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REPORT OF AN AD HOC PANEL OF IMCO AND GESAMP EXPERTS TO REVIEW THE ENVIRONMENTAL HAZARDS OF NOXIOUS SUBSTANCES OTHER THAN OIL TRANSPORTED BY SHIPS

Attached hereto for information is a copy of the Report of an Ad Hoc Panel of IMCO and GESAMP Experts to Review the Environmental Hazards of Noxious Substances Other than Oil Transported by Ships (GESAMP IV/19/Supp.1). This Report, which was prepared in response to the specific enquiry from IMCO shown at Annex I, has been the principal source of scientific advice for the Maritime Safety Committee and its sub-committees concerned in the preparation of the draft International Convention for the Prevention of Pollution from Ships, 1973 particularly with regard to the formulation of the draft Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk.

Subject to certain considerations, the Report was approved by GESAMP at its fourth session (18 - 23 September 1973) "as an accurate and scientifically based document which would be particularly useful for the purposes of the 1973 IMCO Conference on Marine Pollution". Subsequently, in January 1973, the Panel reviewed the Report taking into account the comments made by GESAMP, and included hazard profiles for some 200 additional substances, advice which would assist in the determination of insignificant levels of concentration for certain hazardous substances and other information requested by IMCO. In its present revised form, the Report will be brought to the attention of GESAMP at its fifth session (18 - 23 June 1973) and the Conference will be informed of any views expressed by the Group in this connexion.

GESAMP IV/19/Supp.1
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IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN

JOINT GROUP OF EXPERTS ON THE SCIENTIFIC ASPECTS OF MARINE POLLUTION

(GESAMP)

REPORT OF AN AD HOC PANEL OF IMCO AND GESAMP EXPERTS TO REVIEW THE ENVIRONMENTAL HAZARDS OF NOXIOUS SUBSTANCES OTHER THAN OIL TRANSPORTED BY SHIPS

which met at
IMCO Headquarters, London
1972/73

N O T E S

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

2. This Report contains the outcome of the work of an Ad Hoc Panel of IMCO and GESAMP Experts which met at IMCO Headquarters from 21-25 February 1972, 26-28 June 1972 and 22-26 January 1973. It is a supplement to the Report of the Fourth Session of GESAMP, held at WMO Headquarters, Geneva, from 18-23 September 1972 (GESAMP IV/19).

3. Copies of this Report in English and French only may be obtained from the IMCO Secretariat, London.

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

IDENTIFICATION OF NOXIOUS AND HAZARDOUS SUBSTANCES

Report of an Ad Hoc Panel of IMCO and GESAMP Experts to Review the Environmental Hazards of Noxious Substances Other than Oil Transported by Ships

I. PREAMBLE

1. At its eleventh session (22 - 26 November 1971) the IMCO Sub-Committee on Marine Pollution in preparing for an International Conference on Marine Pollution to be held in 1973, noted certain difficulties in utilizing the categories of pollutants as identified by the IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) (GESAMP III/19, Annex V) for developing control measures for operational discharges and for the construction and equipment of ships carrying dangerous chemicals in bulk. The Sub-Committee agreed to provide GESAMP with background information on present operational practices on chemical tankers and dry bulk carriers and prepared a detailed inquiry, a copy of which is attached at Annex I, requesting GESAMP to review available lists of products and consider their hazard in the environment if released accidentally or discharged deliberately into the sea during the normal operation of a chemical tanker or bulk carrier, e.g. during tank washings, etc.

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

2. In making this request, the IMCO Sub-Committee stressed the need for an urgent response by GESAMP, to meet the time constraints imposed by the preparatory work for the Conference. To meet this situation, therefore, it was decided in consultation with the Chairman of GESAMP (Dr. M. Waldichuk) to convene, as soon as possible, a meeting of an ad hoc panel of experts to prepare a rated list of noxious and hazardous substances for subsequent approval by GESAMP at its fourth session. This Panel met at IMCO Headquarters, London, from 21 - 25 February 1972 and from 26 - 28 June 1972, under the Chairmanship of Dr. H.A. Cole. A list of items considered at the meetings is shown at Annex II and a list of participating Experts is shown at Annex III.

3. At its fourth session (18-23 September 1972) GESAMP concurred with the views of a working group which, during the session, considered the Panel's report in detail. It was noted that, since the report had been prepared in response to a specific enquiry from IMCO, it contained basic data which were being used in the formulation of technical provisions for inclusion in a draft International Convention for the Prevention of Pollution from Ships, 1973. GESAMP agreed that the report was an accurate and scientifically-based document which would be particularly useful for the purposes of the 1973 IMCO Conference on Marine Pollution. The Group recognized and approved that, in the absence of sufficient data on lethal threshold concentrations, it has been necessary to use LC_{50} values. It was stressed, however, that, as indicated in its review of bio-assay methods (GESAMP IV/19, paragraph 3.1.1 of Annex IV), there is limited biological significance in such values and that evaluation of threshold concentrations is preferable and should be encouraged.

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

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

6. Subject to the foregoing considerations, GESAMP approved the Panel's report for issue as a supplement to its report and for use as a reference document for the IMCO Conference in 1973. The Group well understood the need to establish a mechanism for continually updating the list of substances as recognized by the IMCO Sub-Committee on Marine Pollution.

7. Subsequent to the fourth session of GESAMP, the Panel was requested by the Ad Hoc Working Group of the IMCO Sub-Committee on Marine Pollution (4-8 September 1972) to compile hazard profiles for at least an additional 200 substances including some refined oil products commonly transported by sea.

8. This work was carried out by the Panel at an additional meeting held from 22-26 January 1973 and the results were incorporated in the list of substances set out in Annex IV to this Report. At that meeting, the Panel finally reviewed the Report taking account of the views expressed by GESAMP and agreed upon the text set out in the following paragraphs. Furthermore, the Panel was requested by the Joint Meeting of IMCO Sub-Committees on Marine Pollution and on Ship Design and Equipment (27 November - 8 December 1972) to give advice which would assist in the determination of insignificant levels of certain substances considered by IMCO experts as presenting a major hazard to either marine resources or human health or causing serious harm to amenities or to other legitimate uses of the sea, if released during tank washing or deballasting operations. (The Panel's advice on this question is set out in paragraphs 60 - 64.)

II. GENERAL

9. At its first session, the Panel received background information and lists of substances carried in bulk or in packages by ships, together with a report prepared by the Government of Norway on pollution caused by the discharge of noxious substances other than oil through normal operational procedure of ships engaged in bulk transport. A suggested rationale for selection of hazardous polluting substances was provided by the Experts from the United States as a basis for discussion. Early in the session, the Panel was also fortunate in receiving first-hand information on current practices in bulk carriers from Captain Page of the International Chamber of Shipping.

10. In a preliminary general discussion at its first session, the Panel considered the problem of radioactive substances carried in ships. It was noted that such cargoes fall within Class VII of the International Maritime Dangerous Goods Code and will therefore be considered in due course by the IMCO Sub-Committee on the Carriage of Dangerous Goods with respect to the adequacy of the packaging etc., with a view to preventing accidental pollution. Moreover, the Panel felt that the assessment of the hazards of radioactive pollution was a matter for specially selected experts. It was therefore decided at that session to confine the attention of the Panel to non-radioactive substances.

11. The Panel agreed to consider all shipborne noxious and hazardous substances other than oil as presently defined in the 1954 Oil Pollution Convention. It was recognized, however, that several of the products concerned could, in a future Convention, be included within a revised definition of oil.

12. The Panel was aware that, although it was primarily concerned with the consequences of pollution of the marine environment, there was also a need to take into account the problems of pollutants discharged into fresh water since ships transporting bulk chemicals, ores and packaged goods must at times enter river estuaries and inland waters for the purpose of loading and discharging cargoes. It was further noted that such areas may be sources of potable water.

13. The Panel did not consider questions relating to the effects of polluting substances upon the vessel or its crew since this aspect was not within its purview. Nevertheless, it was necessary to consider human health hazards with respect to people who might come into contact with a substance, its vapour or its solution after release into the environment.

III. ESTABLISHMENT OF CRITERIA

14. At the request of the IMCO Sub-Committee on Marine Pollution, the Panel, at the second session, took into account comments submitted by the Governments of Sweden (MP XIII/2(c)/3), Norway (MP XIII/2(b)/1) and the United States (MP XIII/2(c)/5, Section VI).

Rationale used for evaluating noxious substances other than oil

15. The members of this Panel were requested to evaluate substances, when released into the sea, under at least four degrees of hazard, according to each of the following effects: damage to living resources; hazards to human health; reduction of amenities, and interference with other uses of the sea. The rationale as given here should provide a basic understanding of the decision mechanism which was used to evaluate these substances. Because IMCO must ultimately make an evaluation of all material shipped, no attempt was made to develop a rationale to select particularly hazardous materials out of those currently being shipped. The task therefore was to develop a rationale to evaluate any substance which is carried as a bulk liquid or dry cargo or a packaged cargo.

16. As illustrated in Figure 1, seven steps were identified as essential to provide sufficient breadth for making an evaluation of hazard that will identify potential harm to man and the marine resources. Step 1 limited the evaluation to substances transported by ship. It was necessary to omit the oils as defined in the 1954 Convention for Prevention of Pollution of the Sea by Oil in Step 2. Because the Panel was to rate substances in a range extending from definite harm to minimal hazard, the concept of biological magnification or accumulation was examined. As noted in Step 3, biological accumulation was the first evaluation to be made on each substance. The significance of this evaluation is that it is very difficult to establish a safe limit of discharge for these bio-accumulative materials and that even small discharges can be

hazardous. Very low levels of these substances in the receiving water may be concentrated by marine life and either pose a direct threat to those organisms, to their predators, including man, or render seafood unpalatable.

17. The second evaluation to be made on each substance is illustrated in Step 4 and is concerned with the lethal damage a substance may cause to living marine resources. Fish were selected as one of the most sensitive marine groups for which toxicological data are available with information on shrimp being used to fill in the gaps. The 96 hour TLm test* (concentration of the substance during 96 hours' exposure at which 50% of the test organisms are killed) was used to provide the basis for making five rankings of the toxic potential. It was considered that if the substance would not be lethal according to this test at greater than 1000 ppm (mg/l) then it posed no toxic hazard to marine life. The stress of toxic effect of environmental reactions such as biochemical oxygen demand (BOD) from the water body were considered and evaluated. A special note was made of those insoluble substances which might blanket the sea-bottom (D), if released in large quantities.

