Water Pollution Control - A Guide to the Use of Water Quality Management Principles
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P*ublished on behalf of the* United Nations Environment Programme, the Water Supply & Sanitation Collaborative Council and the World Health Organization by E. & F. Spon

ISBN 0 419 22910 8

Chapter 10* - Framework for Water Pollution Control

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10.1 Introduction

This chapter synthesises the aspects of water pollution control presented in Chapters 1-9 and brings their main themes together in order to recommend an approach for comprehensive water resources management. There is, inevitably, some repetition of key messages from the preceding chapters. However, for a more detailed treatment of the specific aspects of water pollution control presented below, readers are advised to study the appropriate chapters. Examples of the different approaches to water pollution control can be found in the case studies indicated.

10.1.1 Background: Agenda 21

In recent years water quality problems have attracted increasing attention from authorities and communities throughout the world, especially in developing countries but also in countries in transition from centrally planned economies to market economies. In the latter, previously neglected aspects of environmental protection are now becoming a major obstacle for further and sustainable economic and social development.

Degradation of surface and groundwater sources has previously been an inherent consequence of economic development and remedial action to compensate for, or to reduce, environmental impacts have always been a lesser priority. Consequently, when the impacts of pollution and the costs of remedial actions are finally acknowledged, the cost of preventive precautionary measures is higher than if they had been implemented at the appropriate time. Thus, negligence of water quality problems often leads to a waste of (economic) resources, resources that might have been used for other purposes if the water quality problems had been given proper attention in the first place.

The international community has now acknowledged the severity of the problems incurred by deteriorating water quality and agreed formally to take action to protect the quality of freshwater resources. The most recent demonstration of this was provided by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, from which came "Agenda 21". In Chapter 18 of this document (UNCED, 1992), on protection of the quality and supply of freshwater resources, key principles and recommendations for sound water resources management are laid down. These were crystallised, matured and elaborated through a series of preparatory meetings, including the Copenhagen Informal Consultation (CIC) in 1991 and the International Conference on Water and the Environment (ICWE) in Dublin in 1992.

The principles for water resources management that have formed the basis for the guidelines presented here are derived from the conclusions reached in Dublin and Rio de Janeiro and are:

- Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.

- Land and water resources should be managed at the lowest appropriate levels.

- The government has an essential role as enabler in a participatory, demand-driven approach to development.

- Water should be considered a social and economic good, with a value reflecting its most valuable potential use.

- Water and land-use management should be integrated.

- Women play a central part in the provision, management and safeguarding of water.

- The private sector has an important role in water management.

10.1.2 Scope of guidelines

The recommendations and principles from Agenda 21 cover water resources management in general, i.e. including availability of water, demand regulation, supply and tariffs, whereas water pollution control should be considered as a subset of water resources management. Water resources management entails two closely related elements, that is the maintenance and development of adequate *quantities* of water of adequate *quality* (see Case Study V, South Africa). Thus, water resources management cannot be conducted properly without paying due attention to water quality aspects. It is very important to take note of this integrated relationship between water resources management and water pollution control because past failures to implement water management schemes successfully may be attributed to a lack of consideration of this relationship. All management of water pollution should ensure integration with general water resources management and vice versa.

The approach presented in this chapter concentrate specifically on aspects that relate to water quality, with special emphasis on the conditions typically prevailing in developing countries and countries in economic transition (e.g. eastern European countries). The intention is to demonstrate an approach to water pollution control, focusing on processes that will support effective management of water pollution. A step-wise approach is proposed, comprising the following elements:

- Identification and initial analysis of water pollution problems.

- Definition of long- and short-term management objectives.

- Derivation of management interventions, tools and instruments needed to fulfil the management objectives.

- Establishment of an action plan, including an action programme and procedures for implementation, monitoring and updating of the plan.

The suggested approach may be applied at various levels; from the catchment or river basin level to the level of international co-operation. The Danube case study (Case Study IX) is an example of the latter. This chapter demonstrates the approach by taking the national level as an example.

10.2 Initial analysis of water quality problems

Management of water pollution requires a concise definition of the problem to be managed. The first task is recognition of an alleged water quality problem as being "a problem". This assumes an ability to identify all relevant water quality problems. The next task is to make sure that useful information is acquired that enables identification and assessment of existing and potential future water quality problems. Thus managers must be able to identify problem areas that require intervention within the water quality sector or the sector for which they are responsible. Nevertheless, even if all existing and potential water quality problems could be identified it may not be feasible to attempt to solve them all at once. All managers are limited by budgetary constraints imposed by political decision makers. Therefore, tools for analysis and prioritisation of water quality problems are indispensable and help make the best possible use of the available resources allocated to water pollution control.

10.2.1 Identification of water quality problems

On a national scale, or regional scale depending on the size of the country, the initial step should be to conduct a water resources assessment. In this context, a water resources assessment is an integrated activity, taking into account water pollution control as well as more general water resources issues. At this very early stage it may be difficult to determine whether a certain problem is purely one of water quality or whether it also relates to the availability of water resources. For example, an identified problem of supplying clean water to a local community may be a problem of scarcity of freshwater resources but may also be caused by inadequate treatment of wastewater discharged into the existing water supply source, thereby rendering the water unfit for the intended use. The water resources assessment should constitute the practical basis for management of water pollution as well as for management of water resources. The recommendation of preparing water resources assessments is fully in line with that given in Agenda 21 (UNCED, 1992), according to which water resources assessments should be carried out with the objective "... *of ensuring the assessment and forecasting of the quantity and quality of water resources, in order to estimate the total quantity of water resources available and their future supply potential, to determine their current quality* *status, to predict possible conflicts between supply and demand and to provide a scientific database for rational water resources utilization".*

Box 10.1 Summary of water resources assessment

Objective

- To establish a basis for rational water resources management and water pollution control

Action

- To estimate the spatial and temporal occurrence of quantities and qualities of water resources.

- To assess water requirements and development trends, and associated requirements for water quality.

