The Sancor Marine Pollution Research Programme 1986 - 1990

Programme developed under the aegis of the South African National Committee for Oceanographic Research.

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PREFACE

The South African National Committee for Oceanographic Research (SANCOR) programme consists of a number of cooperative research programmes developed by the scientific community in South Africa in collaboration with the relevant decision-making bodies. These programmes are managed by the Foundation for Research Development (FRD) of the Council for Scientific and Industrial Research (CSIR). They usually depend upon cooperation among organisations and disciplines for the solution of many and diverse problems. They have also contributed to the increasing awareness by the scientific community of the value of such cooperation.

The objective of the SANCOR programme is to gain knowledge of the basic structures, processes and relationships in the marine environment around southern Africa in order to provide a fundamental scientific understanding and to facilitate:

- the efficient exploration, exploitation and conservation of living and non-living marine resources;
- the judicious management of the coastal zone;
- improved prediction of weather and climate; and
- improved utilisation of environmental information in maritime activities.

The Marine Pollution Research Programme (MPP) is one of the series of SANCOR programmes. The others in SANCOR are the Benguela Ecology Programme, Programme on Coastal Processes, Estuaries Programme, Marine Linefish Programme and the Marine Sedimentology Programme. Up to 1985 research into those aspects of oil pollution covered by the Prevention and Combating of Pollution of the Sea by Oil Act (No. 6 of 1981) has been coordinated by the SANCOR Steering Committee for Oil Pollution Research, with the financial support of the Department of Transport, and did not form part of the MPP. However, as from 1986 studies on the levels and environmental effects of hydrocarbons in the ambient marine environment will be part of the MPP (*South African National Scientific Programmes Report* No 99, Brown 1985). Close interaction is required with all these programmes as well as those of the organisations listed in Table I, which are all involved in marine pollution research as part of their ongoing activities.

The principles which have guided the formulation of other SANCOR programmes have also been used in the development of this framework for the Marine Pollution Programme by active scientists, in consultation with the appropriate statutory authorities. It is intended to serve as a general guide for research for the next five years (1986 - 1990), and to provide potential participants with a clear indication of the direction in which the programme should develop and the problem areas which should receive the most urgent attention. It should thus assist institutions or individuals already in the programme, as well as any others who wish to commence this type of research, to draw up detailed project proposals.

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1. INTRODUCTION

A useful definition of marine pollution is: "Pollution of the marine environment means the introduction by man, directly or indirectly, of substances (including micro-organisms and pathogens) or energy into the marine environment (including estuaries) which causes, or is likely to cause such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities including fishing and other legitimate uses of the sea, impairment of quality for use of sea-water, and reduction of amenities".

In the past, the effects of man along the South African coastline were limited to the major metropolitan centres. In addition to these, recent industrial decentralisation has been encouraged, with specific major developments in Saldanha Bay, False Bay, Mossel Bay, Algoa Bay, East London, the Natal South Coast, and Richard's Bay. In keeping with these developments has been an increase in the discharge of sewage and industrial effluents to sea, as well as an increased discharge via rivers of contaminants (such as biocides) into the sea. In addition, inputs from diffuse sources, such as atmospheric deposition (for example, lead) and land runoff, have also increased.

Details of specific discharges have been summarised (*South African National Scientific Programmes Report* No 39, 1979), and information on current point source discharges to the sea is available from the Department of Water Affairs. This was discussed at a workshop held in Hermanus during May 1983 (*South African National Scientific Programmes Report* No 90, Lord *et al.* 1984). In all, there are now 65 direct discharges to the sea, of which twelve are major outfalls. The largest of these are in Natal.

The current universal problem concerning the use of the sea for disposal of waste relates to the need to be able to assess properly the influence that discharges of effluent[1] or solid waste to the sea have, or could have. These discharges must then be limited to levels which can be assimilated without adverse effect by the receiving waters. The ability to absorb waste is commonly termed the "assimilative capacity" of the receiving water. It is clearly dependent on the nature of the receiving waters (especially mixing characteristics and ecological fragility), as well as on the nature of the discharge. Exceeding the assimilative capacity of a system will not only cause loss of ecological viability (with which human health problems may be associated) and aesthetic appeal, but will also incur economic and sociological penalties. Sound scientific guidance is required to control existing development and to influence future development. The Marine Pollution Research Programme is specifically directed at contributing to the pool of scientific knowledge required for management.