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* <u>Definitions</u>

LD_{50} - The dose of a substance which will, within a specified period of time, kill 50% of a group of test animals to which it has been administered. The dose is generally expressed in terms of mg of the substance administered for each kg of the animal's body weight.

Oral LD_{50} - The LD_{50} of a substance which has been administered by the oral route to animals, the dose being expressed in the terms stated above.

TL_m - The concentration of a substance which will, within the specified time (generally 96 hours) kill 50% of the exposed group of test organisms, often specified in parts per million (mg/l). The bioassay may be conducted under static or continuous-flow conditions.

18. The third evaluation to be made on each substance was the hazard to human health likely to result from drinking water contaminated by the substance (Step 5 in Figure 1). The risk from drinking contaminated water was rated in terms of the amount of chemical needed to kill 50% of a group of animals (LD_{50})* when each animal was given a single dose by mouth. This method was preferred to the more sophisticated criteria because the LD_{50} data were readily available.

19. The fourth evaluation, Step 6 in Figure 1, is an assessment of potential harm to amenities, including both recreational uses and aesthetic values. Aspects, such as the use of beaches and coastal areas for bathing, sailing and other recreation, and amenity values such as colour of water, odour, presence of scums and floating material were considered.

20. Steps 3 to 6 constitute the review of the required significant parameters that may be regarded as inherent properties of the various substances. In making this sequence of evaluations it will be apparent that the quantities of materials involved may play a vital role. A small quantity of a biologically-accumulated poison and a large quantity of a beach-fouling material would both be regarded as potentially hazardous.

21. One final evaluation was made, as illustrated in Step 7, which was an attempt to examine the potential of a substance to create hazards, as defined in the previous categories. This effort used hypothetical bodies of water in which the quantity of the substance being carried could be shown to be potentially dangerous. Despite its inherent limitations and assumptions, this procedure enables amounts of various substances discharged into particular water bodies to be related to their initial concentration and potential effects.

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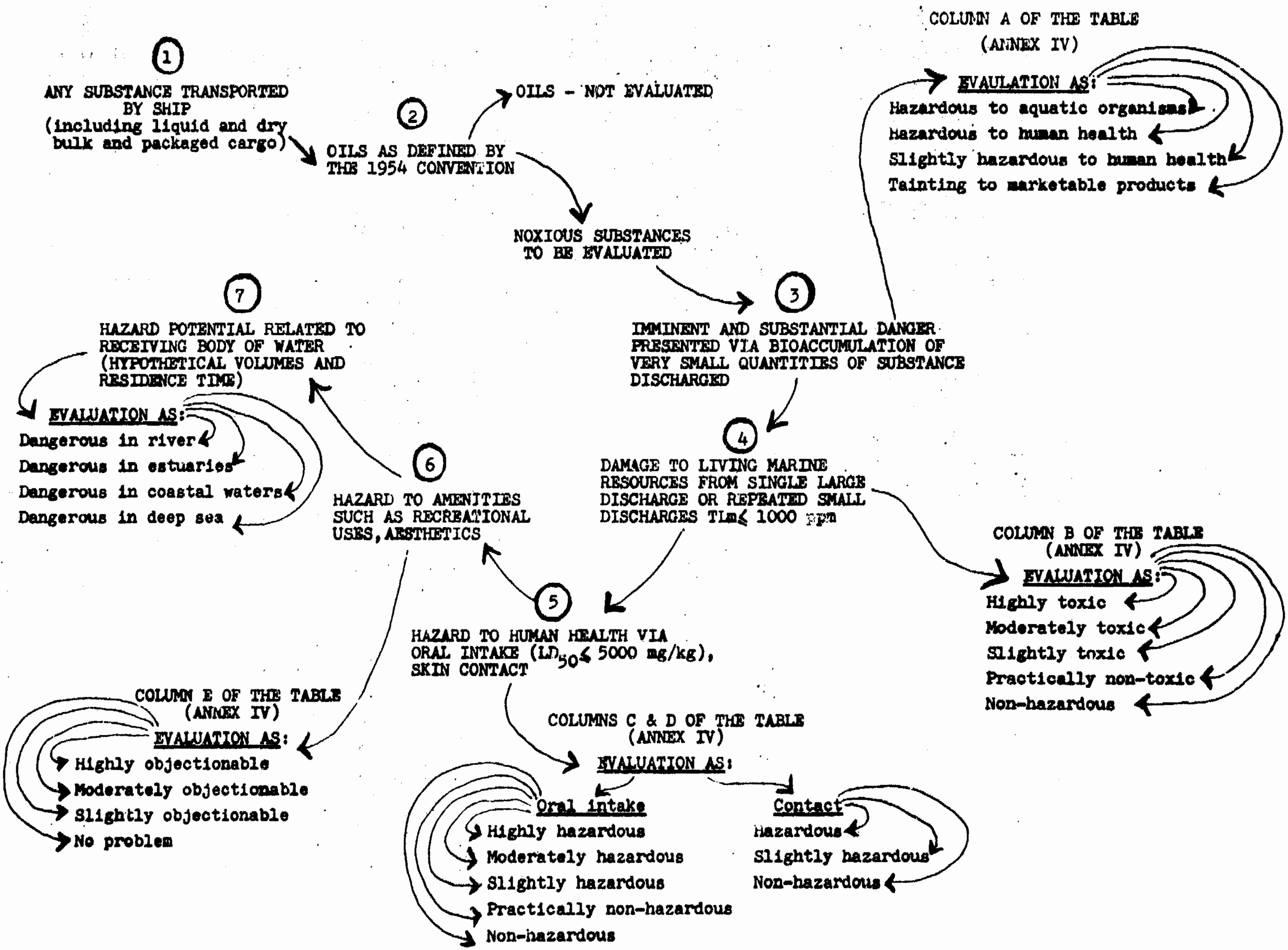
* See footnote "Definitions" on page 7.

Figure 1. RATIONALE FOR EVALUATION OF NOXIOUS SUBSTANCES



IV. EXAMPLES OF HAZARD RATINGS

22. In considering the most appropriate way of providing the hazard ratings requested by IMCO, the Panel agreed to construct, on the basis of the foregoing rationale, a hazard profile of selected substances in tabular form (Annex IV) showing the degree of hazard presented by each substance under the following main headings:

A. Bioaccumulation

23. Bioaccumulation occurs if an aquatic organism takes up a chemical to which it is exposed so that it contains a higher concentration of that substance than is present in the ambient water or its food. The process is reversible. Where the rate of metabolism or elimination of the substance is high and the degree or period of exposure small, bioaccumulation may be short-lived. Where the rates of metabolism and elimination are low or the degree or period of exposure great, bioaccumulation may be of long duration. The Panel also recognized that metabolites may be formed from ingested substances which may be more poisonous or ecologically damaging and/or have a longer biological half life than the original polluting material, e.g. DDT → DDE.

24. The hazard presented by a substance is increased if it is accumulated in aquatic organisms since these may eventually be poisoned. In addition, certain substances concentrate in the parts of fish and shellfish which, if eaten by man, result in accumulation in human tissues. This may be a hazard to human health.

25. When bioaccumulation occurs and there is no tainting or similar effects, it is designated by a "+" in column A. When bioaccumulation is known to occur but the retention time is short, such as one week or less, it is designated by a "Z". Accumulation

of nutrient substances is disregarded. Bioaccumulation may render the flesh of edible fish and shellfish unpalatable and/or interfere with consumer acceptability owing to taint or colour. Such accumulation is indicated by the letter T.

26. The following are examples of potentially harmful substances which degrade slowly, if at all, and therefore tend to accumulate in the marine ecosystem. The Panel considered that release from ships of such compounds should be avoided:

Aldrin
BHC isomers
Cadmium compounds
Chlordane
DDT
Dieldrin
Endrin
HCB (Hexachlorobenzene)
Heptachlor (epoxides)
Lead compounds
Mercury compounds
Polyhalogenated biphenyls

B. Damage to Living Resources

27. In order to establish a ranked order of hazards to living resources, the Panel considered that the most practical method was to use available 96-hr TLm data. Data from bioassay tests on the compounds listed in the table (Annex IV) for marine species were used when available; otherwise, data from tests on freshwater species were used. In a few instances extrapolations were made based on data for similar substances (these are appropriately indicated in the Table). Where information was available for more than one aquatic organism, the figure for the most susceptible species was generally used.

28. In a few instances the Panel was aware that a chemical was likely to be altered after its release into the marine environment. Where such a change was known to lead to an increase in toxicity, the rating given, both for aquatic and human toxicity, was based on the toxicity of the most toxic metabolite.

29. Most of the 96-hr TLm test data available were derived from tests with adult or juvenile aquatic organisms usually from upper levels of the food chain. The Panel recognized, however, that other stages, e.g. larvae or eggs, or organisms lower but critically important in the food web, might be much more susceptible than the organisms or stage of organism tested. There are instances where phytoplankton, benthic algae sea weeds or rooted aquatics may be seriously harmed by particular substances; such circumstances were taken into consideration.

30. Although the Panel recognized that at the present time acute toxicity TLm data are more complete and therefore present the best method of ranking substances according to hazard, it was aware that chronic or sub-lethal effects may ultimately be more important ecological considerations. Fish are known to be able to detect concentrations as low as 10^{-3} to 10^{-8} mg/l of a range of substances. Behaviour and chemo-reception (as involved in food finding, mating, migration) might be adversely affected by concentrations considerably lower than the 96-hr TLm.

C. <u>Hazards to Human Health</u>

31. The Panel considered that there are three principal ways in which injury to human health can occur from substances polluting the sea and waterways, namely:

(i) from ingestion of water containing the substances;

(ii) from ingestion of fish and shellfish which have accumulated toxic substances;

(iii) from the adverse action of the substance or its vapour, or the substance in solution, on the skin or eyes, and from absorption through the skin to affect internal organs.

The risk that serious harm could occur by other mechanisms was considered to be negligible.

Ingestion of water containing the chemical

32. It was recognized that ingestion of water contaminated by polluting substances may pose acute and long-term problems. In dealing with this problem, the Panel chose to consider it as a problem of acute toxicity in that consumption of contaminated water is likely to be rare and to extend over a short time period. The degrees of hazard are listed in terms of the median lethal dose (LD_{50}) of the substance. While it is desirable to base the LD_{50} figures on knowledge of the weights of substances likely to be ingested in water, the precise data from which these can be calculated are not available. The Panel therefore rated this hazard in terms of the oral LD_{50} values, as determined in suitable mammalian species, on the assumption that the hazard increases with toxicity.

