WATER QUALITY AND HEALTH

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ABSTRACT

Water quality can affect human health in various ways: through breeding of vectors, presence of pathogenic protozoa, helminths, bacteria and viruses, or through inorganic and organic chemicals. While traditional concern has been with pathogens and gastro-intestinal diseases, chemical pollutants in drinking-water supplies have in many instances reached proportions which affect human health, especially in cases of chronic exposure. Treatment of drinking-water, often grossly inadequate in developing countries, is the last barrier of health protection, but control at source is more effective for pollution control. Several WHO programmes of the International Drinking-Water Supply and Sanitation Decade have stimulated awareness of the importance of water quality in public water supplies. Three main streams have been followed during the eighties: guidelines for drinking-water quality, guidelines for wastewater reuse and the monitoring of freshwater quality. Following massive investments in the community water supply sector to provide people with adequate quantities of drinking-water, it becomes more and more important to also guarantee minimum quality standards. This has been recognized by many water and health authorities in developing countries and, as a result, WHO cooperates with many of them in establishing water quality laboratories and pollution control programmes.

KEYWORDS

Drinking-water; water quality monitoring; wastewater reuse; water-borne diseases; Water Decade; technical cooperation.

INTRODUCTION

In developing countries, biological and microbiological pollution of water courses and drinking-water supplies remain widely prevalent, and now chemical pollution and physical factors such as ionizing radiation also have to be considered. In addition, the production, storage, transportation, manipulation, use and disposal of chemicals carry with them risks of human environmental exposure. These latter problems arise through rapid urbanization and industrialization, as well as through the use of production technologies which are often incompatible with environmental and health requirements.

It is clear that the battle against environmental health hazards cannot be won easily, for as old problems are solved, new ones appear as the unwanted by-products of industrialization and economic development. This has been seen in the industrialized countries where microbiological pollution of water supplies and massive pollution of cities have been largely solved, only to find "new" potential hazards in the form of minute quantities of various chemical compounds posing a potential threat to the health of the people. Much of the chemical contamination found in air, water and food is due to inadvertent releases during production and use of chemicals, as well as due to inconsiderate discarding of waste materials. A number of well-known endemic diseases have a chemical etiology, such as...
fluorosis, and many others are strongly suspect, such as the Kashin-Beck disease. Several naturally occurring chemicals are toxic under certain circumstances and cause poisoning in man and animals. It is the developing countries which are more frequently subjected to endemic diseases of chemical etiology, but they are the least equipped to identify and deal with them (WHO, 1987a).

Although the absolute number of people being adequately supplied with drinking-water has drastically increased during the International Drinking Water and Sanitation Decade (see figure 1), there is much less progress on the safeguarding of the quality of the water provided. Communicable water-related diseases, with diarrhoeas in first place, are still the most widespread health problem, particularly in the under-served rural areas of developing countries. Appropriate measures to protect drinking-water quality, not only from microbiological contamination, but also from chemicals, are still needed in many countries. Lack of human and financial resources severely hamper the public health and public works authorities to discharge their responsibilities with regard to drinking-water quality surveillance and control. National drinking-water quality standards, where they exist, are often not supported by the necessary laboratory services to monitor compliance or to stimulate improvements in the safety of the water supplied.

![Fig. 1. Service coverage improvements during the Water Decade](https://iwaponline.com/wst/article-pdf/23/1-3/201/112405/201.pdf)

Even in urban areas where major improvements have been made in the production and distribution of good-quality water, contamination of water supplies occurs frequently within the dwellings of high-rise apartment buildings. Similarly, in the rural areas contamination occurs within the household itself during handling and storage.

In the following, three concentration areas of WHO's programme in this field are described: drinking-water quality, wastewater reuse, and the quality of freshwater bodies. All three have an obvious immediate bearing on human health. This paper starts with a general review of health effects related to water and ends with an overview of WHO's programme in the area of water pollution control.
HEALTH ASPECTS OF WATER QUALITY

Human health may be affected by the ingestion of contaminated water, either directly or through food, and by the use of contaminated water for purposes of personal hygiene and recreation. Health hazards are also associated with various industrial and agricultural applications. The contamination of water by viruses, pathogenic bacteria, and other parasites can occur either at the water source itself or during conveyance of the water from source to consumer. In many developing countries, water in rivers, ponds, and canals is used for a variety of purposes - ablutions, washing clothes, the disposal of human excreta, needs - so it becomes highly polluted and therefore an important vehicle for the domestic transmission of infections and infestations.