- To assess whether the available resources meet the present and projected demands and requirements in terms of both quantity and quality.

Result

- An overview of the current and expected status and problems of general water resources and water quality.

More specifically, the recommended assessment should identify the occurrence (in space and time) of both surface and groundwater quantity and their associated water quality, together with a tentative assessment of trends in water requirements and water resources development (see Box 10.1). The assessment should be based, as far as possible, on existing data and knowledge in order to avoid unnecessary delays in the process of management improvement. The objective of the assessment is not to solve the problems but to identify and list the problems, and to identify priority areas within which more detailed investigations should be carried out. As stated by WMO/UNESCO (1991), "*Water Resources Assessment is the determination of the sources, extent, dependability, and quality of water resources, on which is based an evaluation of the possibilities for their utilization and control".* An example of implementation of water resources assessments is given in Case Study IV, Nigeria.

10.2.2 Categorisation of water quality problems

Identified water quality problems may fall into different categories requiring application of different management tools and interventions for optimal resolution of the problems. For example, it is important to know whether a certain water quality problem pertains only to a local community or whether it is a national problem. If a problem exists at the national scale it might be necessary to consider imposing general effluent standards, regulations or other relevant measures. By contrast, if the problem is limited to a small geographic region it might only be necessary to consider issuing a local by-law or to intervene to settle a dispute through mediation.

It may also be useful to categorise water quality problems as either "impact issues" or "user-requirement issues". Impact issues are those derived from human activities that negatively affect water quality or that result in environmental degradation. User-requirement issues are those which derive from an inadequate matching of user-specified water quality requirements (demand) and the actual quality of the available resources (supply). Both types of issues require intervention from a structure or institution with powers that can resolve the issue in as rational a manner as possible, taking into consideration the prevailing circumstances.

According to the traditional water pollution control approach, user-requirement issues would often be overlooked because the identification of such problems is not based on objectively verifiable indicators. Whereas an impact issue can be identified by the presence of, for example, a pollution source or a human activity causing deterioration of the aquatic resources (e.g. deforestation), user-requirement issues are identified by a lack of water of adequate quality for a specific, intended use.

10.2.3 Prioritisation of water quality problems

In most cases the resources (financial, human, and others) required for addressing all identified water quality problems significantly exceed the resources allocated to the water pollution control sector. Priorities, therefore, need to be assigned to all problems in order to concentrate the available resources on solving the most urgent and important problems. If this is not done the effect may be an uncoordinated and scattered management effort, resulting in a waste of scarce resources on less important problems. Ultimately, the process of assigning priority to problems requires a political decision, based on environmental, economic, social and other considerations, and therefore it is not possible to give objective guidelines for this. Nevertheless, some aspects to be considered when assigning priority to water quality problems can be identified as follows:

- Economic impact.
- Human health impact.
- Impact on ecosystem.
- Geographical extent of impact.
- Duration of impact.

As an example, the uncontrolled proliferation of the water hyacinth, *Eichhornia,* in some water bodies may lead to a deterioration in water quality, for example due to oxygen depletion caused by the decay of dead plants, but may also hamper navigation and transport, perhaps with considerable economic consequences. Thus, based on this simple analysis, combating the proliferation of water hyacinth should be given a higher priority than might be indicated by purely environmental considerations.

Another aspect to take into account in assigning priority is the geographical extent of the impact, i.e. whether a particular problem, for example caused by a discharge of wastewater, has only a local impact in an area of a few hundred meters along the river or whether there is an impact in the entire river system downstream of the discharge. The likely answer depends, for example, on the size of the discharge and the retention time in the receiving water bodies, the degradability of the pollutant, and the occurrence of sensitive species in the receiving water body. In addition, the duration of impact should be considered. A discharge of easily degradable organic material may cause considerable deterioration in water quality but only for the duration of the discharge.

When the discharge ceases the impact also disappears, although there is often a time lag between the discharge ceasing and no further effects being detected. By contrast, the discharge of a persistent pollutant that is bioaccumulated in the aquatic environment can have an effect long after the discharge has ceased.

10.3 Establishing objectives for water pollution control

When establishing objectives for water pollution control, an essential task is the definition of the ultimate aim. An ultimate aim of effective water pollution control might only be achievable after some considerable time due to financial, educational or other constraints. The further the aims are from the initial situation the more difficult it is to put strategy into practice because a lot of assumptions and uncertainties need to be included. To overcome this problem the following step-wise strategy should be considered:

- Identification of required management interventions.
- Definition of long-term objectives.
- Analysis of present capacity.
- Definition of realistic short-term objectives.

10.3.1 Required management interventions

Having identified and classified relevant water pollution problems, and having assigned priority to them, the next step is to identify appropriate interventions to cope with the problems. For every problem identified, therefore, an assessment should be made of the most appropriate means for intervention. Furthermore, an indication should be given of the relevant administrative level(s) to be involved. The proposed interventions may vary significantly in detail and scope. Depending on the problem in question and the existing institutional framework for management of water pollution, they may range from formulation of a national policy for a hitherto unregulated issue to the establishment of a database containing water quality monitoring results in a local monitoring unit. Examples of typical, required management interventions are:

- Policy making, planning and co-ordination.
- Preparation/adjustment of regulations.
- Monitoring.
- Enforcement of legislation.
- Training and information dissemination.

In many countries, no comprehensive and coherent policy and legislation exists for water pollution control or for environmental protection (see Case Study XIII, Yemen). This does not prevent water pollution control from taking place before such policies have been formulated and adopted, but the most efficient and effective outcome of water pollution control is obtained within a framework of defined policies, plans and co-ordinating activities. There may be obvious shortcomings in the existing situation that need urgent attention and for which remedial actions may be required independently of the overall general policy and planning. Such interventions and remedial actions should be taken whether or not an overall policy exists. A lack of policy should not delay the implementation of identified possibilities for obvious improvements in water pollution control. In many developed countries, regulations supporting legislation are also lacking, inadequate or outdated (see Case Study X, Russia). Adjustment of regulations is an ongoing process that has to adapt continuously to the socio-economic development of society.

