1.7 Water Quality Assessment Around the World: The Role of Chemistry with Particular Reference to Brazil and Malaysia

Deborah Chapman
Environment Consultant, Kinsale, Republic of Ireland

Introduction

Access to water of adequate quality is essential for human health, food production and sustainable development. Every human use of water (whether for drinking, irrigation of crops, industrial processes or recreation) has a minimum acceptable quality. This quality can be described in terms of physical, chemical or biological properties.

Physical properties, such as temperature and turbidity, are often easy and cheap to measure but rarely give sufficient information on water quality when measured alone. It is important to understand the physical properties of a water body as an aid to interpretation of chemical or biological information. Chemical properties, such as major ions and dissolved elements, describe basic water quality, and when combined with measurements of metals and organic chemicals can give some insight into man's impact on a water body. Chemical measurements can be made using techniques with a wide range of complexity and sophistication. Most of the variables required for the determination of basic water quality can be undertaken by relatively cheap and simple methods.

Biological properties can be described by studying the individual species, or whole communities, present in a water body. These methods indicate changes in water quality arising from combined impacts on a water body (natural and/or man-made), but rarely indicate the precise cause of a change in quality. They can be cheap to perform but are usually based on a knowledge of regional flora and fauna. Therefore, any particular method cannot be used around the world without local adaptation.

The assessment of water quality is an evaluation of the characteristics of the water in relation to defined objectives. Typical objectives include: (i) determination of suitability for specific uses, eg. drinking water or irrigation, (ii) determination of the impact of human activities, eg. industrial discharges, (iii) determination of trends in water quality, (iv) determination of natural water quality, ie. unaffected by man and (v) determination of fluxes of pollutants, nutrients and suspended solids from river basins to coastal waters and oceans. Monitoring is the activity which gathers the necessary information and data to enable assessments to be made.

Global Water Quality Monitoring and Assessment

Many large rivers and lakes cross international boundaries. The increasing use of such water bodies for waste disposal in recent decades has necessitated the expansion of water quality monitoring and assessment activities from a local to an international scale. Consequently the need for global information on water quality has become more urgent. The Global Environment Monitoring System (GEMS), which is a component of the United Nations Environment Programme (UNEP), began collecting water quality data on a global scale in 1978 as part of the GEMS/WATER programme. This programme, implemented by the World Health Organisation (WHO) and supported by UNEP, UNESCO (United Nations Educational, Scientific and Cultural Organisation) and WMO (World Meteorological Organisation), also aimed to promote and establish water quality monitoring in the developing regions of the world through training and support.

Countries participating in the GEMS/WATER programme carry out as many of the defined chemical measurements as they are able, at selected sites from important water bodies. There are relatively few stations in any one country. Brazil currently has twelve stations, all situated on the eastern side of the country. Malaysia, which is a relatively small country, currently has seven river stations. GEMS/WATER sites are often already in use as part of the nation's own water quality monitoring programmes. A list of the basic measurements required to be made at all sites is given in table 1. The results of the monitoring are submitted to the WHO Collaborating Centre on Surface and Ground Water Quality at the National Water Research Institute (NWRI), Burlington, Ontario, Canada where they are stored in the GEMS/WATER computer database. These data indicate that most developing countries participating in the programme can make the basic chemical measurements using techniques recommended in the 'GEMS/WATER Operational Guide' (1). However, few developing countries regularly submit results obtained using techniques such as Atomic Absorption Spectroscopy (AAS) which are recommended for the detection of metals. This led to problems in using the data available in the GEMS/WATER database when the first global assessment of surface water quality was undertaken by GEMS in 1989, ten years after the programme began. However, by using additional published material the global assessment (2,3) was able to identify nine principal water quality problems which are either widespread around the globe or emerging as possible future global issues. These were:

1. Organic matter pollution: Principally arising from domestic wastewater and affecting developed and developing countries.

2. Accelerated nutrient enrichment: Arising largely from the widespread use of phosphorus in detergents and affecting mainly lakes from all regions of the world.

3. Salinisation: Often associated with poor irrigation practice or excessive irrigation.

4. Nitrate enrichment: A problem mainly for developed countries, especially in regions of high nitrate fertiliser use on agricultural land. It is particularly a problem where groundwaters used as drinking water sources become contaminated. High nitrate levels present a health risk to bottle-fed infants.

