Pipeline discharges of effluents to sea

Proceedings of a workshop held at Hermanus, South Africa, 24-26 May 1983

D A Lord, F P Anderson and J K Basson (Editors)

Workshop held under the aegis of the South African National Committee for Oceanographic Research

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Cover:
The pipeline at Richards Bay (photograph supplied by Dr D A Lord)

PREFACE

There are at present 61 marine pipelines in use along the South African coast for waste disposal. The majority of these are small and discharge sewage; however, the number of pipelines discharging industrial effluents is increasing. To cope with this increase in 'demand' on the use of the sea, requires the implementation of proper procedures which will result in pipelines being well designed and suitably located, and which will minimise any adverse effects of such discharges.

In South Africa, the scientific community has traditionally provided a substantial portion of the scientific and engineering research results which enable major projects such as marine pipelines to be undertaken. In recognition of the increasing complexity of involvement in such issues, the South African National Committee for Oceanographic Research (SANCOR) agreed to a recommendation by its Marine Pollution Committee (MPC) that a workshop on the marine disposal of effluents be organised. At a preparatory meeting of interested oceanologists held on 26 January 1983 during the 5th National Oceanographic Symposium in Grahamstown, it was agreed that there was value in encouraging and developing the more holistic, and predictive, approach to marine discharges, and that this could be suitably initiated at an appropriate workshop. A committee consisting of Dr J K Basson (convener), Messrs H P L Ahrens, F P Anderson, N Geldenhuys and Dr D A Lord was appointed to structure the workshop.

The title of the workshop "Pipeline Discharges of Effluents to Sea" includes all major single source discharges - primarily through pipelines, but also direct from shore, such as heated water from the Koeberg nuclear power station. The workshop was held in Hermanus, Cape, from 24 to 26 May 1983 and was structured to encourage a logical flow of information.

The first session entitled 'Marine Disposal Options' was designed to elucidate the planning procedures used in the selection of marine disposal options. The second session, entitled 'Establishing Safe Limits' was wholly technical in nature, and emphasised those aspects which need to be considered during the conceptual design phase. The third session, 'Monitoring', concentrated on the assessment of environmental effects, as well as on the hydraulic operation and structural integrity of the pipeline itself.

These proceedings contain the formal presentations made at the workshop as well as syntheses of the discussions held after each session. It is intended that these proceedings will become a useful reference work when consideration is given to new marine disposal projects.

Forty-four experts were invited to attend the workshop, including representatives from all relevant state departments, representatives of coastal industries and municipalities producing effluent, physical, chemical, biological and geological oceanographers, research engineers, consultants and contractors, as well as ecologists.
The major objectives of the workshop were

a) to establish guidelines for the optimal use of research results in making decisions concerning pipeline discharges of effluents to sea and

b) to establish the state of our knowledge, identify gaps in our understanding and to recommend further research required relating to safe discharges of effluent to sea.

ABSTRACT

The rational development of major projects involving the marine disposal of effluents by pipelines requires the close cooperation of planners, scientists and engineers.

In May 1983, a workshop entitled 'Pipeline Discharges of Effluents to Sea' was organised in Hermanus, Cape, in order to summarise the existing knowledge in South Africa on marine disposal, and to ensure the collaboration of all interested parties. These proceedings include the full submissions of all participants as well as summaries of the discussions held, and are presented within the sections: Marine Disposal Options; Establishing Safe Releases; and Monitoring.

OPSOMMING

Die rasionele ontwikkeling van belangrike projekte wat betrekking het op afvoer van uitvloeisels na die see deur middel van pyplyne, vereis noue samewerking tussen beplanners, wetenskaplikes en ingenieurs.

'n Werksessie met die tema 'Pipeline Discharges of Effluents to Sea' is gedurende Mei 1983, in Hermanus, Kaapprovinsie, gereël met die doel om kennis wat tans in Suid Afrika bestaan oor afvoer na die see op te som en ook om die samewerking van alle belanghebbende partye te verseker. Hierdie verrigtinge sluit die volledige voorleggings van al die deelnemers in sowel as opsommings van die besprekings wat gehou is en word aangebied in die afdelings: Mariene Verwyderingskeuses (Marine Disposal Options); Vasstelling van Veilige Vrylatings (Establishing Safe Releases) en Monitering (Monitoring).

ACKNOWLEDGEMENTS

The workshop was organised by the Marine Pollution Programme of the South African National Committee for Oceanographic Research. Funds for research undertaken through the Marine Pollution Programme are derived from the Department of Environment Affairs and their continual involvement and support are gratefully acknowledged.

A report of this workshop would not be complete without the organizing committee expressing its gratitude to all those who participated in the workshop and to their making it interesting and informative. They say a picture is worth a thousand words, and so many thousands of words were saved by taking a group photograph of those attending the workshop.

Special thanks are due to Mrs Hanny Ridder for preparing preliminary and final manuscripts, and to Mrs Ansie Wolvaardt and Miss Annette Schnetler for their organization of the meeting.

TABLE OF CONTENTS

	Page
PREFACE	(iii)
ABSTRACT	(v)
OPSOMMING	(v)
ACKNOWLEDGEMENTS	(v)
INTRODUCTION - PIPELINE DISCHARGES OF EFFLUENTS TO SEA : J K Basson	1
MARINE DISPOSAL OPTIONS	
THE RATIONALE BEHIND REGIONAL DEVELOPMENT IN ITS COASTAL CONTEXT : N Viljoen	6
THE ROLE OF THE DEPARTMENT OF ENVIRONMENT AFFAIRS IN INDUSTRIAL DEVELOPMENT AT THE COAST : G C D Claassens and H J Best	10
A REVIEW OF ALTERNATIVE DISPOSAL OPTIONS: CASE STUDY OF WASTE DISPOSAL IN DURBAN : D C MacLeod	15
THE PARTICIPATION OF THE SCIENTIFIC COMMUNITY IN DECISIONS CONCERNING DISCHARGES : D A Lord	19
RAPPORTEURS' COMMENTS ON DISCUSSION : A M Little and N Geldenhuys	26
ESTABLISHING SAFE RELEASES	
TECHNICAL CONSIDERATIONS - AN OVERVIEW : F P Anderson	27
ESTABLISHING SAFE RELEASES - OCEANOGRAPHIC CONSIDERATIONS	
NEARSHORE OCEANOGRAPHY : E H Schumann	29
CHEMICAL ASPECTS OF DISCHARGES : G A Eagle	32
BIOLOGICAL ASPECTS OF DISCHARGES : A C Brown	35
RAPPORTEURS' COMMENTS ON DISCUSSIONS : R J Watling and G Brundrit	39

ESTABLISHING SAFE RELEASES - WATER QUALITY CONSIDERATIONS

RELEVANT TOXICITY TESTING: RICHARDS BAY AS A CASE STUDY : A D Connell 40

ASSESSMENT OF SAFE DISCHARGE LIMITS IN THE NUCLEAR INDUSTRY : D van As 42

THE CASE FOR WATER QUALITY CRITERIA FOR SOUTH AFRICAN MARINE WATERS : D A Lord 50

RAPPORTEURS' COMMENTS ON DISCUSSION : A G S Moldan and D van As 57

ESTABLISHING SAFE RELEASES - PHYSICAL, ENVIRONMENTAL AND ENGINEERING CONSIDERATIONS

ENGINEERING DESIGN : K S Russell 58

SEA-BED INVESTIGATIONS FOR OCEAN OUTFALLS : B W Flemming 63

PIPELINES IN THE SURF ZONE : D H Swart 68

SUBMARINE PIPELINES: PRACTICAL CONSIDERATIONS IN THEIR DESIGN AND INSTALLATION : A Moss-Morris 73

RAPPORTEURS' COMMENTS ON DISCUSSION : H P L Ahrens and G de F Retief 78

MONITORING

THE PHYSICAL TESTING OF PREDICTIVE MODELS : G de F Retief and G K Prestedge 79

ENVIRONMENTAL MONITORING: THE DESIGN OF SAMPLING STRATEGIES : T C Gilfillan 85

THE MONITORING OF DISCHARGES FOR COMPLIANCE : J A Lusher 91

RAPPORTEURS' COMMENTS ON DISCUSSION : R P van der Elst and G C D Claassens 97

CONCLUSION 99

LIST OF PARTICIPANTS 102

TITLES IN THIS SERIES 106

INTRODUCTION - PIPELINE DISCHARGES OF EFFLUENTS TO SEA

J K Basson

INTRODUCTION

The use of the sea for the disposal of man's waste products has always been a matter for argument between planners and ecologists. Although in recent years much progress has been made towards a better understanding of the scientific aspects, the biggest problem is still to incorporate the complex real oceanographic data into predictive models.

SANCOR

In South Africa the National Committee for Oceanographic Research (SANCOR) coordinates oceanological investigations with the following overall objective:

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;
- the fuller understanding of climate; and
- improved utilization of environmental information in maritime activities.

Consequently, six main programmes have been constituted: Benguela Ecology, Coastal Processes, Estuaries, Marine Pollution, Marine Linefish and Marine Sedimentology.

MARINE POLLUTION PROGRAMME

Review

The Marine Pollution Programme (MPP) initiated a survey in 1974 to determine and assess the sources, concentration levels, pathways and consequences of pollutants in impact areas, in estuaries and at coastal and ocean reference stations around the coast of South Africa. Information obtained up to 1975 showed that, in general, the South African coastline was relatively unpolluted, except for a few isolated instances (e.g. Table Bay, Durban Harbour, and East London). Since then, the pace of coastal industrialization has increased, and substantially more discharges are reaching the sea. The MPP expanded its surveys, culminating in a 3-year monitoring programme which ended in April 1982. The results for this period 1976-1982 are currently being compiled in two separate interpretive reports, while specific details have been published by participating groups. All data for these programmes are now being stored in the South African Data Centre for Oceanography (SADCO) data base management system, while all historical data should be in the system by March 1984. During the last five years, emphasis on estimating the fate and effects of discharges has increased. This type of work, which relies heavily on sophisticated techniques for chemical analysis, and the measurement of sub-lethal effects, is essential in developing predictive skills. At the request of the Department of Transport (DOT), the MPP has also become involved in research in various aspects of oil pollution arising from ships.

During this process of evolution, four major groups have associated themselves with the programme: the Sea Fisheries Research Institute (SFRI), the National Research Institute for Oceanology (NRIO), the National Institute for Water Research (NIWR), (Durban) and, more recently, the University of Port Elizabeth (UPE). Previously, the National Physical Research Laboratory (NPRL) also participated in the programme.

Monitoring

Monitoring changes (or the lack thereof) with time will always be an integral part of a pollution-oriented programme. However, its relative contribution should be limited. To date, monitoring in South Africa has been primarily of a chemical nature, by the measurement of total concentrations of various chemical compounds, and to a lesser extent, on biological indicators such as the structure of selected communities of organisms.

All groups have developed and demonstrated skills for the analysis of low levels of heavy metals and nutrients while, in addition, emphasis on the detection and measurement of organic pollutants (especially hydrocarbons, and biocides) is now being included in the programme. The analysis of meiofaunal communities has become an accepted technique for estimating the level of organic enrichment of sandy substrates.

The monitoring of the effect of sewage discharges to the sea is accomplished primarily through measuring bacterial content of seawater; procedures for the assessment of relative pollution of nearshore waters have been developed mainly by NIWR in monitoring the effects of the Durban sewage outfalls.

Specific Studies

Based on current knowledge, the South African marine environment is still relatively unpolluted except for a few specific areas. The most obvious pollution problem is oil, with about 38% of the world movement of oil by sea transported around the Cape of Good Hope in 1977 (c.f. the disastrous Venpet-Venoil collision on 16 December 1977); specific attention is therefore given to oil pollution by a special steering committee.

Whereas a reference background has been established and sites of major pollution concern identified, the programme has now been directed into conducting detailed surveys in areas specifically designated by the Department of Environment Affairs as important. The purpose of these surveys is to develop the necessary information upon which planning and control efforts can be based. Currently, attention is focussed on important site surveys i.e. Table Bay, East London, Richards Bay, False Bay and Saldanha Bay.

Oil Pollution research is financed by the Department of Transport and managed by the MPP, including an aquarium facility; the Sea Fisheries Research Institute conducts appropriate research on effects of oil pollution, which it funds itself. Every effort has been made in this programme to produce results which would be of optimum use to the DOT. With the successful completion of the earlier phase where the effect of oil on various organisms and systems was assessed, most of the emphasis of the current and future projects will be placed on the specific information needed for the compilation of contingency plans. This does not, however, mean that research of a more fundamental nature will necessarily be given a lower priority. Recommendations have been made for attention to be given to problems which might have particular relevance to South Africa, such as the chronic effects of oil on pelagic fish eggs and larvae or on sensitive areas such as estuaries.

Fate and Effects of Discharges.

Upon release into seawater, virtually all materials will undergo some type of change (e.g. precipitation, degradation, decomposition). In addition, as availability to organisms and toxicity of these materials is totally dependant on their chemical form, the proper understanding of these processes of change is important especially for potential contaminants. At present, work is being conducted to ascertain the 'availability' of a number of toxic metals (Hg, As, Se) from sediments, as well as concurrently devising a numerical method of assessing the relative 'pollution status' of nearshore sediments by taking into account the natural origin of such trace metals.

Considerable development of methods for measuring the effects of effluents (i.e. toxicity) has occurred; specifically the assessment of sub-lethal effects in the laboratory. To date, a suite of measurement techniques has evolved, which take into account differences in coastline as well as in locally abundant and sensitive organisms.

Interaction with Other Programmes

The MPP shares common interests with most of the major SANCOR programmes (Estuaries, Coastal Processes, Benguela) as well as with numerous other programmes in and out of the CSIR. Programmes ouside of SANCOR of direct relevance to the MPP, are the Marine Disposal Programme (NRIO contract), and the National Materials Programme, which is placing emphasis on the reutilisation of waste materials currently being discharged into the sea, particularly sewage sludge and phosphogypsum. In addition to institutional reports and conventional publications, MPP results have also appeared as South African National Scientific Programmes Reports:

No 5. Bibliography on marine pollution in South Africa. D A Darracott and C E Cloete. June 1976. 131 pp.

No 8. South African marine pollution survey report 1974-1975. C E Cloete and W D Oliff (editors). September 1976. 60 pp.

No 39. The Transfer of Pollutants in Two Southern Hemispheric Oceanic Systems. Proceedings of a workshop held at Plettenberg Bay, South Africa, 23 - 26 April 1979. 188 pp.

No 41. Bibliography of Marine Biology in South Africa. D A Darracott and A C Brown. 250 pp.

No 44. A manual of methods for use in the South African Marine Pollution Monitoring Programme. R J Watling. July 1981. 82 pp.

No 46. South African legislation with respect to the control of pollution of the sea. André Rabie. January 1981. 73 pp.

No 51. South African Marine Pollution Monitoring Programme 1979-1982. R J Watling and C E Cloete (editors). July 1981. 52 pp.

FUTURE DEVELOPMENTS

To a large extent, much of the traditional work related to pollution has been an assessment of effects after the fact. The fullest potential of this programme will be reached when predictive capability exists. At present there is a well experienced group of workers in this field in SA and the intention is to build upon these skills, supplemented with a greater contribution of physical measurements as well as a greater reliance on the systematic analysis of problem situations (as handled by conventional systems analysis and critical path analysis). Perhaps the best illustration of this type of approach of marine discharges can be taken from the atomic energy community e.g. the pre-operational investigation of safe radioactive releases to the sea from the Koeberg nuclear power station.

The capacity of an environment to accept radioactivity safely, in addition to that naturally present, depends on various local factors such as dispersion conditions, the habits of the local population and the accumulation of pertinent radionuclides by critical organisms. These factors were investigated for Koeberg by means of surveys, as well as by analyses to determine concentration factors for various stable elements in edible marine organisms. This investigation provided reasonable estimates for safe release rates of 19 radionuclides considered to be pertinent. Subsequently, a considerably more stringent regulatory limit was prescribed, which will be controlled by post-operational monitoring of the critical pathways.

Unfortunately, the planning and even construction of conventional marine discharge facilities often take place without due regard to the resulting ecological aspects which are left in abeyance until the plant is in operation, at which time curtailment of effluent releases can be effected only at great inconvenience and cost.

MARINE POLLUTION WORKSHOP

Consequently, SANCOR agreed to a recommendation by its Marine Pollution Committee that a workshop on the marine disposal of effluent be organised. A meeting of interested oceanologists during the 5th National Oceanographic Symposium (24 - 28 January 1983, Grahamstown) agreed that there existed a need to further develop and encourage a more holistic (and predictive) approach to marine discharges, as well as to provide specific recommendations concerning the management of coastal discharges; an ad hoc group, consisting of Dr J K Basson (convener), Messrs H P L Ahrens, F P Anderson, N Geldenhuys and Dr D A Lord, was appointed to structure the workshop.

The title of the workshop "Pipeline Discharges of Effluents to Sea" includes all major point source discharges - primarily through pipelines, but also direct discharges from shore (e.g. Koeberg).

The objectives are:

- to establish guidelines for the optimal use of research results in making decisions concerning pipeline discharges of effluents to sea

- to establish the state of our knowledge, identify gaps in our understanding and recommend future research priorities relating to safe discharges of effluent to sea.

Persons who have been invited to attend include representatives of relevant state departments, representatives of coastal industries and municipalities producing effluent, physical and chemical oceanographers, engineers (research as well as consulting) and biologists/ecologists.

The workshop has been structured to produce summaries of each session to be compiled as a final document emphasizing

- the provision of guidelines to decision-makers on the use of environmental information

- the provision of information on the full extent of the available scientific information for use

- the setting of priorities for research

- ensuring close association between various disciplines.

THE RATIONALE BEHIND REGIONAL DEVELOPMENT IN ITS COASTAL CONTEXT

N Viljoen

THE HISTORICAL BACKGROUND

Coastal Development

All over the world coastal cities developed as fortresses and later as commercial gateways at strategic locations to serve specific hinterlands along transportation axes. This pattern also developed in southern Africa, but with two major differences.

RSA Uniqueness

Whereas the world's ports developed almost exclusively at river estuaries with these waterways as the backbone of the transportation system to the interior, only one of our harbours is truly river-based and the water transport mode is non-existent. Furthermore, in the whole world only South Africa has more than half of its economic activity concentrated in one overpowering metropolitan complex on a high plateau some 2000m above sea level and 700 km from the coast. As the coastal cities represent about one quarter of the national product, the order of our transport linkage problems to and from the PWV-complex become abundantly clear.

Location of Ports

Fortunately however, our port cities are well situated and strategically placed to serve their respective hinterlands. For decades these harbours primarily handled the import of capital goods in the early developmental phases (Cape Town to Kimberley and Durban to Johannesburg) as well as creating opportunities for exporting primary agricultural products such as wool (Port Elizabeth).

As the country developed, the export of other mass cargo became possible (East London grain terminal) and the import of semi-processed raw materials stimulated manufacturing industry (Port Elizabeth motor industry). As import substitution developed on a vast scale, the competitive advantages of some of our coastal cities changed and declined until their export function has now become their real competitive advantage.

The Mass Cargo Gap

After the second world war it became evident that the capacity of our harbours would soon become insufficient and their capacities have since been greatly increased by enlargement and modernisation as well as containerisation. However, due to physical limitations and harbour-bound development over many years, South Africa could not compete in a new world trade structure based upon modern mass-handling and transportation techniques resulting in surprising economies of scale and low unit tariffs.

South Africa's economic future will be determined amongst others by her capability to continue to exploit her mineral resources, to beneficiate them and to market them competitively on world markets. To this end it was essential to develop two completely new harbours, Richards Bay on the east coast, and Saldanha on the west coast. These two deep-water harbours are now the latest addition to our strategic gateways to the world as well as to the whole of southern Africa in our bid to remain internationally competitive.

THE GOOD HOPE PLAN

The National Physical Development Plan

The National Physical Development Plan (NPDP) is now being revised after its first publication in 1975. This document propagated the concept of regional development not only to assist in the spatial planning of the country, but also to direct the translation of such guidelines into co-ordinated development strategies. It is therefore not surprising that the NPDP forms the basis of the new Regional Development Strategy.

The Regional Concept

At this particularly specialised forum, it is only necessary to acknowledge that in all countries the natural over-concentration of economic activity in a few major conurbations and the lagging of backward areas need to be progressively balanced, in order to attain the optimum potential development of the whole country and to alleviate the costs of over-concentration in one or two metropoles. It is also the only way in which the multi-national and ethnic character of southern Africa can duly be acknowledged, and the rapid rate of urbanisation rationally planned.

The Good Hope Plan

One of the main facets of the Good Hope Plan is thus structured upon this regional development concept, with eight Development Regions identified - each with its own homogeneity, hierarchy of nodal points, development opportunities and constraints. A Regional Development Advisory Council has been instituted for each region to enhance the local content of proposals, to formalise and strengthen the advisory channels to central government and to create the necessary consultative ability on the regional level. On the national level a National Regional Development Advisory Council has been instituted.

The Industrial Development Component

The first component of a total development strategy has now been operative for more than a year, namely the industrial decentralisation initiatives with incentives to private enterprise which are considered to be of the highest level and sophistication worldwide. The Government's sincerity and commitment to this programme is illustrated by several fundamental policy issues.

Firstly, the need has been reconfirmed to concentrate effort towards regions on broad priorities based upon their relative needs. Secondly, to concentrate progressively upon only a few centres with the inherent potential for growth, thereby recognising and acknowledging the ability of any government to allocate sufficient scarce resources only on a limited scale to mobilise private sector investment. Thirdly, the need to reinforce the on-going development of the neighbouring states.

These parameters have led to the highest priority for two coastal regions, namely Region D (Eastern Cape-Transkei-Ciskei) and Region E (Natal-Kwazulu-Transkei).

Deconcentration and decentralisation

No country can hope to alleviate its problems of regional disparity without a carrot-and-stick policy. The government's declared intention has therefore always acknowledged the role of our large metropolitan conglomerations but has reaffirmed the need to institute wide-ranging negative control measures without seriously affecting their inherent economic strength.

On the incentive side, deconcentration points, still within the influence sphere of the metropoles, have been most successful. Selected decentralised development centres far away from the metropoles, with their own specific advantages and opportunities, have had to be underpinned with higher incentives and the provision of an infrastructural base, both physical and social.

The most important medium-term goal is still to create balancing growth poles with their own regional potential to develop into future metropolitan areas in their own right with their own hinterlands in order to really compete with the existing urban conurbations.

REGIONAL PRIORITIES COASTWISE

Against this background one can now evaluate the role of coastal development.

Three future metropolitan complexes have been indentified, namely Richards Bay, East London and Saldanha. Unexpectedly perhaps, all three are on the coast and two are identified with the Development Regions with the highest South African priority. Both Richards Bay and East London are also associated with the neighbouring states with the highest needs to create employment. The most urgent development pressures in just about every sector are manifested in these regions.

Sectoral development is insufficient and the pressing need for "total" development has brought a new sense of urgency to these regions and to the identified development points. The constraints can therefore be more clearly outlined and the development strategies more clearly formulated as comprehensive co-ordinated action programmes.

A further five development points with future coastal impacts have also been declared, namely Tongaat, a deconcentration point South of Durban, a Natal South Coast centre, a Pondoland (Transkei) point, and George. The deconcentration point Atlantis on the developing West Coast axis to Saldanha, also has an important coastal component. (Mossel Bay may of course develop on its own account if exploitable gas or oil strikes continue).

At all these centres special incentives apply and the government will assist in the provision of physical and social infrastructure on a priority basis in order to fulfill its basic function to create the atmosphere of assurance and the physical structure for private sector initiatives.

Considering then the inevitable need to set priorities due to the limited scarce recources, and the need to ensure our international competitive advantages, what should the oceanographic community and the coastal planners be concentrating upon?

- Become acutely aware of the needs of the existing three coastal metropolitan regions, the optimum reactive solutions to their inevitable growth problems, bearing in mind the government's differential attitude towards each of them.

- Associate own priorities closely with the front-end needs of the three developing metropolitan areas as expressed from time-to-time by government directives, regional strategies and guide plans.

- Evaluate sectoral opportunities or constraints in terms of these parameters e.g. coastal conservation initiatives, recreation centres, small-craft harbours and other seaside facilities, littoral mineral exploitation, marine defences, international trade and shipping, nuclear energy, etc.

- Direct research priorities within these broad guidelines, and assure the high technology know-how upon which better informed policy-making and decision-taking will need to be based in formulating the country's grand policy.

- Ensure that one of the few international competitive advantages, namely Southern Africa's capacity still to accept pollution in several sectors, is developed in a responsible way, amongst others by structuring a sound framework for marine discharges.

THE ROLE OF THE DEPARTMENT OF ENVIRONMENT AFFAIRS IN INDUSTRIAL DEVELOPMENT AT THE COAST

G C D Claassens
H J Best

INTRODUCTION

The siting of industrial development in the Republic has been and will undoubtedly for some time to come, be governed by the socio-economic and political factors prevailing in the country. To date, water legislation and especially pollution control considerations, have played a relatively minor role as factors influencing the siting of industries.

E.g. Growth areas such as Richards Bay, East London (Berlin) and Hammersdale were selected on socio-economic and political grounds. In all these cases the State provided either directly or indirectly the necessary infrastructure including, as in the case of Richards Bay and Berlin, facilities for effluent disposal to sea.

ROLE OF THE DEPARTMENT IN SITING OF INDUSTRIES

The Minister of Environment Affairs and Fisheries is empowered by the Water Act of 1956 to regulate the siting of industries. In terms of section 12 of the Act, any person who desires to establish or expand an industrial undertaking which will use more than 300 m^3 of public water on any one day, or an average of 250 m^3 per day over one month, must apply for a permit to authorise such use. The Minister is required in the act to consider such application with due regard inter alia whether it would not be desirable in the public interest or with a view to the decentralization of industries or the nature of the wastewater effluent or waste which will be occasioned by the operation of the industry etc. ....that the industry be established at a place other than the place stated in the application.

The Minister has already publicly declared that the aforementioned consideration should and would receive greater attention in future, especially in the light of the rapidly increasing salinity hazard to which the country's fresh water resources are being exposed.

Industries producing highly saline effluents or effluents containing intractable yet non-toxic organics, would for example be a natural selection for siting at growth points near the coast from where effluents could be safely disposed of to sea.