33. The Panel recognized that this broad statement is modified in the individual case by factors such as degradation of the substances by water or aquatic life and the extent, if any, of their removal by water treatment processes or evaporation. It was also recognized that LD_{50} values may be different when

determined on pure chemicals and on the dilute solutions such as occur in polluted water. Despite these facts, and because the factors discussed would reduce rather than increase the hazard from particular chemicals, the Panel felt that rating in terms of the mammalian oral LD_{50} figures was valid as an indication of the potential toxic hazard from ingestion of contaminated water in the majority of cases.

34. In some cases, however, where the mechanism of toxic action of a substance (and hence its LD_{50}) was altered markedly by a change in concentration, the use of the LD_{50} figure determined on a pure or concentrated substance gave a misleading impression of the degree of hazard involved in its ingestion in dilute solution. In such cases (e.g. with acids and alkalis) a more realistic hazard rating was set using knowledge of the properties of the dilute solutions and without reference to the LD_{50} figures for the pure or concentrated substance.

35. The Panel emphasized that description of a substance as non- or slightly hazardous does not indicate that water polluted with this substance is safe for drinking. A completely different set of toxicological criteria is needed to define the standards for potable water for municipal supplies. The ratings are intended merely to reflect the degree of concern that should be shown when these chemicals are released. The hazard has been rated in five groups ranging from "high toxic hazard" (LD_{50} < 5 mg/kg body weight) to "no hazard" (LD_{50} > 5000 mg/kg) in Column C.

<u>Ingestion of fish and shellfish which have accumulated toxic substances</u>

36. See Bioaccumulation.

D. Human Health Hazard: Other aspects of injurious action of chemicals

37. The Panel recognized that some substances, their vapours, or aqueous solutions, may cause irritation and injury to the skin, mucous membranes and eyes. A few substances may cause allergic reactions in a large proportion of an exposed population. Absorption of some compounds can occur through skin, leading to injury to the internal organs. Because of their physical properties, certain substances are liable to contaminate beaches; these may pose a particular hazard to human health from direct contact or from inhalation of their vapours. It was considered that the narcotic action of vapours from volatile substances is unlikely, in other than the most confined conditions, to present a serious health risk and was not considered further. It has been possible to recognize three categories of hazards from contact with the substances in aqueous solution, described as "hazardous" (II), "slightly hazardous" (I) and "non-hazardous" (0) in Column D (Annex IV). The various categories are described below:

Rating	Description	
0	Not hazardous	Substances which on short exposure are unlikely to lead to ill health. Substances which are not absorbed to a significant extent through the skin. Substances which evaporate rapidly, the substance and vapour not causing irritation to the skin, eyes and mucous membranes or lungs. Note: The effects from prolonged or repeated contacts have not been considered

Rating	Description	
I	Slightly hazardous (substance in solution)	Contact likely to lead to mild skin irritation (reddening with or without slight pain) of a temporary nature. Vapour likely to cause temporary, mild irritation to eyes or mucous membranes to a degree that subjects find unpleasant. No injury to internal organs.
II	Hazardous (substance in solution)	Contact leads to severe irritation, causing pain and burns of the skin and mucous membranes and injury to the eyes on short contact. The vapour may cause similar injuries and damage to the lungs even at low concentrations. Substances may be strongly allergenic to large proportions of the population. Absorption of substance through skin may lead to damage to internal organs.

E. Reduction of Amenities

38. For the purpose of this report, amenities are defined as values of the recreational use or scenic aspects of the environment. Reduction of amenities by polluting substances released from ships may occur as a consequence of the presence of poisonous, irritant or strong smelling substances in coastal areas used for bathing, boating or other recreational purposes, or from the occurrence on the sea surface or on the beach of objectionable scums, slicks or other floating or suspended materials. Impairment of scenic values may also be brought

about by extensive discolouration of the water or by conversion of some of the liquid substances into solids by polymerization on exposure to air and sunlight.

39. Where substances are both persistent and either poisonous, irritant, foul-smelling or otherwise obnoxious, the seriousness of the effect on amenities will be greatly increased. While transient interference with recreational use of coastal areas, lasting perhaps for up to 48 hours, may be regarded merely as a nuisance, longer-term persistence of effects, particularly the presence of poisonous or irritant substances may create serious problems in areas of importance to the holiday and tourist industries. For this reason substances capable of producing such long-term effects are given a high hazard rating in Columns D and E of Annex IV.

40. A hazard to human health may occur if noxious liquid or solid substances, contained in drums or packages, are lost from a ship and are washed up on the shore. The local hazard arising from such containers or packages, if opened or split, will be similar to that considered and evaluated in the handling and carriage of dangerous goods. If the substances concerned can be identified by markings on the containers or packages, or otherwise designated dangerous, then the IMCO Dangerous Goods Code should be used for guidance on procedures for handling, to supplement the ratings of environmental hazards provided in this report. If the substances cannot be identified, then the containers and packages should be regarded as hazardous to human health and the environment until proved to be otherwise; in such circumstances, local closure of beaches may be desirable.

41. In making its assessments of the effects of particular substances on amenities, the Panel had in mind the potentially damaging situations where a ship has discharged deliberately, or as a consequence of an accident, a substantial amount (usually several tons at least) of the substance under consideration into relatively shallow coastal water immediately adjacent to recreational beaches. Releases due to tank washings will produce lesser effects, and unless either very toxic or otherwise highly obnoxious substances are involved, only minor reduction of amenities would be anticipated. The cumulative local effect of repeated discharges may be more serious.

42. The risk of fire due to inflammable materials carried ashore was not considered in relation to amenities, as the Panel understood that fire risks generally are fully considered by IMCO in other contexts.

F. Interference with other uses of the sea

43. The Panel agreed that problems relating to "interference with other uses of the sea" involved a wide variety of possible effects which are not directly attributable to specific polluting characteristics as such. For this reason, it was not felt to be appropriate to assign hazard ratings under this heading. Nevertheless, the Panel noted that problems of this character should be taken into account in dealing with pollution prevention, such as:

(i) interference with fishing or navigation through deposit of solid objects, containers or bulky materials on the sea floor in shelf waters;

(ii) interference with ship operation from persistent floating or suspended materials such as plastic netting, bags or sheets;

(iii) underwater corrosion of structures in docks or harbours;

(iv) impairment of water quality for industrial use.

V. NOTES ON QUALIFYING FACTORS

Climatic Effects

44. The Panel was aware of the effect of climatic conditions on the severity of pollution by some of the substances considered. This particularly applies to those substances which are biologically degraded, where the rate of degradation is temperature dependent. Temperature effects may also apply to those compounds which undergo chemical change in the marine environment by either interaction with salts in sea water or through chemical degradation in the water.

45. Bacteriological activity has been clearly shown to be temperature and pressure dependent. A recent observation on food left in the submersible ALVIN, which sank into some 6,000 ft. of water and remained there for a year, showed that at the low temperature and high pressure at this depth the food had remained virtually unchanged, quickly undergoing decomposition once it was exposed to atmospheric temperature and pressure. Many organic chemicals are broken down by bacteriological degradation. It is anticipated that degradation will be most rapid in warm tropical waters and slowest in cold Arctic waters, with an intermediate rate in temperate waters. The persistence in Arctic climes of materials which are biodegradable in temperate waters, could have serious long-term consequences.

46. Those materials, which are nutrients or undergo degradation to nutrient compounds, such as fertilizers and some detergents, may have their most acute effects in warm tropical waters where metabolic processes are rapid. These effects might be particularly objectionable in waters which are partially enclosed, and where water exchange is slow. The enrichment could recycle for a long time through uptake of nutrients by local populations of aquatic plants and animals. Enrichment is less likely to be a problem in Arctic waters, but could be a matter for concern in temperate harbours and estuaries.

47. Climatic variations from season to season, particularly at higher latitudes, make it difficult to apply any consistent rating of hazards according to climatic zones or by latitude. The Panel recognized the local and temporal variability of many of the meteorological phenomena, such as temperature, winds, rainfall, solar radiation, all of which have an effect on the extent of pollution caused by many of the substances carried by ships. For example, the short intensive duration of sunlight in Arctic regions can be seriously affected by materials which impede light penetration through colour, turbidity or stimulation of phytoplankton. However, it is difficult, if not impossible to apply, in quantitative terms, any qualifications based on climatic conditions, to hazard ratings.

48. It might be possible to consider qualitatively the effects under three broad classes of climatic conditions: (a) Arctic; (b) Temperate; and (c) Tropical. In this regard, a number of highlights of climatic effects can be summarized:

(1) Biodegradable compounds, (having a high biochemical oxygen demand) such as molasses, can have an acute effect on dissolved oxygen concentration in tropical and semi-tropical waters.

(2) Nutrient-containing or nutrient-yielding substances may lead to undesirable enrichment in all waters, but particularly in enclosed tropical waters. Among other things, this can reduce light penetration with the increased phytoplankton blooms.

(3) Insoluble, lighter-than-water substances may be particularly persistent in cold waters where bacterial degradation is slow and accumulation can occur with repeated discharges to create a hazard to aquatic life and wildlife, for example seals, polar bears and other mammals living on and under the ice.

VI. EVALUATION OF POTENTIAL DISCHARGES

49. The method set out with examples in Annex V was developed to demonstrate the relationship between a quantity of a discharged material, the properties of aquatic systems which may be receiving the material and the aquatic toxicity rating of the material. It must be pointed out that the prediction of water quality profiles in aquatic systems is complex and is still being developed.

50. The importance of currents, turbulent mixing and diffusion to dilution and dispersion of materials introduced into the marine environment is fully recognized and reasonably well understood. The modifying factors such as stratification, caused by freshwater run-off and solar heating, are qualitatively understood and in a few instances have been evaluated.

51. Perhaps of secondary importance, but often significant are the effects of the physical and chemical characteristics. Waters heavily loaded with suspended materials from either natural or man-made sources will interact with introduced substances in a different way than clear waters. For example, colloidal suspensions of clay in fresh water will adsorb certain chemicals, including nutrients, which will be precipitated as the clay is flocculated on mixing of fresh water with sea water. These materials may be fixed in the sediments or could leach into the overlying water to affect bottom fishes and other organisms.

52. There could be chemical interaction of dissolved organic and inorganic materials in the receiving waters with introduced substances. A neutralization or antagonism of one substance toward another sometimes occurs in the ultimate effect on aquatic organisms. Examples are the heavy metals which are less harmful in seawater and hard fresh water than in soft fresh water. On the other hand, there may be synergism where materials interact to give more than an additive harmful effect on organisms. In some instances, such as with endosulfan, the toxicity is actually higher in saline water than in fresh water.

