Water quality criteria for the South African coastal zone

J A Lusher (Editor)

Report of the **ad hoc** working committee established by the MARINE POLLUTION COMMITTEE OF THE SOUTH AFRICAN NATIONAL COMMITTEE FOR OCEANOGRAPHIC RESEARCH (SANCOR)

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PREFACE

Experience in regulating the nature of discharges from domestic and industrial outfalls on the South African coast over the last few years has shown how difficult it is to ensure compliance with prevailing requirements, accommodate the needs of industry and protect the marine environment by applying standards for the discharge of individual substances. To date freshwater standards have played a major part in the implementation of effluent discharge control in South Africa.

A marine pollution workshop was organized in May 1983 by the South African Committee for Oceanographic Research (SANCOR) with the following objectives:

to establish guidelines for the optimum use of research results in making decisions concerning pipeline discharges of effluents to sea, and

to summarize existing knowledge, identify gaps in knowledge and recommend future priorities for research on safe discharge of effluents to sea.

The workshop endorsed the recommendation that South Africa prepare its own water quality criteria for marine and estuarine waters and a small ad hoc committee under the chairmanship of Dr J A Lusher was appointed for this purpose.

Such water quality criteria would provide guidelines on the limits which must not be exceeded if a certain end use of the water is to be maintained in perpetuity. They would not have any legal status as opposed to water quality standards which are current, legally enforceable levels established by the licensing authority.

The ad hoc working committee had its first meeting at Franschhoek, Cape Province, during November 1983. Each member of the Committee had prepared a document on a specialized field of study and from these documents the meeting had to prepare a draft publication on water quality criteria for South African marine and estuarine waters. It was realized from the outset that a radical departure from the methods adopted by other agencies might be necessary. All the available literature on water quality criteria was surveyed in order to extract the best approach for what were seen as specifically South African problems. Simplicity was considered to be of great importance as the criteria would not be used by scientists or experienced administrators alone. A further requirement was that the publication should clearly point the way to further studies. The Committee hopes that these aims have been achieved and that this publication will not only provide a scientific guide but will also contribute to the preservation of our marine environment.

SYNOPSIS

Water quality criteria reflecting the needs of the South African coastal zone are presented for beneficial uses encompassing maintenance of ecosystems, recreation, ocean migration, edible and non-edible resources, desalination, mineral exploitation, industrial purposes and miscellaneous uses.

The following criteria are identified and applied to each beneficial use, as appropriate: aesthetics/physical hazards, conservative properties, nutrients, toxic inorganic and organic materials, microbiological parameters, tainting, and radioactivity.

Special attention is given to South African needs by discussing in detail the role played by toxic inorganic and organic materials, the significance of effluent discharges, and the relevance to coastal engineering of mixing zones.

SINOPSIS

Maatstawe vir watergehalte, ingestel op die behoeftes van die Suid-Afrikaanse kusgebied, word voorgestel vir voordelige gebruike wat bewaring/behoud van ekosisteme, ontspanning, oseaanmigrasie, eetbare en nie-eetbare hulpbronne, ontsouting, mineraalontginning, nywerheids-doeleindes en ander gebruike insluit.

Maatstawe ten opsigte van die volgende word uitgeken en soos toepaslik aangewend vir elke voordelige gebruik: estetiese oorwegings, fisiese gevare, behoudingseienskappe, voedingstowwe, toksiese anorganiese en organiese stowwe, mikrobiologiese parameters, besmetting en radio-aktiwiteit.

Spesiale aandag word aan Suid-Afrikaanse behoeftes geskenk deur die rol van toksiese anorganiese en organiese stowwe, die belangrikheid van uitvioeisels en die belangrikheid van vermengingsones vir die kusingenieurswese in detail te bespreek.

ACKNOWLEDGEMENTS

Many persons and institutions contributed to this report. For photographs, thanks are due to the Sea Fisheries Research Institute, the National Research Institute for Oceanology and the Electricity Supply Commission. Funding was made possible by the South African National Committee for Oceanographic Research through the Marine Pollution Programme. Acknowledgement for permitting the participation of staff is made to the Directors-General of the Department of Environment Affairs, the Department of Water Affairs and the Department of Health and Welfare and also to the Director-General of the South African Bureau of Standards and the Chairman and Chief Executive Officer of the Water Research Commission.

A special word of thanks should go fco the many staff members, both scientific and administrative, of the National Research Institute for Oceanology who gave freely of their expert help. Finally, special mention should be made of the energy and enthusiasm of Dr D A Lord as co-ordinator of the Marine and Earth Sciences Programmes of the, then, Co-operative Scientific Programmes (now known as the Foundation for Research Development) of the Council for Scientific and Industrial Research.

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CONTENTS

Page

PREFACE (iii)

SYNOPSIS/SINOPSIS (iv)

ACKNOWLEDGEMENTS (v)

CHAPTER I 1

INTRODUCTION 1

The Beneficial Use Concept 1
Water Quality Criteria 2
Zones of Mixing 3
Guide to Use of Report 3

CHAPTER II 6

RECOGNIZED BENEFICIAL USES 6

Beneficial use No 1: Maintenance and preservation of ecosystems 7
Beneficial use No 2: Direct-contact recreation 8
Beneficial use No 3: Migration of aquatic life 8
Beneficial use No 4: Collection or culture of aquatic life for food 9
    4.1 Filter feeders 9
    4.2 Non-filter feeding edible organisms 10
Beneficial use No 5: Collection of aquatic life for uses other than food 10
Beneficial use No 6: Supply for desalination and potable water recovery 11
Beneficial use No 7: Recovery of minerals 11
    7.1 Evaporation 11
    7.2 Mining 11
Beneficial use No 8: Use of seawater for industrial purposes 12

    8.1 Food processing 12
    8.2 Cooling water 12
    8.3 Washing water 12
Beneficial use No 9: Miscellaneous uses 12

CONTENTS (continued)

CHAPTER III **13**

DEFINITION OF HATER QUALITY CRITERIA 13

Basis for Selection of Criteria 13
Method of Presenting Results 14
List of Water Quality Criteria 14
a. Aesthetic Criteria and Physical Hazards 14
b. Conservative Materials and Properties 15
  pH 15
  Dissolved oxygen 15
  Salinity . 16
  Turbidity and colour 16
  Suspended solids 16
  Temperature 16
c. Nutrients and Biostimulants 17
  1. Nutrients and other biostimulants 17
  2. Ammonia (expressed as nitrogen) 17
d. Toxic Inorganic Materials 17
e. Organic Compounds and Cumulative Materials 18
f. Microbiological Parameters 18
g. Fish-tainting Substances 19
h. Radioactive Substances 21

BIBLIOGRAPHY **22**

APPENDIX I: TOXIC INORGANIC MATERIALS / **Al**

APPENDIX II: ORGANIC COMPOUNDS AND CUMULATIVE MATERIALSA5

APPENDIX III: EFFLUENT CHARACTERISTICS AND THEIR RELATIONSHIP TO WATER QUALITY CRITERIA **A8**

APPENDIX IV: ZONES OF MIXING **All**

AD HOC WORKING COMMITTEE

TITLES IN THIS SERIES

In South Africa, man's pressure on the coastal zone is increasing rapidly. The coastal zone is an ecologically sensitive area where estuaries, rocky shores, beaches and offshore reefs provide the major habitats for countless plants and animaLs. It is essential that development of the coastal zone should go hand in hand with the sound management not only of marine ecosystems and resources but also of 'land-based' activities which may affect estuaries, dunes, cliffs, beaches and so on.

At present there are 61 marine pipelines in use for waste disposal along the South African coast. While the majority of these are small or discharge domest ic sewage, the number of pipelines discharging industrial effluents is increasing. To cope with this increasing discharge, proper procedures must be adopted to ensure that pipelines are well designed and suitably located so as to minimize adverse effects.

An important consideration in managing marine ecosystems is to ensure that the quaLity of the seawater does not deteriorate beyond acceptable levels. Such levels or conditions are termed **Water Quality Criteria** (WQC) and are defined as:

> "those limits which must not be exceeded in order to maintain the chemical, physical and biological characteristics of a selected portion of the sea or estuary."

The assessment of ill effects requires a knowledge of the composition of discharges and their influence on the selected ecosystem, a matter of considerable complexity. The reduction or elimination of such effects requires serious consideration, in the earlier stages, of the influence of marine discharges. In addition, an assessment of factory processes and waste treatment technology (including alternative methods of disposal), the selection of suitable routes and outfall sites for pipelines, the design of diffuser sections and a thorough knowledge of the fate and effects of discharges is essential.

The involvement of the marine sciences research community in a number of major pipe Line projects led to a recommendation being made to the South African National Committee for" Oceanographic Research (SANCOR) that a suitably constituted group of experts prepare water quality criteria for South African marine and estuarine waters. This publication is the result of their deliberations, and represents a synthesis of available international literature with a considerable amount of South African information pertaining to this topic.

THE BENEFICIAL (JSE CONCEPT

It is normal that along any given stretch of coastline the water is used for a variety of different (and often competing) activities. The water quality criteria for some of these uses may be different; for example, the requirements for bacteriological quality of seawater for the cultivation of shellfish are far more stringent than they would be for seawater which is to be used as cooling water in a power station. Consequently each of these different uses must be recognized. This type of use is appropriately designated **beneficial** use.

Beneficial use and water quality criteria may be associated by rephrasing the definition already given:

> "Water Quality Criteria are the scientific yardsticks upon which a decision or judgment may be made concerning the ability of water of a given quality to support a designated beneficial use."

