1998.

4. **Environmental impacts of coastal aquaculture (Working Group 31)**

Lead Agency:	FAO
Co-sponsors:	UNEP, UNESCO-IOC, WHO, and with support of IUCN-The World Conservation Union
Chair:	D. Weston

A meeting of the Working Group will be held in Xiamen, China, Autumn 1997.

5. **Input of oil into the marine environment from sea-based activities (Task Team)**

Lead Agency:	IMO
Co-sponsor:	UNEP[3]
Chair:	P. Wells

A meeting of a task force of 4-5 experts will be convened in late 1997-early 1998 to evaluate available data sources on input of oil from sea-based activities into the marine environment, and to consider approaches that might be used to produce reliable input estimates. This Task Team was established by GESAMP XXIV (1994); however, its activities had been delayed due to lack of financial resources.

9. OTHER MATTERS

9.1 *Participation of GESAMP sponsoring organizations and other organizations in GESAMP sessions*

9.1.1 Concern was expressed about the absence of the WHO Technical Secretary of GESAMP and expert (s) supported by this organization in the present session, as well as the indication by the FAO Technical Secretary of GESAMP that his organization may have to follow suit due to financial constraints.

9.1.2 The absence of observers from organizations which traditionally attended GESAMP sessions and followed the work carried out by GESAMP was noted.

9.1.3 Cooperation of GESAMP with programmes of its sponsoring organizations (e.g., IMO/GESAMP Panel of Experts, preparation of the LBA Report in support of implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities being coordinated by UNEP, and the planned GESAMP/ GIWA cooperation on reports expected from Working Group 26) were cited as examples of useful "outreach" of GESAMP's own programme. The Technical Secretaries of all GESAMP sponsoring organizations were urged to consider promoting similar joint activities with non-sponsoring organizations and their programmes whenever such activities might benefit GESAMP's own work.

9.1.4 In view of the serious financial constraints of GESAMP sponsoring organizations, they were urged to address GESAMP-related activities in the most cost-effective way and to avoid incurring unnecessary expenses (e.g., organizing meetings in places that are more expensive than necessary).

9.2 *GESAMP reports*

9.2.1 The Joint Intersecretariat was urged to consider ways and means of enhancing the impact of GESAMP reports. Distribution of GESAMP Reports and Studies through the agencies' official country focal points and to relevant agency-convened meetings were not considered sufficient. Many GESAMP inputs were considered of interest to a broader audience (scientists as well as technical and policy making bodies in national administrations) and the proper channels of communication to this audience should be explored. It was noted that only a few GESAMP outputs have been solicited by Governments in response to their needs (e.g., the outputs concerning the hazards of cargoes carried by ships, the planned LBA Report), which automatically enhances their impact and application. It was noted that many GESAMP reports are not adequately appreciated because they were prepared without adequate concern for their end-users.

9.2.2 The language in GESAMP Reports and Studies is frequently too technical to be understood by managers and policy-makers. As a corrective measure, and without compromising the scientific accuracy of such studies, it was agreed they should regularly contain an executive summary highlighting in correct, but non-technical, language the main issues covered in the study and its main conclusions. This will assist any intelligent non-specialized reader to understand the scope of the report and its relevance.

[2] Pending approval from Headquarters.
[3] Pending availability of financial resources.

9.2.3 It also was suggested that every GESAMP expert should use all available opportunities (e.g., meetings, publications) to spread information about GESAMP and its activities. Experts were urged to publish in the open scientific literature, when appropriate, the results (or parts thereof) obtained through GESAMP working groups, with appropriate reference to GESAMP as the driving force behind these publications.

9.2.4 GESAMP strongly suggested a summary of important issues and recommendations covered during each GESAMP session be prepared in a way that it can be distributed widely and be understood by laymen, Government officials, the press, etc.

9.3 *GESAMP and the 1998 Year of the Oceans*

The input of GESAMP in activities associated with the 1998 Year of the Oceans should not be ignored, and the Joint Intersecretariat was invited to consider the best way to address a coordinated approach to this issue.

9.4 *International Arctic Seas assessment project*

9.4.1 Since GESAMP XXIII, IAEA has reported annually to GESAMP on the progress of the International Arctic Seas Assessment Project (IASAP). The project was completed in 1996, and its executive summary, including conclusions and recommendations formulated by the project Advisory Group, was provided in January 1997 to IMO, as Secretariat of the London Convention (1972).

9.4.2 The objectives of the IASAP project were to:

(i) Assess the human health and environmental risks associated with radioactive wastes dumped in the Kara and Barents seas; and

(ii) Examine possible remedial actions related to the dumped wastes and advise on whether or not they are necessary and justified.

9.4.3 The main results and conclusions of the IASAP project are:

(i) Current releases from identified dumped objects are small, and localized to the immediate vicinity of the dumping sites. Overall, the levels of artificial radionuclides in the Kara Sea from all sources are low, and the associated radiation doses are negligible compared to those from natural sources;

(ii) Projected maximum future dose rates to the public in typical local population groups arising from radioactive wastes dumped in the Kara Sea are very small, less than 1 microSv/year, which is more than three orders of magnitude smaller than the doses from natural sources. Projected future doses to a hypothetical group of military personnel patrolling the foreshores of the fjords in which wastes have been dumped are much higher (up to 4 milliSv/year) and comparable in magnitude to doses from natural sources;

(iii) Projected future doses to various marine organisms, ranging from phytoplankton to seals and whales, are insignificant in the context of effects on populations; and

(iv) Based solely on radiological grounds, remediation is not warranted. However, to avoid possible inadvertent disturbance or recovery of the dumped objects, and because the potential doses to the hypothetical group of military personnel are not trivial, this conclusion depends upon maintenance of some form of institutional control over the access and activities in the vicinity of the fjords of Novaya Zemlya used as radioactive waste dump sites.

9.4.4 The main IASAP report, as well as detailed reports on the findings of three IASAP working groups, will be published in 1997 in the IAEA series. Results achieved in different working areas of the project also are being published.

10. DATE AND PLACE OF NEXT SESSION

GESAMP noted that its twenty-eighth session tentatively would be hosted by the World Meteorological Organization in Geneva, Switzerland, from 20 to 24 April 1998.

11. ELECTION OF CHAIRPERSONS

GESAMP unanimously re-elected Ms. H. Yap as Chairperson and Mr. P. Wells as Vice-Chairperson for the next intersessional period and the twenty-eighth session of GESAMP.

12. CONSIDERATION AND APPROVAL OF THE REPORT OF THE TWENTY-SEVENTH SESSION

The report was considered and approved by GESAMP on the last day of the session, which was closed by the Chair on 18 April 1997.

Annex I

AGENDA

1. Adoption of the provisional agenda
2. Report of the Administrative Secretary
3. Evaluation of the hazards of harmful substances carried by ships
4. Environmental impacts of coastal aquaculture
5. Storage of CO_2 in the deep sea
6. Review of the state of the marine environment:
   - .1 provisions, administrative arrangements, timetable
   - .2 structure, outline and contents of review reports
7. Matters of particular concern regarding degradation of the marine environment
8. Future work programme
9. Other matters
10. Date and place of next session
11. Election of Chairpersons
12. Report of GESAMP XXVII

Annex II

LIST OF DOCUMENTS

Agenda item	Document	Submitted by	Title
1	GESAMP XXVII/1	Admin. Sec.	Provisional agenda
3	GESAMP XXVII/3	IMO	Reports of the 32nd and 33rd sessions of the EHS Working Group (Working Group 1)
4	GESAMP XXVII/4	FAO	Towards the safe and effective use of chemicals in coastal aquaculture - Report of the GESAMP Working Group on Environmental Aspects of Coastal Aquaculture (Working Group 31)
	GESAMP XXVII/4/1	FAO	Comments and suggestions received on the Report of the Working Group 31 - "Towards safe and effective use of chemicals in coastal aquaculture"
	GESAMP XXVII/4/2	FAO	Summary of the Report of the Working Group on Environmental Impacts of Coastal Aquaculture-"Towards safe and effective use of chemicals in coastal aquaculture"
5	GESAMP XXVII/5	UNESCO-IOC	Storage of CO_2 in the deep sea-Report of the Correspondence Group
6	GESAMP XXVII/6	UNEP	First meeting of the Working Group on Marine Environmental Assessments (Report of the meeting, Geneva, 17-18 May 1996)
	GESAMP XXVII/6/1	UNEP	GESAMP Working Group on Marine Environmental Assessments: A progress report
	GESAMP XXVII/INF.1	UNEP	Intersecretariat consultation on implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (Report of the meeting, Geneva,13-14 May 1996)
	GESAMP XXVII/INF.2	UNEP	Joint intersecretariat/ interagency consultation on implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities(Report of the meeting, Geneva, 15-16 May 1996)
	GESAMP XXVII/INF.3	UNEP	Technical meeting on the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities clearing-house (Report of the meeting, Geneva, 26-27 September 1996)
	GESAMP XXVII/INF.4	UNEP	First meeting of the steering group for the Global International Waters Assessment (GIWA) (Report of the meeting, Geneva, 24-27 February 1997)
8	GESAMP XXVII/8	IMO	Proposal to set up a working group to evaluate ecological and human health effects from endocrine disrupting substances discharged into the marine environment

Annex III

LIST OF PARTICIPANTS

A. MEMBERS

J. Michael Bewers
Head, Marine Chemistry Division
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
Canada B2Y 4A2
Tel: (1 902) 426 2371
Fax: (1 902) 426 6695
e-mail: m_bewers@bionet.bio.dfo.ca

Richard G. V. Boelens
Manager, QSR Office
c/o Forbairt Laboratory
Shannon Town Centre
Co. Clare
Ireland
Tel: (353 61) 361 499
Fax: (353 61) 360 863
e-mail: qsr@marine.ie

Tim Bowmer
Head, Environmental Toxicology Group
Toxicology Division
TNO Nutrition and Food Research Inst.
Schoemakerstraat 97
P.O. Box 6011
2600 JA Delft
The Netherlands
Tel: (31 15) 269 62 52
Fax: (31 15) 257 26 49

Sabine Charmasson
IPSN/DPRE
Base IFREMER-CT
B.P. 330
83507 La Seyne sur Mer Cedex
France
Tel: (33 4) 94 304 829
Fax: (33 4) 94 878 307
e-mail: scharma@ifremer.fr

Robert A. Duce
Dean, Professor of Oceanography & Meteorology
Texas A & M University
College of Geosciences and Maritime Studies
Room 204, O & M Building
College Station, Texas 77843-3148
U.S.A.
Tel: (1 409) 845 3651
Fax: (1 409) 845 0056
e-mail: rduce@ocean.tamu.edu

Danny Elder
Champ Courier
Marchissy 1261
Switzerland
Tel: (41 22) 368 1178
Fax: (41 22) 368 2104
e-mail: delder@iprolink.ch

Robert M. Engler
Senior Scientist
USAE Waterways Experiment Station
CEWES-EN
3909 Halls Ferry Road
Vicksburg, MS 39180
U.S.A.
Tel: (1 601) 634 3624
Fax: (1 601) 634 3726
e-mail: Englerr@EX1.WES.Army.mil.us

Ong Jin Eong
Centre for Marine and Coastal Studies
University Sains Malaysia
11800 Penang
Malaysia
Tel: (604) 657 7888, ext. 3511/
(604) 656 3672
Fax: (604) 657 2960/656 5125
e-mail: jeong@usm.my

Michael Huber
Scientific Director
Orpheus Island Research Station
Sir George Fisher Centre for Tropical Marine Studies
James Cook Univ. of North Queensland
Townsville, Queensland 4811
Australia
Tel/Fax: (61 77) 77 7336 (Orpheus Island)
Tel: (61 77) 81 4817 (JCU Campus)
Fax: (61 77) 75 5429
e-mail: michael.huber@jcu.edu.au

David Insull
5 Holland Rise
Kings Sutton
Banbury
OX17 3RZ United Kingdom
Tel: (44 1295) 810 973
Fax: (44 1295) 812 423

Stjepan Keckes
21 L. Brunetti
Borik
52210 Rovinj
Croatia
Tel: (385 52) 811 543
Fax: (385 52) 811 543

Piamsak Menasveta
Aquatic Resources Research Institute
Chulalongkom University
Bangkok 10330,
Thailand
Tel: (66 2) 218 8161
Fax: (66 2) 254 4259
e-mail: piamsak@chulkn.chula.ac.th

Oladele Osibanjo
Department of Chemistry
University of Ibadan
Ibadan
Nigeria
Tel: (234 1) 545 0963 or 820 626 or
(234 2) 810 2198
Fax: (234 1) 820 626 or 545 1097 or
(234 2) 810 3118 or 810 2198
e-mail: library@ibadan.ac.ng or
osibanjo@infoweb.net

Peter G. Wells
Environmental Conservation Branch
Environment Canada
45 Alderney Drive
Dartmouth, Nova Scotia
Canada B2Y 2N6
Tel: (1 902) 426 1426
Fax: (1 902) 426 4457
e-mail: pwells@is.dal.ca

Donald Weston
University of California, Berkeley
Environmental Engineering and Health
Sciences Laboratory
1301 South 46th Street
Richmond Field Station - Bldg 112
Richmond, CA 94804-4603
U.S.A.
Tel: (1 510) 231 5626
Fax: (1 510) 643 6264
e-mail: dweston@uclink.berkeley.edu

Helen Yap
Marine Science Institute
University of the Philippines
Diliman, Quezon City 1101
Philippines
Tel: (63 2) 922 3959
Fax: (63 2) 924 767
e-mail: hty@msi01.cs.upd.edu.ph

B. SECRETARIAT

International Maritime Organization (IMO)

Oleg Khalimonov
Administrative Secretary of GESAMP
4, Albert Embankment
London SE1 7SR
United Kingdom
Tel: (44 171) 5873 119
Fax: (44 171) 5873 210

