# 1. Conceptual Framework

## *1.1 Introduction*

This publication, *Guidelines for the Surveillance and Control of Drinking Water Quality,* explains how to plan programs for the surveillance and control of water quality. It defines the criteria to be used when determining the level of intervention, indicates the desired scope of legislation, regulation, policy and basic management, and identifies the main support tasks that will be needed for an effective planning of future surveillance and control work.

The plans proposed in these Guidelines are based on successful experiences and recent scientific information. The procedures recommended here take into account an ample range of implementation levels, from basic to advanced. The procedures described, which can serve as a reference for drawing up standards and directives and for designing programs or other types of conditions, should be applied with care, bearing the following factors in mind: the sanitary vulnerability of the community; the availability of human, material and economic resources; the institutional status (public or private) of the water-supplying companies or institutions, and their capacity; the institutional status and capacity of the body responsible for surveillance at the national and local levels; and sanitary legislation currently in force. These Guidelines place emphasis on some elementary surveillance and control procedures which are indispensable if we are to guarantee safe water for human consumption.

During the implementation stage of a water surveillance and control program, a uniform level of intervention for the whole country, region or department does not necessarily need to be established. The health authorities or regulatory institution will be able to define the most appropriate local level of surveillance and control, bearing in mind the capacity of the laboratories both of the surveillance institution and of the supplier. The criterion must be not to waste the funds available by demanding high levels of surveillance and control, when the institutions responsible for this work are not able to provide such levels. Usually, when requirements exceed the capacity of these institutions, programs simply do not get implemented.

Countries drawing up directives or standards for water surveillance and control programs should make a careful evaluation of the costs and benefits involved, in order to set priorities reflecting possible impacts on human health.

Finally, in developing countries where communicable diseases are a public health problem, surveillance should focus on determining improvements in the bacteriological quality of the drinking water, minimizing risk factors which lead to the deterioration of water quality in the distribution system, and improving or modernizing practices in the operation, maintenance, design and construction of water supply systems.

### *1.1.1 General*

The main aim of the *Guidelines for the Surveillance and Control of Drinking Water Quality* is to define the strategies that will make it possible to detect, foresee, and prevent the pollution of drinking water, in order to minimize the incidence of waterborne diseases. This guide, along with the *Guidelines for Drinking Water Quality* published by the World Health Organization (WHO), is addressed to persons who work in the protection of public health and in the preparation of national, regional or local directives, standards, plans or programs on the subject, as well as to individuals and institutions linked with, or committed to, the water supply service.

Since water is indispensable for life, consumers must have a satisfactory water supply, so the supplier must make every effort to provide water of the best quality under any given circumstances. In this context, the first line of defense is the evaluation of the physical, chemical and microbiological quality of the water. Such an evaluation is made by performing analyses and carrying out surveillance and control of the treatment processes.

The surveillance and control of the microbiological quality of water for human consumption should be routine activities. It must be realized that these activities are of the utmost importance. It has been recognized that the greatest risk of falling prey to diseases caused by pathogenic microorganisms lies in the consumption of water polluted by human or animal feces. However, risks of this kind cannot be completely removed because such diseases can also be spread by personal contact, sprays and food. The importance of water quality surveillance and control is that the safety of the water supplied is the factor that will reduce the possibility of diseases being spread as mentioned above, as it facilitates personal habits of hygiene and hygiene in the home.

The health risk represented by chemical substances in the water differs from that posed by microbiological pollutants, in that the effects of the latter are usually more acute. There are few chemicals which, in concentrations that can normally be detected in polluted water, cause health problems with immediate effects; rather, deterioration in health caused by chemicals in the water will usually become apparent only after long periods of exposure. The chemicals which take on special significance are therefore represented by cumulative contaminants. This is why the surveillance and control of chemical contaminants are considered to be of secondary importance when the water is polluted by microorganisms.

The use of chemical disinfectants plays a very important role in the conservation of the microbiological quality of water. It is true that these disinfectants can form chemical by-products hazardous to health, but the risk is extremely small in comparison with the risks posed by inadequate or deficient disinfecting of the water.

Another factor of great relevance is the evaluation of the organoleptic characteristics of the water, that is, those which can be detected by the consumers' senses, such as turbidity, color, odor, and taste. This is an essential aspect because deficiencies in these characteristics can cause

customers to reject the supplied water and start using an alternative, uncontrolled water source. However, it is also recognized that the absence of unpleasant sensory effects does not necessarily guarantee that the water is safe for human consumption.

