PREFACE

GESAMP, the Joint Group of Experts on the Scientific Aspects of Marine Pollution, was established in 1969 and is today co-sponsored by the International Maritime Organization (IMO), Food and Agriculture Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Meteorological Organization (WMO), World Health Organization (WHO), International Atomic Energy Agency (IAEA), United Nations and United Nations Environment Programme (UNEP). According to its present terms of reference, the functions of GESAMP are:

- to provide advice relating to the scientific aspects of marine pollution 1/; and

- to prepare periodic reviews of the state of the Marine environment as regards marine pollution and to identify problem areas requiring special attention.

Since its beginning GESAMP involved a large number of experts as members of GESAMP or GESAMP Working Group and produced, at the request of the sponsoring organizations, numerous reports 2/.

This document is the edited and approved original English version of the report of the GESAMP Working Group on the Principles for Developing Coastal Water Quality Criteria which met from 25-29 November 1974 at FAO Headquarters, Rome, and from 20-25 October 1975 at the Inter-University Center for Postgraduate Studies in Dubrovnik, Yugoslavia with the following members participating: Mr. J.S. Alabaster, Dr. A.L. Downing, Mr. D.J. Hansen, Dr. C.S. Hegre, Dr. S. Keckes, Mrs. S. de Maeyer, Dr. R. Pavanello (assisting as WHO Technical Secretary of GESAMP), Dr. G. Tomczak, FAO (Technical Secretary), and Dr. M. Waldichuk (Chairman).

Contributions from the following outside reviewers were appreciated by the Group: Mr. T.W. Beak, Dr. V.J. Cabelli, Dr. J. Cairns, Jr., Dr. J.C. Davis, Mr. E.E. Geldreich, Dr. R.H. Hann, Dr. E.M. Hassan, Dr. C.D. Levings, Dr. D.M. McLean, Dr. J.C. MacLeod, Dr. B. Moore, Dr. V. Pravdic, Mr. A. Preston, Mr. S.W. Reeder, Prof. P. Strohal, Prof. R.O. Sylvester, Dr. C.H. Thompson, Dr. J.F. Uthe, Dr. A. Walton, and Dr. V. Zitko.

The Working Group was charged with identifying gaps in present knowledge and with evaluating the nature and extent of problem areas in order to establish an order of priority of coastal water quality characteristics which should be considered for the formulation of coastal water quality criteria.

The activities of the Working Group were organized by FAO, acting as the "lead agency", with financial support from UNEP.

1/ GESAMP defined marine pollution as "introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea-water, and reduction of amenities."

2/ V. Pravdic: GESAMP, The First Dozen Years. UNEP, 1981.

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ABSTRACT

Coastal water quality criteria were considered for the protection of human health and amenities, ecosystems and living resources. For all uses, criteria must be based on cause-effect relationships. Twenty-one principles were developed, of which five pertain to goals, ten to methodology and six to implementation.

Development of criteria for the protection of ecosystems is difficult because of the physical scale involved, costs and complexity of measurements required and our relative inexperience in this field. Protection of human health in consumption of sea food is often achieved through regulations of the quality of these products; but such regulations should not influence the role of criteria for the the quality of the water where fish and shellfish are grown. Criteria for bathing waters should ideally be based upon well-founded dose-response relationships, which are unavailable at present. In attempting to meet this situation, WHO has recommended guidelines for acceptable bathing water quality. Protection of health and amenities should also be considered in terms of exposure-response relationships. At present, difficulties arise in obtaining these relationships because of lack of means for quantitative assessment of aesthetic enjoyment. Ideally, all factors individually and in combination affecting the survival and well-being of marine organisms in all stages of their life cycle should be considered in developing water quality criteria to protect them.

DDT was chosen as an example to illustrate the application of principles in developing water quality criteria because of the diverse adverse effects of DDT and its metabolites on various components of the ecosystem, e.g. acute and chronic toxicity to marine life, bioaccumulation and implication in reproductive failure through eggshell-thinning in fish-eating birds. An attempt to apply principles to develop criteria for the protection of amenities indicated that information on exposure-effect relationships is inadequate, and that at present, only the threshold value of perception can be utilized in practice.

It is recommended that if continuation of this study is considered desirable, specialized sub-groups be set up to formulate tentative coastal water quality criteria for particular water characteristics. On amenities specifically, priority should be given to the establishment of threshold levels of acceptability for turbidity, colour, slicks and odours contributed by various pollutants, taking into account the self-purification capability of the marine environment.

1. INTRODUCTION

At the Fifth Session of GESAMP (IAEA, Vienna, 18-23 June 1973) an ad hoc working group was formed to examine the problem of developing coastal water quality criteria. Two of the sponsoring agencies of GESAMP had special interest in such criteria as they relate to water pollution control: FAO, for protection of marine living resources; and WHO, for protection of human health. Moreover, IMCO was interested in water quality criteria in preparation for the International Convention for the Prevention of Pollution from Ships (IMCO, 1973) and has continued its interest through recent deliberations of its Marine Environmental Protection Committee.

