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WATER QUALITY MANAGEMENT: DESIGN, FINANCING AND SUSTAINABILITY CONSIDERATIONS – II[1]

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ABSTRACT

The sustainable management of water quality has policy, technical, institutional and financial components. In many developing countries restricted funding is usually combined with fragile or unstable institutions and limited technical capabilities to deal with an expanding range of water quality problems. Therefore, there needs to be a priority on establishing a coherent and realistic national policy response to water quality management so that limited funds and strengthening of capacity are strategically focused on essential issues, and institutional inertia or competition is eliminated. For example, the present state of many national data programs, for which there are no clear data objectives and no defined users of the data, represents an expensive failure of national policy.

At the technical level, there has been great progress in western nations in developing more cost-effective monitoring, analytical protocols, and assessment methods. This flows not only from better scientific knowledge, but also from recognition that conventional monitoring programs are inefficient, expensive, and often not very useful. Regrettably, financial institutions and ODA programs tend to reinforce conventional approaches in developing countries with the result that these countries have little opportunity to develop a new, more appropriate and more sustainable data paradigm. In lesser developed countries where public health is the major concern, the traditional model of a centralized monitoring program often does not work, suggesting that a new model of decentralized community-based monitoring would be more effective.

Growing national priorities for remediation of water quality in lake and river basins demonstrate the gap between needs and abilities in developing countries. This gap has a profound effect both on the types of interventions that are being (or should be) implemented and on how these can be sustained in developing countries. The increasing need for defensible, rational, remediation programs argues for a new model for capacity building so that the role of the consultant (company) is reduced to one of facilitator and not the primary implementer. Conventional approaches to river and lake restoration, such as dredging, are often ineffective and expensive. Alternative technologies that are more effective and sustainable are usually not considered because they do not fit into conventional engineering solutions.

Financial sustainability is not a simple problem. It requires, in the first-instance, a well-defined and targeted program that meets specific management needs. It includes potential for cost-avoidance and cost-reduction as well as cost-recovery and income generation. It also depends on management and business skills at the program level and on fiscal policies and accountabilities at the state level that permit earnings retention and reinvestment. Experience suggests that redesign of national water quality data programs, including technical, institutional and legal components, is an effective first step to achieving cost-efficiency.

1. INTRODUCTION

Although the "global water crisis" tends to be viewed as a water quantity problem, water ***quality*** is increasingly being acknowledged as a central factor in the water crisis. Ironically, the fact that some five million persons, mainly children and infants, die annually from water-borne

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diseases, was not enough to mobilize international action about water quality. It is only since United Nations agencies (WMO, 1997), 1998 meetings of the Commission on Sustainable Development, the General Assembly, and other organizations began looking at the overall contribution of massively polluted water to the global water crisis that the world has started to take water quality seriously. The contribution of water quality to this crisis is mainly through the loss of a wide variety of beneficial uses, including large-scale ecological dysfunction and collapse, loss of economic opportunity and its role in public health and poverty. Water quality is also intimately linked to the issue of sustainable food production.

In China, where an attempt was made to calculate the overall cost of water pollution to the national economy (Smil, 1996), the cost in 1990 was estimated to be 0.5% of GDP or, in dollar terms, more than the value of all exports from China in that year. Using data from Weng (1999) it is estimated that in 1998 the proportion of surface water in China that is so grossly polluted that it is unfit for any use is between 13 and 27% -- this in a country with a current mean annual water deficit of some 40 bm^3. It is significant that many informed technical experts in this field are now of the opinion that remediation of water quality is now at least, if not more, economical than developing new sources of supply in many countries.

The water quality situation in developing countries is highly variable reflecting social, economic and physical factors as well as state of development. And while not all countries are facing a crisis of water shortage, all have to a greater or lesser extent serious problems associated with degraded water quality. In some countries these are mainly associated with rivers, in others it is groundwater, and in yet others it is large lakes; in many countries it is all three. Because the range of polluting activities is highly variable from one country to another, and the nature of environmental and socio-economic impacts is equally variable, there is no "one-size-fits-all" solution. There are, however, some common denominators in the types of actions that are required for sustainable solutions. The challenge for national and multilateral agencies, and the subject of this paper, is how to carry out water quality control and remediation programs that are cost-effective and sustainable.

