GUIDELINES FOR DRINKING-WATER QUALITY

Vol. 3. Drinking-water quality control in small-community supplies

WORLD HEALTH ORGANIZATION

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Volume 3

Drinking-water Quality Control in Small-community Supplies

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PREFACE

The *Guidelines for drinking-water quality* are intended to supersede both the *European standards for drinking-water*[a] and the *International standards for drinking-water*,[b] published in 1970 and 1971, respectively. Volume 1 of the guidelines contains guideline values for various constituents of drinking-water, while Volume 2 contains the criteria monographs that were prepared for each substance or contaminant and on which the guideline values are based.

The present volume deals specifically with drinking-water supplies for small communities, and particularly those in rural areas, with the main emphasis on the microbiological quality of such supplies. It contains information on sanitary inspections, the collection of water samples, simple methods for bacteriological analysis, and methods for determining residual chlorine, suitable for use in rural areas, which take account of the difficulties likely to be faced in the field. It also covers the remedial and preventive measures necessary if water quality is to be maintained, and the community participation which is essential in combating waterborne enteric disease. Conditions will obviously vary from country to country as a result of differences in economic, geographical, cultural and social conditions, but it should be possible for the methods described here to be adapted accordingly. Selected guideline values for drinking-water quality relevant to small community supplies are also given. Like those contained in Volume 1, these are not standards in themselves, but should be carefully considered in the context of the national or local situation when standards or regulations designed to safeguard drinking-water supplies are established. The long-term goal should be the attainment of these guideline values.

It is hoped that the present volume will be useful to all those concerned with drinking-water quality in the rural areas of developing countries, including not only laboratory staff, field workers in surveillance programmes, and those engaged in carrying out remedial measures for safeguarding drinking-water quality, but also administrators and other officials responsible for drawing up or improving national drinking-water quality-control programmes. It is also hoped that it will contribute towards the achievement of the national targets established under the International Drinking Water Supply and Sanitation Decade.

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[a] *European standards for drinking-water*, 2nd ed. Geneva, World Health Organization, 1970.
[b] *International standards for drinking-water*, 3rd ed. Geneva, World Health Organization, 1971.

The preparation of this volume was begun at an Interregional Meeting on Drinking-Water Quality Surveillance for Rural Community Supplies, held in Bangkok on 29 November–3 December 1982, when a detailed outline was agreed. The final version is the outcome of the work of a number of contributors and reviewers whose names are given in Annex 1; their assistance is greatly appreciated. Financial support was provided by the Danish International Development Agency (DANIDA) and by the United Nations Environment Programme, and their contributions are gratefully acknowledged.

CONTENTS

1. WATER QUALITY

1.1 Application of guideline values

Guideline values for drinking-water quality are given in Volume 1 of the *Guidelines for drinking-water quality*, which also explains how these values are to be interpreted.[a] A guideline value represents the level (a concentration or a number) of a constituent that ensures an aesthetically pleasing water and does not result in any significant risk to the health of the consumer. The quality of water defined by the guideline values is such that it is suitable for human consumption and for all usual domestic purposes, including personal hygiene. When a guideline value is exceeded the cause should be investigated with a view to taking corrective measures. The amount by which, and the duration for which, any guideline value can be exceeded without affecting public health will depend on the specific substance or characteristic involved.

In developing national drinking-water standards based on the guidelines, it will be necessary to take account of a variety of local geographical, socioeconomic, dietary and industrial conditions. This may lead to the formulation of national standards that differ appreciably from the guideline values. In the case of small-community supplies, particularly in developing countries, the parameters used in assessing and measuring the quality of water intended for public supply must necessarily be limited in number. Similarly, the guideline values given have often to be considered as long-term goals rather than rigid standards that have to be complied with at all times and in all supply systems.

Although any national or regional health authority will make its own choice of parameters and set its own standards, the present guidelines require that those selected should cover the most essential aspects of drinking-water quality. Bearing in mind that emphasis is placed first and foremost on the microbiological safety of drinking-water supplies, only a very limited number of physicochemical parameters are considered to be of general significance for small-community supplies. Wherever chlorine disinfection is applied, the residual chlorine level is considered the most convenient and meaningful parameter to be monitored.

