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MARINE WATER QUALITY MANAGEMENT IN SOUTH AFRICA

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ABSTRACT

In South Africa the ultimate goal in water quality management is to keep the water resources suitable for all "beneficial uses". Beneficial uses provides a basis for the derivation of water quality guidelines, which, for South Africa, are defined in *Water quality guidelines for the South African coastal zone* (DWAF, 1991). The CSIR has developed a practical approach to marine water quality management, taking into account international trends and local experience, which can be applied to any coastal development with potential influence on water quality. The management plan is divided into three logical components, i.e.

- site-specific statutory requirements and environmental objectives;
- system design with specific reference to influences on water quality; and
- monitoring programmes.

Within this management approach water quality issues are addressed in a holistic manner, through focused procedures and clear identification of information requirements. This paper describes the procedures and information requirements within each component of the water quality management plan, with specific reference to marine disposal systems. Ideally, the management plan should be implemented from the feasibility and conceptual design phase of a development and the timing of the different procedures within the development process are therefore also highlighted. However, the logical lay-out of procedures allows for easy initiation (even to existing disposal system) at any stage of development.

KEYWORDS

Coastal zone; disposal; management; marine; South Africa; water quality.

INTRODUCTION

In South Africa the ultimate goal in water quality management is to keep the water resources suitable for all designated uses. To achieve this goal, the Receiving Water Quality Objectives (RWQO) approach has been adopted. This requires that management objectives be based on water quality requirements of designated uses in the receiving marine environment, taking into account both point and diffuse waste loads. At the same time it also recognizes that the marine environment has a certain capacity to assimilate waste without detrimental effect (DWAF, 1991). The CSIR, taking into account international trends and local experience, has developed a practical approach to marine water quality management which can be applied to any coastal development with potential influence on water quality. The management plan is divided into three logical components, i.e

- site-specific statutory requirements and environmental objectives;

- system design with specific reference to influences on marine water quality; and
- monitoring programmes.

With particular reference to a marine disposal system, the basic philosophy in water quality management in South Africa is to manage waste disposal into the marine environment in such a way that the quality of the seawater, subjected to the influence from the effluent, remains suitable for the designated uses of the area. The overall development of a marine disposal system can typically be divided into three phases, i.e. feasibility and conceptual design, detailed design and construction and operations.

Obviously, the success of the development depends on proper management, one of the integral parts being a marine water quality management plan. The procedures and information requirements for each component of the water quality management plan are described with specific reference to marine disposal systems. The timing of the different procedures in relation to the development process are also highlighted.

MARINE WATER QUALITY MANAGEMENT PLAN – A PRACTICAL APPROACH

Statutory requirements and environmental objectives

Establish statutory requirements. With any development it is essential to define the present legal and regulatory framework governing the activity, as well as any future requirements under consideration by the authorities. To establish the statutory framework it is necessary to obtain information on national and regional legislation and policies relating to marine disposal and marine water quality management.

In South Africa the Department of Water Affairs and Forestry (DWAF) is the custodian of the national water resources, including coastal marine waters (DWAF, 1991). Other departments involved include the Departments of Environment Affairs and Tourism (environmental protection, dumping at sea and clean-up of oil spills), Health (issues related to human health) and Transport (prevention of oil pollution at sea).

A number of acts are applicable in managing and controlling marine water quality (DWAF, 1992). These include the Water Act 54 of 1956, Health Act 63 of 1977, Sea Fisheries Act 12 of 1988, Dumping at sea control Act 73 of 1980, Seashore Act 21 of 1935, Prevention and combating of pollution of the sea by oil Act 6 of 1981 and the Environmental Conservation Act 73 of 1989.

With specific reference to marine disposal from land-based sources, the Water Act 54 of 1956 prohibits such actions unless exemption has been granted by the Minister of Water Affairs and Forestry.

Exemptions are granted under the following conditions (DWAF, 1992):

i. An official application has been lodged with the DWAF.
ii. A full scale Integrated Environmental Management (IEM) investigation has been carried out to determine the best disposal option for the effluent. IEM is a means of providing guidance in the planning and implementation of development projects. Its purpose is to ensure that the possible environmental consequences of development proposals are investigated and understood before decisions are taken, thus paving the way for informed decision-making and accountability for decisions taken.
iii. It is neither justified nor practically feasible to treat the effluent sufficiently to return it to its source of origin or to make it available for re-use.
iv. The effluent will not result in the deterioration of the marine environment to such an extent that it interferes with the beneficial uses.
v. Public opinion has been taken into consideration.

