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Water Quality Management: An Introductory Framework

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ABSTRACT *Much has been written and discussed in recent years on the water crisis and the belief that the world may run out of water in the foreseeable future. The main issue, however, is not physical scarcity of water but poor management. It is primarily a crisis due to mismanagement. An important result of such poor management practices has been the continual deterioration of water quality on a global basis. The main emphasis in the past and present has been on water quantity management, including allocation. Managing water quality is still not receiving adequate attention, because it is significantly more complex, difficult and expensive compared with water quantity management.*

Much has been written and said about how the world is facing a water crisis because of the physical scarcity of this resource, and how the present situation can only get worse in the coming years. In fact, numerous books and papers have been published during the past decade about this so-called water crisis due to physical scarcity. The media regularly carry frightening stories as to what the world will do when "it runs out of water", as if water was a non-renewable resource like oil, and "water wars". Without question, the water crisis has captured the attention of the media and a good section of the general public, as well as numerous water professionals. However, scientific and rational analyses of all the available data indicate that the world is not facing a crisis because of physical scarcities of water, but that it is indeed facing a crisis arising from continued poor management of its water resources.

From the United States to the United Arab Emirates, and throughout the continents of Asia, Africa and Latin America, past and existing water management practices and processes have left, and continue to leave much to be desired, and in all countries there is significant room for improvement. If this could be achieved, the world's water needs for all activities can be successfully met on a long-term basis. We already possess sufficient knowledge, technology, management expertise and capacity to ensure that the current water situation can be significantly improved. However, continuation of the current business-as-usual management practices will undoubtedly give rise to serious water

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problems in different parts of the world in the foreseeable future. Implementation of new, innovative and business-unusual practices, which are already known and are being used in some areas, can ensure that the world will not face a water crisis in the foreseeable future.

While much global attention in the past and more recently has been focused primarily on water quantity and allocation issues, poor water management has created a serious problem in terms of quality in many parts of the world. While developed countries have made significant and commendable progress in controlling point sources of pollution during the past three to four decades, commensurate progress has simply not occurred in developing countries. Consequently, most water bodies within and around the urban centres of Asian, African and Latin American developing counties are already heavily contaminated due to poor water management and widespread neglect of water quality considerations, both politically and socially. Unfortunately, there are no visible signs that the governments and people of these developing countries are aware of the seriousness of the problem or the dangers it poses to human health and ecosystems now and in the future. Thus, if a future water crisis develops, it will be due not to the physical scarcity of the resource, but because water quality is steadily deteriorating in most developing countries. Anecdotal evidence indicates that the health and environmental costs of such water quality deterioration are already in billions of dollars each year. These costs will continue to rise significantly at least during the 2011–2020 period, if not for much longer.

Worldwide, the situation is significantly worse with regard to nonpoint sources of pollution. Currently one would indeed be hard pressed to find a single developing country with a serious and implementable plan for managing nonpoint sources, let alone one with any record of making a serious and sustained effort for their control. Consequently, nitrogen (N), phosphorous (P), and potassium (K) contaminations of rivers, lakes and aquifers are everywhere increasing, albeit at a much higher rate in developing countries than in industrialized nations. Accordingly, and not surprisingly, most water bodies in and around areas where agriculture and animal husbandry are practised at intensive scales in developing countries already show serious signs of contamination and eutrophication.

Even in developed countries, although limited progress has been made in controlling NPK contaminations, without effective control of nonpoint sources it is impossible to ensure good ambient water quality conditions. In general, developed countries have not regulated nonpoint sources with the same zeal and vigor as for point sources. There are two main reasons for this difference. First, conceptually and technically, it is far more complex and difficult to regulate nonpoint sources compared to point sources. For example, at present there is simply no technology available which can measure pollutant discharges from a single farm unit with any degree of confidence. Accordingly, concepts such as effluent charges or tradable discharge permits, which may work quite well with point sources, can at best be of limited value for managing nonpoint sources. Equally, defining upper limits of contamination per unit of time has not been of much help. Usable and cost-effective policy instruments to regulate nonpoint sources simply do not exist at present. Thus, not surprisingly, the main causes of contamination of surface water in the developed world at present are from nonpoint sources.

