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MATCHING WATER QUALITY PROGRAMS TO MANAGEMENT NEEDS IN DEVELOPING COUNTRIES :

THE CHALLENGE OF PROGRAM MODERNIZATION

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ABSTRACT

Developing countries face an array of traditional and modern water quality problems -- from faecal contamination to toxic chemicals. Moreover, they do so in an economic environment that is severely restricted, an institutional environment which is often poorly structured, and for which the modern scientific knowledge base is frequently poorly understood and applied. Agencies in many developing countries recognise this as a major impediment to sustainable development, especially as water quality has become one of the leading economic issues for the purposes of development and investment (Matthews, 1994). Water quality programs tend to suffer from traditional approaches, both of methodology and legal/administrative. The consequence is that many water quality programs are grossly inefficient, produce often unreliable data and which in any case are not generally useful for making management or investment decisions, and face decreasing economic and political support. Program modernization is essential to achieve the twin goals of greater efficiency and greater relevance in meeting data needs for contemporary water quality management purposes. Modernization reduces costs, may reduce the amount of equipment and infrastructure required, often reduces the amount of data collected, and more closely matches the abilities of developing countries where, for example, knowledge of advanced environmental chemistry may be limited but where knowledge of biological systems is strong.

INTRODUCTION

The developed world has had the luxury of facing major problems of environmental degradation sequentially in time -- faecal contamination and water supply, eutrophication, acid rain, toxic chemicals, ecosystem dysfunction, etc... In contrast, developing countries are facing these simultaneously. Moreover, they do so in an economic environment that is severely restricted, an institutional environment which is often poorly structured, and for which the modern scientific knowledge base is frequently poorly understood and applied. Agencies in many developing countries recognise this as a major impediment to sustainable development, especially as water quality has become one of the leading economic issues for the purposes of development and

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investment.

Typically, the water quality data programs of developing countries fall into one of two categories: (a) programs that focus on "traditional" parameters such as major ions, nutrients and microbiology; and (b) those that attempt to include some toxic chemicals (metals and some organic contaminants such as OC pesticides and PCB). Additionally, those rapidly developing countries with concerns for toxic organic and inorganic chemistry almost always adopt the Achemical list≅ approach to monitoring. This is equivalent to the 1970's "Priority Pollutant" approach of the US-EPA which has been demonstrated to be inefficient and costly in the USA and which is now producing inefficiency and rigidity in developing countries just at the time when the USA and other western countries are adopting much cheaper, more flexible, and more effective alternatives.

A common observation of water quality programs is that they tend to be inefficient, the data are of uncertain reliability, program objectives are poorly linked to management needs for data, the analytical technology is often old and inefficient, the focus is on water chemistry even though water is known to be a poor monitoring medium for many toxic chemicals, and databases are incapable of mobilization for management purposes (Ongley, 1993). The concept of program efficiency includes consideration of all these factors, ranging from appropriate selection of parameters and sampling medium, to institutional inefficiency. It has legal and regulatory implications, especially where the regulatory framework imposes rigidity and prevents the use of more cost-effective field and analytical methods. However, the greatest inefficiency tends to lie in the assumption that conventional water quality programs produce data that can be used to make managerial decisions on pollution control, water resources planning, and related investment decisions. The fact is that such programs are designed mainly for descriptive rather than prescriptive purposes, with the result that nations tend to spend much money producing data that are not closely linked to decision-making and, not infrequently, not used at all!

DATA FOR DECISION-MAKING

In developing a monitoring program it is necessary to identify the principal reasons for which monitoring data (chemical and biological) are required. Generally, these are as follows:

a) Description of water quality at the regional or national scale, including determination of trends in time and space.

b) Determination of whether or not water quality meets previously defined water quality or regulatory objectives for designated uses, including public health.

c) Managerial resolution of specific pollution management issues, including post-audit functions.

d) Decisions for investment options based on potential benefits from proposed or alternative remediation options.

e) Comprehensive assessment of river basins, especially to determine the relative importance of point versus nonpoint source pollution sources.

f) Regional or river-basin planning, including the development and audit of national/regional policies on land use relative to polluting land use activities.

g) Reporting of compliance to international standards or action plans. An example is the forthcoming Global Plan of Action for Prevention of Pollution of the Marine Environment from Land Based Sources of Pollution which is likely focus upon inputs of nutrients, organic micropollutants (=Persistent Organic Pollutants [POPs]) and, possibly, environmental estrogens at the global level, plus metals at local and/or regional levels.