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[1] The term "effluent" as used in this document has been defined in the Water Act No. 54 of 1956 as amended, as "residual water or any other liquid produced by, or resulting from the use of water for industrial purposes, including any substances dissolved or suspended therein, but excluding any liquid produced for commercial purposes".

A review of existing South African legislation with respect to the control of pollution of the sea has been completed (*South African National Scientific Programmes Report* No 46, Rabie 1981) and this will be updated during the next five years. This summarises all legislation relating to the control of pollution of the sea within the jurisdiction of the Republic of South Africa. The most important Acts controlling pollution of the sea are: Water Act (No 54 of 1956 as amended, 1984), Sea Fisheries Act (No 58 of 1973), Prevention and Combating of Pollution of the Sea by Oil Act (No 6 of 1981) and Dumping at Sea Control Act (No 73 of 1980).

In addition, water quality criteria (WQC) have been proposed for the South African marine environment (*South African National Scientific Programmes Report* No 94, Lusher 1984). Such WQC provide guidelines on the limits which must not be exceeded in a particular water body if a certain end use of water is to be maintained in perpetuity. They do not have any legal status, as opposed to water quality standards, which are current legally enforceable levels established by the licensing authority. However they do play a necessary and important role in that they are required in the design of pipelines and can also be used to formulate legal standards for permit control.

2. PAST RESEARCH ON MARINE POLLUTION IN SOUTH AFRICA

The Marine Pollution Research Programme (MPP) was originally one of the seven programmes of the National Programme for Environmental Sciences (NPES). A number of the subprogrammes of the NPES have now been incorporated in other National Programmes. Thus the MPP has become part of the SANCOR Programme, due largely to the close association with the marine sciences community. This transfer was completed in April 1982, with the MPP now forming a significant component of SANCOR.

In the past, international investigations and research into marine pollution problems have been directed more frequently at those issues where gross problems have been encountered, or where catastrophic effects have been recorded. They have, in general, been limited to a fairly short list of known pollutants such as oil, radioactive wastes, chlorinated hydrocarbons and a few metals, especially mercury and cadmium. Many of these studies have been ones of problem identification and examination. In South Africa, this process has resulted in the development of valuable information on various aspects of marine pollution and it has seen the development of a number of groups of skilled scientists working around the coast.

The details of the sampling programmes that were undertaken (*South African National Scientific Programmes Report* No 51, Watling *et al* 1981) as well as compilation of the chemical methods used for analysing samples (*South African National Scientific Programmes Report* No 44, Watling 1981) have been published. Results of individual studies undertaken during this period have also been widely published. An interpretative report of all data collected during the three year period 1976 - 1979 has been completed (*South African National Scientific Programmes Report* No 73, Gardner *et al*. 1983), while an interpretative report of all data collected during the three year period 1979 - 1982 is being compiled and is scheduled for completion in 1985. In future these interpretative reports will be compiled to cover longer periods.

All data from these programmes are now being stored in the South African Data Centre for Oceanography (SADCO). Relevant historical data have also been entered in the system.

Concurrent with these developments, a considerable amount of pollution research has been undertaken which is beyond the financial support of the MPP. This work, frequently conducted under contract by various institutions, has greatly assisted in establishing a feasible approach to problems of marine pollution.

Syntheses of available information on various areas, e.g., False Bay, Saldanha Bay, Richards Bay and East London are available or in preparation.

3. OBJECTIVES

The programme sets out to advance our understanding of the occurrence and effects of marine pollution processes. The long-term objectives may be stated as follows:

> To provide a scientific understanding of the effects of waste disposal on the marine environment, in particular, the interactive physical, chemical and biological processes which occur. This understanding is directed towards providing sound scientific advice to the controlling authorities for dealing with waste disposal to the marine environment, implying that information should be presented to the controlling authorities in a suitable form.

