Managing Water Quality in Developing Countries

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Over the next decade the management of water quality will be one of the outstanding issues relating to the protection and conservation of the national stock of water. In the past, particularly in countries well-endowed with water resources, this has been considered to be a relatively negligible problem. However, the rapid growth of population in major urban centres, industrialization and the heavy dependence on chemical products in the agricultural sector are leading to a serious deterioration of water quality.

This paper reviews the nature of the pollution issue, the institutional requirements to deal with the problem in an effective and comprehensive manner and the near-term actions which governments should take to protect their existing water resources.

1. INTRODUCTION

It may be expected that over the next decade the management of water quality problems will be one of the outstanding issues relating to the protection and conservation of the national stock of water in each country. In the past, particularly in countries well-endowed with water resources, this has been considered to be a relatively negligible problem. However, the rapid increase in population in major urban centres, industrialization and the heavy dependence on chemical products in the agricultural sector are leading to a serious deterioration of water quality in developing countries.

Today there is widespread realization that water quality management is an economic imperative for nations as they face increasing, and often competitive, demands on the use of this important resource. To protect water quality adequately, governments will need to understand the technological aspects of pollution problems, and will need to respond with effective policies and institutions.

This paper reviews the nature of the pollution problem, the institutional requirements to deal with it, and the near-term actions that governments should take to protect their existing water resources.

2. SOURCES OF POLLUTION AND ITS EFFECTS

Water bodies are increasingly subject to a variety of pollution sources attributed to urbanization, industrialization, the proliferation of chemical products, and even natural sources. The term 'pollution' correctly means the discharge of any material in quantities that interfere with a desired use of the water body. Implicit in this definition is the recognition that a discharge may or may not be a waste material, and that it may be either of anthropogenic origin or naturally occurring. It also recognizes the assimilative capacity of receiving waters, and implies that discharges do not constitute 'pollution' until and unless the

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particular discharge characteristics of the water body result in concentrations of discharged material that interfere with the use of the water.

Pollutant sources may be categorized as either point or non-point sources. Point sources are discrete 'end of pipe' discharges such as, for example, an industrial waste-water effluent or domestic waste from a municipal sewerage system. By contrast, non-point sources exert an impact over a diffuse area. Waste characteristics, i.e. mass rates and pollutant concentrations, are more difficult to determine for non-point sources than for point sources which are more amenable to study.

It is important to note that various substances present in pollutant discharges may already be present in the receiving water at background levels. Examples are minerals and certain metals (iron is common in many locations) which may come from natural geological formations. Anthropogenic sources add to these background levels. The background levels therefore define a lower boundary of potential water quality objectives.

2.1 URBAN SOURCES OF POLLUTION

The environmental effects of domestic wastes grow exponentially as communities grow in size from villages and towns to cities and metropolises. As population density increases, so does the spatial concentration of human and household wastes. Many urban centres in developing countries lack modern sanitation facilities for the collection and disposal of domestic wastes. This is particularly true in urban fringe areas which have been created through unplanned and uncontrolled growth due to tremendous migration of peoples from rural areas. As a result of this lack of facilities, human excrement and sullage is placed at curbsides, in ditches, or at best in open pits and dung heaps. The health risks through direct exposure to those wastes are obvious. Additionally, however, wastes disposed of in that fashion result in urban runoff highly polluted with pathogens and organic materials that can have a serious impact on the water quality of nearby surface water and shallow groundwater

Urban centres in developing countries have also undergone a concentration of modern industry and attendant industrial water pollution during the last two decades. Although most countries recognize the need to combat pollution from industrialization, controls are generally inadequate.

2.2 INDUSTRIAL WATER POLLUTION

It is estimated that the demand for water from industrial users will increase rapidly over the next two decades in the developing countries. For example, it has been estimated that in India industrial and other non-agricultural uses will claim 16% of consumptive use in the year 2000 compared with only 8% in 1975 (Varma, 1978). If unchecked, this increase in industrial water use will naturally be accompanied by an increase in industrial water pollution.