53. This short document cannot begin to describe fully the large number of inherent combinations of the character of the discharged material and the receiving system's physical and chemical properties. However, some generalized assumptions can be made which will permit those concerned with regulation of shipping to have some feeling for the relationship between system and discharge character and the numerical values used to evaluate the aquatic toxicity hazard of various materials. As a result, those concerned with regulation of shipping will have some rough idea of the magnitude of concentrations and the problem with which they might have to cope in different types of aquatic systems.

54. In each of the examples in Annex V assumptions which were made have been carefully specified along with those system and material characteristics or properties which need to be considered in a more detailed analysis. The hypothetical examples were chosen on the basis of an evaluation of real aquatic systems of which the Panel had intimate knowledge. These are major navigable systems currently in use by commercial shipping.

55. Substantial information as to the specific size of discharges of material in different ranges of toxicity may be derived from the examples provided in Annex V. Extreme caution is recommended, however, to ensure that the results are not extrapolated to systems substantially different from those described, or used in such a way as to ignore background environmental stresses or concurrent effects from other materials discharged into the system. They do NOT indicate safe discharge levels but are intended only as an indication of what might be harmful in the rather special hypothetical areas described.

56. By extrapolating Table A, it may be determined that from 3 to 30 tons of a material with a 3 rating in Column B of the Rating Table (TLm = 1-10 mg/l), (depending on toxicity within the range), would cause death of a coastal area community with a $\frac{1}{4}$ mile square area 60 ft. deep. From 50 to 500 tons would cause damage to the aquatic community over a 1 mile square area.

57. From the estuary data shown in Table B, it may be determined that a quantity of from 0.75 tons to 7.5 tons of a material with a 3 rating in Column B of the Rating Table would cause death to aquatic organisms within the tidal prism.* It must be noted that this is the effect of a single discharge occurring once within the flushing period, under the assumption that no other waste loads or environmental stresses are present.

58. Daily discharges of non-degrading materials with a 3 rating in Column B of the Rating Table of from approximately 40 lbs to 400 lbs from all sources would have the same effect as the above single discharge values of 1500 lbs and 7.5 tons, respectively.

59. Similar analyses coupled with rational judgement can yield much additional useful information, such as that shown in the table below. This table is presented with some hesitancy because of the danger of its being misused or misinterpreted. However, it provides a useful way of displaying the ranges of dangerous discharges shown above and to emphasize the particular effect of very hazardous materials (i.e. those with TLm value less than 1).

Toxic discharge levels which would be expected to kill most aquatic life in specified systems:

Material Aquatic Hazard level	Toxicity Ranges (TLm) ppm	Rivers* (1000 cfs)	Estuary*	Shallow* Coastal Waters
1	100-1000	6.6-66 tons	62.5-625 tons	5000-50000 tons
2	10-100	1320-13200 lbs	6.25-62.5 tons	500-5000 tons
3	1-10	132-1320 lbs	0.62-6.25 tons	50-500 tons
4(a)	0.1-1.0	13-132 lbs	125-1250 lbs	5-50 tons
4(b)	0.01-0.1	1.3-13 lbs	12.5-125 lbs	0.5-5 tons
4(c)	<0.01	<1.3 lbs	<12.5 lbs	<0.5 tons

* See examples 1, 2 and 3 in Annex V for assumed system and material characteristics and metric equivalents.

* The volume enclosed within a tidal range in a given estuary upstream of a given point.

VII. ADVICE CONCERNING THE ESTABLISHMENT OF INSIGNIFICANT LEVELS OF CONCENTRATIONS

60. At a Joint Meeting held from 27 November to 8 December 1972, the IMCO Sub-Committees on Marine Pollution and on Ship Design and Equipment considered the draft 1973 Convention including in particular Annex II - Regulations for the Control of Pollution by Noxious Liquid Substances Other than Oil Carried in Bulk. The Panel was informed that for the purposes of these Regulations, noxious liquid substances were being grouped into three categories on the basis of the hazard profiles shown in Annex IV to this Report. In particular the Panel noted the draft texts of the following Regulations as shown in the Fourth Draft of the Convention (MP XIV/8).

- Regulation 3 containing the definitions of Categories A, B and C together with the Guidelines for categorization set out in Appendix I to Annex II
- Regulation 7 concerning the Discharge of Noxious Substances other than Oil, in particular with reference to the prohibition of discharge of bilge or ballast water or other residues or mixtures containing substances in Category A except when the concentration of the substance in the mixture, which remains in the tank after dirty ballast and/or tank washings are discharged ashore, is at or below an insignificant level to be shown in Appendix II to Annex II and in accordance with other restricting provisions
- Regulation 11 with particular reference to the Measures for Control of the discharge of residues and mixtures containing substances of Category A.

61. In the context of the above-mentioned draft Regulations, GESAMP was requested to give advice which would assist in the determination of what concentration of each particular substance in Category A could be regarded as an "insignificant level". On this question the Panel took the view that bioaccumulated substances pose the major problems and that with these materials the total amount of material involved is of much greater importance than the concentration discharged. The amounts of such materials permitted to be discharged should be reduced to the lowest practicable level. Concentration discharged is however also important, especially for those substances with a high toxicity to aquatic life. The Panel recognized that the concentration of a substance which is toxic to aquatic life can be modified by environmental factors such as climate, by synergistic effects of other pollutants, etc. They further recognized that the likely dilution after discharge would be dependant upon hydrographic conditions. The Panel considered, however, that their advice should be based on the toxicity of a substance to marine life and the bioaccumulation hazard. Human health hazard would arise only from bioaccumulation.

62. Based on the assumption that discharge would be made with the vessel, underway and off-shore, the Panel considered that the minimum dilution achieved on discharge would be 1 in 1000. They were, however, aware of studies which indicated that under certain conditions the dilution would be considerably greater and in others perhaps somewhat less.

63. Based on the assumption of a dilution factor of 1000 the Panel considered that for a material with an aquatic toxicity rating of 4 and a known bioaccumulation rating (+) a concentration of 0.1 mg/l in the discharge could be regarded as insignificant, provided that suitable limitations were imposed on the total amount discharged.

64. The Panel considered that the relative importance of the degrees of bioaccumulation hazard they had indicated was +,T and Z in decreasing order. On this basis they agreed that the problem posed by a substance with a toxicity rating of 4 (TLm $<$ 1 ppm) and a bioaccumulation rating T was less than that posed by a substance rated +,4 but roughly equivalent to that posed by one rated +,3 (bioaccumulated and TLm 1-10 ppm). The Panel accordingly present the following proposed order of hazard:

$$+,4 > T,4 > Z,4 > 0,4$$

$$T,4 \simeq +,3$$

$$Z,4 \simeq T,3$$

and suggest that the insignificant levels to be established for tank washings etc. should take into account these gradings.

VIII. FUTURE WORK

65. The hazard profiles completed by the Panel relate to some 450 substances selected partly because they figure prominently in the materials transported by sea in bulk or in packages, partly because they are highly toxic and therefore likely to cause damage if released, and partly from other considerations. Although the list of substances transported in bulk as liquids or solids or in packages comprises several thousand items, a Norwegian study, based on replies received to a questionnaire, indicates that only 260 types of liquid cargo were included in the 16,362,735 tons of substances other than oil reported as transported in 1970. In this total tonnage, 20 types of substances were reported as accounting for about 73% of the total discharges of liquid chemicals in tank washings.

66. Having regard to these figures and to the fact that the possible ways of dealing with discharges arising from tank cleaning are very limited (being restricted, practically speaking, to retention on board or discharge either in harbour, in shallow coastal water, in

shelf waters or in the deep sea), it may be argued that it is unnecessary at this stage to complete hazard profiles for more than a representative range of substances transported, in order to provide adequate guidance for those engaged in the consideration of ship design and construction, the stowage and handling of cargoes, and in the consideration of regulations for the discharge of tank washings. If the range of substances for which profiles were completed included the majority of the very highly toxic chemicals and of those substances which are transported in very large quantities, the information provided might meet satisfactorily the immediate needs of IMCO. It is appreciated, however, that at a later date hazard assessments in respect of environmental pollution will be needed for all substances carried in bulk or in packages so that they can be properly classified in relation to any regulations or codes of practice that may be implemented.

67. The present report, with its profiles of some 450 substances, the accompanying explanation of how the ratings were derived, and how these may be related to amounts likely to be discharged in particular environmental situations, represents the first step in the process of complete evaluation of the potential environmental effects of accidental or deliberate discharges of substances transported by ships. The extension of hazard assessments to all substances carried in bulk or packages would be a longer-term task, requiring more precise descriptions of many substances now grouped for cargo description purposes and especially the acquisition of additional data regarding their behaviour and toxicity in the aquatic environment. All assessments produced will require up-dating from time to time as new knowledge becomes available.

68. The Panel believes that, having established and tested the rationale for hazard evaluation and having applied it to a wide range of substances carried as bulk liquids, solids or packages, its main task has been successfully accomplished. Future work will be of a more routine nature and the Panel believes that it should become the direct responsibility of an IMCO body such as the Marine Pollution Sub-Committee which should make appropriate continuing arrangements for this purpose. The principal tasks will be the revision and up-dating of existing hazard profiles in the light of advancing knowledge and the evaluation of additional substances as required for the purposes of the Convention. Such work will require extensive literature search and data evaluation and might become the responsibility of a Selected Group of Experts drawn from the delegations of the Member Countries. Experience has shown that to make substantial progress the Members of such an expert group must engage in intersessional work using national data sources and expertise.

Reference Material

69. The Panel's assessments were based upon an examination of a large number of original papers relating to individual studies of substances and groups of substances, and available in the National Agencies and Departments. In addition, use was made of published and unpublished data available to individual experts. The following short list of publications containing data on the physical, chemical and toxicological properties of substances was found to be useful:

Water Quality Criteria, State Water Quality Control Board, Sacramento, California

Water Quality Criteria Data Book, Environmental Protection Agency, Washington D.C.

Toxicity of 4346 Chemicals to Larval Lampreys and Fishes, U.S. Department Interior, Fish and Wildlife Service

Handbook of Analytical Toxicology, Chemical Rubber Co.

The Condensed Chemical Dictionary, Rose A. & E. and Turner, F.M., Reinhold

The Merck Index, Merck & Co. Inc.

Handbook of Chemistry and Physics, Chemical Rubber Co.

Industrial Hygiene and Toxicology, 2nd Revised Edition, Vol.II., Ed. Patty, F.A., Interscience Publ.

The Toxicity of Industrial Solvents, Browning E., Elsevier

The Toxicity of Industrial Metals, Browning E., Butterworth

Extra Pharmacopoea 26th Edition, Martindale, The Pharmaceutical Press

Evaluation of the Hazard of Bulk Water Transportation of Industrial Chemicals - A Tentative Guide, USA National Academy of Sciences.