The inability of most national monitoring programs in developing countries to meet many of these objectives requires rethinking of the role and practice of water quality monitoring. There is no single type of program that meets all objectives, therefore the modernization of water data programs requires a careful evaluation of objectives, a knowledge of alternative methods of achieving the objectives, and the ability to implement change that will enhance efficiency throughout the program (data collection, laboratory operations, data assessment, and mobilization/use for the client).

MODERNIZATION

This paper focuses on the types of considerations that program managers must make to implement program modernization. It is necessarily selective. The background for this material lies mainly in the involvement by the author in program redesign and training in a number of countries -- both developed and developing.

A. Legal and Institutional Considerations

Role of Government in Water Data Programs: The role of government in monitoring is being re-evaluated in many countries. The old model -- government does everything and pays for everything, is being replaced by market forces in many countries. This means that some governments, especially in developed countries, are reducing their direct participation in monitoring and enforcement, and are concerned primarily with setting and enforcing rules and standards. There is no reason why developing countries cannot make the same change. Market forces will produce more efficient laboratories and decrease the need for government expenditures. Under market economic conditions, there is greater efficiency and less cost to government if industrial monitoring is carried out by industry with data reported to government agencies. This mechanism is used by USA, Canada and many European countries. A critical role of government is, however, in developing and enforcing national data standards through programs of quality assurance and laboratory accreditation. National standards cannot be achieved simply by regulating analytical methodology -- variation in methods, matrix problems/recovery efficiencies as well as deliberate cost-cutting, operator error, corruption of data files, and outright fraud are part of the realities of the laboratory business. National standards impose a strict regimen on all aspects of laboratory operations and, in some cases, field operations, so to ensure the reliability of the final data products. The present situation in some countries where there is devolution of decision-making authority to local levels, has been the loss of national data standards, which is catastrophic for developing countries that require reliable data for evaluating and deciding upon investment alternatives for remediation and/or development.

Commitment by Management To Change: The rational and comprehensive management of change is very difficult in large organizations. Senior management often resort to budget solutions (reduced budget = reduced number of stations) rather than to a serious examination of how modern monitoring technologies, regulations and institutional structures can introduce greater efficiencies. It is essential that commitment be demonstrated at the most senior levels of an organization. An example of commitment is in the realm of **training.**

Changing Legal and Regulatory Standards for Greater Efficiency: The use by many countries of rigid legal standards both for the parameters used for regulation and for the types of analyses that are permitted, is inflexible and inefficient. The US-EPA has now recognized that the rigid codification of analytical standards has not been as effective as once thought, is expensive both for government and industry, and does not provide the flexibility to permit new and more efficient regulatory methods. The alternative, as used in Canada, is "performance based" techniques which offers simpler and more cost-effective bases for attaining program goals. In "performance based" techniques the method is not rigidly prescribed, however the outcome must meet predetermined requirements of accuracy and precision. An example is the requirement in some countries to use atomic absorbtion spectrophotometry (AAS) for metals, whereas new techniques using emission spectroscopy reduces costs by one to two orders of magnitude by its ability to perform multiple simultaneous analyses on a sample.

Maintenance of rigid legal standards ensures that countries will repeat the costly mistakes of many North American and European water quality programs as it will not permit use of new and more efficient methods such as screening methods, and use of toxicity as a regulatory mechanism. In some cases, legal restrictions extend to the requirement to use out-dated field methods which precludes cheaper methods such as portable DO meters and proxy data such as turbidity measurements instead of direct measurement of suspended sediment concentration. In China, for example, monitoring is restricted to standards and types of analyses identified by Chinese law. Therefore, more efficient and modern methods, especially those of biological screening are difficult or impossible to use for most purposes. The consequence is that, without greater flexibility, monitoring in China is unlikely to be able to modernize significantly (except to build bigger and more expensive laboratories).