In this paper, we explore the key aspects of water quality management that should enter into national water programs irrespective of the type of pollution or the type of water body concerned. These components reflect important technical, institutional, legal, financial and business issues which should be included in national water policies. We also examine here the barriers to sustainable capacity development, especially as the pace of development and scope of water quality problems almost always grow faster than any ability to build and sustain in-country capacity.

2. THE POLICY REGIME IN WATER QUALITY MANAGEMENT

Apart from effluent regulations and, sometimes, national water quality guidelines, a common observation is that few developing countries include water quality within a meaningful national water policy context. Whereas water supply is seen as a national issue, pollution is mainly felt at, and dealt with, at the local level. National governments, with few exceptions, have little information on the relative importance of various types of pollution (agriculture, municipal, industrial, animal husbandry, aquaculture, etc.) and therefore have no notion of which is of greatest economic or public health significance. Usually, freshwater quality management is completely divorced from coastal management even though these are intimately linked. Consequently, it is difficult to develop a strategic water quality management plan or to efficiently focus domestic and donor funds on priority issues.

A national water policy should include the following water quality components:

1. A policy framework that provides broad strategic and political directions for future water quality management.

2. A strategic action plan for water quality management based on priorities that reflect an understanding of economic and social costs of impaired water. This plan will include the following components:

   - A mechanism for identifying national priorities for water quality management that will guide domestic and donor investment.
   - A consideration of options for financial sustainability including donor support, public-private sector partnerships, regional self-support initiatives, etc..
   - A plan for developing a focused and cost-effective data program for water quality and related uses, as a basis for economic and social planning.
   - Establish specific mechanisms for providing drinking water monitoring capabilities, at the community level if necessary.
   - Establish (national) data standards: These must realistically reflect national needs and capabilities. Nevertheless, the objective is to ensure reliable data from those organizations that produce information for national water management purposes and at the community level for drinking water monitoring.
   - A regulatory framework that includes a combination of appropriate water quality objectives (appropriate to that country and not necessarily based on "western" standards) and effluent controls. This includes both surface and groundwater.
   - A process for tasking specific agencies with implementation so that accountability is firmly established and inter-agency competition is eliminated.
   - A methodology for public input into goals and priorities.

3. RETHINKING THE PRINCIPLES OF DATA PROGRAMS

The over-arching problem of data programs (monitoring and data use) was summarized by Ongley (1993) as:

> "… a common observation amongst water quality professionals is that many water quality programs, especially in developing countries, collect the wrong parameters, from the wrong places, using the wrong substrates and at inappropriate sampling frequencies, and produce data that are often quite unreliable; the data are not assessed or evaluated, and are not sufficiently connected to realistic and meaningful program, legal or management objectives. This is not the fault of developing

> countries; more often it results from inappropriate technology transfer and an assumption by recipients and donors that the data paradigm developed by western countries is appropriate in developing countries. "

Regrettably, many countries including many developed countries, entrust data programs to agencies having data-collection as their primary mandate, with the result that water quality data programs exhibit a high degree of inertia and for which there are few identified users of the data. The consequence is that such data programs tend to be **data-driven** rather than needs-driven. The usual outcome is that these programs become rapidly outdated by failing to shift program priorities towards modern pollution issues, are not subjected to periodic and critical technical review, are not cost-effective, and produce data which are rarely used. Such programs usually do not produce information that is useful for national planning, for policy development, for investment targeting, or for regulatory purposes.

Water quality monitoring, as practiced in most developed countries, is based on the premise that with enough data, a well designed program can answer most types of water quality management issues. This has been referred to as a data-rich or data-driven approach in which the objective is primarily to gather high quality data. This has recently been challenged by the United States government which found that, despite years of expensive data programs, one cannot tell whether the nation's waters are getting better or worse. The consequence has been the realization that these mainly chemistry-focused programs are expensive, focus on data production rather than on data use, collect more data than is necessary, often do not reflect the types of data that managers need, and can be replaced by cheaper and more effective methods. The outcome in Canada and the United States has been a substantial shrinkage of conventional water quality data programs and an expansion of alternative approaches. **Regrettably, this expensive and often ineffective chemistry-focused approach is the one now being adopted by developing countries and is being recommended by international and multilateral organizations.**

Most developing countries are "data-poor" environments as well as being challenged by economic restrictions. This, together with lack of sufficient technical and institutional capacity and often a poor scientific knowledge base, suggests that the conventional "western" approach to water quality monitoring and management is not well suited to many if not most developing countries. ***It is, therefore, timely to promote a new water quality paradigm that is more suitable, affordable, and sustainable in developing countries.*** The need for a new paradigm has been recognized in several parts of the developing world during the "Vision" exercise carried out by the Global Water Partnership and the World Water Council over the past two years.