In addition to the presence of high levels of a contaminant, any non-seasonal or sudden changes in level may be indicative of acute pollution of the water source. Immediate sanitary inspection and microbiological, physical or chemical analysis would be the first steps towards determining the necessary remedial measures, which are described in Chapter 7.

[a] *Guidelines for drinking-water quality. Vol. 1. Recommendations*, Geneva, World Health Organization, 1983, pp. 1–2.

1.2 Microbiological aspects

Ideally, drinking-water should not contain any microorganisms known to be pathogenic. It should also be free from bacteria indicative of excremental pollution. To ensure that a supply of drinking-water satisfies these guidelines, it is important that samples should be examined regularly for indicators of faecal pollution. The primary bacterial indicator recommended for this purpose is the coliform group of organisms as a whole. Although as a group they are not exclusively of faecal origin, they are universally present in large numbers in the faeces of man and other warm-blooded animals, and thus can be detected even after considerable dilution. The detection of faecal (thermotolerant) coliform organisms, in particular *Escherichia coli*, provides definite evidence of faecal pollution.

Guideline values ensuring bacteriologically safe supplies of drinking-water are provided in Volume 1 of the guidelines. Although developed for large water-supply systems, the values for piped and unpiped water supplies are also applicable to small-community supplies and are therefore reproduced in Table 1. Background information on the significance and choice of indicator organisms as well as the selection of analytical methods is given in Chapter 5.

It has been demonstrated that chlorination can produce virus-free water from faecally polluted source waters when the concentration of free residual chlorine is at least 0.5 mg/litre for a minimum contact period of 30 minutes at a pH below 8.0 and a turbidity of 1 nephelometric turbidity unit (NTU) or less. It is also desirable to maintain a free residual chlorine level of

Table 1. Guideline values for bacteriological quality[a]

Organism	Unit	Guideline value	Remarks
A. Piped water supplies			
A.1 Treated water entering the distribution system			
faecal coliforms	number/100 ml	0	turbidity < 1 NTU; for disinfection with chlorine, pH preferably < 8.0, free chlorine residual 0.2–0.5 mg/litre
coliform organisms	number/100 ml	0	following (minimum) contact time of 30 minutes
A.2 Untreated water entering the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	3	in an occasional sample but not in consecutive samples
A.3 Water in the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	3	in an occasional sample but not in consecutive samples
B. Unpiped water supplies			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	10	should not occur repeatedly; if occurrence is frequent and sanitary protection cannot be improved, an alternative source must be found if possible

[a] Adapted from *Guidelines for drinking-water quality. Vol. 1. Recommendations*, Geneva, World Health Organization, 1983, p. 19.

0.2–0.5 mg/litre in the distribution system to reduce the risk of microbial regrowth. The detection of chlorine in this concentration range provides an indication of the absence of post-treatment contamination.

There should be an immediate increase in disinfectant application to achieve a free chlorine residual of 0.2–0.5 mg/litre in all portions of the distribution system when total coliform densities of more than 3 organisms per 100 ml are found in successive samples or when 1 or more faecal coliforms per 100 ml are detected.

Chlorine is pre-eminent as a disinfectant because of its ready availability and cheapness, as well as the ease with which it can be used, controlled and measured in water. The most common methods and techniques for the determination of residual chlorine are described in Chapter 6.

1.3 Biological aspects

It is not easy to give guidelines on biological hazards that are generally applicable. This is particularly true in respect of parasitic protozoa and helminths, and the application of any guidelines and procedures proposed must be governed by epidemiological considerations in at least two respects: (1) many parasites have a complex geographical distribution and it may be unnecessary to take precautions against those not occurring locally; and (2) the majority of waterborne parasites are also transmissible by other routes, such as food and direct faecal-oral spread, and these routes should also be considered.