By the term "beneficial use" is meant the desired uses of marine and estuarine waters. Those identified as being of importance in South Africa are listed on p. 6. This list is not presented in any particular order of priority and is subject to revision as required. A complete set of water quality criteria which have been established for each of these beneficial uses is given in Chapter III.

Beneficial uses will, of course, vary from area to area. Ideally, the identification of beneficial uses to be protected will take into account the following:

nature and extent of existing uses
anticipated future uses and demands
factors affecting environmental quality and degree of use, for example land use, industrial growth points, nature of. discharges, etc.
social and economic consequences of policy objectives
feasibility of attainment.

It should be noted that the sole purpose of identifying beneficial uses for protection is to provide a basis for the derivation of water quality management objectives and not to specify permissible uses, as in land-use planning.

WATER QUALITY CRITERIA

Water quality criteria, defined according to physical, chemical, biological or bacteriological characteristics, are considered under the following general headings:

Aesthetic criteria
Conservative materials and properties
Nutrients and biostimulants
Toxic inorganic materials
Organic compounds, including biocides, hydrocarbons and chlorinated organics
Microbiological parameters
Fish-tainting substances
Radioactive materials.

For each of these, a detailed description of the procedures that were used to assess suitable water quality criteria is given in Chapter III. Although the working group strongly endorsed the use of water quality criteria as a very valuable tool for the management of marine disposal, from an ecological point of view this approach often over-simpLifies the complex interactions which occur in nature. Criteria must, therefore, be applied with prudence.

The difference between criteria and standards should be noted. Standards are current, legally enforceable levels established by an authority. They are not necessarily based upon sound scientific knowledge and may, indeed, be arbitrary. Water quality criteria are not legally enforceable standards but rather levels of a variety of chemical constituents which should not be exceeded if these resources are to be maintained in perpetuity.

Water quality criteria provide guidelines in establishing acceptable discharges. Standards could later be developed from water quality criteria once these have been implemented and been subject to environmental monitoring.

ZONES OF MIXING

Where effluent of a quality lower than that of the receiving water is discharged, there will be a zone surrounding the point of discharge where the specified water quality critera will not be achieved.

This mixing zone is a specifically defined area where allowance is made for the mixing of wastes with the receiving body of water and where water quality criteria do not apply, provided no recognized beneficial use is significantly threatened.

The waters **adjacent** to the mixing zone should, however, comply with the water quality criteria accorded to the designated beneficial use for that particular body of water.

The impact on a beneficial use in the receiving water as a whole will depend on several features of the mixing zone, including its configuration, its size in relation to the receiving waters as a whole, its location and the composition of its waters with respect to the type and concentration of pollutants. As the maintenance and preservation of aquatic ecosystems is frequently the limiting beneficial use of waters, mixing zones are generally considered in terms of their effect on biota. However, aesthetic appearance is an equally important quality consideration within mixing zones.

It is generally accepted that **mixing zone specifications should be established on a case-by—case basis** after consideration of the assimilative capacity of the receiving waters and of the type and sensitivity of the particular biological communities involved. As far as possible the size, location and quality of water in the mixing zone should be defined in such a way as to minimize the impact on the biota of the receiving waters and on other beneficial uses (see Appendix IV).

GUIDE TO USE OF

REPORT 1. Basic

information

(a) A list of beneficial uses recognized in South Africa appears on p 6. These are numbered from 1-9 and each is discussed in detail on pp 7-12.

(b) A list of water quality criteria appears on p 14. These are described on pp 14-21 and in each case a recommendation is made. In the case of TOXIC INORGANIC MATERIALS and ORGANIC COMPOUNDS AND CUMULATIVE MATERIALS, a detailed discussion is provided in

Appendices I and II respectively, as these have been formulated with particular regard to South Africa.

(c) For those who know what they are looking for, a grid is provided on the next page, 1 inking beneficial use (by number) to water quaLity criteria (by name). The number at each intersection refers to the number of the page on which the criteria are stated.

2. Special Copies

Engineers will find relevant material on p 3 (ZONES OF MIXING) and Appendix IV, where policy regarding pipeline discharges and the minimum information required for pipe design are discussed in detail..

Units. All units used in this report, other than oceanographic ones, are according to the Systeme International as adopted by the South African Bureau of Standards. Oceanographic units follow the conventions of the International Association for the Physical Sciences of the Oceans.

WATER QUALITY CRITERIA REQUIRED FOR SPECIFIED BENEFICIAL USE

Beneficial use		1	2	3	4,1	4,2	5	6	7,1	7,2	8,1	8,2	8,3	9
Criteria														
A. Aesthetic & hazard		14	14	14	14	14	14	14	14	14	14	14	14	14
B. Conservative materials	pH	15	15	15	15	15	15	15	15	15	15	15	15	-
	dissolved oxygen	15	-	15	15	15	15	-	-	-	-	-	-	-
	salinity	16	16	16	16	16	16	16	16	-	16	-	-	-
	turbidity and colour	16	16	16	16	16	16	-	16	16	16	16	16	-
	suspended solids	16	16	16	16	16	16	16	16	16	16	16	16	16
	temperature	16	16	16	16	16	16	16	-	-	16	16	16	-
C. Nutrients	all	17	17	17	17	17	17	17	17	17	17	17	17	17
	ammonia	17	-	17	17	17	17	17	17	17	17	17	17	17
D. Toxic inorganics		17	17	17	17	17	17	17	17	-	17	-	17	-
E. Organics and cumulative		18	18	18	18	18	18	18	18	-	18	18	18	-
F. Microbiological parameters		18/19	18/19	18/19	18/19	18/19	18/19	18/19	18/19	-	18/19	18/19	18/19	-
G. Fish tainting substances		-	-	-	19	19	-	-	-	-	19	-	19	-
H. Radioactivity		21	21	21	21	21	21	21	21	21	21	21	21	21

CHAPTER II

RECOGNIZED BENEFICIAL USES

No 1 Maintenance and preservation of ecosystems No 2

Direct contact recreation No 3 Migration of aquatic life

No 4 Coilection or culture of aquatic life for food

  4.1 Filter feeders

  4.2 Non-filter feeding edible organisms

No 5 Collection of aquatic life for uses other than as food No 6 Supply for

desalination and potable water recovery

No 7 Recovery of minerals

  7.1 Evaporation
  7.2 Mining

No 8 Use of seawater for industrial purposes

  8.1 Food processing
  8.2 Cooling water
  8.3 Washing water

No 9 Miscellaneous uses

BENEFICIAL USE NO 1

MAINTENANCE AND PRESERVATION OF ECOSYSTEMS

Any ecosystem is made up of a physico-chemical environment supporting a more or less stable community of organisms adapted by evolution and interacting in such a way that there is transport of energy and materials through the system and recycling of material resources within the system. Thus an ecosystem can be viewed in terms of abiotic elements such as sunlight, temperature, pH and inorganic nutrients and biotic elements which are the interacting organisms and populations which constitute an ecological community. The biotic components of the ecosystem can be divided into three main groups according to their trophic status within the system. The trophic levels comprise primary producers such as algae which support the primary consumers such as herbivores, filter feeders and detritivores which in turn support the secondary consumers or carnivores.

Ideally, ecosystems are relatively stable in that they maintain a balance between the inputs to and outputs from the system. This does not imply that they are static but rather that the regulatory mechanisms sucessfully dampen the oscillations which might result from such factors as seasonally fluctuating annual cycles. Occasionally an ecosystem will be disturbed as a result of, for example, a storm but after a period of recovery will regain its stability.

In other instances, where a consistent change in the physical or chemical conditions occur, the quality of an ecosystem can decline. Pollution is one factor which, depending on its extent, can result in the destabilization of an ecosystem to the point of its total extinction. An important factor in the understanding of ecosystems is that because of the integrated nature of the, system, an interference with one element or process may have far-reaching repercussions for other parts of the system as a whole.

Pollutants can achieve their detrimental effects by both physical and chemical means and these effects can range from lethal to sub-lethal. Lethal effects usually result from exposure to the pollutant at high concentrations for a short period while sub-lethal effects are often the result of lower concentrations for extended periods. Sub-lethal effects do not result in the death of the organisms but rather disrupt their normal physiological or behavioural functions, eventually leading to disruption of the population as a whole. Physical effects of pollutants include direct smothering of the organisms as well as habitat alteration.

The South African coastline is influenced by two major current systems and supports a widely diverse marine biota. The cold Bengueia Current, which flows in a northerly direction along the west coast, is rich in nutrients and supports a cold temperate water fauna. This includes relatively few species when compared with warm temperate faunas, but each species is represented by many individuals which grow large in the cold nutrient-rich waters. On the other hand, the warm Agulhas Current flows in a southerly direction broadly following the continental she If along the east coast so Chat adjacent to East London it is about 32 km offshore and about 190 km off Mossel Bay. These low-nutrient waters support a more diverse community with smaller numbers of individuals a ad many tropical spec ies. The south coas t is intermediate between these two situations with few tropical species but many warm water endemic species.

As most industrial activity is Located in areas of high urban density the greater part of the coastal waters are unpolluted and undisturbed. To maintain or improve this situation, water quality criteria must be set to ensure that all physical and chemical conditions which influence the ecosystem in one way or another are maintained.

BENEFICIAL USE NO 2

DIRECT-CONTACT RECREATION

The South African coastline, which is approximately 2 500 km in extent, is being increasingly used for direct contact-recreation. These activities, where the human body is completely or partially immersed in the seawater, include bathing, diving, surfing, windsurfing, waterskiing and sailing. In the past these activities were concentrated mainly around areas of high urban density such as Cape Town and Durban as well as in certain estuarine areas. More recently, however, with the increasing affluence of the general population these recreational areas have spread further afield and some 20 per cent of the coastline is now being used for recreational purposes.