The present concern about chemical pollutants in water relates not so much to acute toxic effects on human health as to the possible long-term effects of low-level exposure, which are often unspecific and difficult to detect. Only the more evident and important ones will be covered in the following.

Water-borne diseases

The importance of water-borne diseases has long been recognized. A drinking-water supply contaminated either by excreta or wastewater containing organisms of enteric disease, or by an individual infected by such organisms, can easily spread the contaminated water throughout the whole or part of the water distribution system, resulting in an explosive outbreak of disease affecting hundreds or perhaps thousands of people. Such outbreaks, typically of typhoid fever, cholera, or shigellosis, have occurred many times. Infectious hepatitis as a water-borne viral disease can be added to this list. Massive sewage pollution of a river in New Delhi in 1955 resulted in the contamination of a river-derived drinking-water supply and a substantial outbreak of hepatitis. Over 7,000 cases of manifest jaundice were reported, though it is thought the total number of cases must have been nearly 30,000.

Although the effects of an acute epidemic are dramatic, it is the continuing occurrence of endemic cases which is more devastating in the long run. Thus, the acute diarrhoeal diseases with their continuing high prevalence and mortality rates, centred mainly on young children, present one of the greatest health problems of the developing world.

Hygiene-related diseases

Diarrhoea is one of the most common conditions in developing countries, its effect being greatest among children during their first five years of life and enhanced by the severe malnutrition which so frequently co-exists. Pathogens causing diarrhoeal diseases are of faecal origin, conveyed by food or drink or by direct person-to-person transmission. Improvements in water quality, water availability and utilization, and in excreta disposal facilities, are considered essential elements in any remedial programme. Many epidemiological studies have confirmed the importance of safe and adequate water supplies in curbing diarrhoea and other water-borne disease.

Frequently the organisms of enteric diseases are transmitted to food by poor hygiene in the home. This may either be the result of failing to wash ones hands thoroughly after defaecation, or conveyance of the organisms directly from faecal matter to food by flies. Once contaminated, poor water and food storage conditions may permit the organisms to multiply readily in the food, thus increasing its level of contamination. Adequate amounts of clean water would not only help in this, but also diminish the risk of propagation of other diseases, particularly dermal diseases such as skin irritation, sepsis, dermatitis and eczema.

Water-associated diseases

Schistosomiasis (bilharziasis), a disease which may be caused by one of four differing species of trematode: S. mansoni, S. haematobium, S. japonicum or S. intercalatum, is highly prevalent in the developing countries. Its victims are severely incapacitated and thus bring about important socio-economic consequences to affected communities. Man is the principal reservoir of infection. The people at risk are those who work in, swim, or are otherwise directly exposed to infected water. The use of an alternative supply water and facilities for safe excreta disposal, combined with education of the public, will reduce the hazard, although persons who continue to bath, play, or are in contact with the water while working, will still be at risk.
Onchocerciasis (river blindness) is a filarial disease common in developing countries, notable mainly as a prominent cause of eye disorders and blindness. Transmission is by the bite of *Simulium* flies. Infection is more likely to be conveyed to persons frequenting the river banks, including those going down to the river to draw water or to wash clothing. As with schistosomiasis, the provision of pure water within the community will help to control the prevalence of this condition by reducing the need to visit the most infective areas.

Ancylostomiasis (hookworm disease) is also widely distributed through tropical and sub-tropical countries, giving rise to anaemia and general debility, and in children to cause mental and physical retardation. As with schistosomiasis and onchocerciasis, the use of safe water, coupled with safe excreta disposal, can control the hazard for people using the contaminated sites.

Dracunculiasis (Guinea worm disease) is common in some tropical areas including, for example, certain parts of India and the savanna belt of West Africa. It is transmitted by the female worm, usually located under the skin of the lower part of the body of an affected person. Since this disease is spread by water drawn from contaminated places such as step wells or water-holes, it can be controlled by the introduction of a safe water supply.