ANNEX I

INQUIRY TO GESAMP

The Inter-Governmental Maritime Consultative Organization (IMCO) has scheduled an International Conference on Marine Pollution for the fall of 1973. Presently under consideration is a draft convention which will address pollution of the marine environment by the marine transportation of bulk and packaged "noxious substances"; a "noxious substance" being a product or concentration of a product, other than oil, sewage or garbage or refuse, yet to be defined.

The following decisions are examples of those that have to be made by the Conference concerning the marine transportation of "noxious substances" to minimize any damage to the marine environment.

1. What degree of containment is required, that is, the structure of vessels carrying the products in bulk or the containers for packaged shipments?

2. What degree of sophistication is required for cargo (product) handling and control?

3. What limit, if any, should be placed upon cargo (product) shipment size?

4. What limit, if any, needs to be placed upon the intentional discharge of substances in the process of tank washing?

5. What degree of operational control must be placed upon vessels carrying "potential noxious substances"?

The decisions to be made concerning the carriage of "noxious substances" will directly affect mankind in general by not only protecting the environment but changing the cost or even the availability of certain products basic to his society. IMCO must make these decisions and solicits the assistance of GESAMP in reaching these decisions.

Therefore, IMCO requests GESAMP to review the attached list of products and consider their hazard to the environment if released accidentally or deliberately into the water.

Specifically GESAMP is requested:

(1) to evaluate substances under at least four degrees of hazard, according to each of the following effects when released into the sea:

(a) damage to living resources;

(b) hazards to human health;

(c) reduction of amenities;

(d) interference with other uses of the sea;

in doing so, take into account the release in the following four forms:

(i) through normal operation of ships other than the disposal of shore-generated waste;

(ii) through marine casualties to ships carrying cargoes in bulk;

(iii) through marine casualties to ships carrying cargoes in packages;

(iv) through accidental spillage (e.g. overflow).

(2) to indicate how their hazard ratings apply to areas such as rivers, estuaries, inshore waters, enclosed seas, and deep ocean, under the different climatic conditions,

(3) to specify as far as possible criteria and critical parameters used in determining hazard ratings of the substances.

IMCO is prepared to provide such information as it has and to assist GESAMP as much as possible in this extremely necessary and important task. The time constraints dictate an urgent response from GESAMP. It would therefore be desirable to receive their reply if possible by 31 May 1972.

ANNEX II

AGENDA FOR THE FIRST SESSION

OPENING OF THE MEETING

1. Election of Chairman
2. Adoption of the agenda
3. Establishment of criteria and critical parameters as a basis for the evaluation of hazards
4. Evaluation of substances, in at least four degrees of hazard according to their effects
5. Consideration of how to apply hazard ratings to different areas under different climatic conditions
6. Other matters
7. Report to GESAMP

AGENDA FOR THE SECOND SESSION

OPENING OF THE MEETING

1. Adoption of the agenda
2. Report on related technical activities of IMCO
3. Selection of substances and evaluation of their hazards in expansion of the Table annexed to the Preliminary Report to GESAMP (NHS/10, Annex IV)
4. Report to GESAMP

AGENDA FOR THE THIRD SESSION

OPENING OF THE MEETING

1. Adoption of the Agenda

2. Reports on related technical activities of IMCO

3. Outcome of the Fourth session of GESAMP and action arising therefrom, including review of the hazard ratings of substances placed in brackets.

4. 1. Selection of substances and evaluation of their hazards in expansion of the Table annexed to the Report to GESAMP.

   2. Arrangement for future work.

5. Advice concerning the establishment of insignificant levels of concentration of Category I substances in mixture.

6. Establishment of Effluent Standards for Sewage from Ships*

7. Consideration of the Report.

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* This item was dealt with in a different context and was reported separately to the Sub-Committee on Marine Pollution.

ANNEX III

LIST OF EXPERTS

Dr. H.A. Cole (Chairman)
Ministry of Agriculture, Fisheries and Food
Fisheries Laboratory,
Lowestoft,
Suffolk.

Dr. G.J. Van Esch,
Head, Laboratory of Toxicology
National Institute of Public Health
Bilthoven,
Netherlands.

Dr. Roy W. Hann, Jr.
Head, Environmental Engineering Division,
Civil Engineering Department,
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Ministry of Agriculture, Fisheries and Food
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Dr. M. Sharratt
Senior Medical Officer (Toxicology)
Department of Health and Social Security
Alexander Fleming House
Elephant and Castle
London, S.E.11

Dr. C. Hugh Thompson
Chief of Hazardous Materials Branch
Division of Oil and Hazardous Materials
Office of Water Programs
United States Environmental Protection Agency
Room 512, Bldg. 2,
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Arlington, Va., U.S.A.

Dr. M. Waldichuk
Programme Head
Fisheries Research Board of Canada
Pacific Environment Institute
4160 Marine Drive
West Vancouver B.C., Canada

ANNEX IV

HAZARD PROFILE OF SELECTED SUBSTANCES

Substances	Bioaccumulation	Damage to living resources	Hazard to human health: Oral intake	Hazard to human health: Skin contact and inhalation (solution)	Reduction of amenities	Remarks
	A	B	C	D	E	
Acetaldehyde	0	2	1	0	x	
Acetic acid	-	2	0	0	0	
Acetic anhydride	0	2	0	0	0	
Acetone	0	1	0	0	0	
Acetone cyanohydrin	0	4	3	II	xx	
Acetonitrile (Methyl cyanide)	0	0	1	0	0	
Acetyl Chloride	,	2	1	0	0	
Acrolein	T	4	3	I	xxx	
Acrylic acid	0	(2)	1	I	xx	
Acrylic latex	0	?	0	0	xx	? in Column B due to possible presence of unknown inhibitors.
Acrylonitrile	0	3	3	II	xxx	
Adiponitrile	0	1	3	I	x	
Aldrin	+	4	2	I	xxx	
Alkyl benzene sulfonate						
(straight chain)	0	2	1	0	0	
(branched chain)	0	3	1	0	0	
Allyl alcohol	0	3	2	0	xx	
Allyl chloride	0	2	2	0	xx	
Allyl isothiocyanate	0	(2)	2	II	xx	
Alum (15% solution)	0	1	0	0	0	
Alumina	0	D	0	0	0	
Aluminium phosphide	0	(3)	4	II	0	

Substances	A	B	C	D	E	Remarks
Aminoethylethanolamine (Hydroxyethylethylene-diamine)	0	(1)	1	0	0	
Ammonia (28% aqueous)	0	3	1	I	0	
Ammonium arsenate	+	3	?	?	0	
Ammonium nitrate	0	1/BOD	1	0	0	Fertilizer
Ammonium phosphate(s)	0	1/BOD	0	0	0	Fertilizer
iso-Amyl acetate	0	2	0	0	x	
n-Amyl acetate	0	2	0	0	x	
n-Amyl alcohol	0	1/BOD	1	0	0	
tert-Amyl alcohol	0	0/BOD	1	0	0	
Amyl mercaptan	T	2	2	0	xxx	
Aniline	0	2	2	II	xx	
Aniline hydrochloride	0	2	2	II	0	
Anthracite	0	D	0	0	0	
Antimony compounds	+	2	1-3	0	x	
Antimony lactate	+	2	2	0	0	
Antimony potassium tartrate	+	2	2	0	0	
Apatite	0	D	0	0	0	Slow nutrient action
meta-Arsenic acid	+	(3)	3	0	0	Solid
ortho-Arsenic acid	+	(3)	3	0	0	Liquid
Arsenical flue dust	+	3	2	0	0	
Arsenic bromide	+	3	4	I	0	
Arsenic pentoxide	+	(3)	3	0	0	
Arsenic trichloride	+	3	4	I	0	
Arsenic trioxide	+	3	2	0	xxx	
Atrazine	0	3	1	0	xxx	
Azinphos methyl (Guthion)	+	4	3	II	xxx	
Ball clay	0	D	0	0	0	
Barium azide	+	2	2	0	xx	
Barium cyanide	+	4	3	I	0	

Substances	A	B	C	D	E	Remarks
Barium oxide	+	2	1	0	0	
Barley	0	0/BOD	0	0	x	
Bauxite	0	D	0	0	0	
Benzene	0	2	1	0	x	
Benzidine	0	(3)	2	II	xxx	
Benzyl alcohol	0	1/BOD	1	0	0	
Benzyl chloride	(0)	3	(2)	I	xx	
Beryllium chloride	(+)	2	2	0	0	
Beryllium powder	(+)	2	2	0	xxx	
Borax	0	1	2	0	0	
Bordeaux arsenites	+	2	3	0	xx	
Bran pellets	0	0/BOD	0	0	0	
Brazil nuts	0	0	0	0	0	
Bricks	0	0	0	0	0	
Bromine	0	3	2	II	xx	
Bromoacetone	(Z)	2	(2)	I	xx	
Bromobenzyl cyanide	(Z)	2	(3)	II	xx	
Brucine	(Z)	(3)	3	I	0	
Butadiene-1,3(inhibited)	----Not applicable----					Gas
n-Butane	----Not applicable----					Gas
n-Butyl acetate	0	1	0	0	0	
sec-Butyl acetate	0	1	0	0	x	
iso-Butyl acrylate	0	1	1	0	x	
n-Butyl acrylate	0	0	1	0	xx	
iso-Butyl alcohol	0	1	1	0	x	
n-Butyl alcohol	0	0/BOD	1	0	0	
Butyl butyrate	(T)	1	0	0	x	
Butylene glycol(s)	0	1/BOD	0	0	0	
Butyl methacrylate	0	1	0	0	x	
iso-Butyl methacrylate	0	1	0	0	x	

Substances	A	B	C	D	E	Remarks
n-Butyraldehyde	0	3	0	0	x	
iso-Butyraldehyde	0	2	1	I	x	
Butyric acid	T	1	0	0	x	
Butyrolactone	0	0	1	I	x	
Cacodylic acid	+	3	2	0	xx	
Cadmium chloride	+	4	2	0	0	
Calcium arsenate	+	2	3	0	xx	
Calcium arsenate and arsenite (solid mixtures)	+	2	3	0	xx	
Calcium chloride (solution)	0	0	0	0	0	
Calcium cyanide	----See Hydrogen cyanide----					
Calcium hydroxide (solution)	0	1	0	0	0	
Calcium hypochlorite (bleaching powder)	0	3	1	I	x	
Calcium phosphate	0	D	0	0	0	
Camphor oil	T	0	2	0	xx	
Carbaryl (Sevin)	+	4	1	0	xx	
Carbon, anode pellets	0	D	0	0	0	D assumes small particles
Carbon disulphide	+	4	2	I	xx	
Carbon tetrachloride	Z	2	1	0	xx	
Castor oil	0	0/BOD	0	0	x	
Caustic potash	0	2	1	I	0	
Caustic soda	----See Sodium hydroxide----					
Cement	0	D	0	0	0	
China clay	0	D	0	0	x	
Chloral	0	(3)	2	0	0	
Chlorine	0	4	NA	II	xx	Gas
Chloroacetic acid	0	2	2	0	0	
Chloroacetone	(Z)	2	3	II	xxx	