Criteria that apply to these areas should ensure that the aesthetic and hygienic qualities of the waters are maintained at sufficiently high levels. This includes protection against floating or submerged objects which could pose a physical hazard.

BENEFICIAL USE NO 3

MIGRATION OF AQUATIC LIFE

Unlike the more sedentary organisms, migratory species are not adapted to existence within the environmental constraints of a localized, well-defined habitat. Instead, they are adapted to a complex behavioural pattern which leads them to depend on a range of habitats which are often widely separated. By exploiting a range of habitats, each at a time most., favourable to them, these species are able to compensate for specialized feeding habits and low fecundity amongst other factors, all of which are common characteristics of the biology of migratory species .

Because the life histories of migratory species are defined by their migratory cycle, the survival of such species frequently depends upon the continuing suitability of all habitats exploited by them or through which they pass for particular activities such as feeding, courting, breeding, resting, moulting, etc. As long as the habitats along the migratory route remain unperturbed, it is possible for the migratory species to optimize their use of each, thereby providing necessary links in the life cycle.

Species that use different habitats during their life cycle and who migrate include fish that use estuaries as nursery grounds, pelagic fish on the west coast, sardines off the Natal coast and whales on the south coast.

Criteria are set under this schedule to ensure that the water quality along these migration routes remains at a sufficiently high level so as not to interfere with this migratory pattern.

BENEFICIAL USE MO 4

COLLECTION OR CULTURE OF AQUATIC LIFE FOR FOOD

A large variety of marine organisms are collected annually around the South African coast line for human consumption. Of these the majority are harvested commercially, either through the exploitation of natural stocks or from culturing activities, while a small proportion is privately collected for personal consumption. The exploitation of offshore stocks such as the demersal and pelagic fisheries is apparently not affected to any significant degree by land-based pollutants. On the other hand, the species found inshore as well as those that are cultured in sheltered areas are highly vulnerable.

The criteria listed under this schedule have been developed to protect these exploitable stocks at three levels of increasing sensitivity:

> first, the concentration of a pollutant should not reach a level in the marine environment which causes mortality of the species concerned. Historically this level has been determined in the laboratory using LC^g tests (the concentration of the pollutant required to kill 50 per cent of the test population within a specific time).
>
> second, the pollutant should not be at levels that cause sub-lethal or chronic effects to the organism concerned. These effects include impairment to reproductive capacity, disruption of escape response or any other manifestation that disrupts the normal viability of the organism. These levels can also be determined in the laboratory using multigeneration and behavioural response tests, although with more difficulty.
>
> last, since these organisms are used for human consumption, pollutant levels that taint edible flesh need to be adequately controlled. A list of such compounds and the concentrations at which they cause tainting is presented in the table on page 20. Health considerations are also taken into account. These include viral or bacterial contamination as well as the accumulation of heavy metals that may reach levels hazardous to human health.

In addition to the above considerations, pollutant levels should not reach concentrations that may affect a particular part of the ecosystem on which the organism in question is dependant. For example, phytoplankton as a food source or seaweeds as habitats should not be affected.

4.1 Filter feeders

The main organisms in this category are oysters and black, brown and white mussels. Oysters are commercially cultivated in Knysna and Langebaan lagoons and to a lesser extent in the Swartkops estuary.

Eight per cent of commercial harvesting of natural stock oysters takes place in the Mossel Bay, Knysna and George districts.

Black and white mussel stocks are not commercially exploited but collected for personal consumption. These mussels occur from Walvis Bay to Port Elizabeth but are collected mainly on the coastline close to areas of high urban density.

In areas where filter feeders are collected, stringent criteria are required as toxic pollutants are filtered from the seawater and can accumulate in the body tissue of the organism. Oysters have a filtration rate up to 6-10 £ h~* and mussels from 16 to 18 *2 h*~*-.

4.2 Non-filter feeding edible organisms

Organisms falling into this category include the rock lobster and abalone. Commercial catching of rock lobster takes place on the west coast between Port Nolloth and the Cape Peninsula (3 600 tons annually), the south coast between the Agulhas Bank and Port Alfred (314 tons tail mass annually) and the east coast between Durban and St Lucia (114 tons annually). The greatest concentration of fishing activity takes place in the Saidanha/St Helena Bay area. The main diet of the rock lobster is the black mussel. Because of the commercial importance of this resource and sensitivity in so far as human health implications are concerned, strict water quality criteria need to be set in these areas.

Sixty per cent of the commercial ab alone catches are collected in the Hawston, Hangklip and Gansbaai areas. As abalone are browsers and not filter feeders, the water quality criteria in these areas do not need to be as strict as for filter feeders. However, criteria for maintaining levels of natural stocks are still required.

BENEFICIAL USE NO 5

COLLECTION OF AQUATIC LIFE FOR USES OTHER THAN FOOD

Seaweed used as a foliar spray, bait organisms and seals fall into this category.

The criteria adopted f^or these areas ensure that the water quaLity is maintained at levels that sustain natural healthy stocks.

Kelp used for the . manufacture of a ' foliar spray is obtained by controlled cropping of a standing stock at Kommetj ie on the west coast of the Cape Peninsula. Gelidiiim is also hand-plucked in the Port Alfred area and Gracilaria collected in Saldanha Bay.

The most common bait organisms collected on a commercial basis are white mussel and red bait. Two hundred and fifty thousand mussels and eleven thousand kilogrammes of red bait are collected and sold annually. In addition to this, private anglers collect these organisms as well as other estuarine and marine species such as polychaet worms, mud prawns, etc.

Sealing activities are not significantly affee ted by land-based pollutants and are thus considered to be irrelevant in the application of water quality criteria.

BENEFICIAL USE NO 6

SUPPLY FOR DESALINATION AND POTABLE WATER RECOVERY

Desalination of seawater in South Africa has not assumed the importance it has in other countries. Although studies have been made of the fouling effect of nutrient-rich seawater used as prime feed, the main thrust of research has been towards the desalination of purified sewage effluent and of brackish groundwater. The main reasons for this are that very large supplies of brackish groundwater are found in the western half of the country and in Namibia, and that relatively high rainfall is experienced in the largest city in the western half of the Cape Province, Cape Town. However, the experience of the City of Durban during the 1983 drought makes it quite clear that land-based water supply schemes in Natal are subject to severe limitations which traditional engineering can no longer overcome except at very high cost. Quite apart from other considerations, much suffering is caused by drought in the poorer rural areas. This could be alleviated by the installation (as needed) of "package" desalination units fed by seawater.

Protection of this beneficial use requires adequate control of health-related parameters such as bacteria and toxic and radioactive substances to ensure the production of potable water that conforms to drinking water standards. In addition, the intake water should be free of any substance or material that could interfere with the efficient running of a desalination plant.

BENEFICIAL 0SE NO 7

RECOVERY OF

MINERALS

7.1 Evaporation

Salt recovery by means of evaporation is achieved by pumping seawater into evaporation pans on land, allowing the water to evaporate under the influence of the sun and collecting the salt fraction that remains. This is done at Walvis Bay, on the Berg River and on the Koega River near Port Elizabeth. Criteria are set to ensure that the quality of the salt recovered is not" altered in any way and that the pumping operation is not disrupted.

7.2 Mining

The extraction of diamonds from the sea bed takes place up to a distance of 1 000 m offshore in concession areas between the Berg and Orange rivers. In addition to this the mining of certain minerals, including ilmenite and zircon, will be undertaken up to a depth of 20 m between the Tugela River and Richards Bay. Oil rigs are conducting exploratory drilling tests up to 100 km from the coastline off the southern Cape coast as well as to a lesser extent in the Orange River region.

Criteria are set to ensure that these operations are not disrupted by the presence of undesirable floating objects, excessive algal growth or suspended material.

BENEFICIAL USE NO 8

USE OF SEAWATER FOR INDUSTRIAL PURPOSES

8.1 Food processing

In South Africa the use of seawater in food processing is restricted to the fishing industry. Seawater is used to transport catches from the boats to various sections of the fish factory and as wash water during the processing of white fish, rock lobster and abalone. The majority of factories using seawater are situated at St Helena Bay and Saldanha Bay on the west coast and at Hout Bay, Hermanus and Gansbaai further south. At Saldanha Bay and Hout Bay, seawater is also used for the storage of live rock lobsters in holding tanks.

The criteria allocated to this beneficial use must ensure that the water quality is maintained at a level that does not result in contamination from a human health point of view or in tainting of the product.

8.2 Cooling water

Seawater is used as a cooling agent in fossil fuel power stations situated at Durban, East London, Port Elizabeth and Cape Town as well as at the Koeberg nuclear power station near Cape Town. To a much lesser degree seawater is used in some cooling processes in certain industries situated on the coast, for example as cooling water for fishmeal evaporators.

Seawater designated for this beneficial use should be free from physical objects.

8.3 Washing water

Apart from use in the fishing industry, seawater is also used in large quantities for washing crushed conglomerate during the extraction of diamonds. This takes place on the west coast at Alexander Bay and Kleinzee.

Criteria allocated for cooling waters should apply in this case.

BENEFICIAL USE NO 9 MISCELLANEOUS USES

Other miscellaneous beneficial uses of the sea include the generation of energy by tides, races or waves, navigation and ships passage and cable lines.

The relevant criteria must ensure the unobstructed passage of shipping and boats, the suitability of the water used for essential services on these craft and prevention of undue corrosion or scaling of equipment associated with these uses.

BASIS FOR SELECTION OF CRITERIA

The suite of plants and animals comprising life in seawater is highly diverse. All plants or animals do not exhibit the same response or degree of harm from a given concentration of a toxicant or potential toxicant within the environment. In establishing a concentration of a specific constituent it is therefore necessary to evaluate effects on the more sensitive species that are present in order to ensure their safety.