1.3.1 Protozoa

Species of protozoa known to have been transmitted by the ingestion of contaminated drinking-water include *Entamoeba histolytica* (cause of amoebiasis), *Giardia spp*. and, rarely, *Balantidium coli*. These organisms can be introduced into a water supply through human or, in some instances, animal faecal contamination.

Coliform organisms do not appear to be a good indicator for *Giardia* or *E. histolytica* in treated water because of the greater resistance of these protozoans to inactivation by disinfection. In non-disinfected water, the presence of indicator bacteria could suggest the presence of pathogenic protozoa. Since there is no good indicator for the presence or absence of pathogenic protozoa, drinking-water sources not subject to faecal contamination should be used where possible.

1.3.2 Helminths

The infective stages of many parasitic roundworms and flatworms can be transmitted to man through drinking-water. A single mature larva or fertilized egg can cause infection and it is clear that such infective stages should be absent from drinking-water. However, the water route is relatively unimportant except in the case of *Dracunculus medinensis* (the guinea-worm) and the human schistosomes, which are hazards that are primarily encountered in unpiped water supplies. While there are methods for detecting these parasites, they are quite unsuited for routine monitoring.

Dracunculus may be a cause of severe morbidity in rural populations and is transmitted by freshwater copepods, such as *Cyclops*, which represent an obligatory intermediate stage. Larvae reach the copepods when a blister on the limb of an infected person bursts and the larvae are washed into open wells and ponds. The parasites infect man when the copepod is ingested. In order to determine whether a risk of infection exists, copepods may be collected in plankton nets and examined for parasitic larvae under the microscope; the prevalence of the disease in man should also be investigated. Neither of these measures is suitable for routine use.

1.4 Chemical and physical aspects

Although in the rural areas of developing countries the great majority of water-quality problems are related to bacteriological or other biological contamination, a significant number of very serious problems may occur as a result of chemical contamination of water resources. Such contamination may arise from certain industries, such as mining and smelting, or from agricultural practices and malpractices (e.g., the use and misue of nitrates as fertilizers), or from natural sources (e.g., iron, fluoride). In order to establish whether such problems exist, a selected number of physicochemical parameters may need to be measured. However, particularly in the case of rural water supplies in developing countries, it could be both very costly and physically impracticable to cover a large number of parameters, and in most cases, testing may initially have to be limited primarily to sanitary inspection and bacteriological analysis.

If there are chemical constituents of local significance, the levels should be measured and the results evaluated in the light of the guideline values and other recommendations made in Volume 1.[a] In other areas, although no general recommendations or universally applicable selection of parameters can be given, there are a few indicative parameters of practical importance, which can provide useful guidance in assessing water quality. Guideline values for turbidity, colour, and taste and odour are recommended for use in the surveillance of small-community supplies.

1.4.1 Turbidity

High levels of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria and exert a significant chlorine demand. In all processes in which disinfection is practised, therefore, the

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[a] *Guidelines for drinking-water quality. Vol. 1*, op. cit.

turbidity must always be low, preferably below 1 NTU for effective disinfection. The recommended guideline value is 5 nephelometric turbidity units (NTU) or 5 Jackson turbidity units (JTU), but levels should preferably be less than 1 NTU when disinfection is practised. Turbidity in excess of 5 NTU (5 JTU) may be noticeable and consequently objectionable to consumers.

1.4.2 Colour

Colour in drinking-water may be due to the presence of coloured organic matter, e.g., humic substances, metals such as iron and manganese, or highly coloured industrial wastes. Experience has shown that consumers may turn to alternative, perhaps unsafe, sources, when their water displays aesthetically displeasing levels of colour. It is desirable, therefore, that drinking-water should be colourless.

The guideline value is 15 true colour units (TCU). Levels of colour above 15 TCU can be detected in a glass of water by most people.

1.4.3 Taste and odour

Water odour is due mainly to the presence of organic substances. Some odours are indicative of increased biological activity, others may originate from industrial pollution. Sanitary surveys should always include investigations of possible or existing sources of odour, and attempts should always be made to correct an odour problem.