A typical weakness in legislation, which should be avoided, is the tendency to state explicitly within the act economic sanctions for non-compliance (such as fees, tariffs or fines). It is much more complicated and time consuming to change or to amend an act than to amend the supporting regulations and management procedures. Hence, stating economic sanctions within an act entails an associated risk that enforcement of the legislation could become ineffective and outdated due to economic inflation. Examples of inadequate, or lack of enforcement of, existing legislation are widespread and can be illustrated by Case Studies III, IX, X and VI (Philippines, Danube, Russia and Brazil).

Improvement in water quality monitoring systems is an intervention required world-wide, not only in developing countries. There are, however, huge differences from country to country in the shortcomings induced by inadequate, existing monitoring systems. In most developing countries the problem is one of too little monitoring due to a lack of allocated resources for this activity. In several central and eastern European countries the problem is different. Extensive monitoring programmes have been functioning for many years and many raw data have been collected. What has been missing in a number of cases is an ongoing analysis and interpretation of the data, i.e. transformation of the data into useful information, followed by a subsequent adjustment of the monitoring programmes.

10.3.2 Long-term objectives

Definition of long-term objectives includes the identification of key functions that will have to be performed in order to achieve reasonably effective water pollution control at all administrative levels. This evaluation and description of necessary management functions and levels should be made without giving too much consideration to the existing administrative capacity at various administrative levels. It may be assumed, for example, that there is a reasonable capacity to carry out the necessary tasks designated at each level in the long-term strategy. However, a reasonable assessment of the full potential for development of the general level of management should form the basis for the long-term objectives. If the present situation is characterised by extremely scarce financial and human resources and major obstacles to economic and social development, it would not be appropriate to define very high standards of water pollution control in the long-term objective, simply because this situation would most likely never occur. The situation obtained by fulfilling the long-term objectives for water pollution control, should be one that is satisfactory to society (considering the anticipated general level of development at that future moment).

The guiding principles for water resources management (see section 10.1) should be reflected in the long-term strategy. For example, management at the lowest appropriate level should be pursued through the identification of the lowest appropriate level for all identified key functions, irrespective of the present level of management. For some functions, the lowest appropriate level is a local authority or unit, while for other functions it is a central authority (e.g. Case Study I, India). The case study for China (Case Study II), however, provides an example of the opposite approach, i.e. centralised control of pollution. Table 10.1 gives an example of how elements of a long-term strategy for water pollution control could be described.

10.3.3 Analysis of present capacity

Having defined long-term objectives it is necessary to assess how the present situation matches the desired situation. The key issue is identification of the potential of, and constraints upon, the present management capacity and capability in relation to carrying out the management functions defined in the long-term objectives. Such aspects as suitability of institutional framework, number of staff, recruitability of relevant new staff, educational background, and availability of financial resources should be considered. The needs for training staff and for human resources development to enhance management performance should also be identified and plans made for initiation of this development.

In many countries, problems associated with an absence of clear responsibilities, with the overlapping of institutional boundaries, duplication of work and a lack of co-ordination between involved institutions, are common obstacles to effective water pollution control (see Case Studies V, III, XIII, X and IV for South Africa, Philippines, Yemen, Russia and Nigeria).

The analysis must include all relevant administrative levels, for example through intensive studies at the central level combined with visits and studies in selected regions at lower administrative levels. The regions or districts should not be selected randomly but with a view to selecting a representative cross-section of diversity in water quality problems and their management. An example of such an analysis is given in Table 10.2.

10.3.4 Short-term strategy

In relation to short-term strategy, the duration of the "short-term" has to be defined. A period of approximately five years is suggested, because this is roughly the planning horizon that can be controlled reasonably well and foreseen without too much dependency on future development scenarios.

Table 10.1 Summary of long-term strategy for water pollution control

Function	National level	Intermediate level	Local level
Formulation of international policies	Defining the country's position with regard to cross-border issues of water pollution. Providing information for negotiations with upstream and downstream riparian states	None	None
Wastewater discharge regulation	Processing waste-water discharge applications and issuing discharge permits	Commenting on applications in relation to district development planning. Organising public hearings. Assisting in checking that permissions are adhered to. Disseminating information on national standards through public health authorities	Assisting in the monitoring of potentially harmful discharges; framing and enforcing local rules and maintaining structures to avoid contamination of domestic water sources through sub-district water and sanitation committees and water user groups

Source: Directorate of Water Development/Danida, 1994

The output of the capacity analysis provides the basis for establishing a short-term strategy, taking into account the identified potential for, and constraints associated with, achieving the long-term objectives. For example, a long-term objective might be to decentralise water quality monitoring activities. However, if the current manpower skills and analytical capabilities at the lower administrative levels do not allow implementation of this strategy (see Case Study VII, Mexico), a short term strategy might be defined, maintaining monitoring activities at a central level but simultaneously upgrading the skills at the lower levels by means of training activities and orientation programmes. Alternatively, monitoring could be restricted in the short-term to those activities that can currently be carried out by the lower levels, and additional monitoring activities could be gradually included along with upgrading of manpower skills and analytical facilities.

In general, when defining the short-term strategy it should be ensured that the fulfilment of the short-term objectives will significantly contribute to achieving the long-term objectives. An example of definition of a short-term strategy for water pollution control, based on the above example of a long-term strategy with identified potentials and constraints, is given in Table 10.3.