On the other hand, sanitary inspection makes it possible to detect conditions or situations that increase the risk of water pollution, but which cannot always be determined by routine analyses unless the contamination is occurring at the same time that the sample is being taken. Sanitary inspection is a sensory evaluation of the physical conditions of the water production, storage and distribution facilities, principally of the most vulnerable parts and those most closely associated with the conservation of water quality. It enables structural or operational deficiencies to be detected in the supply system. Sanitary inspection consists of: (a) evaluation of physical conditions; (b) evaluation of the level of hygiene and (c) evaluation of operational practices. "Physical conditions" refers to the safety of the different components of the system; the "level of hygiene" refers to order and cleanliness in the facilities and their surroundings; and "operational practices" refers to the operational procedures of production and distribution of the water supply system.

### *1.1.2 Nature of the Guidelines*

It should be emphasized that these Guidelines contain recommendations to facilitate the drawing-up of surveillance and control plans, and to help identify the programs that will need to be put in place at a given level of intervention to conserve or protect drinking water quality. In conjunction with these Guidelines, the following concepts must be applied:

a) The suggested levels of action represent different degrees of intervention aimed at minimizing the risk to health posed by the consumption of polluted water.

b) National standards, directives and programs should take into account the sanitary, geographic and socioeconomic situation and any condition which could put the quality of drinking water at risk.

c) The plan to be formulated must be practical and appropriate to the country's situation, and it must protect the public health of the population served by the communal or private water supply system.

d) If non-compliance with water quality standards is detected, this does not necessarily mean that the water is not totally fit for human consumption, but it can indicate deficiencies in the system's infrastructure or operations, which increase the risk to consumers' health.

e) The proportion of samples that fail to comply with quality standards, and the period during which this situation lasts, serve to evaluate the risk to water consumers' health.

### *1.1.3 Importance of the Quality of Drinking Water*

Water for human consumption has been defined in the World Health Organization (WHO) *Guidelines for Drinking Water Quality* as that water which is "*adequate for human consumption and for all normal domestic use, including personal hygiene.*" Implicit in this definition is the principle that the use of this water should not present any risk of disease to consumers.

Recognition of water as a vehicle for the transmission of diseases dates from long ago. Diseases prevalent in developing countries, where the water supply and sanitation are deficient, are caused by bacteria, viruses, protozoa and helminths. Such organisms cause diseases which range from minor gastroenteritis to serious and fatal epidemic diseases.

Nevertheless, water quality alone is not enough to ensure the benefits of human health. Three additional requisites must be met: **quantity, continuity and reasonable cost**. Quite apart from the responsibilities of the supplier, the consumers themselves must be knowledgeable about the appropriate use of water, adequate nutrition, and food hygiene, as well as the proper disposal of excreta. Messages aimed at improving habits and customs related to good water use should therefore be conveyed through educational programs complementary to the activities of the supplier, designed to prevent the public from having the false impression that water quality by itself prevents diseases.

Water that is fit for human consumption when it enters the distribution system can deteriorate before reaching the consumer. Once in the distribution system, water can become contaminated for different reasons: crossed connections; backsiphonage; broken pipes; fire hydrants, home connections, defective tanks and reservoirs; and during the laying of new pipes or repair work carried out with few security measures. Another recontamination factor, of great importance in cities or localities where there is a shortage of water, is the interruption of the supply as a result of rotation of service from one supply area to another in an attempt to cover the demand for water.

Thus, in systems where the water supply is limited, the deterioration of its physical, chemical and, above all, microbiological quality by the time it reaches the customer's home is frequently a consequence of inadequate manipulation and storage.

### *1.1.4 Health Impact of Pathogenic Agents in the Water*

The provision of good quality water was one of the eight components of primary health care identified at the International Conference on Primary Health Care held in Alma-Ata in 1978.

In most countries the main risks associated with the consumption of polluted water refer to microorganisms. As indicated in Chapter 18 of "Agenda 21" of the United Nations Conference on the Environment and Development, "*approximately 80% of all diseases and more than a third of the deaths in developing countries are caused by the consumption of*

*contaminated water, and on average up to a tenth of the productive lifetime of each person is taken up by water-related diseases*."