Chemical hazards in drinking-water

Natural waters rarely contain toxic substances in sufficient quantities to be a hazard. There are however exceptions. Fluoride is one example - it can occur naturally at different concentrations. At levels of less than 1.5 mg/l they are beneficial in that they render the teeth more resistant to decay; above 2.0 mg/l mottling of the teeth may occur. At still higher levels, skeletal fluorosis occurs and can be particularly severe in hot countries where much water is consumed. Naturally occurring radioactive substances (radon), is another example of natural contamination which, in higher concentrations, may lead to health problems via the water route.

Most often, however, chemical contamination of water supplies arises from industrial, agricultural or other man-made sources. Nitrate pollution of drinking-water is a good example. A certain amount of nitrates in water may come from natural sources, but excess is likely to occur in water as a result of sewage discharges or farm effluents, or the use of nitrogenous fertilizers on the land. Nitrates in drinking-water may cause infantile methaemoglobinemia, a condition in which haemoglobin in the blood is converted to methaemoglobin with serious or possible fatal effects. The condition occurs only in bottle-fed infants and has not been observed when the nitrate level in a drinking-water is less than 10 mg nitrate-N/litre. Although there are many more chemicals causing severe water pollution and/or health problems, the few examples quoted already illustrate the most common cases experienced in rural areas of developing countries.

GUIDELINES FOR DRINKING-WATER QUALITY

Before determining what type of treatment should be given to drinking-water, some basic questions on the actual definition of "safe" drinking-water have to be resolved. The first question concerns the knowledge of risks to human health associated with the different biological agents, physical properties and chemical constituents of drinking-water. This question addresses several aspects, including:

- routes of human exposure and their relative significance;
- evidence of health effects and their biological significance;
- identification of the most sensitive population groups at risk;
- expected dose/effect relationships in exposed populations.

Based on answers to the above, which can be difficult to obtain for the different water constituents, one can proceed to the second question which deals with the appropriate intervention levels. How to determine a quantitative level for water constituents which will ensure the safety of a drinking-water supply? In using a generic approach to determine these critical levels, the World Health Organization developed guideline values as the centerpiece of the new Guidelines for Drinking-Water Quality (WHO, 1984). The nature of these guideline values is characterized by the following main features:

(a) A guideline value represents the level of a constituent that ensures an aesthetically pleasing water and does not result in any significant risk to the health of the consumer.
(b) The quality of the water is such that it is suitable for human consumption and for all usual domestic purposes, including personal hygiene.

c) The guideline values have been derived to safeguard health on the basis of lifelong consumption; short-term exposures to higher levels of chemical constituents may be tolerated for certain substances.

Depending on the nature of the water constituent and its predominant health impact, the rationale followed in determining a certain guideline value varies a great deal. In the case of bacterial pathogens, resort to indicator organisms is taken, and as a support measure for implementation, the conditions of chlorine disinfection and residual chlorine levels are specified (WHO, 1985).

The health risk due to toxic chemicals in drinking-water differs markedly from that caused by microbiological contaminants. It is not very likely that any one chemical could result in a widespread and acute health problem, except, of course, in cases of largely accidental and massive contamination of the supply. The problem of chemicals is mainly one of cumulative effects brought about by long-term low-level ingestion. To assess and quantify potential effects on human health associated with the intake of chemicals, heavy reliance on toxicological laboratory animal studies is inevitable, since the available epidemiological and clinical evidence is limited.

The recommended values contained in the WHO Guidelines for Drinking-Water Quality, issued in 1984, are based on toxicological and other support data available up to 1981. Since that time new toxicological and other scientific data have become available for some of the substances for which tentative guideline values were established in the 1984 Guidelines as well as for other compounds for which there had been insufficient data available to establish guideline values. In addition, concern has been expressed regarding a number of substances which had not previously been considered.

In response to this need, a consultation to initiate the work on the revision of the WHO Guidelines for Drinking-Water Quality was convened in Rome in October 1988. The principal objective of this consultation was to discuss and agree upon the way the revision of the Guidelines would be carried out. The meeting was organized in collaboration with the Ministry of the Environment of Italy (WHO, 1989a). It is envisaged that the next edition of the Guidelines will be published in 1992.