The ad hoc working group at the Fifth Session of GESAMP agreed that coastal water quality criteria are desirable and that these should be examined jointly for the protection of human health and living resources. The Fifth Session of GESAMP concluded that principles should be established for the development of coastal water quality criteria, and prepared terms of reference for a working group, which was expected to work intersessionally to complete this task. Accordingly, the "Working Group on Principles for Developing Coastal Water Quality Criteria" was formed at the Sixth Session of GESAMP (Geneva, 22-28 March 1974).

Responding to a recommendation of the report of the Fifth Session of GESAMP (para. 20), the Group defined "criteria" as the required scientific information on which a decision or judgement may be based concerning the suitability of the environment to support a desired use, recognizing that the health of man is paramount and that the latter can be affected either directly or indirectly. The Group wished to emphasize the distinction that should be drawn between, on the one hand, scientifically-derived criteria, and, on the other, water quality objectives, "norms" and also some control measures, including standards, which may or may not be derived from them.

The Group considered that criteria for the marine environment should include consideration of all aquatic compartments rather than water alone. It defined "coastal waters" arbitrarily as the coastal region containing waters having a salinity of more that 0.5 part per thousand and extending to the edge of the continental shelf or, in the case of the islands, comparable areas. Considering the request in the same paragraph, that the audience for whom the criteria are established be determined, the Group concluded that its report and recommendations, as well as any criteria that might be formulated therefrom, might be for the benefit of international and national groups of scientists and interested persons.

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

The Group considered that the "critical path" 1/ method outlined by Preston (1974) was consistent with the above, since it could be viewed as a series of

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1/ The "critical path" approach recognizes that there may be several routes by which pollutants may reach a target, and that identification of their relative importance is necessary in developing criteria.

interacting dose-response relationships, in some of which the dose would be amenable to expression as aqueous concentration for a given purpose, and in others as mass flow. For example, it would be possible to express criteria related to human health in terms of concentrations of material in an edible fish product, without excluding the possibility of also expressing them in terms of the concentration of the same material in the water or other media, given the necessary data relating the two. Also, it would be possible for criteria regarding a particular waste to be expressed in a number of ways, the choice being dependent on the target or use to be protected.

The Group reconsidered its terms of reference, namely:

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

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

(iii) to formulate tentative coastal water quality criteria.

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

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

(1) Ecosystems

(2) Human health

(a) fish and shellfish
(b) bathing waters
(c) aesthetics

(3) Living resources

(a) fisheries
(b) fishing activity
(c) aquaculture
(d) others, including birds and mammals

However, the Group recognized that other uses, such as production of sea salt and algae for domestic consumption, desalination, transportation and waste disposal are also important and might warrant attention in the future.

2. SUMMARY OF PRINCIPLES

The following preliminary list of recommended principles for the development and application of water quality criteria should not be used or taken out of context without a careful study of the document as a whole. The succeeding sections from which these recommendations arise provide definitions and valuable insight in applying them to unforeseen circumstances. Furthermore, sections on specific uses contain guidelines as to the meaning and value of environmental data relative to those uses, and suggest forms of expression of criteria in relation to a specific use. A procedure which might be used in establishing criteria has been given in some detail in section 7. Unless otherwise stated, the principles apply to all uses.

2.1 Principles related to goals

(1) Environmental criteria are considered as the required scientific information on which a decision or judgement may be based concerning the suitability of the environment to support a desired use.

(2) The health and welfare of man is a paramount consideration and can be affected by changes in environmental quality either directly or indirectly and at either the individual or population level (p. 1, para. 3).

(3) It is recognized that the health and welfare of man will continue to be affected both beneficially and detrimentally by his own activities and that value judgements involved in setting standards (which are outside the scope of this report) must be made in determining the extent to which the various aspects of man's health and welfare relating to coastal waters are protected.

(4) Coastal ecosystems are recognized as having a bearing on the health and welfare of man by being of scientific interest and aesthetic value to him, as well as offering man the potential for rational exploitation of food and other resources.

(5) In some situations, the development of criteria and achieving the desired protection of the environment may be either unnecessary or impossible because they cannot be utilized. If this were accepted, there would be little point in seeking to establish cause-effect relationships in any detail. For example, in the preservation of endangered species and ecosystems in their existing condition for various uses, e.g. marine parks and preserves for scientific study, the requirement would be the virtual exclusion of man-made changes (p. 5, para. 5). Also, in the case of some substances for which the dose-response relationship cannot be reasonably quantified and which constitute a hazard, e.g. floating driftwood, plastics and containers, it is not feasible to devise criteria, but ideally the objective sought should be the virtual exclusion of the substances by all reasonable means (p. 13, para. 2).

2.2 Principles related to methodology

(6) In developing criteria to protect a particular water use, effort should be made to identify the critical factors on which this use depends. This implies

not merely establishing that there are real problems to solve but, that the principal causative agents involved, including those causing changes through natural degradation processes, as reflected in biochemical oxygen demands, have been identified.

(7) Studies of real field situations, whether or not change has been noted, are an essential element in establishing whether a problem really exists or not (p. 6, para. 3; p. 7, para. 3; p. 10, paras. 1 and 2; p. 10, para. 7; p. 11, para. 6; p. 12, para. 1).

(8) Field studies are also seen as an essential element in developing valid criteria. They are envisaged as including intensive investigations of specific incidents, e.g., an oil spill, as well as long-term surveillance programmes of both disturbed and undisturbed situations.