In terms of the Physical Planning Act (Act 88 of 1967), the establishment of industries outside proclaimed industrial areas is subject to approval by the Department of Industries, Commerce and Tourism. An inter-departmental advisory committee, the so called committee of 7, was established to consider applications. The Department of Environment Affairs is represented on this committee and would in future place much larger emphasis on the nature of wastes or effluents that would be generated by applicants. Such wastes or effluents will either have to be purified to higher standards of purity if so demanded by environmental conditions at the site stated in the application and/or approved by the other members of the committee on the basis of socio-economic or political considerations, or the applicant would have to move to another site of his choice where wastes and effluents could be safely accommodated from an overall environmental and ecological point of view.

PROVISIONS IN WATER ACT, 1956 FOR DISCHARGES TO SEA

Section 21 of the Water Act, 1956 contains two basic requirements in respect of industrial users of public water, including sea water. Non-compliance with any one or both of these two basic requirements is subject to exemption through a permit issued in terms of section 21(5) of the act. These basic requirements can be summarized as follows:

- All public water abstracted for industrial use should be returned to the nearest point of the bed of the public stream from which water was abstracted; or if abstracted from the sea, to the sea;

- All effluents must be purified so as to conform to the requirements as the Minister may from time-to-time, after consultation with the S.A.B.S., prescribe by notice in the Government Gazette.

The above basic requirements do not apply in respect of a person supplied with water by the Minister or by any local authority having the right to control and supply water from whatever source within its area of jurisdiction, if the Minister or, as the case may be, such local authority, has undertaken the duty of disposing of effluents and accepts the effluents into any sewer under the control of the Minister or the local authority. In these instances the owner of the sewer is responsible to meet the requirements of the Water Act.

Any industry which is supplied with fresh water and wishes to discharge effluents to sea, requires authority for such discharge through an exemption permit issued in terms of section 12(5) of the act. If such discharger uses sea water and the seawater is being contaminated in any way through usage, a permit would likewise be required.

The Minister must consider applications for exemptions for discharge to sea with due regard to the regulations made under section 10(1) of the Sea-Shore Act, 1935 (Act No. 21 of 1935) and section 13(1) of the Sea Fisheries Act, 1973 (Act No. 58 of 1973), and shall not issue such a permit unless he is satisfied that any point fixed by him for discharge to the sea is in such proximity that it is unlikely that any person will be prejudicially affected and that the dilution of effluent by sea water or other water will be such that marine fauna or flora will not be detrimentally affected. The conditions imposed in connection with any such permit must at least be as effective for the purpose of preventing pollution as any conditions or requirements which may have been recommended by the S.A.B.S.

STANDARDS FOR SEA DISCHARGE

Effluent standards promulgated to date are intended to regulate effluent discharges to fresh water resources and are not applicable to sea discharges. No standards nor guidelines for sea discharges under South

African conditions are currently available to guide the Department of Environment Affairs in considering permit applications.

EVALUATION OF DISPOSAL OPTIONS

In evaluation of disposal options along the coast, the potential reclamation and re-use of effluents, especially domestic sewage effluent, receives first priority. None of our coastal areas are blessed with unlimited fresh water supplies. Sooner or later, the limited supplies will have to be supplemented by effluent reclamation and re-use. Considerable savings in capital expenditure on new and expensive water supply schemes can already be affected by effluent reclamation and re-use. For example, a feasibility study on the reclamation and re-use of sewage effluents in the East London area is presently being carried out with the eye on a possible postponement in construction of the rather expensive Amatole Government Water Scheme. Should the option of sea disposal be allowed on the grounds of short term benefits to the discharger, permission for such discharge will never be granted in perpetuity. The validity of permits will be made to expire after sufficiently short intervals of time to facilitate reassessment of options on a reasonably continuous basis.

ISSUING OF DISCHARGE PERMITS

Due to the lack of qualitative guidelines for the discharge of effluents into our coastal waters, the Department reverts to consultation with various authoritative organizations wherever the option of sea disposal is allowed. In these consultations, as wide a spectrum of appropriate disciplines as possible is being involved. Factors which normally receive consideration are the following:

(a) The highest quality of effluent obtainable with the "best practicable means" at the disposal of the applicant and the toxicity of this highest obtainable quality;

(b) The oceanographic properties of the point of discharge. i.e. direction and strength of prevailing currents and prevailing winds.

(c) The maximum concentration of various effluent constituents that can be tolerated at any particular point of discharge without creating distress to the marine fauna and flora at that particular point. The E.P.A. guidelines are often consulted in this regard.

(d) The engineering properties of the pipeline that would through dilution with sea water, achieve the required safe concentration of hazardous constituents. i.e. length of pipeline into the sea, depth of water above point of discharge and configuration of dispersers if any.

(e) The extent and nature of monitoring required to control the efficiency of discharge.

The number of sea outfalls presently discharging into our coastal waters, is indicated in Table 1. Figure 1 shows the approximate location of some of the major outfalls.

Table 1: Sea outfalls along the South African Coastline

Type of outfall	number	Average daily discharge in m^3/d
Domestic sewage	22	66 000
Domestic sewage containing industrial effluents	9	355 000
Industrial effluent	30	232 000

Apart from limitation in the validity of permits, permits for sea discharge would normally contain conditions in respect of the minimum frequency of monitoring of the sea environment at the outfall; the extent and nature of monitoring (e.g. sediments and water column as well as indicated organisms); the frequency of inspection of the pipeline for mechanical damage and quality and quantity of effluent that may be discharged into pipelines. It is also required from dischargers to continuously improve the quality of effluents through the best practicable means at their disposal

CONCLUSION

Monitoring results at most of the sea-outfalls have up till now indicated that little hazard is caused to the sea environment in the vicinity of the outfalls. Damage to fauna and flora, if any, was in most cases limited to small areas in the immediate surroundings of the point of discharge.

These optimistic findings should however never cause grounds for complacency as our coastal waters cannot be expected to have an unlimited capacity to absorb pollutants without ill effects.

The Department therefore strongly supports any effort directed towards the establishment of guidelines for the discharge of effluents to sea along the coast.

ACKNOWLEDGEMENT

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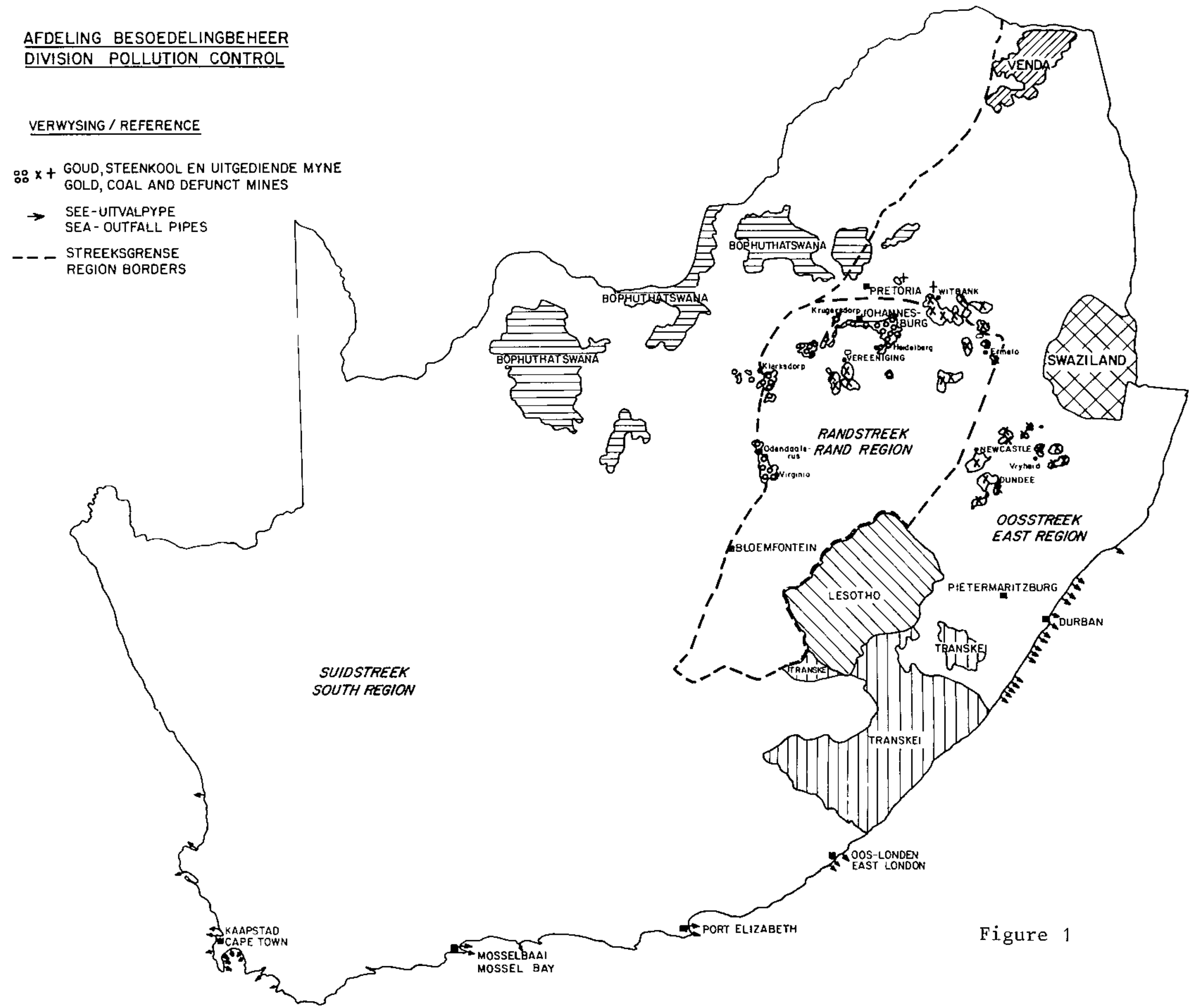
AFDELING BESOEDELINGBEHEER
DIVISION POLLUTION CONTROL
VERWYSING / REFERENCE
GOUD, STEENKOOL EN UITGEDIENDE MYNE
GOLD, COAL AND DEFUNCT MINES
SEE-UITVALPYPE
SEA-OUTFALL PIPES
STREEKSGRENSE
REGION BORDERS
VENDA
BOPHUTHATSWANA
BOPHUTHATSWANA
BOPHUTHATSWANA
PRETORIA
WITBANK
Krugersdorp
JOHANNES-BURG
Heidelberg
VEREENIGING
Ermelo
SWAZILAND
Klerksdorp
RANDSTREEK
RAND REGION
Odendaals-rus
Virginia
NEWCASTLE
Vryheid
DUNDEE
OOSSTREEK
EAST REGION
BLOEMFONTEIN
LESOTHO
PIETERMARITZBURG
DURBAN
TRANSKEI
TRANSKEI
TRANSKEI
SUIDSTREEK
SOUTH REGION
OOS-LONDEN
EAST LONDON
PORT ELIZABETH
KAAPSTAD
CAPE TOWN
MOSSELBAAI
MOSSEL BAY

Figure 1

A REVIEW OF ALTERNATIVE DISPOSAL OPTIONS: CASE STUDY OF WASTE DISPOSAL IN DURBAN

D.C. Macleod

This paper is a review of the alternative methods of disposal of sewage sludge in Durban and an assessment of the feasibility of each of these, followed by reasons for the selection of a marine disposal option.

Durban is divided into four main catchment areas and these will be dealt with separately.

CENTRAL WASTE WATER TREATMENT WORKS

This Works is situated on the seaward side of the Bluff and the total site area is only 3,25 ha, of which 0,4 ha is available for sludge treatment. The ultimate design inflow to the Works is 140 000 m^3 per day Average Dry-weather Flow (A.D.F.) and it will be appreciated, therefore, that the available site area is extremely limited.

Sludge treatment on this site comprises passing the clarifier underflow through Dorclones and a grit classifier to 15 m diameter thickeners from which the thickened sludge is pumped through disintegrators to Mercobowl centrifuges. The dried slugde is fed to a fluidised bed incinerator which has a capacity of 35 000 kg solids per day and operates at a temperature of 800°c. The ash is carted from the site to a refuse dump.

The total cost (1968 prices) of the sludge treatment facility was R1 212 842 and because the thickener overflow and centrate could be bled back to the sea outfall from which the settled effluent was discharged, it was possible to adjust the use of polyelectrolyte and furnace fuel so as to obtain the most economical operation of this plant.

SOUTHERN/NORTHERN WASTE WATER TREATMENT WORKS

The sludge treatment plant for these two Works was purchased under combined contracts and the processes, therefore, were initially similar. The ultimate design capacity of the Southern Works is 360 000 m^3 per day A.D.F., of which it is intended that 140 000 m^3 per day will ultimately be reclaimed for industrial usage with the balance of the effluent being discharged to sea through a sea outfall. At both plants sludge digestion in the mesophyllic range is provided.

Initially, thickeners were provided at the Southern Works to thicken the sludge from 4 to 6%, and the digested sludge was treated in Porteous Heat Treatment Plant, whereafter the sludge was dried in filter presses. The initial capacity of this plant was sufficient to handle sludge from a daily sewage flow amounting to 90 000 m^3 and the cost of the plant (1968 prices) was R2 050 050.

Problems were experienced with breakage of press plates and an Alpha-Laval Centrifuge with a capacity of 500 kg dry solids per hour was installed as a trial to operate in parallel with the filter presses. The cost of this installation at 1973 prices was R34 300. As a result of this experimental work, a Sharples Centrifuge with a capacity of

1 000 kg dry solids per hour was installed at a cost of R110 000 to take the place of the filter presses. As a result of experience at the Central Works, it was decided to install secondary degritting plant similar to that operating in conjunction with the thickeners at the Central Works and this plant was commissioned in 1974 at a cost of R44 000.

The plant at the Northern Works had an initial capacity sufficient to deal with a sewage inflow of 45 000 m^3 per day, but thickeners were not provided and the total cost (1968 prices) of this installation was R1 210 796. When it became necessary to increase the capacity of this plant, filter presses from the Southern Works were moved across and because of the satisfactory performance of thickeners at the Central and Southern Works, it was decided to install thickeners and secondary degritting plant at the Northern Works. This was done in 1979 at a total cost of R240 000.

KWAMASHU WASTE WATER TREATMENT WORKS

Drawing on experience gained at the three Works mentioned above and in the light of information available at the time that the specification was being prepared, it was decided at this Works to take the primary tank and waste activated sludge through a thickener straight to centrifuges, using a polyelectrolyte as a conditioner, and then to incinerate the dewatered sludge. The incineration plant at this Works comprises two Hereshoff furnaces, each having 75% of the full capacity, because it was found that the annual shutdown required for this type of plant would cause sludge handling problems at this Works where there was no sea outfall available as an emergency outlet. The design capacity of the Works initially was 50 000 m^3 per day A.D.F. (one-half of the ultimate), but of course the installed capacity of the furnaces is such that they will not require to be doubled should incineration still be the favoured method of treatment with further expansion. The centrifuges at this Works are Guinard, two of which, operating in parallel, are designed to cope with the incinerator capacity. The furnaces are of the multi-hearth type and are capable of incinerating sludge at the rate of 950 kg per hour dry solids. The total cost of this installation, which was completed in 1975, was R1 160 000.

Both at the Northern and KwaMashu Works, effluent is discharged to river and must therefore comply with the General Standard. Particular difficulty has been experienced with the Porteous Plant liquor at the Northern Works and major expansion of the effluent treatment plant has been required in order to handle this problem.

Whilst the sludge from the Porteous process is sterile, no adequate market has been found for the use of this sludge, because although it has a value as a soil conditioner, its fertiliser value relative to that of artificial fertilisers makes the cost of transport unattractive. Therefore, apart from a limited amount of the dried sludge which is used by the Municipal Parks Department, the rest of this material continues to be used for landfill at the site of the Southern and Northern Works. Ash from the KwaMashu Works is similarly dumped on site.

SLUDGE DISPOSAL TO SEA

The two submarine outfalls that have been in operation since 1968/69 have been the subject of continuous monitoring and, in fact, for a twelve-month period sludge was discharged untreated through the Central Works Outfall because of an accident which damaged the fluid bed incinerator. The fact that no harm was caused to the marine environment nor to the bathing beaches by the discharge of settled effluent through these two pipelines led the Water Research Commission to agree that one of the research projects relating to disposal of sewage sludge in South Africa should involve the use of these two sea outfalls.

The necessary temporary permit was obtained from the Minister of Environment Affairs and for a twelve-month period sludge was discharged through the Central Works Outfall. Thereafter, sludge has been discharged through the Southern Works Outfall and the second twelve-month period will expire in May 1983.

The original monitoring programme was expanded to take account of the fact that heavy metals would be discharged with the sludge and the sediments are also examined for chlorinated hydrocarbons.

The results of this monitoring programme have proved so satisfactory that officials of the Directorate of Water Affairs are recommending an extension by twelve months of the temporary permit in order that discharge of sludge through the sea outfalls may continue whilst the detailed report on this research project is being examined by the Water Research Commission and the Department of Environment Affairs.

Apart from the high capital cost of the sludge treatment processes outlined above, operating costs of these processes are also high and an indication of these costs is given in a publication by the Institute of Water Pollution Control (Southern African Branch) in the July 1982 edition of I.M.E.S.A. Insofar as Durban is concerned, there are considerable potential savings for the city and industry in particular if sewage sludge from the two Works can continue to be discharged to sea.

A comparison of the operating costs for the Central Works for 1980/81 with those for 1981/82 shows that notwithstanding the fact that salaries for this Works increased by R48 690 over the twelve-month period, there was still a saving of R174 880, due to the fact that the sludge treatment plant was closed down. The flow through the Southern Waste Water Treatment Works at the present time is some 30% higher than that through the Central Works, so that the potential saving at present is of the order R400 000 for these two Works.

Against this saving, of course, must be offset the cost of monitoring the discharge to sea, but this is likely to be only of the order R60 000 per annum.

In addition to the saving in operating costs, it is estimated that the next extension of the sludge treatment plant would have to start in 1984 and the cost of this extension would be of the order R3,5 million.

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THE PARTICIPATION OF THE SCIENTIFIC COMMUNITY IN DECISIONS CONCERNING DISCHARGES

D A Lord

INTRODUCTION

The objective of this contribution is to promote discussion on those mechanisms which are in existence or could be established, whereby the technical community in South Africa contributes, or could contribute, relevant information and advice for use in the decision making processes concerning discharges to the sea.

An important place to start is to recognise that the scientific community in South Africa has a rather unique opportunity for participating in decisions in partnership with various responsible bodies in South Africa, which is very different from other 'similar' countries. The reasons for this are partially historical, and include the facts that in the marine sphere, the scientific arm of the civil service is not large which allows for more direct involvement by the various scientists, and secondly, the fact that the marine community is still sufficiently small that direct interaction between all parties is still possible.

Both aspects are changing, but perhaps more important, public scrutiny of all major developments has increased markedly. A good example of this is the significant public attention paid to the pipelines at Richards Bay, Durban, and Green Point. Noteworthy is the fact that this attention has been mainly concerned with the possible ill-effects of the discharges on the immediate surroundings (rather than what else to do with the effluent), and it is particularly into this discussion that the scientific community has been drawn. To properly assess ill-effects requires a knowledge of the composition of discharges and their influence on the selected ecosystem; which is a task of some considerable complexity, but one that is to some degree, after the fact. As we know, to properly reduce and eliminate effects requires a far greater influence of the earlier stages of the considerations of marine discharges and includes 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, as well as a thorough knowledge of the fate and effects of discharges.

The scientific community can contribute substantially at all these stages, and its involvement at an early stage in a project can contribute materially to the provision of the right kind of information, as well as to the optimal use of manpower. It must be said that this type of pre-involvement is definitely on the increase with the result that specific projects, such as the Richards Bay pipeline and the proposed Saldanha Bay pipeline, have received considerable attention relatively early on.

THE SCIENTIFIC COMMUNITY IN SOUTH AFRICA

Before proceeding further, it is worthwhile to list the groups involved in this work in South Africa (see tables 2.1 and 2.2). These lists are very general, and do not do justice to fully describe each group's capability.

Table 2.1: List of groups involved in scientific aspects relating to discharges to the sea

	Engineering	Phys Ocean	Chem Ocean	Biology	Waste Treatment Technology
NRIO	X	X	X	X	
NIWR			X	X	X
Natal University	some			X	X
UPE		X	X	X	
Stellenbosch University	X				
UCT	some	some	X	X	some
ORI				X	
SFRI		some	X	X	
FRD	X	X			
UKOR	X	some	X		X
Private Firms Various	X	some			X

Table 2.2: Bodies who fund and coordinate fundamental work

CSIR	- directly through institute budgets - through Cooperative Scientific Programmes, where funds for this type of work are obtained from DEA - specific programme areas are: . CSP Marine Pollution Programme Waste Management Programme . NRIO Marine Disposal of Effluents Steering Committee
DEA	- contracts to various active groups, to perform specific tasks
WRC	- contracts to various groups to conduct research having relevance to the pollution of fresh water (e.g. sludge disposal options)
MUNICIPALITIES AND WATER BOARDS	- Pipeline operators normally have to contract out aspects such as design, construction and monitoring
PRIVATE ENTERPRISE	- Organisations that use pipelines (e.g. factory) normally have to contract out aspects such as design, construction and monitoring

THE CONSULTATIVE PROCESS

With this 'who's who' in the marine world, the real question is: how do you use this group most effectively? In doing this we have to recognise that the scientific community clearly has its own limitations, dictated by its interests, expertise and experience.

There would be little point in having this discussion at all, if South Africa had a formal process whereby every major project was required by law to be assessed for its environmental consequences. Such a process is conventially called an Environmental Impact Assessment (EIA). However, South Africa does not have a formal EIA procedure. So the first question to be considered is:

SHOULD A FORMAL EIA PROCEDURE BE DEVELOPED FOR A REVIEW OF MAJOR PROJECTS IN SOUTH AFRICA?

This would essentially require the Department of Environment Affairs (DEA) to screen all development programmes, and to isolate those with potential environmental effects (virtually all pipeline projects would fall into this category). These would then be subjected to a formal EIA. The involvement of the marine community would be automatic under these circumstances. For example, the initial screening process would be conducted by a multidisciplinary panel, established by the DEA including relevant marine experts.

The present feeling in South Africa is that a formal EIA procedure is not warranted (this is a subjective assessment). It is of interest to note that in a number of countries in the world where a formal EIA is required, there is some scepticism about its value. For example, an interesting observation made in a recent review of Sweden's very rigorous EIA process is "..... what remains as the largest and most difficult problem with consultation in environmental protection is whether it in fact increases the effectiveness of policy in solving environmental problems, or whether the consultation's overall result is to make policy less effective than it could be".

However, there are features of an EIA process which are important in considering any process of consultation. In particular, these are:

1. Consultation should be at a sufficiently early stage.

This should occur at the inception of a proposal, when there is a real choice between various courses of action.

2. Consultation should be continuous.

This means that involvement should form an integral part of the decision-making process, proceeding through all the development stages of a proposal through to implementation and subsequent monitoring.

3. Consultation will take two different forms.

Early involvement will comprise mainly a review of existing data, soliciting recommendations and considerations of alternative disposal strategies, and some limited field work; all of this normally relying on conventional wisdom. Later involvement will normally involve detailed field work and design, and would include the generation of new information and technology.

A GUESS AT FUTURE MARINE DISPOSAL REQUIREMENTS TO THE YEAR 2000

To do this, we should be looking through the eyes of the DEA, especially the Planning and Water Pollution Control Directorates, as this is where early decisions are taken.

Projecting future needs in South Africa in the medium term (up to the year 2000) there appear to be a number of dominant factors in play.

Firstly, increasing demands for fresh water will limit the acceptability of large volume marine discharges, especially as water reclamation is both feasible and economic - particularly from sewage.

Secondly, decentralisation plans and associated growth points will encourage industry only in specific areas. These include; Vredenburg/Saldanha, East London and surrounds, Richards Bay and George. Most of these areas, which are coastal, are already served with some form of marine discharge, or proposed marine discharge. Of these only George has no marine disposal facilities. [Proposed disposal systems include those areas where studies are, or have been undertaken]. So in the near future, the marine disposal scene is unlikely to see many major new works over and above those mentioned, but what it will probably see are proposals for the expansion of existing facilities, the increased use of existing facilities and the disposal of more concentrated materials. The disposal of such concentrates by barge are possible as well, a subject outside the scope of this workshop.

Thirdly, it is generally being accepted that marine disposal is only one of the options available for effluent treatment and/or disposal. In any industrial infrastructure, a considerable amount of prior deliberation is required before final decisions are made. This process will need to consider all options, and alternatives, specifically from a regional point of view. Involvement of the marine community in these developments then, will continue at a project level, but could be expanded to include a greater level of contribution where development is still at a conceptual level.

HOW CAN THE MARINE COMMUNITY CONTRIBUTE TO THE PROCESS OF CONSULTATION

First, and foremost, the community must provide thorough, correct and properly digested information to the various statutory bodies and agencies for their use. At no time must the quality or integrity of information be in question. I believe the marine community in South Africa is achieving this goal, as evidenced by the high standard of technical reports on Richards Bay, Durban, Saldanha Bay and False Bay. In fact, this goal of scientific excellence is currently being attained at a project level, that is, when specific goals have been defined. However, what the scientific community is not yet doing, is to 'digest' our scientific tomes into brief and informative summaries. One of the consequences is that those less involved frequently don't have access to the general conclusions and recommendations of scientific study; and the public sector is part of this group.

To enhance this type of information transfer process, the following recommendations can be considered:

1. For major projects, part of the scientific task is to produce an accompanying information publication (Note: this is <u>not</u> an executive summary).

2. Public meetings can be used as a rapid and effective method of communication.

A second area for activity is for the marine community to produce 'tools' for assisting in the decision-making process, frequently in an unsolicited manner. Along these lines, I can think of the proposal to establish Water Quality Criteria for South African Marine and Estuarine waters. The need for these have been widely recognised, with the scientific community capable of 'writing down the numbers'. Also along these lines are the multi-generation toxicity tests which have been developed - an excellent example of a relevant and meaningful system which has been developed for screening of effluents. From a design and engineering point of view, advancements in numerical simulation methodology, coupled with better physical oeanographic data, has allowed for very refined predictions of plume mixing and dispersion. These still have to be field verified, but the techniques are developed.