The ideal data base for criteria development should consist of information on the majority of the organisms present and also indicate the community response to a range of concentrations of the material under consideration. Such information is seldom available. However, a large body of information is available on the toxicity of individual materials.

Toxicity to aquatic life is generally expressed in terms of values which produce acute (short-term) or chronic (long-term) effects. Acute toxicity refers to limited exposure times usually in the range 24 to 96 hours. Chronic toxicity refers to effects through an extended period of time, equal to the lifetime of an organism or to the time span of more than one generation. Some chronic effects may be reversible but most are not. Some of the most useful information on chronic effects has been obtained from measuring the effects of toxicants on the reproductive success of selected organisms. >

In addition to direct effects on plants and animals, certain materials can be concentrated within the body tissues of these organisms to reach levels far higher than those in the surrounding water. These can then be damaging to the host organisms themselves or to consumers of the host organisms. The best example of such 'bioaccumulating' materials is the group of chlorinated organic compounds. For materials such as these, data on acute and chronic toxicity is far less useful. The establishment of criteria is usually based on combining information on 'bioaccumulation[1] factors, residues in various organisms, consumption rates and associated health risks. By applying a suitable safety factor criteria can be developed.

In establishing the water quality criteria presented here, certain fundamental principles were dominant. First, in establishing a concentration as a criterion for a given constituent it was assumed that other factors in the aquatic environment are acceptable for maintaining the integrity of the water. Second, it was assumed that reproduction represents the most sensitive stage in an organism's life cycle, and data relating to the reproductive.success of organisms was consequently given the strongest consideration in assessing criteria. Third, natural variations in water (especially in estuaries) were not considered as it was accepted that criteria represent upper limits for response and that they are, therefore, not influenced by variations at lower levels.

METHOD OF PRESENTING RESULTS

The criteria are presented mainly in the form of a single concentration which should not be exceeded. It is recognized that this is unrealistic as there is always a finite possibility that this value will be exceeded, even for a short period of time. However, these criteria are the upper limits of concentration beyond which sublethal effects have been noted, and are therefore considered to be levels beyond which deleterious effects could be expected if long-term exposure occurred.

Should these criteria be used in the preparation of guidelines for discharges, natural fluctuations may need to be considered.

A second reason for presenting criteria in this simple form is that sampling of the sea to determine whether or not criteria are being exceeded requires extremely wel 1 designed and detailed sampling programmes. In almost all cases this is neither feasible nor practical, nor is it considered to be necessary. Consequently, most results of programmes for monitoring the quality of receiving water are obtained from a series of single random samples$_3$ and the statistical value of. such data is limited.

The analysis of seawater samples for water quality should always be done by reliable analysts using accepted methods which have been proven in intercalibration exercises. It will be noted that criteria are presented in a uniform manner for all South African waters as there is no scientific justification for making any distinction between the warmer east and south coast waters and the cold west coast waters.

LIST OF HATER QUALITY CRITERIA

a. Aesthetic criteria and physical hazards

b. Conservative materials and properties

- pH
  dissolved oxygen
  salinity
  turbidity and colour
  suspended solids

  temperature

c. Nutrients and biostimulants

d. Toxic inorganic materials

e. Organic compounds and cumulative materials

f. Microbiological parameters

g. Fish tainting substances

h. Radioactivity.

a. Aesthetic Criteria and Physical Hazards

Unless otherwise specified, the following aesthetic criteria should apply to all marine and estuarine waters regardless of the designated beneficial use:

Waters should not contain floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating materials and residues from land-based sources in concentrations that may cause nuisance or in amounts sufficient to be unsightly or objectionable.

Waters should not contain materials from land-based sources which will settle to form putrescent or objectionable deposits.

Waters should not contain materials from land-based sources which will produce colour, odours, turbidity or taints or other conditions to such a degree as to be unsightly or objectionable.

Waters should not contain submerged objects and other sub-surface hazards which arise from other than natural origins and which would be a danger or cause nuisance or interfere with any designated use,

b. Conservative Materials and Properties

To use all available information sources in an attempt to establish water quality criteria which take account of all possible marine interactions would result in an unwieldy and complex system. In the belief that simplicity is more likely to succeed in practice, only those conservative materials and properties which have the most marked importance to marine communities, have been considered.

It should be noted that a number of factors (pH, salinity, turbidity, temperature) tend to be less variable in the sea than in estuaries and the **relative** importance of these should be k;ept in mind when applying the criteria. An example is suspended solids borne by South African rivers entering the sea, which often rise to levels where the application of a simple measuring device (such as the Secchi disk for assessing water transparency) is impractical.

pH

1. For the culture of aquatic life for food and maintenance of ecosystems, the pH should lie within the range 7,3 to 8,6. Where natural circumstances obtain, the variation should be not more than 0,2 units from the observed natural extremes encountered in the area.

2. For direct-contact recreation, the pH should be not more than 0,5 units different from that normally encountered in the area.

3. For industrial uses, the pH should lie between 6,5 and 9.

Dissolved oxygen

For the maintenance of ecosystems, aquaculture and harvesting of sea food, dissolved oxygen should not fall below 5,0 rag 2^{-1} and the median should be at least 6,0 mg 2^{-1} over any 24 hour period. It should be measured at mid-depth up to a maximum of 2 m.

Salinity

For all marine biological purposes the salinity should lie within the range 33 to 36*10~^. In estuaries, non-natural influences should not change the salinity beyond the range recorded over an extended period.

Turbidity and colour

For all marine biological purposes, the combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more than 10 per cent from the seasonal background values.

Suspended solids

For all marine biological purposes, concentration of suspended solids should not be increased by more than 10 per cent of ambient concentrations and should not exceed 80 mg *Z* ~*- except as a result of natural conditions.

Temperature

For all biological uses, including aquaculture and the maintenance of existing ecosystems, the maximum acceptable weekly variation in ambient temperature caused by artificial sources should not exceed the normal range by more than 2°C.

c. Nutrients and Biostimulants

The breakdown of organic wastes by bacterial action releases inorganic compounds essential for plant nutrition into the marine environment. These include nitrogen and phosphorus and some/trace metals. Nitrogen and phosphorus are also present in sewage effluents and urban runoff and are major components of agricultural fertilizers which may be washed into estuaries and from there into the sea. These nutrients are not in themselves toxic or a danger to human health. On the contrary, problems associated with nutrients are related to excessive growth of aquatic plants, because release of increased concentrations of nitrogen and phosphorus into coastal' waters stimulates their growth. These elements are then used up in the production of organic matter by phytopiankton. Upwelling of nutrient-rich deeper water, land drainage and decomposition of organic matter, combined with,turbulence and mixing, redistribute and increase the nutrient concentrations. Although eutrophication is a serious problem for inland waters and lakes, the turbulence of the water in the coastal zone generally prevents this from occurring in marine waters. However, in serai-enclosed embayments or estuaries receiving large amounts of waste, eutrophication can occur. Decomposition of organic matter can then lead to reductions in the dissolved oxygen concentrations in water.

In the absence of any documented evidence of harmful effects of nutrients along the South African coast, narrative criteria governing nutrient concentrations rather than numerical levels are proposed.

1. Nutrients and other biostimulants

For all beneficial uses, waters should not contain nutrients and other biostimulants from land-based sources in concentrations that are capable of causing excessive or nuisance growths of aigae or other aquatic plants or deleterious reductions of dissolved oxygen.

2. Ammonia (expressed as nitrogen)

For all marine biological purposes, ammonia should not exceed 600 yg 2~^{l}.

d. Toxic Inorganic Materials

This section considers only the toxic metals and cyanide and fluoride. The normal suite of metal elements is included (see Appendix I, Table 1) but the less commonly considered candidates, such as silver, cobalt, selenium, ant imony, beryllium and tin, have al 1 been mentioned at one time or another. Silver and selenium in particular are attracting increasing attention.

The concentrations of the elements under consideration in the marine waters of South Africa are listed in Appendix I. They agree well with levels detected overseas.

The following maximum concentrations are recommended for all beneficial uses except mining and cooling water:

	$\mu g\ \ell^{-1}$
Arsenic	12,0
Cadmium	4,0
Chromium	8,0
Copper	5,0
Lead	12,0
Mercury	0,3
Nickel	25,0
Silver	5,0
Zinc	25,0
Cyanide	12,0
Fluoride	5 000

In alt cases these levels must be attained in the sea upon completion of initial dilution.

Most metals are found in marine organisms at levels many times above those present in the water. Thus while a toxic substance may not be present in a chronically toxic concentration in the water, it may be found in edible mussels or oysters, for example, to a tissue level exceeding the standards laid down for human consumption. It is important, therefore, that metal levels should be monitored in such organisms. In the case of mercury, levels in edible bivalve molluscs should not exceed 0,5 mg kg "I (wet mass) or 2,0 mg kg*"* (wet mass) for the combination of three of the most Coxic elements, mercury, lead and cadmium.

e. Organic Compounds and Cumulative Materials

Analysis of seawater and marine organisms has revealed the presence of both aromatic and aliphatic hydrocarbons as we11 as the organochlorines which are entirely synthetic.

In the open ocean, concentrations of hydrocarbons are usually low and their origin is not easily determined, although origin is usually apparent in areas of massive contamination.

Organochlorine compounds have been produced, primarily as biocides, since the early years of this century. Most are environmentally stable and can accumulate and 'concentrate through the food chain. They are of fundamental environmental concern because of their initial impact on the ecosystem and their effect on the consumers of marine organisms.