Untreated industrial wastes can have serious impacts on receiving water bodies. The specific effects in any given case are dependent on the assimilative capacity of the water body and the characteristics of the waste. It is difficult to summarize industrial waste characteristics concisely, because of the wide spectrum of industry classifications, the diversity of production technologies and modes of operation employed within each industry, and differences in raw material inputs. Nevertheless, the World Bank has studied waste streams in over 30 classes of industries and has developed guidelines for effluent limitations (World Bank, 1984).

The major industries in the traditional sector which are causing widespread water pollution are those which process primary products (often for export), such as sugar and oilseed mills, mineral extraction and processing facilities, coffee factories and tanneries. Agro-industries can become a major source of pollution when an increasing proportion of the population becomes involved in production of cash crops and industries begin concentrating in growing areas.

2.3 POLLUTION IN RURAL AND AGRICULTURAL SETTINGS

Even in rural areas, far from industrial and municipal discharges, pollution of water resources may occur as a result of natural causes or man's manipulation of the environment.

Agricultural operations may have an adverse impact on the quality of water resources in several ways. One way is through drainage and runoff from fertilized cropland. Heavy organic loadings, sediments, micro-organisms, and high concentrations of nitrogen and phosphorus nutrients can be washed into low lying streams, rivers and lakes, contributing to oxygen depletion, eutrophication and undesirable growth of aquatic plants and weeds. Pesticides may also be present in the runoff. The problem is accentuated in temperate climates where spring thaws result in unusually high loadings of short duration.

Agricultural operations may also affect receiving waters through the return flows of irrigation water. Although similar in composition to cropland runoff, irrigation return waters are typically discharged in the form of a point source. Runoff and drainage from animal feedlots are also high in organic loading, micro-organisms and nutrients. Relative to croplands, however, wastewater quantities generated from feedlots are relatively small and their impacts are relatively localized. Improved farm management practices can be introduced to reduce pollution from these sources and simultaneously conserve resources.

Forestry operations, particularly if not properly managed and controlled, can also have an impact on water quality. Logging operations can result in increased runoff, carrying sediments and nutrients to water courses. The problem has become extremely serious in some developing countries, where whole mountainsides have been virtually denuded for fuel.

Contamination of water supplies by domestic wastes is perhaps the most serious water quality problem in rural areas. It has been estimated that on average from 1970 to 1980, only 29% of the population in rural areas of developing countries had access to safe drinking water (United Nations, 1980b). This condition results primarily from a lack of basic sanitation. During the same 10-year period, only 13% of rural populations in developing countries were estimated to have access to sanitary excreta disposal. Sanitary facilities are lacking and people are unaware of the cause/effect relationships between indiscriminate excreta disposal and health. It is therefore common for excreta to be disposed of in rivers and lakes used for water supply. Another common practice is for excreta to be eliminated into fields, ditches or garbage heaps from where it can be washed by rainfall to nearby water supplies. The health effects are staggering; a major proportion of all sickness and disease (including such deadly diseases as diarrhoea, polio, typhoid and others) can be attributed to inadequate water or sanitation.