Table 1. Basic Variables to be monitored at all GEMS/WATER Monitoring Stations

Variables	Rivers	Lakes and Reservoirs	Groundwaters
Water discharge/level	*	*	*
Total suspended solids	*		
Transparency	*		
Temperature	*	*	*
pH	*	*	*
Electrical Conductivity	*	*	*
Dissolved Oxygen	*	*	*
Calcium	*	*	*
Magnesium	*	*	*
Sodium	*	*	*
Potassium	*	*	*
Chloride	*	*	*
Sulphate	*	*	*
Alkalinity	*	*	*
Nitrate plus nitrite	*	*	*
Ammonia	*	*	*
Total Phosphorus, unfiltered	*	*	
Total Phosphorus, dissolved	*	*	
Silica, reactive	*	*	
Chlorophyll a	*	*	
Fluoride			*

5. Pesticide contamination: Pesticides are used all over the world with different levels of control applied to their use. Many pesticides end up in surface water and a few have been detected in groundwaters. They are harmful to the aquatic environment and can present a human health risk to water users when in high concentrations.

6. Suspended particulate matter: Deforestation and changing agricultural practices are making large areas around the world susceptible to soil erosion. The soil is washed into rivers, increasing their suspended matter load.

7. Metal contamination: This currently affects some of the major rivers in the developed world and is a growing problem in newly industrialising regions. The contamination arises from such sources as industrial waste discharges and mining operations.

8. Acid precipitation: Acidification of surface waters, particularly lakes, is occurring in areas of the world where susceptible waters are affected by acid depositions resulting largely from the burning of fossil fuels. The problem is thought to be extending to some developing regions of the world.

9. Synthetic organic micropollutants: These are man-made chemicals not normally occurring in the environment and their potential environmental effects, transformations and persistence are usually not adequately known or understood. Detecting such chemicals can be technically difficult and expensive, and most are not routinely included in monitoring activities.

One of the conclusions reached by the group of experts considering the global assessment of water quality was that the GEMS/WATER programme should be reviewed and possibly revised. This has been undertaken and the new programme took effect in 1990 (4). A greater emphasis has been placed on the assessment activities of the programme and many new stations have been selected to fulfil the revised objectives. These objectives are:

A. To provide water quality assessments:

   (i) to define the status of water quality,

   (ii) to identify and quantify trends in water quality,

   (iii) to define the causes of observed conditions and trends,

   (iv) to identify the types of problems that occur in specific geographical areas,

   (v) to provide the information and assessment in a form that resource management and regulatory agencies can use to evaluate management alternatives and make necessary decisions.

B. To provide information on the fluxes of toxic chemicals, nutrients and other pollutants for the world's major river basins to the continent/ocean interfaces.

C. To strengthen national water quality monitoring networks in developing countries, including the improvement of analytical capabilities and data quality assurance.

The revised global network consists of:

Baseline stations (total 46) away from sources of direct pollution and human activity. These stations provide information on background levels of water quality and the global transport of pollutants.

Trend stations (total 250) which represent human impact and are, therefore, located in areas with multiple or specific impacts on water quality.

Global river flux stations (total 67) which are located downstream, on major rivers with large drainage basins in order to determine fluxes of organic and inorganic contaminants, nutrients, etc. to the continent/ocean interface.

To aid in future assessment of GEMS and other water quality data, NWRI has developed microcomputer-based software for the statistical treatment, synthesis and presentation of the data. The software package is known as RAISON (Regional Analysis by Intelligent Systems on a Microcomputer) and integrates the use of maps with tabulated and graphically presented data. Hence it is possible to illustrate on one page the trends in water quality variables at selected sites, superimposed on a map showing the locations of the chosen sites. Many forms of graphical presentation are possible, including methods which indicate the statistical variability of the data sets. When GEMS/WATER data are examined in this way it is possible to observe differences in water quality for geographical regions, observe variability in monitoring results for single sites and to make comparisons of national data with global averages. However, when examining the graphical presentation of data from single sites, caution must be applied in their interpretation. The accuracy and reliability of the analytical measurements may not be known without further reference to the results of analytical quality control programmes carried out as part of the GEMS/WATER programme or by the individual laboratories themselves. This can be illustrated by the measurements for total mercury concentrations using AAS at a GEMS station in Brazil (Rib. Serra Asul-Fraz Sobradinho). During 1986 and 1987, values as high as 8.00 $\mu g\ l^{-1}$ were recorded in the GEMS database for this station. However, the maximum value for mercury recorded from all global stations submitting data to the GEMS database from 1982 to 1984 was only 0.5$\mu g\ l^{-1}$. This suggests that the results from the station in Brazil are abnormally high and should be investigated further to determine the cause, which could be due to analytical difficulties or severe environmental problems.

Approaches to Water Quality Monitoring and Assessment in Developing Countries: Brazil and Malaysia

Many developing countries have now initiated their own national water quality monitoring programmes. Chemical monitoring, combined with some physical measurements, provides the best method of obtaining regular assessment of the impact of development on countries' water resources. The facilities for advanced analysis of trace quantities of metal or organic chemical pollutants are often not available for regular monitoring.