(9) In developing valid criteria, priority should be given to establishing the exposure-effect relationships for these fators (section 7). In each case, these should take full advantage of the critical path approach (p. 1, para. 6; p. 6, para. 4).

(10) As a general principle, it is important to establish the reliability and relevance of criteria in order that the desired protection of the water use can be accomplished with confidence at minimum cost. This is particularly applicable where it is necessary to rely heavily on responses observed under laboratory conditions (p. 11, para. 2).

(11) Where data are inadequate, it must be accepted that to some extent the use of arbitrary procedures has to be invoked in developing criteria (as well as for setting standards), for example, based upon the highest exposures found to cause no undesirable effect, in combination with an appropriate application factor and assumptions about the comparability of diverse data (pp 17-19).

(12) The most effective criteria will be those that take into account, to the greatest degree, differences in local circumstances, such as population susceptibility and environmental factors (p. 6, paras. 1 to 4; p. 10, paras. 3 and 4). This principle does not exclude the possibility that criteria may be applicable to large geographical areas and to a variety of specific uses, such as different fisheries involving related species.

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

(14) Criteria for the protection of a given use should be established independently of other uses, which may or may not be made of a coastal area of concern.

(15) The validity of criteria should be frequently reviewed in the light of new knowledge (p. 10, para. 5).

2.3 Principles related to implementation

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

(17) The precision and accuracy with which criteria are established and expressed should be related to the nature and extent of the problems to which they are to be applied.

(18) It should be recognized that where no exposure-effect relationship has been established for practical reasons, there may be justification for using as criteria devices, such as a threshold response, as in the case of aesthetics, of the recommended maximum (or minimum) permissible levels of water quality characteristics issued as guidelines by authoritative international agencies, as in the case of human health. This might apply, for example, where costs of control measures are small relative to those involved in establishing criteria. In such a case, it is assumed, in effect, that there has been general acceptance of the desirability of some control measure which could obviate the need for a criterion (p. 5, para. 5; p. 11, para. 5; p.13, para. 2; p. 16, para. 8).

(19) Ideally, scientifically-based criteria should not be influenced by factors such as the feasibility and cost of remedial action. For example, the availability of an effective inexpensive method for decontamination of oysters does not necessarily obviate the need for water quality criteria for aiding prevention of the original contamination. However, in developing coastal water quality criteria, priority should be given to those aspects which are not already adequately covered by effective product or waste treatment.

(20) With substances that in the judgement of qualified scientists may be excessively harmful in coastal waters, e.g. transuranic elements, all practical measures should be taken to avoid such a release, and the criterion of no recognized acceptable threshold level may be adopted.

(21) Where a given coastal water is subject to several desired uses, the standard adopted should be based on the criteria for the most demanding use.

3. ECOSYSTEMS

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

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

The status of an ecosystem can be described at any given time by a number of more or less informative techniques. Most descriptive, but least manageable, is a complete description of the numbers and distribution of each species and life stage present. Such voluminous data are not easily treated in a similar fashion to responses such as percentage mortality or percentage reduction in photosynthesis. A number of other techniques have been developed to reduce such data to indices of various dimensions, which can each be used as a single parameter for comparison of systems for evidence of stress. When differences are noted, it is still necessary to return to the original species data, in order to assess the significance of the change (such as altered dominance or species composition).

For two reasons, such ecosystem data from the field are difficult to use in establishing cause-effect relationships. First, there is often a long "lag" between onset of low-level stress and system response. Secondly, the degree of response to protracted low-level stress must exceed the sometimes extreme natural variability in order to appear significant. Thirdly, natural systems are most often subjected to multiple stresses simultaneously. Ecosystem characterization by indirect measures of function has become an increasingly important and sensitive technique. Here, measurements of nutrient flux, energy budget, carbon turnover rate, productivity/respiration ratio and the like, have proven to respond to altered environmental conditions more rapidly than the system as a whole. As a penalty, it is to be expected that such parameters are subject to greater and more frequent short-term variations than are the communities whose function they reflect.

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

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

Not all systems are equally robust. It may be argued that arctic systems are less resilient than others. Also tropical systems, while containing a great diversity of species, are particularly fragile with respect to thermal stress, since the majority of organisms already live near the upper limit of their thermal tolerance (Wood and Johannes, 1975). More generally, in systems with many species, the complexity of interactions provides some stability and is also responsible for the fact that alterations in one portion of the system can cause desirable or undesirable effects in seemingly unrelated portions of the system. For example, bioaccumulation of toxic substances may produce a hazard to consumers, including man.

3.1 Impact of ecological consideration on the development of principles

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

The essential differences involve varying time scales for exposure (constant, intermittent or cyclical stress), alterations of the pollutant before or during exposure, and the route of administration to the target organism (e.g. via water, suspended sediment or food particles, and detritus). Consideration of these differences has led to the formulation of basic procedural requirements for obtaining data on which well founded defensible criteria should be based. Observance of one or all of these requirements is essential to criteria development, dependent on the resource for which a specific criterion is to be set, and the importance of those characteristics in limiting its use. Not surprisingly, a generation of completely adequate information on which to base criteria requires, in almost all cases, satisfaction of all requirements listed in section 7.