Table 10.2 Example of an analysis of present management capacity

Functions	Potentials	Constraints
Formulation of international policies	Establishment of a Water Policy Committee has been agreed	Lack of formal agreements between upstream and downstream riparian countries. Lack of reliable information on the quantity and quality of shared water resources
Wastewater discharge regulation	Staff with necessary knowledge available at national level. Required administrative structures and procedures at national level are relatively uncomplicated. District Water Officers can assist in monitoring activities	Lack of qualified staff at district local level to deploy for discharge control. Lack of monitoring equipment. Very limited access to laboratory facilities

Source: Directorate of Water Development/Danida, 1994

Table 10.3 Example of a short-term strategy for water pollution control

Functions	National level	Lower levels
Formulation of international policies	Establish Water Policy Committee, its secretariat and its international subcommittees	None
Wastewater discharge regulation	Establish unit for administering wastewater discharge permits as per regulations	Identify wastewater dischargers requiring licensing. Establish procedures for administering the licensing system as per regulations. Local authorities to report on pollution problems and to comment on wastewater discharge applications

Source: Directorate of Water Development/Danida, 1994

10.4 Management tools and instruments

This section discusses a number of management tools and instruments together with principles for their application and for the combination of different tools (for a more thorough description of tools and instruments see preceding chapters). The range of tools and instruments should be considered as an input to the overall process of achieving effective water pollution control, that is a toolbox for the water pollution manager. They are necessary means to address the identified problems. The manager's task is to decide which tool(s) will most adequately solve the present water pollution problem and to ensure that the selected tool(s) are made available and operational within the appropriate institutions.

10.4.1 Regulations, management procedures and by-laws

Regulations are the supporting rules of the relevant legislation. Regulations can be made and amended at short notice, and in most cases need only the approval of the minister to become binding. In specific cases, approval by the cabinet may be necessary. Regulations specify the current policies, priorities, standards and procedures that apply nationally.

Management procedures are a set of guidelines and codes of practice that ensure consistent responses in problem solving and decision making. Such procedures contain a further level of detail supporting the legislation and the regulations and specifying the steps to be taken in implementing particular provisions, such as regulation of wastewater discharge. Regulations and procedures pertaining to wastewater discharge would typically include, for example, descriptions of procedures for applying and granting a permit to discharge waste-water to a recipient, procedures for monitoring compliance with the permit, fees and tariffs to be paid by the polluter, and fines for non-compliance.

As a general rule it should be ensured that only regulations that are enforceable are actually implemented. If the existing enforcement capacity is deemed insufficient, regulations should be simplified or abandoned. Regulations and management procedures made at the national level need not necessarily apply uniform conditions for the entire country, but can take account of regional variations in water pollution and socio-economic conditions.

By-laws (that are binding on local residents) can be made by a legally established corporate body, such as a district or province government and can, for example, determine the regulation and pollution of local water resources. By-laws made by lower level institutions cannot contradict those made by higher level institutions (see Chapter 5).

10.4.2 Water quality standards

Water quality standards are, in fact, part of regulations but are discussed separately here because some important aspects relating specifically to the use of standards should be noted (see Chapters 2 and 5). Numerous sets of water quality standards, or guidelines for water quality standards, have been issued during the course of time by various agencies and authorities (e.g. United States Environmental Protection Agency (EPA), World Health Organization (WHO), European Union (EU)) intending to define the maximum acceptable limit of water pollution by various pollutants. Standards for ambient water quality (quality objectives) are commonly designated according to the intended use of the water resource (e.g. drinking water, fishing water, spawning grounds), while effluent standards are usually based on either of the following two principles, or a combination of both (see Case Study II, China):

- Fixed emission standard approach, requiring a certain level of treatment of all wastewater, regardless of the conditions and intended use of the receiving water body.

- Environmental quality standard approach, defining the effluent standards in order to enable compliance with the quality objectives for the receiving water body.

Standards or guidelines developed according to the first approach must be very restrictive in order to protect the environment effectively, because they must take into account the most critical situations and locations. Thus, this approach might lead to unnecessary treatment costs in some situations. In other cases, it may lead to inappropriate treatment and excessive pollution, depending on the applied emission standards and the assimilative capacity of the receiving water body (see Case Study V, South Africa). The major advantage of this approach is its rather simple administrative implications.

The second approach allows for a more flexible administration of environmental management, and optimisation of treatment efforts and costs because the level of treatment may be tuned to the actual assimilation capacity of the receiving waters (which must be assessed on an individual basis). The problem with this approach is the difficulty in practical application; knowledge of the assimilative capacity requires studies of the hydraulic, dispersive, physico-chemical and biological conditions prevailing in the water body. In addition, plans for future development in the area should be taken into account. The above factors suggest that a strategy based on the fixed emission standard approach may be the most appropriate, at least as a starting point in many developing countries because of their often limited administrative capacities. However, the dangers associated with automatically adopting water quality standards from western industrialised countries must be emphasised. The definition of water quality standards should, to a large extent, be a function of the level of economic and social development of a society. For example, a number of water quality standards applied in western countries are based on the best available technology (BAT) and generally achievable technology (GAT) principles. These require organisations to treat their wastewater according to BAT for hazardous substances and according to GAT for other substances. Whereas the economic costs of applying these principles may be affordable in a highly industrialised country, they may be prohibitive for further industrial and economic development in developing countries.

In central and eastern European countries, water quality standards and emission standards are often more stringent. In some cases they are too stringent to be met and in other cases they are even too stringent to be measured (see Case Study IX, Danube). As a result the standards have often been ignored by both polluters and managers. In addition, the necessary administrative capacity to enforce very high water quality standards may exceed that available. As mentioned previously, it is highly recommended that only regulations that can be enforced are implemented.

Water quality standards applied in developing countries should, therefore, be adjusted to reflect the local (achievable) economic and technological level. The implication of this approach is that standards may be tightened along with the rise in economic capability to comply with higher standards. Furthermore, since a high level of wastewater treatment is often easier and cheaper to achieve when considered during the planning and design phase of any industrial production, more strict effluent standards (when compared with existing discharges) may be imposed on new discharges of wastewater. These measures would allow for both economic development and the gradual increase in environmental protection.

10.4.3 Economic instruments

The use of economic instruments is on the increase in many countries but is far from reaching its full potential. Until now, most governments have relied primarily on regulatory measures to control water pollution. However, application of economic instruments in water pollution control may offer several advantages, such as providing incentives for environmentally sound behaviour, raising revenue to help finance pollution control activities and ensuring that water quality objectives are achieved at the least possible (overall) cost to society.