These objectives may be very general and are broken down into closely defined, short-term goals, aimed at answering specific questions of scientific and management importance. This is done below by listing some of the major sources of pollution and the related key questions which need attention.

4. SOURCES OF POLLUTION

4.1 PIPELINES AND OTHER POINT SOURCES

Pipelines are widely used in this country for the discharge of effluents. The fact that new pipelines are being built at present, while other possible ones are being investigated, demonstrates that the use of this method of disposal could expand in the foreseeable future (*South African National Scientific Programmes Report* No 90, Lord *et al.* 1984). Other point sources of pollution include open channels or streams carrying effluent. The effects of these discharges on the marine environment clearly fall within the scope of the MPP, and a greater understanding of these effects may lead to improved guidelines for effluent disposal in the future.

Pipeline disposal relies heavily on rapid initial dilution and subsequent dispersal of an effluent in the receiving waters so as to reduce the concentrations of noxious materials. This initial dilution depends on the design of the discharge pipe, the density of the effluent, the depth

at which discharge occurs, the presence of vertical stratification in the water column and the prevailing currents. Subsequent or secondary dilution depends on the characteristics of the effluent, climatic and oceanographic conditions prevailing at and around the disposal site over a period of time.

Within the last few years, considerable progress has been made concerning the development of numerical models to assist in optimising design of diffusers to achieve maximum initial dilution. This work will naturally continue, with the results being of immediate value to the MPP. The prediction of secondary dispersion relies on a thorough understanding of the prevailing coastal processes.

Upon release to seawater, virtually all materials undergo some type of physical or chemical change, for example, precipitation, deposition, degradation, decomposition and oxidation. Since the chemical form of these materials has an important bearing on their availability and hence toxicity to biota, a proper understanding of these processes of change is important for assessing their potential effects on the environment.

4.2 NON-POINT SOURCES

An unknown amount of pollution enters the marine environment through aerial deposition as well as runoff from land based non-point sources. These include rivers, deliberate stormwater discharge, as well as seepage of groundwater contaminated by the discharge from septic tanks or soak pits. In addition, emissions to the atmosphere, for example, lead or synthetic organic compounds, can travel long distances before entering the sea and can therefore be very widespread. No guidelines exist at present for the use or treatment of such materials; particular attention needs to be paid to confined areas such as harbours, embayments and estuaries.

4.3 PETROLEUM HYDROCARBONS

Inputs of petroleum hydrocarbons to the marine environment can be classified under two broad headings: accidental and chronic. The former result from tanker accidents or accidents from drilling platforms or other oil installations. These spills may range in size from a few litres to large spectacular spills of many thousands of tons. They are unpredictable and can cause considerable environmental damage over limited areas. Chronic inputs of petroleum hydrocarbons include discharges from ships during routine operations, deliberate discharge of wastes through sewers and drains, land runoff via stormwater drains, particularly in urban areas, and atmospheric input. Chronic inputs are included in the two subsections above and are simply repeated here for emphasis.

4.4 STORMWATER DISCHARGE

Stormwater discharge can fall either in the point or non-point source category and is typified by the fact that no direct control over quality can be maintained and very little is known about the extent and characteristics of this source in South Africa.

4.5 DUMPING AT SEA

This country is a contracting party to the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter (London Dumping Convention, LDC 1972). This confers obligations on South Africa to provide input into meetings of the Scientific Group of LDC, as well as to control dumping by effective legislation. In addition, the LDC requires that contracting parties monitor the effects of waste disposal at dump sites. At recent meetings of contracting parties to the LDC a wide variety of enquiries has been generated which should be addressed by the marine science community. Difficulties also arise in the execution of national legislation (the Dumping at Sea Control Act) whereby controlled dumping of waste materials at selected dump sites is regulated, and in this respect the advice and assistance of the marine science community is required in dealing with these. Also, at present dredge spoil from most of South Africa's harbours is dumped at specifically designated dump sites. Some of these dredge spoils contain high concentrations of metals. Very little is known about the composition and effects of the dredge spoil in South Africa and it is therefore important that this source of pollution is investigated further.