To summarise then, cooperation and involvement at a technical or project level is excellent, with ample evidence of this fact. However, there is room for more effective information transfer.

Apart from this where else can we be more effective? I believe there are two areas: during early planning, as well as during post installation monitoring.

INVOLVEMENT IN EARLY PLANNING

It is here that we can possibly make a major change in our thinking, as it could be said that interaction at this stage has not been fully explored.

Planning complex industrial development programmes requires the assembly of all the pertinent information, with decisions finally being made using a variety of factors and weighting their importance. Procedures do exist to do this (multifactorial or matrix techniques) and were in fact used to assist in the early planning of the Saldanha/Vredenburg developments.

The Richards Bay development is one where such a decision making process could be used to considerable benefit, as even now, a number of different and perhaps competing requirements are being recognized, these being:

a) Fresh water demands (It has been assessed that the combined yield of fresh water of rivers, lakes and the Goedertrouw Dam will be fully utilized by 1993).

b) Eutrophication of the freshwater supplies for Richards Bay is being observed, with aerial fallout of phosphorus postulated to be the cause.

c) There is no comprehensive plan for handling other industrial wastes - particularly those not acceptable at sanitary landfill sites. Some of these may be amenable to waste exchange, materials recovery and/or marine disposal. With industrial growth projected for Richards Bay, such wastes will be generated, and their fate should be sealed before they are generated.

d) Dredge spoils from the Richards Bay harbour have been dumped relatively close to shore, and in the vicinity of the proposed pipeline outfall. Apart from the ecological disturbance which occurs when dredge spoils are dumped, the proper assessment of the effects of the pipeline discharge has been made substantially more difficult.

International experience indicates that a set of conditions as variable as these can only be handled using the complex planning procedures previously mentioned, administered by a Regional Authority.

Therefore, the following options are offered for consideration:

1. For discrete industrial areas such as Richards Bay, responsibility for comprehensive Waste Management should be lodged with an appropriate Regional Planning and Management Authority. The Mhlatuze Water Board could be used as the start of such an Authority. Such an Authority would screen and review all waste management activities - with marine disposal being one option - and would base its recommendations on genuinely holistic assessments.

2. A formal procedure could be established within DEA for review of all major projects. Where deemed necessary, technical expertise could be co-opted. This could be done by appointing appropriate 'ombudsmen' within the DEA and the marine community, or any other similar mechanism.

POST INSTALLATION MONITORING

The days of dead fish in the bay are over; the blatant polluters have been eradicated and controlled discharge is more the order of the day.

How do we tell whether installations are efficient and whether discharges are harmful or not; and how do we know when to say "We are satisfied there is no significant effect"? This is a very difficult task, one that is receiving increasing attention. The problem I want to deal with here is not to consider the technical complexities of fine tuning designs and monitoring longterm effects, but rather, how are these findings transferred to the relevant authorities?

Our committee system that we use in a very effective way to influence scientific quality and content, is not specifically designed for rapid information transfer. Results are conventionally still fed back to parent committees. What we need is direct dialogue between control authority and research work. The steering committee for the Durban sludge disposal experiment embodies many of the characteristics of this process, and could be used as a model.

SUMMARY

1. At a project level, good cooperation and rapport exists between statutory bodies and technical activities. There is room for additional transfer of technical information.

2. A formal EIA process for all major projects in South Africa could ensure close consultation at all stages of a project. However, this would require an increase in centralised authority and responsibility.

3. Favourable consideration should be given to ensuring that responsible regional authorities exist for consideration of all waste disposal activities in that region.

4. Where research is undertaken on specific disposal projects, mechanisms should be established to allow direct interaction between responsible authorities and those conducting the research.

RAPPORTEURS' COMMENTS ON DISCUSSION OF MARINE DISPOSAL OPTIONS

A M Little
N Geldenhuys

Not unexpectedly the workshop revealed certain overall strategic needs. The first was the need to co-ordinate physical planning and research so as to be able to determine the best possible options for disposing waste to sea.

It followed that research in the coastal areas should be tackled on a regional basis, and acceptable levels of pollution need to be established within these regions. Techniques for the management of all wastes must be developed. This proposal would be in contra-distinction to treating only individual sources of pollution in an ad hoc manner.

A "sensitivity areas" atlas should be prepared which would show the locality of particularly sensitive environments where disposal of wastes to sea would be most undesirable; those where only limited amounts of certain pollutants would be acceptable subject to strict controls; and those areas capable of receiving effluents in a controlled manner without creating long-term environmental or biotic degradation.

Priority should also be given to the overall planning of existing and proposed industrial growth points (as set out in the National Physical Development Plan). This planning must draw together the industrial, residential, commercial and other needs and integrate them with environmental considerations like fresh water demands, means of disposing of wastes and the like.

To a large degree, co-ordinated planning by researchers and planners would obviate the demands for comprehensive environmental impact assessments to be obligatory. Environmental assessments would also be directed only to particularly sensitive aspects of any proposed development.

The co-ordination of research and physical planning would be a service to the public and particularly to private enterprise since it would provide sound guidelines for use by entrepreneurs and decision-takers.

Finally, and flowing from the above points, the necessity to develop a positive campaign to keep the public informed was stressed. Not only must private enterprise be informed of potential for development and constraints on it, but that sector which is concerned about the measures which are being taken to protect the environment must be consulted. This need was underlined in more than one session.

TECHNICAL CONSIDERATIONS - AN OVERVIEW

INTRODUCTION

F P Anderson

Because of the expected presence of a number of people that have never been involved in any study leading to the conceptual design of a marine pipeline, it was considered by the organising committee to be advisable to give a broad outline of the varied facets of the problem so that the individual presentations will be seen to be part of a whole and not a collection of unrelated specialist reports.

I deliberately did not discuss this presentation with any of the authors contributing to the section "Establishing Safe Releases" so as to avoid the danger of producing a mere summary of what you are to hear during the full session. This implies that the views expressed here are mine and I accept full responsibility for them.

An effluent should only be discharged to sea if:

1. the total quantity is within the assimilative capacity of the ocean in the general vicinity of the discharge, and

2. the dilution rate is such that outside an acceptably small area surrounding the discharge, all objectionable material will occur at concentrations which will, to the best of our knowledge, be harmless to the environment and its inhabitants.

The first of the above criteria implies a good knowledge of the water circulation patterns in an area measured in tens of kilometres around the discharge so that one is sure that all material discharged into this area, will leave it within a reasonable period of time. This should ensure that there will not be a build-up of material (and concentrations) which could be harmful.

The second ensures that the pipeline is so designed that effluent concentrations are kept low over as large a part of the above area as possible. A much more detailed knowledge of the sea, such as currents, density structure and turbulence within an area of say one kilometre of the discharge will be needed.

These deceptively simple statements lead to numerous complex and very difficult questions which can only be answered by experts from all the marine disciplines working in concert.

Let us look at a simplified view of the activities of a number of scientific disciplines in order to illustrate the kind of links between them that make it possible to find satisfactory solutions to marine pipeline discharges.

The marine biologist has to determine what organisms live in the area, how they are distributed and how they interact with each other and with their environment. This implies an understanding which will enable the biologist to devise an energy budget so that the effect of an effluent (or one component of an effluent) on the ecosystem as a whole can be estimated when it in fact initially affects only a small part of the community within the ecosystem. Thus a toxic component of the effluent may kill off one link in the food chain, or it may be absorbed at one level and eventually deleteriously affect another organism at a much higher level (even man). In either case the environment has been disturbed unacceptably.

On his own, the biologist cannot make predictions on the effects of an effluent without the chemist to provide him with essential answers to questions such as, what chemical reactions take place when an effluent mixes with seawater, and hence in what form do these toxic materials occur in the sea and finally how many of them occur naturally in the sea (and within existing organisms) and at what concentrations?

Between them, the biologists and chemists can now devise toxicity tests to quantify the effects of an effluent on the biota living within the area to be affected by the discharge and, as a result, provide a water quality that should be striven for in, or met by, the final pipeline design.

The physical environment within which the biological and chemical activity occurs must be understood in order for predictions about the fate of effluents discharged into the sea to be made, and prediction is after all the basis upon which the whole design is based. In essence, the physical oceanographer has no problem measuring currents, densities and turbulence, but where the real problem arises is in the understanding of the processes giving rise to the measured or observed phenomena and of course in how the ocean is going to behave in the future. It is also the transfer of knowledge of this complex four-dimensional water-movement problem from the mind of the physical oceanographer to the dilution prediction models of the design engineer, that creates further headaches for all concerned.

Assuming all has gone well and it appears possible to design a discharge, on paper, that will satisfy everyone in terms of short and long term effects of the effluent on the environment, one now has to establish whether a pipeline can in effect physically be laid in the area.

The nature of the sea bottom, presence of rock, depth of sand, stability of sediments etc. etc. have to be investigated and the forces on the pipeline due to currents and wave action, particularly in the surf-zone, have to be established.

Only when all this information has been put together, can the feasibility of a pipeline be determined, and the final question from the planners point of view be asked; i.e. what would such a pipeline cost?

Even then, the final word on the environment has not been spoken until the contractor has found out under what conditions he has to construct and lay the pipeline, so that he can plan the whole exercise to take advantage of the most favourable wave, wind and current conditions, or else use equipment that can withstand the worst conditions to be expected.

This very brief account has been designed to inform the uninitiated, and not to instruct the expert, and the impression given that studies occur in a fixed sequence is an artefact of the essentially two-dimensional nature of information transfer by means of the written word.

NEARSHORE OCEANOGRAPHY

E H Schumann

SCOPE

The subject of nearshore oceanography needs to be seen in the light of the requirements imposed by the very concept of discharging effluents into the sea. In other words, the basic idea is that the effluent will be diluted by the sea into which it is discharged, while at the same time being removed from the locality by the prevailing currents. Such a view is simplistic, in that it ignores concepts such as the decay or degradation of the effluent itself, or the deposition and interaction with sediments, but it does demonstrate that a knowledge of ocean currents is a prime requisite for the design of an effluent discharge.

Dilution is also to a large measure a function of the engineering aspects of the pipeline, and this will be dealt with elsewhere. Of importance here are the vertical density structure and possible associated motions, as well as the current shear. Nearshore oceanography in this context therefore devolves to an analysis of ocean structure and existing currents, and any external forces or influences that may play a part in their characteristics.

Of necessity the area of immediate interest lies within a few kilometers of the coast, since outfall pipelines generally do not extend much further offshore. However, such a region must be seen in the context of its overall situation, particularly since the eventual "sink" for the effluents may be far away. Any programme of measurements then also needs to be carefully considered, and an understanding built up of the oceanographic conditions; a straightforward statistical analysis of currents measured at one point may provide a completely erroneous answer.

OCEAN CURRENTS

In the nearshore regime around southern Africa, the dominant current generating force is probably the wind. The presence of the coastline and the bottom bathymetry in combination with the Coriolis effect (due to the rotation of the earth) is also of major importance.

The actual mechanism whereby the wind imparts its momentum to the ocean is still poorly understood, but the variability of the wind is then evident in the variability of the currents. Low frequency signals, with periods of the order of days, may also propagate along the coast; this in turn means that it is not necessarily the local wind which has the greatest influence on the currents. Topographic features on land may significantly alter the wind field, while differences at the air/sea and the land/sea interfaces can mean that winds offshore can differ markedly from those onshore.

Another effect of the wind lies in the generation of surface gravity waves, although these may propagate into a coastal area from many thousands of kilometres away. The greatest effect of these waves is felt in the surf zone; however, since effluent disposal generally occurs in deeper waters, this zone will not be considered here. The high frequency wave orbital velocities also play a negligible part in the transport of effluent, so that it is really only the wave-induced drift which is of importance. Details of the wave field need to be known in order to gauge its importance.

Tidal currents generally tend to be ignored when considering the southern African coastal situation. However, recent measurements have shown that they could be very important under certain conditions. In particular, such currents generally mean that water particles execute closed paths in the form of ellipses, which implies that effluent will not be transported away. A similar situation holds for inertial currents, i.e. executing circular paths with periods of 11.97/(sin latitude) hours.

Influences emanating at the open ocean boundary also need to be considered, particularly where the continental shelf is very narrow. Extreme examples of such areas exist along the southern Natal and Transkei coasts, where the influence of the strongly-flowing Agulhas Current is felt within a few kilometres of the coast.

STRATIFICATION

Stratification in the water column will not only affect the dilution of effluents through the variations in density, but it also has a marked effect on the type of motions that can exist. Thus in situations with a marked pycnocline i.e. a significant change in density at a particular depth, baroclinic motions can take place where the current above the pycnocline may be oppositely directed to that below.

Factors affecting the stratification therefore need to be known. These involve:

a) the origin of the waters making up the water column

b) the locality, e.g. is it a protected area in terms of wind and currents

c) the extent of solar heating and cloud cover

d) the local winds

e) the local currents

f) the wave field

Winds, waves and the induced internal motions play an important part in the extent to which the water column is mixed. Here the seasonal variation is often very marked; for instance it is well known that on shelf areas such as the Agulhas Bank strong pycnoclines occur in the summer, while well-mixed conditions occur in winter. Seasonal upwelling, such as occurs on the west coast, will also dramatically alter the coastal ocean structure.

MEASUREMENT AND ANALYSIS

With all the factors discussed above to be considered, it is very important that a carefully-considered measurement programme be initiated in any effluent outfall investigation. Each situation will need to be analysed separately, taking into account any past measurements and knowledge of the prevalent oceanographic conditions.

The actual siting of measurement points will depend on the locality. The number of points will then also depend on a knowledge of conditions and the requirements of the discharge itself, however, will probably involve more than one such site. The vertical structure of the ocean will also need to be monitored, while the local wind field needs to be known as well as the wave field.

In order to acquire meaningful data, it is essential that measurements be made regularly (e.g. every fifteen minutes) over a period long enough to cover most conditions, and to determine seasonal variations. This means that self-recording instruments need to be deployed, and this in turn implies that fairly sophisticated, computerized data analyses facilities must be available.

CHEMICAL ASPECTS OF DISCHARGES

G A Eagle

INTRODUCTION

Chemical processes are closely interrelated with sedimentation processes and the functions of living organisms in the marine environment. Marine chemistry may therefore be seen as the link between physical processes on the one hand and biological processes on the other. This presentation will attempt to highlight the specialist role which the chemist can play in linking other disciplines together.

THE PROBLEMS

In addressing any problems related to the discharge of waste through submarine pipelines, the chemist normally tries to answer two basic questions:

1. What happens to the waste which is discharged?

2. Is the waste, or any constituent of the waste, accumulating in the environment to the extent that it may cause some harmful effect?

The first of these questions can again be divided roughly into two parts:

a) Where does the waste go?

   Here the chemist must work very closely with the physical oceanographer in determining currents, density gradients and other factors which may influence the physical dispersion of the waste. In the case of existing pipelines this can be simply stated. One must follow the pathway of some suitable tracer compound or element from the source to its sink. In the case of a planned pipeline, the difficulties in answering the question are increased. Here he must attempt to assess the pathway of an unknown waste which may be discharged through a proposed pipeline whose exact location is yet to be determined. Clearly then certain assumptions will have to be made and the final conclusions will have to be based on some approximations.

b) Does the waste undergo any physical or chemical changes on discharge to sea?

   This is a second aspect to the question of what will happen to the waste and is probably the direction in which the chemist may be able to make the most meaningful contribution. A number of common types of changes are known to occur. For example high concentrations of iron in acidic wastes may precipitate out on contact with seawater of a higher pH. The resulting iron hydroxides sediment out, carrying with them other pollutants, either co-precipitated or absorbed onto the surfaces of the particles. Dissolved material may also enter the food chain and may emerge in the form of particulate faecal material. Again, such material may enter the sediments in a particulate form. It is well known that many elements are more toxic in the organic than the inorganic form, e.g. most heavy metals. In the marine environment, chemical reactions, often biologically mediated, may take place, in which a metal may be converted from the inorganic (less toxic) form in which it is discharged into a far more toxic organic form.

Another aspect which deserves very careful consideration is the fact that most pipelines in South Africa carry more than a single effluent. In such cases it is important that possible reactions which may take place within the pipeline itself must be considered. For example, an effluent containing a high concentration of organic compounds may be discharged through the same pipeline as a chlorinated effluent. This could possibly result in the formation of chlorinated organic compounds in the pipeline itself. Thus it could happen that the material emerging at the end of the pipe may be far more toxic than either of the individual effluents entering the pipeline. Synergistic and antagonistic effects must also be considered, where the toxic effect of the combined effluents may be greater or less respectively, than the sum of the effects of the individual effluents.

The second question of importance is to determine whether a pollutant is accumulating in the environment to the extent that it may cause some harmful effect. This implies that intimate knowledge of the background concentrations, including seasonal and spatial variations, is available. This requires that detailed information must be collected over a long period of time. Clearly in the case of an existing pipeline it is not possible to collect this information and comparison has to be made to some other suitable reference area. In this regard it may be more profitable to try and determine background concentration in sediments or biota, rather than in water, because they present a more time averaged picture of the situation. Some compounds, particularly the synthetic organics, are far more persistent in the marine environment than others. This problem is compounded by the vast array of organic compounds which exist in the marine environment.

If a particular pollutant is indeed found to be accumulating, then one is still required to determine whether this is significant for the ecosystem, whether some detrimental effect could be caused as a result. In this regard close liaison with a biologist is required. This aspect will not be covered here, since it will be dealt with by other speakers.

It is a common misconception that by diluting an effluent to some predetermined level, the problems of toxic waste discharge simply go away. In certain cases, when the discharge takes place into a strong longshore current, where eddies do not occur, then dilution will indeed reduce the potential toxicity of a waste. However, where re-circulation takes place, or where some chemical or biological reaction causes a pollutant to accumulate in a relatively small area, it is important that the total amount discharged as well as the concentration must be taken into account. It is important that the accumulative capacity of the receiving waters is not exceeded.

THE ADVISORY ROLE OF THE SCIENTIST

Scientists traditionally are reluctant to give answers to questions unless they are certain of these answers. The time has come however, where scientists may be forced to give considered opinions as to the likely effects of discharges. This is an issue from which we must not retreat. Based on the information available to us at the time, we, the scientists, must not be afraid to state our opinions on questions of environmental concern, even if we are not one hundred percent sure of the answer. If we are not prepared to give such opinions, then guesses may be made by others less qualified to do so. However, in order for our opinion to have the maximum chance of being correct, we must have at our disposal all available information related to the question. Thus an urgent plea is made for better communication between planners and scientists.

BIOLOGICAL ASPECTS OF DISCHARGES

A C Brown

Effluents can affect every aspect of the life of marine organisms, from subtle physiological changes to effects which are soon lethal, from disruption of normal behaviour patterns to a reduction in growth rate, lowered gamete production or developmental abnormalities.

The impact of all the effects of pollution on a population is best summed up in terms of reduced reproductive potential. Other useful indices, such as scope for growth or adenylate energy charge, are themselves, in the ultimate analysis, indices of reproductive capabilities.

The important features of a biological community reside in the interactions of the populations involved. However the study of ecotoxicology, which takes cognisance of this fact, is still in its infancy. Moreover, ecotoxicological studies at a particular site are too lengthy and costly to be contemplated. One is therefore compelled to study changes in particular populations of selected species.

The species selected for study (whether for predictive or for monitoring purposes) should include representatives from all, or at least several, trophic levels, including that of the primary producers, as the whole community depends on them.

As reproductive potential is the criterion which must be employed, organisms with a fast rate of turnover should be selected, e.g. sandy-beach meiofauna rather than macrofauna, rocky-shore amphipods and isopods rather than long-lived limpets, zooplankton rather than fishes.

Field studies by themselves have by and large proved unsatisfactory as far as predicting or assessing the biological impacts of pollution are concerned. Field studies must always go hand in hand with laboratory toxicity testing, preferably of a sublethal nature.

Although monitoring is essential, the prediction of biological effects must be the aim of biological pollution research.

Pollution which causes the extermination of dominant species is clearly unacceptable, as is gross reduction in community biomass. At lower levels of pollution, biomass and ecological complexity may not be seriously affected but some species may flourish at the expense of others. Whether this is acceptable or not must depend on the particular instance and all the factors involved.

ASSESSING THE EFFECTS OF EFFLUENTS ON MARINE LIFE

Research conducted over the past 20 years or so has made it abundantly clear that there is no aspect of the lives of marine organisms which is immune to the effects of pollution. These effects range from subtle physiological changes, such as increased fragility of the lysosomes and other cellular organelles, to reactions which are very soon lethal, from disruption of normal behaviour patterns to a reduction in the rate of growth, lowered gamete production or developmental abnormalities. It has also long been apparent that assessing toxicity, or even ranking pollutants, by measuring short-term lethal concentrations (LC_{50}s) is naive and frequently very misleading. For example, some marine animals react to extremely low levels of chemical pollution by ceasing to feed, often because they are no longer attracted to the chemicals emanating from their food; this spells death to the population even though there may be no other symptoms and short-term LC_{50} tests may show the animals to be highly resistant to the pollutant. It is also necessary to bear in mind that pollution effects may be indirect; for example, discoloration or particulate matter reduces the penetration of light and this in turn may reduce photosynthesis.

Clearly, therefore, what one needs in practice is a criterion which will embrace all the effects of pollution on plants and animals in a meaningful and useful way. In this regard, some workers have put their faith in criteria such as "scope for growth" or the adenylate energy charge (a measure of the energy available to the cells). Both of these values may be reduced in response to sublethal levels of pollution and it is true that both indices give a good indication of physiological condition, at least in some species, and so may be useful in monitoring; but they are not by any means all-embracing as far as the future of the populations in the field is concerned. They may, in fact, give quite satisfactory values while the population is nevertheless endangered by the failure of fertilisation or a tendency to produce non-gastrulating larvae. In fact, the more one thinks about it, the more one is forced to the conclusion that the only criterion which is really all-embracing is the reproductive potential of the population - its ability to produce successive generations of healthy individuals in numbers which are adequate to replace the older generations. This potential is reduced by the untimely death of adults, by a reduction in growth rate, through reproductive abnormalities, through anomalies in development, by impaired physiological state and by nearly all other pollution effects. Indeed, if there are pollution effects which have no impact on the reproductive potential, they may be regarded as trivial as far as that population is concerned.

Theoretically, whether one is monitoring or trying to predict the effects of pollution, one should consider the ecosystem as a whole and cognisance should be taken of the fact that the important features of a biological community reside in the interactions among the species present. In this context, pollutants should be considered as specific ecological factors which, like changes in salinity or temperature, may modify the dynamics of the ecosystem as a whole by affecting one or more species. This concept is, in fact, a cornerstone of the field now known as ecotoxicology, a subject which augers well for the future but is, at the moment, in its infancy.

In any case, in the practical business of assessing pollution effects at particular sites or better, in particular bodies of water, proper ecotoxicological studies are far too time-consuming and costly to be viable, particularly as, in the present state of our knowledge, one cannot guarantee the usefulness of the results. Generally a decision is needed in a relatively short space of time and money, of course, is always limited. One is forced, therefore, to select a few species from the community for, hopefully, detailed study.

Bearing in mind the essentially dynamic nature of an ecosystem, those species selected should be drawn from all, or at least from several, trophic levels. Where not all such levels can be studied, the emphasis should be on the lower trophic levels, including the primary producers, as the whole community depends on them. Moreover, as reproductive capability is the ultimate criterion to be considered, the species selected for study - either in the field or in the laboratory, or both - should not only be relatively sensitive and relatively common but must have a fast rate of turnover, so that a number of successive generations can be studied in a realistically short space of time. For example, sandy-beach meiofauna would be a better choice than members of the macrofauna, rocky-shore amphipods and isopods rather than limpets which may live for 20 years or more, zooplankton rather than fishes.

It must be admitted that field studies by themselves have by and large proved disappointing as far as predicting or assessing the biological impacts of pollution are concerned, the exceptions being cases where pollution is so intense that nearly everything dies at once - and then you hardly need a biologist to assess the impact. Where pollution is less intense, and chronic rather than acute, we are in some trouble, partly because of our limited understanding of ecosystems and how they work, partly because every ecosystem is different and partly because sampling methods are inadequate. They are especially inadequate at sub-tidal levels and indeed it may be said that the further out to sea a pipe-line extends, the more inadequate sampling is likely to be. Compounding the problem is the fact that by and large, the concept of reference sites is not valid. Neither can one place too much faith in the concept of pollution decreasing diversity.

Difficulties of sampling the benthos are real enough but the problems of quantitative sampling of the plankton and free-swimming organisms are horrific. They may be partly overcome by the use of enclosed water columns, such as the CEPEX system and the MERL system, both of which have been used to assess the effects of different levels of pollution on marine communities; but there are still some difficulties in the interpretation of results and the cost of maintaining the systems is extremely high so that some of the systems constructed in Europe have had to be abandoned for financial reasons.

We should be aware that great changes in ecosystems may occur in the absence of any pollution. Such changes may be cyclic but they may also be non-cyclic and unpredictable. On the other hand, quite serious pollution may occur without damage to the ecosystem being immediately apparent. For these and other reasons, I firmly believe that, although the ultimate testing ground must be the sea itself, field studies should at present always go hand-in-hand with laboratory experiments on the sub-lethal effects of pollution. Moreover, the field and laboratory studies must be integrated and ideally should be undertaken by a single team who know their animals and plants.

In field studies, appropriate data are difficult to collect and even more difficult to interpret. On the other hand, the danger in laboratory studies is that one may completely miss important pollution effects due to the design of the experiments. For example, one effect of pollution is to cause many benthic animals, such as limpets and sea-urchins, to relax their grip on the rocks. The first storm is then likely to detach them and wash them away, often up the shore, where they die of exposure. This loss of adhesion will be missed in the laboratory unless it is specifically tested for. This sort of phenomenon is another reason for combining field and laboratory studies and for employing an expert, someone who knows the plants and animals, and how they behave and react, and who has also a good knowledge of the literature. It is, in fact, my chief criticism of South African biologists that they are not sufficiently acquainted with the literature. Such knowledge saves time and money and may prevent faulty conclusions.