B. Technical

Laboratory Programs: Recognising that there are economic and cultural limitations to issues of efficiency, one of the greatest barrier to modernization is the inefficiency and, in some instances, duplication of government laboratories within small geographical areas. Sample volumes are small and therefore preclude economies of scale that are possible with modern, automated instrumentation. Many laboratories are equipped with sophisticated AA's and GC's, but do not have autosamplers without which volume analysis is impossible and data accuracy jeopardized. In some countries, laboratories having approximately 30 staff handle some 2000 samples (mainly of Alow-end≅ analyses) per year -- about what a modern laboratory would process in 2-3 weeks. Gains in efficiency of a factor of x10 are possible and achievable. Gross inefficiency also produces waste in training, equipment procurement and infrastructure costs because of the need to train more operators than are necessary, to purchase equipment that is not efficiently utilized, and to build and maintain redundant facilities.

The objective of laboratory optimization is faster turn-around time at lower costs per sample of water, sediment and tissue, and for any toxicological tests that may be included in the analytical program. Modernization may involve some or all of the following considerations:

- X Sample handling, with special consideration for samples that may be used for legal purposes.
- X Turn-around time required
- X Reporting requirements
- X Sample tracking -- level of automation
- X Client access to databases

- X Types of analyses that are meaningful -- totals/filtered for water; sediment and tissue analyses; toxicological testing.
- X Detection levels required and appropriate instrumentation.
- X Level of QC required for different types of clients
- X Type of QA required for lab operations and interlab comparison
- X Availability of certified pure reagents

- X Personnel available and/or needed, and training required.
- X Operating budget and cost-recovery
- X Ambient air quality (site limitations)
- X Facility infrastructure, including ambient laboratory temperatures and stable electric power supply

- X Workplace safety and health

Multiple Techniques Within Monitoring Programs: Most monitoring programs tend to be relatively inflexible and are unable to accommodate many of the new approaches to monitoring. In part this tends to reflect old-fashioned legislation on water quality and, in part, a reluctance on the part of managers to change. Nowadays, monitoring is a comprehensive activity that includes many different approaches to problem solving including fixed site monitoring, field surveys, emergency mobile monitoring, toxicity assessment, and environmental effects monitoring which focuses on instream biological response to control measures. A useful summary of some of the new procedures in provided in a recent Dutch report by the Ministry of Housing (1995)

Biological assessment and toxicity assessment are increasingly being used as part of modern monitoring and enforcement programs and, in some countries, are dramatically reducing the need for expensive chemistry. The interpretation of toxicological tests is now well understood and has at least as much, and usually more, relevance to decision-making as chemical data. Toxicity is used by several Canadian provinces, US states and a number of European jurisdictions for industrial effluent testing as a cheap and effective screening method.

New Screening and Diagnostic "Tools": There now exist many new and cost-effective techniques for water quality monitoring which are more cost-effective, produce more useful information that is linked directly to decision-making, which save time, and have reduced instrumentation needs. These methods follow from the recognition that 1970's type chemical monitoring is not very useful for **managing** rivers and lakes. These Atools≅ include a wide range of new biological, biochemical, chemical and toxicological techniques. Selection amongst these many new techniques depends very much on the objectives of the program and the ability to integrate these techniques into the water program. These new tools produce useful information quickly and cheaply, and can be used to define which parameters need further expensive and detailed analysis. They also include methods which are outright substitutes for conventional data programs or which are used to determine whether there is reason to continue with a more detailed and expensive analysis.

As examples, simple inexpensive field kits are available for screening samples for toxicity. Toxicity Evaluation Identification (TIE) is a procedure which permits accurate determination of those chemicals which cause toxicity to selected organisms and which should be added to the monitoring program. Indeed, "TIE" is usually sufficiently precise that it allows identification of a particular industry group that needs to be studied or regulated first. One could completely replace traditional chemical monitoring of large and polluted rivers with a combination of benthic surveying (for DO and nutrient conditions), use of sentinel organisms (for target toxic chemicals), and cheap toxicity testing. The data produced by such a program are inexpensive, and more relevant for **managing** the river, especially as chemical data are not directly related either to human health or to the ecological "health" of the river. Also, it is now widely accepted that toxic chemicals of concern are frequently none of those routinely included in chemical analytical protocols and in many countries, and exist at concentrations that are known to be of concern, but which are below the detection levels used in most laboratories.

Data Quality Objectives: While much of the monitoring in many countries appears to be established according to legal requirements, monitoring stations should begin the use of Data Quality Objectives (DQO's) to ensure greater communication between the monitoring program and those that use the data. DQO=s are a process through which the laboratory and the client mutually examine the type of data needed for the management issue at hand, the level of reliability required, reporting requirements, etc.. The objective is to ensure that the client understands the costs, the limitations, and the uncertainty in the information produced by the monitoring program. This process is essential when monitoring programs achieve greater flexibility in choice of methods, etc. In a market economy, the DQO process, either formal or informal, becomes the basis for a contract between the monitoring station and the paying client.