Substances	A	B	C	D	E	Remarks
Chloroacetophenone	?	?	2	I	xxx	
m-,o-Chloroanilines (liquid)	(Z)	(2)	(2)	I	xx	
p-Chloroanilines(solid)	(Z)	(2)	(2)	I	xx	
Chlorobenzene	Z	3	1	0	x	
Chlorodinitrobenzene	(Z)	3	3	II	xxx	
Chloroethane (Ethyl chloride)	Z	(1)	NA	0	0	Gas
Chloroform	Z	2	1	0	xx	
Chlorohydrins (crude)	0	(1)	2	II	xx	
Chloronitrobenzenes	(Z)	(2)	2	I	xx	
Chlorophenates, Chlorophenols (solid)	---See Sodium pentachlorophenate---					
Chlorophenates, Chlorophenols (liquid)	---See Sodium pentachlorophenate---					
Chloropicrin	(Z)	(3)	3	II	xxx	
Chloropicrin, mixtures	----See Chloropicrin----					
Chloropicrin and methyl bromide, mixtures	----See Chloropicrin----					
Chloropicrin and methyl chloride, mixtures	----See Chloropicrin----					
Chloroprene	0	(2)	1	I	x	
Chlorosulphonic acid	0	2	1	I	0	
p-Chlorotoluene	Z	(3)	1	I	x	
Chrome concentrates	0	D	0	0	0	
Chrome ore	0	D	0	0	0	
Chromic acid (Chromium trioxide)	0	3	1	0	0	
Citric acid (10%-25%)	0	1/BOD	0	0	0	
Clay	0	D	0	0	0	
Coal (dust)	0	D	0	0	x	
Coal (large)	0	0	0	0	0	

Substances	A	B	C	D	E	Remarks
Cocculus (solid)	0	4	4	0	xx	It is assumed that picrotoxin is in extractable form
Coconuts	0	0	0	0	0	
Coconut oil	0	0/BOD	0	0	x	
Codfish, fresh salted	0	0	0	0	x	
Cod liver oil	0	0/BOD	0	0	x	
Coke	0	0	0	0	0	
Coke breeze	0	D	0	0	x	
Colemanite	0	1	2	0	0	
Copper acetoarsenite	+	2	3	0	xx	
Copper arsenite	+	3	3	0	xx	
Copper concentrates (sulphides)	+	2	1	0	0	
Copper cyanide	+	3	3	I	xx	
Copper ore	--See Copper concentrates (sulphides)--					
Copra	0	0/BOD	0	0	x	
Cotton seed cake	0	0/BOD	0	0	x	
Creosote	----See Cresols----					
Cresols	T	3	2	I	xx	
Cresylic acid	----See Cresols----					
Crotonaldehyde	0	3	2	I	xx	
Cumene	0	2	1	0	x	
Cupriethylene diamine	+	(3)	(2)	I	x	
Cyanides	---See Potassium cyanide---					ill-defined
Cyanides (solutions)	---See Potassium cyanide---					ill-defined
Cyanogen bromide	0	4	3	II	xx	
Cyanogen chloride	0	4	3	II	xx	
Cyclo-hexane	0	2	0	0	0	
Cyclohexanol	0	1	1	0	0	
Cyclohexanone	0	1	1	0	0	

Substances	A	B	C	D	E	Remarks
Cyclohexylamine	0	(1)	2	0	0	
p-Cymene (iso-Propyltoluene)	0	(1)	1	0	x	
D.D.T	+	4	2	0	xxx	
Decahydronaphthalene (Decalin)	0	(1)	0	0	x	
Decane	0	(1)	(1)	0	0	
iso-Decyl alcohol	0	0	0	0	0	
n-Decyl alcohol	0	0	0	0	0	
Decyl octyl alcohol	0	0	(1)	0	0	
Diacetone alcohol	0	(1)	1	0	0	
Diammonium phosphate	0	1/BOD	0	0	0	fertilizer
Dibenzyl ether	0	(2)	(2)	0	x	
Dibutyl ether	0	(0)	0	0	0	
Dichloroanilines	(Z)	4	2	I	xx	
o-Dichlorobenzene	Z	4	1	0	x	
Dichlorobenzenes	Z	4	1	0	x	
Dichlorodifluoromethane	---Not applicable---					insoluble gas
Dichloroethyl ether	Z	2	2	I	x	
Dichloropropene - Dichloropropane mixture (D.D. Soil fumigant)	Z	2	1	0	xx	
Diethanolamine	0	0	1	0	0	
Diethylamine	0	2	2	I	x	
Diethylbenzene (mixed isomers)	0	2	1	0	0	
Diethylene triamine	0	(2)	1	I	x	
Diethyl ether	0	1	1	0	0	
Diethylene glycol	0	0/BOD	0	0	0	
Diethylene glycol monoethyl ether	0	2	0	0	0	
Diethylketone (3-Pentanone)	0	1	1	0	0	

Substances	A	B	C	D	E	Remarks
Diethyl sulphate	0	(2)	1	I	0	
Di-iso-butylene	0	(1)	1	0	0	
Di-iso-butyl ketone	0	1	0	0	0	
Di-iso-propanolamine	0	2	1	0	x	
Di-iso-propylamine	0	2	1	0	x	
Di-iso-propyl ether	0	(1)	0	0	0	
Dimethoate (Cygon)	0	4	2	I	xxx	
Dimethylamine (40% aqueous)	0	2	1	I	0	
Dimethyl formamide (Form-dimethylamide)	0	1	0	0	0	
Dimethyl ethanolamine (2 Dimethylaminoethanol)	0	(2)	(1)	0	0	
Dimethyl sulphate	0	(2)	2	I	0	
Dinitroanilines	0	2	2	II	xx	
4,6-Dinitroorthocresol	T	4	3	I	xxx	
Dinitrophenol(s)	T	3	3	I	xxx	
Dinitrotoluenes	0	2	1	0	x	
1,4-Dioxane	0	(2)	0	0	0	
Dipentene	0	(0)	0	0	x	
Diphenylamine-chloroarsine	+	(4)	4	II	xxx	
Diphenylchloroarsine	+	(4)	4	II	xxx	
Diphenyl/Diphenyloxide mixtures	0	(1)	0	0	x	
Dipropylene glycol	0	0/BOD	0	0	0	
Diuron (Karmex)	0	3	1	0	xx	
Dodecylbenzene	0	2	0	0	0	
Emery stone	0	D	0	0	0	
Endosulphan (Thiodan)	+	4	2	0	xx	
Endrin	+	4	3	I	xxx	
Epichlorohydrin	0	3	2	I	xx	

Substances	A	B	C	D	E	Remarks
2-Ethoxyethyl acetate	0	(1)	0	0	0	
Ethyl acetate	0	1/BOD	0	0	0	
Ethyl acrylate	0	1	1	0	x	
Ethyl alcohol	0	0/BOD	0	0	0	
Ethyl amyl ketone	0	(2)	1	0	x	
Ethylbenzene	0	2	0	0	x	
Ethyl bromoacetate	0	1	3	I	xxx	
Ethyl cyclohexane	0	1	1	0	0	
Ethyl dichloroarsine	+	4	(4)	I	xxx	
Ethylene	0	0	NA	NA	NA	Gas
Ethylene chlorohydrin (2-Chloro-ethanol)	0	(1)	2	II	xx	
Ethylene cyanohydrin	0	(1)	0	0	0	
Ethylene diamine	0	2	1	I	x	
Ethylene dibromide	Z	2	2	I	xx	
Ethylene dichloride	Z	2	1	0	x	
Ethylene glycol	0	0/BOD	0	0	0	
2-Ethylhexyl acrylate	0	(1)	0	0	x	
2-Ethylhexyl alcohol	0	2	0	0	x	
Ethyl lactate	0	(1)/ BOD	(1)	0	0	
Ethyl parathion	0	4	4	II	xxx	
2-Ethyl 3-propyl acrolein	(T)	(1)	1	0	x	
Fatty alcohols(C_{12}-C_{20})	0	0/BOD	0	0	x	
Fentin acetate (dry)	0	2	2	0	xxx	
Ferric arsenate	+	2	3	0	xx	
Ferric arsenite	+	3	4	0	xx	
Ferric chloride	0	2	1	0	x	
Ferrous arsenate	+	2	3	0	xx	
Fertilizer NPK	0	0	1	0	0	Fertilizer

Substances	A	B	C	D	E	Remarks
Fishmeal	0	0/BOD	0	0	xx	
Fluorspar	0	D	0	0	0	D assumes powder
Fluosilicic acid	0	(2)	2	II	0	
Formaldehyde (37-50% solution)	0	2	2	I	0	
Formic acid	0	1	1	I	0	
Furfural	0	2	2	0	x	
Furfuryl alcohol	0	2	2	0	0	
Glycerine	0	0/BOD	0	0	0	
Ground nuts (shelled)	0	0	0	0	0	
Guano	0	0/BOD	1	0	x	Fertilizer
Gypsum	0	0	0	0	0	
Gypsum fines	0	D	0	0	0	
Haematite	0	0	0	0	x	
Heptachlor	+	4	2	0	xxx	
n-Heptane	0	0	0	0	0	
Heptanoic acid	0	(1)	1	0	0	
Heptene (mixed isomers)	0	0	0	0	0	
Hexaethyl tetraphosphate	0	4	4	II	xxx	
Hexaethyl tetraphosphate and compressed gas mixture	0	4	4	II	xxx	
Hexamethylene diamine	0	(2)	1	I	x	
n-Hexane	0	0	0	0	0	
Hydrazine	0	3	2	1	0	
Hydrochloric acid	0	1	1	0	0	
Hydrocyanic acid	0	4	3	II	0	
Hydrofluoric acid (40% aqueous)	0	3	2	II	0	
Hydrogen cyanide	0	4	3	II	0	
Hydrogen peroxide (greater than 60%)	0	2	0	0	0	