Having predicted and/or monitored the biological effects of pollution, we then have the difficult task of deciding the extent to which these effects are acceptable or not. A potentially valuable tool in this regard as far as management is concerned, is the concept of the assimilative capacity of the ecosystem. This may be defined as that level of stress which an ecosystem can absorb without causing irreversible change, an irreversible change being damage from which the system will not recover rapidly when the stress is removed. However, although this is a valuable concept, we must not be lulled into thinking that it solves our problems. Concepts do not, in fact, solve problems and, like this one, they often raise more questions than they answer; but they may give us a goal, something we can work towards with a clear knowledge of where we are going. I believe, therefore, that this idea of an assimilative capacity is one that we should pursue.

RAPPORTEURS' COMMENTS ON DISCUSSIONS OF ESTABLISHING SAFE RELEASES - OCEANOGRAPHIC CONSIDERATIONS

R J Watling
G Brundrit

The recurrent theme of the discussions was that it was fundamental to establish an effective framework within which all disciplines concerned with marine disposal of wastes could exchange ideas prior, during and after pipeline installation.

The importance of physical oceanography, chemistry and biology was discussed in relation to marine pipelines. It was pointed out that there is a great variability in the physical structure of the marine environment from site to site; consequently each locality must be considered on its own. Changing oceanographic conditions affect the movement of water and waste away from the discharge site and so no specific guidelines as to the exact number and type of measurements can be established in advance.

It is essential that detailed information be available at the earliest possible stage of any project and that information remains current throughout the project's life.

The chemist must answer the questions: what happens to the waste; where does it go; does it change its chemical form and hence toxicity and does it accumulate? It is important to realize that effluents are complex mixtures of chemicals and investigations of synergistic and antagonistic effects associated with effluent mixing must be undertaken prior to the establishment of safe discharge criteria.

From the biological point of view, pollution affects every aspect of marine life. Various methodologies have been used to assess these effects but all have their own limitations. However, the essential feature that must be established in defining the ecological impact of a pollutant must be the effect that this has on the reproductive potential of a test organism and ultimately the ecosystem as a whole.

Because of the diverse nature of parameters to be measured and the inconclusive nature of some of the resulting data, it is impossible to produce definitive answers to many questions concerning marine outfall criteria within a realistic timescale. Consequently the scientific community should be encouraged to provide "considered opinions" at the earliest possible stage of any project without necessarily having all the conclusive evidence at hand.

RELEVANT TOXICITY TESTING: RICHARDS BAY AS A CASE STUDY

A D Connell

Toxicity testing has three major roles to play in pipeline discharges, the first being to aid in the prediction of environmental impact, secondly to yield data concerning the dilutions required by the pipeline, and thirdly for the testing of effluents after discharge begins, both to ensure that these maintain quality and comply with predictions, and to advise any further requests for discharge into an existing pipeline. A further important role is in testing the efficiency of alternative treatment techniques for effluents before they are discharged into the pipeline from the factory, in order to assist the industrialist to achieve the most cost effective pretreatment before the effluent leaves the factory.

In the case of Richards Bay, our research began some years before the pipeline plan was launched, because we were asked to investigate the effect of fluoride from Alusaf on the estuarine fauna of Richards Bay. A literature search revealed no information on fluoride in the marine environment, and the United States Environmental Protection Agency (1976) Quality Criteria for Water suggested a maximum level of 1,5 mgl^{-1} in seawater. This figure was lifted directly out of freshwater studies and, with the 1,3 - 1,7 mgl^{-1} fluoride normally found in seawater, was quite inadequate. Our studies showed fluoride to be toxic to the estuarine amphipod Grandidierella at 5,5 to 6,5 mgl^{-1} and the upper limit of 5,0 mgl^{-1} in seawater was therefore adopted.

Chemical analyses of all the components which appeared to be important in the effluents to be discharged from the Richards Bay pipeline, and calculations of their concentrations in the receiving waters at dilutions required to achieve the required 5 mgl^{-1} fluoride have subsequently been used to try to ensure that at the dilutions required for fluoride, no other element, compound or combination of compounds will have any directly toxic effect in the area of discharge.

Estimating the toxic effect of individual elements or compounds, or combinations of elements or compounds on organisms in the receiving waters is probably an impossible task, and it is therefore necessary to test the proposed effluents singly, and in combination, to check their toxicity with suitable organisms. We tested both the major effluents separately and in combination, using the amphipod Grandidierella, and found no toxic effects at dilutions of about 800 times. Since these were the dilutions at which fluoride was present at about 5 mgl^{-1} it was evident that no single or combination of constituents was more toxic to the amphipod than fluoride alone.

Subsequent to these tests being completed, design of the pipe has been improved, and thus at present, from our experiments, dilutions appear to be adequate to ensure no directly toxic effect in the vicinity of the pipeline.

In addition to the above tests, others have been conducted in troughs, to try to predict the depth of gypsum on the sea bed at which benthic communities will be adversely affected. These studies are presently still continuing, but initial findings suggest that 10 mm will be sufficient to cause changes. It has been predicted, however, that all the gypsum will dissolve as a result of the jet diffusers on the gypsum pipe. If that is so, then the only undissolved material will be unreacted rock, which should behave in the same way as sand, and apart from the area of physical smothering, no adverse effect is envisaged.

A problem in these studies has always been one of obtaining effluent of the sort that will be discharged from the pipeline. While in the case of Richards Bay, one contributor, the paper mill, has not yet been built, the other major contributor, Triomf, is not necessarily dumping onto its present land-based site what it will ultimately be discharging to sea. Therefore, while every care has been taken to ensure that tests have been conducted on effluents of the type that will be discharged (in the case of the paper mill, from "sister" mills abroad), it remains essential that on commencement of discharge, tests will be repeated at regular intervals to ensure that planned effluent qualities are achieved and maintained. We have both short term and long term tests available, the former using the eggs of the marine coral reef amphiprionid fish *Dascyllus trimaculatus* and in the case of these comparative tests, the short term test is the more appropriate. These are conducted over about 5 days, until all the larvae in the controls have become fully developed with the yolk sac exhausted, and the eyes and mouth completely formed. The longer term tests with *Grandidierella* are conducted over periods of two to three months, with the population continuously exposed in flow-through conditions, to a constant level of toxicant of effluent. In this way population increases are monitored at different concentrations for comparison with control tanks. Thus the entire life cycle (25 days) for several generations, is completed in the presence of the diluted effluent.

ASSESSMENT OF SAFE DISCHARGE LIMITS IN THE NUCLEAR INDUSTRY

D van As

INTRODUCTION

Routine releases from the nuclear industry to the environment are controlled by three principles, viz. that the practice creating the effluents should be justified, radiation doses resulting from the discharges should be kept as low as reasonably achievable (ALARA), and radiation dose limits should not be exceeded now or in the future from all practices which result in radiation exposure (1).

As implied by these principles, international dose limits do exist; however because of the nature of the exposure routes, these doses cannot be physically measured, in practice it is necessary to assess individual and population exposures by means of mathematical models. These models require data on the composition of the effluent, local environmental parameters and the distribution and habits of the surrounding population. Both individual doses and collective dose commitments are obtained, the latter being used in an optimisation procedure to achieve the ALARA principle (2).

Verification of the assessment is obtained from a programme of regular environmental monitoring of strategic links in the environmental cycle (3).

NATURE OF THE EFFLUENTS

The operation of a nuclear reactor leads to a large inventory of radioactivity - more than 200 individual nuclides are produced. Under normal operating conditions, the radioactivity due to fission products is extremely well contained within the fuel cladding, while radioactive corrosion products are contained in the primary and secondary cooling systems (Fig. 1). It is consequently very difficult to predict the quantity, nature and composition of the specific radionuclides present in the effluent. Typical effluent discharges are shown in Table 1, (4) with the fission nuclides caesium - 134 and 137, tritium and the corrosion nuclides iron - 59, manganese - 54, cobalt - 60, chromium - 51, antimony - 54 normally the most prominent constituents.

Radioactivity can not be destroyed but does decrease with time due to the natural decay process. This property makes temporary storage an alternative that must be considered in the optimization process to achieve ALARA.

FATE OF RADIOACTIVE EFFLUENTS

Effluents are normally bulked in storage tanks, monitored, treated and analysed before being released to the ocean in the cooling water. The latter has a flow rate of some 100 $m^3.s^{-1}$ and the effluent is highly diluted when released to the ocean. As a first approximation it is accepted that rapid physical and chemical equilibrium will be attained between the radioactive species and their stable counterparts in the ocean. The known physical-chemical forms are precipitates and colloids, absorbed fractions on silt and sediments, chelated organic complexes and ionic forms.

For the Koeberg nuclear power station site specific distribution factors of the various elements between solution, silt, sediment and edible biological species are determined (Table 2)(5). From these results so-called concentration factors are calculated, viz. the ratio of the concentration of an element per unit mass of the particular medium to that of a unit mass of seawater. The marine bio-materials investigated included algae, seaweeds, molluscs, crustaceans and fish. Particular attention was given to those species edible for human beings, and concentration factors for the elements Cr, Mn, Fe, Co, Zn, Sb and Cs were determined (Table 3).

EXPOSURE PATHWAYS

The exposure of an individual to radiation is a function not only of the level of radioactivity in the environment but also of his personal use of that environment. Thus, in most situations in which radioactive materials are introduced to the environment, there will be numerous and complex pathways by which each of the released nuclides may ultimately cause radiation exposure to man. However, a comprehensive investigation of all such pathways is not necessary, as a study of each situation will indicate that certain nuclides and exposure pathways are dominant. These nuclides and pathways are designated as critical.

In order to recognize the critical pathways a habits survey of the local population using the beach and the sea as a source of food and recreation was carried out. This revealed the number of hours spent by fishermen tending nets and gathering bait, and by bathers swimming and sunbathing. In the absence of fishing activities of commercial importance, the quantities of seafood consumed weekly by the local population were conservatively taken as the daily quota of crustaceans and molluscs allowed to be gathered under existing regulations.

RADIATION DOSE LIMITS

No dose limits exist for life other than human, but because of the length of man's lifecycle and the fact that higher forms of life are more sensitive to radiation, these limits would adequately protect other species. For all species other than man, it is the effect on populations rather than on individuals which is of importance.

In the absence of proof of a threshold dose below which radiation effects do not occur, the International Commission on Radiological Protection has postulated a linear dose-effect relationship. Thus, all radiation doses down to the lowest level are considered detrimental, although the effects in the range below 10 rem (100 mSv) have not been shown to be statistically significant. The Atomic Energy Commission (AEC) Licensing Branch which is the national regulatory authority, has set the limit for exposure of the public due to the nuclear power reactors at Koeberg at 25 mrem.a^{-1} (250 uSv.a^{-1}). On the assumption of the linear dose-effect relationship, this is equivalent to a risk factor of 10^{-7} per year (by comparison the risk of being killed in a road accident is 3×10^{-4} and being killed by lightning is 2×10^{-6} per year).

DISCHARGE LIMITS

The relationship between a unit release of a particular nuclide and the annual radiation dose from this nuclide through a particular food chain, is obtained from a mathematical model of the various environmental pathways by substituting site-specific data for the various transfer parameters, population distribution and local consumption and usage data (6). A simplified form of this calculation is shown in Table 4, and the discharges that would result in the dose limit are shown in Table 5.

Discharge limits for the various radionuclides will be determined by the composition of the effluent and the quantities specified will be such that annual dose limit will never be exceeded in the most exposed person or group (i.e. critical group). In addition, the collective dose commitment, i.e. the sum of the dose to the entire population for the lifetime of the nuclear reactor, will be calculated. This dose, in units of man-rem, must now be optimised in order to conform to the principle of ALARA. Optimization is achieved by reducing the collective dose to a value such that the cost of further reduction is not justified by the additional protection obtained. A value of $100 per man-rem is generally accepted. This then demands that protective action, which in the case of liquid effluent could be temporary storage to allow for decay or decontamination procedures, is mandatory when the cost of saving 1 man-rem is less than $100, but is not justified when it exceeds this amount, with the proviso, however, that the dose-limits are adhered to.

CONCLUSION

In the nuclear industry, the discharge of radioactive effluent is controlled by a system of dose limitation. The application of this system to conventional effluents require

- a quantitative relationship between intake and effect so as to establish intake limits,

- environmental models that will allow calculation of the relationship between discharge and intake,

- a measure of the total detriment due to the discharge. (This is related to the collective exposure but is only valid in cases where no threshold limits exist. The detriment is expressed in terms of a monetary value which is then used in a cost-benefit analysis to obtain a level of protection which is optimum in terms of the cost of pollution reduction).

Through such a system discharge limits can be established for the desired level of risk (safety). The validity of the assumptions used in the model must however be verified by a comprehensive environmental monitoring programme.

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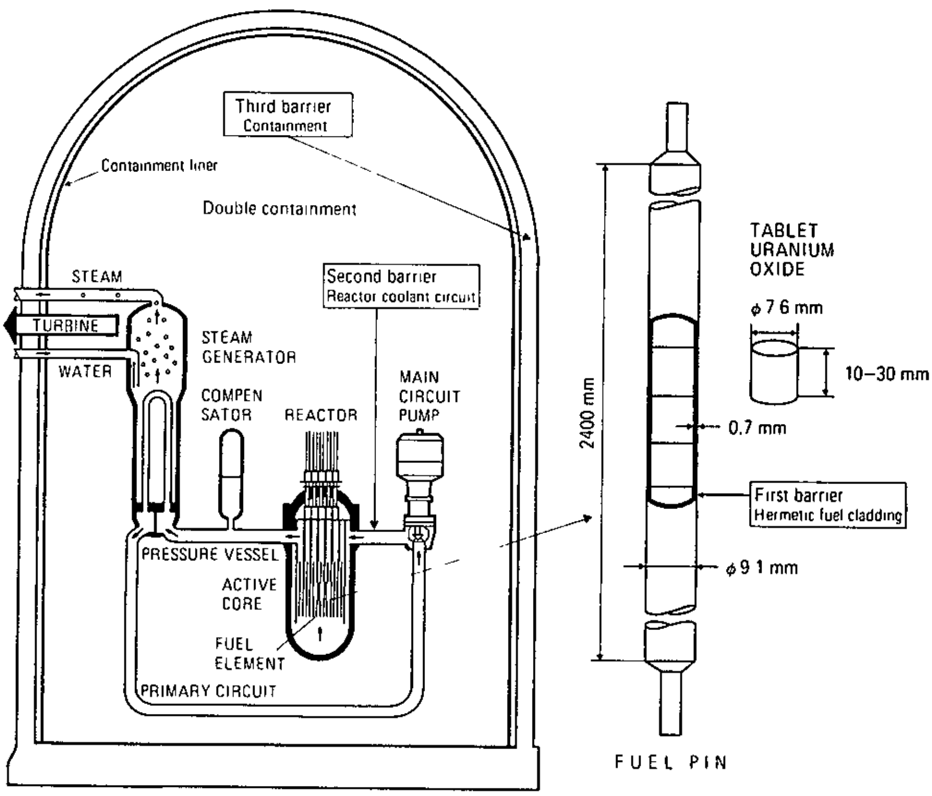


Fig. 1 Barrier system of nuclear power plants to control releases of radioactive substances; an example for a pressurized water reactor. (8)

Table 1 : Summary of Liquid Effluents from U.S. Power Reactors (4)

Facility	Mixed Fission and Activation Products			Tritium		
	Curies Released	Average Concentration ($\mu Ci/ml$)	Percent of MPC Limit	Curies Released	Average Concentration ($\mu Ci/ml$)	Percent of MPC Limit
Boiling Water Reactors						
Oyster Creek	10.0	8.62×10^{-9}	32.3	61.6	5.31×10^{-8}	0.00177
Nine Mile Point	34.6	7.80×10^{-8}	3.18	27.8	6.28×10^{-8}	0.00209
Millstone 1	51.5	8.35×10^{-8}	7.04	20.9	3.39×10^{-8}	0.00113
Dresden 1	6.75	2.32×10^{-8}	23.2	43.3	1.48×10^{-7}	0.00493
Dresden 2,3	22.1	1.49×10^{-8}	14.9	25.9	1.81×10^{-8}	0.0006
LaCrosse	48.5	1.46×10^{-7}	6.39	120.0	3.61×10^{-7}	0.012
Monticello	2.90×10^{-6}	2.78×10^{-16}	2.05×10^{-8}	7.60×10^{-5}	7.31×10^{-15}	2.44×10^{-10}
Big Rock Point	1.09	1.06×10^{-8}	0.88	10.4	1.07×10^{-7}	0.0034
Humboldt Bay	1.40	7.78×10^{-9}	0.11	13.0	7.22×10^{-8}	0.00241
* Pilgrim	1.45	5.58×10^{-8}	7.98	4.18	1.61×10^{-7}	1.61
Quad Cities 1,2	2.41	1.73×10^{-9}	1.73	4.70	3.38×10^{-9}	0.000113
Pressurized Water Reactors						
* Maine Yankee	0.0169	1.75×10^{-10}	0.0919	9.22	9.57×10^{-8}	1.91
Palisades	6.81	8.50×10^{-9}	0.005	208.0	2.60×10^{-7}	0.430
Yankee	0.0206	1.28×10^{-10}	0.0249	803.0	4.97×10^{-6}	0.166
Indian Point 1	25.4	5.12×10^{-8}	2.88	574.0	1.16×10^{-6}	0.040
R.E. Ginna	0.375	5.18×10^{-10}	0.00234	119.0	1.64×10^{-7}	0.00547
Connecticut Yankee	4.78	6.20×10^{-9}	0.233	5890.0	7.64×10^{-6}	0.255
H.B. Robinson	0.826	3.82×10^{-9}	3.82	405.0	1.88×10^{-7}	0.000625
San Onofre	30.3	5.22×10^{-8}	1.49	3480.0	5.99×10^{-6}	0.2
Point Beach 1,2	1.53	3.11×10^{-9}	0.0052	563.0	1.13×10^{-6}	0.037
* Surry 1	0.0252	1.83×10^{-10}	0.00395	5.03	3.64×10^{-8}	0.091
Nonwater Reactors						
Peach Bottom 1	0.0209	1.57×10^{-9}	1.57	1.7	1.28×10^{-7}	0.0427
Fermi	0.222	9.53×10^{-9}	7.53	None		

* Operated less than one year

Table 2

Concentrations of trace elements in seawater from the Cape West Coast (µg/litre) (5)

Physical state	Location	Cr	Fe	Zn	Co	Mn	Sb
Dissolved	Surf-zone	0.08±0.07	1.7±0.3	1.2±0.5	0.02±0.01	0.7±0.2	0.7±0.7
	Off-shore	0.06±0.04	3.9±2.9	3.2±2.1	0.06±0.05	0.7±0.2	0.3±0.2
Particulate	Surf-zone	0.4 ±0.3	61±4	<0.5	-	0.3	-
	Off-shore	0.5 ±0.5	8.8±2.6	<0.9	-	0.1	-

Concentration of trace elements in marine organisms (µg/g fresh weight, i.e. p.p.m.) (5)

		Cr	Fe	Zn	Co	Mn	Sb	Cs
Molluscs	*Choromytillus meridionalis*	0.10±0.06	20±7	16±1	0.038±0.006	2.7±1.1	0.20 *	0.0072±0.0027
	Donax sera	0.24±0.03	59±27	18±4	0.038±0.024	1.0±0.4	0.18±0.08	0.0072±0.0054
	Haliotus midae	0.50±0.25	18±14	12±2	0.025±0.007	0.17±0.07	0.083*	0.0010±0.0011
Crustacean	*Jasus lalandii*	0.08±0.08	2.7±1.3	17±2	0.0039±0.0015	0.27±0.06	0.12±0.07	0.0098±0.0038
Seaweeds	*Ulva spp.*	0.45±0.38	39±13	5.6±4.1	0.038±0.013	4.1±2.8	0.16±0.09	0.011±0.001
	Ecklonia maxima	0.13±0.15	3.3±1.2	1.2±0.6	0.0064±0.0021	0.25±0.09	0.082±0.028	0.0095±0.0025
	Prophyra capensis	0.47±0.30	37±22	11±7	0.054±0.013	6.1±2.0	0.21±0.15	0.0056±0.0067
	Suhria vittata	0.87±0.11	49±4	9.4±2.3	0.048±0.004	3.7±2.1	0.23*	0.0071±0.0009
	Gigartina radula	0.23*	40±10	5.6±1.1	0.018±0.003	2.0±0.4	0.24*	0.023*
Other	*Parechinus*	<0.1*	11*	9.4*	0.006*	-	-	-
	Pyura	-	230*	12*	0.075*	-	-	-
Linefish	*Seriola pappei*	1.0±1.8	14±3	6.7±1.5	0.0080±0.0049	0.29±0.08	0.057±0.042	0.040±0.008
	Argyrozona argyrozona	<0.1*	3.2*	3.2*	0.0026*	0.44*	0.029*	0.024*
	Johnius hololepidotus	0.72±0.97	7.2±5.4	3.8±0.8	0.0022±0.0004	0.14±0.06	0.018±0.006	0.031±0.002
	Pachymetopon grande	3.0*	5.2*	3.5*	0.0020*	0.23*	0.19*	0.018*
	Atractoscion aequidens	-	7.7*	5.7*	0.0041*	0.26*	0.059*	0.025*
	Chrysoblephus gibbiceps	<0.1*	5.8*	4.6*	-	0.16*	0.0020*	0.015*
	Lithognathus lithognathus	0.11*	5.0*	4.9*	0.0031*	0.21*	0.019*	0.044*
White fish	*Merluccius capensis*	0.26±0.44	4.9±3.3	3.7±0.4	0.0037±0.0011	0.22±0.11	0.075±0.062	0.038±0.008
	Xiphiurus capensis	0.92±1.54	4.4±2.9	4.8±2.0	0.0032±0.0013	0.21±0.10	0.037±0.032	0.028±0.027
	Synaptura marginata	1.3±1.8	4.5±3.3	4.0±1.6	0.0031±0.0004	0.17±0.12	0.14±0.09	0.0057±0.0015
Pelagic fish	*Trachurus trachurus*	0.14*	10*	4.4*	0.0081*	0.11*	0.028*	0.022*
	Sardinop ocellata	-	22*	11*	0.033*	0.91*	0.26*	0.013*
	Scomber japonicus	0.65±0.85	17±2	7.2±2.2	0.020±0.017	0.28±0.14	0.19±0.17	0.037±0.013
	Mugil richardsoni	<0.1*	6.7*	4.1*	-	0.19*	0.024*	0.0072*
	Scombrops dubius	-	3.5*	3.6*	0.0034*	-	0.055*	0.025*
Other fish	*Lophius piscatorius*	<0.1*	3.0*	3.7*	0.0062*	0.12*	0.066*	0.014*
	Triglia capensis	<0.1*	4.5*	3.7*	0.011*	0.11*	0.020*	0.032*

* single determination

Table 3

	Average concentration factors (5)							
	Species	Cr	Fe	Zn	Co	Mn	Sb	Cs
Molluscs	*Choromytillus meridionalis*	1 300	11 800	13 300	1 900	3 900	290	21
	Donax sera	3 000	35 000	15 000	1 900	1 400	260	21
	Haliotus midae	6 300	10 600	10 000	1 300	240	120	3
Crustacean	*Jasus lalandii*	1 000	1 600	14 200	200	390	170	29
Seaweeds	*Ulva spp.*	5 600	23 000	4 700	1 900	5 900	230	22
	Ecklonia maxima	1 600	1 900	1 000	320	360	120	28
	Porphyra capensis	5 900	22 000	9 200	2 700	8 700	300	16
	Suhria vittata	11 000	29 000	7 800	2 400	5 300	330	21
	Gigartina rachula	2 900	24 000	4 700	900	2 900	340	68
Other	*Parechinus*	-	6 500	7 800	300	-	-	-
	Pyura	-	135 000	10 000	3 800	-	-	-
Linefish	*Seriola pappei*	12 600	8 200	5 600	400	410	81	120
	Argyrozona argyrozona	-	1 900	2 700	130	630	41	71
	Johnius hololepidotus	9 000	4 200	3 200	160	200	26	91
	Pachymetopon grande	38 000	3 000	2 900	100	330	270	53
	Atractoscion aequidens	-	4 500	4 800	210	370	84	74
	Chrysoblephus gibbiceps	-	3 400	3 800	-	230	3	44
	Lithognathus lithognathus	1 400	2 900	4 100	160	300	27	130
White fish	*Merluccius capensis*	3 300	2 900	3 100	190	310	110	110
	Xiphiurus capensis	11 500	2 600	4 000	110	300	53	82
	Synaptura marginata	16 300	2 600	3 300	160	240	200	17
Pelagic fish	*Trachurus trachurus*	1 800	5 900	3 700	410	160	40	65
	Sardinop ocellata	-	12 900	9 200	1 700	1 300	370	38
	Scomber japonicus	8 100	10 000	6 000	1 000	400	270	110
	Mugil richardsoni	-	3 900	3 400	-	270	34	21
	Scombrops dubius	-	2 100	3 000	170	-	79	74
Other fish	*Lophius piscatorius*	-	1 800	3 100	310	170	94	41
	Triglia capensis	-	2 600	3 100	550	160	29	94

Table 4 : Calculation of the Annual Discharge

Dose limit			25 mrem
	Critical organ - liver		
Body burden			$4,7 \times 10^{-2}$ μCi
Daily intake			1×10^{-2} μCi.d^{-1}
	Critical food consumption	100 g.d^{-1}	
Permissible concentration in food			1×10^{-4} μCi
	Biological concentration	1×10^{4}	
Permissible concentration in seawater			1×10^{-8} μCi.cm^{-3}
	Physical dilution	3×10^{9} m^{3}	
Permissible release			30 Ci.a^{-1}

Table 5 : Restrictive DWL's and corresponding Release Rates for Duynefontein assumed cooling-water dilution rate of 100 m^3/sec = $3,15 \times 10^9$ m^3/yr (7)

Nuclide	DWL seawater (pci/cm^3)	Critical material	Release rate** (Ci/yr)
^{90}Sr	0.88	fish	140
^{91}Y	6,6	lobster, abalone, mussels*	1000
^{95}Zr	13	lobster, abalone, mussels*	2000
^{95}Nb	8,8	fish	1400
^{106}Ru	2,2	lobster, abalone, mussels*	340
^{137}Cs	2,4	fish	370
^{141}Ce	20	lobster, abalone, mussels*	3200
^{143}Pr	1,1	lobster, abalone, mussels*	180
^{144}Ce	2,2	lobster, abalone, mussels*	340
^{147}Nd	1,3	lobster, abalone, mussels*	200
^{147}Pm	4,4	lobster, abalone, mussels*	700
^{51}Cr	1,4	fish	220
^{54}Mn	0,92	black mussel	150
^{59}Fe	0,048	white mussel	10
^{60}Co	0,85	white mussel	130
^{65}Zn	0,14	lobster	30
^{124}Sb	1,1	white mussel	180
^{3}H	26 000	fish	$4,2 \times 10^{6}$
^{239}Pu	0,38	lobster, abalone, mussels*	60
β-γ mixture	0,33	external exposure (sunbathers and mussel diggers)	50

mussels = white mussel and black mussel
** Release rates have been based on 25 mrem.
annual exposure of individual members of the public

THE CASE FOR WATER QUALITY CRITERIA FOR SOUTH AFRICAN MARINE WATERS

D A Lord

INTRODUCTION

There is at present no standard procedure for providing design criteria and for exercising control of discharges to marine waters in South Africa. To date, discharges to the sea have generally been handled individually (and in most cases quite effectively). With a potential increase in discharges to the sea, it has been recognised that some form of normalisation is required to assist in the appropriate location and regulation of discharges and in the successful design and engineering of such discharges.