2.4 Effects of pollution

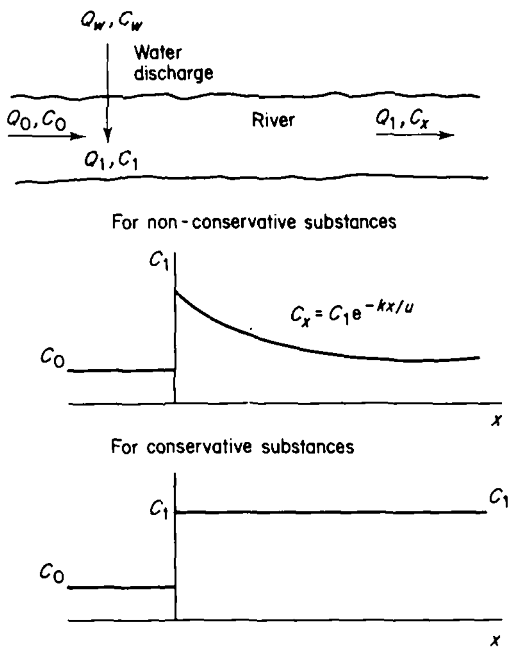
The effects of a pollutant on a water body depend on the characteristics of the discharge and natural characteristics of the water body. Pollutants can be categorized as either conservative or non-conservative substances. Organic pollutants as well as some inorganic pollutants and many micro-organisms are degraded by natural self-purification processes within the water body. Their concentration reduces with time. Hence, they are termed non-conservative. The rate of decay of these non-conservative pollutants is a function of the particular pollutant, receiving-water quality, temperature and other environmental factors. However, many inorganic chemicals, such as heavy metals, are not affected by natural processes. The concentration of these conservative substances can only be reduced by dilution (Tebbut, 1982).

Figure 1 compares the concentration of a conservative substance versus a non-conservative one over an equal stretch of river assuming constant flow throughout. As seen, while the concentration of the non-conservative substance decays with time, the concentration of the conservative substance remains constant.

Whatever the resultant concentration for a given discharge to a given body, the significance of that concentration depends on the desired use of the water. The main effects of pollution may be:

(a) contamination of water supplies, resulting in health risks and increased load on water treatment facilities;
(b) fish kills or decline in fish productivity;
(c) pollution of irrigation water, posing health risks or inhibiting crop productivity;
(d) degradation of recreational and aesthetic aspects of water;
(e) creation of odour nuisance; or
(f) hindrance to navigation.

The relative importance of these points is a function of the desired use of the water body. Parameters important for various uses are presented in Table I. Each use will have specific water quality requirements. Because water is often a



Q_o = upstream flow (vol./time)
C_o = upstream concentration (mass/vol.)
Q_w = wastestream flow (vol./time)
C_w = wastestream concentration (mass/vol.)
$Q_1 = Q_o + Q_e$
$C_1 = (Q_o C_o + Q_w C_w)/Q_1$
C_x = downstream concentration at distance x (mass/vol.)
x = downstream distance (length)
K = decay rate (1/time)
U = velocity of river (length/time)

Fig. 1. Comparison of concentrations of conservative and non-conservative substances in the same stretch of a river.

scarce resource, it is desirable to practise multipurpose use. Obviously, however, the water quality requirements for the various uses will not always be compatible (Tebbut, 1982). In setting water quality objectives for a particular water body, society must consider the costs of attaining the objectives versus the beneficial uses of the water.

Potable water supply, for example, is a vital use of many freshwater sources in both developing and industrialized countries. The levels of pathogenic organisms and toxic substances are critical for a potable water supply, and waters intended for this use must be protected from such pollutants. However, the degree of protection, as reflected by the standards adopted, is subject to risk–benefit analysis. The risk–benefit approach has recently been espoused by the World Health Organization (WHO). Earlier drinking water standards developed by WHO in 1971, have been superseded by the new WHO *Guidelines for Drinking-Water Quality* (1984). The Organization's current posture is to encourage nations to develop their own individual and appropriate standards in the context of the prevailing environmental, social and economic conditions (Thompson and Wernicke, 1984). WHO recognizes that the implementation and enforcement of standards, and the actual achievement of water quality in compliance with those standards, can be a costly proposition. Countries will have to weigh (qualitatively or quantitatively) the total costs of resources devoted to pollution control versus the benefits to be reaped by the investment, and consider the risks imposed by lesser degrees of control. As expressed by Thomann (1972), 'The central question in water quality management is: "To what level are we . . . willing to invest moneys (or forego some other opportunity or live with some particular problem) to protect, enhance or otherwise utilize a particular body of water?" '

Risks and benefits are easily illustrated when considering another major use of water in developing countries: commercial and subsistence fishing. Pollution of fisheries risks declining catches and adverse health, taste and odour effects. Conversely, the benefits of pollution control include continuing or improving fish productivity and wholesomeness of this important food source. The main pollution parameters to be controlled for fisheries are dissolved oxygen, pathogenic organisms, toxic substances, temperature, non-biodegradable substances (such as DDT) that concentrate in the food chain and substances that impart undesirable taste or odour to the fish (Lohani, 1982).