The main types of economic instruments applicable in a water pollution context include (Warford, 1994; see Chapter 6):

- Resource pricing.
- Effluent charges.
- Product charges.
- Subsidies or removal of subsidies.
- Non-compliance fees (fines).

Prerequisites for the successful implementation of most economic instruments are appropriate standards, effective administrative, monitoring and enforcement capacities, institutional co-ordination and economic stability. Various degrees of administration are associated with the application of different economic instruments. Effluent charges, for example, require a well-established enabling environment and large institutional capacity and co-ordination. By contrast, product charges are relatively simple to administer (Warford, 1994).

Among the key factors in the successful implementation of economic instruments is the appropriate setting of prices and tariffs. If prices are set too low, polluters may opt to pollute and pay, as seen in some eastern and central European countries (see Case Study IX, Danube). Moreover, artificially low prices will not generate adequate revenues for system operation and maintenance (see Case Study VII, Mexico). Setting appropriate prices is very difficult because, ideally, prices should cover direct costs, opportunity costs and environmental costs (externalities) (Nordic Freshwater Initiative, 1991).

Economic instruments incorporate the polluter-pays-principle to various degrees. Subsidies, for example, clearly counteract the polluter-pays-principle but may, in some cases, be applied for political or social reasons. By contrast, effluent charges go hand-in-hand with the polluter-pays-principle. In the case of resource pricing, progressive charging scales may be used to allow large-scale users to subsidise the consumption of small-scale users, and thereby balance considerations of social needs and sustainable use of the resource.

10.4.4 Monitoring systems

There are a number of important elements to consider in relation to the implementation and functioning of a monitoring system (see Chapter 9):

- Identification of decision and management information needs.

- Assessment of capacity (economic and human) to maintain the monitoring system.

- Proper design of the monitoring programme and implementation of routines according to defined objectives.

- Data collection.

- Data handling, registration and presentation.

- Data interpretation for management.

Traditionally, monitoring programmes collect data either from chemical and biological analysis of water samples or from on-line field equipment. However, depending on available laboratory facilities, instruments, transport and human resources, for example, all monitoring programmes are restricted in some way and may collect data primarily by direct sampling. A number of information gaps often have to be filled, therefore, before a rational decision about monitoring system design can be taken with respect to a specific water quality problem. Although they are less accurate, indirect techniques for obtaining the necessary information exist for a variety of water quality-related factors. It is possible, for example, to obtain reasonable estimates of pollution quantities from various sources from a knowledge of the activities causing the pollution (see Box 10.2).

Box 10.2 An example of indirect estimation of pollution load

Load estimates can be based on, for example, measurements available from a monitoring system. However, very often it is only possible to cover part of a lake or river catchment with monitoring stations, and hence only some of the major contributors to pollution load, due to the limited resources available. The rest of the catchment has to be taken into consideration using experience and representative measurements from elements of a similar catchment. Furthermore, it is possible to give recommendations of unit loads from personal equivalents (p.e.) in relation to economic status. Unit loads from different types of industry and run-off of pollutants from, for example, agricultural land and forests can also be deduced according to the farming or forestry practised.

Another frequent problem associated with traditional monitoring programmes is the lack of coupling between measured concentrations and water flow or discharge measurements, thereby rendering quantification of pollution transport difficult. Estimation techniques also exist for these situations, where hydrometric networks are not established or functioning, or where instruments are not available for measuring flow, such as in wastewater discharges.

The actual design of a fully operational and adequate national monitoring system must, from the beginning, take account of the requirements of the additional management tools which are being considered for use (see Case Study III, Philippines). The complexity and size of the area to be monitored, the number of pollutants monitored, and the frequency of monitoring, have to be balanced against the resources available for monitoring. To a large extent the data that become available determine the level of complexity of the management tools that can be supported by the monitoring system. An example of the kind of support needed for other management tools is the requirement for reliable and frequent data to support the enforcement of effluent standards (see Case Study XII, Jordan). In this situation the monitoring programme needs to be tailored to suit the detailed requirements for enforcement, as defined in the supporting regulations.

10.4.5 Water quality modelling tools

Modelling tools are treated here as any set of instructions based on a deterministic theory of cause-effect relationships which are able to quantify a specific water quality problem and thereby support rational management decisions. This can be done at different levels of complexity, some of which are discussed below:

- *Loadings.* Preliminary decisions can be taken with respect to reduction of loadings from a ranking of the size of actual pollution loadings to a particular receiving water body. The rationale is to assess where the greatest reduction in pollution can be obtained in relation to the costs involved.

- *Mass balances.* Mass balances can be established using load estimates from pollution sources in combination with the water flow or residence time in the water body. The significance of the different loadings can be evaluated by comparing their magnitude to their contribution to the resulting concentration of the pollutant in the receiving waters. The significance of the different loadings for the pollution level of the receiving water body provides the rational basis for decisions on effective reduction of the pollution level in those waters.

- *Effect evaluation.* Assessment of changes in the identified pollution sources and their resulting concentration in the receiving waters can be made at various levels, from using simple, empirical relations to long-term mass balance models. An example of a well known empirical relation is the Vollenweider method for estimating eutrophication effects in lakes (Vollenweider, 1968, 1975, 1976). Based on experience from measurements in a large number of lakes, the method relates pollution discharges and static lake characteristics (such as water depth and retention time) to expected effects on the Secchi depth and algal concentrations. Effect evaluation may also combine considerations about cost effective pollution reduction at the source, the resulting pollution concentration in receiving waters and the resulting effects in the ecosystem.

- *Simple mathematical mass balance models.* Application of this tool allows consideration of the possible changes over time in relation to any reductions proposed in pollution load. Many types of these biogeochemical models have been developed over the years and some are available in the public domain.