Manfred Nauke
IMO Technical Secretary of GESAMP
4, Albert Embankment
London SE1 7SR
United Kingdom
Tel: (44 171) 735 7611 or 587 3124
Fax: (44 171) 587 3210

Food and Agriculture Organization of the United Nations (FAO)

Heiner Naeve
FAO Technical Secretary of GESAMP
Fishery Resources Division
Room F-506
Via delle Terme di Caracalla
I-00100 Rome
Italy
Tel: (39 6) 5225 6442
Fax: (39 6) 5225 3020
e-mail: heiner.naeve@fao.org

United Nations Educational, Scientific and Cultural Organization - Intergovernmental Oceanographic Commission (UNESCO-IOC)

George Kitaka
Acting UNESCO-IOC Technical Secretary of GESAMP
UNESCO-ROSTA
P.O. Box 30592
Nairobi
Kenya
Tel: (254 2) 622.364
Fax: (254 2) 215 991
e-mail: uhnai@unesco.org

World Meteorological Organization (WMO)

Alexander Soudine
WMO Technical Secretary of GESAMP
41, Avenue Giusseppe-Motta
Geneva
Switzerland
Tel: (41 22) 730 8420
Fax: (41 22) 740 0984

International Atomic Energy Agency (IAEA)

Kirsti-Liisa Sjoeblom
IAEA Technical Secretary of GESAMP
Waste Safety Section
Division of Radiation and
Waste Safety
Wagramer Strasse 5, P.O. Box 100
A-1400 Vienna
Austria
Tel: (43) 1 2060 ext. 22667
Fax: (43) 1 2060 7
e-mail: sjoeblom@nepo1.iaea.or.at

United Nations (UN)

Ismat Steiner
UN Technical Secretary of GESAMP
Division for Ocean Affairs and
the Law of the Sea
Office of Legal Affairs
United Nations
2 UN Plaza (Room DC2-0470)
New York, NY 10017
U.S.A.
Tel: (1 212) 963 3951
Fax: (1 212) 963 5847
e-mail: steiner@un.org

United Nations Environment Programme (UNEP)

Omar Vidal
UNEP Technical Secretary of GESAMP
Water Branch
P.O. Box 30552
Nairobi
Kenya
Tel: (254 2) 622 015
Fax: (254 2) 622 788
e-mail: omar.vidal@unep.org

C. OBSERVERS

Terttu Melvasalo
Director, Water Branch
United Nations Environment Programme
P.O. Box 30552
Nairobi
Kenya
Tel: (254 2) 622 034
Fax: (254 2) 622 788
e-mail: terttu.melvasalo@unep.org

Magnus Ngoile
Coordinator
Marine and Coastal Programme
IUCN-The World Conservation Union
Rue Mauverney 28
CH-1196 Gland
Switzerland
Tel: (41 22) 999 0001
Fax: (41 22) 999 0002
e-mail: mail@hq.iucn.org

John Pernetta
Senior Programme Officer
UNEP/Global Environment Facility Unit
P.O. Box 30552
Nairobi
Kenya
Tel: (254 2) 624 153
Fax: (254 2) 520 825
e-mail: john.pernetta@unep.org

Walter Rast
Deputy Director, Water Branch
United Nations Environment Programme
P.O. Box 30552
Nairobi
Kenya
Tel: (254 2) 623 244
Fax: (254 2) 622 788
e-mail: walter.rast@unep.org

Annex IV

REVISED GESAMP HAZARD EVALUATION PROCEDURES

Prepared by the Working Group on the Evaluation of the Hazards of Harmful Substances Carried by Ships

1. Column A: Bioaccumulation and Biodegradation

1.1 The tendency of substances to bioaccumulate and biodegrade will be reflected in sub-columns under column A. The **Bioaccumulation sub-column (A1)** would contain two sets of information:

A1a the log octanol/water partition coefficient (log Pow, also often referred to as log Kow), and

A1b the bioconcentration factor (BCF) measured with fish or shellfish as target organisms.

1.2 Log Pow values tend to provide conservative data, whereas a measured BCF does provide definitive information on the potential of a substance to bioaccumulate under "steady state" conditions. The measured BCF often might result in less severe hazard ratings, due to processes such as metabolism which may enhance the excretion of a chemical. In the case where both BCF and log Pow data were provided, the BCF would overrule the log Pow. In the event that only log Pow data are available, and if the value exceeds [to be determined] mg/l, the product will be considered bioaccumulative, unless measured BCF data show otherwise. Substances with very high log Pow values (>ca7) are presumed to be so poorly soluble in water as to pose no further potential for bioaccumulation, assuming also that substances with molecular weights >700 are also assumed not to be accumulated (OECD ref.). Determining exact cut-off points may require further consideration for major chemical groups.

1.3 Log Pow values are applicable to organic chemicals only. To assess the bioaccumulation potential of non-organic compounds, some surfactants, and some organo-metallic compounds, bioconcentration measurements may be carried out and a BCF reported.

1.4 The following test methods are recommended:

log Pow: OECD 107, OECD 117, or a slow stirring method (under development by OECD);

BCF: OECD 305C, OECD 305E, the recently revised OECD 305 flow through test, or equivalent methods (e.g., ASTM and US-EPA methods).

1.5 For "Bioaccumulation" in sub-column A1 a ranking scheme has been developed as follows:

0 - No potential to bioaccumulate
(log Pow < 1 or >ca7, or molecular weight >700; no measurable BCF)

1 - Very low potential to bioaccumulate
(log Pow 1 - <2; BCF 1 - <10)

2 - Low potential to bioaccumulate
(log Pow 2 - <3; BCF 10 - <100)

3 - Moderate potential to bioaccumulate
(log Pow 3 - <4; BCF 100 - <500)

4 - High potential to bioaccumulate
(log Pow 4 - <5; BCF 500 - <4, 000)

5 - Very high potential to bioaccumulate
(log Pow >5; BCF >4, 000)

1.6 With regard to **biodegradation (sub-column A2)**, substances are considered to be "readily biodegradable", if in 28-day biodegradation studies the following levels of degradation are achieved:

- in tests based upon dissolved organic carbon (DOC): 70%; or
- in tests based upon oxygen depletion or carbon dioxide generation: 60% of the theoretical maxima; or
- where only COD and BOD_5 data are available, the ratio of BOD_5/COD 0.5; or
- where other convincing scientific evidence is available to demonstrate that the substance can be degraded (biotically and/or abiotically) in the aquatic environment to a level of > 70% within a 28-day period.

The exact values of biodegradation should be reported together with methods that have been applied.

1.7 The tests to be applied should preferably be those developed for marine environments, e.g., OECD 306 or freshwater tests suitably adapted to marine conditions; however, freshwater tests, e.g., OECD 301 A-F series, or ISO and ASTM equivalents, may also be acceptable.

1.8 The information to be included as ratings in Column A2 (Biodegradability) will be expressed as:

R	=	readily biodegradable
NR	=	not readily biodegradable
NI	=	No information available (see also paragraph 4.34 below)

2. Column B: Aquatic Toxicity

2.1 Column B is divided into two sub-columns, one representing results from acute aquatic toxicity tests, and a second sub-column with information on the (sub)chronic toxicity of the respective substance, wherever available or appropriate.

2.2 With regard to **"acute toxicity"** the ratings shall cover the range from > 1000 mg/l down to <0.01 mg/l.

2.3 Data from the following three standard tests shall be used:

- a 96 hr LC_{50} fish test;
- a 48-96 hr LC_{50}/EC_{50} crustacean test; and
- a 72 hr or 96 hr IC_{50} microalgal growth inhibition test.

The lowest LC_{50}, EC_{50} or IC_{50} (i.e., from the test showing the highest toxicity) shall be used to assign the toxicity rating.

2.4 The test data bands as per tests OECD 201, 202 and 203 and their international equivalents (ISO and ASTM) and their ratings should be included in column B1 (Acute toxicity); their linkage to chronic toxicity ratings in column B2 is as follows:

B1 Acute toxicity			**B2 Chronic toxicity**		
0	-	non-toxic *(> 1000 mg/l)*			
1	-	practically non-toxic *(100 - 1000 mg/l)*			
2	-	slightly toxic *(10 - 100 mg/l)*	2	-	low chronic toxicity *(NOEC > 1 mg/l)*
3	-	moderately toxic *(1 - 10 mg/l)*	3	-	moderate chronic toxicity *(NOEC 0.1 - 1 mg/l)*
4	-	highly toxic *(0.1 - 1 mg/l)*	4	-	high chronic toxicity *(NOEC 0.01 - 0.1 mg/l)*
5	-	very highly toxic *(0.01 - 0.1 mg/l)*	5	-	very high chronic toxicity *(NOEC 0.001 - 0.01 mg/l)*
6	-	extremely toxic6 *(< 0.01 mg/l)*	-		extremely high chronic toxicity *(NOEC < 0.001 mg/l)*

2.5 Chronic and sub chronic toxicity data are important for evaluating the hazard of substances under certain circumstances, such as:

- poorly soluble substances where the acute toxicity is difficult to measure accurately;
- where definite chronic effects are suspected, e.g., endocrine disrupting, reproductive; and
- for substances that degrade slowly and are bioaccumulative.

2.6 Suitable tests for measuring chronic toxicity include the 14-28d prolonged fish test (OECD 204), the 21d daphnia reproduction test (OECD 202) or the fish early life stage test (OECD 210, ASTM E-1241-92). Data from either marine or freshwater standard aquatic toxicity tests from recognized authorities are deemed appropriate.

2.7 The results from a chronic test should preferably be expressed as a No Observed Effect Concentration (NOEC) following internationally accepted test procedures. The test bands and their ratings to be included in column B2 are given in 2.4 above, which shows the linkage between acute and chronic ratings. The acute to chronic ratio in the table takes a factor of at least 10 into account between acute and chronic toxicity for polar and non-polar narcotic industrial compounds, but not for reactive compounds and those with specific modes of toxic action. These should be independently rated for chronic toxicity.

2.8 Where definite chronic effects are suspected, e.g., endocrine disrupting, reproductive, etc., a hazard may be indicated by placing a value in column B2 if a dose/effect relationship is known, or by placing a statement in the remarks column.

3. Column C: Acute mammalian toxicity by swallowing, skin penetration and inhalation

3.1 Under Column C the hazards related to three potential exposure routes should be described: swallowing, skin contact and inhalation. In determining the hazard rating, values from the most susceptible mammalian species should be used, except if there was convincing evidence that toxicity in humans might be different.

3.2 Wherever possible, ratings for **peroral toxicity** should be derived from acute LD_{50} data based on standard 14 day post-dosing observation tests with rats, such as OECD 401, 402, 403, 420 and 423. However other test data obtained from literature using other protocols for other mammalian species could be used, if considered acceptable, after careful review. Tests based on constant concentrations are preferred. With regard to **inhalation toxicity**, data from standard tests with rats as test animals are preferred, using 4 hr LC_{50} studies where possible. When only values for other exposure times are available, extrapolation to 4 hr should be done, taking into account the physical properties of the material, its mechanism of acute toxicity, and exposure concentration/mortality relationships. Conversion from ppm (vapour) to mg/l should be undertaken using the formula:

$$\text{mg/l} = \text{ppm} \times \frac{\text{molecular weight}}{22.45}$$

For **percutaneous toxicity**, data from standard tests with rabbits are preferred, using 24 hour occlusion with two weeks of observations.

3.3 The ratings and the data on which these should be based are as follows:

Rating	Relative Hazard	Peroral (mg/kg)	Percutaneous (mg/kg)	Inhalation (mg/l)
0	Negligible	> 2000	>2000	>20
1	Slight	500-2000	1000-2000	10-20
2	Moderate	50-500	200-1000	2-10
3	Moderately high	5-50	50-200	0.5-2
4	High	<5	<50	<0.5

4. Column D: Irritation, corrosivity, and evidence for specific health concerns

4.1 Skin irritation and eye irritation should be rated separately. It was further agreed to introduce a new sub-column on other specific health concerns. For both sub-columns on skin irritation and eye irritation a numerical rating system will be used. Column D with these sub-columns D1 and D2 was developed as follows:

Tissue	Rating	Hazard
Skin	0	Not irritating *(no clinical signs of injury and/or inflammation)*
	1	Slightly irritating *(mild erythema without perceptible swelling; reversible)*
	2	Moderately irritatin *(marked erythema with obvious swelling)*
	3	Highly irritating and corrosive *(marked erythema, severe oedema, corrosive by 4 hour occluded contact; other signs of tissue injury, e.g., ulceration, ecchymoses)*
	4	Severely irritating and corrosive *(severe erythema, severe oedema, corrosive by 3-minute occluded contact, other indications of severe tissue injury, e.g., ulceration, ecchymoses, sloughing)*
Eye	0	Not irritating *(no clinical signs of injury and/or inflammation)*
	1	Slightly irritating *(reversible conjunctival hyperaemia with or without chemosis)*
	2	Moderately irritating *(marked conjunctival, obvious chemosis, transient mild corneal injury)*
	3	Highly irritating and corrosive *(severe and sustained conjunctoblepharitis and chemosis; moderate corneal injury which may be permanent)*
	4	Severely irritating and corrosive *(severe and sustained conjunctoblepharitis and chemosis; irreversible corneal injury, which may be associated with deformity, ulceration and vascularization of the cornea)*

4.2 The Sub-column on **specific health concerns** addresses specific organ or tissue toxicity and long-term and repeated exposure toxicity, including chronic exposure-related adverse health effects. Thus, for example, this column deals with, but is not limited to, persistent acute toxic effects, carcinogenicity, developmental and reproductive toxicity, mutagenicity, and immune-mediated responses, including skin, respiratory and photo-induced sensitization. Their presence will be indicated by "YES" in the column D3, and the nature of the adverse effects listed in the Remarks Column.