The risk of catching water-borne diseases is proportional to the degree to which pathogenic microorganisms are present in the water. However, this relationship is not necessarily a simple one, since risk also depends on other factors such as the amount consumed and the susceptibility of the host. Water for human consumption is only one vehicle for the transmission of diseases. Because of the multiplicity of means of transmission, not only improvement in quality and availability of water, but also the sanitary disposal of excreta and the application of adequate rules of hygiene, are important factors in the reduction of morbidity and mortality caused by diarrhoeal diseases.

Independently of the agents which affect drinking water quality, we must be aware of the risks caused by inadequate protection of water sources, bad management of water during the treatment process, and the poor conservation of its quality in the distribution systems and customers' homes. The absence of diseases in communities supplied with water of bad or doubtful quality does not mean that the population is not subject to the risk of an epidemic.

The list of water-borne agents which constitute a problem worldwide and which can produce adverse effects on health includes microorganisms, chemicals and radionuclides. Among the microbiological agents are bacteria, such as the *Vibrio cholerae, Salmonella* and *Shigella*; viruses such as hepatitis A and E; and protozoa such as *Giardia* and *Cryptosporidium*. Among the chemical agents are inorganic components such as nitrates, fluorine, arsenic; heavy metals such as lead, cadmium, mercury; and organic components such as substances for industrial use, toxic chemicals used in agriculture, and disinfection byproducts.

Outstanding among the many cases of transmission of diseases related to the microbiological quality of drinking water are outbreaks of *Criptosporidium* associated with defects in the treatment process, and entero-hemorrhagic *E. coli* associated with the replacement of water meters and ruptures in the distribution pipes, among others.

In Latin America, in 1991, the spread of cholera was attributed to inadequate water and sanitation supplies, and to the lack of environmental control measures.

### *1.1.5 Benefits of the Surveillance and Control of Water Quality*

The good quality of drinking water assures the consumer of protection against the presence of pathogenic agents and physical and chemical compounds harmful to his or her health. The information provided by drinking water surveillance and control programs, in addition to the obvious benefit of reducing water-borne diseases, provides a means of improving the quality of the water supply service.

Improvement in the quality of the water supply service is achieved by: a) identifying the need to extend the basic sanitation infrastructure, b) rehabilitating the water supply system, c) training

staff in charge of the operation, maintenance and administration of the water supply and sewage services, d) identifying measures for preserving water sources, and e) bringing up to date the regulations, standards and codes of good practice relating to the quality of water for human consumption. In addition, the processing of information at the regional or national level will make it possible for the country to plan national investment in extending service coverage, and improving and rehabilitating services in the water and sanitation sectors.

### *1.2 Background, Present Situation and Trends*

Before 1991 the countries of Latin America and the Caribbean focused on quantity rather than quality of water for human consumption. The outbreak of cholera in Peru that year was a severe blow to that trend and showed up the poor sanitary conditions of water supply services, especially with regard to water quality. In consequence, many of the governments of the Region applied for aid through the mechanisms available within the Region.

At the "International Conference on Water Quality," sponsored by the Pan American Health Organization and held in Lima, Peru in 1996 at the Pan American Center of Sanitary Engineering and Environmental Sciences, PAHO/CEPIS, one of the recommendations was that the countries of the Region develop programs for the surveillance and control of drinking water quality.

A similar request was made to the PAHO by the American heads of state at the Summit Meeting of Santa Cruz de la Sierra in 1996, and to address these needs the Organization drew up a ***Regional Plan for Improving the Drinking Water Quality***, which contained a diagnosis and a specific proposal of action. The diagnosis clearly recognizes that the situation is not the best with respect to the monitoring and control of drinking water quality.

Although the coverage of drinking water services has increased in absolute terms, nevertheless with respect to quantity and quality, in relative terms, the values have fallen. Almost at the end of the twentieth century PAHO figures showed that only 41% of the population were consuming treated and disinfected water which could be considered "safe."

A historic report shows that countries which in the 1950s and 1960s had active surveillance and control programs discontinued them in the 1970s and 1980s. Although the alarm caused by the reappearance of cholera triggered some important initiatives, there can be no question that in many cases the initiative failed for lack of political support. Moreover, there was an evident lack of good, up-to-date instruments to design programs coherent with the circumstances facing the governments and institutions of the countries concerned.