- *Advanced ecological models.* If higher level effects of pollution loadings on an ecosystem are to be determined, more sophisticated ecological models are available. Such models may create the basis for a refined level of prediction (see Case Study III, Philippines) and should be used in cases of receiving waters with high complexity and importance, provided sufficient resources (financial, human or institutional) exist or can be allocated.

The above examples serve to illustrate that quantitative assessments of pollution problems can be performed at various levels of complexity, from hand calculations to advanced state-of-the-art ecological modelling.

10.4.6 Environmental impact assessment and cross-sectoral co-ordination

Impact assessment plays a central role in the process of providing information on the implications for water quality arising from development programmes and projects. However, in addition to impacts on the physical environment, impacts on the water resources often imply impacts on the biological and socio-economic environment. Assessments of impacts on water quality should, therefore, often be seen as an integral part of an environmental impact assessment (EIA). Environmental impact assessments are being used increasingly as environmental management tools in numerous countries (see Case Studies II and IV, China and Nigeria).

The main objectives of impact assessments used for the purposes of water quality management are to identify potential impact on water quality arising from proposed plans, programmes and projects. They therefore serve:

- To assist decision makers in making informed decisions on project developments and final project prioritisation.

- To provide, where possible, relevant and quantitative water quality information so that potential impacts can be avoided or reduced at the project and programme design stage.

- To provide a basis for development of management measures to avoid or reduce negative impacts under, and/or after, project implementation.

The impact assessment should form an integral part of multiple resource development planning and feasibility studies for the projects. It should provide for a quantified assessment of the physical, biological and related economic and social impacts of proposed projects as well of the likelihood of such impacts occurring. Thus, the impact assessment should accomplish its purpose by providing decision makers with the best quantitative information available regarding intended, as well as unintended, consequences of particular investments and alternatives, the means and costs to manage undesirable effects, and the consequences of taking no action.

An important element in any impact assessment is the encouragement of public participation in the process. The general public should be given an opportunity to express their views on proposed projects and programmes, and procedures should be established for considering these views during the decision making process. In many cases, non-governmental organisations (NGOs) with considerable insight in environmental issues can be identified and may provide valuable contributions to the impact assessment. Public participation can often ease the implementation of projects and programmes as a result of the increased feeling of ownership and influence that it produces amongst directly-involved users (see Case Studies III, V, VI and IX for the Philippines, South Africa, Brazil and Danube).

In addition to identifying and describing water quality impacts that a proposed programme or project would cause if no management measures were taken, an impact assessment should:

- Specify the necessary measures to protect water quality.

- Ensure that these are included in the project implementation plan.

Finally, evaluations of water quality impacts and technical and economic feasibility should be linked so that effective project modification and water quality management can be developed. Water quality aspects and economic evaluations should be linked to ensure that both water quality benefits and drawbacks of the project, as well as the costs of water quality management, can be accounted for in a subsequent cost-benefit analysis.

The operational functions of the water quality impact assessment should be to provide the necessary background for:

- Approval or rejection of wastewater discharge permit applications.

- Inclusion of operation conditions in wastewater discharge permits.

- Input to EIAs.

- Inclusion of water quality consequences in the final prioritisation of development projects (made by authorities at different levels).

- Developing modifications in the technical design of development projects with the aim of protecting water resources.

Capacity for making and overseeing water quality impact assessments should be developed within the relevant water or environment authorities, although the actual assessments should not necessarily always be made by the authority itself, for example line ministries, local authorities or private companies may undertake the task. However, detailed procedures and guidelines should be developed and co-ordinated with the development of general EIA procedures within the country.

The integrated water resources management approach implies that sectoral developments are evaluated for possible impacts on, or requirements for, the water resources and that such evaluations are considered when designing and allocating priority to development projects. Consequently, the water resources management systems must include cross-sectoral information exchange and co-ordination procedures, techniques for evaluation of individual projects with respect to their implications for water resources, and procedures ensuring that water resources aspects are included in the final design and prioritisation of projects.

As a general rule a rapid screening of the project for possible water resources implications, regarding water quality as well as other aspects, should be carried out and if the project is likely to cause water related problems it should be subject to:

- Impact assessment (possibly EIA).

- An evaluation of possible specific requirements affecting the involved water resource and recommendations for project design to fulfil such requirements.

- Identification of possible interaction with, or competition from, other planned or ongoing projects in relation to use of the same water resource.

- Recommendations on possible improvements in project design to provide optimal exploitation of water resources.

Finally, the evaluations and recommendations should be included in the prioritisation process of the project emphasising both environmental and economic implications arising from the water resources issues.

The integration of water pollution issues in the prioritisation process makes it necessary that tools and procedures exist for securing adequate exchange of information between bodies preparing the project, the water pollution authorities and the final decision makers. These requirements are:

• That information about new proposals for projects which may impact or imply specific requirements for water quality should reach the water pollution authorities in good time for the elaboration of impact assessments and recommendations before final decisions are taken (including consideration of potential alternative exploitation of the involved water resources).

• That the same authorities should possess rapid access to relevant information about registered, planned and ongoing water-related projects through, for example, adequate database tools.

10.4.7 Principles for selecting and combining management tools

When deciding on which management tools and instruments to apply in order to improve water pollution control in a given situation, some underlying principles should be considered to help achieve effective management. The principles are:

• Balance the input of resources against the severity of problem and available resources.
• Ensure sustainability.
• Seek "win-win" solutions, whereby environmental as well as other objectives are met.

Balance the input of resources

This principle entails a reasonable input of financial, human or other resources to handle a specific problem, according to the priority and severity previously assigned to that problem. For example, if the discharge of waste-water is concentrated at a few locations in a country, leaving most regions or districts unaffected by wastewater discharge, and if this situation is anticipated to continue, there would be no need to build technical and administrative capacities to handle the problem in all regions or districts. Similarly, the treatment requirements and the threshold size for activities requiring a wastewater discharge permit might be more lenient if only a few dischargers exist and if the receiving waters show no symptoms of pollution.