5. Column E: Interferences with other uses of the sea

5.1 The current column E will be expanded to cover potential effects of operational discharges and accidental releases of chemicals in relation to maritime transport on other uses of the sea, i.e. fisheries, use of coastal amenities, effects of viscous slick-forming substances on wildlife and the effects of sinking substances smothering the seabed. These are included under three sub-columns:

E1: Tainting of seafood
E2: Interferences with coastal amenities
E3: Effects on wildlife and bottom habitats

5.2 In the absence of data indicating the potential of a chemical to **taint seafood**, data on its sensory properties, demonstrated by its odour detection threshold in aqueous solution, may be used. The relationship between the potential of a chemical to taint and its odour detection threshold in water has been discussed previously (EHS 31/8, EHS 29/17, EHS 28/15, EHS 27/15).

5.3 Four ratings should be used to indicate in Sub-column E1 the **potential of a substance to taint seafood**. These are:

"Tt" - the substance has been tested for tainting seafood and found to taint at concentrations at or below 1 mg/l

"To" - the substance has been tested for its sensory properties (odour) and shown to have an odour detection threshold in aqueous solution at 1 mg/l or below

"Ta" - the substance is liable to taint seafood in analogy with other similar chemicals of its group.

"NT" - the substance has been tested for tainting and found not to taint below 1 mg/l; or the odour detection threshold in water is above 1 mg/l; or consideration of properties of a substance indicates that it is not liable to taint.

5.4 In regard to **interferences with coastal amenities**, the current rating system which indicated the degree of interferences with "Xs" should be replaced with numerals (0-3).

5.5 The Sub-column E2 on interferences with coastal amenities shall include the following:

Rating	Relative Interference	Outcome
0	None	None
1	Slightly objectionable	Warning may be issued but no interference with amenities and hence no closure
2	Moderately objectionable	Warning issued and possible partial closure of amenities due to short-term physical hazards or minor health effects
3	Highly objectionable	Warning issued leading to closure of amenities because of physical hazards or serious potential adverse health effects

5.6 Guidelines for the above ratings are as follows:

0
- No health problems from exposure to material
- Physicochemical properties will not cause physical hazards

1
- Material may produce mild irritant effects
- Physical properties of material may cause short-term physical hazards

2
- Material remains on amenity and may cause physical hazards
- Objectionable odour but not associated with feelings of ill-health
- Material could produce reversible acute systemic toxic effects by common exposure routes
- Material is irritant but not corrosive
- Material is a skin sensitizer
- Evidence from laboratory studies that the substance could produce long-term adverse health effects

3
- Material will persist on beach, resulting in physical hazards and increasing potential for exposure
- Objectionable odour that may result in symptoms of ill-health (e.g., nausea and headache)
- Likely to produce serious toxic effects from acute exposure conditions
- Severe irritant and/or corrosive
- Respiratory sensitizer
- Human carcinogen and/or other evidence for other serious long-term adverse health effects

5.7 **Effects on marine wildlife and on benthic habitats** of substances entering the marine environment due to their unique physical/chemical properties shall be set out in sub-column E3 by the use of a descriptive rating system, i.e.:

Fp - persistent slick-forming substance, not likely to evaporate or to dissolve quickly

S - sinking substance that would deposit on the seabed, not likely to dissolve quickly

5.8 Persistent floaters will be identified by using the following parameters:

-	Density	:	sea water
-	Vapour pressure	:	0.3 kPa
-	Solubility	:	0.1% (liquids)
		:	10% (solids)

In addition to the above characteristics, other criteria, such as a viscosity of > ca 10 cSt should be taken into account to identify products that would persist on the water surface, due to slow spreading and consequential low evaporation rate. A viscous slick-forming substance would be assigned with "Fp" in the hazard profile.

5.9 With regard to the identification of "sinking" substances (S), the following criteria shall be used:

-	Density	> seawater
-	Solubility	0.1% (liquids)
-	Solubility	10% (solids)

6. Column F: Remarks

6.1 The Remarks Column shall be maintained in a revised evaluation system identifying the following:

- Reactivity with sea water.
- Gases
- Chemicals for review (reasons for review shall be noted). A chemical is to be reviewed to improve the overall hazard evaluation in light of new evidence.
- Specific health concerns. This identifies the nature of the known or potential health effects, the presence of which are highlighted in Columns B2 or C. In particular, attention shall be drawn to the following:

  Aspiration hazard
  Lachrymator
  Convulsant
  Cholinesterase inhibitor (ChE inhibitor)
  High acute (peroral), (percutaneous), (inhalation) toxicity
  Severe irritant
  Sensitizer (skin and/or respiratory)
  Immunotoxic
  Hematotoxic
  Methaemoglobin generator
  Phototoxic
  Photosensitizer
  Neurotoxic
  Delayed neurotoxicity
  Reproductive toxicity
  Testicular toxicity
  Development toxicity
  Delayed lung injury
  Epigenetic carcinogen
  Animal carcinogen
  Human carcinogen

- Specific environmental concerns (e.g., endocrine inhibiting properties, food chain accumulation of persistent substances).

7. **General**

In cases where sufficient data are not available, or where the information submitted for evaluation are of poor or suspect quality, the note "NI" - "No Information Available" shall be included in the respective column of the hazard profile.

Terms of Reference of the Working Group

To examine and evaluate available data and to provide such other advice as may be requested, particularly by IMO, for evaluating the environmental hazards of harmful substances carried by ships, in accordance with the rationale approved by GESAMP for this purpose.

Members attending the Thirty-third Session of the Working Group

Dr. P.G. Wells (Chairman)
Environment Canada
Environmental Conservation Branch
45 Alderney Drive
Dartmouth, Nova Scotia
Canada B2Y 2N6
Tel: +1 902 426 1426
Fax: +1 902 426 4457
E-mail: pwells@is.dal.ca

Dr. B. Ballantyne
Applied Toxicology Group
Union Carbide Corporation (K-3)
39 Old Ridgebury Road
Danbury
Connecticut 06817-0001
U.S.A.
Tel: +1 203 794 5220
Fax: +1 203 794 5275
E-mail: toptox@aol.com

Dr. C. T. Bowmer
Department of Environmental Toxicology
Toxicology Division
TNO Nutrition and Food Research Institute
Schoemakerstraat 97
P.O. Box 6011
2600 JA Delft
The Netherlands
Tel: +31 15 2 696252
Fax: +31 15 2 572649

Dr. T. Höfer
BGVV
Ref.823
Thielallee 88-92
D-14195 Berlin
Germany
Tel: +30 8412 3267
Fax: +30 8412 3685
E-mail: thomas.hoefer@bgvv.de

Dr. M. Marchand
CEDRE
Technopôle Brest-Iroise
Boite Postale 72
29280 Plouzane
France
Tel: +33 02 98 49 12 66
Fax: +33 02 98 49 64 46
E-mail: cedre@ifremer.fr

Dr. S. Micallef
IMO/UNEP Regional Marine Pollution
Emergency Response Centre for the
Mediterranean Sea (REMPEC)
Manoel Island
Malta
Tel: +356 337297
Fax: +356 339951

Mr. M. Morrissette
Director of Technical Support
Hazardous Materials Advisory Council
Suite 301
1101 Vermont Avenue, NW
Washington, D.C. 20005-3521
U.S.A.
Tel: +1 202 289 4550
Fax: +1 202 289 4074
E-mail: staff_nmac@radix.net

Dr. T. Syversen
Norwegian University of Science and Technology
Faculty of Medicine
Department of Pharmacology and Toxicology
Medisinsk Teknisk Senter
N-7005 Trondheim
Norway
Tel: +47 73 59 88 48
Fax: +47 73 59 86 55
E-mail: tore.syversen@medisin.ntnu.no

Dr. M. Wakabayashi
Tokyo Metropolitan Research Institute
for Environmental Protection
7-5 Shinsuna 1-Chome Koto-ku
Tokyo 136
Japan
Tel: +81 3 3699 1331 (ext. 350)
Fax: +81 3 3699 1345
E-mail: w_meiko@tokyo-eikem.go.jp

IMO SECRETARIAT

Dr. M. Nauke
IMO Technical Secretary of GESAMP
International Maritime Organization
Marine Environment Division
4 Albert Embankment
London SE1 7SR
United Kingdom
Tel: +44 (0)171 735 7611
Fax: +44 (0)171 587 3210
E-mail: mnauke@imo.org

Annex IV

REVISED GESAMP HAZARD EVALUATION PROCEDURES

Prepared by the Working Group on the Evaluation of the Hazards of Harmful Substances Carried by Ships

1. Column A: Bioaccumulation and Biodegradation

1.1 The tendency of substances to bioaccumulate and biodegrade will be reflected in sub-columns under column A. The **Bioaccumulation sub-column (A1)** would contain two sets of information:

A1a the log octanol/water partition coefficient (log Pow, also often referred to as log Kow), and

A1b the bioconcentration factor (BCF) measured with fish or shellfish as target organisms.

1.2 Log Pow values tend to provide conservative data, whereas a measured BCF does provide definitive information on the potential of a substance to bioaccumulate under "steady state" conditions. The measured BCF often might result in less severe hazard ratings, due to processes such as metabolism which may enhance the excretion of a chemical. In the case where both BCF and log Pow data were provided, the BCF would overrule the log Pow. In the event that only log Pow data are available, and if the value exceeds [to be determined] mg/l, the product will be considered bioaccumulative, unless measured BCF data show otherwise. Substances with very high log Pow values (>ca7) are presumed to be so poorly soluble in water as to pose no further potential for bioaccumulation, assuming also that substances with molecular weights >700 are also assumed not to be accumulated (OECD ref.). Determining exact cut-off points may require further consideration for major chemical groups.

1.3 Log Pow values are applicable to organic chemicals only. To assess the bioaccumulation potential of non-organic compounds, some surfactants, and some organo-metallic compounds, bioconcentration measurements may be carried out and a BCF reported.

1.4 The following test methods are recommended:

log Pow: OECD 107, OECD 117, or a slow stirring method (under development by OECD);

BCF: OECD 305C, OECD 305E, the recently revised OECD 305 flow through test, or equivalent methods (e.g., ASTM and US-EPA methods).

1.5 For "Bioaccumulation" in sub-column A1 a ranking scheme has been developed as follows:

0 - No potential to bioaccumulate
(log Pow <1 or >ca7, or molecular weight >700; no measurable BCF)

1 - Very low potential to bioaccumulate
(log Pow 1 - <2; BCF 1 - <10)

2 - Low potential to bioaccumulate
(log Pow 2 - <3; BCF 10 - <100)

3 - Moderate potential to bioaccumulate
(log Pow 3 - <4; BCF 100 - <500)

4 - High potential to bioaccumulate
(log Pow 4 - <5; BCF 500 - <4, 000)

5 - Very high potential to bioaccumulate
(log Pow >5; BCF >4, 000)

Recommendations are provided to assist in the safe and effective use of chemotherapeutants and pesticides in coastal aquaculture. While the overriding consideration should be to minimize use of these chemicals, it is recognized that use of aquacultural chemicals is essential. Governmental authorities, the aquacultural and pharmaceutical industries, and the scientific community all have important roles to play in order to ensure that this use is consistent with protection of environmental quality and human health. In particular, regulatory mechanisms need to be put in place (and enforced) for registration and control of the use of aquacultural chemicals in order to protect human health, the natural environment and the sustainability of the industry itself.

Terms of Reference of Working Group 31

The following tasks for future work of Working Group 31 were recommended by GESAMP XXIII:

1. The establishment of scientifically-based monitoring requirements and procedures for aquaculture pollutants leading to the assessment of the environmental capacity of existing and planned coastal aquaculture operations;

2. **The preparation of review and guidance documentation for the safe use of chemicals in coastal aquaculture *(dealt with in this study)*; and**

3. The review of concepts and experiences related to the integration of aquaculture into coastal area management schemes.

Members of the Working Group

Celia Lavilla-Pitogo
Erlinda Cruz-Lacierda
Jurgene Primavera
Southeast Asian Fisheries Development Center (SEAFDEC)
Aquaculture Department Tigbauan
P.O. Box 256
5021 Tigbauan, Iloilo
The Philippines
Tel: (63-33) 335 1009
Fax: (63-33) 335 1008
e-mail: seafdec@mozcom.com

Mali Boonyaratpalin
Feed Quality Control and Development Division
Department of Fisheries, Ministry of Agriculture and Cooperatives
Kasetsart University, Ladyao, Jatujak
Bangkok 10900
Thailand
Tel: (66-2) 579 9525
Fax: (66-2) 562 0513
e-mail: oapct@ku.ac.th (with Apichart Termvidchakorn)

Valerie Inglis
Institute of Aquaculture
University of Stirling
Stirling FK 9 4 LA
Scotland
United Kingdom
Tel: (44-1786) 467 910
Fax: (44-1786) 472 133
e-mail: vbmi2@stir.ac.uk

Palarp Sinhaseni
Dept. of Pharmacology
Faculty of Pharmaceutical Sciences
Chulalongkorn University
Phrayathai Rd.
Bangkok 10330
Thailand
Tel: (66-2) 251 1900-2 Ext. 164
Fax: (66-2) 255 8227
e-mail: fphapsh@chulkn.car.chula.ac.th

Don P. Weston (Chairman)
University of California, Berkeley
EEHSL
1301 South 46th Street
Richmond Field Station - Bldg 112
Richmond CA 94804-4603
United States of America
Tel: (1-510) 231 5626
Fax: (1-510) 643 6264
e-mail: dweston@uclink.berkeley.edu

David J. Alderman
Centre for Environment, Fisheries and Aquaculture Science
Fish Diseases Laboratory
Barrack Road
The Nothe
Weymouth, Dorset DT4 8UB
United Kingdom
Tel: (44-1305) 206 600 (direct: 206 641)
Fax: (44-1305) 206 601
E-mail: d.j.alderman@cefas.co.uk

Ewen McLean
Biotechnology Laboratory
Aquaculture Section
Aalborg University
Solingardsholmsvej 57
DK-9000Aalborg
Denmark
Tel: (45-98) 158 522
Fax: (45-98) 142 555
e-mail: i5em@civil.auc.dk

Uwe Barg (Technical Secretary)
Fishery Resources Division
FAO
Viale delle Terme di Caracalla
00100 Rome
Italy
Tel: (39-6) 5225 3454
Fax: (39-6) 5225 3020
e-mail: uwe.barg@fao.org

Annex VI

STORAGE OF CO_2 IN THE DEEP SEA

Executive Summary

One of the proposals for ameliorating global warming putatively associated with carbon dioxide accumulation in the atmosphere is to inject fossil-fuel CO_2 directly into the deep ocean. Essentially, this process is intended to short-circuit the gradual absorption of CO_2 from the atmosphere to the ocean that occurs naturally and, thereby, accelerate the approach to long-term equilibrium between the atmosphere and the ocean.