Most of these requirements are also recognized by EIFAC (1964) and, taken as a whole, embody the principles underlying the formalized "critical path" technique referred to earlier. The Working Group gave some thought to classifying the various known stresses according to the applicability of the various requirements in the establishment of criteria for them in relation to a given use, but agreed that this approach would offer them little real help, for it is unlikely that consideration of various uses would result in similar groupings of requirements. Also, even within a reasonably inclusive group such as inorganics, extreme variations are known to occur in duration of biological effect as a result of recycling pathways, bioaccumulation and physical or chemical alteration. The same may be assumed for groups or chemicals not yet considered or even synthesized. Furthermore, the pattern of fluctuation in concentration with time within a class or for a single compound, is extremely variable between points of introduction where criteria may be of value. This is also true for major environmental variables such as dissolved oxygen, temperature, salinity and pH value. In general, the greater the temporal variation, the greater the obligation to test using a multi-factorial approach approximating the extreme limits of local variation of each factor, as well as the observed local rates of fluctuation. It should be borne in mind that the most common appearance of most contaminants is as a component of a mixture of which the total effect is of concern. Consideration of the components of the mixture is likely to indicate the complexity of procedures required for developing criteria.

3.2 Application of criteria for the protection of ecosystems

It has been assumed above that the observed ecosystems' response is the best measure of whether the degree of protection being offered is adequate. The difficulties noted here in measurement and significance of response are not novel and run directly parallel with the response of single organisms. Death of an organism/ecosystem is admittedly undesirable, but the significance of behavioural, hormonal and enzymatic alterations becomes progressively less clear. At what point does adaptation become a liability? The development of criteria to protect a specific ecosystem should be subject to the same approaches being applied to single species. That is, a dose-response relationship can be developed in which the response being described is a function (usually a desirable one in terms of human value).

Perhaps it can be seen from the foregoing that development of criteria for the protection of ecosystems is not essentially different from developing other criteria. It does differ in the physical scale, cost and difficulty of measurements which must be conducted, as well as in our relative inexperience in performing and interpreting them.

4. HUMAN HEALTH

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

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

The observed no-effect level is of course related to the choice of the indicator(s) of response and the sensitivity of the methods available or adopted for its measurement. The same can be said for the identification and measurement of the exposure. Unless evidence is available that such sub-clinical changes changes are simply adaptive, and do not prejudice survival, reproduction or or quality of life, they must be assumed to be detrimental. There are, however, well established principles, such as those enunciated by Bradford Hill (1965), which should be used for testing the significance of cause-effect relationships derived from epidemiological data.

4.1 Fish and shellfish

Factors other than water pollution may influence the microbiological and hygienic quality of fishery products. Catching, handling, processing, storage, marketing and the way the product is prepared may affect the transmission of disease by such products, and occasionally falsely indicate inferior water quality. These factors should not influence the role of criteria for quality of the water where fish and shellfish are grown.

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

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

Table 1 : Characteristics of principal bacterial and viral fish- and shellfish-borne diseases in man

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

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

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

Table 1 (cont'd) Characteristics of principal parasitic fish- and shellfish-borne diseases in man

The adequacy of the basis for criteria should be taken into account when contemplating control action, which could involve, for example, the closure of fishing grounds, requirements for the reduction of input of pollutants and the restriction of consumption of contaminated fishery products. Such actions can also be supported by sanitary surveys. Particular attention should be given to molluscan shellfish which may be vectors for viral hepatitis. Molluscs may also serve as one of the routes by which metals and other bioaccumulated materials reach predators, including man.

4.2 Bathing waters

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

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

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

Although there is no demonstrable correlation between faecal indicators and pathogens, except for Salmonella, several countries have introduced norms of bacteriological quality based upon the faecal coli index. After a long discussion about the linking of faecal indicators with the presence of pathogens and about the dose-response relationship for pathogens occurring in seawater, the Group wished to emphasize that criteria for bathing, like those for other uses such as fisheries, should ideally be based upon well founded dose-response relationships. Nevertheless, at the present state of knowledge and under certain circumstances, an indicator organism characteristic of the contamination by sewage of human or animal origin may be used to indicate a potential hazard to human health because of the possible presence of human pathogens, expecially antibiotic-resistant strains. To meet this situation, WHO has recommended guidelines for acceptable bathing water quality (WHO, 1975). It should be borne in mind, however, that any dose-response relationship would vary as the susceptibility of the population changes.

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

4.3 Aesthetics

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

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

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

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

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

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

Determining thresholds of sensibility presents a variety of difficulties. In certain instances, these could be obviated by taking into account the fact that assessment of detectability in a comprehensive scientific manner would be expensive, and that it might be possible, in cases where material which causes offence can be easily and cheaply eliminated, to make a pragmatic decision that no material of this kind should be released. However, it seems quite feasible to develop meaningful relationships between amounts of substances present and sensory perception of turbidity, due to suspended matter released in waste waters, or recognition of colour, foams, and slick. Some progress toward this end has already been reported (Newton, 1975; Selleck, 1975). Developing such criteria for turbidity, which results from the growth of organisms induced by polluting discharges, also seems feasible in principle, though more difficult in practice.

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

5. LIVING RESOURCES

5.1 Fisheries

The sections dealing with ecosystems and the impact of the ecological concepts on the development of principles for water quality criteria are pertinent to criteria for fishery resources. A fishery is necessarily in a state of dynamic equilibrium, e.g. where a sustained yield is being obtained, and any change in the balance caused by altered chemical, physical and biological factors is not necessarily incompatible with the use of its resources.