Unfortunately, this situation tends not to be recognized by institutions such as the World Bank, UNDP and others, and in many ODA programs, which tend to take for granted that what is needed is to reinforce existing programs and to build capacity along conventional "western" lines. What is missing is a critical appreciation of the profound shortcomings of conventional approaches and a failure to encourage national and sub-national agencies to re-appraise their programs relative to specific management needs for data, and to take advantage of more sustainable and cost-effective ways of doing business. Unfortunately, the current situation results in: (i) loan and ODA programs that focus on data programs in the more advanced developing countries tend to reinforce existing inefficiencies, and (ii) in less advanced developing countries, the effect is to reinforce aspirations for a "western style" program that will lock the country into an expensive, usually unsustainable, and technically inferior (relative to current alternatives) program.

As examples of this situation, in a recent program of the World Bank in one large developing country, "modernization" of monitoring was largely linked to procurement of advanced equipment and laboratory infrastructure which local experts say is unlikely to have much impact on the types of data that are really needed for decision-making. The decisions appear to have been largely driven by in-country technical staff for whom advanced facilities were out of reach and who had no responsibility for the larger issues of program efficiency or relevancy. In contrast, a World Bank program in Mexico responded to the Mexican government's desire to fundamentally restructure the national water program with the result that water quality data program and related legal and institutional change, was measurably more efficient and effective and was able to effect a savings of 66% of the amount that the national agency originally requested to extend its existing program (Ongley and Barrios, 1997).

The solution to this situation is a process now referred to as "modernization" of water quality programs (Ongley, 1997, 1998). This addresses policy, institutional, legal and technical components of water quality programs. It also takes advantages of a large number of improvements in monitoring and assessment technologies that reduce costs, increase efficiencies, improve accuracy, and focus programs on meaningful data objectives. Because multilateral agencies have not, generally, recognized the seriousness of the data problem, even for their own lending programs, there remains **a lack of written practical guidelines for carrying out the modernization process.**

4. DESIGN ISSUES IN WATER QUALITY MONITORING

4a. Data Objectives:

The first design criteria in any water quality program is to determine what are the management issues for which water quality data are required. The technical aspects of data collection will flow from this decision, especially as there are now very cost-effective alternatives to conventional monitoring practice. Establishing of data objectives in Mexico, for example, resulted in a radical shift in national monitoring practice which produced the savings noted above. Also, these new methods will permit a much higher level of regulatory compliance. Most importantly, data programs are now seen to have value insofar as they will provide a service for someone other than the monitoring agency itself.

Generally, there are three categories of data objectives. Entries in the following categories may shift between categories, depending on the situation.

- ***Descriptive data*** that are typically used for government policy and planning, meeting international obligations, and for public information.

- Data specific to ***public health***.

- ***Regulatory concerns***.

Establishing of data objectives includes: a prioritization of issues; identification of those organizations that have need of specific data for these types of issues; development of practical interactions with these organizations to ensure that data of the correct type, with appropriate quality assurance, and mechanisms of transmission to the user(s) are mutually acceptable and affordable; and assessment of institutional capacity to produce such data. Questions of finance are explored below, however the importance of "affordability" must be dealt with at the time of interacting with data users so that the costs are understood, and the client knows what is, and is not, possible under the prevailing economic situation.

The reader will note that "research/science" is not a data objective. Experience indicates that national programs of monitoring that mix scientific with management objectives of the type noted above often become hybrids that are (1) more expensive that is necessary and often ill suited for management purposes, and (2) often not sufficiently rigorous to produce the type of data required by researchers. Therefore, monitoring for research purposes should be clearly separated from other monitoring programs, or added to them only within a very specific context.

4b. Efficiency, Effectiveness and Technical Innovation:

Historically, and still in most developing countries, the focus in monitoring has been on the production of simple chemical (such as major ions) and indicator bacterial data. With some limited exceptions, major ion data is of little practical value. Bacteriological data tend to be intermittent and too frequently are not disseminated to those who drink the water. Unfortunately, in addition to faecal pollution, many developing countries are now facing one or more of the types of water pollution that exist in highly developed countries – acidification, eutrophication, and contamination. The value of modernization of water quality programs lies in the prioritization of issues and the development of cost-effective data and management programs that can focus on these issues. In a number of countries where this writer has carried out program reviews, efficiency of the data-collection component is estimated at ≈10% of a focused, well managed and technically efficient program.