Within that context, and bearing in mind the appearance of a more executive tendency in these countries, as well as the presence of top and intermediate level officials and technical staff who recognize the need for specific action and the lack of instruments appropriate to the real situation of the countries, the need for drawing up an appropriate framework to support this favorable trend was identified.

The Regional Plan, together with other regional and local initiatives, is a contribution toward satisfying the need for a framework document. It is our hope that the present Guidelines will be a useful addition to that effort, since they present a methodology that can be applied by governments, agencies, public and private companies and customers in general, to help improve the quality of water supply services.

## *1.3 General Concepts, Principles and Objectives*

### *1.3.1 Sanitary Surveillance of Drinking Water Quality*

Sanitary surveillance can be defined as *"the combined measures adopted by the competent authorities to evaluate the risk to public health of the quality of water provided by public and private water systems, as well as to evaluate the degree of compliance with legislation linked with water quality."*

In theory, sanitary surveillance has two major components: (a) correlation of the physical, chemical and microbiological quality of the water with the incidence of waterborne diseases transmitted, in order to determine the health impact; and (b) permanent and systematic review of the information on water quality to confirm that the source, treatment and distribution conform to established objectives and rules. Thus, the permanent examination of the supply system, by means of sanitary inspection and evaluation of drinking water quality, as well as the analysis of the community's epidemiological profile, serve the institution responsible for sanitary surveillance as risk evaluation instruments.

From the above it can be deduced that sanitary surveillance is an activity of **investigation** generally carried out by the competent public health authorities, directed toward identifying and evaluating risk factors associated with public water systems and which can imply a threat to the health of the population. It is an activity which is preventive as well as corrective in ensuring the reliability and safety of water for human consumption. Surveillance is **preventive** because it facilitates the early detection of *risk factors* so that action can be taken before abnormalities in water quality occur or negative health impacts are produced. It is **corrective** because it permits the identification of *sources of outbreaks of water-related diseases* in order to act on them, re-establish water quality and keep the problem from spreading. If good use is made of the information resulting from this type of analysis or evaluation, it will be possible to improve standards on drinking water quality, as well as operational, maintenance, distribution and storage procedures and the regulations concerning design, construction, building materials or chemicals employed in water treatment.

Sanitary surveillance can be applied just as well to public and private water supply systems as to water collected from individual sources or by other means. Therefore, the responsibility of the institution in charge of sanitary surveillance is to supervise all supply systems and sources of water potentially usable for human consumption.

### *1.3.2 Control of Drinking Water Quality*

Control of water quality can be defined as *"the combined activities carried out on a continual basis by the supplier to verify that the quality of the water supplied to the population conforms to legislation."*

This definition of quality control implies that the water supplier is responsible for the quality of the water that it produces and distributes, and for the security of the system which it operates. The supplier can comply with these obligations by means of a combination of preventive maintenance and good operational practices, supported by the ongoing evaluation of the quality of the sources, of the treatment processes and of the distribution system, together with sanitary inspections. These measures together ensure the good quality of the water and the absence of recontamination in the distribution system.

A supply area is normally assigned to the public or private supplier. The supplier's responsibility in terms of quality of the product delivered (water of the quality stipulated in legal standards) covers the water from the time it leaves the treatment plant or supply wells until it enters the customer's home. The quality of water in the home is the responsibility of its inhabitants.

On the other hand, the quality of water distributed by tank trucks or other means which do not imply the participation of public or private suppliers, and which are common in periurban areas, is not usually the responsibility of the water supplier. In such cases the quality control activities are generally assumed by a public or private institution.

In periurban and rural areas where the water supply services are administered by the community itself, these services must, as in the previous case, be controlled by a public or private institution. Usually, the Ministry of Health entrusts this task to the institution responsible for sanitary surveillance. However, it is recommended that a unit independent from the sanitary surveillance department carry out the control work, even though both may belong to the same Ministry and use the same central laboratory. The use of the same laboratory is recommended in order not to duplicate the investment in analytical infrastructure.