In establishing criteria, it should be recognized that a successful fishery depends upon several essential requirements, including the successful completion of all stages in the life cycles of the fish and their food organisms. It also depends upon the absence of conditions that would cause fish to avoid a region where they would otherwise be present, or to congregate in a region where imminent danger exists, food is lacking, or substances are present which could taint the flesh of fish or give rise to the accumulation of substances to levels harmful to the fish or to the consumer.

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

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

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

5.2 Fishing activities

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

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

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

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

Containerized wastes of various kinds have been recovered by trawl fishermen, and these can damage fishing gear, as well as pose a hazard to fishermen when brought on deck. Such wastes can include noxious chemicals, radioactive substances of low and intermediate level, and military materials, including nerve gases, all of which have been dumped in the sea. Water-logged wood, sometimes escaping from booms of logs towed in coastal waters, presents occasional but sometimes serious problems in certain local areas.

Criteria for seawater quality and bottom characteristics, as they affect fishing activities, cannot be developed in the way normally followed for other uses. Guidelines for control of dumping of solids and containerized wastes are dealt with in the recent international conventions on dumping of wastes at sea (U.K., 1972), and on the prevention of pollution from ships (IMCO, 1973). The scientific criteria for the selection of sites for dumping of wastes into the sea have been considered by the GESAMP Working Group on the Scientific Basis for Disposal of Wastes into the Sea (GESAMP, 1975).

5.3 Aquaculture

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

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

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

Some of the more widely practised forms of aquaculture are involved in the rearing of shellfish, particularly oysters and mussels. Water quality is especially important for these bivalves because of their tendency to accumulate substances such as micro-organisms and metals from the water. Moreover, they are sometimes eaten raw or partially cooked. This requires good sanitary practices in rearing and handling for the protection of the consumer.

Part of the world human population, especially in Japan, utilizes cultured seaweeds for a portion of its diet. This again demands good quality water for production of an acceptable product. Excessive turbidity, for example, could retard photosynthesis, and the presence of dissolved noxious substances could be not only hazardous but might also impart an unacceptable flavour.

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

5.4 Others, including wildlife

Other natural living marine resources which must be taken into account in developing coastal water quality criteria include seaweeds, both for their commercial value and for their contribution to the ecosystem that supports other plant and animal communities. It is well known, for example, that the discharge of sewage off the coast of southern California has been accompanied by a decline of the giant kelp beds.

A major component of the living marine resources in coastal waters, outside of the fisheries, is wildlife. Water fowl are vulnerable to such sea surface pollutants as oil. Fish-eating birds are top predators and therefore are highly susceptible to adverse effects of bioaccumulated substances, such as metals and persistent organics. The problem of eggshell thinning causing reproductive failure in raptorial birds, as a result of DDT and its metabolites in the environment, is considered as an example in section 8.

Although little is known about the relationship of water quality to survival of other species of mammals such as whales, porpoises, narwhals, seals and polar bears, some attention should be paid to the effects of coastal water pollution on these aquatic animals, particularly in the Arctic where degradation of organic substances is slow. The presence of oil in "breathing holes" used by seals in ice-covered areas could be particularly unfavourable.

Marine mammals, because they are air-breathing, present a special problem in oil pollution and in other surface-contaminating phenomena. The sea otter, and presumably also the fur seal, require clean water for protecting the insulating quality of their fur. The sea otter in captivity rapidly succumbs to illness and eventually dies when its fur becomes matted.

6. OTHER ASPECTS

The Group recognized that environmental quality criteria have to be developed for other uses of the coastal zones. These range from underwater marine parks and preserves for which maximum protection is required, to seabed mining and transportation requiring minimal environmental quality. The Group felt that it lacked expertise to deal with any of these other uses in any detail, but considered it might be worthwhile to direct attention to a number of specific uses where coastal water quality is vital.

6.1 Desalination

The growing need for freshwater in many parts of the world requires looking to the sea as a source. The uses of desalted water may range from drinking to industrial processing. In the case of drinking water and possibly that of irrigation, the quality is relevant to public health. The potable product must meet standards set by public health authorities and, therefore, sea water used for this purpose must also be of reasonably high quality. The degree of contamination that could be tolerated would depend also in part on the process used in desalination. In general, the relationship between concentrations of substances before and after treatment has to be established as part of the development of criteria; in the particular case of evaporative processes, for example, attention would have to be focussed on volatile constituents.

6.2 Food-processing water

Coastal water contaminated by sewage can present a serious economic problem in fish-processing because of health risks. Water intakes may have to be extended or alternative sources found. Criteria for quality of food-processing water may be as demanding as those for drinking water.

6.3 Extraction of chemicals from sea water

A certain degree of water quality control must be maintained in plants using sea water for extraction of such chemicals as bromine and magnesium. However, the contaminants which have to be guarded against depend on the material extracted and on the process used. Undoubtedly, oil may present a problem in all such extraction operations. The industry of extraction of pharmaceuticals from marine organisms is dependent on the maintenance of water quality suitable for their growth.