4.6 SEABED ACTIVITIES

There are indications that human activities involving disturbance of the benthos are increasing in South African waters. Recent developments include seabed mining of zircon off the Natal north coast and the SOEKOR project off Mossel Bay, while diamond mining off the north west coast of South Africa is long established. The extension of mining concessions to the southern part of the west coast makes this activity of even greater importance. These seabed activities can be broadly divided into those involving penetration and disturbance of substrata and those involving the benthos only (littoral to deep-sea).

5. KEY QUESTIONS

The following key questions are considered to be important and to require answers. They are not in any order of priority since the priorities differ from place to place.

1. For pipeline discharges, how efficient is the dilution and dispersal of effluent under the most conservative conditions? In addition how closely does the behaviour of the effluent agree with the predictions of this behaviour, for example, smothering and dilution?

2. What is the effect on the environment of effluent discharged at specific coastal sites? This includes physical effects, e.g., smothering, accumulation of toxic materials in water, sediments and biota, as well as biological effects. Results must always be compared with a suitable baseline or reference. Ideally this should be obtained at the same site before discharge commences. Can discharge of effluents in the sea, e.g., from a pipeline, inhibit or prohibit exchange of organisms between estuaries and the sea?

3. Can observed effects on the marine environment be attributed to any specific component(s) of the effluent and, if so, which one(s)? This applies particularly to pipelines which discharge mixed effluents from a number of sources. Can the toxic effects of such components be reduced, for example, through pre-treatment?

4. What are the fluxes and rates of accumulation and transfer of pollutants in the environment? What are the cumulative effects of long-term discharges and what are the time scales for these processes?

5. How can information on the effects of pollutants, the mechanisms of these effects, and rates of accumulation, be put into models which would improve our predictive capabilities? How could such models help to provide better management advice and how should this be conveyed to the relevant authorities?

6. In what way can environmental considerations be incorporated into cost/benefit analyses of disposal options?

7. What are the concentrations of important contaminants in the sediments, water and biota of the South African marine environment and how are these changing with time?

8. What pollutants enter the marine environment from diffuse sources and are the amounts of these pollutants significant compared with those discharged through point sources?

9. Certain short-term comparative bioassays, which indicate the relative toxicity of various effluents, are in use at present, for example, the viability and growth of eggs and larvae of the coral reef fish *Dascyllus trimaculatus* and the sea urchin *Parechinus angulosus*. These are useful for the direct testing of the toxicity of given effluents. How can bio-assays, used as standard toxicity tests for the testing of effluents, be improved and simplified for general application? What is the relationship between these laboratory tests and field assessments?

10. Effects of effluents on the natural marine environment are difficult to detect. The usual approach is to try and relate changes in benthic community structure to the degree of stress, but efforts should not be limited to only the benthic community. Which biological testing techniques would provide the most cost-effective and realistic way of quantifying the effects of pollution in the field? A constant problem in this regard is "How hard should we keep looking for subtle effects before we are satisfied that we are implementing sufficient control over our disposal practices"? The problem of establishing when an environmental change justifies action probably remains one of the most difficult problems facing administrators. Standardisation of techniques and the statistical evaluation of results are important requirements.

11. Recent advances seem to indicate that subtle biological effects are most readily measurable at the molecular or cellular level of the organism. How are these results related to changes in community structure and what are the mechanisms by which pollutants produce these effects?

12. What is the die-off or inactivation rate of pathogenic and other micro-organisms, including viruses and parasites, present in effluents discharged at or into the sea? What factors prolong or shorten the survival of these organisms in seawater?

13. Since it is becoming generally accepted that faecal coliforms and other individual microbial indicators are not ideal indicators of sewage pollution in the marine environment, what other indicators, or range of indicators, can be used?

14. Very little is known in the South African context of the health hazards related to the accumulation of toxic substances such as mercury, cadmium and trace organic compounds, in seafoods. At what concentration in the marine environment do pathogens or chemical substances, such as non-biodegradable organic compounds or heavy metals, accumulate in seafoods to the extent that they could pose a danger to human health? Maximum permissable levels of toxic substances in seafood need to be identified and standards should be developed for application in South Africa.

15. What are the advantages and disadvantages of disinfection of effluents before discharge at or into the sea? For example, does chlorination of effluent result in the formation of polychlorinated hydrocarbons? What policy can be recommended in this regard?