### *1.3.3 Relationship between Sanitary Surveillance and Control of Water Quality*

The little difference between the concepts of sanitary surveillance and quality control leads to the fact that there is not a clear division of responsibilities between the unit responsible for sanitary surveillance and the one responsible for water supply, since the mission of both is to assure adequate quality of drinking water. The WHO has differentiated between the two activities in the following way:

> *In general, it is the responsibility of the authorities in charge of local water supply to guarantee that the water provided be of the quality stipulated in the standards. Nevertheless, an independent body (national, state, provincial or*

*local) can better perform the work of sanitary surveillance* (that is to evaluate the risk to public health of the quality of water provided by the supplier and to determine its degree of compliance with the legislation related to preservation and conservation of water for human consumption). *While it is true that both functions complement each other, experience has shown that they are performed better when carried out by institutions independent of each other, because of conflicts of priorities which emerge when the two functions are combined.*

Quality control differs from surveillance in institutional responsibility, in the type of activity involved, in the geographical areas of intervention, the frequency of sampling, and the interpretation and application of the results, but they share common traits in planning and implementation.

In countries where **regulatory entities** exist, these can facilitate surveillance through directives which oblige suppliers to implement quality control programs for drinking water and periodically to report the results of their evaluation of the water supply systems. In such cases, surveillance can be called operational surveillance.

While the supplier is responsible for routine control of water quality, for monitoring to ensure good operational practices, and for taking measures to improve the quality of the supply, either the body responsible for sanitary surveillance or the regulating entity is responsible for periodically carrying out an audit of safety aspects, summarizing the data provided by the supplier, and promoting improvements in the quality of the water supply service.

Wherever the water supplier has set up an effective program for quality control, and either the regulating entity verifies its compliance or the supplier is efficiently audited by an external institution, the body in charge of sanitary surveillance can place more emphasis on populations who have been receiving less attention, urban as well as rural and periurban. In this way the supplier and the regulating entity become fundamental parts of sanitary surveillance; it is important, therefore, that both be conscious of the role they play in the surveillance process.

In summary, the supplier evaluates the quality of the water provided to determine its degree of compliance with the quality standard and reports the results to the regulatory entity or to the sanitary surveillance body, which validates or verifies by sampling the quality of the water in the distribution network and audits the supplier in everything related to the operational and administrative processes associated with the quality control program.

However, external auditors are selected (by the sanitary surveillance body) to perform the analytical quality control in the laboratories of the regulatory entity and of the supplier. The external auditor reports to the sanitary surveillance body about the work and the reliability of the analytical processes. This information in then passed on to the regulatory entity and to the supplier so that the latter can take corrective measures, if necessary.

For its part, the epidemiology office of the Ministry of Health reports to the sanitary surveillance body on the incidence and prevalence of diseases related to water quality, information which is then correlated with data provided by the supplier to investigate the probable origins of the diseases. If a consistent correlation is obtained, improvements in the water quality standard or regulations or procedures linked to the preservation and conservation of water in the distribution system can be introduced. Figure 1. summarizes the relationship between surveillance and control, emphasizing the main responsibilities of each.

### *1.4 Legal Framework*

The effectiveness of sanitary surveillance programs, operational surveillance and quality control of drinking water depends on legislation which responds to national, jurisdictional and constitutional situations, among others. The legal framework covers three interconnected areas: political, legislative and regulatory.

**Political** intervention is fundamental for facilitating the revision, modification, preparation and adoption of laws and regulations which enable programs to be developed for the surveillance and control of drinking water quality. **Legislative** intervention provides a legal framework which must be of the highest level. The legal framework is made up of the pertinent laws, decrees and resolutions.

Conceptually, **legislation** should identify the institution responsible for surveillance and confer on it the authority to verify that regulations and standards relating to the conservation and preservation of the quality of drinking water are adhered to. It places special emphasis on assessing the safety of the water and of the sanitary infrastructure by studying the results of analyses, sanitary inspections and specific audits; as well as verification of the reliability of the information provided by the supplier. This surveillance body must also be given the authority to oblige the supplier to take the necessary corrective measures in cases of emergency, especially when microbial contamination has been detected.

The legislation must also define the responsibility of the surveillance body and that of the control unit regarding evaluation and follow-up of water quality at the sources of supply, in the production process, and in the distribution network; it must specify sanctions for single or continuous violations of regulations; and define who is responsible for establishing the quality standard for drinking water. In addition, the legislation must take into account the fact that sanitary and operational surveillance are first and foremost a function of support and advice, and only in the second place a function of punishment for failure to comply with standards and regulations.

With regard to the supplier, its authority, functions, and legal rights and obligations must be specified, with emphasis on the fact that it is legally obliged to provide water that meets the established standards, and to supervise, inspect, operate and maintain the water supply system. Moreover, the supplier must be considered capable of bringing lawsuits against third parties to protect its water sources and its distribution system from any source of foreign contamination.