The third, and perhaps most important, use of water in developing countries is irrigation. In India, for example, agricultural uses of water account for about 90% of all water used (Varma, 1978). Because of its importance to food production, irrigability will often play a governing role

TABLE I
Water uses and quality considerations

Water uses	*Important quality parameters*
Power	Dissolved oxygen, pH
Flood protection	—
Irrigation	Dissolved solids, conductivity, sodium adsorption ratio
Potable water supply	Pathogenic organisms, toxic substances, turbidity, colour, hardness
Industrial water supply	Hardness, pH, dissolved oxygen
Navigation, transportation	Suspended solids, pH
Fishing (commercial and subsistence)	Dissolved oxygen, CO_2, pH, pesticides, heavy metals, pathogenic organisms
Recreation	Pathogenic organisms, pH
Nature conservation (wildlife and aesthetics)	Dissolved oxygen, pathogenic organisms, toxic substances
Waste disposal	Dissolved oxygen

Adapted from Pescod (1974).

in deciding pollution control strategies. Of particular concern is the protection of irrigation water from high concentrations of salinity and sodium. Salinity, as measured by electrical conductivity and total dissolved solids, causes plasmolysis of plant cells at concentrations that vary with the plant type, contact period and ambient temperature (Lohani, 1982).

Degradation of water resources by uncontrolled pollutant discharges can therefore have significant adverse effects on important sectors of the economy of a developing nation, particularly with regard to agriculture, fishing and potable water supply. Governments must develop effective policies and institutions to correct current detrimental effects of pollution and to protect water resources for future generations. The attainment or maintenance of pristine water resources is neither economically justifiable nor, in many cases, technically achievable. Rather, it is efficient for a society to define the desired uses of specific water bodies, and for water quality objectives to be formulated to provide for those uses.

3. INSTITUTIONAL REQUIREMENTS

Unless the efforts of water quality management rest on a firm, defensible legal foundation, they are virtually certain to fall short of their objectives. While most developing countries have basic legislation empowering government agencies to control some forms of water pollution, the laws may not be totally suitable in light of prevailing political, economic and cultural realities (Fano and Brewster, 1982). For this reason, they may not be as effective as would be desirable. Similarly, many developing countries lack the institutional capabilities and technological resources to enforce pollution control laws.

Enforcement considerations are of prime importance and countries have available to them several policy instruments for dealing with water pollution, among which are the following (Fano and Brewster, 1982):

(a) direct charges on effluents as an incentive to polluting entities to reduce waste loads;
(b) subsidies to promote pollution control, using tax rebates or payments to offset costs of pollution control;
(c) government standards on effluents from production processes, limiting discharge levels of certain substances into water courses;
(d) government licences under which permits will only be issued to entities using 'clean' processes; and
(e) requirements of environmental impact statements from potential investors of new projects.

3.1 ECONOMIC INCENTIVES

Various economic incentives may be applied to induce polluting entities to reduce discharges on the basis of self-interest. In a market economy, most resources are allocated to their most efficient use by price. Many environmental resources, water quality in particular, are unpriced and remain outside the market. Water quality may be degraded or 'used up' by pollutant discharges, but this is not reflected in the price system. Such use of a resource is termed as an 'externality' because the cost of its use, in terms of environmental degradation, is not borne by the user of the resource (Anderson *et al.*, 1977).

Theoretically, if the costs of consuming water quality could be quantified and charged to the polluting entity, he would discharge less. An effluent charge levied by government on the quantity of pollutants in a discharge should have the same effect as the market price on the polluting entity's decision to consume water quality. This approach, known as the 'polluter-pays principle', internalizes to the polluting entity to some degree, the cost of using an environmental resource.