Upon approval, exemption is granted containing specifications on the volume and quality of the effluent and the specific area of discharge. Regular monitoring of the volume released and the concentration of specific variables in the effluent is required. In addition, chemical, physical and biological monitoring of the receiving water body could be specified. Aspects of the design, maintenance and monitoring of the equipment used to facilitate the release of the effluent, for example a pre-treatment plant, macerator, pipeline or stand-by facilities, could also be specified (DWAF, 1992). Violation of the conditions of exemption is a punishable offence and exemptions could at any time be withdrawn by the Minister if the above requirements are not complied with or if the disposal system does not perform according to specifications (DWAF, 1992).

Ideally, the statutory requirements need to be established in the feasibility and conceptual design phase of the disposal system.

Determine site-specific environmental objectives. As with any management plan, site-specific management goals are necessary to establish criteria for the design of the system and to provide a reference framework for future performance evaluations.

In South Africa the ultimate goal in water quality management is to keep the water resources suitable for all designated uses. The term "beneficial use" is used to describe the designated uses of South Africa's marine and estuarine waters. The recognized beneficial uses together with their general water quality objectives are presented in Table 1 (DWAF, 1992). Identification of beneficial uses provides a basis for the derivation of water quality guidelines, which, in the case of South Africa, are defined in "Water quality guidelines for the South African coastal zone" (DWAF, 1992). Water quality guidelines define the level of acceptability of water quality properties and constituents in relation to the different beneficial uses. These, in turn, provide a basis for developing site-specific water quality objectives for management purposes.

Table 1. Beneficial uses of the South African coastal zone

BENEFICIAL USE	GENERAL OBJECTIVES
Basic Amenity	To prevent public nuisance arising from visual and odour problems
Maintenance of Ecosystem	To ensure that all physical, chemical and biological conditions defining the structure of, and processes within, the ecosystem are maintained
Recreation: Primary contact Secondary contact	To ensure that water quality is suitable from an aesthetic, safety and hygienic point of view
Collection or culture of aquatic life for food: Filter feeders Non-filter feeders	To ensure that water quality is suitable for the culture of aquatic life for human consumption (health and taste)
Industrial purposes	Will depend on the specific industry

An example of beneficial uses and their associated water quality guidelines is illustrated in Fig. 1. Site-specific environmental objectives for marine water quality management therefore require,

- site-specific water quality objectives, based on the beneficial uses and associated water quality guidelines,
- baseline data on the ecological status and sediment conditions at the particular site.

To determine the above-mentioned environmental objectives the following information is required:

- data on ambient water quality condition of the area;
- data on existing waste streams discharging into the area; and
- data on the ecology and sediments of the area.

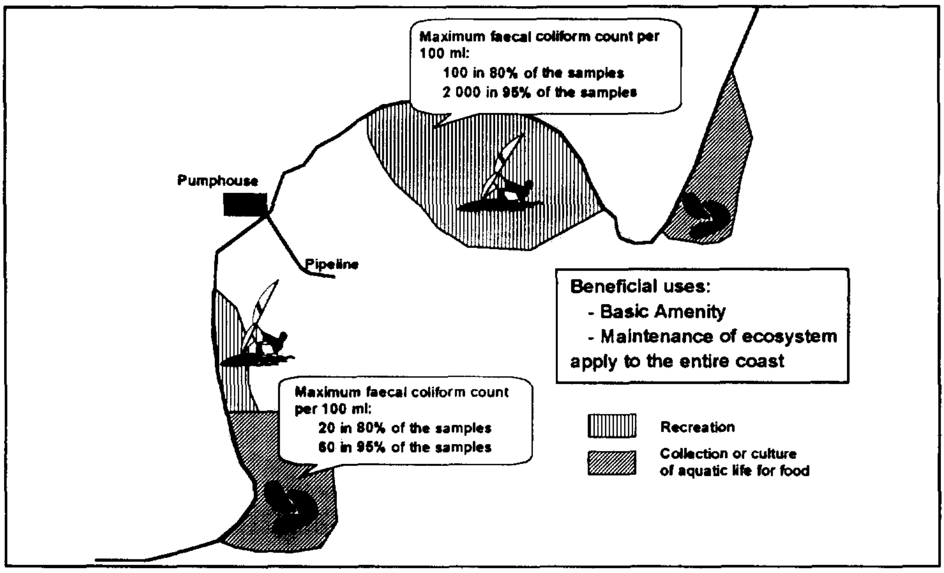

Figure 1. Example of beneficial uses and associated water quality guidelines.

Owing to the large natural variability which may occur in the marine environment, an accurate assessment of the status at a particular site is often only possible through intensive and long term data acquisition programmes. However, as a first estimate a 'snapshot' assessment of the status may suffice. This may include:

- analysis and summary of any water quality and ecological studies previously conducted in the area;
- collection of water quality samples from a grid of sampling stations, under dominant wind, wave and current conditions; and
- grid sampling of sediments (relevant chemical characteristics) and ecology (meiofauna, benthic macrofauna, macrophytes, etc.).