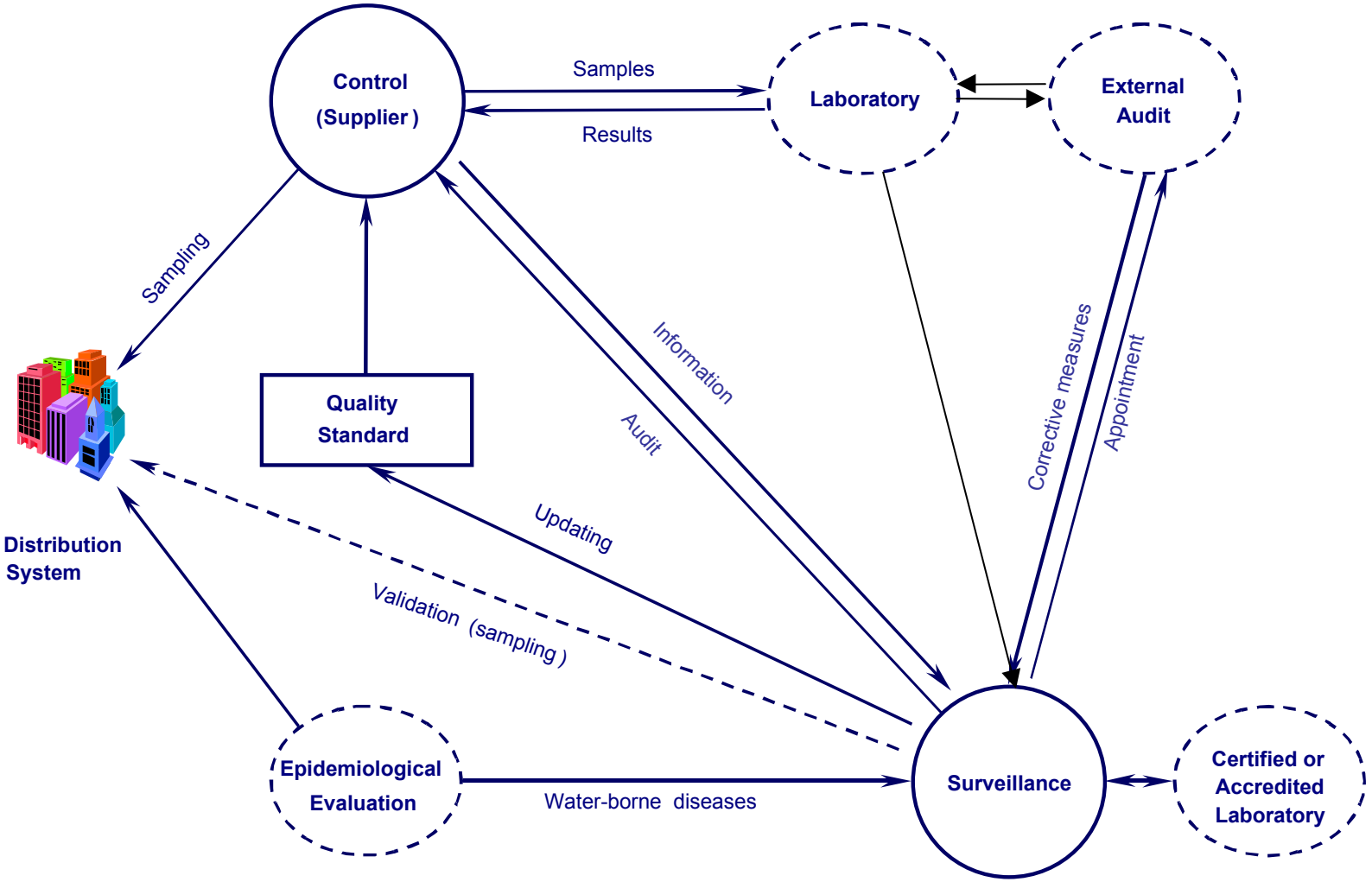


**Figure 1. Relationship between Control and Surveillance of Drinking Water Quality**

With reference to the **regulatory** area, the actions of the pertinent authorities and institutions involved in the surveillance and control of water quality must be backed up by **regulations, standards** or **codes of practice** which stipulate the quality of water to be supplied, acceptable treatment processes, appropriate treatment and distribution practices, design and construction criteria, types of building materials, the quality of chemical products to be used in water treatment, and the type of care required in water distribution, among other specifications.