Optimization of the National Network: Optimization is a complex and unfamiliar task to many agencies. While optimization may mean reduction in the size of the network and rationalization of the types of parameters, it can also include change in monitoring sites and the addition of more relevant parameters or in limited situations, the expansion of the network to include important un-monitored rivers and lakes. Optimization also includes the detailed analysis of historical data sets in order to identify and eliminate data that do not change or that change in a very predictable way (e.g. annual cycles) or that consistently report ND's (not-detectable). Optimization includes reconsideration of types of data, including use of biological survey methods and measures of toxicity, plus use of sentinel organisms for determining the presence of important industrial parameters.

Information Systems: Database and information systems in most monitoring agencies in developing countries are not efficient and are not effectively used for information processing, analysis and visualization of data, and decision-support functions. This has two types of implications -- one is that data are not easily accessible for management purposes. The second is that water quality programs remain largely invisible because of the lack of highly visible data products; the result is often that such programs fail to win managerial and political support.

Modern information systems include: database and data archiving, GIS (Geographical Information Systems), analytical tools (statistics, graphics, etc.), decision-support capabilities, and visualization (output display) capabilities. They should be capable of being operated by non-specialists with a minimum of training. One such example is Canada=s RAISON system (accessed via e-mail <nwri.software@cciw.ca>) which has been adopted by the United Nations GEMS/Water Programme as well as by many water agencies. Great care should be taken to match real GIS requirements with the type of GIS system purchased, especially as GIS is only part of a full information system. Indeed, the GIS requirements of most water agencies is, in fact, quite small (usually limited to handling georeferenced site information, spatial mapping, and limited map overlaying) and which can be met by many inexpensive GIS software packages. Large commercial GIS systems should only be used for specialized GIS activities because the learning requirements are substantial, the hardware and software costs are high, and only specialists can efficiently use such systems. Contrary to GIS vendors, GIS is only one part of a complete information system.

In Mexico, for example, the Mexican Water Commission (Comision Nacional del Agua -- CNA) is a partner in the development process of suitable inexpensive software based on the RAISON software platform. The main reasons are the high cost of providing commercial packages (in Spanish) to all the regional offices, and the need to develop simple applications for routine tasks that can be operated by relatively unskilled operators. These tasks include source inventories, data interpretation, and standard report writing. This approach will integrate with most GIS systems in the Mexican government and link directly to commercial databases.

Quality Control / Quality Assurance / Accreditation / GLP: Data quality in many developing countries is a serious problem. Increasingly QA/QC and GLP (Good Laboratory Practices) is a major part of bilateral assistance programs in developing countries. The problem of reliable data within a laboratory has too many facets to discuss here. These include not only the normal quality control steps during analysis, but also the difficulty in many countries of obtaining pure reagents or of ensuring that so-called certified reagents are, in fact, pure. Site conditions in many developing countries is a major problem, especially the location of laboratories in highly polluted airsheds of major cities. Rarely do laboratories have proper air handling systems that can deal with such problems. This is particularly acute for metals and, given the recent experience with contamination of samples in very well operated North American metals programs, suggests that metals data are especially unreliable in developing countries.

A major advancement and absolute necessity, especially in large countries with many laboratories, is an accreditation program that establishes common performance criteria for all labs responsible for water quality data used by government. Modernization requires rigorous application of these principles both in government laboratories and in those private laboratories that serve government needs.

Reporting: For descriptive purposes at the national scale, monitoring should increasingly focus and report upon biological conditions and measures of toxicity including the use of sentinel organisms for determining the presence of important industrial parameters. This follows from the recognition that chemical data are difficult to interpret or to relate to the actual ecosystemic state of the water environment. Chemical parameters should include general indicators such as AOX as an indicator of total chlorinated compounds. A limited number of key parameters (especially for parameters that are controlled or prohibited) could be included. Data should be integrated into several useful indices that describe the water according to water use. Surface water sites should be reported separately from a national effluent monitoring program. If there are a large number of river sites, the sites should be integrated (for reporting purposes) into river reaches.