Water quality criteria data for the more important chemicals in these two groups are listed below. Others should be deaLt with on a case-by-case basis. Data for the hydrocarbon concentrations quoted were obtained from the Federal Register (1979), Sheur (1973) and Sittig (1981).

For marine biological purposes the concentrations listed below should not be exceeded.

Multiple (Linked Ring) Hydrocarbons
biphenyl 15 ug -6~1
Polynuclear (Fused Ring) Aromatic Hydrocarbons

These compounds include benzo(a)pyrene, benzo(b)£luoranthene, benzo(a)-anthracine, benzo(_e)pyrene, benzo(j_) fluoranthene, benzo(k_)fluoranthene , anthracene, chrysene, dibenzo(A,H)anthracene, fluorene, fluoranthene, indeno(l, 2, 3-C,D)pyrene, phenanthrene and perylene. All 0,3 ug Z~*-.

Chlorinated Hydrocarbons	**Concentration (ug ■£""!)**
Aldrin	1,3
Chlordane	0,004,
Chlorinated naphthalenes	2,8
Chlorobenzene	130
Dichlorobenzene	1 500
DDT and derivatives	0,001
Dieldrin '	0,001
Endrin	0,003
Heptachlor ,	0,004
Lindane ■	0,16
Methoxychlor	0,03
Pentachlorophenol	3,7
Polychlorinated biphenyls	0,03

Toxaphene	0,07

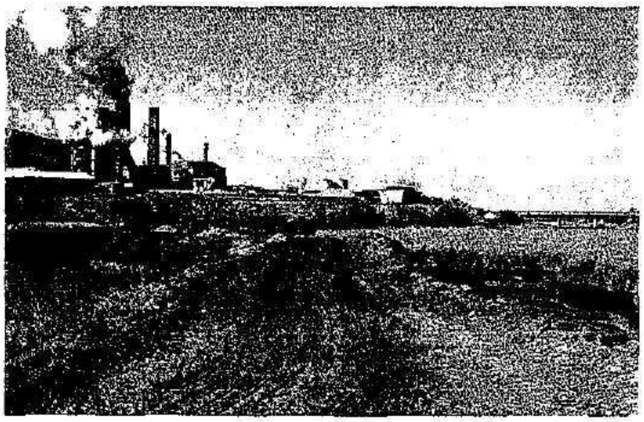
f. **Microbiological Parameters**

Arbitrariness of criteria in this context is inevitable. The relationship between numbers of specific disease-producing organisms present in the marine environment and the occurrence of clinical symptoms in humans is not clear cut and depends on a wide variety of variables in the organism, the host and on characteristics of the aquatic environment.

Despite the above reservations and their known shortcomings, indicator organisms are included in setting microbiological marine water quality criteria for direct contact recreation and the collection or culture of filter feeders for human food. These criteria must be seen in the perspective of the requirements for design evaluation and control of

The Heuningnes River on the Cape south coast entering the sea through a double sand spit – an example of a dynamic river mouth still in pristine condition.

(Photo: ECRU, NRIO)



Richards Bay, where harbour and industrial development have been imposed on Natal's second largest estuarine system. Substantial efforts are being made to conserve the southern part of the system in an ecologically healthy state by separating it from the harbour by means of an earthern berm-wall and by providing a separate mouth to the sea.

(Photo: C Best, NRIO)

Degradation of an estuary and its associated floodplain by sugar milling operations on the Natal south coast.

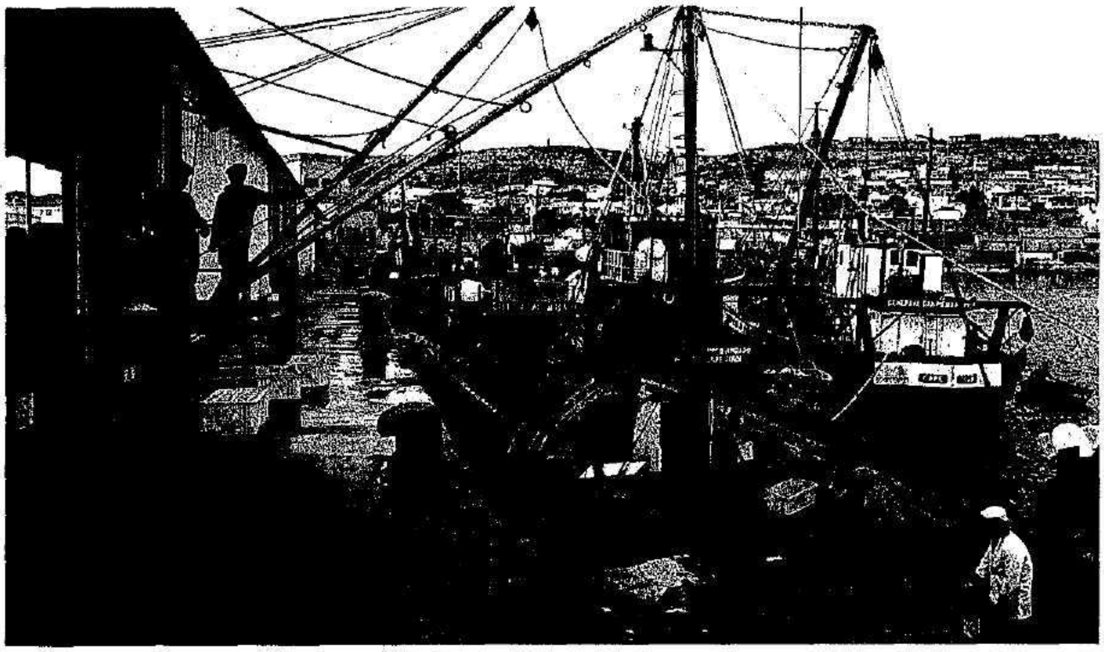
(Photo: ECRU, NRIO)

A rocky shelf in the intertidal zone of the Zululand coast which is rich in marine life and particularly vulnerable to oil pollution.

(Photo: D Lord, UPE)

A benthic food web on the seabed off the Cape south-west coast showing a diversity of marine organisms including the commercially important Cape rock lobster, Jasus lalandii.

(Photo: R Harding, SFRI)



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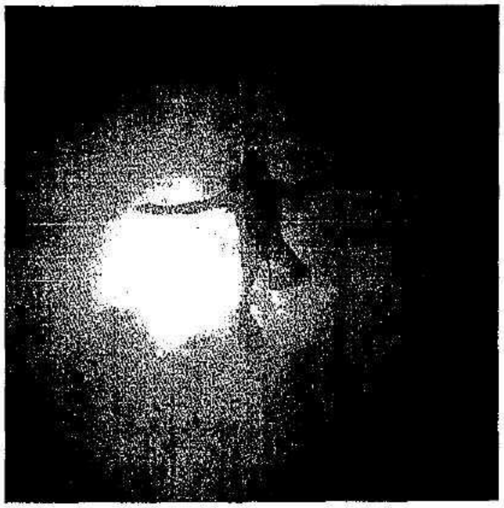

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1

Trawlers off-loading catches at a fishing harbour on the Cape south coast.

(Photo: C Best, NRIO)

2

The exhilaration of free diving as a recreational activity in unpolluted coastal waters.

(Photo: R Harding, SFRI)

3

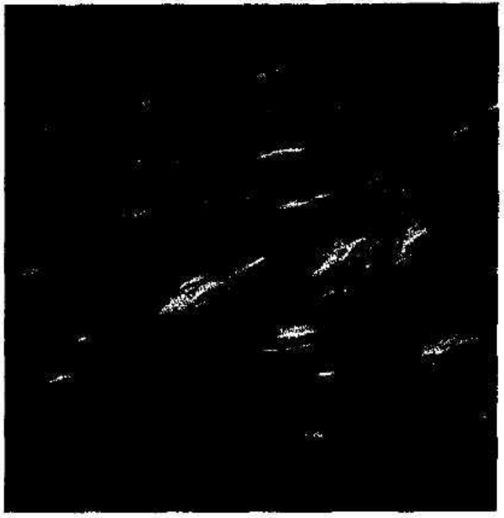
A migratory shoal of the yellowtail, Seriola lalandi, *a species of fish which occurs around the whole of the Southern African coastline.*

(Photo: R Harding, SFRI)

4

A diver collecting samples for research purposes in a kelp bed ecosystem off the Cape west coast. Kelp is harvested for agar production and other uses in the chemical industry.

(Photo: R Harding, SFRI)



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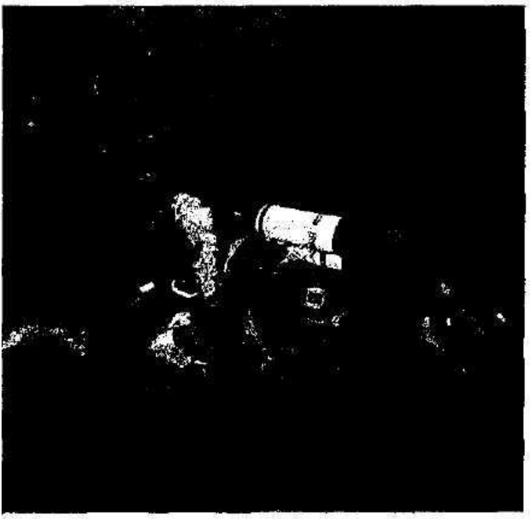

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Diamond mining operations on the west coast.

(Photo: J Möller, NRIO)

6

Discharge from a fish-processing plant on the west coast causing organic pollution in the nearshore zone.