Even though developing countries have given more attention to managing point sources of water contamination, compared with small or at most limited effort for controlling nonpoint sources, unfortunately the current situation even in terms of point sources is often very grim. For example, assessments done by the Third World Centre for Water Management indicate that at present no more than about 12–14 per cent of point sources of

wastewater in Latin America are collected, adequately treated and then discharged to the environment in a safe manner. In other words, even in 2010, more than 85% of wastewater in Latin America is being inadequately treated (Biswas *et al.*, 2006). Such an independent and objective assessment simply does not exist for Africa and Asia at present, but it can be said with some degree of confidence that the situation in Asian developing countries is probably similar to Latin America, and it is probably somewhat worse for Africa. Even for a developed Asian country such as Japan, according to the Japan Sewage Works Association (2010), the percentage of the population of Japan with access to sewerage services increased from 8.3% 3 to 72.7% in 2008. This means that more than 27% of the Japanese population did not have access to wastewater treatment by 2008 (Figure 1).

The current global water quality situation raises some serious questions regarding the use and relevance of the Millennium Development Goals (MDGs) for water and wastewater management in the developing world. It should be noted that when the MDGs were proclaimed, no goal was proposed for wastewater treatment. This goal was added retrospectively in 2002 during the Johannesburg Summit.

There are some fundamental problems with the current wastewater goal, especially in terms of how it is being defined at present and also how it is being monitored and interpreted, both nationally and internationally. During the run up to the United Nations Water Conference held in Mar del Plata, Argentina, in 1977, which was instrumental in proposing the 1980s as the International Water Supply and Sanitation Decade, the word "sanitation" meant that wastewater would be collected from households, taken to a wastewater treatment plant where it would be properly treated, and thereafter discharged to the environment in a safe manner. However, this simple idea was subsequently corrupted very significantly so that in its current interpretation it bypasses any serious water quality management considerations.

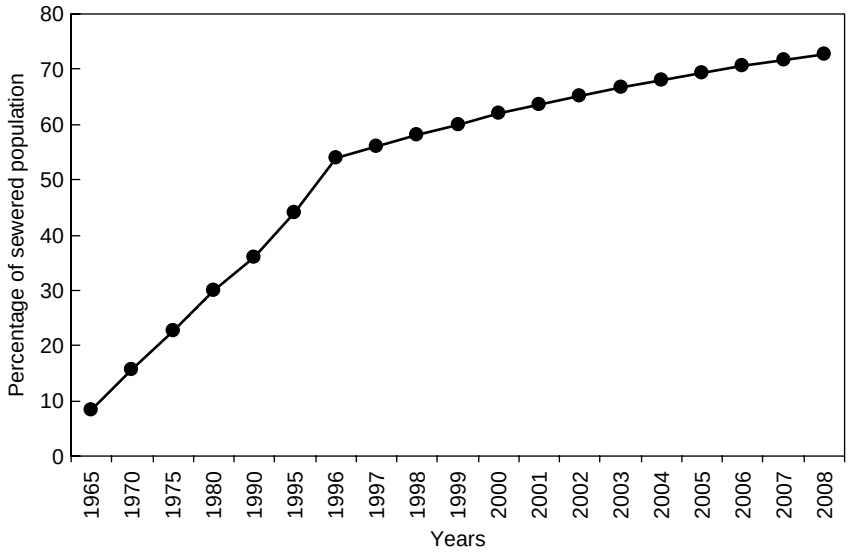

Figure 1. Sewered Population in Japan, 1965–2008. *Source*: Japan Sewage Works Association, 2010, Sewage Works in Japan, Tokyo.

At present, under the MDG interpretations, it is assumed that people have access to sanitation as long as wastewater is collected from their houses. Thus, inhabitants of cities such as Delhi or Mexico are supposed to have near total sanitation since the wastewater is taken away from their houses. Yet Delhi currently discharges almost all its wastewater into the river Yamuna virtually without any treatment, and Mexico City Metropolitan Area pumps its untreated wastewater down to Mezquital Valley. In spite of these unacceptable practices, which significantly damage the quality of surface and groundwater bodies, both international and national organizations claim that the two cities have almost full access to sanitation! This unfortunate situation and interpretation are widespread in the developing world, and condoned by various international organizations. Continuous discharge of untreated or partially treated wastewater has contributed to serious contamination of quality in nearly all water bodies in or around the urban centres of all developing countries because of the continuation of such unacceptable and unsafe practices. Yet the inhabitants are claimed by the various international bodies to have full access to sanitation. It is truly a sad and unacceptable situation which simply transfers the problem to outside the urban centres, and thus severely contaminates the water bodies that the downstream urban areas are forced to use.