C. Capacity Building

Training: Contemporary needs of water managers for water quality data and for informed analysis and interpretation, is often beyond the technical ability of staff in many developing countries. Managers of monitoring programs are often not committed to sufficient training, especially for junior staff. Investment in infrastructure, equipment, etc., is not effective or efficient without a commensurate investment in training. In the 1995 redesign of the Mexican national water quality program, a significant percentage of the program resources are dedicated to training and professional development. This training includes activity-oriented training for the bulk of field and laboratory staff, and advanced training in Mexico and abroad for key staff who will be the leaders of the program in the future. In contrast, certain other countries are reluctant to invest in training as a matter of program strategy and tend to rely on training that can be obtained a low or no cost from donors. Unfortunately, experience suggests that while such courses may be individually of merit, collectively they do not comprise a well-structured and balanced program that meets the needs of the agency. Also, there is often little if any follow-up. A strategic training program also needs to include consideration of the types, numbers and length of foreign Atraining≅ missions undertaken by domestic staff.

There is much use by many countries of Ashort courses≅ by foreign professional. Experience indicates that short courses are generally valuable only in two circumstances -- one is for the raising of awareness of new types of monitoring and assessment methodologies; the second is the training in very specific topical areas having limited scope (e.g. training in a particular methodology). Training programs overseas that involves extensive visits to labs etc, especially for junior staff, are not particularly cost-effective. Foreign training should be restricted to highly specialized training (e.g. specialized analysis, computer training, etc.), for extended educational purposes (advanced degrees), and for senior staff who need familiarization with foreign environmental management methods, policies and regulations.

A national strategic training program should establish training goals of "x" number of PhD and MSC degrees within the next An≅ years for the purpose of developing a core group of professionals around which the next generation of monitoring will be built. The principal mechanisms for advancement of monitoring programs in developing countries include:

X On a competitive basis, identify the best persons for foreign education in environmental chemistry and toxicology, environmental assessment, etc.

X Increase the number of persons with advanced degrees within monitoring programs.

X Promote persons with advanced foreign education and suitable experience to positions of management responsibility.

Other mechanisms include the development of long-term relationships with foreign companies and agencies for importation of appropriate methodologies. This may be done through international aid programs and, in some cases, with specialized foreign agencies (e.g. US-EPA). However, the relationship with foreign agencies and companies can increasingly be expected to be of a commercial nature due to the economic change that is occurring in most western countries. Also, for many developing countries, commercial relationships are consistent with developing market economies, and offer a fast-track solution to training, program efficiency and financial sustainability of the program by the development of a market-based program in which the government is one of the clients.

Institutional Development: Institutional development is necessary to deal with all aspects of program management, legal change, etc.. Below are two very specific types of institutional development that are essential if modernization of data programs is to be successful.

a) Client-Oriented Programs: It is essential that managers of monitoring programs regard their work as a service for clients. Clients in most cases are the different levels of government however, as the move to a market economy increases, there may develop the need to work with other types of clients. Use of ***Data Quality Objectives*** (DQOs) ensures greater communication between the monitoring program and clients that use the data. The objective is to ensure that the client understands the costs, the limitations, and the uncertainty in the information produced by the monitoring program.

b) Revenue Generation: Data programs can be put on a revenue-generating basis, especially if the government is considered to be a client. A revenue basis is essential for financial sustainability of program; it is also a major tool in creating the appropriate business approach to data programs. A business approach ensures that data programs are relevant and efficient, well connected to users, and are operated according to good scientific and business practices. There are many ways to accomplish this, however the major message here is that government managers of water programs usually find the concept of revenue very difficult to accept. Hence, institutional change requires education about alternative approaches to the business of water data programs. Experience shows that modernization creates opportunities for revenue generation for government laboratories and opportunities for creative partnerships between government agencies and the private sector. In many developing countries, a revenue base may provide the funds to adequately compensate staff to achieve personnel stability.

CONCLUSIONS

Program modernization is essential to achieve the twin goals of greater efficiency and greater relevance in meeting data needs for contemporary water quality management purposes. Modernization reduces costs, may reduce the amount of equipment and infrastructure required, often reduces the amount of data collected, and more closely matches the abilities of developing countries where, for example, knowledge of advanced environmental chemistry and toxicology may be limited. Modernization is a complex and comprehensive activity that includes legal and institutional considerations, technical issues, and a strategic program of capacity building.

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