Substances	A	B	C	D	E	Remarks
Ilmenite	0	0	0	0	0	
Iron concentrates	--- See Haemetite ---					
Iron ore	--- See Haemetite ---					
Iron pyrites	0	0	0	0	0	
Isopentane	0	1	0	0	0	
Isophorone	0	1	1	I	x	
Isoprene	0	1	0	0	0	
Isopropyl acetate	0	0	1	0	0	
Isopropyl alcohol	0	0/BOD	0	0	0	
Isopropylamine	0	2	1	I	x	
Kieserite	0	1	1	0	0	
Kyanite	0	0	0	0	0	
Lactic acid	0	1/BOD	1	0	0	
Latex (may contain inhibitors)	0	?	0	0	xx	? in Column B due to the possible presence of unknown inhibitors
Lead arsenates	+	3	2	0	xx	
Lead arsenites	+	3	3	0	xx	
Lead concentrates (sulphides)	0	0	0	0	0	
Lead cyanide	+	3	3	I	xx	
Lead ore	----See Lead Concentrates(sulphides)----					
Ligroin	0	0	1	0	0	
Lime soda	0	?	1	I	0	
Limestone	0	0	0	0	0	
Lindane (gammexane, BHC)	+	4	2	0	xx	
Liquid sulphur	0	0	0	0	0	
London purple	+	3	2	0	xxx	
Magnesia	0	0	0	0	0	
Magnesite	0	0	0	0	0	
Magnesium arsenate	+	?	3	0	xx	
Maize (not seed grain)	0	0/BOD	0	0	x	

Substances	A	B	C	D	E	Remarks
Malathion	0	4	1	0	xx	
Maneb	0	3	1	0	xx	
Manganese concentrates	0	D	0	0	0	
Manganese ore	0	D	0	0	0	
MCPA	0	2	1	0	xx	
Mercuric acetate	+	4	3	0	0	
Mercuric arsenate	+	4	3	0	xx	
Mercuric chloride	+	4	3	0	0	
Mercuric cyanide	+	4	3	I	0	
Mercuric nitrate	+	4	3	0	0	
Mercuric potassium cyanide	+	4	3	I	0	
Mercuric sulphate	+	4	3	0	0	
Mercurous nitrate	+	4	3	0	0	
Mercurous sulphate	+	4	3	0	xx	
Mercury alkyl	+	4	4	II	xxx	
Mercury ammonium chloride	+	4	3	0	0	
Mercury benzoate	+	4	3	0	0	
Mercury bisulphate	+	4	3	0	xx	
Mercury bromides	+	4	3	0	0	
Mercury compounds, inorganic	+	4	3	0	xx	ill defined
Mercury compounds, organic	---See Mercury Alkyl---					ill defined
Mercury gluconate	+	4	3	0	0	
Mercury iodide	+	3	3	0	xx	
Mercury oxycyanide	+	4	3	I	0	
Mercury potassium iodide	+	4	3	0	0	
Mesityl oxide	0	(2)	1	0	0	
Methyl acetate	0	1/BOD	1	0	0	
Methyl acrylate	0	1	2	I	xx	

Substances	A	B	C	D	E	Remarks
Methyl alcohol	0	0/BOD	0	0	0	
Methylamyl acetate	0	0	0	0	0	
Methylamyl alcohol	0	1	1	0	0	
Methyl bromide and Ethylene dibromide (liquid mixtures)		---See	Ethylene	dibromide---		Methyl bromide=gas
Methyl chloride	0	0	0	0	0	gas
Methyl cyanide		---See	Acetonitrile---			
Methylene chloride	Z	1	1	0	0	
Methyl ethyl ketone (2-butanone)	0	0	1	0	0	
2-Methyl-5-Ethylpyridine	(T)	1	1	0	xx	
Methyl iso-butyl ketone	0	0	1	0	0	
Methyl methacrylate	0	1	1	0	x	
2-Methylpentene	0	(1)	(1)	0	0	
alpha-Methylstyrene	0	(1)	1	0	x	
Molasses	0	0/BOD	0	0	x	
Monoethanolamine	0	1	1	0	0	
Monoethylene glycol-monoethyl ether (Methyl cellosolve)	0	1	0	0	0	
Monoisopropanolamine	0	2	1	0	x	
Monomethyl ethanolamine	0	2	1	0	x	
Mononitrobenzene	0	2	1	I	xx	
Mono-iso-propylamine	0	2	1	I	x	
Monopropylene glycol	0	0/BOD	0	0	0	
Morpholine	0	(1)	1	I	0	
Naphthalene (molten)	T	3	1	0	x	
Naphthenic acids	(T)	3	1	0	x	
Alpha,- Beta - Naphthylamines	0	3	1	0	xx	
Naphthylthiourea	0	(3)	4	I	xx	

Substances	A	B	C	D	E	Remarks
Nickel concentrates (sulphides)	0	0	0	0	0	
Nickel ore	0	0	0	0	0	
Nitric acid (90%)	0	2	1	II	0	
2-Nitropropane	0	1	2	I	x	
o-Nitrotoluene	0	2	1	0	x	
Nonyl alcohol	0	(2)	1	0	0	
Nonyl Phenol	0	2	1	I	x	
iso-Octane	0	(1)	(1)	0	0	
iso-Octanol	0	2	0	0	x	
n-Octanol	0	2	(1)	0	x	
Oleum	0	2	1	II	0	
Olive Oil	0	0/BOD	0	0	x	
Oxalic acid (10-25%)	0	1	1	0	0	
Parathion	0	4	4	II	xxx	
Paraquat	0	3	2	I	xxx	
Pentachloroethane	Z	(3)	2	0	x	
n-Pentane	0	2	0	0	0	
Perchloroethylene (Tetrachloroethylene)	Z	2	0	0	x	
Perlite	0	0	0	0	0	
Petalite	0	0	0	0	0	
Petroleum coke	0	0	0	0	0	
Phenol	T	2	2	I	xx	
Phosphorus (elemental)	+	4	4	II	xxx	
Phosphoric acid	0	1	0	I	0	
Phthalic anhydride (molten)	0	2	1	0	0	
Pig iron	0	0	0	0	0	
Pitch coke	0	0	0	0	0	
Polychlorinated biphenyl (dioxane less than 1ppm)	+	4	1	0	xx	

Substances	A	B	C	D	E	Remarks
Polypropylene glycol	0	0/BOD	0	0	0	
Potash (Potassium minerals)	0	0	0	0	0	
Potassium chlorate	0	1	2	0	0	
Potassium cyanide	0	4	3	I	0	
Potassium permanganate	0	3	1	0	xx	
Potatoes	0	0/BOD	0	0	x	
Propane	0	0	0	0	0	Gas
beta-Propiolactone	(T)	2	2	I	xx	
Propionaldehyde	0	1	1	0	x	
Propionic acid	0	1	1	0	0	
Propionic anhydride	0	1	1	0	0	
n-Propyl acetate	0	(2)	0	0	0	
n-Propyl alcohol	0	1/BOD	1	0	0	
n-Propylamine	0	2	1	I	x	
iso-Propyl cyclohexane	0	1	0	0	0	
Propylene glycol	0	0/BOD	0	0	0	
Propylene oxide	0	0/BOD	0	0	0	Treated as Propylene glycol
Propylene tetramer	0	0	1	0	0	
Propylene trimer	0	0	1	0	0	
Pumice	0	0	0	0	0	
Pyridine	T	1/BOD	1	0	xx	
Pyrite residue	+	3	0	0	0	
Quicklime	0	1	0	0	0	
Rutile	0	0	0	0	0	
Sand	0	0	0	0	0	
Saltpetre - (sodium nitrate)	0	0	0	0	0	Fertilizer
Shell sand	0	0	0	0	0	
Silicon tetrachloride	0	1	1	0	0	

Substances	A	B	C	D	E	Remarks
Simazine	0	3	0	0	xx	
Sodium arsenate	+	3	2	0	0	
Sodium biochromate (solution)	0	2	1	0	0	
Sodium carbonate	0	1	0	0	0	
Sodium chloride	0	0	0	0	0	
Sodium hydroxide	0	2	1	I	0	
Sodium pentachlorophenate (solution)	T	4	2	0	xx	
Sorbitol	0	0/BOD	0	0	0	
Soya bean meal	0	0/BOD	0	0	x	
Stannic chloride	0	2	1	0	0	
Stone	0	0	0	0	0	
Styrene monomer	0	2	1	0	xx	
Sugar (brown raw)	0	0/BOD	0	0	0	
Sulphur	0	0	0	0	x	
Sulphuric acid	0	2	1	I	0	
Superphosphates	0	0	0	0	0	
Talc rock	0	0	0	0	0	
Tallow	0	0/BOD	0	0	xx	
Tetra ethyl lead	Z	3	3	II	xxx	
Tetrahydrofuran	0	1	1	0	0	
Tetrahydro naphthalene	0	2	1	0	x	
Tetramethylbenzene	0	1	1	0	0	
Tetramethyl lead	Z	3	3	II	xxx	
Titanium slag	0	0	0	0	0	
Titanium tetrachloride	0	1	1	0	0	
Toluene	0	2	0	0	x	
Toluene diisocyanate	0	(3)	1	I	xxx	
Toxaphene	Z	4	2	I	xxx	
Trichloroethane	0	2	1	0	x	

Substances	A	B	C	D	E	Remarks
Trichlorethylene	Z	2	0	0	0	
Trichlorofluoromethane	----Not applicable----					Insoluble gas
Tridecanol	0	0	0	0	0	
Triethanolamine	0	1	0	0	0	
Triethylamine	0	2	1	I	x	
Triethylene glycol	0	0/BOD	0	0	0	
Triethylenetetramine	0	0	1	I	x	
Trimethylbenzene	0	(2)	1	0	0	
Tripropylene glycol	0	0/BOD	0	0	0	
Tritolyl phosphate (Tricresyl phosphate)	(0)	(3)	0	0	xxx	
Turpentine (wood)	T	2	1	0	x	
2-4 D	(T)	3	2	0	xx	
2, 4, 5-T	0	3	1	0	xxx	
Urea	0	0/BOD	0	0	0	Fertilizer
Vermiculite (natural)	0	0	0	0	0	
Vinyl acetate	0	2	1	0	x	
Vinylidene chloride	(Z)	(1)	0	0	x	(1) rating in Column B due to presence of unknown inhibitors
Warfarin	0	?	3	0	xx	
Wine	0	0/BOD	0	0	0	
Woodbark	0	0/D/BOD	0	0	x	
Wood pulp (bulk)	0	0/D/BOD	0	0	x	
p-Xylene	0	2	1	0	x	
Xylene (mixed isomers)	0	2	1	0	x	
Zinc concentrates (sulphides)	0	0	0	0	0	
Zinc ore (sulphides)	0	0	0	0	0	
Zircon	0	0	0	0	0	