According to the philosophy underpinning the Millennium Development Goals, the number of people who do not have access to sanitation should be reduced by half between 1990 and 2015. If the existing situation with wastewater management is correctly and objectively interpreted with regard to Latin America, it is unacceptable. In 1990, less than 10% of the Latin American population had access to proper wastewater treatment and disposal. By 2010, the overall situation had improved only incrementally to around 12–14%. On the basis of the current trends, significantly less than 20% of the Latin American population would have access to proper sanitation by 2015, when the Decade will end. In 2000, when the MDGs were proclaimed, the goal would have been that by 2015, 44% of the people in Latin America should have access to proper wastewater treatment and disposal. Sadly, for the continent as a whole, far fewer than 20% of its population will have access to wastewater treatment. This means that the water quality in most parts of Latin America will not show any appreciable improvement. On the contrary, continued disposal of untreated and partially treated wastewater can only further aggravate water quality conditions of receiving bodies.

The situation in terms of the MDG for Latin America is shown graphically in Figure 2. Continuation of the prevailing erroneous interpretation and the use of wrong statistical information mean that at best water quality management problems in the developing world can only be solved in an abstract and academic sense. In reality, the problem is likely to worsen significantly in the coming years.

In developed countries, a determined long-term effort is necessary to successfully control nonpoint sources in order that ambient water quality conditions can be maintained at a desired level. In developing countries, initial efforts should emphasize controlling discharges from point sources, since technically, economically, institutionally and politically they are easier to control compared to nonpoint sources. In addition, use of agrochemicals in developing countries per unit area is generally significantly less than in developed countries. Thus, nonpoint sources of contamination are often much less of a problem at present compared to industrialized countries.

No one single solution could address effectively and efficiently the different water quality concerns of all counties. Equally, different countries give different priorities to

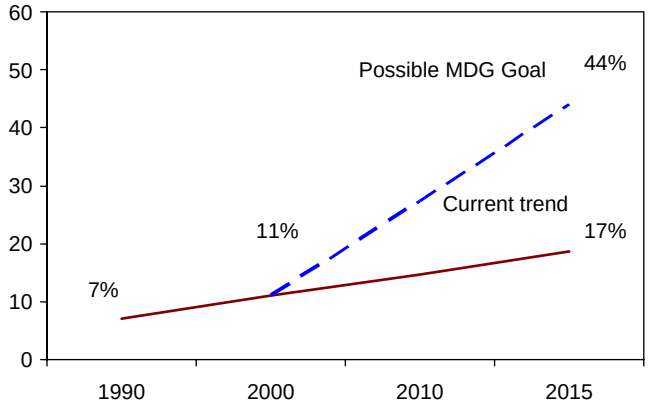

Figure 2. Appropriate MDG GOAL: Percentage of population in Latin America with wastewater treatment.

water quality management. Even for a single country, there is often no one single magic bullet that could address and solve the various water quality problems faced. Countries, and the various regions within a country, are often heterogeneous in terms of population densities, levels of industrial, agricultural and human activities, as well as physical climatic, economic, institutional and environmental conditions. Management and technical capacities may often vary significantly from one region to another, even within one specific country. Use of approaches such as command and control, public education and involvement, and use of economic and legal instruments are likely to be helpful under specific conditions. Equally, other requirements such as steps that could be taken to build up social and political awareness of the problems arising from continuing water quality deterioration, and pressure to take countermeasures to reduce the problem, could be helpful. A groundswell of public opinion that water quality is an important socio-political issue is necessary in order that country- and region-specific water quality management policies and programmes can be formulated and implemented.

What is often not realized at present is that water quality management is significantly more complex than water quantity management. In most countries, even now, institutionally and academically, water quality considerations often have significantly less weight than the importance accorded to water quantity issues. Technical and management capacities to control water pollution are often at a much lower level than for water quantity. Reversing these trends is likely to be difficult and challenging (Biswas, 2008).