The combined perception of substances detected by the senses of taste and smell is often called "taste". "Taste" problems in drinking-water supplies represent the largest single class of consumer complaints. Generally, the taste buds in the oral cavity specifically detect inorganic compounds of metals such as magnesium, calcium, sodium, copper, iron, and zinc.

Changes in the normal taste of a public water supply may signal changes in the quality of the raw water source or deficiencies in the treatment process.

As water should be free of objectionable taste and odour for the large majority of the consumers, the guideline criterion is "not offensive to most of the consumers".

2. PLANNING FOR WATER-QUALITY SURVEILLANCE AND CONTROL

2.1 Organizational framework

The precise meaning of "surveillance" in relation to the control of drinking-water quality is not always clear. As used here, it means the keeping of a careful watch at all times, from the public health point of view, over the safety and acceptability of drinking-water supplies. Surveillance requires a continuous and systematic programme of surveys, carried out at different points of the water distribution system. A surveillance programme aimed at ensuring a consistently acceptable level of drinking-water quality, if it is to be fully effective, may also require legislation supported by regulatory standards and codes of practice. However, in developing countries—many of which lack adequate community water supplies—and in particular in the rural areas and urban squatter settlements of such countries, surveillance should take into account local conditions and be adapted to the levels of economic and manpower development.

The organizational arrangements aimed at ensuring compliance with the requirements of legislation, standards, or codes of practice for drinking-water quality must provide for surveillance to be shared between the water-supply agency and a separate, and preferably independent, surveillance agency. The former is responsible at all times for the quality and safety of the water it produces. In this publication, the routine testing and monitoring carried out by the water supplier will be called water-quality control testing; this should not be confused with the separate checking and testing carried out by the surveillance agency. Both water-quality control testing and testing by the surveillance agency should be applied to all the types of water available to the community, e.g., piped or unpiped, treated or untreated supplies, derived from any suitable source, such as rivers, ponds, wells, roof run-off, etc.

The surveillance agency should preferably be established with national support and operate at central, provincial (regional), and local levels, usually through the health authority. It should be concerned with the public health aspects of drinking-water supplies, and have overall responsibility for ensuring that all such supplies under its jurisdiction are free from health hazards. To this end, it should carry out periodic sanitary inspections and analyses of water samples to determine whether the suppliers are fulfilling their responsibilities.

Because the water-supply agency and the surveillance agency have different and sometimes conflicting interests, it is important that the latter is separate and independently controlled. Nevertheless, the roles of the two agencies are essentially complementary since their surveillance activities, although independent, in combination result in the proper control of drinking-water quality.

Some important aspects of the surveillance programme are as follows:

(*a*) The agency should have the sole responsibility within the health authority for providing surveillance services to protect the public from waterborne diseases and other hazards associated with the water supply.

(*b*) Water-quality surveillance should be integrated with other environmental health measures, especially sanitation.

(*c*) Surveillance requires specialized knowledge and the agency should thus include personnel specially trained in matters such as sanitary engineering, community health, epidemiology, chemistry, biology, etc.; additional support should be provided by the medical profession, particularly during an outbreak of enteric disease.

(*d*) Health authorities should possess centralized laboratories and other services which can be advantageously used for the conduct of programmes of surveillance of water supplies.

(*e*) Periodic reports to the government regarding the public health situation of the country's water supplies are essential.

If the operational standards of water-supply agencies are high, the duties of the surveillance agency can be reduced to a minimum. In these circumstances, the surveillance agency, while still retaining the ultimate responsibility for ensuring the safety of all public water supplies, should be able to give greater attention to the supply systems having water of the poorest quality.

Both the programme and the level of surveillance should be adapted to local conditions and the economic resources of the country and take into account the following:

—the type of water-supply system (size, type of source, water quality, etc.);
—the equipment used and available;
—local employment practices and level of training of personnel;
—the socioeconomic level of the community served by the water-supply system;
—community participation;
—geographical and climatological conditions;
—the local communication and transportation infrastructure.