The regulations, standards or codes of practice must be based on a health risk/health benefit ratio to ensure that the procedures adopted are consonant with the situation of the country. These procedures will therefore take national priorities into account, as well as sanitary, economic, human and institutional factors.

The power to promulgate and modify water quality standards, codes of practice and other technical regulations relating to the protection of human health should be invested in the competent sector, usually represented by the Ministry of Health.

Where regulatory entities exist, they will be able to issue directives which may eventually require of the suppliers a quality superior to that specified in the standard, but never lower. Regulatory entities will not be able to issue directives that in any way contradict the regulations, standards or codes issued by the competent authorities.

In conclusion, in order for the surveillance program to be effective, the regulatory entity and the surveillance body need the pertinent laws to be in place, as well as the mechanisms to monitor compliance with those laws. It is also important for the surveillance body to establish a positive, supportive relationship with the supplier. Without detriment to the above, the existence of legislation that is out-of-date or in process of being updated should not be a taken as a reason to postpone or prevent the execution of programs for the surveillance and control of drinking water quality.

### *1.5 Political and Institutional Framework, and Responsibilities*

In many countries the institution responsible for surveillance is the Ministry of Health and its regional or local offices. In other countries it is the environmental protection agency or the departments of environmental health of local governments. Preferably, the surveillance body should be a national institution designated by law and operative at a central and decentralized level, so that it will be able to provide efficient service at the local or district level. The institution made responsible for sanitary surveillance should have the sole responsibility for this surveillance, whose purpose is to protect people from water-borne diseases and from other hazards associated with water supply systems.

Surveillance bodies are under the obligation to evaluate water quality data obtained from the supplier in compliance with its quality control program, as well as to validate, through selective sampling, the supplier's own sampling program.

Additionally, the sanitary surveillance body must qualify and select the independent auditors who will be in charge of auditing the suppliers' laboratories in order to guarantee the quality of results of analyses.

These activities should be complemented by a follow-up of the supplier's compliance with any corrective measures prescribed, and its compliance with submitting regular reports on the state of water quality at the regional and national level. These reports will serve as a planning tool for investments to improve water quality in particular and the water supply service in general.

One important responsibility of the sanitary surveillance body is that of working in coordination with the suppliers and the epidemiology office of the Ministry of Health, and of correlating the information obtained from both sources, in order to identify and evaluate the risk factors connected with water quality and the supply service which can represent danger to consumers' health.

In those cases where the responsible institution has the mandate – in addition to sanitary surveillance – to effect water quality control in places not served by public or private suppliers, it is essential that there be two executive units working independently. This will reduce to a minimum the likelihood of disputes that would arise if both activities were carried out by a single institution. In this way, problems detected by the control unit or observations made by the sanitary surveillance unit can be tackled independently by each of the parties involved, maintaining a relationship between the two which is similar to that described between the supplier and the sanitary or operational surveillance body.

Water quality control is carried out by the supplier. Within the supplier's organization, the quality control department is responsible for planning, sampling, inspection, recording, identification of support measures, and follow-up of corrective measures. This department must work with, and coordinate with, the highest levels of the organization, especially its management, and act as a support unit in decision-making processes.

Diagnoses made by the water quality control area, and corrective measures it designs will be based on results obtained by the quality control program in its two basic aspects: analytical (results of laboratory analyses) and sanitary inspections.

It is of the utmost importance that the water quality control department in the supplier's organization work independently from the water production and distribution areas, and independently from the laboratory. However, there must be constant coordination between them to deal with aspects of the safety and effectiveness of the different processes of obtaining, maintaining and re-establishing – when necessary – water quality. The water production and distribution areas must not take any steps to re-establish the treatment process or supply service in an affected area without first obtaining the approval of the quality control department.

By the same token, the commercial, engineering, hydrology, treatment plant, human resources development and public relations areas, among others, must maintain a close coordination with the water quality control department with respect to their responsibilities

Finally, it is important that the organizational structure of the areas responsible for quality control in the water company, and for sanitary surveillance in the surveillance body, be conducive to ensuring compliance with the legislation, standards or codes of practice on drinking water quality. Their organizational structures should also be such as to enable the two units to undertake complementary tasks.