The proposal presented here discusses the options available to achieve this, and calls for the development of Water Quality Criteria for South African marine and estuarine waters.

The words 'Water Quality Criteria', 'Water Quality Standards', and 'Effluent Standards' are frequently used. For consistency it is suggested that in South Africa, we use the internationally accepted meanings of these words (given in Appendix 1 of this paper).

THE CONTROL OF DISCHARGES - AN INTERNATIONAL PERSPECTIVE

There are two ways of controlling discharges of effluents. The first of these is by prescribing effluent standards for given industrial types, the second is by indicating the water quality which must be maintained to support a certain end use. Each of these systems is being used at various places in the world and their merits are discussed.

Effluent Standards as a Means for the Control of Discharges

The control of the discharge of effluents by the use of effluent standards is in use in South Africa for discharge to fresh water, and in both Canada and the USA for example for discharge to all waters. In South Africa, there is one set of standards for discharge to freshwater, called the General Standards, which are in use for all effluents. (See Appendix II of this paper). In Canada and the USA, the development of standards has been more complex than this, and in fact, for each type of discharge, a different standard has been developed. (See Table 2.1).

Table 2.1: List of effluent standards issued in Canada, under the Water Act, and the Fisheries Act

- Phosphorous regulations
- Pulp and Paper
- Chlor Alkali
- Petroleum Refining
- Fish Processing
- Base Metal Mining
- Food and Textiles
- Other discharges: must meet the general requirements of the Fisheries Act which states that the effluent must not be accutely toxic (i.e. LT_{50} at 100% concentration must be greater than 96 hours).

To meet these standards, generally effluents must be treated to a point where they have "no toxicity". This will normally require sophisticated effluent treatment.

The problems with universal effluent standards are

a) they usually only consider concentrations and not total load (however, if the standards are very strict, this doesn't matter)

b) they take no account of differences in receiving water i.e. discharge to a small stream or to the open ocean must meet the same standards.

The advantages of universal standards is that there is no incentive for discharge to clean water to make use of additional assimilative capacity, and secondly, monitoring and enforcement is far simpler.

Water Quality as a Means for the Control of Discharges

The control of discharges by prescribing the water quality to be maintained where discharges occur is currently the method used for the control of discharges especially to marine waters, in places such as the California coast, the coast of Australia (New South Wales, Victoria and Western Australia), New Zealand, and for certain beaches of the EEC.

The advantages of water quality as a means of control is that differences in the sensitivities of receiving waters can be accommodated while the major significant disadvantage of this technique is that natural systems can legally be very rapidly loaded to their 'acceptable limit'. Any further discharges to the same body of water then requires a complete overhaul of all permits allowing discharge to that body of water. In addition, monitoring of the subtle effects of a discharge on a receiving body of water is notoriously difficult.

WHICH ROUTE SHOULD SOUTH AFRICA CHOOSE?

At first glance, it appears as if regulated effluent standards offer the simplest way of discharge control. This was the conclusion reached by both the USA and Canada in 1972, and systems were developed accordingly.

For discharge to fresh water, this type of control is usually essential; however, for discharge to marine waters there is now a major shift in regulatory philosophy in these two countries - one that will reduce reliance on treatment technologies and instead place far greater demand on the scientific capabilities to estimate the impacts of pollutants on ocean systems. For marine waters, effluent standards are finding less favour, due to a combination of circumstances, but most particularly because the control of industry is virtually impossible when no demonstrable effect of an effluent can be proved.

This philosophy of allowing effluent discharge provided water quality is maintained has been developed in some detail by the State of California who, for example, in 1978 developed the 'Water Quality Control Plan for Ocean Waters of California' based on the philosophy of maintaining water quality for specific uses. In addition, the US Environment Protection Authority (EPA) is now allowing the discharge of sewage sludge to sea contrary to its 1972 philosophy; the reasons cited by the EPA being that no 'measurable' deterioration in the water quality in specific areas has been demonstrated to have been caused by previous sludge dumping.

This does not mean that ocean disposal can be practised indiscriminately, and that if specific effluent standards don't exist, then water quality criteria must be available to resolve acceptable discharge levels.

Accepting the fact that the will exists in society (especially in industry and regulatory agencies) to maintain water quality in perpetuity, then the control of discharges in this manner represents an acceptable procedure, both to dischargers, and to those who control discharges.

THE DEVELOPMENT OF WATER QUALITY CRITERIA FOR SOUTH AFRICAN MARINE WATERS

Basic Proposal

It is proposed that Water Quality Criteria be established for South African marine waters using existing available information and the steps to be taken to do this are shown below:

Identify those waters under consideration.

Initially it is recommended that the criteria should be established for all marine and estuarine waters, and should extend out to the limits of the Exclusive Economic Zone (EEZ) of South Africa.

Identify existing reference information.

A considerable amount of information exists which could be directly incorporated into the preparation of water quality criteria for South African marine waters specifically; these include:

a) Water Control Plan for Ocean Waters of California, 1978

b) EPA; Water Quality Criteria for Fresh- and Saltwater

c) Water Quality Criteria for Marine and Estuarine Waters of Western Australia

d) Water Quality Criteria for Ocean Discharge, New South Wales, Australia

e) New Zealand: Water Quality Standards

f) EEC: Bathing Beach Water Quality Criteria

g) Published and unpublished South African laboratory toxicity and field data.

(This list is not exhaustive but indicates the large amount of relevant data available).

It should be noted that for certain water quality requirements, existing overseas information will be of little assistance. An example of this is the development of bacteriological criteria with regard to sewage discharge. In Australia, where water temperatures and offshore conditions are not dissimilar to those experienced in parts of South Africa, only faecal coliforms are incorporated into water quality criteria. In Natal by comparison where cholera is found, other pathogenic indicators must be included into water quality criteria.

The uses which are made of marine waters must be listed. These can be termed ' Beneficial Uses'; examples being - body contact recreation, navigation channels, shellfish growing areas, fishing grounds, harbours, etc.

The most comprehensive example available of this type of subdivision of water uses is that for Western Australia (see table 4.1).

Table 4.1 Water quality criteria: Western Australia

The following beneficial uses are identified

1. DIRECT CONTACT RECREATION
2. HARVESTING AQUATIC LIFE (excluding molluscs)
3. HARVESTING MOLLUSCS
4. HARVESTING AQUATIC LIFE - NON-EDIBLE
5. PASSAGE OF FISH AND OTHER AQUATIC LIFE
6. AQUACULTURE
7. PRESERVATION OF AQUATIC ECOSYSTEMS
8. PRESERVATION OF FORESHORES AND BANKS
9. MARINE/SCIENTIFIC
10. FLUSHING WATER
11. SUPPLY (AGRICULTURE/DESALINATION)
12. INDUSTRIAL SUPPLY
13. NAVIGATION

The concept of MIXING ZONES must be addressed.

By definition, water quality within mixing zones is lower than receiving water quality. Consequently it may not be possible to totally protect a number of beneficial uses within such areas. Therefore restrictions must be placed on the nett area allocated to mixing zones and/or on the frequency of maintaining the desired water quality.

This is an extremely difficult task, and will involve some subjectivity. The only example I know of where an attempt has been made to assess what constitutes an acceptable maximum mixing zone, is that of the US EPA in stating (specifically for the Great Lakes) ".....that the combined areas of all mixing zones within a lake should not exceed 10 % of the lake's surface area". Normally this will effect a much smaller percentage of the lake's volume.

For the marine environment, particularly where multiple pipelines are possible, designation of an acceptable mixing zone will require close consideration.

Establishment of a Working Group to Develop Criteria

A small (6-8 person) working group of active and involved persons must be established to develop draft criteria. Assuming that the time consuming steps are the collection of available information, the review, collation and interpretation of this information (which would be done with 3-4 meetings of such a group), and the publication of the draft, it is estimated that the entire process could be undertaken within a calender year.

These criteria will serve the interests of all involved in marine disposal in South Africa.

APPENDIX 1

Water Quality Criteria

Water Quality Criteria (or guidelines) are lists of conditions which must not be exceeded, in order to sustain a certain end use of that water in perpetuity. These conditions are usually expressed either as concentrations, or in a narrative form.

The development of water quality criteria (or guidelines) is essentially a scientific task, and requires a knowledge of the effects on the material under consideration upon the ecology of the given body of water receiving the discharge.

Water Quality Standards

Water quality standards are those numbers (i.e. concentrations) which have been legally set as being the upper limit not to be exceeded. The use of standards requires an appropriate law, as well as necessary enforcement.

Effluent Standards

Effluent standards are those legal levels which must not be exceeded in the effluent being discharged, before any mixing with receiving water occurs.

APPENDIX II

GENERAL STANDARDS

Quality standards for any waste water or effluent produced by or resulting from the use of water for industrial purposes in all areas of the Republic of South Africa other than in the catchment areas draining into rivers or portions of rivers described in the Schedule.

Colour, odour or taste : The waste water or effluent shall contain no substance in concentrations capable of producing colour, odour or taste.

pH : The pH of the waste water or effluent shall be between 5,5 and 9,5.

Dissolved oxygen : The waste water or effluent shall contain dissolved oxygen to the extent of at least 75 % saturation.

Typical (faecal) coli : The waste water or effluent shall contain no typical (faecal) coli per 100 millilitres.

Temperature : The temperature of the waste water or effluent shall not exceed 35°C.

Chemical oxygen demand : The chemical oxygen demand of the waste water or effluent shall not exceed 75 milligrams per litre after applying the chloride correction.

Oxygen absorbed : The oxygen absorbed by the waste water or effluent from acid N/80 potassium permanganate in 4 hours at 27°C shall not exceed 10 milligrams per litre.

Total dissolved solids:

- The total dissolved solids content of the waste water or effluent shall not have been increased by more than 500 milligrams per litre above that of the intake water.

- If the intake water is not public water, such waste water or effluent shall not contain total dissolved solids to an extent which, as a result of the disposal of waste water or effluent, will increase the total dissolved solids content of any public or private water, including underground water, to such a degree that such water is rendered less fit for the purpose for which it is ordinarily used by other persons (including the Government, the South African Railways and Harbours Administration and any provincial administration) entitled to the use thereof, or for the propagation of fish or other aquatic life, or for recreational or other legitimate purposes.

Suspended solids : the waste water or effluent shall contain not more than 25 milligrams per litre of suspended solids.

Sodium content :

- The total sodium content of the waste water or effluent shall not have been increased by more than 90 milligrams per litre above that of the intake water.

- If the intake water is not public water, such waste water or effluent shall not contain sodium to an extent which, as a result of the disposal of the waste water of effluent, will increase the sodium content of any public of private water, including underground water, to such a degree that such water is rendered less fit for the purposes for which it is ordinarily used by other persons (including the Government, the South African Railways and Harbours Administration and any provincial administration) entitled to the use thereof, or for the propagation of fish or other aquatic life, or for recreational or other legitimate purposes.

Soap, oil or grease : The waste water or effluent shall contain not more than 2,5 milligrams per litre soap, oil or grease.

Other constituents : The waste water or effluent shall comply with the requirements given in Table II.

TABLE II

Constituents	Maximum concentration in milligrams per litre
Residual chlorine (as Cl)	0,1
Free and saline ammonia (as N)	10,0
Arsenic (as As)	0,5
Boron (as B)	1,0
Hexavalent chromium (as Cr)	0,05
Total chromium (as Cr)	0,5
Copper (as Cu)	1,0
Phenolic compound (as phenol)	0,1
Lead (as Pb)	1,0
Cyanides and related compounds (as Cn)	0,5
Sulphides (as S)	1,0
Fluoride (as F)	1,0
Zinc (as Zn)	5,0

The waste water or effluent shall not contain any other constituents in concentrations which are poisonous or injurious to humans, animals, fish other than trout, or other acquatic life or deleterious to agricultural use.

Methods of testing : The methods of testing for the above-mentioned requirements will be as published in the **Government Gazette** from time to time.

Industries exempted from compliance with any quality requirements as regards their effluents : None of the above-mentioned requirements shall apply to effluents arising from the use of water in mechanical or similar processes in which the physical, chemical or bacteriological quality of the abstracted water is not materially affected.

(Government Notice 909 of 28 May 1971).

RAPPORTEURS' COMMENTS ON DISCUSSION OF ESTABLISHING SAFE RELEASES - WATER QUALITY CONSIDERATIONS

A G S Moldan
D van As

During this session the limits for discharge in the nuclear industry, human health aspects of marine discharges and the use of toxicity testing in developing guidelines for industrial discharge were described. From these presentations it was apparent that the control of effluents from the nuclear industry was clearly defined while the discharge of industrial and municipal effluents was dealt with on an individual basis with these procedures being less formalised. A system of standardising these procedures by means of establishing water quality criteria along the lines of those adopted by Western Australia, amongst other countries, was proposed. It was pointed out that the receiving water quality criteria would consist of two parts: the designated uses of the waters involved, and the water quality criteria for the waters based upon these uses. Water quality criteria are numerical and descriptive limits for water constituents which are designed to protect designated uses of a body of water e.g. dissolved oxygen may not be less than 4.0 mg/l, or no floating scum or debris should be present. These criteria would act as guidelines which would assist in establishing limits for industrial and municipal discharges. At a later stage, once these criteria have been verified through monitoring and further toxicity testing, it could be possible to elevate these criteria to a system of standards.

It was agreed that this system of controlling discharges to sea could be used to great benefit in South Africa. A proposal to establish a formal working group with the task of identifying beneficial water uses, designating limits for the protection of these water bodies and to address the concept of "mixing zones" was accepted. This group will produce a draft document which will be distributed to all interested parties prior to its finalisation. Once this has been completed the formulation of standards can be considered by the relevant responsible bodies.

ENGINEERING DESIGN

K.S. Russell

SYNOPSIS

The present and projected development of coastal areas necessitates the disposal of large quantities of industrial and domestic wastewater. The method of disposal must be selected to minimise the detrimental effects of the effluent discharge on the environment.

A properly designed and located diffuser system at the end of a sea outfall provides an efficient method of maximising initial dilutions and achieving the regulatory requirements.

The paper describes (1) the process of dilution and the subsequent dispersion of the discharged effluent and (2) summarises briefly the oceanographic data and marine surveys required for the engineering design aspects of an ocean outfall.

GENERAL

The construction of a marine pipeline for the disposal of pollutants requires not only sound engineering design of the structure but siting of the pipeline also requires close interaction and co-ordination with marine biologists and chemists (collectively termed the "marine ecologists") responsible for assessing the environmental impact of the scheme.

Ocean outfalls are acceptable primarily because of the large dilutions which can be achieved in the disposal of waste material in the sea; consider, for example, the levels of E Coli in sewage:

Raw domestic sewage	-	$10^7 - 10^8$/100 ml
Full biological treatment to Royal Commission Standard	-	$10^6 - 10^7$/100 ml
E E C Mandatory standard of bathing waters	-	2000/100 ml in 95% of samples taken
Dilution required for treated sewage	-	500 - 5000

While large quantities of waste can be absorbed by the sea these must be introduced so that the environment is not materially polluted and so that pollution standards, in the area of the pipeline and at the adjoining beach, are maintained in accordance with the public health, aesthetic, ecological and recreational considerations.

DILUTION

The total dilution, S_T, after the release of buoyant effluent from an outfall is given by

$$S_T = S_j \times S_e \times S_d$$

where S_j = the jet diffusion occurring between the discharge and the ambient sea water as the effluent rises to the sea surface

S_e = the eddy diffusion due to turbulent mixing as the effluent field moves with the current; this dilution is normally about one-tenth of that due to the jet diffusion

S_d = decay depending upon the nature of the effluent and the time of transit

<u>Jet dilution - S_j</u>

The jet dilution is directly dependent on the effluent density, the water depth and on the design of the diffuser section. For a buoyant effluent discharged from a single outlet into a uniform, stagnant, ambient fluid the jet dilution is found as follows:

$$S_j = 1{,}74\ S_m$$

where S_j = average dilution across the jet

and S_m = minimum centreline dilution

$$S_m = 0{,}107 \left(\frac{h/d_j}{F}\right)^{5/3}$$

h = effective depth above jet axis

d_j = outlet port diameter

F = jet Froude number

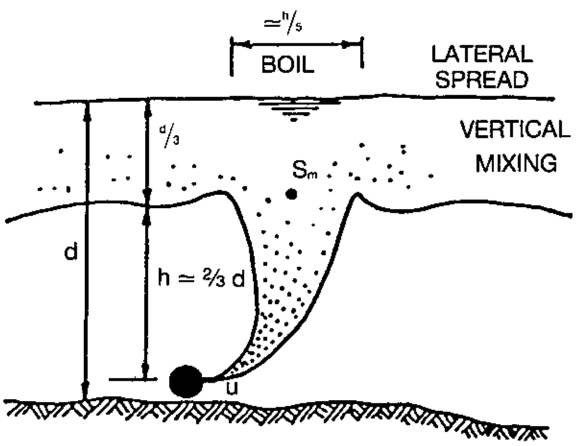
$F = u/\sqrt{\Delta\rho' g d}$

where ρ_s = specific density of sea water

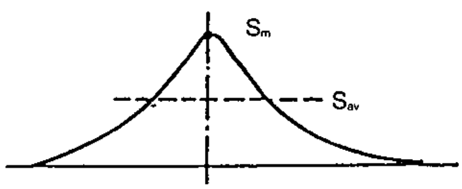
ρ_{eff} = specific density of effluent

u = discharge velocity

$\Delta\rho' = (\rho_s - \rho_{eff})/\rho_s$



HORIZONTAL JET IN STILL WATER



CONCENTRATION DISTRIBUTION ACROSS BUOYANT JET

If instead of being discharged through a single outlet, the effluent is discharged through a series of smaller outlets at the end of the pipeline, the degree of dilution can be greatly increased. The hydraulic design of the diffuser to optimise the size and spacing of the discharge ports so as to obtain maximum dilution for minimum loss of power (i.e. minimum pumping costs) is very much a repetitive "trial and error" process and very suited to computerised design methods. As a guide to planners, an outfall extending into, say, 15-20 m waterdepth can be expected to optimally achieve dilutions of about 150-200 at the surface.

Eddy diffusion - S_e

Further dilution occurs during transport of the waste by currents and dispersion by turbulence from the action of wind and waves. The eddy dilution at any point at a distance downstream of the source and on the centre-line of the field can be calculated according to a number of theories. The majority of these theories contain a dispersion factor or coefficient, determination of which may require in situ field measurements involving the release of tracer material, such as rhodamine dye, and its subsequent tracking and sampling.

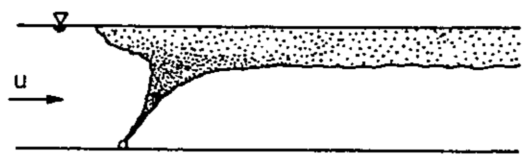
Roberts (1979) performed extensive laboratory tests to determine dilution for a diffuser located in a current. His research results indicate that the minimum surface dilution S_m can be expressed as

$$\frac{S_m q}{ud} = f(F',\Theta)$$

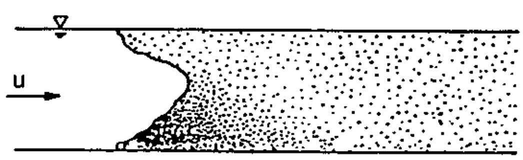
where q is the discharge per unit length of diffuser, u the ambient current speed, d the water depth, Θ the angle of current with respect to diffuser orientation and F' a Froude number which describes the relative magnitudes of the forces on the effluent due to buoyancy and the inertia of the ambient current and which is defined as

$$F' = u^3/(\frac{\Delta\rho}{\rho} gq)$$

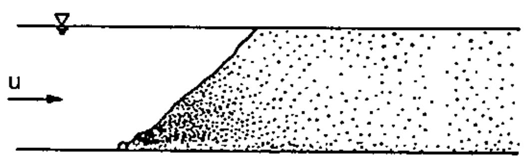
where $\frac{\Delta\rho}{\rho}$ is the relative density difference between effluent and ambient and g is gravitational acceleration. Roberts found that the Froude number F' is the dominant parameter in determining the shape of the flow field and the dilution.



a) F < 0.2 Plume and upstream wedge.



b) 0.2 < F < 1. Forced entrainment and upstream wedge.



c) F > 1. Forced entrainment, no upstream wedge.

Using the graphs given by Roberts (1979) it is also relatively simple to determine the concentrations at any distance from the source.

Decay - S_d

Decay is obviously dependent on the specific constituent of effluent in which we are interested and must be determined experimentally. In many cases the decay may be neglected. The decay may be expressed by:

$$S_d = e^{-kt/3600}$$

where k is the decay constant (per hour) and t the time after release (seconds). If the time taken by the effluent to travel through the pipe is neglected, the time t is given by:

$$t = \frac{x}{u}$$

where x is the distance along the current trajectory from the source and u is the ambient current speed.

Although there are certain gaps in the knowledge of diffusion processes, dilutions can be calculated with sufficient accuracy for most practical purposes by simplification of the situation so that these mathematical techniques can be applied. The main shortcoming is that the sea is usually regarded as having a uniform current field while in reality there are considerable variations in current speed and direction, both spatially and over the vertical. Provided extensive prototype records are available of the environmental inputs (wind, wave, current, density) statistical techniques can be used to provide estimates of the frequency of occurrence and levels of concentrations on which to base a sound environmental assessment.

OCEANOGRAPHIC DATA

Environmental data on wind, waves and currents are necessary not only for the design of the diffusers and assessment of the environmental impact of the pipeline but also for the structural design of the pipe and for determining the most cost-effective method of construction.

DATA RECORDED AND ANALYSIS

WIND	DIR, VEL	DAILY/MONTHLY/ANNUALLY MAXIMUM/MINIMUM/AVERAGE DIRECTIONAL DISTRIBUTION ON-OFF/PARALLEL VECTORS EXCEEDANCE/PERSISTENCE
WAVE	DIR, HEIGHT, PERIOD	
CURRENTS	VEL, DIR, DEPTH, DURATION	
TIDES	HEIGHT/PERIOD	

DENSITY STRUCTURES

APPLICATION OF DATA FOR DESIGN PROCESS

WIND	SURFACE DRIFT, WAVE PREDICTION
WAVES	DISPERSION OF EFFLUENT, FORCES ON PIPELINE AND CONSTRUCTION JETTY, REQUIREMENT FOR DESIGN OF CONSTRUCTION, PLANT AND BARGES, SEDIMENT MOVEMENT
CURRENTS	DILUTION OF EFFLUENT, TRANSIT TIME TO COAST, FORCES ON PIPELINE, SEDIMENT MOVEMENT
TIDE	WATER LEVEL VARIATION, TIDAL CURRENTS

PIPE ROUTE

Before the pipeline is laid, extensive sea-bed surveys, consisting of topographic, seismic, side-scan surveys and diving investigations are essential to define the pipeline route and to insure against damage caused by foundation problems. The "envelope of movement" of the sea-bed in the highly variable surf-zone must be determined to avoid undermining of, and subsequent damage to, the pipeline which could necessitate costly repairs and even shut-down of factories discharging into the pipelines.

A marine pipeline, in the context of engineering, is a complex structure, requiring, for the South African coastline, specific protection through the hostile surf-zone. In deeper water the submarine pipeline is normally placed on the unprepared sea-bed. The forces on the pipeline due to waves and currents must be calculated to ensure that the outfall will not be damaged by catastrophic events and to determine the anchorage system for securing the pipe to the sea-bed along its route. The pipeline is also subject to many (often simultaneous) forces - especially during construction.

CONCLUDING REMARKS

The design of an ocean outfall is basically an interactive process involving not only engineering factors but also economics, aesthetics, health, planning, sea fisheries and other social and intangible factors. These in combination clearly indicate the need for a comprehensive **Environment Impact Statement** requiring continued joint cooperation between the various disciplines involved and concerned with the design.

SEA-BED INVESTIGATIONS FOR OCEAN OUTFALLS

B W Flemming

INTRODUCTION

The siting of ocean outfalls faces two major technical constraints. The first is defined by the overland accessibility of the coastline and the second by the suitability of the beach and nearshore environment for pipe laying. Thus, before any sea-bed survey can commence, it is necessary to identify and demarcate all potential onshore access points to the sea.

It is furthermore important to acknowledge that in many cases a compromise has to be reached between overland accessibility and offshore suitability. Keeping these constraints in mind it is clear that a final decision on any particular pipe route will be governed by considerations such as technical feasibility and overall costing of the project, which incorporates an assessment of the desired and expected life expectancy of the outfall.

The demand of any sea-bed investigation is therefore not simply to provide the necessary background data required for the actual design and construction of the outfall, but in the first place to supply the client with sufficient information for a decision on the most cost-effective solution.

OFFSHORE SITE CRITERIA

Ocean outfalls have been constructed under a wide range of environmental conditions and there is no ultimate best solution, but rather a corresponding variety of optimal solutions. In some cases even the best available solution may be inadequate. In the South African context the majority of ocean outfalls are (or will be) situated at relatively exposed localities and under such conditions sandy bottoms are generally preferred to rocky bottoms.