The grid of stations and selection of chemical and biological parameters must be sufficiently large to provide enough data to evaluate any future impact which the disposal system may have on the marine environment.

Ideally, site-specific environmental objectives need to be established in the feasibility and conceptual design phase, with continuous updating through the development process, as more detailed information becomes available.

System design with specific reference to influence on marine water quality

Establish effluent characteristics and required dilutions. The purpose of this step is to estimate the dilution factor required for the effluent to meet site-specific water quality objectives. To conduct this procedure the following information is required:

- site -specific water quality objectives (see previous section);

- the present flows, volumes and composition of the effluent (typical composition of domestic sewage is given in Table 2);
- pre-treatment options; and
- future scenarios on possible expansions.

In the ideal situation, the effluent characteristics and required dilution need to be established for the *feasibility and conceptual design phase*, with additional refinement during the detailed design and construction phase, where necessary.

Preliminary structural design. Structures in the marine environment are exposed to external forces such as waves, currents, sediment dynamics and other marine activities (for example, ship anchoring and fish trawling). For the preliminary analysis additional investigations such as geophysical surveys and preliminary geotechnical studies may be required for appropriate route selection of the pipeline, selection of appropriate construction techniques and preliminary cost estimates.

For the preliminary structural design the following need to be established:

- headworks lay-out (pre-treatment facilities and head provision);
- surge protection;
- risk of exposure of structures on the seabed;
- pipeline protection;
- diffuser lay-out and protection;
- appropriate manufacturing materials;
- construction methods (including launching, trenching and backfilling options); and
- cost estimates.

Preliminary structural design should be investigated during the *feasibility and conceptual design phase* of development.

Refinement of preliminary hydraulic design to ensure compliance. The refinement of the preliminary design is necessary to ensure that the required dilutions can be achieved for all physical conditions, thus qualifying marine disposal as a feasible option from an environmental point of view. If compliance cannot be achieved by an economical/practical outfall design, pre-treatment processes can be reviewed in order to improved the effluent quality.

The refinement of the hydraulic design should also be conducted in the *feasibility and conceptual design phase.*

Detailed hydraulic design. Should marine disposal be selected as the most appropriate option, the detailed hydraulic design needs to be investigated. For the detailed design phase, a review of the hydraulic design (including the headworks and surge protection) and achievable dilutions should be conducted using the final specification on effluent characteristics, detailed data on nearshore processes and specified construction materials. The principle objectives to be met in the hydraulic design are:

- the main pipe velocities must be high enough to prevent settling of suspended matter and to prevent the intrusion of seawater;
- provision must be made for the 'flushing' of the pipeline if scouring is required or to purge seawater;
- the port flows and the main pipe velocities must be evenly distributed along the entire diffuser section; and
- the diffuser must be optimized in order to achieve the highest initial dilutions within practical means.

Depending on the availability and extent of data on relevant nearshore processes obtained during the preliminary design, it may be necessary to conduct additional field exercises, including:

- detailed nearshore circulation patterns (surface and sub-surface currents, including Lagrangian and Eulerian measurements);
- detailed density profiles of the water column to establish the occurrence of stratification;
- continuous wind records;
- dispersion studies using conservative tracer materials; and
- local die-off rates of microbiological organisms.

Table 2. Typical composition of raw domestic sewage (taken from WRc, 1990)

PARAMETER	CONCENTRATION
Suspended solids	250 - 400 mg l^{-1}
Biochemical oxygen demand	300 - 500 mg l^{-1}
Ammonia nitrogen	25 - 50 mg l^{-1}
Total phosphorus	15 - 25 mg l^{-1}
Fats	100 - 200 mg l^{-1}
Arsenic	< 0,1 mg l^{-1}
Cadmium	< 0,02 mg l^{-1}
Chromium	0,2 - 0,5 mg l^{-1}
Copper	< 0,02 mg l^{-1}
Mercury	< 0,02 mg l^{-1}
Zinc	0,4 - 0,7 mg l^{-1}
Faecal coliform	2 -30 x 10^6 per 100 ml

Detailed structural design and construction. If available geophysical information and wave data, as outlined in the preliminary design phase, are not sufficient for the detailed structural design, additional field exercises may need to be conducted, including bathymetric surveys, sidescan sonar and seismic surveys, sediment probing, geotechnical investigations and wave recordings.

Monitoring programmes

A sound monitoring programme is an essential component for continuous evaluation of both the mechanical and environmental performance of a disposal system. Monitoring programmes should focus on potential problems associated with the development. Parameters selected for monitoring should allow for immediate detection of a problem and be able to quantify the magnitude and occurrence thereof.