3.1.1 Effluent charges

The effluent charge system involves government setting a charge at a level at which the marginal cost of pollution is slightly greater than the marginal cost of pollution control. As a result of such a charge, polluting entities are induced to initiate pollution control measures for cost-saving purposes. Economists generally consider this system to be the most effective means of reducing water pollution.

Effluent charges have been used in several European countries. Czechoslovakia provides a good example (Anderson *et al.*, 1977). The government imposes a basic charge on biochemical oxygen demand (BOD) and suspended solids (SS), and adds a surcharge of from 10% to 100% of the basic charge, depending on the extent to which the concentration of BOD or SS is increased in the receiving waters. The charges are based on the costs of operating existing treatment facilities, and do not reflect capital costs for new or expanded facilities. Consequently, the effect of this scheme is to induce proper operation of existing facilities, but not to induce capital investments. The Czech system does, however, allocate collected revenues to subsidies for such investments. Information on discharge levels is reported by the dischargers themselves with spot checks by government inspectors and penalties for falsification, assuring the accuracy of reports.

The generation of revenue is an important advantage of the effluent charge system. Another advantage is that it requires less information than other approaches and therefore has lower administration costs.

For developing countries considering the introduction of effluent charges, some of the following suggestions (United Nations, 1980a) regarding favourable ingredients of such a system might be useful:

(a) when an effluent charge system is introduced, initially low rates can be established with dates for specified rate increases indicated;
(b) the charges can be related to a few pollutants which are comparatively easy to measure by techniques which yield consistent results;
(c) the administration of an effluent charge system is greatly simplified by a table of pollution coefficients, establishing levels of pollution per unit of output or per employee. Provisions must be made for sampling and for basing payments on actual discharge of pollutants; and
(d) an effluent charge system should emphasize regional differences, including the assimilative capacity of the water course.

3.1.2 Tax incentives

Tax reductions for investments in pollution control are another important form of economic incentive. The Environmental Code of the Philippines, enacted in 1977, allowed half of the tariff duties and compensating tax on imported pollution control equipment to be waived for a period of five years from the date of enactment (UNDP Task Force on the Human Environment, 1978). Similar rebates were available for domestically produced equipment. The Code also made available tax deductions for certain pollution control research.

Other countries offer tax incentives to new industries to site their facilities away from urban concentrations. Still others allow industries to accelerate the depreciation of treatment facilities in computing taxes.

The nature of a tax incentive system is, in effect, to subsidize capital investments in pollution control facilities. This may be particularly attractive in those countries where few such facilities currently exist. Tax incentives do not, however, encourage non-structural means of pollution control such as alterations in production processes and raw material inputs.

3.2 POLLUTION CONTROL STANDARDS

Direct regulation has been used in many countries, notably the USA and the UK, to achieve significant gains against environmental degradation. Using this approach, government sets maximum allowable limits on discharges for particular pollutants or industries and establishes the administrative and judicial means to enforce these standards.

3.2.1 Ambient and effluent standards

Ambient water quality standards specify the minimum conditions which must be met for specific parameters at specific locations in a water body. For example, an ambient standard for a specific river may require that dissolved oxygen, averaged over a 24-h period at a selected river mile point, must not fall below 4 parts per million (ppm) on more than one day per year. Effluent standards, on the other hand, specify the mean or maximum permissible discharge of a pollutant from a particular source.

Ambient and effluent standards together are complementary components of an approach to water quality management. In situations where numerous waste discharges exist, achieving an ambient water quality standard through independent regulation of the various effluents will be impossible. Rather, the government must co-ordinate the various effluent standards in such a way as to achieve the desired goals in the receiving water body (Kneese and Bower, 1972)

One disadvantage of this system is that it does not provide an incentive to dischargers to reduce waste generation beyond that necessary to meet regulatory requirements. Enforcement is usually carried out by spot-checks by government inspectors, with penalities imposed on violators. Violators may prefer to delay compliance with standards and to engage the government in long legal battles. By contrast, a system of effluent charges provides an immediate economic incentive for the polluting entity to reduce its discharges.