(Photo: A G S Moldan, SFRI)

7

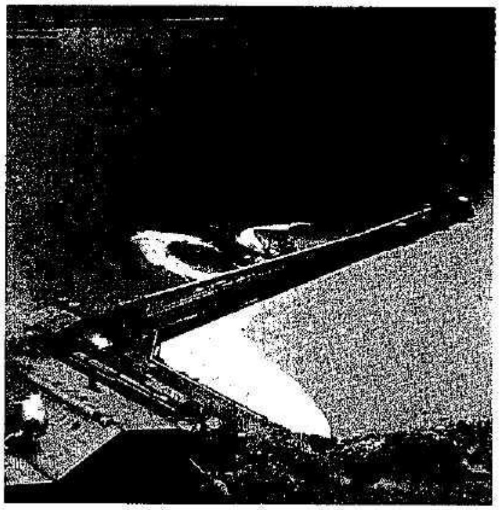
The Koeberg nuclear power station on the Cape south-west coast which uses seawater as a cooling agent.

(Photo: ESCOM)

8

Mass mortality of the white mussel, Mactra glabrata, *at Langebaan lagoon on the west coast.*

(Photo: A G S Moldan, SFRI)



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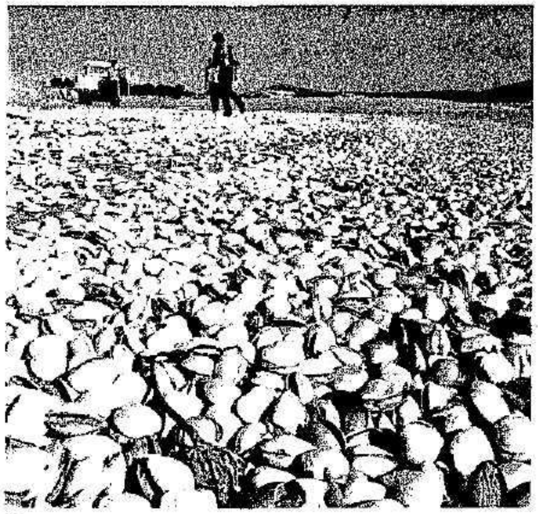

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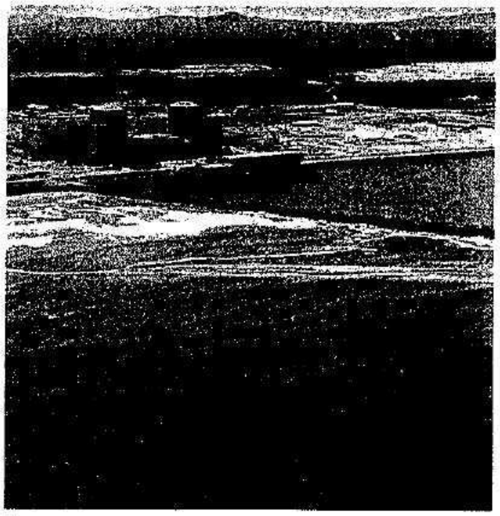

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The aesthetic value of a scene like this in itself is sufficient reason for preserving the coastal environment.

(Photo- R Harding. SFRI)

waste disposal to prevent the creation of health hazards in marine and estuarine environments.

In view.of the paucity of scientific data relating to the quantification of health hazards, these microbiological criteria should be evaluated against the background of epidemiological experience in the human population at risk.

In some instances, the levels set out below may be exceeded in the vicinity of certain outfalls, for example, those for sewage discharge. They may be regarded as limits above which intensive monitoring and further investigations need to be carried out, followed by appropriate action.

Microbiological Criteria

Beneficial use No. 2. Direct contact recreation (e.g. swimming, diving, windsurfing)

	Maximum acceptable count
Faecal coliforms per 100 ml	100 (50%)
	400 (90%)
	2 000 (99%)

Beneficial use No. 4. Collection of filter feeders for food use

	Maximum acceptable count
Faecal coliforms per 100 ml	15 (50%)
	45 (90%)

[(X%) = percentage of samples to comply with given count]

g. **Fish-tainting Substances**

Although there have been no reported cases in South Africa involving the consumption of fish and fish products contaminated with tainting substances, it is considered desirable to make a recommendation in view of the potential for such events.

Taste or odour-producing substances (whether alone or in combination with other substances), or compounds liable to give rise to such substances, should not be present at concentrations chat can cause undesirable tastes or odours in fish flesh- or other edible products of aquatic origin.

The table *on* the next page lists the concentration of chemical compounds in water and their concentrations that can cause tainting of the flesh of aquatic organisms.

Concentrations of chemical compounds in water that can cause tainting of Che flesh of aquatic organisms:

Tainting agent	y g 2 ~
acetophenone	500
acrylonitrile	18 mg£~^
m-cresol	200
o-cresol	400
p-cresol	120
cresylic acids (meta, para)	200
n-butylmereaptan	60
o-sec, butyl phenol	300
p-tery. buty1 phenol	30
o-chlorophenol	1
p-chlorophenol	10
2,3-dichlorophenol	84
2,4-dichlorophenol	1
2,5-dichlorophenol	23
2,6-dichlorophenol	35
2-methy1, 4-chiorophenol	75
2-methyl, 6-chlorophenol	3
o-phenylphenol	1 mg£~*-
2,4,6-trichlorophenol	3
phenol	1 mg£~*
diphenyloxide	50
3,3-Dichlorodiethyl ether	90
p-dichlorobenzene	250
ethylbenzene	250
ethanethiol	240
ethyiacrylate	600
formaldehyde	95 mgZ"^
petrol	5
kerosene	100
kerosene plus kaolin	1 mg£~l
isopropylbenzene	250
naphtha	100
naphthalene	1 mg^"-'-
naphthol	500
2-naphthol	300
dimethylamine	7 mg^"-*-
a-methylstyrene	250
oiL, emulsifiable	15 rag^"-*-
pyridine	5 mg-^"-'-
pyrocatechol	800
pyrogallol	20 mg£""^
quinoiine	500
p-quinone	500
styrene	250
toluene	250
outboard motor fuel, as exhaust	500
guaiacol	82

Reference: Water quality criteria, 1972. Washington DC: National

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h. Radioactive Substances

The release of radioactive materials from industry to the environment is controlled by three principles, namely, that the practice creating the effluent should be justified, that radiation doses resulting from the discharges should be kept as low as is reasonably achievable (ALARA) and that radiation dose limits should not be exceeded now or in the future in the case of all practices which result in radiation exposure.

The dose limits used to control these discharges cannot be measured physically because of the nature of the exposure routes. In practice, however, mathematical models are used to assess individual and population exposures. These models require data on the composition of the effluent, local environmental parameters and the distribution and habitats of the surrounding population. Both individual doses and collective dose commitments are obtained, the latter being used in an optimization procedure to achieve the ALARA principle.

Verification of the assessment is obtained from a programme of regular environmental monitoring of strategic links in the environmental cycle.

The concentrations of radioactive materials present shall not exceed the requirements of the Atomic Energy Corporation of South Africa.

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The Environmental Protection Authority of Victoria, Australia, provides a series of "application factors" and levels for "T", the threshold concentration of chronic sub-lethal effects. They also provide a formula for calculating the level a toxicant should not exceed, given by the value of the calculation N+(T-N)/5, where N is the natural background concentration and T is as above. The formula does at least ensure that the selected level falls between T and N with a tendency to be nearer N than T.

Table 1: Comparison of three parameters for toxic substances in the California "Ocean Plan" (1983) and the factors linking them

	Lowest toxicity data available $\mu g\ \ell^{-1}$	Factor	6 month median concentration $\mu g\ \ell^{-1}$	Factor	Average seawater concentration $\mu g\ \ell^{-1}$
As	232,0	29	8,0	5,3	1,5
Cd	6,4	3,8	2,0	20	0,1
Cr	14,6	7,3	2,0	10	0,2
Cu	6,4	2,1	3,0	1,5	2,0
Pb	26,0	2,8	9,0	225	0,04
Hg	1,6	5,3	0,3	5,0	0,06
Ni	80,0	11,4	7,0	3,5	2,0
Ag	8,0	20,0	0,4	2,5	0,16
Zn	56,0	2,7	21,0	2,6	8,0
CN	30,0	10	3,0	–	–

Table 2 shows the calculated values of toxicants listed in the California Ocean Plan using values for N and T from the "Ocean Plan" document. The levels (middle column, Table 2) do not always agree well with the six-month median concentration from the "Ocean Plan" document listed in the middle column of Table 1 above.

Table 2: Recalculation of Table 1 using formula N+(T-N)/5 where N is normal seawater concentration and T is lowest known chronic toxicity level

	"T" ($\mu g\ \ell^{-1}$)	Toxicant level (not to be exceeded) ($\mu g\ \ell^{-1}$)	"N" ($\mu g\ \ell^{-1}$)
As	232,0	47,6	1,5
Cd	6,4	1,6	0,1
Cr(VI)	14,6	3,08	0,2
Cu	6,4	2,88	2,0
Pb	26,0	5,2	0,04
Hg	1,6	0,368	0,06
Ni	80,0	17,6	2,0
Ag	8,0	1,7	0,16
Zn	56,0	17,6	8,0
CN	30,0	-	-

In view of this inconsistency a slightly different approach was used in this publication. Where a reasonable set of reliable chronic toxicity data was available - from studies on marine organisms, the Maximum Allowable Toxicant Concentration was selected as being safely below the lowest known toxic response level. Chronic toxicity is defined as an observable toxic effect after ■ exposure for an extended period of time equal to the lifespan of the organism or the span of more than one generation. Where data appeared unreliable (for example, As and Ni) a more conservative level was selected, with guidance from available water quality criteria documents.