The following monitoring programmes should be considered:

Pipeline inspection. The stability of the pipeline and the diffuser need to be checked regularly, especially after major storms to ascertain that no undesired displacements or damage has occurred. An underwater video recording of the entire length of the outfall, the diffusers and ports can be used to check operational efficiency. These inspections should be conducted annually or after a major storm.

Hydraulic performance of the discharge. The aim of this monitoring exercise is to determine whether the discharge practice is achieving the predicted required dilutions. This could be ascertained by introducing a conservative tracer into the outfall scheme and measuring initial dilution and the reduction of concentrations in the moving effluent plume (Toms and Botes, 1987; Botes, 1995). These tests should be conducted after commissioning of an outfall, when substantial changes occur to effluent quantity or composition, after any alterations to the system or if performance is suspect for any reason.

Effluent monitoring. This monitoring programme provides data for day to day control to ensure that design quality and flow conditions of the effluent are continuously maintained (usually specified in the permit).

Standard sampling and analytical methods need to be clearly stipulated and monitoring should be done on a short term bases.

Environmental impact monitoring. The purpose of this step is to check for compliance with site-specific environmental objectives and, where necessary, to mitigate any detrimental effect in a timely manner. This involves the selection of appropriate chemical and biological indicators, both in the water column and sediments, using the baseline environmental surveys conducted during the feasibility phase as a reference framework. In the selection of appropriate chemical and biological indicators the following should be considered:

- general water quality conditions;
- accumulation of possible toxic compounds; and
- diversity and abundance compared to the initial status of the ecology.

The selection of indicators, the monitoring frequency and the spatial coverage need to be determined for each site specifically and need to be confirmed with the controlling authorities.

Ideally the design of monitoring programmes should be done during the *feasibility and conceptual design phase*, while the implementation thereof forms part of the operational phase. Where any of the above-mentioned monitoring and assessment programmes show compliance, monitoring should still be continued to establish any long term impacts, if any. Where impact or non-compliance is implicated appropriate mitigation steps need to be taken. However, the decision to go ahead with the construction of a marine disposal system should be dependent upon reasonable confidence that no detrimental impact will result.

CONCLUSION

Procedures and information requirements for the marine water quality management plan, with specific reference to marine disposal systems, can be summarized schematically as illustrated in Fig. 2.

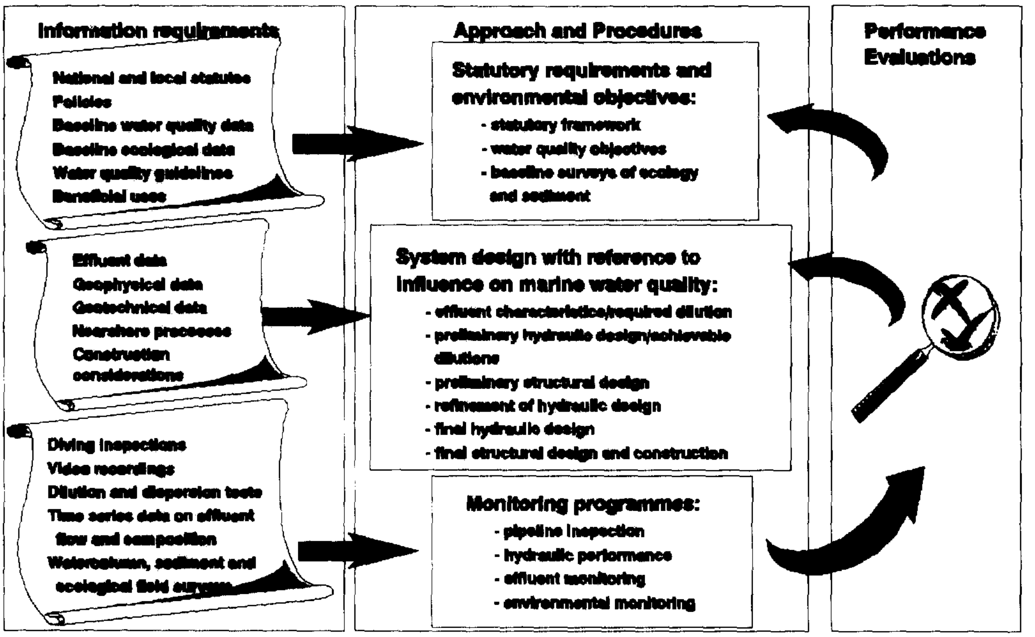

Figure 2. Schematic summary of the marine water quality management plan.

Within this management approach, water quality issues are addressed in a holistic manner, through focused procedures and clear identification of information requirements.

Ideally, the management plan should be implemented from the feasibility and conceptual design phase of a development. However, the logical lay-out of procedures allows for easy initiation at any stage of development, even to existing disposal systems.

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