Another disadvantage, of particular concern to developing countries, is that the administrative and enforcement expenses involved are enormous (Anderson *et al.*, 1977). The political and economic costs of an effective programme of direct regulation are too high for most governments to bear.

3.2.2 Mixed systems: charges and standards

Mixed systems may be viewed as either regulatory programmes, in which charges play an enforcement role, or as charge systems in which specified discharge levels have been exempted from the charge (Fano and Brewster, 1982).

Mixed systems have been enacted in the German Democratic Republic and in Hungary. Both countries levy charges on all discharges in excess of fixed effluent standards. This has the effect of providing an immediate economic incentive to reduce discharges. There is no incentive, however, to reduce discharges below that necessary to meet effluent standards.

3.3 ENVIRONMENTAL IMPACT ASSESSMENT

In recent years, developing countries have become increasingly aware of the necessity for predicting the impact of a new development project, industrial or otherwise, on environmental resources, including water quality. Environmental impact assessments (EIA) have been used for this purpose in industrialized nations for more than a decade. Many developing nations have enacted legal provisions requiring EIAs from investors and developers. Many are modelled on the US National Environmental Policy Act (NEPA). NEPA's requirements for an EIA are extremely thorough and comprehensive. For small projects, and in situations where funding is inadequate for a detailed EIA, other approaches such as 'fatal flaw' and diagnostic level assessments may be more applicable (Thompson *et al.*, 1983).

Whatever the level of detailed selected for an EIA, the basic objectives of an assessment are twofold. One is to develop information for planning and decision-making that will assure that a proposed development is compatible with its environment; the second is to determine the total cost and net overall benefit that an action will incur. This includes not only the direct financial costs and revenues arising from construction and operation, but also the broader environmental costs and benefits due to redirection of natural resources (Thompson *et al.*, 1983). Environmental costs and benefits are frequently not quantifiable in strict monetary terms, and must be judged qualitatively.

The advantage of an EIA lies in its ability to predict environmental consequences of a development project and to influence the project concept and design to avoid or reduce adverse impacts.

4. ESTABLISHING A NATIONAL PROGRAMME

The institutional requirements necessary to manage the quality of the water resources of a nation effectively must be carefully planned and developed. An incentive system must be planned, institutions created or existing institutions strengthened and water quality management plans prepared. Good planning and institution-building will result in the efficient use of human and financial resources to achieve desired water quality objectives.

4.1 MAKING AN INCENTIVE SYSTEM WORK

A workable incentive system is the core of a comprehensive water quality management programme. Incentives are required in order to induce entities to reduce levels of discharges. Economic, regulatory and administrative incentives have already been discussed, as have informal incentives, such as education and persuasion. Countries currently practising water quality management through an incentive system typically employ some mix of incentives—economic, regulatory, administrative and informal (Bower, 1982).

The chosen incentives must be backed by surveillance and enforcement programmes. A surveillance programme comprises monitoring and inspection activities. Compliance monitoring determines whether a discharge conforms to permit conditions or not. In addition to compliance monitoring, monitoring of ambient water quality determines the extent to which desired water quality objectives are being met in the receiving water body. On-site inspection of pollution control facilities completes the surveillance programme. Inspections determine whether or not specified equipment is installed and is properly operated and controlled.

An enforcement programme is based on a set of sanctions for failure to comply with pollution control requirements (Bower, 1982). Administrative sanctions may be informal—such as warning notices or meetings—or formal—such as the issuing of orders or fees, or revocation of permits. More-severe judicial penalities, such as civil penalties (fines), injuctions or criminal penalties may also be imposed.

Many developing countries lack the technical hardware and the specialized human resources necessary to carry out an adequate surveillance programme. Where lacking, the country must establish laboratory facilities for the analyses of waste waters and ambient water samples. Capabilities for storing, retrieving, and analyzing the large amounts of data so generated must also be established.