HEALTH ASPECTS OF WASTEWATER REUSE

For more than three centuries, application of wastewater to cultivated land has been practised both as a land treatment system and as an irrigation scheme. The two approaches, however, should not be considered as equal in terms of concept, engineering design and final objectives. While land treatment involves the use of the soil surface, the soil matrix and plants for the treatment of wastewater to a certain level, wastewater irrigation presents a suitable practice to provide water, nutrients and organic matter to crops. Although land treatment provides measurable benefits to agriculture, it is directed mainly to the reduction of organic waste loads. No matter how the practice is considered in terms of concept, land application of wastewater should be recognized both as an effective water pollution control measure and as a means of conserving water through recycling in areas suffering from water shortage.

There is no doubt that in developing countries well-managed wastewater irrigation systems have a great potential for improving health, quality of life and social conditions by providing better nutrition through improved food supply and a better ecological balance between the city and its rural surroundings with rural job and settlement opportunities. However, the possible negative health effects must be the major concern of public health authorities and institutions in charge of reuse schemes: sewage farm workers, consumers of crops, meat and milk products in wastewater-irrigated fields and pastures, and nearby dwellers, are the groups exposed to the risk of transmission of communicable diseases.

A scientific group meeting on health aspects of wastewater reuse in Geneva (WHO, 1989b) made a deep and thorough review of the available literature, research findings and case studies collected during the last decade. Relevant studies were provided by the United Nations Environmental Programme, World Health Organization, World Bank, Food and Agriculture Organization, The International Reference Centre for Wastewater Disposal, London School of Hygiene and Tropical Medicine, The Hebrew University of Jerusalem, University of Leeds,
University of Newcastle upon Tyne and others. The available information, mainly with respect to extensive epidemiological data and case studies from several developing countries, was reviewed in two previous meetings (Engelberg, Switzerland, July 1985, and Adelboden, Switzerland, June 1987), attended by experts, environmental scientists and epidemiologists involved with health aspects of wastewater and excreta use in agriculture and aquaculture.

The scientific group meeting was held in order to review the use of wastewater in agriculture and aquaculture and its health effects, and to recommend guidelines and alternative measures for the control of infectious disease transmission based on epidemiological findings and technological advances in wastewater treatment. The conclusions and recommendations of the scientific group are as follows (WHO, 1989b):

- municipal wastewater is a valuable resource which should be utilized with adequate health safeguards since it reduces environmental pollution and increases agricultural production;
- reuse of wastewater should be considered the preferred method of disposal and considered an integral part of water resources planning;
- in order to provide health safeguards to the exposed groups, wastewater reuse should be supported by an integrated set of measures including wastewater treatment, crop restriction, appropriate wastewater application and human exposure control;
- Governments are urged to adopt standards based on microbiological guideline values, appropriate to various types of irrigation conditions;
- stabilization ponds should be preferred to conventional treatment systems for reuse schemes due to their simplicity and ability to remove pathogens with consistency;
- health protection measures must be monitored and evaluated to ensure their effectiveness in order to contribute towards the validation of the recommended guidelines.

Following this meeting, WHO now disseminates the findings of the scientific group and assists Member States in planning and implementing wastewater reuse schemes and in developing appropriate legislation, institutions and training programmes. By assuming that the use of wastewater in agriculture and aquaculture is increasing in importance, research into a number of subject areas is being continued and intensified. This includes studies on wastewater quality control, human exposure assessment, epidemiological studies and an evaluation of socio-cultural aspects.

FRESHWATER QUALITY MONITORING

Any water quality management programme requires information on the present water quality, the influence of man's activities on water quality, and criteria for the existing and planned uses. In many instances, this information can be generated only from a record of long-term water quality data and past experience of use of water. Further, in order to endorse relevant laws and to evaluate the effectiveness of the management programme, water quality measurements become indispensable.