6.4 Industrial-cooling water

The main characteristic of sea water desired for cooling purposes in thermal power plants, nuclear reactors and other industrial systems is low temperature. Therefore, cooling intakes are usually set at a depth where the coldest water can be obtained. Although other characteristics of the water may not be too important, oil and suspended matter drawn into the cooling system can present problems.

7. SUGGESTED PROCEDURE FOR ESTABLISHING CRITERIA

(1) Critically review the relevant literature.

(2) Determine physical, chemical and biological characteristics, including variability in space and time, which influence the desired use or property of the environment. This can be partially achieved by preliminary field observations and laboratory experiments. Such data, together with judicious use of mathematical modelling techniques, will limit the number of variables to be considered.

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

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

(5) Determine the chemical and physical fate and distribution of the stress in the system taking into account time factors. This will require chemical, physical and/or biological analyses of various compartments in the system as well as hydrological data.

(6) Determine the portions of the population or use in the area to be protected (or chosen for study) that are subject to each of several different degrees of risk. This information will be needed when deriving standards from criteria, and requires estimation of the rates of input to defined portions of the system.

(7) Determine the exposure/response relationship which holds for the local system in question. This is a fundamental and nearly universally applicable procedure and will involve determination of the most vulnerable point in the system (e.g. top predator, man, fish, life stage, required food organism, enzyme system, physiological process).

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

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

8. EXAMPLES OF APPLYING PRINCIPLES

The relevance and application of the principles has already been considered to some extent in relation to criteria for ecosystems, but a more detailed appraisal is desirable. In choosing other topics, attention was given to those that could be tackled reasonably thoroughly in the time available and also to those that might reveal some of the strengths and weaknesses of the approach developed to date. Some important topics, however, such as the effect of metals on fisheries and human health would clearly demand considerable effort in reviewing the appropriate literature with the thoroughness considered necessary. One subject, the effect of DDT in coastal waters, was chosen because it appeared to be more amenable to study, since there was a substantial amount of 'well-founded' data available, and furthermore was of interest because the chemical was synthesized and introduced into the environment by man. DDT can be used to illustrate most facets of the application of principles to develop criteria for protection of different components of the ecosystem. Another subject, coastal water amenity, in contrast to DDT, was of interest partly because of the lack of quantitative data available.

8.1 DDT as an example

In terms of biological effects, chemicals such as DDT can be taken up directly from the water and exert a toxic effect on marine organisms; these chemicals may also be bioaccumulated and adversely affect predators. In addition, certain regulatory bodies, through concern about possible health hazards, have specified maximum permissible levels in edible fish products. If these are exceeded, the commercial exploitation can be adversely affected. Therefore, criteria are required to relate body burden to aqueous concentrations or other environmental levels.

8.1.1 Data base

DDT is probably one of the most studied chemical pollutants. Consequently, a brief summary can include only a small portion of the available references. The following discussion attempts to illustrate a basis for selection of water quality criteria, rather than to provide a comprehensive critical review of literature.

(i) Acute toxicity

Laboratory tests lasting 48 to 96 hours show that DDT is acutely toxic to organisms that live in coastal waters (NAS-NAE Committee on Water Quality Criteria, 1973). The 96 hour LC50 1/ for p,p' DDT in static tests ranged from 0.4 to 89 ug/l for seven estuarine fishes (Eisler, 1970) and from 0.6 to 6.0 ug/l for three species of crustaceans (Eisler, 1969). The 48 hour LC50 in ug/l in flow-through tests was 0.4 for *Mugil curema*, 5.5 for *Fundulus similis*, 10 for *Callinectes sapidus* and 1.0 for *Penaeus aztecus*, and from 7 to 9 ug/l reduced the growth of *Crassostrea*

1/ Concentration lethal to 50 per cent of test organisms in 96 hours.

virginica by 50 per cent (Butler, 1963). The 96 hour LC50 in flow-through tests for Morone saxatilis was 0.53 ug/l (Korn and Earnest, 1974). In a test in which the actual concentration of DDT in water was measured by chemical analysis, the 96 hour LC50 to P. aztecus was 0.13 ug/l (Schimmel, unpublished data), which is almost an order of magnitude lower than that found in the test reported by Butler (1963).

(ii) Chronic toxicity

The long-term toxicity of DDT has been studied using juvenile or adult shrimp (Nimmo, Wilson and Blackman, 1970), crabs (Lowe, 1965), oysters (Lowe et al., 1970) and fishes (Butler, 1969); however, no laboratory data are available on effects of DDT on the entire life cycle of coastal organisms. Information on the effect of DDT on entire life cycles of coastal aquatic species is necessary if scientifically derived application factors relating to acute and entire life-cycle toxicity data (Eaton, 1973), rather than arbitrary application factors (NAS-NAE Committee on Water Quality Criteria, 1973), are to be used to estimate water quality criteria that would be expected to protect these species from chronic effects of DDT.

(iii) Bioaccumulation

The presence of DDT in coastal waters and other environments may affect fish and birds by its adverse effects on reproduction. Also, DDT may affect a commercial fishery because of excessive concentrations in tissues of organisms that are consumed by humans. Excessive concentrations of DDT in gametes of spotted seatrout, Cynoscion nebulosus, were associated with a decline in numbers of juvenile seatrout (Butler, Childress and Wilson, 1972). Similar quantities of DDT in eggs of lake trout, Salvelinus namaycush, adversely affected their reproduction (Burdick et al., 1964). Decreasing populations of raptorial and fish-eating birds, such as eagles, ospreys, peregrine falcons and brown pelicans, have been associated with the use of DDT (Blus et al., 1972; Hickey and Anderson, 1968).