In most countries, the technology of monitoring has not changed since the 1970's, yet some of the largest advances in monitoring in recent years involve technical innovation that serve to reduce costs and increase efficiency. Types of innovation include:

- Biological assessment, including miniaturized laboratory and field bioassays for toxicity, and use of rapid in-stream assessment techniques.
- Immunoassay kits for field testing of specific chemical compounds.
- Kits and other innovative approaches that lend themselves to decentralized community-based bacteriological monitoring of drinking water supplies.
- Simple histological techniques using red and white blood cell counts from fish to determine presence of pollutant stress.

- Use of enzymatic indicators in organisms such as fish to determine presence/absence of categories of toxic contaminants.
- Miniaturization, automation and simplification of laboratory analytical methods.
- Field techniques such as "lipid bag" technology for sampling for low levels of lipophilic toxic chemicals that are otherwise difficult to detect.
- Greatly improved understanding of use of sediment as a chemical indicator of water quality.
- Greatly improved understanding of chemical transport in water that has provided new insight into more efficient sampling protocols.

For more advanced developing countries or where there are issues such as contamination from point and non-point sources, the conventional and expensive chemical approach to monitoring can be effectively replaced by new diagnostic tools such as diagnostic chemistry and biological assessment. While these never completely replace bench chemistry, the trend is to use these inexpensive diagnostic tools to determine whether or not the pollutant load meet certain predetermined levels of risk before any expensive chemistry is performed. Many of these tests are now field portable in kit form and/or are capable of automation in the laboratory so that large numbers of analysis can be produced with a high degree of quality control at low cost. While field kits and other diagnostic tests require an initial investment, they can greatly reduce the cost of equipment and the number of skilled personnel that are required to operate central laboratories. Moreover, the data produced by these techniques have immediate relevance in decision-making about quality of the sampled environment. Also, developing countries produce many biologists but few environmental chemists.

Another area of technical innovation that has considerable merit in developing countries is the application of new decision-support (DSS) capabilities drawn from the field of information technology (IT). These techniques are particularly useful in data-poor environments that are typical of developing countries. There is a large knowledge-base (***domain knowledge***) in the scientific community on most types of water quality management issues which, when supplemented by ***local knowledge***, can greatly facilitate decisions on water quality management. The objective of a well–designed decision support system (DSS) is to put domain knowledge into the hands of local practitioners in such a way that the user is guided through a complex task to a conclusion for which the results can be expressed in degrees of confidence. Although decision-support technology is now well known, there has been little effort by the international community to systematically develop these technologies and related data and knowledge bases so that these can be applied to typical water management issues in data-poor or knowledge-poor environments.

4c. Network Design:

In general, technical innovation has had a major impact on the design of monitoring networks. Contrary to practice in most countries the three types of data noted in #4a (above) are not cost-effectively provided under a single type of monitoring protocol. For example, the conventional fixed-site network is adequate mainly for production of descriptive information that is useful for public information and for broad policy issues. Generally, however, such networks are of little value for regulatory purposes, for determining management options in cases of aquatic pollution, or for related investment decision-making. For this latter group of issues, technical innovation and progress in our scientific understanding of cause and effect has provided a broad range of diagnostic and analytical tools that make regulatory monitoring and enforcement cheaper and easier, and more enforceable in courts of law.

The conventional concept of a national water quality network operated by a (centralized) national agency is probably not appropriate in many developing countries that have neither the economic nor technical resources to operate a national network. The fixed site network that is recommended by most water agencies, is expensive and inflexible, especially as many priority issues can be more effectively dealt with by the more flexible survey approach.

For a substantial number of less advanced developing countries and regionally within some more advanced developing countries, where the priority water quality issue is that of public health, there is further reason to rethink the conventional model of a national network of water quality stations operated by a central agency. In many countries, this type of network is not able to provide timely public health data to communities due to limited budget, small number of stations, poor communication facilities, etc.. An alternative model is to develop community-based monitoring of drinking water supply. Canada's International Development Research Centre (IDRC, 1999) has developed a basic monitoring protocol for application in under-developed Latin American and Asian countries by school children and administered over the Internet. In this approach, simple indicators of bacterial pollution are used by each village on its own water supply. Using a simple concept of risk, the community decides if treatment is necessary or, if the water has been treated, whether or not the level of treatment is satisfactory. The essential requirements are for (1) the creation of a community-based group that takes responsibility for water quality, and (2) provision by donors or by the central government of the basic supplies and quality assurance required to operate the program. This approach also requires a shift in thinking from conventional analysis which, although it provides accurate indications of bacterial contamination, is largely unavailable to local populations, to a risk-based approach that identifies the potential for health effects but which is easily implemented at the local level.