Nevertheless, more simple chemical measurements can be used to monitor the changes in overall quality of regional water resources as can be illustrated by reference to Brazil and Malaysia.

These two countries are very different in size. The total land area of Brazil is 8,457 x 10^3 km^2 and of Malaysia is 329 x 10^3 km^2(5). Whereas Malaysia has a national monitoring programme designed and administered by the Department of Environment in Kuala Lumpur, water quality monitoring in Brazil is conducted by state agencies. Only a few Brazilian states have extensive programmes and make the results widely available.

In the rapidly industrialising state of São Paulo, Brazil, chemical measurements are used to produce a Water Quality Index for river stations. The index is based on the measurements of pH, Biochemical Oxygen Demand (BOD), total nitrogen, total phosphate, temperature, turbidity, total residue, dissolved oxygen and faecal coliforms (ie. bacteria associated with human faeces). The results of these analyses at any site are used to calculate an index value between 0 and 100 (see ref. 6 for details of the calculation of the index). A value between 80 and 100 indicates excellent water quality, between 52 and 79 indicates good, between 37 and 51 adequate, between 20 and 36 inadequate for conventional water treatment and between 0 and 19 totally inadequate water quality. These five categories are used to produce a colour map each year with five different colours indicating the stretches of rivers conforming to the five levels of water quality. This method of data analysis and presentation has the advantage that it clearly illustrates the changes in river water quality from year to year and the extent of the river systems which can be classed as excellent or inadequate. No expert knowledge is required to understand the presentation, making the approach particularly suitable for informing managers, policy makers and the general public.

In the 'Environment Quality Report' of 1988, the Malaysian Department of Environment analysed the sources of complaints about water pollution. This showed that 51% of the complaints related to effluents high in organic matter, such as those from the rubber and palm oil industries and animal husbandry. Since 1978 the Malaysian government has been carrying out extensive water quality monitoring. According to the 1988 report, 3009 samples were collected from 575 sites on 87 major rivers. The assessment of river quality is based on five main measurements: BOD, COD (Chemical Oxygen Demand), suspended solids, ammoniacal nitrogen and pH. Metals and nutrients are also studied at selected locations. The choice of measurements reflects the nature of the principle pollution problems and the difficulty involved in analysing other variables. In 1988 over 2,000 analyses were undertaken for variables such as suspended solids, conductivity and BOD, whereas less than 1,000 were made on any of the common heavy metals and less than 300 for organic chemicals such as pesticides. The results are compared with standards for water quality set by the government. Assessment is principally based on the examination of regional variations in water quality, the status of the rivers eg. whether polluted rivers are deteriorating or improving and trends in individual rivers. Over the period 1985-88, river water quality has improved in general but the situation with respect to suspended solids in polluted rivers has deteriorated. Further details of the assessments are available in the annual 'Environment Quality Reports' published by the Department of Environment, Kuala Lumpur.

Conclusions

Chemical monitoring plays a major role in the GEMS/WATER global water quality monitoring and assessment programme. Simple chemical techniques provide the means for determining basic water quality and a basis for monitoring systems in developing countries. Chemical data are an essential component of water quality management and can be used, for example through water quality indices, to present the results of water quality assessments in a readily understood and attractive form.

References

1. WHO 1987 GEMS/WATER Operational Guide. World Health Organisation, Geneva.

2. Meybeck M, Chapman D and Helmer R [Eds] 1989 Global Freshwater Quality: A First Assessment. (Blackwell).

3. UNEP/WHO 1988 Assessment of Freshwater Quality. Global Environment Monitoring System, United Nations Environment Programme, Nairobi and World Health Organisation, Geneva.

4. WHO 1991 GEMS/WATER 1990-2000 The Challenge Ahead. WHO/PEP/91.2, World Health Organisation, Geneva.

5. UNEP 1989 Environmental Data Report, 2nd Edition, 1989/90. (Blackwell).

6. CETESB 1990 Relatorio de Qualidade das Aguas Interiores do Estado de São Paulo - 1989. Companhia de Technolgia de Saneamento Ambiental, São Paulo.

The Author

BSc (1st Class Hons) in Environmental Biology, Chelsea College, University of London 1978. PhD in Limnology, Royal Holloway College, University of London 1981. 1981-83 St Thomas's Hospital London; Cancer Research 1983-86 Department of Zoology, University of London: Marine pollution research. 1986-90 The GEMS Monitoring and Assessment Research Centre (MARC), King's College, London: Deputy Director 1988-90. Freelance Environment Consultant, Kinsale, Republic of Ireland, principally engaged over the last nine months as a temporary adviser to WHO and UNESCO in relation to the GEMS/WATER programme.