8.1.2 Examples of possible approaches to development of water quality criteria

Probably no single number should be used as a permissible concentration of DDT for all uses in all coastal waters. Currently available data on the direct toxicity of DDT in water and its biomagnification in fishes to concentrations that adversely affect reproduction of piscivorous birds, or could affect a fishery as a food source for humans, support the use of these data to calculate permissible concentrations. The following discussion should be considered as an example of a method of approach to the derivation of a criterion and not as presenting criteria for DDT approved by this Group.

8.1.2.1 Application factors with acute toxicity data

DDT is acutely toxic to many coastal fishes and crustaceans at concentrations less than 1 ug/l, with the lowest 96 hour LC50 being 0.13 ug/l (brown shrimp). No scientifically derived application factors for DDT are available for coastal organisms, and if criteria are to be derived at all, arbitrary factors have to be used to estimate the expected chronic effects of persistent chemicals. In these circumstances, it might be better to utilize application factors derived from experimental data on phylogenetically similar species than to use an entirely arbitrary factor such as 0.1 or 0.01.

8.1.2.2 Bioaccumulation and adverse effects on birds

A water quality criterion for DDT, based on bioaccumulation potentials from water to fish to predacious birds, must use data that contrast concentrations in water, in prey-fish and adverse effects on birds. Because critical data are missing, certain assumptions become necessary about the comparability of field and laboratory data and about the responses of different species. The Group considered alternative approaches in relation to bird reproduction utilizing the following seven specific sets of information.

1. Water-to-fish bioconcentration factors (Estuarine and Laboratory)

Water-to-fish bioconcentration factors of 10,000 to 41,000 have been found in laboratory studies (Hansen and Wilson, 1970) and in an estuary (Woodwell, Wurster and Isaacson, 1967).

2. Water-to-fish bioconcentration factors (Freshwater)

The above estimated of bioconcentration factors from water to fish of 10,000 to 41,000 are probably conservative, and although laboratory studies using freshwater fishes also support factors of this magnitude, data from the Great Lakes indicate that environmental accumulation factors may be as great as 2 million (Reinert, 1970). One reason for this difference may be that trophic levels are involved in field exposures. Also the concentration factors calculated from the data of Woodwell, Wurster and Isaacson (1967) may be too low, because the concentration of DDT in water was not measured and may have been over-estimated.

3. Effect of DDE in food on reproduction of birds (Laboratory)

Laboratory studies have shown that dosages of 3 ug/g of DDE in the food adversely affected reproduction of mallards (Heath, Spann and Kreitzer, 1969), black ducks (Longcore, Samson and Whittendale, 1971), kestrels (Wiemeyer and Porter, 1970) and screech owls (McLane and Hall, 1972).

4. Water-to-bird-egg bioconcentration factor (Estuary)

Woodwell, Wurster and Isaacson (1967) obtained data on DDT in biota from an east coast estuary. They estimated that the concentration in water was 0.05 ug/l and measured 7.13 ug/g in tern eggs which would give a concentration factor of 143,000.

5. Food-to-bird-egg bioconcentration factor (Laboratory)

Laboratory studies with black ducks (Longcore, Samson and Whittendale, (1971), and Coturnix quail (Bitman, Cecil and Fries, 1970) indicate that DDT accumulated in eggs at 6 to 10 times the amount in food.

6. Effect of DDT in bird-egg on reproduction of birds (Field Data)

A concentration of 0.5 ug/g in pelican eggs does not affect reproduction (Blus _et al_., 1972).

7. Inferred effects of DDT on reproduction of birds (Field Data)

DDT and its primary breakdown product, DDE, have been implicated in adverse effects on reproduction of natural populations of raptorial and fish-eating birds, but monitoring programmes generally have not determined the quantities of DDT in water that produced food chain effects on bird reproduction. DDT measured in the Pacific Ocean in the California Current system ranged from 0.0023 to 0.0056 ug/l (Cox, 1971). Concentrations in rivers entering some estuaries along the Pacific Ocean and Gulf of Mexico ranged from 0.005 to 0.08 ug/l (Manigold and Schulze, 1969) and large lakes may contain only a few parts per trillion (parts in 10^{12}) of DDT (Reinert, 1970). Although the quantity of data should be greater, what is available suggests that only a few parts per trillion of DDT in water have produced serious reproduction damage to certain raptorial and piscivorous birds, through bioconcentration and conversion to DDE.

Consideration of this information and various combinations can lead to several conclusions about the effects on bird reproduction expected at various aqueous concentrations, as shown in Table 2.