5. INSTITUTIONAL AND LEGAL ISSUES

In addition to economic uncertainty, many of the problems of water quality monitoring and management are institutional in nature and are too broad to deal with in detail in this paper. The principal institutional issues tend to be:

- Isolation of the data collecting agency from users of water quality data.
- Overlapping mandates and inter-institutional competition.
- Failure to institutionalize adequate quality assurance and quality control over data.
- Lack of communication protocols and/or facilities for transmitting data/information to users.
- Lack of human resource strategies to build and promote competence.
- Uncritical acceptance of donor assistance – this tends to be seen in
  (a) donated equipment which can not be sustained due to lack of skilled personnel, maintenance, spare parts or reagents;

(b) uncritical acceptance of training that is not focused on priority issues;
(c) lack of follow-up by the donor.
(d) promotion by donors of technologies that are more sophisticated than are needed.
(e) use of foreign experts rather than local experts.

- Unwillingness to accept low technology solutions even when these are more sustainable and suited to local skills, etc..

As noted by Ongley (1998) efficient water quality management is usually severely hampered by out-dated legal requirements that cover everything from sampling and analytical protocols, to data standards. The most difficult issues tend to be:

- Out-dated legal requirements calling for specified water quality parameters. One example is dissolved metals which has been abandoned by most western countries (at least for routine monitoring) due to insurmountable field and laboratory errors.
- Codification of analytical methods which locks programs into out-dated methodologies which cannot take advantage of new and more cost-effective techniques.
- Codification of analytical quality assurance and quality control (QA/QC) which, in fact, does little to ensure reliable data in the absence of compliance assessment and enforcement. Unfortunately, codification for QA/QC and for analytical methods, appeals to bureaucrats because of its administrative simplicity.
- Lack of data standards so that there is no ability to develop national data sets using diverse data sources and, therefore, no ability to produce reliable national perspectives on water quality. This also impacts on ODA programs in that donors have no idea what standard of data quality is expected for any particular investment.
- Uncritical acceptance and codification of water quality standards (usually western standards) that are inappropriate to the local situation and are unenforceable.

6. WATER QUALITY REMEDIATION: Science, Knowledge, and Capacity.

It is an unfortunate fact that the rate of increase in types and complexity of water quality problems (indeed, of all environmental problems) will exceed the rate of capacity development for a long time to come. This presents a real dilemma both for lenders and for national governments. It also demands that business models (Section 7) and the conventional approaches to capacity development require rethinking.

When looking at loan profiles of major lending institutions, it is clear that a major developing trend is the remediation of degraded water quality. This tends to fall into two types of projects -- (i) remediation of highly eutrophic lakes (e.g. many such projects in China), and (ii) remediation of contaminated river systems. In the past these have mainly taken the form of infrastructure projects for wastewater management, however there is little evidence that such projects in freshwater environments approach such problems as an integrated problem of watershed management so that the level and target of the investment is commensurate with the anticipated benefits.

Remediation brings into focus the stark reality of profound deficiencies in national scientific competencies and, in some cases, similar deficiencies in foreign "experts". Few developing countries have the technical knowledge or experience to make good judgements about appropriate interventions for remediation of large lakes and complex river systems. This includes problem identification, setting of rational and defensible program objectives, and implementation methods. Two examples will demonstrate this point:

(i) Large and typically shallow lakes in Asia tend to be highly eutrophic with extreme algae problems causing both environmental and economic consequences. A control plan requires a knowledge of point and non-point source loads, and a reliable estimate of the "internal" load of phosphorus that is contained in lake bottom sediments and which may be larger than all the other loads combined. Nevertheless, non-point and internal loads are rarely known (a result of lack of data and lack of knowledge) with the consequence that many lake restoration projects have unrealistic and often unachievable objectives and, in some cases, may produce no change whatsoever in lake quality. In one large lake program now being developed in a major Asian country, the official objectives are, in fact, quite the opposite of what will actually happen, as the lake will inevitably deteriorate for some considerable time before any improvement can be expected.