16. What is the distribution of contaminants in harbour sediments? Are these materials biologically available and do they constitute a threat to the marine environment? What role does the benthic fauna play in recycling these compounds? What management proposals can be developed for improved combating of pollution within the confines of harbours? To what extent can toxic heavy metals be partitioned from the water by certain components of marine sediments such as clay minerals, humic acids, sulphides or metal hydroxides?

17. Are the existing sites used for the dumping of dredge spoil from South African harbours suitable for this purpose? If not, can alternative sites be proposed? In this regard, both water column and seafloor need to be considered. In which areas should dumping not take place under any circumstances? Where can emergency dumping, for example, from damaged chemical carriers, take place?

18. Is there a build-up of toxic material in the existing dump sites and, if so, is this likely to reach harmful proportions?

19. Upon introduction to the sea, chemical compounds can undergo a variety of changes such as precipitation, dissolution, complexation, ionisation or hydration. The resultant forms (chemical species) of such compounds will dictate their reactivity into the sea, particularly with regard to their potential for accumulation or toxic effects. This is particularly relevant for inorganic materials where activities (or effective concentrations) of a specific chemical species are to be established rather than only its total concentration. What are the important chemical species of specific pollutants in water and sediments? What are the rates of transformation of such contaminants (kinetics), and can equilibrium conditions be described (thermodynamics)?

20. The characterisation of organic matter in seawater, particularly its dissolved and colloidal components is another important aspect. In addition characterisation of organic fractions (certain lipids and steroids) for use as tracers of waste is a valuable objective. What role does this play in influencing speciation?

21. For the purposes of the MPP, assimilative capacity is defined as that level of stress which an ecosystem can absorb without causing irreversible changes within the ecosystem. An irreversible change means that the system could not recover by itself if the stress was removed - which implies either irreversible physical change and/or the decimation or loss of important (biologically speaking) species. The concept of assimilative capacity can be used as a very valuable management tool for specific areas, provided it is carefully applied. It requires, first, the definition of an ecosystem and, second, the ability to assess the cause of an irreversible change. In the open sea the system definition requires some arbitrary choice of boundaries. What techniques can be developed for assessing assimilative capacity and how can these be applied to specific areas?

22. The proposed water quality criteria do not represent actual conditions in seawater, but rather upper limits which should not be exceeded in order to maintain a specific use of that water. How can the concept of assimilative capacity be used to justify the choice of water quality criteria in the South African context?

23. How do seabed activities threaten specific areas of the environment, for example, coral reefs or growth areas of seaweed? What type of pollution occurs from these activities? How transient are these effects and can they be predicted?

24. Are seabed activities which give rise to the discharge of solid debris or chemical wastes, for example, muds or oily matter, likely to expand in such a way as to necessitate guidelines for the industry and, if so, what input can the MPP make? Are the seabed formations involved subject to hydrocarbon seeps and, if so, can this form of pollution be expected to increase in the working area?

25. What special pollution problems are faced by South African Transport Services in relation to harbours and their activities? How are contaminants contributed by the activities as well as other adjacent land-based discharges and how are the contaminants distributed? What are the best estimates of daily flux of pollutants and does their transport affect other, adjacent, areas?

26. What are the characteristics of storm water discharge from various forms of land-use areas in relation to the various climatic zones along the South African coast?

6. PRIORITIES FOR THE PERIOD 1986 - 1990

The objectives and key questions of the programme have been set out in detail. However, it is clear that, with the manpower and resources available, it will not be possible to fullfil all these objectives within

the period 1986 - 1990. Many of the key questions are open ended, while others are likely to change as more information becomes available. Therefore in this section an attempt will be made to set certain priorities.

In setting priorities, attention is first focussed on a limited number of areas which are regarded both as vulnerable to pollution and as suitable for the study of pollution processes. It is envisaged that in these areas a whole range of key questions can be addressed on an interdisciplinary and interinstitutional basis. It is thus expected that most of the field work in the programme will be concentrated in these areas and that much of the theoretical and experimental work will be related to them.