Sandy sea-beds have the advantage that the outfall pipe can be completely buried. This is particularly useful in the high-energy nearshore (e.g. the surf zone) where the risk of damage is high. In addition, straightforward trenching is also the quickest and least complicated (and hence most cost-effective) procedure. The main hazard affecting buried pipelines is their excavation and undercutting by large scale swell and current induced sediment movement. Such local conditions will affect decisions on the depth of burial and the frequency of pipe route surveys for monitoring purposes.

Rocky sea-beds in general have a lower rating than sandy bottoms and will only be considered if there are no alternatives . Since a pipeline cannot tolerate long, unsupported sections it is inevitable that either blasting or bridging is required to "smoothen" the pipe route. The pipe is then pinned to the seafloor and this requires diver-controlled precision drilling and/or other underwater construction work. Clearly the entire exercise can never be as cost-effective as trenching. The main hazard to pipelines exposed on the sea-bed are heavy ground swells which can either rip it out of its anchoring or cause extensive damage by moving cobbles and boulders.

SURVEY OBJECTIVES

Sea-bed investigations for ocean outfalls are carried out with a number of specific objectives in mind. The most important of these - listed in order of general priority - are:

a. sea-bed physiography

b. bathymetry

c. sediment thickness

d. geotechnical properties.

The order of priority may, of course, change from case to case. For example, it may appear desirable to obtain a detailed bathymetry before embarking on a physiographic survey, or it may become unnecessary to determine sediment thicknesses if an area is found to be rocky throughout. An important aspect to note is that any survey activity at sea is only meaningful if it is carried out under constant high-precision navigational control. Detailed discussions of various methods including a number of case histories in offshore site investigation can be found in Ardus (1979) and le Tirant (1979).

a. Sea-bed Physiography

A physiographic description of the sea-bed entails both qualitative as well as quantitative information. The qualitative category addresses the general nature of the sea-bed, e.g. whether an area consists of muddy, sandy, gravelly or rocky bottom, or any combination of these. The quantitative category requires an accurate determination of the localities and exact areal extent of each physiographic unit observed in the survey area. Such information can be partially obtained from echo-sounder profiles coupled with sea-bed sampling. The quickest and most reliable method, however, is a side-scan sonar survey with a 100 per cent coverage of the survey area. Sonograph mosaics accurately define both the qualitative and quantitative aspects outlined above. In addition, there are no gaps in the survey data. It should be noted however, that side scan sonar data does not provide accurate bathymetry or precise geotechnical information about the various physiographic units. Relevant information can be found in Flemming (1976), Russell (1978), Milne (1980) and Russell-Cargill (1982).

b. Bathymetry

A bathymetric or hydrographic survey, as it is sometimes referred to, entails the compilation of a detailed topographic map of the sea-bed. For ocean outfall projects a depth resolution of better than 1 m is required, i.e. the depth chart must be contoured at 1 m intervals or smaller. The chart datum is usually taken at mean low-water level and around the South African coastline precision surveys will always need a tidal correction. It should be noted that depth contours are the result of interpolations between individual depth soundings extracted from echo-sounder profiles and that their accuracy is therefore directly proportional to the density of measured soundings. Ideally bathymetric charts should always be viewed in conjunction with side scan sonar data since the two parameters are complementary. Hydrographic surveys are discussed in McQuillin and Ardus (1977) and Milne (1980).

c. Sediment Thickness

In sandy areas, where the best option is to bury a pipe by trenching, it is necessary to probe the thickness of the sediment. This can be done in a number of ways, the quickest and most effective being high-resolution seismic reflection profiling. This method is in principle similar to echo-sounding, except that sound sources are used that can penetrate the sea-bed and then record the echoes reflected from various sediment strata. It is the most complicated part of a sea-bed survey, as it requires highly specialized equipment and considerable skill and expertise, both in its operation as well as in the interpretation of the data. For the purpose of ocean outfalls a sub-bottom resolution of at least 1 m is desirable and this limits the choice of equipment to boomers, pingers and other high frequency (2-7 KHz) sound sources. In this regard it should be noted that a sound source suitable at one site may be unsuitable at another because of differences in the acoustic properties of the substratum. Another important aspect to note is that sub-bottom profiling does not provide any reliable geotechnical information; for example, it does not indicate the absolute level of compaction of the sediment. This has to be established by direct coring or probing. These procedures will be addressed in the next section. Good overviews of seismic reflection methods are presented in McQuillin and Ardus (1977), Dyer (1979), Le Tirant (1979), and Milne (1980).

d. Geotechnical Properties

Geotechnical sea-bed investigations are carried out either in situ or in the laboratory, using sea-bed samples recovered on site. A wide range of geotechnical properties can be measured and only the more common ones are addressed below.

In order to quantify the geotechnical properties of various physiographic units identified by side scan sonar, it is necessary to cover the survey area with a number of selected sample stations. Sediment samples are analysed for their composition, size distribution and other textural parameters, including porosity and permeability, whereas rock samples will provide information on the geology and petrography of exposed bedrock. Samples are usually recovered by a grab (e.g. van Veen or Shipek) which is lowered from the survey vessel. If bedrock is of special interest it may be necessary to use divers for sample recovery.

In areas where geotechnical information is required about the sub-bottom, specialized coring and probing techniques have to be applied. In sand the most effective coring method is a vibro-corer, which can easily penetrate up to the depths normally required in ocean outfall studies, e.g. 3 m. Such cores provide a wealth of useful information, especially on the degree of compaction of the sediments belonging to different strata. A vibro-corer will also penetrate into cemented or indurated sediments like calcrete or aeolianite, although the depth of penetration will depend very much on the degree of cementation. Sediment compaction and depth can also be assessed by diver operated water-jet probes. If longer rock cores are required then a proper underwater rock drill will have to be used. Comprehensive theoretical treatments of geotechnical analyses is presented by Le Tirant (1979) and Almagor (1982). Useful information can also be found in Dyer (1979) and Ardus (1979).

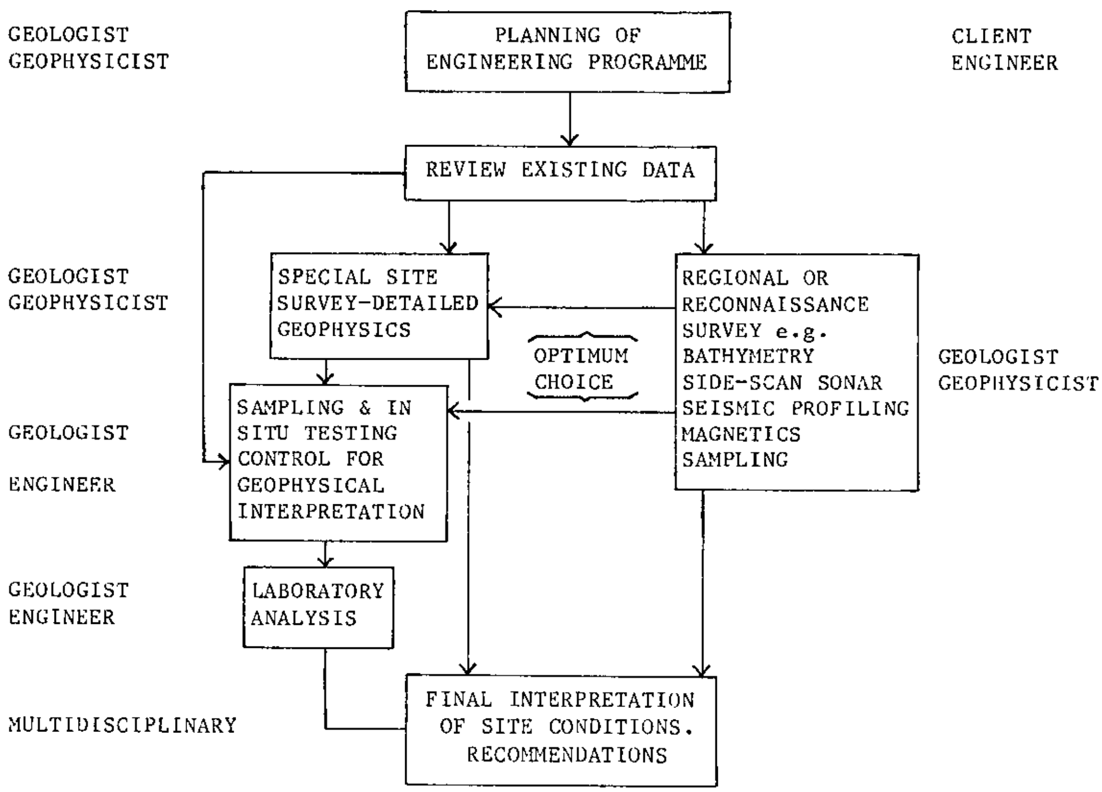
SURVEY STRATEGY

A sound survey strategy can only be developed if the survey objectives are clearly defined and specified. Since most clients are not fully aware of all the implications and requirements associated with sea-bed surveys, it stands to reason that the survey strategy should be developed by mutual consultation and agreement between the various parties involved, i.e. the client, the consulting engineers and the geologist responsible for the sea-bed survey.

The first step in any survey is to establish the suitability of the offshore terrain in the vicinity of an onshore access point. This is most effectively achieved by a side scan sonar survey, as it provides the most comprehensive information about the physiography of the sea-bed. In the case of several potential access points the reconnaissance survey will rapidly establish an order of preference. For example, an area could be unconditionally suitable or totally unsuitable. With this information at hand, a final decision can be made as to which site is the most "suitable" when considering all other constraints of the project.

The next step is to determine the exact route of the pipeline. Again the side scan sonar data will be the deciding factor on homing in on one or more potential routes. In the case of sandy bottom these are then surveyed by high resolution sub-bottom profiling in order to establish the distribution of sediment thicknesses. By combining this information with the side scan data, the exact pipe route can be defined. The immediate vicinity of this route is then investigated with respect to its geotechnical properties using various techniques outlined above.

The attached flow chart gives a simplified overview of the individual steps and communication levels associated with a sound survey strategy for sea-bed investigations.



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PIPELINES IN THE SURF ZONE

D H Swart

THE SURF ZONE

Waves approaching the shore become unstable and eventually break, dissipating their energy in the process. The type of wave breaking depends on the bed slope and the deep water wave steepness H_o/λ_o. The most common breaker types are spilling and plunging. Broadly speaking, spilling breakers occur for waves with a high steepness ($\gtrsim 0,02$) which break on a beach with a mild slope (<0,05). Plunging breakers, on the other hand, are mostly associated with waves having a low deepwater wave steepness and can occur on most beach slopes. In the field plunging breakers mostly occur on beaches with a very pronounced breaker bar (or bars). What frequently happens is that the waves break as plunging breakers only to reform and break as spilling breakers until another breaker bar is reached closer to shore where plunging breakers can again be observed.

Waves breaking as plunging breakers lose a substantial portion of their energy at the breaker point, whereas spilling breakers gradually lose their energy across the breaker zone. The differentiation between spilling and plunging breakers is not very clear cut and it is possible to observe waves breaking as partly spilling/partly plunging with an associated dissipation rate somewhere between the extremes as observed for spilling and plunging breakers.

Although many attempts have been made to determine the exact breaker location theoretically, the best information to date is still empirical of nature. Furthermore, in nearly all cases a plane beach is considered, whereas it is a proven fact that waves might break on a breaker bar even though the wave height is not really close to breaking for the case of a plane beach. A convenient way of determining the initial breaker location is to use the socalled "breaker index", that is, the ratio of wave height to water depth at wave breaking. For spilling breakers the breaker index stays approximately constant across the breaker zone, whereas it decreases sharply from its initial value in the case of plunging breakers.

For spilling breakers the breaker index could be as low as 0,4, although it would more realistically vary between 0,5 and 0,7. In the case of plunging breakers the initial breaker index will typically vary between about 0,7 and 1,0, although values of 1,3 are not uncommon and 1,8 has been observed in specific cases. For plunging breakers which reform the breaker index will then drop to the range normally found for spilling breakers.

The width of the breaker zone depends on the incident wave height and the sea-bed profile and can vary between virtually nothing and more than a kilometre. Typically the median width is of the order of a few hundred metres along the South African coastline.

Sediment is entrained in the violent surf zone by orbital motion over the bed forms, by bulk erosion due to the fluctuating pressure at the bed and due to the excessive turbulence due to wave breaking. This sediment in suspension can be transported out of the area under consideration by residual currents. In this way onshore or offshore transport of sand can take place with a predominance for onshore transport during periods of low wave attack and with offshore transport more prevalent during periods of high storm waves. Obliquely incident waves generate longshore currents in the coastal zone extending to about twice the breaker zone width with the strongest currents in the outer part of the breaker zone. These currents cause the longshore transport of sand. The net transport direction over a year will depend on the variability in the direction of wave attack over a year. Typical values for the magnitude of the net longshore transport could fall between nought and a few million cubic metres per year with an expected median of the order of hundreds of thousand cubic metres/year (e.g. Durban 650 000 m^3/yr, Richards Bay 800 000 m^3/yr).

Gradients in the magnitude of either on-offshore or longshore transport cause accretion or erosion. As a result substantial variations in the bed level in the coastal area can be observed even over a short time span such as days or even hours. The envelope of all beach levels recorded over an extended period, say one year, is called the dynamic swept prism and is indicative of possible variations in seabed level. The dynamic swept prism normally extends from the backshore through the breaker zone to a water depth of approximately 15 m. The difference between the upper and lower envelope of the dynamic swept prism could be as high as 4 m for South African conditions and normally occurs in the surf zone.

DEPTH OF BURIAL OF PIPELINE

It is normal practice to divide the nearshore zone into two areas when determining the elevation of an ocean outfall, namely, the breaker zone and the area seawards of it. It is customary to bury the pipeline to such an extent inside the breaker zone that its crest elevation is below the design lowest sea-bed level. Outside the breaker zone it is sufficient, according to the Town and Regional Planning Commission (1969), to bury the pipeline in the sea bed to half the pipe diameter, provided that sandy conditions occur.

Tests done in the Delft Hydraulics Laboratory for the outer area for a sewer outfall at The Hague in the Netherlands indicated that if the pipeline is buried to a depth of two-thirds of the pipe diameter, possible scour holes under the pipeline will not increase in size but will fill up (DHL, 1966). For this reason a depth of burial of two-thirds the pipe diameter is recommended, rather than the value of one-half the pipe diameter quoted above.

It is felt, however, that the use of the breaker line to distinguish between these two zones is not a conservative enough practice. Although the water movement outside the breaker zone is clearly less turbulant than inside the breaker zone, it is still possible for large sediment movement to take place. To illustrate this point reference is made to the study by Swart (1974) of onshore-offshore sediment movement. Swart found that the bed profile could be divided into three clearly definable areas, each with its own particular sediment transport mechanism, namely,

(i) a backshore area, landwards of the point of maximum wave run-up, where sediment movement normally takes place in the form of slumping due to undercutting;

(ii) the actual developing profile (D-profile), between the point of maximum wave run-up and a limiting depth h_m in seaward direction, within which sediment movement takes place very actively as both bed load and suspended load, with a predominance for the latter, and where sea-bed changes are frequent and often dramatic; and

(iii) a transition zone seawards of the limiting depth h_m, which normally has a rather smooth transitional slope between the developing profile and the original profile and where sediment transport normally takes place as bed load.

Swart (1974) used numerous data sets from both laboratory experiments and observations in the field to determine empirical relationships for the calculation of these profile limits.

With this background it is suggested that the dividing point between complete burial and partial burial be chosen at the seaward limit of the developing profile.

Swart (1974) found the expression by which this seaward limit can be obtained to be:

$$h_m = 0{,}01\ T_p^2 \exp\left(4{,}347 \frac{H_{so}^{0{,}473}}{T_p^{0{,}894}\ D_{50}^{0{,}093}}\right)$$

where T_p is the peak wave period, H_{so} is the deepwater significant wave height and D_{50} is the median particle diameter.

In the design of a pipeline at Richards Bay, for example, it was found that h_m varies between 3,3 m and 9,4 m below actual water level. The mean value was 4,2 m and a depth of 7 m below actual water level was exceeded only 3 per cent of the time.

WAVE FORCES ON PIPELINES

The hydrodynamic forces acting on a submarine pipeline due to wave action are complex and are functions of time. Since the periods and phases of the various forces are mostly different it is difficult to predict the magnitude and direction of the resultant forces at any given time.

Three different types of forces can be indentified, namely drag forces, lift forces and inertial forces.

Drag forces (F_D) are difficult to predict under oscillatory flow as a result of the unpredictability of the behaviour of the wake. Nevertheless, it has remained covenient to express the drag force F_D in a similar way to that in steady flow, namely,

$$F_D = \tfrac{1}{2} C_D D \rho u/u/$$

where C_D is drag force coefficient, D is pipe diameter, ρ is mass density of water and u is the instantaneous water particle velocity.

<u>Lift forces</u> (F_L) on a pipeline sitting on the bed in oscillatory flow are again difficult to predict because of the different wake patterns, but are always directed upwards. For pipes raised some small distance above the bed this is no longer the case and a downward force may result.

$$F_L = \tfrac{1}{2} C_L D \rho u^2$$

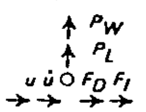
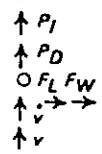
The lift force coefficient C_L is, as in the case of C_D, not constant but varies across the wave period. In the case of pipes off the bottom C_L will have negative value.

<u>Inertial forces</u> (F_I) act on a pipe in oscillatory flow due to the continual accelerations and decelerations. The inertial force per unit length acting on a circular cylinder with diameter D is given by

$$F_I = C_I \rho \, (\pi/4) D^2 \dot{u}$$

where C_I is the inertial coefficient and $\dot{u}$ is the instantaneous value of the horizontal particle acceleration.

Using these three forces it is possible to envisage eight different force components on a horizontal pipe, as can be seen in the diagram below (after Schrecker, 1980), where u and $\dot{u}$ are horizontal components and v and $\dot{v}$ vertical components.

		
Vertical. forces	$P_L = C_L D \frac{1}{2} \rho u^2$ (harmonic, periodicity $T/2$) $P_W = C_W \rho \frac{\pi D^2}{4} \dot{u}$ (harmonic, periodicity T)	$P_D = C_D D \frac{1}{2} \rho \lvert v \rvert v$ (non-harmonic, periodicity T) $P_I = C_I \rho \frac{\pi D^2}{4} \dot{v}$ (harmonic, periodicity T)
Horizontal forces	$F_D = C_D D \frac{1}{2} \rho \lvert u \rvert u$ (non-harmonic, periodicity T) $F_I = C_I \rho \frac{\pi D^2}{4} \dot{u}$ (harmonic, periodicity T)	$F_L = C_L D \frac{1}{2} \rho v^2$ (harmonic, periodicity $T/2$) $F_W = C_W \rho \frac{\pi D^2}{4} \dot{v}$ (harmonic, periodicity T)
	Forces due to horizontal components of motion	Forces due to vertical components of motion

Instantaneous hydrodynamic forces due to waves

The three techniques most commonly used to predict forces on pipelines are those of Morrison (Davis, 1976), Wallingford (Anon, 1980) and Grace (Grace and Zee, 1981). In order to apply these methods the wave particle kinematics should be known. In a recent study CSIR (1982) calculations were done with the linear Airy wave theory, Dean's stream function theory (Dean, 1974) and the Vocoidal wave theory (Swart, 1978). It was concluded that the most consistent answers are obtained by using Grace's technique together with wave kinematics obtained from Vocoidal theory.

In cases where the weight of the pipe is not sufficient to withstand the hydrodynamical forces the stability of the pipe can be increased by adding collars at regular intervals.

Seeing that substantial sea-bed changes can take place over short periods of time, it is possible that a pipe can be exposed in the surf zone during the construction phase in an area of multiple bars and troughs. It could then be subjected to forces exceeding the design condition. For this purpose the area of transect through the hostile breaker zone is frequently protected by a sheetpile structure on both sides to prevent active sediment movement and to keep wave action to a minimum. The exact procedure followed will depend to a large degree on the construction method, the design cross-section of the pipe and the pipe material.

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SUBMARINE PIPELINES: PRACTICAL CONSIDERATIONS IN THEIR DESIGN AND INSTALLATION

A Moss-Morris

It is presumed in this article that the length, diameter and type of diffuser has been determined as given in the previous papers.

Invariably these marine outfalls will be located on reasonably exposed coasts so as to achieve a maximum dilution, both by diffusion in waves and by transport in the offshore current. I will confine myself primarily to those pipelines which are carried some distance out to sea and whose diffusers are located way beyond the zone of breaking waves. There are unfortunately a number of short outfalls in South Africa which currently discharge either on to the beach or into the surf zone. It is hoped that neither type, unless they be stormwater outfalls only, will be built in the future.

There are two main types of pipeline currently available. The first of these are the rigid pipelines which in South Africa in general have been steel pipes formed as one long continuous welded pipe. The alternative pipeline is the flexible pipeline of which there is already at least one discharging off the South African coast and these are in general built of high density polyethylene. Where hot fluids are to be conveyed, polypropylene has also been used. The special features of this type of material is its capacity to safely withstand a strain of 2% even over long periods of time. As this is approximately sixteen times the strain of a steel pipe at its yield stress, the HDPE pipes for the same diameter can be laid to very much sharper radii, probably with a radii of curvature of only 3% of that which would be considered safe for the equivalent steel pipe. Although concrete pipelines are not uncommon on the west coast of the United States, they are normally only used when very large diameter pipes, that is in excess of 2,4 meter are needed and these will not be considered further as none have been built in South Africa of the type being considered.

As explained in Dr Swart's paper, pipelines in the surf zone are subject to rapidly changing seabed levels with considerable onshore/offshore movements taking place in relatively short periods. In addition, in this zone the forces on an exposed pipeline applied by the waves both before and after breaking are very considerable. It is also difficult to obtain reliable data in the surf zone both of the likely depths to which the scour may occur and even of the soil types and properties which exist within the surf zone. The writer would define the surf zone as the area from the highwater level - not the highwater mark - down to a seabed depth of between 7 and 8 meters below water Ordinary Spring Tide or chart datum. During extreme storms the surf zone can extend considerably seaward of this area but it is possible in normal conditions to obtain information on sea bottom conditions in the zone of extreme waves during normal periods. As invariably the pipelines will be placed on reasonably exposed portions of the coast the initial seabed investigation presents quite a problem. The only feasible way to obtain proper reliable information as to soil type and consistency (i.e. to do proper drillings) will normally be to build a jetty across the surf zone for a typical length of 300 to possibly 400 meters. The cost of this jetty which could be a fairly light construction, say in timber in the inshore section, but will probably need to be built of steel piles in the deeper water, may well be a million rand. Unless the jetty can be incorporated in the permanent works, in which case it will cost considerably more, it would seem to be a costly method of obtaining the necessary soil information. I may add that no such exploratory jetty has to the writer's knowledge been built in South Africa but that does not mean that it should not be built. It only means that when a pipeline contract is started we do not normally know the rock level over a length of at least 300 meters in the most crucial zone for the pipe.

Due to the high cost of the jetty, alternative methods of exploration which do not provide the same quality of data but do at least provide basic information have been slowly developed over a number of years. These techniques are primarily the use of high pressure water jets held by a diver, which the writer has successfully used to check whether rock exists within the first four meters of the seabed at the time when the probing is made. This survey must also obviously provide a sea bottom profile which can be done by the use of divers and surveying methods even in the zones where boats cannot safely penetrate. Over the years the CSIR has used a ski-boat system for determining sea bottom levels but this also has many disadvantages. We have now extended this method of diver jet probing to increase the depth which is investigated to a probable six meters by the use of sacrificial casings which are left in the seabed. It is the writer's belief that these probings should be conducted at close centres, particularly where the rock depth is shallow, and for a typical investigation we have suggested that probes to a depth of three meters be carried out at six meter centres and if these should not meet with refusal on rock, that deeper probes to a six meter depth should be carried out at intervals not exceeding 30 meters. From this investigation one will be able to obtain information as to whether the seabed material is sand, gravels or clay and the level at which rock occurs. One will not be able to obtain the relative density of the sand which is a good indicator of the likely levels of scour. However, it is known that the bottom level for scour is clearly the rock surface even if this is a very soft rock for the useful life of the pipeline.

Due to the probable scour and the very high forces occurring on a pipeline in the surf zone, it is common practice for rigid pipelines to endeavour to bury these below the level to which scour is likely to take place. We immediately have a difficulty here which other speakers may have addressed in determining the likely scour level. Observations made from jetties constructed in the surf zone have indicated that in the most active area seabed changes of three and even four meters have been measured in short time periods of no more than three days. It is highly unlikely that any sea bottom profiling will reveal the extreme conditions.

This burial of the pipeline, particularly a rigid pipeline in the surf zone is an exceedingly expensive item and one accompanied by considerable hazard. In the past attempts have been made to provide sheetpiling which is normally taken down to the rock level and then excavated between the two rows of sheetpiling. To provide a continuous open trench for the full length of the surf zone or in shorter lengths to enable sleeves to be laid on the seabed through which the pipeline will subsequently be pushed, is risky. The costs of these sheetpile trenches are high as the sheetpiles themselves are not stable as on one side they are probably excavated down to their toe level. In addition to the soil pressures which are relatively light and could easily be managed, the sheetpiling is subject to wave forces both from breaking and broken waves. These forces are very great and require that the sheetpiles be stabilized by either an independent stiff jetty or, as has been attempted in the past, by numerous raking piles. The cost per meter of this protective works whether sheet piles are used or not far exceed the cost of the pipeline per meter.

Where the rock level is relatively high and uneven such that a rigid pipeline could be damaged were it to span between the high points of the rock, it is then probable that the rock will need to be removed so that the pipeline can follow a smooth curve without overstressing. Due to hostile environment this rock removal, whether the rock be at the seabed or as is not uncommon buried by a couple of meters of sand, will normally require the installation of a jetty from which the excavation and if need be the drilling and blasting of the rock can be undertaken. Where drilling and blasting is needed it is normal practice to place the jetty on one side of the pipeline so as to minimise the blasting effects on the jetty structure. On the other hand, should sheetpiling be required because of the depth of sand which is to be excavated, the jetty will normally perforce be located directly above the pipeline as the jetty structure is used to stabilize the top of sheetpiles. It should by now be apparent how important the initial investigation is in determining at least the rock level. It is also a possibility that a more favourable line could be obtained by moving the landfall of the pipeline possibly a few hundred meters up or down coast. This obviously requires that the investigations previously referred to be made in more than one location.