Dredging of lake bottom sediments is the common response to extreme eutrophication of lakes. The decision to dredge is usually made by in-country program managers who have no knowledge of alternatives and lack the science to determine the likely outcome. Yet, dredging is well known to be largely ineffective, hugely expensive, and often makes the problem worse, not better. Lake Dianchi, a large lake in southwestern China, is just one example where a major dredging program has made the situation worse for reasons that could have been easily anticipated. As a consequence, that national government has announced a major R&D and operations program for Lake Dianchi to develop alternatives, yet the approach and boundaries announced for that program do not reflect present knowledge of lake science and, as a consequence, virtually ensures that the investment will be largely wasted.

(ii) Remediation of contaminated rivers presents another set of problems for which there is insufficient in-country scientific capability to properly scope the issues, define objectives, identify implementation options, and confidently predict expectable results. In many advanced developing countries, for example, the principal regulatory parameter is COD (chemical oxygen demand), yet COD is only an indicator parameter that measures the aggregate effect of a large variety of chemicals, including toxic and/or carcinogenic substances, that have different sources, different environmental pathways, different environmental and human health effects, and different probabilities of being eliminated by alternative remediation options. In-country agencies rarely have the technical capacity to make the analyses that are required to properly scope the various options for remedial interventions.

One conventional approach for river contamination problems in developed countries is to apply a mathematical model which is used to scope the potential management interventions.

Application of this approach in developing countries is common, but is unrealistic in that such models are data-intensive, often proprietary, contain assumptions that may or may not be suitable to the developing country situation, are expensive to apply and are usually contracted from foreign sources. The irony is that such models are considered to be more scientific than simpler methods of analysis, yet simple techniques often provide an appropriate level of resolution for the problem at hand, are much less data-intensive, and rely on domain knowledge supplemented with limited local data collection. Additional problems with this "western" approach, and alternatives, are noted below.

For multilateral and in-country agencies, the conventional solution to problems of capacity is to engage foreign experts. However, this is hardly sustainable when, in most instances:

- Very little capacity building is, in fact, carried out insofar as local agencies do low-level work, with high-level work often done by the foreign company in their home base.
- Advanced models and computer-based systems are often applied that may or may not be appropriate, and are the property of the consultant so they cannot be re-used, modified, or expanded without access to proprietary source code (usually at significant cost).
- Local experts in universities or other institutions not associated with the contracting (in-country) authority are often excluded due to competition for funds and opportunity.
- The local authority (and often the lending institution) is hostage to the conclusions of the foreign contractor which may, or may not, be appropriate or realistic.
- When the same situation arises in the next river or lake, the cycle repeats itself.

Some Solutions for Sustainable Capacity Development

a. Lending institutions need to set measurable performance criteria for capacity development, especially in those projects that require a high degree of foreign expertise. A major objective should be that the foreign consultant (or company) becomes the facilitator and not the "doer" so that real capacity is developed in-country. The same criticism applies to many ODA programs, however there is likely to be little progress so long as the economic benefits of "tied" and "leveraged" aid programs tend to be heavily weighted towards the donor.

b. It is true that developing countries do not want to be hostage to western technologies. However, we must distinguish between technologies and know-how that are the intellectual property of western companies, and domain knowledge (that which is known about some area of science or technology and is in the public domain). The challenge is how to bring domain knowledge into the hands of local decision-makers. One common approach is technology transfer. Usually this consists of workshops, short training, and access via computer-related technologies (the Internet, etc.). This works well for simple technologies that can be learned quickly or for which the underlying principles, if not the actual mechanics, can be easily grasped. It does not work well for complex technologies, such as lake and river remediation techniques that require both an extensive background in aquatic science and implementation expertise. Three alternatives for technology transfer for complex problems are provided below:

- Using knowledge-based (K-B) techniques (a form of information technology), including appropriate computer-based decision-support systems (this is not GIS), it is now possible to put the essential domain knowledge in the hands of a decision-maker in a way which is focused on a particular type of problem (Ongley & Booty, 1999). It is particularly suited to data-poor environments where the application of domain knowledge can often replace extensive and expensive data collection. K-B techniques can deal with the uncertainties in the decision process, including uncertainties rising from the types of data/models/assumptions being used. In the nearer term, K-B techniques are probably most useful in scoping a particular problem, identifying information gaps (and the relative importance to the possible outcomes of these gaps), and selecting from amongst various implementation options. Such systems can be mounted on central web sites and accessed on-demand, or included in distance learning programs as a way of focusing the learning process on particular problems and their solutions. Innovative examples are coming from FAO (1999) in the field of irrigation and land management.