Although the main objective of a surveillance and control programme is to ensure a safe and adequate supply of drinking-water, certain other subsidiary objectives can be defined, for example:

(*a*) determination of trends in drinking-water quality over time;

(*b*) provision of information to public health authorities for general public health protection purposes;

(*c*) identification of sources of contamination;

(*d*) assessment of the performance of water-treatment plants; if necessary, appropriate modifications may be suggested;

(*e*) evaluation of water-supply systems with a view to improving them.

Because of the limited resources available, particularly in developing countries, it may be advisable to start with a fairly basic surveillance programme, and then to improve on it in stages. In planning for the future the aim should be to provide increasing levels of surveillance activity, ultimately reaching an advanced level (see below).

For practical purposes, two levels of surveillance can be identified and characterized as follows:

Initial level: irregular surveillance, or a basic programme that is severely limited in scope and effectiveness;

Advanced level: all surveillance and control elements fully operational.

The principal activities at these two levels of surveillance are summarized in Table 2.

Table 2. Summary of principal activities for initial and advanced levels of surveillance

Activity	Level of surveillance: Initial	Level of surveillance: Advanced
laws, regulations and policies	basic	complete
enforcement	basic	complete
drinking-water standards	bacterial and some physicochemical parameters	numerous parameters as defined in guidelines published by WHO, or equivalent
technical assistance	limited	active
training of:		
staff	on-the-job, plus short courses	as for initial level plus technical institute
waterworks operators	seminars plus short courses	as for initial level plus technical institute
sanitary inspections	all urban and some small communities	all urban, many small communities
approval of sources	all urban and some small communities	all urban, many small communities
sampling and monitoring	urban areas	urban areas and special rural situations
water analysis	bacteria and residual chlorine	as given in guidelines published by WHO, or equivalent
remedial action	as needed	as needed
laboratories	existing health laboratories	as for initial level plus reference laboratory
design standards or criteria	advisory	those applicable nationally
control of cross-connections	advisory	active programme
plumbing code	advisory	codified and enforced
laboratory support services	basic media and re-agents available	fully equipped laboratories available
standards for materials and additives	advisory	approved listing
regulations for special water supplies:		
institutional	hospitals, major rail and air terminals	as for initial level plus other establishments
temporary	none	large camps, markets, fairs, etc.

2.2 Assessment of existing situation

Water-supply systems vary greatly in size, ranging from small systems serving individual families, e.g., from a well or a rainwater cistern, to systems serving many consumers. Adequate and safe water supplies may not be available in a large number of villages in the rural areas and in many squatter settlements in urban areas, where the control, operation, and maintenance of water systems is often inadequate. Small-community populations are often at great risk from waterborne diseases, and their water supplies need to be safeguarded, something that can be achieved only through effective surveillance. Information on general health, gathered at central, provincial (regional), and local (or equivalent) levels, will help to define priorities for the surveillance programme within a country. An inventory of the existing and proposed water-supply systems should be prepared at each level and should include details of the water source, size and type of any water-treatment plant, the distribution systems (if any), populations served, etc. The supporting services available, such as transportation and facilities for analysis, also need to be identified. From an analysis of all the information in the inventory, the workload for the surveillance activity can be assessed and the cost of surveillance calculated; this is essential if a realistic programme is to be undertaken. A suggested form for the inventory of water-supply systems is given in Fig. 1.

Fig. 1. Suggested form for inventory of water-supply systems

Date of inspection Day ☐ Month ☐ Year ☐

General information

Name of supply . . . .

Owned by . . . .

Location . . . .

Persons in charge . . . .

Number of persons served:

—by house connections ☐☐☐☐☐

—by standposts or public hydrants ☐☐☐☐☐

—total ☐☐☐☐☐

Source of water

Groundwater ☐ Surface water ☐ Rainwater ☐

Water collection and treatment

Dug well ☐

Spring ☐

Drilled well ☐

Infiltration gallery ☐

Surface-water intake ☐

Simple rainwater collection system ☐