Analytical methods for measuring various water quality parameters as well as hydrometric measurement methods have been developed and are readily available in manuals of standard procedures (WHO, 1987b). Information on design and operation of water quality measurements is either in the process of evolution or is available in research papers, textbooks and reports. Main considerations and elements required for reliable measurement of water quality through the design and implementation of the global freshwater quality monitoring project GEMS/WATER are described below. The approaches and methods of this project have been used by many Member States to develop and tailor their own water quality observation networks.

Through the Global Environment Monitoring System (GEMS), WHO and UNEP have been actively involved in health-related monitoring of environmental quality for almost ten years now. This is being done by monitoring air and water quality, food contamination, and human tissues and fluids. One of the objectives is to compile and analyze environmental quality data on a global basis; the others are to improve and harmonize measurement methodologies among countries, increase the validity and accuracy of measurements, and support the
development of national programmes. During the past ten years, there have been considerable
achievements in each of these areas.

As part of the GEMS group of projects, the global water quality monitoring project
(GEMS/WATER) was established in 1976 jointly by WHO, UNESCO, WMO and UNEP. The objectives
of the project are as follows:

(a) to collaborate with Member States in the establishment of new water monitoring systems
and to strengthen existing ones;
(b) to improve the validity and comparability of water quality data within and between
Member States; and
(c) to assess the incidence and long-term trends of water pollution by selected persistent
and hazardous substances.

The global water quality monitoring project is based on the active participation of Member
States which routinely monitor the quality of their water resources at selected locations
and provide the data for global synthesis and dissemination. Whenever possible, the
stations for the global network were selected from existing national or local networks.
Where such stations did not exist, new ones were established. Priority was given to water
bodies (rivers, lakes, reservoirs and groundwaters) which are major sources of water for
municipalities, irrigation, livestock and industries. A number of stations were also
included to monitor international rivers and lakes, rivers discharging into oceans as well
as water bodies not yet affected by man's activities (baseline stations).

The years 1977 to 1979 were used as a preparatory phase during which time guidelines were
prepared, specialists were trained in the different regions, and regional and global centres
were established. National institutes were identified in agreement with the governments and
designated as the focal point for GEMS/WATER activities within each country. In addition,
laboratories were designated to conduct the routine sampling and analysis at selected
monitoring sites.

Within WHO the project is implemented through the six WHO Regional Offices, with technical
support being provided by three regional centres for environmental health. In addition,
institutes have been designated as regional reference laboratories for implementing the
analytical quality assurance component of the project. The data centre is located at the
Canada Centre for Inland Waters, Burlington, Canada, which was designated as the WHO
Collaborating Centre on Surface and Ground Water Quality. The Environmental Monitoring
Systems Laboratory, Cincinnati, of the US Environmental Protection Agency serves as the
global centre for analytical quality control. UNESCO has participated in the field of
training and measurement methodology and WHO has concentrated on network design criteria and
hydrological monitoring methods.

The goal for the first phase of the project was to establish a skeleton network of about 300
to 400 stations, based, wherever feasible, on stations already in existence. By mid-1983, a
total of 448 stations had been formally designated by the national authorities in 59
countries. Not all of these have yet taken up routine submission of monitoring data. Thus,
of the 301 designated rivers sites, 255 were reporting data. Likewise, of the 62 designated
lake/reservoir sites, and 85 groundwater sites, 43 and 62 respectively, were reporting data
as of June 1983.

In addition to periodic data summary reports, a variety of reports and statistical
treatments of the raw data are available to the participating institutions. These include
quality control error listings, mass loading computations, and graphic displays.
Non-standard data summaries can be produced by the global data centre upon request. Such
data reports may cover individual stations, types of water bodies, regions or other
compilations required for the assessment of water quality. A first presentation of
collected data was published in the GEMS/WATER Data Summary 1979-1981 which includes
statistically summarized data for the first operational triennium of the project (WHO,
1983). The statistical parameters included in the comprehensive data summary tabulations
are: number of values reported, arithmetic mean, maximum and minimum values, percentile
values, median value and standard deviation. A second GEMS/WATER Data Summary 1982-84 was
issued in 1987 (WHO, 1987). In addition, an assessment of freshwater quality was undertaken
on a global basis which summarized all GEMS/WATER data and other studies on hydrology and
pollution of water bodies (WHO, 1988). The objective of this report is to provide an
evaluation of global water quality in which special attention is paid to the regional
differences revealed by the GEMS/WATER project. Use is also made of other monitoring
networks and programmes to examine temporal trends in water quality. The report also describes the range of strategies available for the control of water pollution and illustrates the consequences of different approaches to pollution problems.