Elements to be considered in South Africa

All the elements (and cyanide) listed on page 17 have been included as they are all considered important world-wide and are all toxic to marine life at concentrations which may be encountered in effluents. The exception to this is silver but its concentration in effluents in our coast is unknown at present. In addition, the presence of fluoride in the discharges at Richards Bay makes the inclusion of this element essential.

The inclusion of selenium in this section might be justified in view of its usage in domestic products such as hair shampoos but very little is known of the toxicity of this element or its level of occurrence in effluents. The increasing use of tin organics in marine paints with known toxicity to marine organisms also gives cause for some concern in South Africa.

Concentrations in South African waters

Concentrations of elements (as compounds) in surface marine waters of South Africa. (Where no information is available values from other countries have been used).

	Conc. in μg l^{-1}	Source
As	2,6 - 3,0	Water quality criteria (USA) 1973 and California Ocean Plan 1983
Cd	0,108 (0,103)*	SADCO
Cr	0,071 (0,024)	SADCO
Cu	0,899 (0,670)	SADCO
Hg	0,055 (0,056)	SADCO
Ni	0,563 (0,385)	SADCO
Pb	0,521 (0,50)	SADCO (probably too high; levels of 0,025 to 0,15 quoted by Scientific Group on Dumping: LDC meeting 24-28 October 1983: Review of lead in the marine environment, 74 pp)
Zn	6,59 (3,74)	SADCO
NH_3-N	0,881 (0,598)	SADCO
F^-	1 350 - 1 450	NIWR, Durban

* East coast data mean (median in brackets) with the following limits:

(a) Sample depth < 20 m

(b) Only data from stations of total water depth < 100 m were used.

SADCO South African Data Centre for Oceanology, NRIO, P 0 Box 320, Stellenbosch.

LDC London Dumping Convention, 1972.

APPENDIX II

ORGANIC COMPOUNDS AND CUMULATIVE

MATERIALS Hydrocarbons

In recent years detailed analyses of seawater as well as marine species ranging from micro-organisms to vertebrates have demonstrated the presence of hydrocarbons, both aliphatic and aromatic, which are similar in nature to petroleum and petroleum products. Also present, however, are other hydrocarbons that are characteristic of living organisms. In the open sea concentrations of hydrocarbons are generally low and the origin of these compounds is not always easily determined. By contrast, in areas affected by massive contamination the hydrocarbons may be present in high concentrations and can be directly related to particular sources of pollution. Estimates of dissolved and particulate hydrocarbons in the sea have been made by many workers; dissolved material is generally defined as that passing through a 0,45 |im pore size filter. Levels of these hydrocarbons generally represent the limit of detection of the analytical methods concerned. Contamination of samples can occur during collection and naturally occurring hydrocarbons can cause errors in analysis.

Data indicate that there is a concentration of dissolved hydrocarbons in the surface layers of the ocean and hydrocarbons have been studied in plankton in some detail. Relatively high concentrations of various hydrocarbons, both saturated and unsaturated have been reported in copepods. Pristane, an isoprenoid hydrocarbon is thought to be derived from phytol, a breakdown product of chlorophylls. Straight chain saturated paraffins are also present in trace amounts and recently Whittle (1974) found that C^g to C34 n-alkahes accounted for about 3,3 per cent (fresh weight) of plankton samples collected from the Clyde and North Sea. By contrast, cycloalkanes and aromatic compounds which are characteristic of both crude oil and refined petroleum products, are not normally present. 'Consequently the implication of oil pollution as a source of hydrocarbons in marine plankton is usually based on evidence of high levels of aromatic compounds in the test samples. It should be noted, however, tha-t polycyclic aromatic hydrocarbons of the benzoOOpyrene type have been identified by ultraviolet fluorescence in trace amounts in plankton samples from inshore areas of the Channel coast of France. The presence of these hydrocarbons does not necessarily indicate oil pollution; land drainage and human sewage are other possible sources. It is also worth noting that derivatives of aromatic hydrocarbons can occur naturally in some marine invertebrates, well known examples being quinone compounds based on napthalene, anthracene and benzo(a)pyrene. Although aromatic hydrocarbons themselves may occur in marine animals as the result of pollution they could arise from synthesis by anaerobic bacteria, particularly in animals that dwell in muds and sediments; this fact must be borne in mind if the use of monitoring organisms or indicator organisms is envisaged for monitoring quality criteria in effluents.

An important factor influencing the toxicity of an oil is the size and nature of the water-soluble fraction. This includes the light aromatic compounds, such as benzene and toluene which are rapidly lost by weathering. Also present, however, are the napthalenes and alkyi derivatives (1- and 2-methy Inapthalene, dimethyl- and trimethy1-napthalene) which are far more persistent. Boyland and Tripp (1971) noted that kerosene was more toxic than crude oil to marine fish and ascribed this difference to the relative quantities of napthalene in the aqueous extracts.

A further point concerns the toxicity of weathered oil and it is now well established that during the weathering of crude oil oxidation processes can lead to the formation of thiocyclanes and alkyl phenols. These substances may affect the toxicity of oil to such organisms as zooplankton but so far little or no work seems to have been done on this aspect.

The few studies that have been conducted with individual hydrocarbons have centred mainly on fish. Most of these studies are concerned with the carcinogen benzo(_a)pyrene either in the aquarium water or in the diet. Once absorbed, it is hydroxylated in liver, concentrated in the bile at least partially in the conjugated form and released into the gut as the gall bladder empties in response to food.

The bi~ and tricyclic aromatic hydrocarbons are among those components of oil which are toxic to fish. Although, the concentrations at which toxicity is likely to occur under natural conditions are not readily derived from the standard toxicity tests which have been carried out on oils and oil fractions, the methods are considered to be sufficiently sensitive to rank the toxicities of these test substances. In many bioassays a major problem is the difficulty of devising test conditions which are analogous to or can be extrapolated to the natural environment. Consequently, it is extremely difficult to set quality criteria for marine effluents containing organic substances.

Organochlorine residues

The organochlorines or chlorinated hydrocarbons have been produced on a large scale for several decades. The polychlorinated biphenyls (PCBs) were first introduced in the late 1920s and have been used in a variety of applications where their particular properties of chemical unreactivity and availability and range of physical states are desirable. There are special problems in analysing the PCBs and interpreting their environmental significance as they cannot be considered one discrete compound.

The DDT group of insecticides was introduced in the mid-1940s and p,p^{T} DDT itself is the most widely used member of the group. Several structurally related compounds including _£,_p'DDD, which is a metabolite of p,p'DDT, also have insecticidal properties. Cyclodiene insecticides were first extensively used in the early 1950s. Although several compounds of the group are insecticidal only three of them may be considered carcinogenic or potentially carcinogenic. These are aldrin, dieldrin and endrin. By comparison with the PCBs, both the DDT group and the cyclodienes consist of a more limited and better defined selection of compounds so that more precise information is available about their behaviour in the aquatic environment. In this respect it is easier to set water quality criteria limits.

PCBs are derived from biphenyls, the DDT group is derived from 1,1-diphenylethane and the cyclodienes are derived from l,4:5,8-dimethanonaphthalene. Ail groups share some common physical and chemical properties which arise partly from their basic hydrocarbon ancestry. The most important of these in influencing their environmental distribution are: the relative unreactivity, appreciable volatility at normal environmental temperatures and insolubility in water. Because they are unreactive and hence fairly stable in various environmental reservoirs they are persistent and are transported in vapour phase rather than liquid phase due to their volatility. Their lipid solubility accounts for their accumulation in fat reserves in marine and other organisms,

Organochlorines have been shown to produce several effects on aquatic organisms. Sub-lethal aqueous concentrations produce changes in temperature selection by fish, learning behaviour and predation by one fish on another. They also cause specific biochemical changes, the best documented of these being interference with the ATP-ases which may occur at tissue organochiorine concentrations not far above those routinely encountered. In general, it is difficult to assess the practical significance of many such experimental observations. The crucial question is whether natural tissue or water concentrations of organochlorines produce any deleterious effect at all. In this respect it is again fundamentally difficult to set quality criteria.

APPENDIX III

EFFLUENT CHARACTERISTICS AND THEIR RELATIONSHIP TO WATER QUALITY CRITERIA

1. Introduction

Normally the chemical characteristics of effluents are given in terms that are not necessarily identical to those parameters used to describe water quality. For example the oxygen demand of an effluent is normally expressed using a characteristic such as the 5-day biochemical oxygen demand (BOD5) or the chemical oxygen demand (COD). However, for water quality purposes it is important to know the amount of oxygen in solution in the water, expressed as dissolved oxygen.

The purpose of this appendix is to provide a guide, to allow standard effluent characteristics to be "translated" to the water quality parameter affected. Such a guide can never be exhaustive; however, this appendix covers most normal effluent characteristics encountered. In any event, and particularly where uncertainty exists, a chemist or chemical engineer should be consulted.

2. Effluent Characteristics and Water Quality Parameter(s) Affected

The following table has been prepared which correlates common effluent characteristics and water quality parameter affected. Details on how these can be related are given in Section 3 of this appendix. Characteristics which are obviously equivalent to water quality parameters, such as temperature, are not included.

Effluent characteristic	Water quality parameter affected*
5-day biochemical oxygen demand and chemical oxygen demand	dissolved oxygen
total dissolved solids including materials such as sodium, calcium, sulphate and chloride	salinity ALSO dissolved oxygen, colour, nutrients, toxic inorganic materials, organic and cumulative materials, fish-tainting substances and radioactive substances
pH, total alkalinity and total acidity	pH
nitrogen and phosphorus-containing fractions (e.g. Kjeidahl nitrogen, total organic nitrogen and total inorganic phosphorus)	nutrients

total solids, settleable solids and total suspended solids	turbidity and suspended solids, ALSO aesthetic criteria, dissolved oxygen, nutrients, toxic inorganic materials, organic and cumulative materials, fish tainting substances and radioactive substances

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[1] The main water quality parameter affected is indicated first. Other water quality parameters which may be affected are included under ALSO.