It is apparent that the flexible high density polyethylene pipes, which are invariably provided with a considerable number of concrete collars to provide the necessary negative buoyancy, may be a means of reducing the costs of the pipeline in this surf zone. Although it is probable that a jetty structure may still be needed to ensure the accurate placing of a flexible pipeline in the surf zone, it should be possible to lay the pipe virtually on the seabed and allow this to move down as and when the seabed erodes, providing adequate negative buoyancy to the pipeline. Due to the flexibility of the pipe such procedure is feasible whereas it would not normally be feasible with an all welded steel line and certainly totally impracticable with a reinforced concrete pipe.

Having dealt with the very difficult portion of the surf zone, we should now possibly turn our attention to the pipeline as a whole. The pipelines I am considering here are in the range of from one to four kilometers long. As it is impractical to really perform any maintenance on the pipelines their design must ensure they are virtually maintenance free throughout their useful working life. The advantage of using steel is that this material, although subject to corrosion, can be protected both inside from the effluent and outside from seawater and can be installed in a continuous length without the necessity of making underwater joints.

The external corrosion protection on the pipeline is itself protected by a concrete weight coating which will vary between 50 and 150 millimeters thick, depending on the pipe diameter and the wave forces likely to be encountered during installation. These pipes are normally preassembled into long lengths on shore and the whole pipeline in point of fact must be able to be stored on shore before the installation is commenced. The normal method of installing this pipeline is by what is called the bottom-pull method. In this method the front of the pipeline is closed, the pipeline is installed along the seabed by being hauled out to sea to a winch normally mounted on a barge and the barge is itself anchored in the sea but can move its position as the pipeline proceeds seawards. The pipe must be provided with sufficient negative buoyancy, so that it is not disturbed by the waves and the currents likely to occur during the installation period. As the pipe has only a very small negative buoyancy compared to that which it will have when filled with the effluent, this is a dangerous procedure which should be undertaken preferably in a weather window if such can be predicted and certainly can not be allowed to occupy too much time. Several pipelines have been broken during the installation period and the costs of joining them are exceedingly high. A major problem of the installation of a pipeline with the bottom-pull method is the difficulty in lowering the pipeline once on the seabed in the surf zone. Because pipelines are relatively rigid a long length of the pipe must be undermined so as to allow the pipe to move down in the trench via the S-bend which will automatically form. Machines for doing this have been developed and work reasonably well in the deeper water where the machines can be towed by tugs. The machines rest on top of the pipe and are guided by the pipeline and as they move along it they remove the supporting sand by a combination of jetting and dredging. The depth which can be achieved is obviously limited by the size of the hole that can be maintained open at any time. The latter is obviously a function of the waves and currents and the writer has been considering only sandy seabeds for this method. Should a clay bottom be obtained it is possible to pre-dredge a trench and if necessary provide a suitable bedding in the trench for the pipe. However, in the offshore section there is but little reason to bury the pipe other than to prevent it being fouled by ships' anchors. In any area where a submarine pipeline occurs anchoring of vessels or even small fishing boats should be prohibited.

The trenching machine previously mentioned or the ploughs which have been tried and used by others are, of course, not really applicable in the surf zone. In this zone therefore it is either necessary to keep a trench open the whole length of the pipeline and where this is not considered feasible a sleeve pipe with relatively simple joints which are sand-tight but by no means watertight can be laid in the short length of trench opened at any one time. The pipelines can then of course be pushed through this from the shore end or pulled through the seaward end of the sleeve.

One of the great advantages of the high density polyethylene lines is the relative ease with which these lines may be laid on the sea bottom in very considerable lengths even up to a length of 2 kilometers. These pipelines are of course floated out and in the closed condition must of necessity remain buoyant. It is unusual to provide the HDP lines with more than about 50% weighting in the floating position as otherwise their laying on to the seabed cannot be performed. If need be additional weights could be attached once the pipes are on the seabed, but this is not normally done except for short lengths of the pipe line. Whereas the bottom pulled pipeline may frequently occupy a period as long as two weeks, for which on our coast it is impossible to obtain a weather forecast, the flexible pipelines are normally placed on the seabed in one or maximum two days. However, this is normally done in relatively calm conditions to prevent undue stressing of the pipe from wave action or movement from currents during the lowering into the seabed.

In the design of the two types of pipeline different criteria are normally adopted. For the rigid pipeline it is customary, unless the pipes are safely buried below scour level, to perform the design for the case of the pipe resting on the seabed at which time it is subject to both uplift and horizontal forces both from drag and inertia effects. However, as the pipelines are relatively rigid it is not always necessary to design for the peak condition at any one location but rather to integrate these forces over a length of the pipe. With regard to the flexible pipes the concrete collars, which provide the negative buoyancy and also support the pipes, will in the normal instance keep the pipeline approximately one half the diameter clear of the seabed. In this situation the uplift force on the pipeline virtually disappears and the negative buoyancy that is required is determined both by the drag and internal forces in the horizontal direction. It is clear that the wave direction as well as wave height and period at any location are required for these stability calculations and for the flexible pipe it is not possible to integrate the forces over the whole or part of a wave length due to the flexibility of the pipe. For both types of pipe it is totally unsafe to use the significant wave as the design criteria since, as is well known, this wave is exceeded by at least 50% to 60% by the 1% of the highest waves. Therefore, for the rigid pipes it is probably necessary to design for an H_1 with at least a 25 to 50 year return period. The flexible pipes which can accept some movement without damage, again provided the radii of curvature induced by these movements do not exceed a 2% strain, it is common practice to design the flexible pipes for the H_1 or the H_{max} associated with the return period of once per year. This will normally result in a smaller design wave with a similar probability of damage to the pipeline.

In the short time available an attempt has been made to highlight the major problems and the major deficiencies in information in regard to the practical aspects of the submarine pipelines.

RAPPORTEURS' COMMENTS ON DISCUSSION OF ESTABLISHING SAFE RELEASES - PHYSICAL, ENVIRONMENTAL AND ENGINEERING CONSIDERATIONS

H P L Ahrens
G de F Retief

The discussions of this topic commenced by assuming that a prior decision had already been made on both the need and the desirability of a pipeline.

The importance of a thorough survey of the proposed pipeline route was emphasised. If there are several landroute options, these should be investigated first. Feasible searoutes can then be examined by establishing local bathymetry, and seabed physiography using side-scan sonar. Potential, or selected pipeline routes should then be examined in considerable detail to establish geotechnical properties accurately.

Methods for designing the hydraulic characteristics of pipelines are based largely on theory, and results of laboratory tests. The difficulty of transferring theoretical calculations to the energetic sea situation was recognised, and it was agreed that the verification of these models is extremely important. Consequently, the engineering design of diffuser systems has progressed in recent years and research should now be directed towards field corroboration of the theoretical diffuser designs now being employed.

Generally, dilution factors associated with pipelines are based on conservative considerations (i.e. low ambient mixing conditions) and consequently it is expected that pipelines should perform better than stated design characteristics.

Novel advancements in the construction and laying of pipelines have been made in the last few years, particularly with the development of high density polyethylene (HDPE) material which is lighter and more flexible than traditional steel or concrete pipes, and therefore far cheaper. This trend towards flexible rather than rigid pipelines raises the need for designers to be made aware of the difference in approach which must be adopted for these differing pipeline concepts, particularly in the marine environment. It should be acknowledged here that both these design aspects are dependent upon the information regarding site data being reliable.

The development of water quality criteria for South African waters will provide a very significant aid for engineers in the design of the hydraulic characteristics of pipelines.

THE PHYSICAL TESTING OF PREDICTIVE MODELS

G de F Retief
G K Prestedge

INTRODUCTION

As described by Wallis (1) and McBride (2) initial dilution and dispersion of an effluent field are usually predicted by numerically integrating the equations of motion. These equations include conservation of mass, horizontal momentum, vertical momentum and buoyancy flux.

It is important to be able to calculate the initial dilution of the effluent and to predict the degree of dilution beyond the initial dilution process as well as the trajectory of the diluted effluent as it is advected laterally by current systems.

Mathematical models are generally formulated on the basis of an entrainment assumption in the areas of initial mixing. Entrainment coefficients used in these models are usually based on the results of small scale laboratory experiments with a length scale two orders of magnitude smaller than the prototype. Furthermore buoyant spreading and plume dispersion resulting from currents and turbulence are usually handled separately. The physical characteristics of the effluent, its constituent components, as well as the surrounding waters can vary greatly from one outfall to another.

In order to verify model predictions, prototype monitoring of the outfall is recommended. Practical considerations often restrict the monitoring possibilities and in this workshop session it is intended to discuss physical verification of model predictions of dilution, plume trajectories and structural soundness of the outfall that will lead to practical suggestions of the various options available.

MODELLING TECHNIQUES

The predictive modelling of physical processes in marine outfall studies can take the form of:

- order of magnitude analyses
- scaled hydraulic models
- numerical models

For a number of reasons field verification of the predictive model is often required. Very often this may be aimed at merely refining modelling technique (state of the art improvement). At times, it may be needed to solve a specific problem such as a disparity in results produced by different modelling methods, or a lack of field data because of time restrictions, or where field conditions go beyond the validity of the model.

Verification can also be useful in comparing predicted concentrations of the effluent with the prototype, with a view to refining the predictions and possibly increasing the effluent discharge without exceeding the concentrations permitted in the receiving water.

In setting up a model verification programme attention should be directed to the specific parameter or process which is considered to be important and which warrants verification. Added to this should be an awareness of the order of accuracy of the model and data collection procedures. Attention should be given to attendant time scales and analysis of data in a statistically sound manner.

In an order of magnitude estimation model results within an accuracy of ± 3 to ± 5 times its true value would not be unexpected (Fischer, H B, et al (3)). Using sophisticated modelling procedures, a total prediction error of ± 25% would be considered good while ± 50% would not be unusual. According to Fischer "It is unlikely that bacterial pollution can be predicted to better than a factor of perhaps 5'.....".

An example of some of the physical processes which can influence sewage effluent are given below (3). For the purposes of this paper phases (1) and (2) are grouped together under the heading of "initial dilution" and phases (3), (4) and (5) are grouped together under the heading of "plume trajectories".

Phase	Phenomenon	Length scale[a] (m)	Time Scale[a] (sec)
(1)	**Initial jet mixing** (rise of buoyant jets over an outfall diffuser in a stratified fluid.)	$<10^2$	$<10^3$
(2)	**Establishment of sewage field or cloud,** travelling with the mean current; lateral gravitational spreading.	10^1-10^3	10^2-10^3
(3)	**Natural lateral diffusion** and/or dispersion.	10^2-10^4	10^3-10^5
(4)	**Advection** by currents (including scales of water motion too large compared to sewage plume to be called turbulence).	10^3-10^5	10^3-10^6
(5)	**Large scale flushing** (advection integrated over many tidal cycles); upwelling or downwelling; sedimentation.	10^4-10^6	10^6-10^8

[a] Approximate orders of magnitude.

INITIAL DILUTION

Initial dilutions in the sea have been determined using precise measurements of salinity and density in the effluent, the effluent field and adjacent uncontaminated ocean waters. Not only is this considered indirect but it is unlikely to be sufficiently convenient unless sophisticated multiparameter profiling equipment is used e.g. digital profiling current meter systems capable of recording current velocity and direction, conductivity, temperature (hence density), time and depth simultaneously.

A practical and often used method is to add a fluorescent dye tracer to the outfall discharge upstream of the diffusers with subsequent monitoring of effluent concentration along the centreline of the plume discharge.

Rhodamin B is advocated as a continuous tracer input into the discharge to represent steady state conditions for the determination of initial dilution. Rhodamin B is considered to be the most usable of the four possible tracers (Rhodamin B, Rhodamin WT, Pontacyl Pink and Fluorescein) as it has a satisfactory photochemical decay rate and is reasonably priced (Grace (4)). The presence of natural fluorescence, for example, in the form of humic acids, could be utilised as a natural tracer if found in the effluent but may produce misleading results in an artificial tracer test, if found in the receiving water.

Fluorescence can be measured directly by a fluorometer preferably on board a boat pumping sampled water continuously through the fluorometer from an intake suspended at the required sampling position. The output, which is either analog or digital, should be accompanied by a read-out from a pressure sensor located at the suction end of the sampling hose to define the depth.

All dilution monitoring should include measurements of ambient current. This is best done by means of an array of fixed current meters with a data capture format suitable for detection of periodic events such as wave beats. Drifting drogues are not generally suitable for initial dilution studies as drift data in Lagrangian form is only useful if averaged over a number of surveys requiring extensive effort. Use of a few drogues as overall indicators may however be prudent, although tracking is often a problem. Provided windage on the markers is acceptably low captive drogues could be considered. A simple windage free method is the use of current indicating bottles after Carruthers (5). Models invariably assume coastal currents to be uni-directional for appreciable lengths of time despite data to the contrary.

The monitoring programme might also include other parameters which are used as input to the mathematical model, such as temperature profiles at discreet points, possibly using bathythermographs, multisensor arrays or simply thermistors. Where the effluent displays certain unique characteristics (e.g. gypsum in Richards Bay pipeline) a specific monitoring programme has to be devised to verify the model studies.

Where wave action is likely to influence outfall characteristics it should be recorded, possibly by waverider buoy or pressure sensor mounted on the outfall. Wave action has been known to result in pressure fluctuations at the diffusers and even result in dye discharged alongside a diffuser to be drawn into the outfall during passage of a wave trough (Grace (4)).

PLUME TRAJECTORIES

As for initial dilution, tracers are also widely used for measuring the depth, position and concentrations of the effluent field. Apart from the tracers mentioned above consideration might also be given to radioactive tracers such as Iodine 131 (7 day half life) and Bromine 82 (36 hr half life) in the form of potassium bromide tablets. Highly specialised equipment and personnel are required for such surveys, limiting their applicability to major studies.

Plume depth and layer thickness determinations should be carried out at discreet positions located by triangulation from the shore. Plume trajectories can be obtained by traverses across the zone of the plume using the continuous fluorometer sampling method described above with the end points of each traverse determined optically from shore or by means of continuous electronic position fixing. The sampling pump should be located downstream of the fluorometer to avoid bubbles induced by the pump affecting results. Depth of the sample pipe intake can be determined from the length and angle of support cable.

Plume trajectories of warm water discharge may be monitored by means of airborne radiation thermometry. This requires calibration to assign temperatures to the colour coded output and has the limitation of recording the temperature of the water surface only. Due to cold water entrainment in the buoyant plume the plume surface temperature does not always accurately reflect the true lateral distribution of the plume. James et al (6) refer to cases where the plume temperature has been higher or lower than ambient temperature. Temperature probes in the form of continuously recording thermistors traversing through the plume can be used in a manner similar to that for fluorescent tracer tracking above. Where the plume is not submerged the general extent of the plume is more easily assessed by aerial photography of fluorescein/Rhodamin dye patterns photographed through a polarising filter. Very useful results have been obtained using a three camera array (James et al (6)).

Where warm water outfalls are sited near to cooling water intakes, temperature probes should also be installed near the intake point to verify the predicted range of intake water temperatures.

Although fluorescent tracers are most generally recommended for field verification work Wallis (1) quotes other authors who have used the following methods to define the stratum depth and thickness and position of the effluent field above an outfall diffuser:

- Taking simultaneous vertical profiles of light transmission, pH, dissolved oxygen and temperature.

- Taking vertical profiles of salinity and density.

These are considered indirect assessments and relate more to the general environmental impact monitoring of the outfall rather than model verification, and appear to be a carry over of pure oceanographic practice.

STRUCTURAL ASPECTS

General failure mechanisms of an outfall structure include settlement, lateral displacement and pipe fracture, differential erosion, liquefaction of support material and flow induced forces on pipe and armouring.

The major model predictions in this regard are likely to be behaviour of bed sediment predictions. Structural stability studies are most likely to require fixed reference points along the pipe that can be checked for relative movements. Positions and elevations should be checked by underwater survey methods. The condition of structural materials should be monitored at prescribed intervals by visual examination. This would include the effects of corrosion/erosion and marine growth on the structural and hydraulic properties of the outfall.

Where innovative design techniques have been used an effort should be made to record wave height and direction for a prescribed period after construction by means of a bi-directional current meter and pressure sensing system mounted on the pipe. A fixed, high frequency acoustic triangulation system, interrogated from shore, can be used to monitor possible pipe motion, or strain sensors can be fitted directly to the pipe where movement is expected to be very small.

FIELD EXPERIENCE

The major difficulties in measuring the performance of an ocean outfall are quoted by Wallis (1) as:

- Mobilization and cost of personnel, boat and equipment.
- Difficulty of locating and making profiles through a submerged effluent field which is not visible from the surface (sewage).
- Continuous movement of the field as a result of meandering and vertical shear in ocean currents.
- Turbulent structure of the effluent field - eddies or cells with different concentrations. Thus the boundary of the effluent field as well as the instantaneous effluent concentration at a point (and hence initial dilution) vary considerably with time.

Added to this are the problems of relating a measured plume to the prevailing coastal conditions and model input conditions. Work by Wallis on comparisons made at four outfalls found that there was reasonable agreement between measured and predicted positions of effluent field, depths of centre of the fields and thickness of the fields.

Similarly reasonable agreement was found between predicted and measured initial dilutions. Generally measured dilutions seemed slightly higher. This was thought to be due to experimental limitations or the effect of ambient turbulence or current shear.

The success of Wallis' work would appear to be related to use of a monitoring method that employs a single sensor (in this case a fluorometer) that can be rapidly traversed through the effluent field. The need for synoptic survey methods is clearly identified where use is made of rapid response sensors or simultaneous multiparameter devices avoiding the problems of taking individual water samples for surface analysis. Where very large volumes of water are involved and very low dilution levels are required to be measured (e.g. outfall studies within large embayments) the individual sample analysis approach might have to be resorted to in conjunction with the sensitive stable tracers using a long life radio-isotope such as tritium.

CONCLUSIONS

- The verification of predictive models is an essential component of any outfall development programme. The design of the model itself should accommodate the type of verification which is envisaged or which can be practically executed. An attempt should be made to include post construction verification as part of the development contract.

- Verification can be costly and time consuming to execute. Every attempt should therefore be made to identify the important parameters requiring verification and the degree of accuracy at which the work is to be carried out. The model can be used to perform a sensitivity analysis of the different parameters to define areas of importance for the verification study.

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ENVIRONMENTAL MONITORING: THE DESIGN OF SAMPLING STRATEGIES

T C Gilfillan

STATISTICIAN'S ROLE IN MONITORING

Sensitive investigations such as the monitoring of the impact of industrial effluent on the environment depend for credibility on how well the conclusions can stand up to searching criticism.

Are the estimates of pollution-sensitive variables to be trusted? Can they be defended - are they valid?

The need to be believed is central to any monitoring programme.

The statistician's role is to ensure valid, defensible estimates that can be believed. Credibility of the monitoring programme is the statistician's responsibility - provided that he is involved from the outset.

There is no alternative! Scientific monitoring programmes as a rule are short of everything, especially a consultant statistician. Too little is done, subtle changes cannot be detected, precious resources are wasted and there is embarrassment all round.

The statistician usually comes in at the end. With sophisticated statistical tools the analysis is done. And, as so often happens the results are not what were wanted - nothing is 'significant'!

Brought in from the beginning, the statistician can study historical data, the background to the problem and so design an appropriate monitoring programme. It is sure to contain unwelcome news. The cost-benefit of inconclusive answers from limited resources becomes all too apparent. But now the monitoring team know what can be had and at what cost.

An example is the survey that was planned to estimate the krill population resources in the South Atlantic. The RSA together with seven other countries were to supply ships for this survey. Advance simulation done in our Division, under ideal conditions and assumptions showed that estimates could be in error by an order of magnitude. Where, say, an estimated population in a region was found to be 10^6, all that could validly be concluded was that the actual population was in the range 10^5 - 10^7. The RSA allocated its resources elsewhere.

THE STATISTICIAN'S ROLE AS APPLIED TO RICHARDS BAY

A number of cruises have been undertaken to collect sediment samples at eleven preselected sites. The benthic macrofauna data from the three cruises of 1981 are used to give some estimate of species diversity in the region of interest.

Let us see what we can learn from this data. Assume first that the sampling sites chosen are ideally placed. From each site only a single sample per cruise was taken. So no environmental error bounds can be placed about the observed number of species. The alternative is to assume an appropriate distribution for the number of species detected. On theoretical statistical grounds, the Poisson distribution seems to be a possibility, in which case the species variance equals the average number of species. The available data do not perhaps support this entirely. It would thus be preferable to seek additional data so as to improve estimated error bounds.

To progress further certain questions need answering.

Firstly, what type of change in species diversity is sought? Do we only look for a deterioration in numbers of detected species? Or do we take note of the nutrient content of the effluent and anticipate an improvement in species diversity?

Secondly, what is a meaningful ('subtle') change in species diversity?

Thirdly, given that a change has occurred, what chance is there of detecting it? What magnitude of change can be detected for a given sample size? And if no change is detected, what possible change will be missed for a given sample size? This is potentially the more embarrassing question when a too-small sample has been taken.

To highlight these questions the data of the three cruises are now analysed. This analysis is based on currently available data, and results are not necessarily conclusive; we return to this point at the end. (Nematodes are ignored in determining species diversity as they are apparently unaffected by high levels of pollution.)

On average 3,8 species per site were observed (per cruise the figures were 3,6; 4,2; 3,7) with variance estimate of 7 (and standard deviation 2,7).

For a given sample size, three questions are asked

- For a test conclusion of 'no change in average species per site' what real change in species diversity could have been missed?

- What chance have we of detecting any given change?

- What change can be detected?

On the basis of 95 % significance levels the following table can be constructed:

COST	Sample Size	EMBARRASSMENT	Conditions for no significant change from $\mu_0=3,8$			Probability of detecting a change of n species per site		
			Interval	Range of $\bar{X}$	Possible range of μ	$n = 1$	$n = 2$	$n = 3$
	11		±2	1,8 5,8	5,8 1,8	0, 18	0, 60	0, 88
	21		±1,2	2,6 5,0	5,0 2,6	0,40	0,92	1,0
	42		±0,8	3 4,6	4,6 3	0,7	1,0	1,0
	75		±0,6	3,2 4,4	4,4 3,2	0,92	1,0	1,0

Comments

Progressively shorter confidence intervals for the true mean number of species per site occur with increasing sample size.

A sample size in excess of 75 is needed to identify a change of one species per site. The probability of detecting such a change will be greater than 0.92.

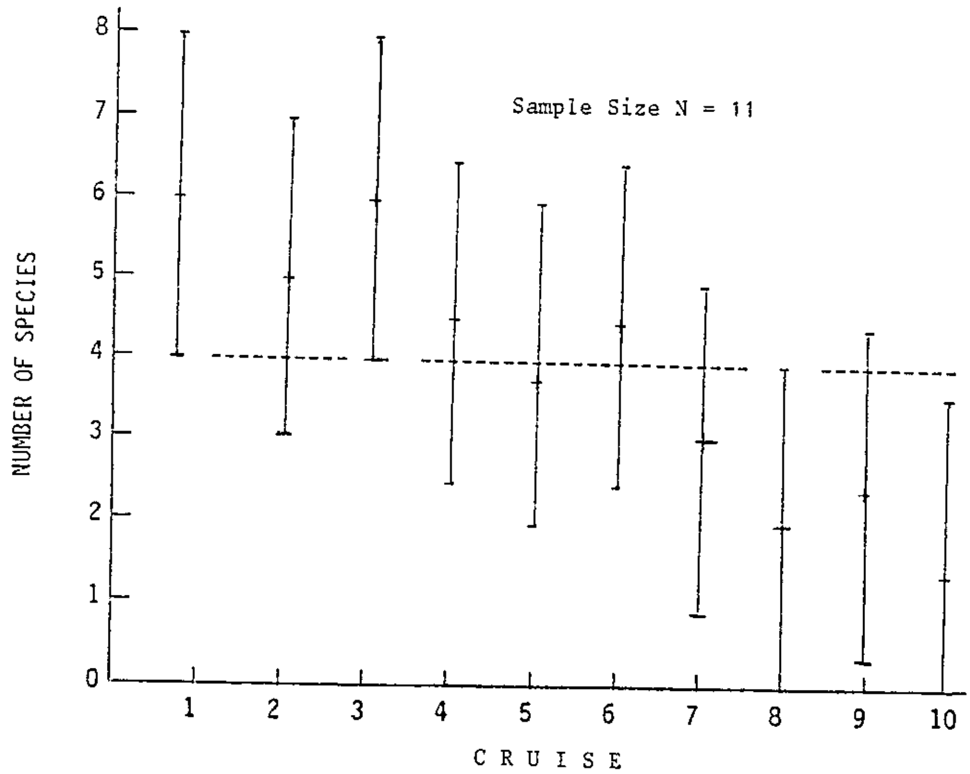
Eleven samples are inadequate for detecting a change of three or less species per site! An improvement or deterioration of two species per site could go undetected, or, even worse, may be reported (has to be reported) when no change in fact has occurred!