Many deveveloping countries also lack effective judicial systems necessary to enforce legal requirements against violators. Where lacking, legal penalties must be established or existing penalties strengthened. In addition, the political will to prosecute violators must be created and maintained at every level of government.

4.2 INSTITUTION BUILDING

A comprehensive water quality management programme entails a variety of activities, including data collection and analysis, research, planning, development and application of incentives, design, construction, operations and maintenance, surveillance, enforcement, and technical and financial assistance. In most cases, a number of government agencies will have responsibility for one or more of these activities (Bower, 1982). Thus, a fundamental task is deciding how to allocate these activities among the various agencies. A more complex task is building the agencies' capabilities to perform their assigned functions.

The efficacy of any institution is dependent on the abilities of the personnel charged with its

Role of clubs/cties/women in WQC/Managmt. ?

operation. Water quality management is a complex discipline comprising elements of law, science, engineering, administration, economics and finance. Qualified specialists with advanced training are therefore required. Developing countries will have to take steps to provide for these types of education, either through indigenous centres of higher learning or by sending specialists to study abroad.

4.3 WATER QUALITY MANAGEMENT PLANS

Various incentive systems which can be applied to curtail discharges have been discussed. Institution building and the technical skills necessary to implement a national water quality management programme have also been discussed. What remains is to consider what degree of curtailment of discharges is necessary for a given water quality objective and what technological control measures are preferred in order to achieve the desired results. This would be determined through the preparation of a water quality management plan.

As discussed earlier, the process begins with the identification of desired water uses in light of social, political and economic demands (see Fig. 2). Having determined the desired uses of a water body, the commensurate water quality objectives are then defined. At this point, a question is posed: does the actual quality of the water body meet the desired objectives? When assessing existing conditions, actual water quality would be determined through a programme of sample collection and testing and data analysis. When considering proposed actions, such as the siting of a new industrial facility, the actual water quality resulting from the change would be predicted through a mathematical model or other analytical means. In either case, if the objectives are met, there is no cause for further action.

When existing conditions do not meet desired objectives, or when analysis of proposed actions indicates resultant violations, a need for intervention is established. A water quality management plan is a rational and orderly procedure for identifying and evaluating alternative control plans and arriving at a preferred alternative. A water quality management plan comprises several components: inventory of pollution sources, determination of cause/effect relationships, identification and assessment of alternative control plans and ranking of

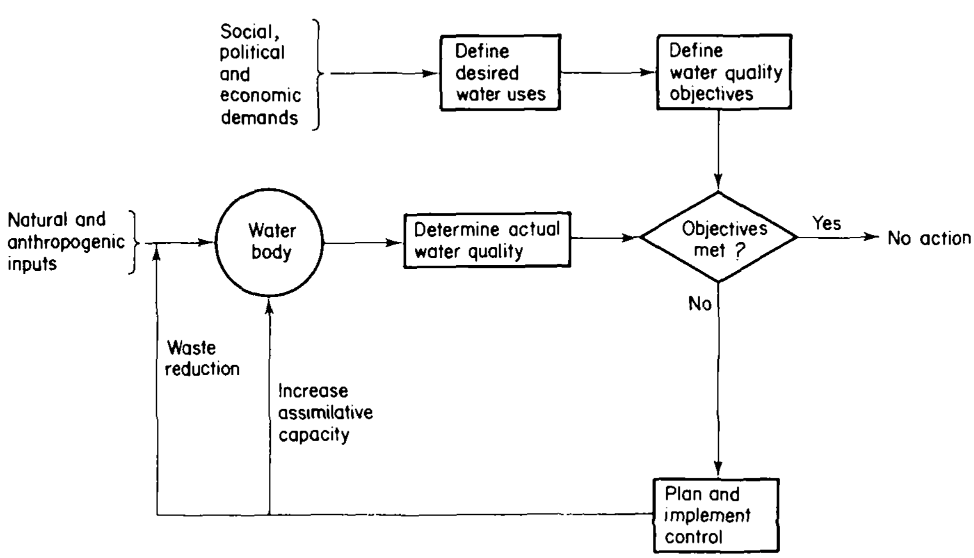


Fig. 2. Overview of water quality management.

alternatives.