3. Relating Effluent Characteristics and Water Quality Criteria

3.1 Oxygen Demand

Organisms living in the coastal zone require oxygen for their well-being (see p 15). Waste materials which contain oxygen-demanding materials therefore can affect water quality. The oxygen demand of an effluent is normally expressed in terms of 5-day biochemical oxygen demand (BOD5) or chemical oxygen demand (COD). The oxygen demand of materials which decompose readily in natural surroundings (such as sewage) are suitably assessed by measuring BOD5, while those less amenable to microbiological decay are more readily measured using COD.

The discharge of oxygen-consuming waste to well-mixed and well-flushed areas is not usually a problem as oxygen is rapidly replenished. For poorly mixed systems or systems of limited volume oxygen depletion is possible.

For well-mixed and well-flushed systems, a conservative (that is, safe) assessment of oxygen demand of a waste can be made by assuming that 20 per cent is consumed during the first hour. This represents a **very** high rate of oxygen consumption. ■■ For example, for a well-designed outfall with an initial dilution of one-hundredfold and a dispersion factor of tenfold, within an hour, provide a total dilution of the waste of one thousand. For example, macerated raw sewage can have a BOD of 500 mg *t*~*- ; after one hour, the unit oxygen demand of the waste on the receiving waters would not exceed 0,5 mg/£ which is insignificant for well-oxygenated waters. The saturated dissolved oxygen content of seawater at 20°C and a salinity of 35,10"^ is 7,5 mg £ ""I and a decrease in dissolved oxygen concentration to 7,0 mg £~1 is not significant to biota.

For poorly mixed systems, the local mixing patterns must be assessed to indicate anticipated dilution and mixing with waters already partially depleted of oxygen. In addition, where potential problems with oxygen demand are foreseen, it is recommended that the precise rates of oxygen demand be assessed for the effluent in question. This information, coupled with knowledge of mixing characteristics, will enable oxygen demand to be more accurately assessed.

3.2 Total Dissolved Solids

Dissolved solids such as calcium, sodium, magnesium, chloride, carbonate and sulphate are not considered toxic, but can affect the salinity of the surrounding water. To estimate this effect the sum total of these dissolved materials must be known. This can then be compared with appropriate criteria or standards, taking into account levels of initial dilution.

3.3 pH, Total Alkalinity and Total Acidity

pH is important and satisfactory levels must be maintained in receiving waters for reasons described on p 15.

Seawater is a powerful buffer and can normally accommodate acidic or alkaline materials provided dilution is adequate. In cases where the pH of a waste is very low or very high, the most convenient way to determine the effect of the waste is to titrate samples of the waste at appropriate levels of dilution, against samples of the water into which the waste will be discharged and to follow the pH of the mixture. A knowledge of the criteria or standards to be met will then al low dilution requirements to be estimated directly.

4. Nitrogen- and Phosphorus-containing Fractions (e.g. Kjeldahl N, total organic nitrogen and total organicphosphorus)

These materials can be broadly classified as plant nutrients or "biostimulants" (see Chapter III, Section c). To assess effects the concentrations in an effluent must be compared with existing levels in the coastal zone, and with anticipated dilution.

5. Total Organic Carbon (dissolved and particulate)

The total organic carbon fraction of a waste is frequently determined in a particulate or dissolved form. Dissolved organic carbon can be considered with nutrients and other biostimulants, and therefore levels in waste, rates of decay (as measured by oxygen demand) and anticipated dilution levels are needed to assess effects.

For particulate organic carbon, consider under total solids as given below.

6. Total Solids, Setcleable Solids and Total Suspended Solids

These materials contribute to the turbidity of the receiving water, to changes in suspended solids levels in the water and to smothering the sea floor. To assess the effects of such materials, rates of settling and rates of disappearance (by dissolution or decay for example) must be known.

APPENDIX IV

ZONES OF MIXING

1. Mixing Zone Policy

C a) Mixing zones are defined areas where allowance is made for the mixing of wastes with the receiving body of water and where water quality criteria do not apply provided no recognized beneficial use is significantly threatened. It is recognized that such limited areas of mixing are unavoidable. The waters adjacent to the mixing zone should comply with the water quality criteria accorded to the beneficial use of that particular body of water.

(b) Mixing zones should be specifically designated or allowance should be made for mixing zones in the determination of effluent limitations in individual cases, subject to the following requirements:

(i) they must meet the criteria for aesthetics

(ii) they must be limited to an area or volume that will minimize interference with existing ecosystems

(iii) they must allow an appropriate zone of passage for migrating fish and other organisms

(iv) they should be designated and located to protect surface water and shallow water shoreline areas

(v) they must not diminish other legitimate beneficial uses.

(c) Mixing zones should not be allowed in instances where the substance discharged bio-accumulates in food chains, concentrates in sediments, is persistent, carcinogenic, mutagenic or teratogenic, or where the ecological or human health effects are potentially so adverse that a mixing zone is not appropriate.

(d) A mixing zone should be designated only after the applicant has demonstrated that the wastes, materials or substances which may exceed the water criteria limits are treated by all available and feasible methods before discharge.

2. Size, Location and Configuration

(a) It is clear that for a particular water body, whether it be an estuary, bay or stream, there is a limit to the extent of the intrusion of mixing zones (both individually and collectively) into aquatic habitats before populations of sensitive organisms collapse. To avoid significant impairment of aquatic ecosystems, restrictions should be placed on the net area alLocated to mixing zones both in terms of the receiving body of water as a whole and in relation to particular zones of special ecological importance.

Different segments of receiving waters often differ markedly in their ecological significance. In general, littoral zones of estuaries, bays and coastal waters are of the greatest biological importance. Accordingly, protection of such areas may require that discharge outlets be located well offshore or onshore in a receiving stream. In general, discharges within the euphotic layer have a more serious impact on the aquatic ecosystem and aesthetics than discharges to deeper water.

(b) Certain areas including spawning grounds, zones of passage and nursery areas for fish are of special significance to the aquatic life of receiving waters as a whole. In general such areas should not be intruded upon by mixing zones. Populations of sedentary and sessile benthic organisms are particularly vulnerable to the effects of mixing zones since their immobility gives rise to the possibility of long periods of exposure to water which is of sub-optimal quality and which may be toxic. Benthic populations are often important sources of food for nektonic populations such as fish, and thus have significance for aquatic populations outside their immediate location. Consequently, design and location of discharges should be such that exposure of the bottom to effluent is minimized.

(c) Where mixing zones overlap, restrictions on water quality should take into account cumulative and synergistic effects to protect aquatic life.

(d) In determining the size of mixing zones, the following should be considered:

- (i) the physical, biological and chemical characteristics of the receiving waters;
- (ii) the effects of the present and predicted discharges on the present and expected water uses and quality of the receiving water;
- (iii) the characteristics of the effluent, including flow rate and composition;
- (iv) the mixing characteristics of the receiving water; and
- (v) adequacy of the design of the outfall and the diffuser system to achieve the desired degree of dispersion and assimilation in the receiving waters.

3. **Mixing zones should be as small as is practical and should not exceed the most restrictive of the following limits:**

(a) The cumulative linear width of the mixing zone(s) intersected by any given cross-section of an estuary, inlet, cove, channel or other body of marine water measured at mean low water should not exceed 10 per cent of the total length of that cross-section, nor should the total horizontal area allocated to the mixing zone in these waters exceed 10 per cent of the surface area measured at mean low water.

(c) Within a zone bounded by the shoreline and a distance of 500 m from the shore or the 10 m depth contour, whichever is further from the shoreline, the cumulative linear length of the mixing zone intercepted on any given cross-section must not exceed 10 per cent of total width of the cross-section.

(d) For submerged discharges characteristic of most municipal and industrial wastes released from submarine outfalls, the mixing zone should be equal in depth to the depth of the water over the diffuser, in width to twice the depth of the water plus the width of the diffuser, and in length to twice the depth of the water plus the length of the diffuser, with the diffuser geographically centred within the mixing zone.

4. Initial Dilution

Initial dilution is the process which results in the rapid turbulent mixing of waste water with ocean water around the point of discharge.

For a submerged buoyant discharge, the momentum of the discharge and its initial buoyancy act together to produce turbulent mixing. Initial dilution in this case is completed when the diluting waste water ceases to rise in the water column and begins to spread horizontally.

For shallow-water submerged discharges, surface discharges and non-buoyant discharges, turbulent mixing results primarily from the momentum of discharge. Initial dilution in these cases is considered to be completed when the momentum-induced velocity of the discharge ceases to produce significant mixing of the waste, or when the diluting plume reaches a fixed distance from the discharge. This distance is specified as the width of the mixing zone.

To simplify and standardize the calculation and use of initial dilution values certain basic information is required to assist the determination of effluent limitations for the discharge. Dilution estimates should therefore be based on waste-water flow characteristics, observed receiving-water density structure, specified diffuser configuration and the assumption that no currents of sufficient strength to influence the initial dilution process flow across the discharge structure.

5. Water Quality

The quality of water within mixing zones affects not only the sedentary populations which remain in the vicinity of discharges but also nektonic species swimming through the zone and planktonic organisms entrained in the diluting waters. The severity of the effects on these organisms will depend on the duration of exposure and the concentration of toxic substances in the mixing zone. Although some free-swimming species may actively avoid mixing zones, others may be attracted by certain substances in the effluent, thus increasing the likelihood of long-term exposure.

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