The above refers to the problem of determining what, if any changes have occurred from one cruise to another. Over a number of cruises, however, trends may in the long-term become more evident. This possibility can also be investigated. Consider thus the following averages from ten hypothetical cruises:

Cruises	1	2	3	4	5	6	7	8	9	10
Average	6	5	6	4,5	3,8	4,5	3	2	2,5	1,5

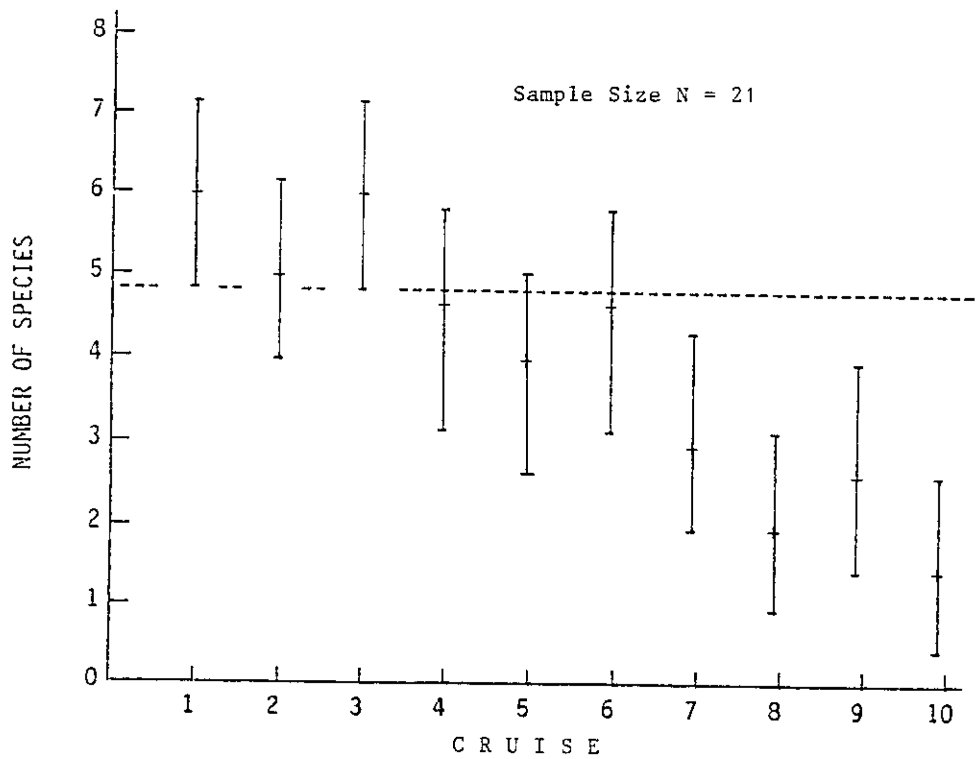
The 95 % confidence bounds for the four sample sizes are shown in figures 1 to 4.

Figure 1



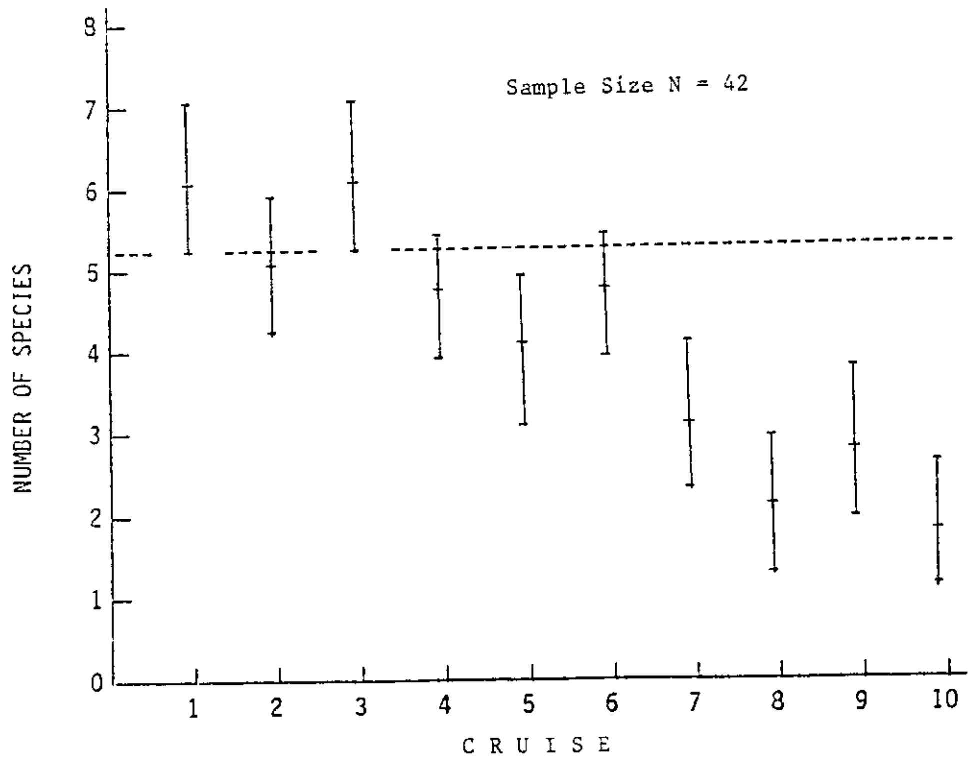
Significant difference detected at eighth cruise

Figure 2



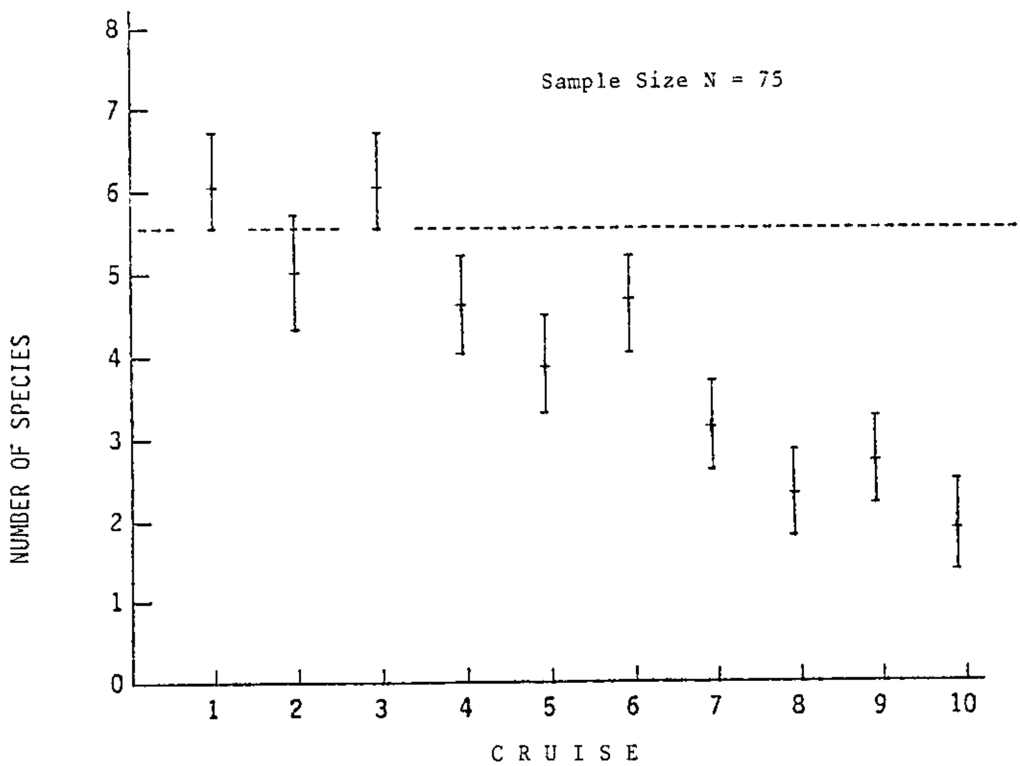
Significant difference detected at seventh cruise

Figure 3



Significant difference detected at fifth cruise

Figure 4



Significant difference detected at fourth cruise

Comment

Even with a sample of eleven sites a change (deterioration or improvement) is eventually detectable as a trend over a number of surveys. Even, however, with quite substantial deterioration in quality as in our hypothetical example, the deteriorating trend is only statistically significant after eight cruises; this may well already be too late to take corrective action.

CONCLUDING REMARKS

The statistician's role is not merely as a convenient 'rubberstamp' for survey results and statistically formulated conclusions (i.e a significant improvement ...., or no significant change has been found since........)

The participation of the statistician in the planning of the survey ensures valid, defensible estimates of the important variable and credible conclusions. Above all his involvement is an insurance against embarrassment.

But avoiding embarrassment is not cheap. Credibility does not come with small samples. To settle for small sample sizes is to run the very real risk of inconclusive results. The survey may then just as well not have been done.

Suggestion for immediate statistical action

What is needed now is up to five replicates at each of the eleven sites to get an estimate of within site variation. This could radically change the required sample sizes as derived in the above, fairly simplistic analysis.

THE MONITORING OF DISCHARGES FOR COMPLIANCE

J A Lusher

SUMMARY OF CONVENTIONS FOR COMPLIANCE

The Paris Convention

This has not been ratified by RSA, since it applies only to the western seaboard of Europe. However its scope is clearly universal and its moral binding force transcends international boundaries. The Convention for the Prevention of Marine Pollution from Land Based Sources was signed in Paris in 1974. The Convention is in effect a contract which states may enter into voluntarily (the Commission of the European Economic Community has also ratified the Convention). Those that do, pledge themselves to take all possible steps to prevent pollution of the sea, to adopt measures to combat marine pollution from land-based sources, and to harmonize their policies to achieve these aims. They also agree to set up and operate a monitoring system within the area covered by the Convention and to establish complementary or joint programmes of research in order to reduce marine pollution. Research into the best means of eliminating or replacing noxious substances may be included in these activities.

The convention definition of pollution is:

"Pollution of the sea is the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as hazards to human health, harm to living resources and to marine eco-systems, damage to amenities or interference with other legitimate uses of the sea".

Pollution from land-based sources means:

The pollution of the maritime area (i.e. all sea areas up to the freshwater limits of estuaries) -

(i) through watercourses;

(ii) from the coast, including introduction through underwater or other pipelines;

(iii) from man-made structures, e.g. oil or gas platforms.

The Annexes to the Paris Convention are quite similar to those of the London Dumping Convention: they list substances felt to be harmful. There is no doubt that if countries follow the Paris Convention in the form in which it is presented, it would, other than in exceptional circumstances, greatly reduce pollution.

The exception is made because, if discharges are controlled by means of fixed emissions, there will be situations where, although the discharge concentration is small, the amount might be large relative to the receiving waters. In this case the acceptance of fixed discharge limits would not necessarily control pollution.

The major problem with such conventions is to ensure that compliance does not exclude the option of using quality objectives as a basis for pollution control.

The London Dumping Convention (LDC)

The Inter-Governmental Conference on the Convention of the Dumping of Wastes at Sea ended in the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other matter, London, 1974. (LDC)

LDC has been ratified by South Africa which therefore has two responsibilities to it: moral and political. The preamble states in part:

"The Contracting Parties to this Convention,

RECOGNISING that the capacity of the sea to assimilate wastes and render them harmless, and its ability to regenerate natural resources, is not limited;

NOTING that marine pollution originates in many sources, such as dumping and discharges through the atmosphere, rivers, estuaries, outfalls and pipelines, and that it is important that States use the best practicable means to prevent such pollution and develop products and processes which will reduce the amount of harmful wastes to be disposed of;

BEING CONVINCED that international action to control the pollution of the sea by dumping can and must be taken without delay but that this action should not preclude discussion of measures to control sources of marine pollution as soon as possible; and

HAVE AGREED as follows:

ARTICLE I

Contracting Parties shall individually and collectively promote effective control of all sources of pollution of the marine environment, and pledge themselves especially to take all practicable steps to prevent the pollution of the sea by the dumping of waste and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea".

It is therefore perfectly clear that the ideals of the Paris Commission are the progenitor of LDC. Therefore, it follows that RSA is bound to consider the effects of land based disposals within an international obligation, quite apart from "dumping" at "sea" as defined in Article III of LDC or in our Dumping at Sea Control Act.

Recently, it has been made clear at Consultative Meetings of Contracting Parties that pipeline discharges will occupy more and more of the time of the Convention: they are lumped with dumping at sea because their effects on the marine environment are similar.

It is for these reasons that Departmental policy with regard to land-based discharges to sea must be crystallised as follows. A general example is given below of how this could be expressed.

BASIS FOR CONSIDERATION OF THE DISCHARGE OF MATERIAL A INTO (AREA)

1. It is considered by the Department that consideration of the impact, if any, of the discharges from (X) and (Y) outfalls should be made within, among other factors, the considerations of the long range strategy for the London Dumping Convention (to which SA is a Contracting Party).

2. The long range strategy has recently been established and has been discussed at the 7th Consultative Meeting of LDC in February 1983. Revision is continuing.

3. In the light of this, the following policy points are relevant to any studies done in .....(or elsewhere for that matter):

3.1 The goal to be sought is protection of the marine environment but not in the black and white terms of opting either to eliminate discharges at some future time or to control them at present. It seems that the central task is to determine:

3.1.1 whether the discharges are the normal - indeed the only - option available to the dischargers for the foreseeable future (say, 25 years);

3.1.2 whether it is necessary to separate the main toxic substances before discharge;

3.1.3 whether, in fact, disposal is beneficial due to presence of nutrients.

3.2 It seems necessary to consider the discharges in the light of similar discharges elsewhere in the vicinity and elsewhere in the country: are they "better" or "worse"? This process should be extended to similar situations on the sea boards of other southern hemisphere countries, notably California, the object being to express a comment on the international acceptability of the discharges.

3.3 The next question to be considered is the acceptability of discharges in the light of increasing population, increasing recreational use of the area and of the discharges occasioned by legitimate industrial use of the area (railways, industries, stormwater, etc).

3.4 What changes can be contemplated in the future to the total ecological structure of the area? Can waste disposal be increased? Is there a case for unified pollution control (for example, of harbour municipal areas).

What pressures on the area can be indentified as increasing ones? At what point does unacceptable risk lie in the disposal contemplated?

3.5 Finally, any investigation must express an opinion on whether co-operation is established between the various planning authorities in the area to such a degree that the marine environment is protected; and, if this is so, to identify possible sources of confusion in the future.

4. So far as purely scientific questions are concerned, the Department would wish to see some attention devoted to the following points:

4.1 Effect of increasing population plus expanding facilities and industrial development.

4.2 The comparative role of the stormwater discharges.

4.3 The future of the area in relation to oil handling.

4.4 Development of marine resources, if any; and of recreational facilities such as small boat harbours or marinas.

4.5 The role played, if any, by dredging, both now and in future.

4.6 The role played by discharges from ships (including rubbish).

A RATIONALE FOR MONITORING

The reasons for environmental control are taken to be obvious and discussed in full in many other sources.

Assuming that allowance is made for the degree of dispersion of substances of interest in the environment, then the prime objective of all studies is to isolate those substances which even in low concentration give rise to scientifically-based anxiety: lead, cadmium and PCBs are examples. The second objective is to define the path of circulation in the biosphere, from source to organism and back to the environment and, running parallel with this, the necessary toxicological studies.

AQUATIC ENVIRONMENT

Again, it is assumed that the reasons for studying the aquatic environment are so obvious as to be not worth repeating here. By aquatic environment is meant:

1. Inland waters
2. Marginal waters occurring at the interface of land and sea
3. Oceans
4. Precipitation and evaporation.

The inclusion of the last is often overlooked and yet it can be a potent means of atmospheric transport of substances; there is, in this category, no boundary between water and air pollution. The role of evaporation in the transport of volatiles or those electron-accepting compounds which can in general hydrate, is almost always ignored in studies of aquatic transport pathways.

So far as each of these categories is concerned, effort must be directed in the following general ways, apart from that enjoined by legislation and apart from those usually considered:

Inland waters

The roles of natural contamination (arising from contact of a water source with the ground); atmospheric deposition (this is assuming an importance hitherto unsuspected); normal agricultural activities and their relation to run-off water quality; excess nutrient problems; urban stormwater quality; application of sludge to land.

Marginal waters

The roles of sewage discharges; persistent-substance accumulation, transport and uptake, (a persistent substance is defined as one which does not degrade at all or with a significantly low "relocation potential"); the identification of low grade long term stress; the identification and assessment of stress factors hitherto unsuspected in the environment (dioxin, illegally imported chemicals); general effects of all these on health (related through the food chain) and in particular, virological/bacteriological studies; metallo-organics; radioactivity measurements.

Oceans

The roles of ocean dumping (specialised study, not taken further here); the discharge of raw sewage (interface between controlling authority and local councils).

Precipitation/evaporation

Role played in eutrophication of dams; the transport of heavy metals (as dust) and particulate matter in general; transport of nitrogen and volatile organics (including metallo-organics).

In all the above, four factors are of paramount importance:

(a) Population location, behaviour patterns and temporal density must be taken into account.

(b) There is a lower limit to stress factors below which it is pointless, impractical and costly to proceed. Therefore there is a lower limit to research efforts. The early identification of this limit so far as possible is essential to prevent fruitless "in-depth" studies. Even if it is argued that there is no ecological lower limit, one is imposed by available funds.

(c) We are dealing with two possible types of effect, slow and (nearly) irreversible and temporally fluctuating. These must be distinguished as early as possible because irreversible effects tend to be more severe.

(d) The existence of synergistic effects must be assumed until they are shown to be absent.

WATER QUALITY MANAGEMENT AND ENVIRONMENTAL QUALITY OBJECT

1. The effort involved should be directly proportional to the degree of bio-degradation of the substance; metals, and polychlorinated organics deserve more attention than nitrogenous compounds or polysaccharide fibres.

2. Unless there are good reasons to the contrary, stepwise improvements in quality are to be sought.

3. A toxicological background is essential. It helps to define such words as "potable", "poisonous", "polluted", "risk" and so on.

4. At the outset of all work, a decision has to be taken in principle as to whether the concept of environmental quality objectives is to be used or not. If it is, the opposing concept of a "general" standard must fall away; if it is not, then the onus rests on the standard determining body to show that its recommendation is both equitable and effective in all cases. This, in my view, is impossible.

   Environmental quality objectives work as follows in the case of an effluent:

Objective:	Protection of defined uses in a given situation.
Quality criteria:	Each use can be defined by quality criteria for the relevant parameters.
Specification of quality in a situation:	Defined by a combination of criteria for each use for which protection is required.
Discharge quality: (Local standard)	Calculated from the specification by reference to dilution, existing quality in receiving area, further use made etc.

   The point at issue is that for many substances which may be present in an effluent the above approach is a departure from accepted practice and also that it can be logically extended backward from receiving waters to industries and sewage works. However, in the context of environmental studies to determine a "baseline" and thereafter to quantify imposed stress, it is an entirely logical procedure.

5. Until such time as detailed studies have determined the criteria needed to preserve a given ecology and their quantitative limits, <u>intermediate</u> criteria, based on preserving existing conditions, must be employed.

RAPPORTEURS' COMMENTS ON DISCUSSION OF MONITORING

R P van der Elst
G C D Claassens

INTRODUCTION

During this session there was unanimity on the importance of effective monitoring, and also, of the proper verification of numerical models which form the basis for pipeline designs.

Predictive models must be verified because many of their parameters are derived from small scale laboratory experiments and may show considerable variance with the real situation. Generally this variance is catered for in the design stage by introducing a suitable margin of safety.

The major reasons for verification of models are

a) improvement of modelling techniques

b) detection of defective design

c) indication of situations where field data was either insufficient or invalid and

d) clarification of any disparity in results between different models.

The three main aspects that require such testing and verification are initial dilution, plume trajectories, and the structural integrity of the outfall pipe.

Finally it was noted that wherever possible the verification of models should form part of development contracts.

The testing for the conformity with standards is an important aspect of monitoring. In terms of international conventions, South Africa carries an international responsibility to minimise and control pollution in the marine environment. Certain policy guidelines exist which the Pollution Control Directorate uses to evaluate the impact of any marine outfall. Although this does not infer instant cessation of any particular discharge, it does consider

a) whether local discharges are "better" or "worse" than those elsewhere

b) whether such discharges are indeed the only options available for the foreseeable future

c) what ecological changes can be expected if discharge is increased.

It was recognized that there is considerable value in compiling a set of environmental quality objectives as an aid to decision making and in order to establish a 'baseline' against which to quantify environmental stress. In this regard the concept of total loading was addressed. Although such loading presents greatest problems in confined water masses, it was considered important to note that the entire ocean was <u>not</u> available for assimilation, even along an exposed coastline.

The importance of collecting adequate background data prior to discharge so that environmental changes could be better interpreted was stressed, although it was agreed that the significance of ecological changes, such as species diversity, were difficult to interpret. Both the range and intensity of perturbation requires quantification before such monitoring can be truly meaningful. It was proposed that a set of monitoring criteria be compiled which would serve to normalise the interpretation of results.

It became apparent that the certainty with which monitoring results could be expressed was directly proportional to effort (and thus cost). Early involvement of a statistician in planning a sampling strategy was seen to be most advisable as it made data interpretation more meaningful and projects more cost effective. However, plants and animals do not themselves adhere to statistical rules, hence it remains paramount for the ecologist to advise the statistician on the precise levels of change that are considered critical.

Based on a hypothetical example taken from Richards Bay, it was demonstrated how variations in sample size and sampling frequency results drastically affect the early detection of any environmental change.

In conclusion it was noted that the dissemination of monitoring results should preferably occur through the responsible regional organisations.

CONCLUSION

Perhaps the most significant accomplishment of the workshop was the interaction which occurred between "planners and decision-makers" (i.e. State and Provincial bodies mainly), the "marine research community" (i.e. biologists, chemists and engineers working mostly on quite specific research interests), and the practitioners (i.e. the consultants and contractors who design and build pipelines). The extremely broad representation at the workshop enabled each of these groups' interests to be presented. It was clear that continual close liaison between the Department of Constitutional Development and Planning, the Planning and Water Quality Branches of the Directorate of Water Affairs and the marine research community is needed to (a) ensure that planners and decision-makers are getting the right kind of information in the form that can be used, and (b) the scientific community can plan their work to properly accomplish their goals in the available time. The role of the practitioners in this interactive process is essential, particularly due to their wealth of practical experience.

It was recognised that industrial development in South Africa will be most strongly influenced by the concept of regional development and decentralization. In this regard, three future metropolitan complexes have been identified, namely Richards Bay, East London and Saldanha. In addition, five development points with future coastal impacts have also been declared, namely Tongaat, a Pondoland (Transkei) point, and George. Atlantis on the west coast also has an important coastal component, while Mossel Bay may develop of its own accord if exploitable hydrocarbon strikes continue.

The Department of Environment Affairs has the responsibility of regulating the discharge of industrial effluents to both marine and fresh-waters. This is accomplished under the Water Act of 1951. Under the act, there are two basic requirements, namely

- All public water abstracted for industrial use should be returned to the nearest point of the bed of the public stream from which the water was abstracted; or if abstracted from the sea, to the sea.

  and

- All effluents must be purified so as to confirm to the requirements .... (of the Minister).

The requirements which are laid down by the Minister in the case of a marine discharge are normally expressed in terms of effluent composition at the point of discharge. The conditions selected are such that "..... (not) any person will be prejudicially affected and that the dilution of effluent by sea water or other water will be such that marine fauna or flora will not be detrimentally affected".

The selection of these permit conditions are based on the available technology for effluent treatment, the oceanographic properties at the point of discharges, and on toxicological consideration of components of the effluent which are of concern.

For major discharges, permit conditions are established after wide consultation with the marine scientific community.

The marine disposal of effluent by pipeline is only one of the options available to a coastal facility for the final treatment and disposal of any of its effluent. The selection of the marine disposal option is based on both economic and ecological considerations. For the City of Durban, the disposal of treated sewage and partially digested sewage sludge by marine pipeline is presently the most economic route for disposal. In addition, no deleterious environmental effects have been observed as a consequence of this means of disposal.

It was also noted that off the east coast, the Agulhas current has considerable potential for use for the well controlled disposal of wastes. The current is close to shore (for example, the edge of the Agulhas current can be only 20 km offshore at East London) and has considerable dispersive capability.

Waste disposal is most appropriately handled on a regional basis, where the concept of waste exchange can be utilised. In addition, the economics of marine disposal will be increasingly influenced by the freshwater requirements of coastal locations, where the recovery of freshwater is becoming increasingly more practical and also needed.

The oceanographic system being considered is very complex, and a number of disciplines must contribute to an objective assessment about the feasibility of discharging effluents to sea. On the other hand, it is also clear that it is simply not possible to look at every aspect in detail. Ascertainable criteria need to be established to decide what levels of pollution are admissable, since in the end it is the pollution hazard - in its various forms - which will determine whether a pipeline and its discharge is acceptable.

An important decision taken at the workshop was to endorse the recommendation that South Africa prepare its own water quality criteria for marine and estuarine waters. The preparation of such criteria will represent a significant contribution to the available information on which standards for the discharge of wastes can be based*.

These criteria do not represent actual conditions in the water, but represent upper limits which should not be exceeded in order to maintain a specific use of that water. (Such uses will range from recreation and boating to industrial cooling water). A small technical subcommittee was appointed to prepare these criteria, and this group will use the substantial amount of local and international information available to complete this task.

The water quality option gives a better measure of the "real" effect of an effluent and means that conditions in the receiving waters need to be determined and carefully followed. It is therefore important to accept that dilution will not necessarily remove a toxic problem and that a careful check needs to be made of what ultimately happens to waste

*Effluent standards are legal limits or levels which must not be exceeded in the effluent being discharged. Water quality criteria are scientific guidelines for concentrations of pollutants not to be exceeded in a specified body of water, and are set up to sustain a particular end use of that water.

discharged into the sea. Physical and chemical changes can occur, where for example, radioactive species quickly attain equilibrium with stable species, and where accumulation of certain toxic materials must always be addressed. In all cases, the major objective of such an effort is to predict any impact.

The importance of proper monitoring, and the measurement of chronic sublethal effects was recognised. It was vividly demonstrated that the sampling intensity needed to adequately assess the presence (or absence) of change is frequently far greater than can be undertaken either practically or economically. Environmental "common sense" must be used to assess the scope of a sensible monitoring programme of manageable size. Nonetheless, the complexities of monitoring the effects of submerged plumes well offshore were recognised, and in the future a larger proportion of effort can be expected to be directed towards such monitoring. In all cases, it was stressed that sound baseline information (or before any stress is applied) was the most important single component of a comprehensive monitoring programme.

Mathematical computer models which are used to simulate discharge and to predict initial dilutions after discharge are an integral part of the pipeline planning. One aspect of the results of these models is the large uncertainty associated with dilution predictions; consequently, for engineering design purposes, dilution figures quoted are conservative. Field verification of such models has received very limited local and international attention; this situation can be expected to change. Apart from the hydraulic functioning of pipeline discharges, very little mechanical monitoring of pipelines is undertaken after construction is complete. With the wide differences in pipeline construction techniques currently being used in South Africa, a unique opportunity exists to obtain some very basic data on pipelines under a variety of operating conditions.

PERSONS ATTENDING MARINE POLLUTION WORKSHOP
24, 25 AND 26 MAY 1983

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* Persons who were invited to the workshop but did not attend.

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