- A second approach is to reconsider the type of business model that is used to access foreign expertise. A business model is a good one for complex issues insofar as companies have the ability to retain or attract the necessary expertise, can keep abreast of new developments in the technology, can raise capital and offer performance guarantees, understand project management, and provide longer-term stability. The problem is, however, that typically the foreign company does the work with some, often low-level, input from local partners that are acquired on a one-time basis primarily to win a contract and, once the job is finished, the firm goes home leaving little real capacity in-country. A better business model is one in which companies nurture local partners within an equity or royalty framework, so that local firms increasingly can compete for the work, but retain ties to the core expertise and knowledge that may lie outside the country. Lending institutions and in-country agencies with contracting-in responsibilities, can influence this type of nurturing by using nurturing criteria within the bid selection process.

- Thirdly, given the growth in complex remediation requirements in Asia, Latin America Eastern Europe, and parts of Africa, there would be merit in introducing an extensive, multi-disciplinary, educational process within large remediation programs. The education process would use the real-world example as a learning environment. This could be included in, for example, GEF projects although it is noted that the GEF does not fund education *per se*. A project in, for example, Asia could train technical staff from various Asian countries in both the technical and managerial practices of a remediation program. Such a program could have degree status within an existing Asian academic institution. The focus might include both scientific and project management aspects.

c. Conventional practice, combined with a lack of knowledge of modern remediation science, is a profound **barrier** to the use of cheaper and more effective approaches. An example is dredging which, as noted above, is well known to be ineffective and expensive for remediation of eutrophic lakes. The track record of dredging in countries such as China and Japan is poor despite the hundreds of millions of dollars spent. Modern science tells us that remediation of large shallow lakes is not possible over short periods of time. Similarly, new "in-situ" treatment processes for contaminated sediments are rejected by engineers in favour of conventional dredging solutions which are often not cost-effective and are environmentally destructive. There are non-conventional and economic technologies that can be successfully applied to deal with a variety of specific problems such as odour, aquatic weeds, etc.. There are remediation technologies that use simple bioengineering that can be applied to parts of lakes such as water intakes and recreational areas. One such example in China has shown that simple and sustainable bioengineering at the water intake offers significant economic advantages over conventional engineering where algal control is required. Yet these various approaches are typically rejected because they are "unorthodox" and do not fit into the conventional engineering mindset.

7. FINANCING AND SUSTAINABILITY

Financial sustainability is a difficult issue, especially in less advanced developing countries. Generally, in the first-instance, it requires a well-defined and targeted program that meets specific management needs. It includes potential for cost-reduction as well as cost-recovery and income generation. It also depends on management and business skills at the laboratory level and on fiscal policies and accountabilities at the state level that permit earnings retention and reinvestment. Experience suggests that redesign of national data programs, including technical, institutional and legal components, is an effective first step to achieving cost-efficiency. As noted above, in some more advanced developing countries in Asia and Latin America, data programs were to be operating at about a 10% efficiency based on purely technical criteria. The ability to achieve even small gains in efficiency translate into savings that can be reinvested elsewhere.

The first step in achieving financial sustainability is a focused national water policy in which the priorities for action and modes of operation are clearly defined. This will drive local and donor activities and will avoid wasteful investments that are not directed to national goals.

Some specific considerations for financing and sustainability include:

a. Focusing Donor Assistance: Often donor assistance is focused on the donor’s preferences for technology (as in tied aid projects) and actions. Closer control over, and scrutiny of, donor assistance and, in particular, the use of low technology approaches, offer greater potential for sustainability once the donor project is completed.

b. Regional Partnerships: Regional centres, funded by donors on a sustained basis, has a much greater chance of success in offering low cost training, quality assurance, and certain types of analytical services that should not be implemented by each country.