This document outlines the technical and scientific basis of this proposal and summarizes the state of knowledge regarding its feasibility and consequences. It is based on a review of the most recent studies in a number of areas of direct relevance to the proposed ocean storage, or injection, mechanism largely conducted within the International Energy Agency's Greenhouse Gas Research and Development Programme.

The following conclusions are drawn from this review:

- for the proposal to be a viable remediation option for global warming, a large proportion of the future carbon dioxide emissions from fossil-fueled electrical generating stations would need to be captured and disposed of in the deep ocean;
- the major outstanding scientific limitations in assessing the feasibility and acceptability comprise:
- the period of retention (residence time) of CO_2 injected into the deep ocean; and
- the consequences of carbon dioxide injection on biological, geochemical and physical conditions in the ocean, particularly effects on marine living resources;
- there exist some legal impediments to the options available for ocean injection of carbon dioxide;
- the social/policy acceptability of the proposed practice will be primarily dependent on unambiguous demonstration of global warming attributable to emissions of carbon dioxide from anthropogenic activities;
- ultimately, should the previous condition be fulfilled, the social/policy acceptability of deep ocean storage of CO_2 will depend on a prior demonstration of a net balance of benefits over detriments taking particular account of economic and environmental factors.

Background

During the 26th Session of GESAMP, a correspondence group was established to study the current status of investigations relating to the proposal for fossil fuel CO_2 storage in the deep ocean as a means of reducing direct releases of CO_2 to the atmosphere. The group was requested to:

- to describe proposals for CO_2 storage in the ocean;
- to evaluate the current state of knowledge regarding the consequences and effects of such storage;
- to identify the major scientific unknowns and uncertainties regarding the assessment of consequences; and
- to make recommendations for any further action by GESAMP.

The Group was charged with reporting to the twenty-seventh session of GESAMP in 1997. This document constitutes the report of the Correspondence Group.

Introduction

There are relatively few options for preventing CO_2 build-up in the atmosphere: greater reliance on nuclear energy; greater utilization of solar, wind, geothermal, hydroelectric, wave, ocean thermal energy conversion or

other renewable energy sources; increased efficiency in the use of fossil fuels; and CO_2 capture from the flue gas products from fossil fuel combustion and its subsequent retention at storage locations.

Capture and injection of CO_2 in the deep ocean has been proposed as a mitigation option for the amelioration of global warming putatively associated with increasing atmospheric concentrations of CO_2. Essentially, the proposed oceanic injection process constitutes a short-circuit mechanism that disposes of fossil-fuel combustion CO_2 directly into the deep ocean, thereby reducing direct injections to the atmosphere and accelerating the process of attaining of atmosphere-ocean equilibrium. It can be viewed as an acceleration of the natural, but slow, process of transferring CO_2 from the atmosphere to the deep ocean which is currently estimated to be occurring at a rate of 2 Gt C per year.

This process of oceanic CO_2 injection (or storage), together with other CO_2 storage options, is being assessed by the International Energy Agency (IEA) Greenhouse Gas Research and Development Programme supported by fifteen countries and several industrial sponsors. It is acknowledged within this latter Programme that a full understanding of complex chemical, biological and oceanographic factors has to be acquired before large scale storage in the oceans could be undertaken. It is axiomatic that, in order for benefit to be obtained from this remediation option, the CO_2 injected into the ocean would have to be retained there for periods comparable with the longevity of fossil-fuel supplies (>200 years) rather than being re-exchanged with the atmosphere on decadal time-scales. This, in turn, means that injection would have to be made below the main thermocline of the deep ocean basins in a form that is quickly assimilated there. Equally, for the option to be effective, oceanic injection would have to involve a substantial proportion of the aggregate global CO_2 emissions from fossil-fuel combustion for a substantial period of time, at least several decades. Other options being assessed by the IEA Greenhouse Gas Programme are large-scale CO_2 storage in aquifers and exhausted oil and gas wells and enhancement of natural CO_2 sinks.

There are many practical problems involved in the concept of releasing CO_2 into the deep ocean, but the two fundamental concerns are the timescale of its return to atmosphere and the impact on the marine environment. Accordingly, the IEA Greenhouse Gas Research and Development Programme is examining the following major scientific and technical issues essential for assessing the feasibility of the option:

- feasibility of capture, assembly, transport and injection of fossil-fuel CO_2;
- oceanic residence time of injected CO_2; and
- associated biological effects.

The IEA Greenhouse Gas Programme has examined, through a series of four international workshops, the key scientific issues and problems of practical implementation, including the legality and public acceptability of the concept. Although reference will be made to legal issues, this report focusses primarily on scientific issues. Necessarily, in presenting a broad view of the concept below, there are topics that go beyond the purview of GESAMP. We will focus on matters of relevance to GESAMP following a synopsis of the overall concept of oceanic injection.

The Concept and Its Potential Application

In general terms, the option consists of a sequence of steps from the recovery of fossil-fuel CO_2 from flue gases to its injection into the ocean. Each of the major steps and their sub-options are summarized below based primarily on the review by Herzog *et al.* (1991).

CO_2 Capture

A number of options exists for the capture of CO_2 from flue gases of coal-fired power plants. Those considered in some detail are:

a) *Air Separation/Flue Gas Recycling*: Oxygen is separated from air in a preprocessing plant. Pulverized coal is combusted in an atmosphere of oxygen and recycled flue gas. Part of the flue gas is recycled into the furnace to maintain original heat transfer rates to boiler components. Water vapour is separated from CO_2 by condensation and absorption in a recyclable dehydrant (triethylene glycol).

b) *Scrubbing Flue Gas with a Recyclable Solvent*: The CO_2 from the flue gas is scrubbed with a solvent, monoethanolamine. The solvent is stripped of CO_2 in a regeneration step and recycled.

c) *Cryogenic CO_2 Fractionation of Flue Gas*: The CO_2 from the flue gas is separated from the other gases by multiple-stage cryogenic absorption and distillation.

d) *Recovery of CO_2 by Selective Membrane Diffusion*: The CO_2 from the flue gas is separated from the other gases by polymer membranes.

e) *Seawater Scrubbing of Flue Gas*: The CO_2 from the flue gas is directly absorbed at atmospheric or elevated pressures directly into seawater.

The process requiring the least incremental energy is air separation/flue gas recycling which can recover essentially all the CO_2 in flue gas. This process requires about 30% of the total energy content of the coal fuel and reduces the thermal efficiency of a typical power plant from about 35% to 25%. In addition, the capital costs of installing air separation/flue gas recycling at a typical 500 MW(e) electrical generating station are of the order of $250,000. For technical reasons, seawater scrubbing would only be applicable for coastal power plants and it is so capital and energy demanding that it was ruled out as a viable option by Herzog *et al.* (1991). All the other options make intense energy demands and reduce thermal efficiencies in power generating plants to less than 20%.

Transport to Storage Site(s)

The captured CO_2 would then have to be placed in a form transportable to any storage site such as a deep continental depository or to a location for marine injection. For other options, the recovered COn62 can be placed in gaseous, liquid or solid form. However, balancing the capital and operating costs of liquifaction [Capital Cost: $70M ($1.6/t CO_2); Operating Cost: 80kWh/t CO_2 ($4/t CO_2) for a 500 MW(e) plant], solidification [Capital Cost: $188M ($4.3/t CO_2); Operating Cost: 166kWh/t CO_2 ($8.3/t CO_2) for a 500 MW(e) plant] and transport associated with marine injection suggests that the most economical form is liquid [transport costs < $10/t CO_2/1000 km] (Ormerod, 1995). It is possible to transport the liquid CO_2 in pipelines or by pressurized containers from individual power plants to common collection points suitable for marine injection but a combination of geographic and economic considerations would dominate the selection of a particular mix of transport processes for a given power generating station. The IEA Greenhouse Gas Programme is also assessing other options for utilizing CO_2 such as in chemical manufacturing, enhancing oil recovery and through direct and indirect biological fixation (Riemer, 1994) but these options are not discussed here.

Storage of Captured CO_2

There are a range of alternatives for the storage of captured CO_2. These include: disposal in deep terrestrial aquifers; disposal in exhausted oil and gas reservoirs; disposal into an insulated terrestrial repository; and marine injection. Clearly, the storage capacity of the oceans is larger than any of the other potential storage reservoirs. In this analysis, we deal only with the ocean storage option.

Marine Injection of CO_2

There are two main alternative forms of marine CO_2 injection: injecting liquid CO_2 in seawater at depth; or isolating CO_2 in solid, liquid or hydrate form either on, or under, the seabed. The actual mode of injection has two further alternatives: discharge from pipelines running from shore across the continental shelf; or dumping from ships. The specific options have been listed by Haugan and Drange (1995) as:

- Disposal in solid form (dry ice). Blocks of dry ice dumped (*e.g.*, from a ship) will sink towards the ocean floor with partial dissolution in the water column and the remainder dissolving at the ocean floor.
- Disposal of liquid CO_2 at a depth where it is denser than seawater (3000 m). If this takes place at the seafloor, the CO_2 is expected to fill up topographic depressions and only slowly be dissolved through a hydrate (CO_2 clathrate) film into the seawater above.
- Disposal of CO_2 in the form of a hydrate deposit on the seafloor.
- Injection of CO_2 at intermediate depths (1500 m) where pure CO_2 is less dense than seawater producing a rising droplet or bubble plume with final dissolution taking place at, or near, the injection depth.
- Injection of CO_2 at intermediate depths such that the increase in seawater density due to CO_2 enrichment becomes appreciable thereby producing a gravity current along the sloping bottom towards the deep ocean.

- Dissolution of unseparated flue gas directly into seawater at the power plant with subsequent transport of the enriched water to the deep ocean through a pipe.

Carbon dioxide injection needs to be made, as already noted, at intermediate or greater depths below the main thermocline to ensure retention for reasonable timescales. In the case of the Pacific, the deep waters are undersaturated with CO_2 and the residence times of deep waters are greater than those of the Atlantic. However, the Atlantic has a greater abundance of calcareous sediments that can provide buffering capacity. All these issues relate to the greatest scientific question associated with this remedial option: *What is the retention time for injected CO_2?* . Preliminary answers to this question have been given by Bacastow and Dewey (1996) who produced predictions of the rate of return of sequestered CO_2 to the atmosphere after injection in the ocean at depths between 900 and 1500 m off Tokyo and New York for a period of a century. Such predictions are made both for pre-industrial (Figure 1) and post-industrial (Figure 2) ocean conditions but neglect the effects of calcium carbonate sediments on the replenishment of $CO_3$2- ions. The difference between pre-industrial and post-industrial conditions is that the latter takes account of the equilibration of the ocean with atmospheric releases of CO_2 up to the year 2000 and the reaction of the ocean-assimilated CO_2 with carbonate ion to form bicarbonate:

$$CO_2 + CO_3 2- + H_2O \; (\; 2 \; HCO_3-$$

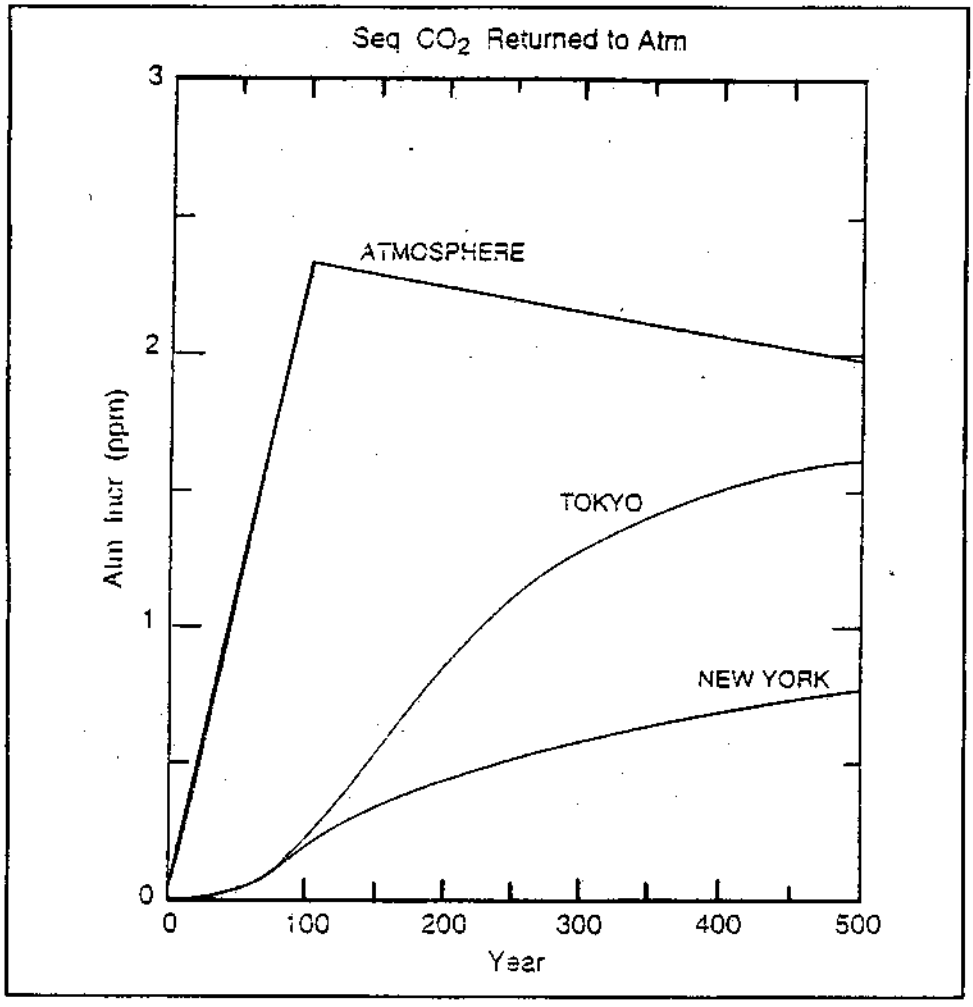

Figure 1
Predicted return of sequestered CO_2 to the atmosphere for 100 years of sequestration beginning in the year 2000 (post-industrial ocean) at a depth between 900 m and 1500 m for two locations, one near Tokyo and the other near New York. The curve labelled Atmosphere indicates the effect of CO_2 on the atmospheric concentration without sequestration based on an anthropogenic fossil fuel consumption scenario (after Bacastow and Dewey, 1996).