LEGEND TO THE HAZARD PROFILES

Column A - Bioaccumulation

+	Bioaccumulated and liable to produce a hazard to aquatic life or human health
0	Not known to be significantly bioaccumulated
Z	Short retention of the order of one week or less
T	Liable to produce tainting of seafood

Column B - Damage to living resources

Ratings		TLm
4	Highly toxic	< 1 ppm
3	Moderately toxic	1-10 ppm
2	Slightly toxic	10-100 ppm
1	Practically non-toxic	100-1000 ppm
0	Non-hazardous	≥ 1000 ppm
BOD	Problem caused primarily by high oxygen demand	
D	Deposits liable to blanket the seafloor	

Column C - Hazard to human health, oral intake

Ratings		LD_{50}
4	Highly hazardous	< 5 mg/kg
3	Moderately hazardous	5-50 mg/kg
2	Slightly hazardous	50-500 mg/kg
1	Practically non-hazardous	500-5000 mg/kg
0	Non-hazardous	≥ 5000 mg/kg

Column D - Hazard to human health, skin contact and inhalation (solution)

II Hazardous (solution)

I Slightly hazardous (solution)

O Non-hazardous (solution)

Column E - Reduction of amenities

Ratings

xxx Highly objectionable because of persistency, smell or poisonous or irritant characteristics; beaches liable to be closed

xx Moderately objectionable because of the above characteristics, but short-term effects leading to temporary interference with use of beaches

x Slightly objectionable, no interference with use of beaches

O No problem

All Columns

Ratings in brackets, ( ), indicate insufficient data available to the Panel on specific substances, hence extrapolation was required.

ANNEX V

Examples of evaluation of potential discharges into selected aquatic systems*

EXAMPLE I

Discharge into Coastal Waters

Purpose: To evaluate the range of concentrations to be found of a material discharged in varying quantities into a typical coastal water.

Assumed material characteristics: the material discharged is assumed to be a water soluble substance which is discharged over a relatively short period of time (i.e. one hour) and which mixes vertically within the water column. The material is assumed not to settle out, volatilize, or degrade within the period of time necessary to disperse over a one square mile surface area.

Assumed system characteristics: the system chosen is a coastal water with a depth of 60 feet such as would be found approximately 40 miles offshore from two major chemical shipping ports.

Method of Analysis and Results: The following table A presents average concentration which would be found if a given discharge of the material was dispersed over areas 0.25 miles square (1/16 sq. mile); 0.5 miles square (¼ sq. mile), and 1.0 mile sq. (1.0 square mile).

---

* NOTE: The US units used in this study have the following equivalents:

1 ton (US) = 2000 lbs = 0·893 long tons = 0·907 metric tonnes

1 pound = 0·454 kilograms

1 gallon (US) = 0·833 Imperial gallons = 3·785 litres

1 statute mile = 1·6093 kilometres

1 sq. mile = 2·59 sq. kilometres

1 foot = 0·3048 metres

TABLE A

Concentration of Materials in Coastal Waters

Amount of Material Discharged	Weight of Material Discharged	Resulting Concentration in ppm		
		¼ mile sq.	½ mile sq.	1 mile sq.
1 pound	1 lb	0.00015	0.00004	-
10 pounds	10 lb	0.0015	0.0004	-
55 gal. drum	458 lb	0.068	0.016	0.004
110 gal. drum	916 lb	0.136	0.032	0.008
1 ton	2000 lb	0.3	0.075	0.019
10 tons	2×10^4 lb	3.0	0.75	0.19
100 tons	2×10^5 lb	30	7.5	1.9
1000 tons	2×10^6 lb	300	75	19
10000 tons	2×10^7 lb	3000	750	190
100000 tons	2×10^8 lb	30000	7500	1900

Weight of ¼ mile sq. x 60 ft. deep

$= (5280 \text{ ft}/4)^2 \times 60 \text{ ft} \times 64.2 \text{ lb/ft}^3 = 6700 \times 10^6$ lbs

Weight of ½ mile sq. x 60 ft. deep $= 26800 \times 10^6$ lbs

Weight of 1 mile sq. x 60 ft. deep $= 107200 \times 10^6$ lbs

$$\text{Concentration (ppm)} = \frac{\text{Weight of Material in lbs}}{\text{Weight of Water in million lbs}}$$

EXAMPLE 2

Discharge into an Estuary

Purpose: To evaluate the range of concentrations to be found under short- and long-term conditions of a material discharged in varying quantities into an estuary.

Assumed material characteristics: the material discharged is assumed to be a water soluble substance which is discharged within a single tidal cycle and which mixes uniformly throughout the estuary cross section. The material is assumed to not settle out, volatilize or degrade within the tidal cycle period.

Assumed system characteristics: the estuary chosen as the example system is an estuary with an average width of 500 ft., a depth of 40 feet, and length of 15 miles. The estuary is assumed to have an average tidal range of one foot and a flushing time of 40 days. The example analysis point is assumed to lie at the approximate centres of shipping 7.5 miles from the upper end of the estuary.

Method of Analysis and evaluation of Results: Two analyses were made and are displayed in Table B. The first is the average concentration which would be expected in the tidal excursion of water passing a discharge point within the tidal cycle. It could either be assumed that the material diffused into this volume or that the discharge occurred during the entire upstream or downstream movement of the water.

The second analysis solves for the average concentration under the assumption that the material from the single discharge remains in the system until it mixes throughout the estuary volume.

Several additional rough assumptions may be made using the above values and the characteristics of this as related systems.

If a uniform discharge were to occur each day of a non-degradable substance as a result of cleaning or loading operations from a single discharge, the cumulative average concentration would be 40 times (i.e. flushing time) the given values for the average concentration throughout the estuary.

If the material discharged daily were to decay at a rate of 0.1 (10%) per day, the resultant concentration would average

$$\frac{\text{(table concentration in ppm)}}{\text{decay rate (i.e. 0.1).}} = \text{approximately 10 times the table concentration}$$

If the decay were as a result of aerobic biological degradation the oxygen demand in this type of system wold be approximately equal to the total ultimate oxygen demand of each day's discharge.

A tidal range of four feet would increase the tidal prism by a factor of 4 and decrease the concentrations for the short time concentration by a factor of 4 (or more if increased dispersion occurred).

In an estuary additional factors not considered in this example may become very important.

The concentration of materials which are lighter than water, or which are discharged into the upper layers of stratified systems, may have concentrations higher than those shown. Similarly heavy materials, or those discharged into the bottom of stratified systems, would tend to have lower initial surface concentrations but may be carried upstream by the saline water wedge for later release into surface layers.

TABLE B

Concentration of Material in Assumed Estuaries

Amount of Material Discharged	Weight of Material Discharged	Resulting Concentration in ppm	
		In tidal excursion	In total Estuary
1 pound	1 lb	0.0008	0.00001
10 pounds	10 lb	0.0080	0.0001
55 gallon drum	458 lb	0.38	0.0046
110 gallon drum	916 lb	0.76	0.0092
1 ton	2000 lb	1.6	0.02
10 tons	2×10^4 lb	16	0.2
100 tons	2×10^5 lb	160	2.0
1000 tons	2×10^6 lb	1600	20
10000 tons	2×10^7 lb	16000	200
100000 tons	2×10^8 lb	160000	2000

$$\text{Length of tidal Excursion} = \frac{\text{Tidal Volume above the point of analysis}}{\text{Cross Section Area}}$$

$$= \frac{500 \text{ ft.} \times 1 \text{ ft.} \times 7.5 \text{ miles} \times 5280 \text{ ft/mile}}{500 \text{ ft.} \times 40 \text{ ft.}} = 980 \text{ ft.}$$

Weight of tidal Excursion water volume

$$= 980 \text{ ft.} \times 500 \text{ ft.} \times 40 \text{ ft.} \times 63.0 \text{ lb/ft}^3 = 1234 \times 10^6 \text{ lb.}$$

Weight of Estuary water volume =

$$= 15 \text{ miles} \times 5280 \text{ ft/mile} \times 500 \text{ ft} \times 40 \text{ ft} \times 63.0 \text{ lb/ft}^3$$

$$= 99800 \times 10^6 \text{ lb}$$

EXAMPLE 3

Discharge into a Freshwater River

Purpose: To evaluate the range of concentrations to be found of a material discharged in varying quantities into a freshwater stream which is used for transportation of hazardous materials.

Assumed material characteristics: the material discharged is assumed to be a water soluble substance which is discharged over a finite period of time (i.e. six hours) and which mixes uniformly throughout the river cross section. The material is assumed not to settle out, volatilize or materially degrade within the discharge period (i.e. 6 hours).

Assumed characteristics: a river with streamflows of 1000 and 5000 cubic feet per second (cfs). The lower flow is a typical summer flow found in several inland streams used for navigation and for the transportation of hazardous materials. The larger flow is a typical flow found in larger navigable rivers used for deep-draft ocean commerce.

The material release time of six hours stated above is chosen to provide for a reasonable time of release of larger cargoes and to provide for reasonable longitudinal mixing.

If the three hour mixing zone were used the concentrations would be twice the shown values. Similarly, if discharge were over a 12 hour period, the values would be one half of those given.

TABLE C

Concentration of materials in the Assumed River

Amount of Discharged	Weight of Material Discharged	Resulting Concentration in ppm	
		1000 cfs River	5000 cfs River
1 pound	1 lb	0.0075	0.0015
10 pounds	10 lb	0.075	0.015
55 gallon drum	458 lb	3.4	0.68
110 gallon drum	916 lb	6.8	1.36
1 ton	2000 lb	15.0	3.0
10 tons	2×10^4 lb	150	30
100 tons	2×10^5 lb	1500	300
1000 tons	2×10^6 lb	15000	3000
10000 tons	2×10^7 lb	150000	30000
100000 tons	2×10^8 lb	NA	300000

<u>Weight of Mixing Volume</u>:

at 1000 cfs : $1000 \frac{ft^3}{sec} \times 62.4 \frac{lb}{ft^3} \times 6\ hr \times 3600 \frac{sec}{hr}$

$= 135 \times 10^6\ lb$

5000 cfs : $5000 \frac{ft^3}{sec} \times 62.4 \frac{lb}{ft^3} \times 6\ hr \times 3600 \frac{sec}{hr}$

$= 675 \times 10^6\ lb$