The areas thus identified are:

Natal : Richard's Bay pipelines, SAICCOR pipeline, Bluff.

Eastern Cape : South-west corner of Algoa Bay, East London.

Western Cape : Table Bay, including the harbour and Camps Bay pipeline.

Southern Cape : The Mossel Bay area.

The above areas cover all the major metropolitan industrial development areas along the South African coast. For each of these priority areas there should be development of a conceptual model showing major inputs, pathways and sinks of potential pollutants. Major harbours and dump sites for the disposal of dredge spoil must receive urgent attention. If major development takes place within the vicinity of Mossel Bay, then this should also be considered as a high priority area. There must also be an expanding emphasis on studying systems in a manner which provides the necessary predictive capabilities for the proper control of discharges at those sites. In this respect close cooperation with the Estuaries and Coastal Processes Programmes should be encouraged.

At present a considerable amount of work is being conducted to measure total amounts of materials in selected components of the ecosystem (water column, sediments, biota), mainly for heavy metals and pesticides. In addition, work is being conducted on a number of toxic elements (Cu, Hg, As, Se), to ascertain their "availability" from sediments. Virtually no work is being conducted on the chemical speciation of these materials in the water column, or on the rates of exchange and equilibria existing between various components of systems.

It should also be realised that it is the responsibility of this programme to investigate pollution problems and to provide statements on the pollution status of the South African marine environment from time to time. For this reason monitoring programmes must be set up which should be carefully planned and aimed at building up long-term data sets of selected contaminants. These should identify trends in the concentrations of contaminants, and must be anchored in the monitoring work which was undertaken by the programme during the first ten years. In addition pipeline performance evaluation studies should also form part of the programme, but surveillance of effluent quality in relation to

statutory standards is the duty of the relevant permit-issuing authorities and for the permit holders, and not the MPP.

Notwithstanding the above priorities, any large-scale pollution event which may take place in the South African marine environment should be investigated as a matter of highest priority.

7. INFORMATION TRANSFER

In the MPP it is essential that information is passed from research organisations to regulatory authorities and other interested parties in a simple, direct and easily understood manner. This is achieved through their participation in the deliberations of the Programme. It is, however, also incumbent on the scientists to present their information in a form which is clearly understood, and readily usable. Both producers and users of the scientific information should constantly strive for improved communication.

The South African Data Centre for Oceanography (SADCO) has been set up at the NRIO to receive all oceanographic data. It must be the duty of all participants in the MPP to ensure that SADCO is kept up to date and that all new data are inserted into the data bank. It is also the duty of all participants to ensure that the data which they insert into SADCO is of an acceptable standard. This can be done through participation in international interlaboratory calibration exercises.

Cooperation with neighbouring states has received scant attention in the past. Because marine pollution shows no regard for political boundaries, cooperation with neighbouring states should be actively encouraged, with the eventual aim of drawing up a regional marine pollution programme for the southern African subcontinent.

In addition the Scientific Group of the London Dumping Convention (LDC) often requests information from South Africa on matters such as the disposal of waste at sea and land-based alternatives, disposal of dredged materials and the relationships between laboratory tests and field assessments. It is the function of the Steering Committee of the MPP to ensure that information on the research direction and achievements in this country are passed on to bodies such as the LDC, through the most appropriate channels, and to ensure that information generated through the LDC is fed back to South African scientists.

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TABLE 1 : Institutions involved in marine pollution research in South Africa.

Council for Scientific and Industrial Research (CSIR)

- National Research Institute for Oceanology (NRIO)
- National Institute for Water Research (NIWR)
- National Research Institute for Mathematical Sciences (NRIMS)

Oceanographic Research Institute (ORI)

University of Port Elizabeth (UPE)

- Department of Botany
- Department of Oceanography
- Department of Zoology

University of Cape Town (UCT)

- Department of Analytical Science
- Department of Zoology

University of Stellenbosch (US)

- Ocean Engineering Research Group at the Department of Civil Engineering

Water Research Commission (WRC)

Department of Water Affairs

Department of Environment Affairs

- Sea Fisheries Research Institute (SFRI)

Department of Health and Population Development

Local authorities of all coastal towns and cities

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