The solubility of CO_2 in seawater is relatively small. Carbonate ions neutralize the increased CO_2 entering the ocean as a result of anthropogenic releases, as the carbonate ion concentration decreases, the buffering capacity decreases and pCO_2 increases. This tends to drive the sequestered CO_2 from the ocean. Carbonate sediments have the potential to replenish the carbonate ion but have not been considered in the models used

to obtain these predictions. An idea of the effects of calcium carbonate dissolution can be gained from Figure 3 which depicts the increase of atmospheric CO_2 with time as a function of the disposal of all the CO_2 from a 1000 MW(e) power plant at two alternative depths (719 m and 3300 m) (after Cole *et al.*, 1995).

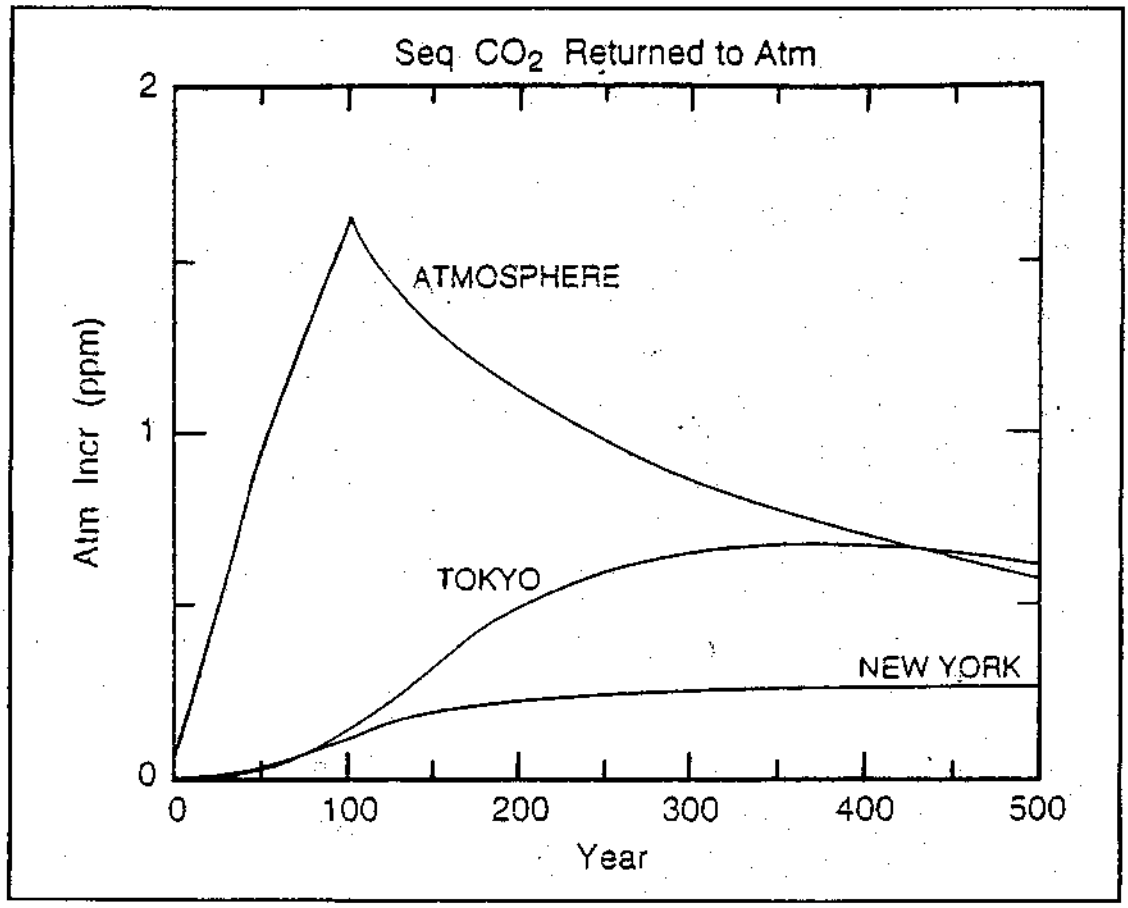

Figure 2
Predicted return of sequestered CO_2 to the atmosphere for 100 years of sequestration beginning in the year 2000 (pre-industrial ocean) at a depth between 900 m and 1500 m for two locations, one near Tokyo and the other near New York. The curve labelled Atmosphere indicates the effect of CO_2 on the atmospheric concentration without sequestration based on an anthropogenic fossil fuel consumption scenario (after Bacastow and Dewey, 1996).

The desirability of CO_2 injection at greater depth can be appreciated from Figure 4 which depicts the fraction of CO_2 retained in the ocean with time following injection at different depths (after Wong and Matear, 1995). Similarly, the overall benefits of disposing of high proportions of future fossil fuel CO_2 emissions into the ocean can be gained from Figure 5 which shows increasing atmospheric CO_2 as a function of deep injection of differing proportions of fossil fuel CO_2 (after Cole *et al.*, 1995).

Marine injection can be made at intermediate depths in the form of liquid CO_2 which is positively buoyant and tends to rise in the form of liquid droplets from any release point. At low flow rates, bubbles form slowly and break off when buoyancy forces exceed surface tension forces. At moderate flow rates, fluid momentum becomes important and a liquid jet forms at the release orifice. The jet lengthens with increasing flow to the point where instabilities become dominant and the jet disintegrates into droplets. At very high flow rates, the stream atomizes into tiny droplets at the discharge orifice. In view of the large volumes of CO_2 likely to be generated for disposal, even from single power plants, discharges are likely to be in the jetting or atomization regimes.

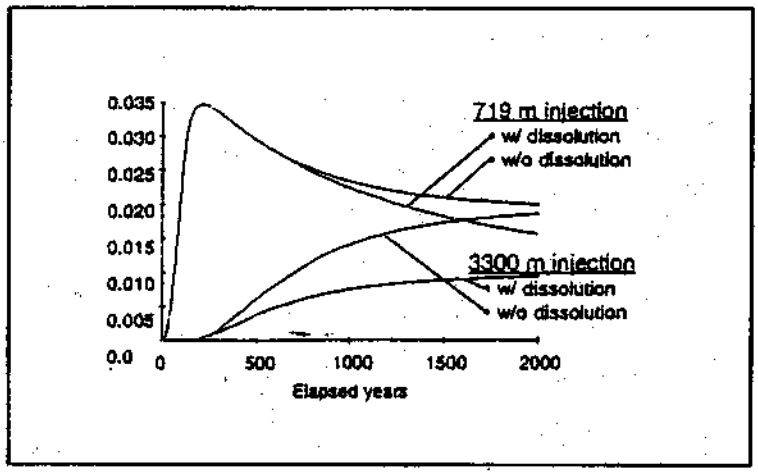

Figure 3
Increase in atmospheric CO_2 as a function of time for sea disposal from 1000 MW(e) plant at intermediate and benthic depths (after Cole *et al.*, 1995)

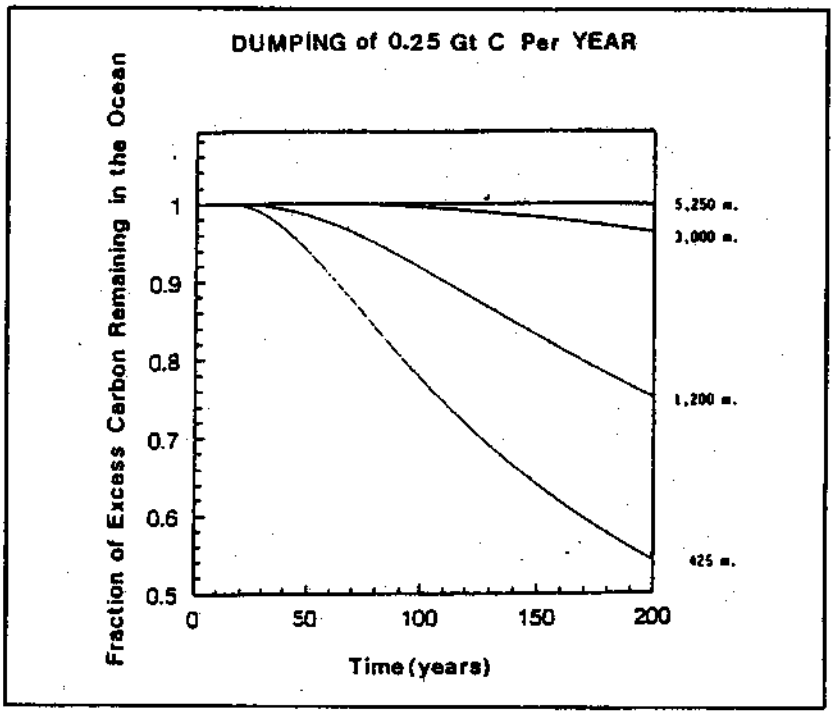

Figure 4
Retained fraction of CO_2 as a function of time for oceanic injection at various depths (after Wong and Matear, 1995)

Major emphasis in current studies of CO_2 disposal are focusing largely on liquid CO_2 injection at intermediate depths for both financial and technical reasons. A summary of the options for liquid CO_2 injection in the ocean is given by Nakashiki *et al.* (1995). The alternative method of disposal is of solid CO_2 either by dumping from ships or placement on, or in, the seabed. The costs of this method of disposal are greater because of the greater costs of solidification and the subsequent requirements of solid CO_2 transport to the disposal site. Solid CO_2 is denser (= 1.56 kg/dm^3) than seawater and therefore has the ability to sink to depth if dumped from ships. Current technology does not extend to the ability to emplace solid carbon dioxide on or on the seabed other than from vessels - either by dumping in the form of uncontained blocks of solid CO_2 or contained in shaped canisters, or 'penetrators', that can enter the seabed and become effectively buried.

Environmental Effects

Environmental effects can be subdivided into those associated with liquid CO_2 releases into seawater at intermediate depths and those associated with solid or liquid CO_2 disposal onto the seafloor. At this stage, the deliberate emplacement of solid CO_2 ***into*** pelagic sediments will be ignored, both because it is an expensive option and the consequences are likely to be partly subsumed by those associated with solid CO_2 disposal onto the seabed.

Introducing large quantities of CO_2, representative of the CO_2 produced from a single coal-fired power plant, directly into the deep ocean, is predicted to result in seawater with a pH of 7 or less persisting for a distance of tens of kilometres from the release point. Far-field effects are also predicted, in small isolated bodies of water, hundreds of kilometres from the release point. The marine ecosystem may be affected for one or more of the following reasons (Ormerod and Angel, 1996):-

A sustained water pH <6.5 is lethal to many coastal marine organisms, and oceanic species would be expected to be more sensitive. Sub-lethal effects on reproduction, growth, metabolic rates and longevity will be experienced with smaller sustained decreases in pH. Marine bacteria, which are responsible for the remineralization and re-cycling of organic carbon, show reductions in their metabolic and growth rates at pH 6.0. Although organisms can withstand substantial short-periods (several minutes) of much reduced pH (Herzog *et al.*, 1995), the limited knowledge of the physiological tolerance of inshore coastal species indicates that an ambient pH in the range 7.0 - 7.5 would be the lower limit of tolerance for some species.

Strata of low pH water within deep water may act as physiological barriers to diel, seasonal and ontogenetic vertical migration by marine organisms. Diel vertical migration occurs in the water column to depths of 1000m and the bathymetric range of some diel migrants is extended to a depth of 1600m on continental slopes.

Primary productivity and benthic activity are often enhanced around shelf breaks. These are also zones where living resources are either currently being exploited or are likely to be exploited in future; the release of CO_2 into such regions is therefore more likely to be disruptive to environmental processes and the exploitation of living resources, than in the open sea away from continental boundaries.

Deep sea benthic organisms, having evolved in environments which are extremely stable chemically, are unlikely to exhibit tolerance or resilience to fluctuations in chemical characteristics beyond their normal experience. However, recent work has indicated a greater tolerance to the natural range of perturbation (for example, to mechanical disturbance, seasonality in carbon inputs and, in some regions, to severe seasonal oxygen stress) than would have been expected.

These potential biological impacts indicate a requirement for more refined engineering solutions which increase the dispersion of CO_2 from a point source and result in smaller pH reductions.