Ensure sustainability

This principle has a bearing upon the methods and technical solutions that should be considered for the purposes of water pollution control. In most developing countries possibilities for the operation and maintenance of advanced technical equipment are very scarce or non-existent. Among donors and recipients of projects there has been a tendency to favour quite advanced and sensitive technical solutions, even in situations where more simple and durable equipment would have been sufficient and adequate (see Case Study VII, Mexico). This can result in entire development programmes failing to be implemented successfully. Thus, as a general rule in many developing countries, it is best to keep technical solutions simple. The recommendation to use simple stabilisation ponds for wastewater treatments is one such example (as in Case Study VII, Mexico).

Sustainability also entails building on existing structures, where appropriate, instead of building new structures. Existing institutions or methods have, to some extent, proved their viability. It is more likely that the allocation of resources for existing institutions would be continued rather than additional resources would be allocated for new institutions.

Seek "win-win" solutions

"Win-win" situations (Bartone *et al.,* 1994; Warford, 1994; see also Chapter 6) are created by applying instruments that lead to improvement in water pollution control as well as in other sectors (e.g. improved health or improvement in economy). This means that the difficult balancing between environmental benefits and other drawbacks is avoided. Economic instruments are often in the "win-win" category.

Regulatory versus economic instruments

Compared with economic instruments, the advantages of the regulatory approach to water pollution control is that it offers a reasonable degree of predictability about the reduction of pollution, i.e. it offers control to authorities over what environmental goals can be achieved and when they can be achieved (Bartone *et al.,* 1994). A major disadvantage of the regulatory approach is its economic inefficiency (see also Chapter 6). Economic instruments have the advantages of providing incentives to modify the behaviour of polluters in support of pollution control and of providing revenue to finance pollution control activities. In addition they are much better suited to deal with non-point sources of pollution. However, setting of appropriate prices and charges is crucial to the success of economic instruments and is often difficult to achieve.

Against this background, it seems appropriate for most countries to apply a mixture of regulatory and economic instruments for controlling water pollution. In developing countries, where financial resources and institutional capacity are very limited, the most important criteria for balancing economic and regulatory instruments should be cost-effectiveness (those that achieve the objectives at the least cost) and administrative feasibility.

Finally, in cases of highly toxic discharges, or when a drastic reduction or complete halt in the discharge is required, regulatory instruments (e.g. a ban) rather than economic instruments should be applied.

Levels of water pollution control

According to Soliman and Ward (1994), the various management tools available may be applied and combined at five categories (levels) of water pollution control, reflecting an increasing level of development and economic and administrative capacity:

- *Crisis management.* Non-proactive mode; doing very little management (e.g. no regulation); action is taken only in response to disasters or emergencies, where a group of specialists is assigned to handle the problem; no efforts made to prevent the problem in the future. This approach is adequate in only a very few cases today.

• *The criteria/standard only strategy.* At this stage, the risk of environmental problems occurring justifies a more proactive approach to water pollution management; water quality criteria and standards may be formulated; monitoring of compliance with standards; still a passive mode of management in which no attempts are made to modify the system.

• *Controlling strategy.* If the results of monitoring using the previous strategy showed that water quality standards have been violated, additional management tools are applied; effluent standards and wastewater discharge permits may be introduced in combination with enforcement and penalty procedures to handle violations. Management has entered the proactive mode.

• *Compliance assistance strategy.* In many developing countries, widespread violations of permits may still occur because the treatment costs needed to meet the effluent standards are higher than many industries can afford. In this situation, decision makers may decide to offer financial aid to firms and municipalities in order to treat their effluents adequately, rather than closing down the installations, which would often be the only alternative to accepting continued violations. Setting priorities for financial and technical assistance is a vital component at this stage, where management has reached a supportive mode.

• *Enhancement of the science/policy of management.* Management designing the future; grants for research in water pollution control and for application of modern techniques; forecasting future potential problems and preparing to prevent the occurrence of such problems; management in an interactive mode.

10.5 Action plan for water pollution control

10.5.1 Components of and processes within an action plan

The preceding sections have described various elements and aspects of what could be considered as an action plan for water pollution control. Some elements are identical to elements from traditional master plans but, contrary to prescriptive and rather rigid master plans, the action plan concept provides a flexible and dynamic framework for development and management of water resources. It is very important to recognise the dynamic nature of the action plan concept because a significant value of the concept lies in its flexibility. The action plan should be continuously monitored and adjusted in order to take account of recent development trends. Only a flexible and non-prescriptive approach will allow for such changes.