The increasing complexity of water quality management can be demonstrated by a number of issues. Only one will be discussed here as an illustrative example: data requirements. For water quantity assessments only a few simple data need to be collected, such as cross-sections of channels and flow velocities. The total number of parameters for which data need to be collected are few, and these parameters do not change with time. In contrast, for water quality management, the type of data required varies with time, geographical locations, nature of pollutants being discharged, or likely to be discharged, and their potential impacts on human health and the environment, as well as a variety of other factors.

As people, especially in some select developed countries, have become more aware of the health and the environmental impacts of water quality deterioration and the

proliferation of industrial activities which continually discharge old and new chemicals to the environment, the number of water quality parameters that need to be monitored has increased almost exponentially in recent years. The knowledge base has also increased significantly in terms of interrelationships between pollutants and human health. In addition, instrument capacities to detect extremely low doses of contamination in water bodies have improved tremendously, for example, it is now possible to detect very low doses of contamination in parts per billion compared to only parts per million a few years ago. Because of these and other associated developments, more and more new and emerging pollutants are being monitored because of their real or perceived adverse health impacts.

Accordingly, the number of water quality parameters being monitored in the drinking water supply systems of some major cities in developed countries has increased significantly during the past decades. Figure 3 shows one such case for the city of Ottawa, where the number of water quality parameters monitored between 1970 and 2000 increased nearly 15 times.

Such a significant increase in the monitoring of over 350 water quality parameters is an expensive process because of the sheer volume of data that has to be collected, analysed in sophisticated laboratories with state-of-the-art instruments, and the technical, management and administrative personnel required for different stages of collection, analysis of interpretation of data collected and their effective management. While major urban centres of developed countries can afford to establish such elaborate data collection, analysis, interpretation and management systems, most developing counties are finding it difficult to establish a successful and usable system which can regularly handle even around 25 water quality parameters. This is just one example of the complexities associated with a good water quality management system compared with maintaining only a water quantity management system (Biswas, 2007).

Because of the unsatisfactory status of water quality management in the world as a whole, the Department of Environment, Government of Aragon, Zaragoza, Spain, the

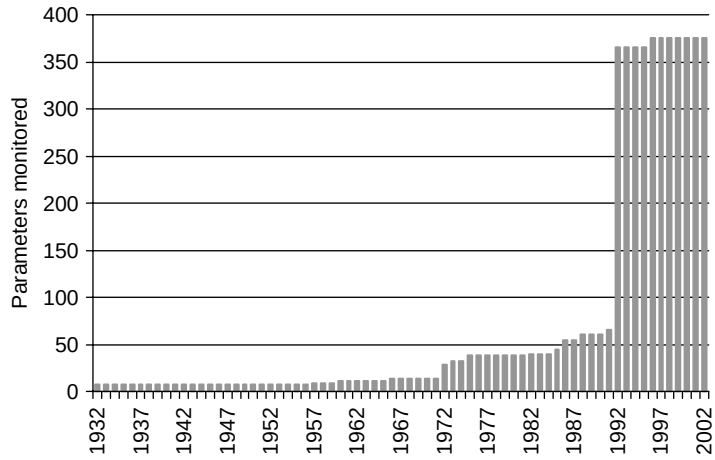

Figure 3. Number of water quality parameters monitored, Ottawa, 1932–2004. *Source*: Biswas (2007).

Third World Centre for Water Management, Mexico, and the International Water Resources Association organized an International Workshop on Water Quality Management in Zaragoza, Spain, in November 2009. Participation at this meeting was by invitation only, and leading experts from different areas of water quality management were invited from all over the world. Most of the current publication consists of the best papers prepared for this workshop including some excellent case studies from China by Jun Xia *et al.*; Egypt by Safwat Abdel-Dayem; Ebro River Basin by Manuel Omedas-Margelí; Zaragoza by Javier Celma; nonpoint sources of pollution by Kevin Parris and by Susan Graham *et al.*; financing requirements by Céline Kauffmann; environmental and economic consequences of hypoxia by Robert Díaz and Rutger Rosenberg; and an overall analysis of the water-land nexus by Malin Falkenmark. The workshop papers are supplemented by a few additional papers on the subject which very specifically complements them. We hope that the present publication will add to the current effort to improve water quality management on a global basis.

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