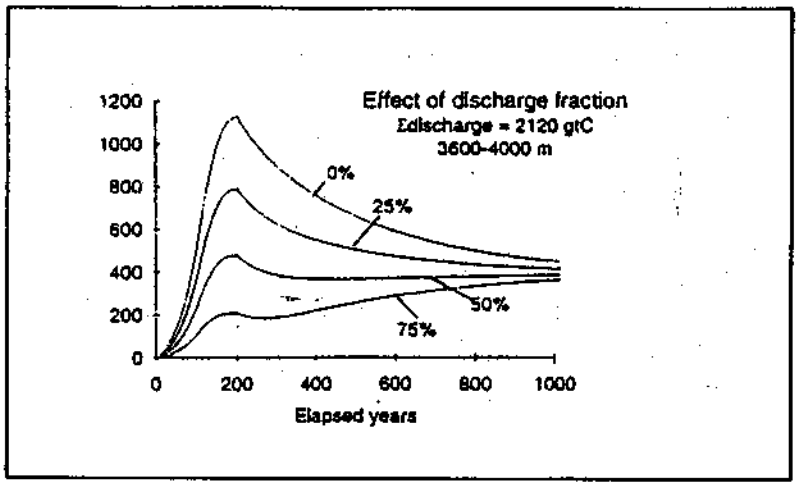

Figure 5
Increasing atmospheric CO_2 with time for deep injection of differing proportions of total fossil fuel CO_2 (after Cole *et al.*, 1995)

Chemistry

The basic chemical reactions involving CO_2 assimilation are as follows:

$$CO_2(g) \xrightarrow{k0} CO_2(aq)$$

$$CO_2 + H_2O \xrightarrow{kH} H_2CO3$$

$$H_2CO_3 \xrightarrow{k_1'} H^+ + HCO_3^-$$

$$HCO_3^- \xrightarrow{k_2'} H^+ + CO_3 2-$$

where k_0 is the solubility coefficient of CO_2 in seawater, k_H is the hydration constant, and k_1' and k_2' the apparent first and second dissociation constants of carbonic acid. The carbonate ion concentration in seawater is an important measure of the buffering capacity of the oceans. Carbonate ions neutralize CO_2 entering seawater through the reaction:

$$H_2O + CO_2 + CO_3 2- = 2HCO_3^-$$

CO_2 is also neutralized by calcium carbonate in suspended particles or in sediments by the reaction:

$$CO_2 + H_2O + CaCO_3 \text{ (solid)} = Ca^{2+} + 2HCO_3^-$$

The amount of $CaCO_3$ available for neutralization in global ocean sediments has been estimated at 4.9 GtC by Broecker and Takahashi (1977). Biogenic CO_2 in the North Pacific Ocean is high due to high productivity and has already consumed sedimentary $CaCO_3$ for neutralization purposes. The carbonate compensation depth, or lysocline, below which little or no carbonate accumulates in sediments slopes upward from about 5 km depth at the equator to about 3 km depth near the Aleutians. Accordingly, there are considerable differences in the availability of $CaCO_3$ among the oceans with about 50% in the Atlantic, 25% in the Indian and 25% in the Pacific despite their contrasting relative areas.

There is a further compounding feature of the chemistry associated with CO_2 assimilation that has a direct bearing on the form of CO_2 injection and its consequences. This is the formation and stability of solid CO_2 hydrate (or clathrate) as $CO_2.6H_2O$ or $CO_2.8H_2O$ under oceanic conditions. Figure 6 presents a segment of the phase diagram for CO_2-H_2O-Hydrate system for a mean hydrate composition of $CO_2.7.3H_2O$ over a temperature range of -10°C to +12°C and a pressure range of 8 to 50 atmospheres (*ca.* 80 - 500 m depth) after Uchida *et al.* (1995).

Taking a range of 0°C to 4°C as the range of deep ocean temperatures, CO_2 hydrate would appear to become important at depths exceeding 12 to 20 atmospheres or about 100 to 200 metres. CO_2 hydrate evidently forms around liquid CO_2 droplets at depths of 500 m (Honda *et al.*, 1995) and as an interfacial layer between liquid CO_2 and seawater at greater depths retarding the rate of CO_2 assimilation. Nevertheless, its existence is as an interfacial transient and is, therefore, of limited concern in terms of large-scale effects. For liquid or solid CO_2 disposal into benthic depths of the major ocean basins, where CO_2 hydrate is more likely to be stable, its effects (physical, chemical and biological) will have to be considered in greater detail. Solid CO_2 clathrate is denser (= 1.13 kg/dm^3) than either liquid CO_2 (= 0.857 kg/dm^3) or seawater and can therefore sink to the ocean floor. For liquid and solid CO_2 injection at extreme depths, uncertainty and concern rests with the stability and lifetime of CO_2 clathrate under benthic ocean conditions. Shindo *et al.* (1995) studied the formation and stability of CO_2 hydrate and report that it appears that hydrate formation initiates slowly in a mixture of water and gaseous CO_2 at high pressure but that CO_2 hydrate forms rapidly and is stable in the presence of liquid CO_2. Therefore, it is assumed that hydrate formation occurs mainly in liquid CO_2, not in water. The CO_2 hydrate covers the liquid CO_2 and hinders dissolution in water. This implies the cessation of the formation of CO_2 hydrate in the absence of liquid CO_2. Thus, although the constructed phase diagrams of Uchida *et al.* (1995) and Wadsley (1995) show that at high pressure low positive temperature regimes CO_2 will co-exist in liquid, clathrate and gaseous (CO_2) forms, the clathrate is not likely to persist much beyond the lifetime of liquid CO_2. Wadsley (1995) has also raised the possibility of the formation of solid gypsum ($CaSO_4 \cdot nH_2O$) and solid sodium hydrogen carbonate ($NaHCO_3$).

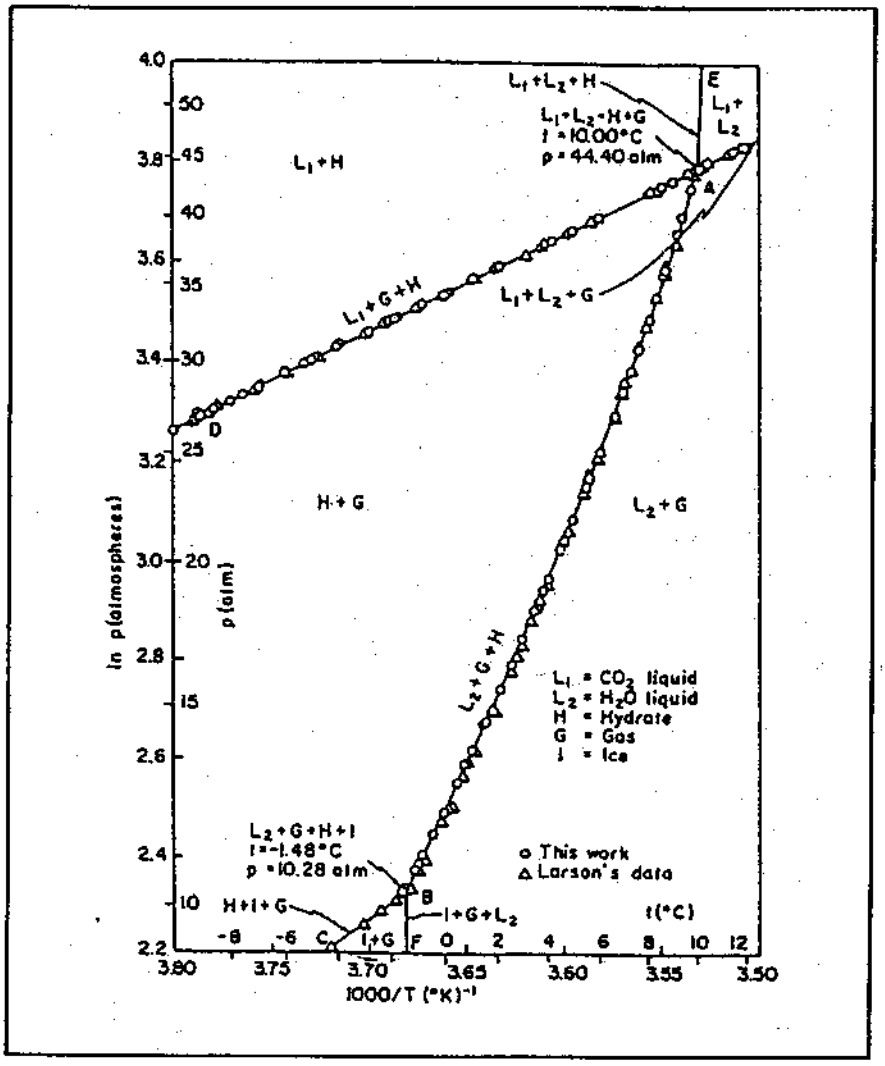

Figure 6
Experimentally-derived phase diagram for the CO_2-H_2O-Hydrate system with CO_2. nH_2O (n = 7.3) (after Uchida et al., 1995)

Liquid CO_2 Injection into Seawater at Intermediate Depth (*ca.* 1000 m)

For this case, we can assume that CO_2 clathrate formation is unlikely to be persistent problem even though it may occur as a transient on the surface of liquid CO_2 bubbles breaking off from a turbulent jet of liquid CO_2. The predominant concern is associated with reduced pH during the neutralization of the CO_2 injected as liquid CO_2 into intermediate depth seawater from, say, a pipeline. From a physical point of view two scenarios can be envisioned: an unconfined release at depths of 1000 - 1500 m forming a droplet plume (high flow regime turbulent jet); and a confined release (in a mixing vessel that creates a dense fluid mixture as described by Adams *et al.*, 1995) at 500 - 1000 m in the form of a dense sinking plume. Both of these scenarios have been studied by Auerbach *et al.*, (1996) for releases of CO_2 from a single 500 MW(e) power plant and 10 such plants. Much of the following analysis is drawn from this work. Table 1 below presents the results of modelling of these releases to determine the extent and magnitude of pH reduction in the receiving waters. The scale of the plume from a single plant unconfined release is shown in Figure 7 as a diagrammatic representation of the extent of pH reduction.

Table 1

Summary of Modelled Releases (after Auerbach *et al.*, 1996)

Scenario	Volume of Water with pH < 7 km^3	Distance to pH = 7 km	Minimum pH (after dissolution)	Minimum pH (diffusion regime)
Droplet Plume				
1 Plant	1.8	23	5.5	6.0
10 Plants	130	60	5.5	6.0
Dense Plume				
1 Plant	7.2	95	4.0	5.7
10 Plants	510	690	4.0	5.5

Having established the scale of pH changes, it is necessary to examine the likely effects on indigenous biota. The pH sensitivity of different zooplankton and benthos was tabulated by Auerbach *et al.*, (1996) and used to produce mortality rates as a function of pH and time of exposure for passive organisms (Figure 8). Clearly, for non-motile organisms experiencing periods of more than about 100 hours entrained in the plume, pH < 6 conditions represent essentially total mortality and pH (6.3 represents 50% mortality. Nevertheless, modelling of the exposure field for passive organisms for the unconfined release and confined release, albeit for injection of CO_2 from a single power plant, yields zooplankton deficit distributions shown in Figure 9 for the unconfined droplet plume and Figure 10 for the confined dense plume liquid CO_2 discharges.

While the zooplankton deficit due to mortality in the plume for the droplet release scenario is not large, only about 5% of the total population at any point, the geographical extent of potential biological effects on zooplankton is quite extensive. The deficit occurs well downstream of the CO_2 injection point because there is a threshold exposure before which there is no mortality. In contrast, the zooplankton deficit due to mortality for the dense plume scenario is substantial over large distance scales (100 - 200 km longitudinally and 1 - 2 km transversely). Because the effect of pH is non-linear and time-dependent, a greater number of organisms are exposed to lower pH for longer time periods in this scenario, the impact is greater than that for the droplet plume scenario. It should be noted that the 10 plant scenarios are not linear multiples of the single plant scenarios. Relative impact depends on the magnitude of the CO_2 releases rates.

As stated previously, there are additional concerns being expressed regarding the biological effects of CO_2 injection. These include effects caused by co-recovered flue gas contaminants such as nitrous and sulphur oxides and trace inorganic contaminants, the effect of increased partial pressure of CO_2, dissolution of living and dead biogenic calcium carbonate, thermal effects, including thermal shock, and pH changes on bacteriological activity in the deep sea. Apart from the issue of co-contaminants of flue gases, which are not tolerated by the solvents used for CO_2 recovery and therefore require to be scrubbed out prior to the recovery of CO_2, detailed assessments of these additional stressors, and the biological and biochemical knowledge of deep sea organisms required to make them, appear, as yet, to be lacking.

Thus, it would appear that the potential for biological effects is considerable over distance scales of about 100 km from the point of discharge of liquid CO_2 at intermediate depths although, clearly, this depends on the size and number of diffusers and the rate of injection. Of course, it also remains to be determined what the longevity and fate of any CO_2 hydrate formed in the discharge is likely to be and whether it can be assumed with confidence that hydrates are transient and of little independent concern.

Solid CO_2 Disposal

For technical and financial reasons, solid CO_2 (dry ice) disposal appears to be an unattractive option unless it is to be dumped from vessels. Dumping from ships, however, comes under the aegis of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter London Convention 1972). In 1993, Contracting Parties to this Convention adopted a prohibition on dumping of industrial wastes (defined as 'wastes generated by manufacturing or processing operations' but with a non-exhaustive list of materials not considered to be industrial waste) at sea that took effect on January 1, 1996. It therefore seems unlikely, unless the Convention can be amended to permit the dumping of CO_2 from ships, that any of the current Parties to the Convention, which include all the OECD Countries except Austria and Turkey, could give approval to such a practice. It should be further noted that the same conclusion would apply to liquid CO_2 disposal from vessels and platforms which would also fall within the purview of the London Convention 1972.

Nevertheless, for completeness, it is appropriate to consider the probable effects of solid CO_2 dumped into the ocean. The density of solid CO_2 (= 1.565 kg/dm³) is such as to ensure that large blocks would sink undergoing dissolution during descent as a result of thermal absorption from the surrounding water. As already stated, ensuring the delivery of solid CO_2 to the seafloor would require the use of degradable containers or sediment penetrators that would deliver packages of solid CO_2 to depths of a few metres within pelagic sediments.