Such centres, because they can access a large market for laboratory and environmental services, have potential for commercial and profitable linkages with (western) environmental and laboratory service companies that could make these centres self-supporting. To be successful, however, governments must accept a commercial model in which profits are vested in the operator(s) of the centre. It is probable that, as markets grow, the operator will expand into each partner country in order to facilitate closer cooperation with the marketplace.

c. Public-Private Sector Partnerships: Contracting-out of monitoring and analysis makes economic sense in some developing countries because of greater efficiency in the private sector. An alternative is the operation of government laboratories by private companies under contract to the government. In countries where there is some enforcement of environmental standards, there is potential for commercial linkages with western laboratory service companies. These linkages can be profitable to both parties, but particularly for the government which may obtain many benefits including a high standard of quality control, importation of new equipment and technologies, in-lab training, etc.. Obviously, the commercial entity will be looking for legal and economic stability in which to grow their enterprise. In those countries having profitable economic activities such as mining or oil extraction and for which there are official concerns over polluting activities, a linkage between these sectors and western environmental service companies that can provide cost-effective assessment and remediation, can also be extended to include other related monitoring and assessment with the bulk of the costs paid by the profitable economic sector.

d. Specific Donor Linkages: Donors generally have little interest in supporting generic national data programs. However, narrowly defined priorities such as community-based monitoring of drinking water supplies, are more likely to appeal to donor(s) who can partner with the national government for the provision of training, supplies and quality control. This type of priority meets donor criteria of gender sensitivity, poverty-reduction, and community improvement, at low cost. Also, funds for such a priority are retained almost entirely in the recipient country.

e. National Data Banks: The abundance of scientific and other donor-funded projects that produce useful data is usually not mirrored in the availability of these data. A condition of all such projects is that all scientific data should be in the public domain and be easily accessible. In a recent study of the Nile basin it was found that there was no central database nor central point of access to the many projects underway in that region.

f. Quality Assurance and Quality Control (QA/QC): This merits special attention as it is amongst the most difficult of objectives to finance and sustain. QA/QC is essential to data programs, is inexpensive, yet donors are reluctant to fund this activity. QA/QC programs are only effective when operated regionally or locally, hence it is necessary to fund a regional centre(s) to carry out this activity on behalf of member states. One possible method of funding is to require that all externally funded water programs contribute some small percentage of budget to a designated regional centre that will provide QA/QC services to member states.

g. Sale of Data and Data Services: The principle of selling national data is well established, despite opposition from certain international organizations. An option for government monitoring agencies is to market their data to developers and international project managers. Clearly, the data must first meet high standards for data quality. A parallel approach could be to require foreign projects to purchase data services from domestic sources rather than importing their own analytical capabilities or exporting samples to their own countries for analysis. In countries with significant potential for this type of business, a commercial linkage between local agencies and foreign laboratory service companies would make very good business sense and would provide a high level of quality assurance to international projects.

CONCLUSION

The water quality situation is highly variable in developing countries reflecting different levels of development and different needs for water quality programs. The conventional paradigm of data collection is not well suited to developing countries and is being abandoned by some developed countries as being too expensive, inefficient and ineffective. Yet, this is the approach that is being promoted by most multi-lateral agencies. There is, therefore, an opportunity to invent a new data paradigm that is more cost-effective and sustainable. This requires an explicit integration of water quality into national water policies so that priorities are established based upon social and economic benefits. New technologies in data collection and in the application of knowledge-based approaches to environmental problem solving offer new hope for data-poor countries. Institutional change, including rethinking of the centralized monitoring model and the devolution of core monitoring activities to the community level, offers opportunities for cost savings and higher levels of response to the public. There remains, however, a lack of written guidelines for carrying out this modernization process.

Models of capacity building, especially for the rapidly expanding needs of water quality remediation, need to be re-examined so that there is genuine enhancement of in-country intellectual and technical capacity that is needed to break the cycle of dependency on foreign organizations and companies for most advanced work. New approaches need to be adopted to bring knowledge into the hands of decision makers. Business models that encourage nurturing of local partners in developing countries by western firms should be encouraged. We need also to break the dependency on conventional approaches towards lake and river restoration such as data-intensive modelling, dredging, and expensive engineering solutions for algae control, by focusing on innovative alternative approaches that are cheaper and more sustainable. Financial and sustainability issues include cost avoidance and cost-reduction, legal and accountability frameworks that encourage good business practices by senior program managers, the use of new cost-effective technologies for monitoring, and a variety of donor/public/private sector linkages that focus on commercial benefits that permit the transfer of certain parts of water quality programs to the private sector.

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[2] GEMS = Global Environment Monitoring System.

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