PROGRAMME IMPLEMENTATION

As concerns drinking-water quality, two programme goals are pursued by WHO. Firstly, where existing infrastructure and resources permit, national drinking-water quality standards are formulated to support country-wide improvement of drinking-water quality. The implementation of such standards must, however, be accompanied by field surveillance activities and with the provisions and means to take remedial action when required. Secondly, in rural areas and small communities where standards as such have little meaning, action plans are developed and implemented to improve the protection of water supplies from bacteriological contamination. This requires regionally or locally based systems linked to primary health care for raising public awareness of the problem and possible solutions, and for implementing minimal water-quality surveillance and providing remedial measures with reliance on appropriate technology and community participation. National/local programmes are also needed to aim at reducing the contamination of water supplies within the dwellings themselves. This requires health education guidelines, surveillance, etc.

The prime goal in the area of freshwater quality is to ensure that the intensive development of water resources for other purposes does not create conflicts for their use as drinking-water sources. National authorities should have the capabilities and means to assess the environmental and health impact that urban, industrial, agricultural and water resources developments have on water quality and to take the necessary protective measures. This requires them to have (i) the necessary legislative mandate including standards and regulations, (ii) adequate monitoring and laboratory facilities, (iii) information on potential environmental and health risks, (iv) appropriate control and treatment technology, and (v) adequately trained staff. Since concern about water resources is typically shared by many national and provincial agencies, strong intersectoral coordination is essential. Of special importance are international water basins calling for coordinated action by Member States involved.

The aim of WHO's technical cooperation in this area is to increase the capacity of Member States to protect the health of their people against water pollution and related diseases. To achieve this aim national health and water authorities must have at their disposal an effective infrastructure and organizational capability to fulfil the various essential functions in this area. The various components and building blocks of a national programme on water pollution control are: awareness and promotion, information systems, policy and legislation, planning and programme development, institutional strengthening, and resources (human and financial). In view of the varying scope and intensity of economic development and related environmental problems, the relative importance of these six categories varies from country to country. Consequently, national priorities have to be set individually for the activities in each area.

Implementation of a national strategy requires a considerable level of country-wide infrastructure which includes an administration capable of issuing and enforcing regulations, laboratories capable of research, forecasting and compliance monitoring, scientists capable of undertaking the necessary hazard assessments and advising their government, engineers and operators capable of applying the necessary control technology and equipment, and communication services which allow for effective and reliable control of existing and new water pollution threats. As stated previously, the greater the level of development the greater the need for more comprehensive machinery. Ministries of health in particular should play an important role in safeguarding the well-being of the people in relation to environmental deterioration which affects health. They should also be influential with and supportive to environmental and water authorities. All levels of government, e.g. federal, provincial, district and local should be involved.

Human resources, in the form of skilled manpower, are essential. This involves the development at the national level of teachers and trainers, training institutions and a wide range of educational material ranging from the highly academic to the extremely practical. The development of a national capability for providing teacher training is extremely important. Continued reliance on outside sources for trained manpower makes water pollution control liable to collapse if circumstances compel the withdrawal of non-nationals, with serious consequences to human health.
Funding is always a difficult area both nationally and internationally. In the development of a strategy and its implementation, the simplest and most cost-effective solutions must be identified and used. This applies equally to individuals, institutions and equipment. A well-developed and clearly formulated strategy will not only make the best use of national resources, but will facilitate the provision of funds by other national and international donor agencies. Developing countries will continue to look to outside organizations for assistance, not only in the form of advice, but finance, technology, equipment, and training with the ultimate goal of national self-reliance. Outside organizations, in turn, must remain aware of the need to improve the effectiveness of their assistance on an ongoing basis. This entails understanding the country's specific situation and socio-economic constraints, allowing for effective development of the human resources without which water pollution control programmes could not come into effect.

REFERENCES