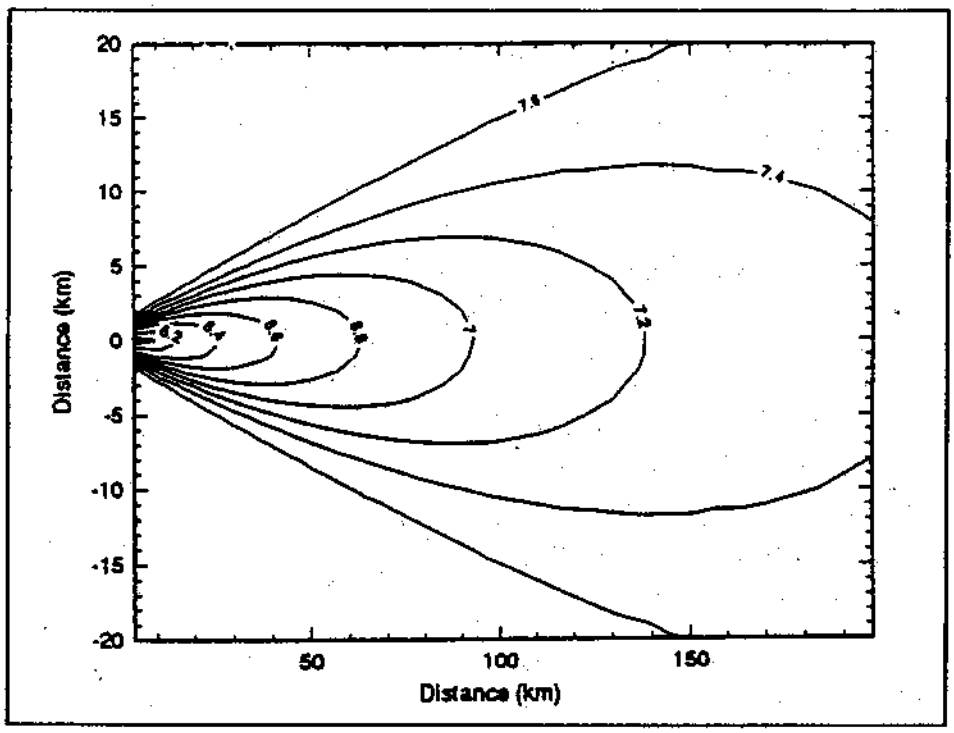

Figure 7
pH distribution at a depth of 1000 m for a one-plant droplet plume release in a 5 cm/s current (after Auerbach *et al.*, 1996)

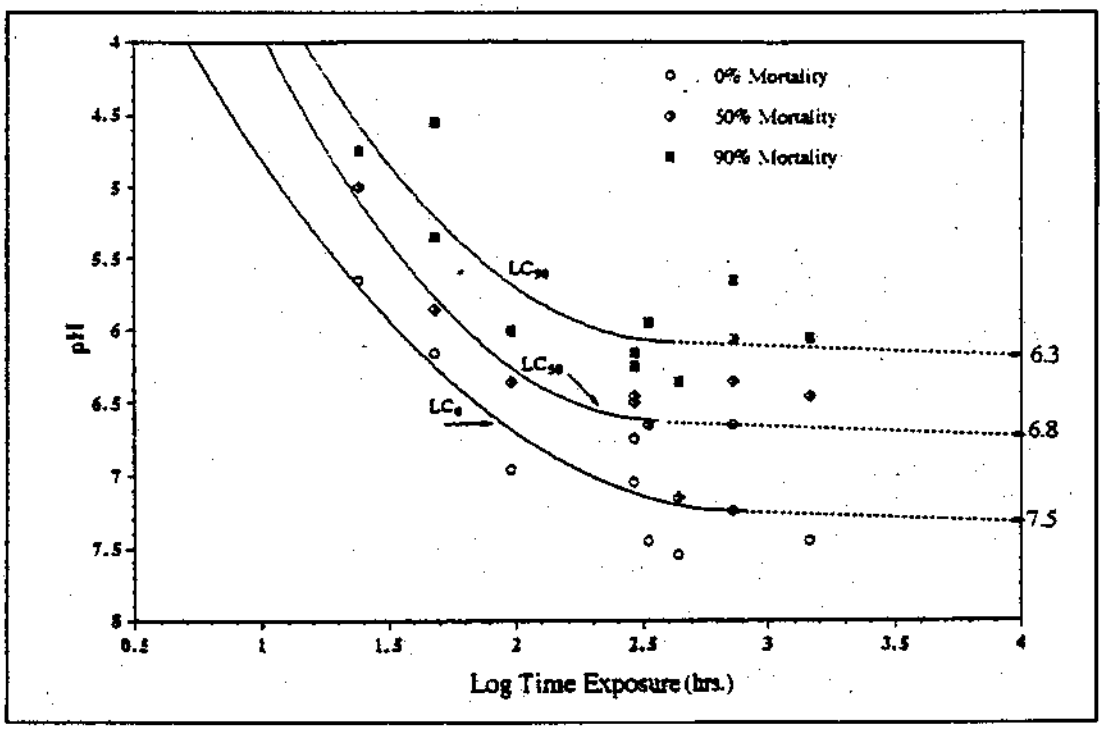

Figure 8
Mortality as a function of lowered pH exposure and exposure time (after Auerbach *et al.*, 1996)

Auerbach *et al.*, (1996) have also modelled the descent of uncontained blocks of dry ice dumped into the surface ocean taking account of experimentally-determined dissolution rates, and a diffusion coefficient that took account of wake effects and ambient turbulence in the water column. The impact of uncontained dry ice dumping within the water column appears to be minimal because of the large depth range over which dissolution occurs. In the modelling of Auerbach *et al*, the seawater pH was never depressed below 5 and the radius in which pH depression exceeded pH 6 was within 200 m of the descent centreline. The modelling of the settling and dissolution of a dry-ice block was based on experimentally-derived dissolution rates measured by the Japanese Central Research Institute of the Electric Power Industry (CRIEPI) (Nakashiki *et al.*, 1991) and the use of a diffusion coefficient that takes account of wake effects and ambient turbulence in the water column (Auerbach *et al.*, 1996). About half of the mass of an initial 3 metre block of dry-ice remained following free-fall descent to 3000 metres (Ormerod, personal communication).

The disposal of a significant proportion of the fossil-fuel CO_2 from power plants directly to the seabed in the form of dry ice, assuming this disposal method was feasible, would entail somewhat different concerns. The first relates to the formation and longevity of solid CO_2 hydrates. They clearly form to slow the rate of liquid CO_2 dissolution. Would they, for instance, persist long enough to blanket portions of the seafloor with attendant mortalities of epi-fauna and in-fauna? To a large extent the answer to this question would depend on the amounts of CO_2 disposed of at individual sites and the projected rates of liquid CO_2 dissolution accounting for interfacial solid CO_2 hydrate formation. Related questions include What would be the effects of localized dissolution of calcium carbonate and on bacteriological activity in affected sediments? These, and a number of other chemical and biological questions appear to remain as yet unresolved.

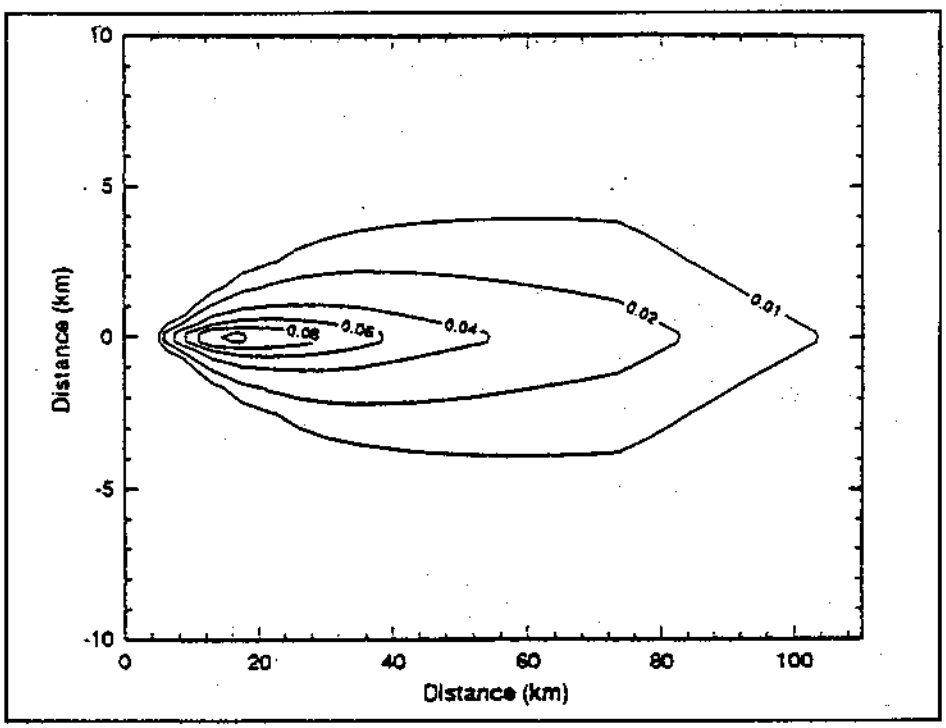

Figure 9
Deficit of zooplankton due to mortality from a one-plant droplet plume
(after Auerbach *et al.*, 1996)

Current Status of Feasibility Studies and Outstanding Deficiencies

It is too early in the process of acquiring relevant information regarding the impacts of all methods of oceanic CO_2 injection, or, indeed, in the development of firm proposals for oceanic injection as a remediation measure for global climate change, to regard either the limitations in contemporary knowledge or the incomplete nature of impact assessments for this practice to be regarded as matters of serious and urgent concern at this moment. The OECD countries interested in investigating the feasibility of this remediation option are collaborating through the IEA's Greenhouse Gas Research and Development Programme. This appears to be entirely consistent with the provisions of the United Nations Framework Convention on Climate Change (FCCC) which entered into force in 1994 and has now been ratified by 157 nations. Its objective is to achieve stabilization of

greenhouse gas concentrations in the atmosphere at a level that prevents dangerous interference with the climate system. It provides general guidelines and statements associated with a framework for mitigating global warming and gives authority to Parties to look to the oceans when considering ways to mitigate global warming. Parties to the Convention are committed to promoting the 'sustainable management of terrestrial and marine ecosystems as sinks and reservoirs for greenhouse gases (not chlorofluorocarbons)'. In this context, sink implies a 'process that removes a greenhouse gas from atmosphere' and reservoir implies 'storage of a greenhouse gas'. This is a radically different stance compared with those of earlier conventions dealing with the protection of individual sectors of the environment, such as the oceans.

Accordingly, there are not only scientific questions to be addressed but also social and legal issues. The remediation option is not yet an urgent one in the context of the projected supply of fossil fuels but, clearly, is one worthy of evaluation. In this connexion, matters relating to the impact on the marine environment can, and should, only be considered in a larger context - *i.e.*, the global environment and the net benefit offered to society by the practice. Any evaluation of net benefit will need to consider the overall consequences of any potential practice of this type with the balance between benefits and detriments having environmental, economic, technical, legal and social dimensions.

At this stage, there appears to be no pressing need for GESAMP, with its remit being restricted to matters relating purely to the marine environment, to become more deeply involved in this topic. GESAMP should, however, through its membership, maintain awareness of developments and progress within the Greenhouse Gas R&D Programme and stand ready to provide further advice on the subject should it be requested by the sponsoring United Nations agencies.

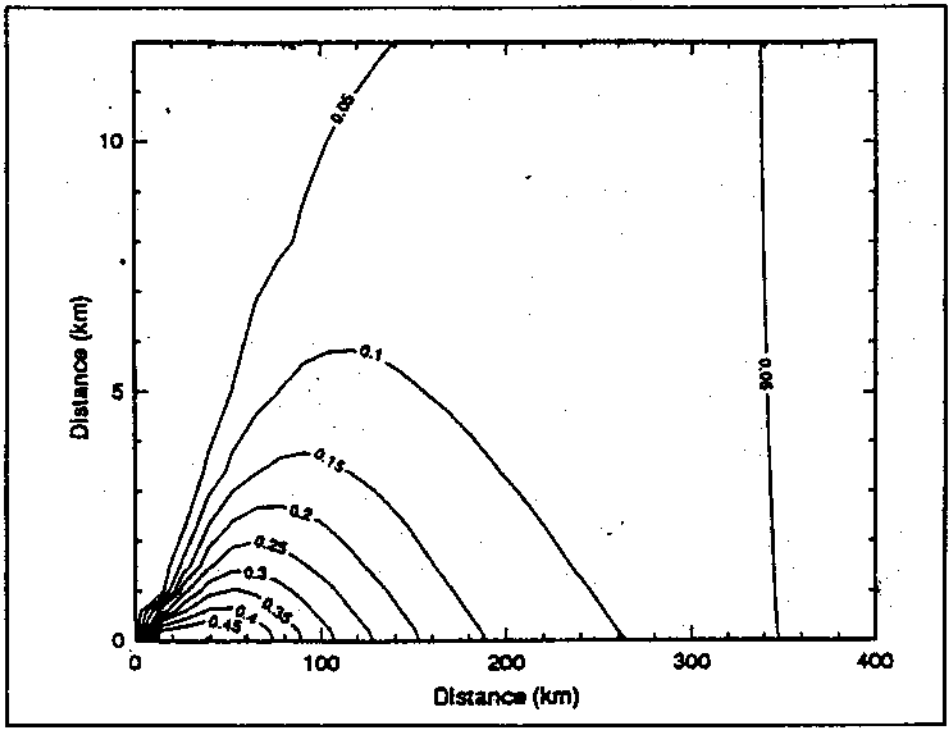

Figure 10
Deficit of zooplankton due to mortality from a one-plant dense plume
(after Auerbach *et al.*, 1996)

Acknowledgements

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Annex VII

LAND-BASED SOURCES AND ACTIVITIES AFFECTING THE QUALITY AND USES OF THE MARINE, COASTAL AND ASSOCIATED FRESHWATER ENVIRONMENT
(preliminary layout/content for the global review)

1. EXECUTIVE SUMMARY

2. **BACKGROUND**: Information on the background leading to preparation of the review and on procedures followed in its preparation.