Table 2 : Summary of results of different approaches to assess the effect of DDT on bird reproduction

Concentration of DDT DDT in water (ng/l)	Expectation of adverse effects	Type of evidence utilized from section 8.1.2.2
75 - 300	High	(1,3)*
2.3 - 8		(7)*
1.5		(2,3)*
1 - 8		(1,5,6)*
3		(4,6)*
0.02 - 0.04	Low	(2,5,6)*

* 1 Water-to-fish bioconcentration factors (Estuarine and Laboratory)
2 Water-to-fish bioconcentration factors (Freshwater)
3 Effect of DDE in food on reproduction of birds (Laboratory)
4 Water-to-bird-egg bioconcentration factor (Estuary)
5 Food-to-bird-egg bioconcentration factor (Laboratory)
6 Effect of DDT in bird-egg on reproduction of birds (Field Data)
7 Inferred effects of DDT on reproduction of birds (Field Data)

Manipulation of input data of this kind and in this way can produce values which indicate the order of magnitude of concentrations that might affect bird reproduction, but the lack of data on any one species in any particular environment prevents the establishment of precise limits below which there are no adverse effects. This example illustrates some of the difficulties of establishing water quality criteria occasioned by the lack of relevant data which necessitates making assumptions about the comparability of field and laboratory data and of the responses of different species. Moreover, the output data have been developed assuming a steady state situation, and the relation between effects caused by this condition and those caused by a mean concentration in the environment where the levels may fluctuate widely, is uncertain.

8.1.2.3 Bioaccumulation in seafood

If the water-to-fish bioconcentration factor is 2×10^6 (only the edible portion is considered here), and if 1 ug/g in edible tissue is deemed the highest acceptable by a regulatory agency, then the water concentration would have to be less than 0.5 ng/l.

8.1.3 Conclusions

From the example, it is obvious that any group which proposes to develop water quality criteria for DDT must consider several principles as already discussed.

(1) Criteria should be developed using toxicity data on organisms from the locality to which the criteria applies and, ideally, should include life-time toxicity tests.

(2) In the absence of life-time studies, it may be necessary to utilize appropriate data on the relationship between acute and life-time studies of phylogenetically similar coastal organisms. Such a procedure, while not ideal, could be preferable to using arbitrary application factors.

(3) Thorough critical reviews of the literature should be made to determine if additonal concentration factors derived from environmental monitoring can be obtained. Production of such data may require improvements in analytical sensitivity.

(4) When developing criteria, additional assumptions which may be necessary should be rigorously tested wherever possible.

8.2 Amenities

Application of the general principles in the development of criteria for the protection of aesthetic enjoyment of amenities requires further consideration of the form of cause-effect relationships that would be of most use. The issues arising are illustrated by reference to forms of criteria that might be appropriate in relation to the influence of pollution on the clarity of coastal waters. The effects of interest are those visible to humans in the environment.

Having attempted to develop the example of criteria for aesthetic satisfaction with regard to water clarity, it soon becomes apparent that, while the various factors contributing to light penetration are well known and numerical relationships between concentrations of pollutants and changes in light penetration can readily be obtained, no quantitative relationships have yet been derived between the degree of appreciation of clarity and such objective measurements. It was also recognized that the degree of appreciation would vary with the subject population, and with any change in balance between contributions by various factors affecting clarity. It is therefore judged necessary at the present time to rely on a threshold value of perception in order to assure protection of this aspect of amenities. As noted earlier in this report, if control of water clarity at this level appears impractical, it will then be necessary to establish exposure-effect relationships. Furthermore, such an approach will be necessary, in order to permit a rational setting of standards involving cost-benefit analysis, to assess both the cost of remedial measures and the value of the amenity.

9. RECOMMENDATIONS

The Working Group must conclude that it has not completely fulfilled the terms of reference assigned to it. Once the Group's programme was initiated, it soon became clear that it could not embark at all on actually formulating criteria and that its major goal would be the consideraton and enunciation of principles. The

Group feels that it has achieved that goal, and in so doing, has formulated a constructive approach to the first and second terms of reference concerned respectively with evaluating the nature and extent of problem areas and with the data required for the formulation of criteria. Furthermore, it has provided an extensive framework within which further effort could be directed. Specific recommendations follow about the way any further effort might be continued.

(1) This report should be used as a basis upon which priorities can be assigned to coastal water quality characteristics for the formulation of coastal water quality criteria.

(2) Specialized groups should be set up to formulate tentative environmental quality criteria for coastal waters. The adoption of the principles and procedures outlined in the present report should be of value in helping them to formulate the criteria, and at the same time facilitate identification of gaps in knowledge and thereby enable them to make recommendations on research needs.

(3) The groups should be so constituted that each is concerned with only part of the whole subject area, namely one related to a particular use, e.g., bathing and human health, amenity, or fisheries, which in some cases should be confined to a particular geographical area. The main reasons are firstly, that the amount of work involved would be very large, and secondly, that the criteria will differ between uses in a given area, and between areas for a given use. It should be recognized that, while focussing on particular pollution problems, the membership should include those qualified to interact adequately to cover all inputs called for in section 7. The Working Group sees advantage in constituting any new subgroups on an international basis.

(4) Having chosen amenity as an example, the Group recommends specifically that in the development of criteria to protect aesthetic satisfaction, pending further information on the nature and extent of the problems, priority should be given to the establishment of threshold levels of acceptability for turbidity, colour, slicks and odours, derived from sewage and other wastes. Ideally, these levels of acceptability should take account of the extent and duration of the effect. Furthermore, objective as well as subjective measures of acceptability should be developed. Such measures would greatly assist the execution of benefit-cost analyses which may be needed to aid decision making in cases where control to threshold levels appears impractical.

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