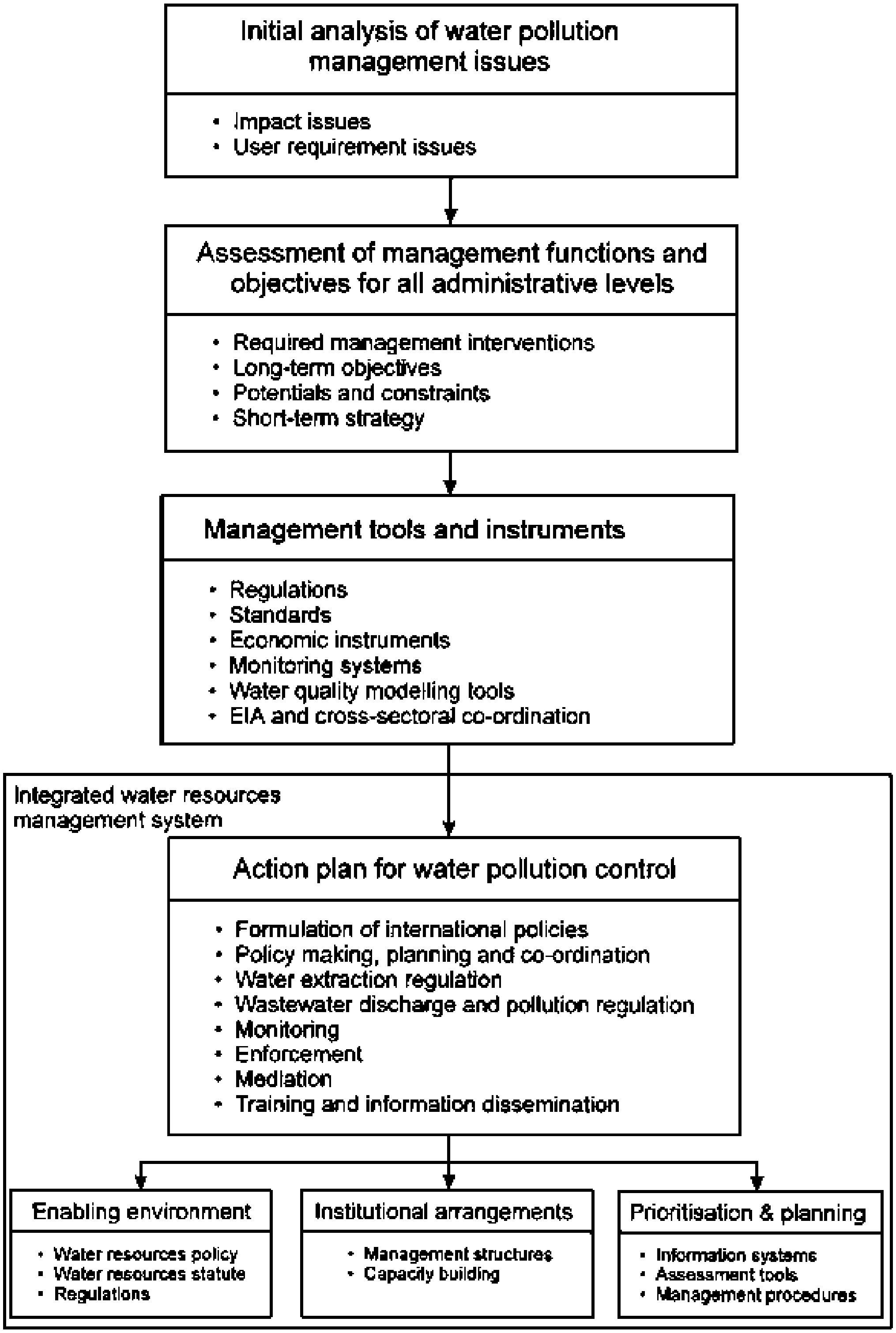
An overview of the components and the processes within the action plan concept are given in Figure 10.1. One of the main results of the action plan is a list of actions proposed for implementation in order to achieve the goal of effective and sustainable water quality management. For easy implementation and updating, the action list should preferably be prepared using a common format for each identified necessary action. For example, each action could be accompanied by information on the background (justification) for inclusion, objective and expected output, and the tasks necessary to be carried out. This information will facilitate easy transformation of the relevant actions into projects, if appropriate. The actions can typically be organised according to the following categories (Figure 10.1):

- Actions supporting the development of an enabling environment, i.e. a framework of national legislation, regulations and local by-laws for encouraging sound management of water pollution and constraining potentially harmful practices.

- Actions supporting development of an institutional framework which allows for close interaction between national, intermediate and local levels.

- Actions enhancing planning and prioritisation capabilities that will enable decision makers to make choices (based on agreed policies, available resources, environmental impacts and the social and economic consequences) between alternative actions.

Figure 10.1 Elements and processes of an action plan for water pollution control



Training and capacity development are an integrated element of the proposed actions that apply to all categories. In addition to skill-based training related to developing assessment capabilities, there may be a need for different training, education and information activities at various levels (such as orientation programmes, curriculum development and extension training) in order to carry out the functions described in the short term strategy.

In accordance with the underlying principles of the government as an enabler in a demand-driven approach but with management occurring at the lowest appropriate levels, it is necessary to create a structure that facilitates decentralisation of management (see Case Study IX, Danube). National agencies should be concerned with essential functions that are not dealt with at other levels and they should act as enablers that review and revise the overall structure so that it responds to current needs and priorities.

The recommended framework should be one that attempts to reach a balance between national and local levels carrying out the identified management functions previously outlined. The envisaged organisational framework should, as far as possible, build on existing structures.

10.5.2 Implementation, monitoring and updating of the action plan

Depending of the number of proposed actions contained in the action plan, a phased implementation of the actions may be desirable. For example, the actions could be scheduled according to the following criteria:

- *Cohesion.* Some actions may cluster together.

- *Conditionality.* The pattern of actions may largely follow the overall pattern of the action plan, i.e. creating the legislative framework which establishes the enabling environment, building the appropriate institutional structures, and producing the required water quality management procedures and tools.

- *Dependency.* Some actions cannot be started until others are completed; for example, training related to developing an integrated extension service cannot take place until agreement has been reached to establish such a service.

- *Urgency.* Some actions are started in the initial phase because they are ranked as high priority.

A feasible, overall concept for phased implementation that might be considered is:

- Creating/adjusting the enabling environment, e.g. policies, legal procedures, regulations.
- Building/shaping the institutional structures.
- Producing/applying the required management tools and instruments.

It is very important to recognise that the action plan will have no significance if the action programme is not implemented, and unless all concerned parties are aware of the principles and procedures of the plan and are prepared to co-operate in its implementation. The action programme is the backbone of the action plan. Therefore, procedures for monitoring the progress of implementation should form part of the plan. Key indicators should be identified illustrating the progress, as well as the associated success criteria.

As indicated above, an obvious key indicator for monitoring the progress of the action plan would be the progress of setting up key institutional structures. Other useful indicators, depending on the actions listed, could be attendance at training courses and workshops, whether or not a permit system for wastewater discharges is implemented, number of analyses performed as part of a water quality monitoring programme. To document the progress of the action plan (or lack of it), a regular system for reporting on the monitoring activities should be instituted.

The action plan as a continuous process calls for frequent updating (see Case Study III, Philippines) and the addition of new actions as contexts change, requirements develop, or as progress falls below expectations or schedules. Modifications of earlier proposed actions may also be relevant. Regular monitoring reports should be accompanied by updated project/action lists.

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