3. **INTRODUCTION**: A concise description highlighting the main:

(i) natural conditions and processes underlying the ecological "health" and interdependence of oceans, coastal areas and associated freshwater environment;

(ii) anthropogenic impacts on these conditions and processes, with particular reference to major relevant land-based activities; and

(iii) socio-economic implications of anthropogenic alterations in natural conditions and processes. Special emphasis on airborne and riverborne pollutants, and the effects of man-induced changes in the hydrological regimes (e.g., excessive exploitation of coastal aquifers and removal of surface waters).

4. **IDENTIFICATION AND ASSESSMENT OF PROBLEMS**[4]: This central section of the report should identify and quantify, whenever possible, the nature, magnitude and severity of the problems (effects and impacts, including economic, social and cultural impacts) posed by land-based activities. Trends in effects and impacts should be analyzed. The global assessment will be largely based on regional reviews and on existing data and information. Therefore, the harmonization of the regional reviews is crucial. The Pressure-State/Impact-Response framework would be followed to help ensure that policy-relevant information will derive from the review.

4.1 **Nature and severity of problems**: The nature and severity of problems posed by land-based activities should be identified and assessed in relation to:

(i) food security and poverty alleviation;
(ii) public health;
(iii) coastal and marine resources and ecosystem health, including biological diversity; and
(iv) economic and social benefits and uses, including cultural values.

4.2 **Sources of degradation**: Three major sources of degradation should be considered:

(i) **coastal and upstream point sources**, such as waste-water treatment facilities, industrial facilities, power plants, military installations, recreational/tourism facilities, construction works (e.g., dams, coastal structures, harbor works and urban expansion), coastal mining (e.g., sand and gravel), research centres, aquaculture, habitat modification (e.g., dredging, filling of wetlands or clearing of mangrove areas) and introduction of invasive species;

(ii) **coastal and upstream non-point (diffuse) sources**, such as urban run-off, agricultural and horticultural run-off, forestry run-off, mining waste run-off, construction run-off, landfills and hazardous waste sites, and erosion as result of physical modification of coastal features; and

(iii) **atmospheric deposition** caused by transportation (e.g., vehicle emissions), power plants and industrial facilities, incinerators and agricultural operations.

4.3 **Contaminants**: Issues associated with major contaminants or group of contaminants (sources, amounts, levels, pathways, effects, etc.) should be analyzed. Contaminants of particular concern are sewage, persistent organic pollutants, radioactive substances, heavy metals, oils (hydrocarbons), nutrients, sediment mobilization and litter.

4.4 **Physical alterations**: The sub-section should also consider habitat modification and destruction in areas of concern.

[4]The layout and annotations of sections 4 and 7 follow the approach recommended in the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) for "identification and assessment of problems" and "establishment of priorities" in development of action at the national level (UNEP(OCA)/LBA/IG.2/7, paragraphs 21 and 22). An alternative way to deal with section 4 would be to treat the identification and assessment of problems in subsections organized according to major sources of problems (e.g., agriculture, industry, commerce, coastal urbanization, tourism, aquaculture, alterations in hydrological regimes, etc.)

4.5 **Areas of concern:** Consideration of problems of specially affected or vulnerable areas, such as:

(i) critical habitats, including coral reefs, wetlands, seagrass beds, coastal lagoons and mangrove forests;

(ii) habitats of endangered species;

(iii) ecosystem components, including spawning areas, nursery areas, feeding grounds and adult areas;

(iv) shorelines;

(v) coastal watersheds;

(vi) estuaries and their drainage basins;

(vii) specially protected marine and coastal areas; and

(viii) small islands.

5. **EMERGING AND FORESEEABLE PROBLEMS:** Identification of emerging and foreseeable problems affecting or affected by land-based activities, including those associated with the predicted climate change, and their potential impact on the marine and coastal environment.

6. **STRATEGIES AND MEASURES**[5]: Identification of options for strategies and measures, including scientific, technical, technological, political, legal, economic and resource management means, measures, policies and practices, which could be applied in dealing with identified priorities for action. They may include:

(i) measures to promote sustainable use of coastal and marine resources and to prevent or reduce degradation of the marine environment;

(ii) measures to modify contaminants or other forms of degradation;

(iii) measures to prevent, reduce or ameliorate degradation of affected areas;

(iv) requirements and incentives to induce action to comply with measures;

(v) identification of institutional arrangements needed to support the implementation of recommended strategies and measures;

(vi) dentification of short-term and long-term data collection and research needs; and

(vii) development of a monitoring and environmental-quality reporting systems.

The results, achievements and effectiveness of strategies, activities and measures undertaken in the past should be analyzed. Options for possible solution of identified problems should be given keeping in mind the various socio-economic conditions in which they would have to be applied, i.e., they should be within the limits of the economic capabilities of the country, or group of countries, which will be expected to apply them, and should be socially and politically acceptable. The economic, financial, legal, technical, technological, scientific, institutional and social constraints in mitigating and solving the identified problems should be highlighted.

7. **PRIORITIES FOR ACTION:** Priorities for action should be identified on the basis of assessment provided under sections 4 and 5 of the review. They should specifically reflect:

(i) concerns expressed in sub-section 4.1 in relation to source categories (contaminants, physical alteration and other forms of degradation, and the source or practice from which they emanate) and the affected (including its uses and the importance of its ecological characteristics); and

(ii) costs, benefits and feasibility of options for action, including the long-term cost of no action.

8. **MAIN CONCLUSIONS AND RECOMMENDATIONS**

9. **REFERENCES:** The review will be prepared on the basis of a critical examination and eclectic use of large amounts of (frequently contradictory) information and data. Therefore it would be advisable to identify the source of data and information used in the preparation of the review.

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[5]The annotations for this section largely follow the approach recommended in the GPA for "identification, evaluation and selection of strategies and measures" in development of action at the national level (UNEP(OCA)/LBA/IG.2/7, paragraph 26).

Annex VIII

**STATE OF THE MARINE ENVIRONMENT REPORT:
A POSSIBLE STRUCTURE/APPROACH**

EXECUTIVE SUMMARY

1. INTRODUCTION

- background/history
- purpose
- terms of reference

2. SCOPE AND STRUCTURE OF THE REPORT

3. COASTAL AND SHELF-SEA AREAS

3.1 etc *Sub-divisions comprising clearly defined and well characterized ecosystems (regional and/or functional).*

3.1.1 etc *For each ecosystem, describe:*

(a) major habitats/communities, resources and human uses;
(b) changes occurring (nature, extent, severity, trends);
(c) causes of change (natural, anthropogenic);
(d) significance of changes in terms of:

- productivity
- sustainability
- biodiversity
- socio-economic effects
- ecosystem dynamics
- local, regional & global dimensions
- *[the Working Group to consider whether there are other relevant criteria]*

4. THE OPEN OCEAN
[*Sub-divide and Assess as in Section 3]*

5. THE MAJOR ISSUES

[*Focusing on regions and ecosystems most affected, i.e., refer to Sections 3 and 4. Note that this section is designed to highlight the most serious issues with global dimensions; choice of headings is critical and should reflect innovative thinking on what the fundamental problems are, and how to best convey these thoughts to policy-makers and others; it is an opportunity to show, and stress, interrelationships; trends, forecasts and socio-economic impacts will be integral factors in the issue selection process (i.e., not issues in their own right). The following are very provisional examples to stimulate thought and discussion within the Working Group].*

e.g., 5.1 Reducing Stock of Natural Assets

- loss of habitat and biodiversity
- loss of high quality amenity, tourism and leisure facilities
- over-exploitation of fish stocks

5.2 Hazards to Human Health

- pathogens
- contaminants in seafood
- food security
- algal toxins

5.3 Pressures on Coastal Zones

- human
- economic
- deficiencies in sewage management
- mariculture
- conflicts of use

5.4 Ongoing Pollution from Industrial, Agricultural and Land-use Practices

- riverine inputs
- atmospheric inputs
- biological responses

5.5 Impacts of Sea-based Activities

- hazards from shipping
- introductions of exotic species
- port and harbour development
- marine accident response mechanisms

5.6 Potential Effects of Climate change

- physical, biological, hydrological
- coastal defences

5.7 Threats to Ecosystem Function

5.8 Critical Gaps in Information

6. PERFORMANCE EVALUATION

- progress since last SOME Report
- policy implementation
- environmental planning and management
- research and monitoring

7. OVERALL ASSESSMENT (*including trends and predictions*)

8. RECOMMENDATIONS

9. CONCLUSIONS

GESAMP Reports and Studies Publications

The following reports and studies are available from any of the Sponsoring Agencies of GESAMP.

Rep. & Stud. No.	Title	Date
1	Report of the Seventh Session	1975
2	Review of Harmful Substances	1976
3	Scientific Criteria for the Selection of Sites for Dumping of Wastes into the Sea	1975
4	Report of the Eighth Session	1976
5	Principles for Developing Coastal Water Quality Criteria	1976
6	Impact of Oil on the Marine Environment	1977
7	Scientific Aspects of Pollution Arising from the Exploration and Exploitation of the Sea-bed	1977
8	Report of the Ninth Session	1977
9	Report of the Tenth Session	1978
10	Report of the Eleventh Session	1980
11	Marine Pollution Implications of Coastal Area Development	1980
12	Monitoring Biological Variables Related to Marine Pollution	1980
13	Interchange of Pollutants between the Atmosphere and the Oceans	1980
14	Report of the Twelfth Session	1981
15	The Review of the Health of the Oceans	1982
16	Scientific Criteria for the Selection of Waste Disposal Sites at Sea	1982
17	The Evaluation of the Hazards of Harmful Substances Carried by Ships	1982
18	Report of the Thirteenth Session	1983
19	An Oceanographic Model for the Dispersion of Wastes Disposed of in the Deep Sea	1983
20	Marine Pollution Implications of Ocean Energy Development	1984
21	Report of the Fourteenth Session	1984
22	Review of Potentially Harmful Substances. Cadmium, Lead and Tin	1985
23	Interchange of Pollutants between the Atmosphere and the Oceans (second report)	1985
24	Thermal Discharges in the Marine Environment	1984
25	Report of the Fifteenth Session	1985
26	Atmospheric Transport of Contaminants into the Mediterranean Region	1985
27	Report of the Sixteenth Session	1986
28	Review of Potentially Harmful Substances. Arsenic, Mercury and Selenium	1986
29	Review of Potentially Harmful Substances. Organosilicon Compounds (Silanes and Siloxanes)	1986
30	Environmental Capacity: An Approach to Marine Pollution Prevention	1986
31	Report of the Seventeenth Session	1987
32	Land-Sea Boundary Flux of Contaminants: Contributions from Rivers	1987

Rep. & Stud. No.	Title	Date
33	Report of the Eighteenth Session	1988
34	Review of Potentially Harmful Substances. Nutrients	1990
35	The Evaluation of the Hazards of Harmful Substances Carried by Ships: Revision of GESAMP Reports and Studies No. 17	1990
36	Pollutant Modification of Atmospheric and Oceanic Processes and Climate: Some Aspects of the Problem	1989
37	Report of the Nineteenth Session	1989
38	Atmospheric Input of Trace Species to the World Ocean	1989
39	The State of the Marine Environment	1990
40	Long-Term Ecological Consequences of Low-Level Contamination of the Marine Environment	1989
41	Report of the Twentieth Session	1990
42	Review of Potentially Harmful Substances. Choosing Priority Organochlorines for Marine Hazard Assessment	1990
43	Coastal Modelling	1990
44	Report of the Twenty-first Session	1991
45	Global Strategies for Marine Environmental Protection	1991
	Addendum 1: Can there be a common framework for managing radioactive and non-radioactive substances to protect the marine environment?	1992
46	Carcinogens: Their Significance as Marine Pollutants	1991
47	Reducing Environmental Impacts of Coastal Aquaculture	1991
48	Global Change and the Air/Sea Exchange of Chemicals	1991
49	Report of the Twenty-second Session	1992
50	Impact of Oil and Related Chemicals and Wastes on the Marine Environment	1993
51	Report of the Twenty-third Session	1993
52	Anthropogenic Influences on Sediment Discharge to the Coastal Zone and Environmental Consequences	1993
53	Report of the Twenty-fourth Session	1994
54	Guidelines for Marine Environmental Assessments	1994
55	Biological indicators and their use in the measurement of the condition of the marine environment	1995
56	Report of the Twenty-fifth Session	1995
57	Monitoring of ecological effects of coastal aquaculture wastes	1996
58	Opportunistic settlers and the problem of the ctenophore *Mnemiopsis leidyi* invasion in the Black Sea	1997
59	The sea-surface microlayer and its role in global change	1995
60	Report of the Twenty-sixth Session	1996
61	The contributions of science to integrated coastal management	1996

Evaluation of the hazards of harmful substances carried by ships

- *More hazardous chemicals are being listed and evaluated*

Environmental impacts of coastal aquaculture

- *As the aquaculture industry grows, so too does the use of chemicals*

Storage of carbon dioxide in the deep sea

- *Can fossil fuel CO_2 be injected into deep oceans as a means of counteracting the effects of global warming?*

Review of the state of the marine environment

- *Periodical assessments of the state of coastal and marine environments are being made. Emphasis is on the effects of, and threats by, humans to coastal and marine waters*

Significant matters regarding degradation of the marine environment

- *Technological developments now allow for much deeper drilling for oil and gas in oceans*
- *Changes to the London Convention and the management of wastes*
- *Biological and ecological effects of marine fisheries*
- *Contaminated marine sediments*