The inventory of pollution sources should be as comprehensive as possible, including point and non-point sources, both natural and anthropogenic. Each source should be characterized by its mass rate and constituents. Responses of the water body to these inputs should then be determined by means of a model. Mathematical models are extremely useful tools in establishing these cause/effect relationships. Actual field data must be used to verify the model.

Alternative control plans should be identified and their induced responses tested by the model. A variety of controls are available to lessen the effects of pollution. Generally, controls fall into one of two groups: reduction of waste discharges or increase of the assimilative capacity of the receiving waters. Alternative control plans must be ranked on the basis of technical economic and environmental feasibility. Plans that do not meet the desired water quality objective may be dropped from further consideration. Cost/benefit analyses should be performed. It must be noted, however, that while some benefits of water quality management are quantifiable, such as increases in fishery or agricultural production, others, such as improvements to public health or increased recreational opportunities, are not. Thus, the use of a quantified cost/benefit ratio may not always be possible. Rankings will often have to be made on the basis of some qualitative consideration of intangible benefits. In a wider environmental context, rankings should also consider any secondary environmental impacts associated with the alternative controls.

The ranking of alternatives will result in the planners recommending one preferred alternative. Nevertheless, all feasible alternatives should be presented to the decision-makers. Social and political considerations may cause the modification of some alternatives, and may affect the outcome of ranking. For this reason, planners should take these considerations into account as much as possible when formulating plans.

Once the decision-makers have selected the preferred control plan, the controls must be implemented by means of an incentive system. A surveillance and enforcement programme should also be implemented to check and impose compliance with the plan.

4.4 PUBLIC EDUCATION

Government efforts to control pollution can be greatly enhanced by the support of its constituents. Education can foster a sense of both personal and communal commitment to environmental protection, particularly when such protection is correctly portrayed as a means towards improving quality of life. As discussed earlier, the degradation of water quality can have significant adverse effects on important sectors of the economy of a nation.

Governments can consider several approaches to public education. The first is the introduction of environmental considerations into the formal science curricula of primary and secondary schools. Students should learn that cause-and-effect relationships inherent in water quality management (and other environmental conerns, for that matter) are understandable, quantifiable and, most importantly, controllable. Secondly, governments can use mass media techniques to generate support for environmental programmes. Finally, governments can support the activities of environmental interest groups which have direct contact with their members, and which command some degree of media attention.

5. CONCLUSIONS

Just as water pollution problems reached near-crisis proportions in many industrialized nations during the past few decades, so too will developing countries be faced with similar water quality issues in the decades to come. Population growth and increased urbanization will result in greater quantities and concentrations of domestic wastes. Efforts to meet growing demands for goods and services, and for commodities such as food and energy, will be attended by increased generation of industrial and agricultural wastes. Indiscriminate disposal of such wastes may render water bodies unusable for agriculture, fishing, water supply, and even navigation and industrial use in severe cases. The economic consequences of a development policy that does not adequately consider environmental protection may be dire.

Developing countries must begin today to address this important aspect of development. Governments need to assess what is now being done and what is lacking in the area of water quality management. Where deficiencies are noted, improvements must be made to the legal basis for pollution control activities, and to the institutions responsible for those activities. A comprehensive national water quality management programme should be planned and coordinated through the various participating institutions. The central activities in such a programme would be the development and implementation of an effective incentive system, backed by thorough surveillance and enforcement activities. Once the institutional framework of a nation is sufficiently developed, rational water quality management plans, based on scientific analysis, must then be prepared and implemented. Towards this end, nations can begin to identify the desired uses of specific water bodies, adopt standards and take inventory of waste discharges affecting or potentially affecting such uses.

Education of environmental specialists will be necessary for most developing countries to fulfil these functions independently. Educating the public and the polluting entities will greatly enhance their acceptance of a comprehensive water quality management programme and will contribute to its success.

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