### *1.6 Goals and Priorities*

When identifying goals, we must bear in mind that sanitary surveillance does not only contribute to the protection of public health and promote improvement in water quality: it also influences the quantity, coverage, cost and continuity of the water supply. For that reason, a systematic data analysis program needs to be set up, to analyze the data obtained by the supplier and those produced by the responsible surveillance unit.

The effectiveness of the surveillance work depends on good planning and specific objectives. The objectives will vary according to the country's national and regional conditions and priorities. They include: a) monitoring quality trends in the water supply service; b) identifying the main deficiencies of the water supply services; c) verifying the operational efficiency of the treatment plants; d) making information available at the pertinent levels for planning future investments in rehabilitation, improvement or expansion of the water supply service; e) detecting sources of contamination; f) improving standards, regulations or codes of practice aimed at enhancing the quality of the services; g) providing sanitary education for users of water supply services, etc.

Goals serve as a link between complementary or specific objectives and the work plan, and should be reviewed periodically to make sure they are consonant with the current situation. When setting up a surveillance program, the goals are usually: a) to make an inventory of the water supply systems; b) to establish methods for water analysis, sampling, data collection, etc.; c) to install regional laboratories for the verification of results from the sampling program; d) to provide training in surveillance; e) to establish the scope of surveillance; f) to define how information will be processed and the kinds of reports to be written, etc.

With respect to the analytical determinations that should be included in the planning of surveillance programs, it must be stressed that the microbiological quality of drinking water is of prime importance, and top priority must be given to monitoring a bacterial indicator such as total coliforms and thermotolerant coliforms. Chemical pollution is also important, but frequently fades to irrelevance in areas where microbial and parasitic diseases are rife, so it is of lower short-term priority.

Some of the concepts mentioned for surveillance in general can be applied when planning and defining the goals for water quality control programs, but generally speaking the supplier places greater emphasis on improving water quality and the supply service than on sanitary education.

Finally, the supplier must be responsible for carrying out a continuous and effective water supply program, including sanitary inspection, supervision, preventive maintenance, continual testing of water quality and preventive and corrective measures aimed at guaranteeing the quality of the water supplied, and in some special cases, the conservation of water quality inside the home.

### *1.7 Regulatory Entities*

The objective of regulatory entities is to guarantee that the water service is provided under the best possible conditions of quality, thereby contributing to the preservation of the health of the population by improving the quality of the water supply.

The regulatory entities are institutions with functional autonomy, and they usually have the following characteristics:

- They issue directives or standards requiring water suppliers to comply with the regulations promulgated by the sanitary authorities. In no case should these directives contradict stipulations made by the sanitary authorities, but they could be even more stringent than the latter in order to achieve a better quality of service.
- They supervise the services of water supply, and sewage and drainage systems.
- They assess the performance of water suppliers at the national, regional and local level, and promote their development.
- They apply sanctions to suppliers which fail to comply with the regulations.
- They validate, process and assess the information provided by the water suppliers. This enables them to have reliable information available on the quality of water produced, supplied and consumed, as well as the quality of the service provided to the community.

The scope and responsibilities of the regulatory entities mean that they are ideal entities for supporting the program of sanitary surveillance of public water systems, since they facilitate the work of the surveillance body from a functional and economic point of view.

The sanitary surveillance body can thus be backed up by the regulatory entities in its supervision of the suppliers' performance. By crossing the information supplied by the regulatory entity with the epidemiological reports, the surveillance body can identify any deficiencies which might have allowed pathogenic agents and physical and chemical contaminants to be transmitted in the water provided to consumers by the supplier. It can also identify in this way the improvement of standards for drinking water quality and for regulations or procedures to be employed in the design, construction and management of the water supply system, and standards referring to the chemical products used in water treatment. The regulatory entity thus plays a "watchdog" role from the operational point of view, and the information obtained in this way often proves crucial for carrying out sanitary surveillance.

### *1.8 Citizen Participation*

In the framework of sanitary surveillance of water quality, participation by the users of the supply system is indispensable. As customers, they have the right to take part in making decisions about their own future, and it is to be hoped that they will be the first to identify the problems. As a result, it is the customers who will be able to warn the supplier and demand the timely adoption of corrective measures.

In addition, if the surveillance personnel establish a close link with the customers, a climate of trust is created, which in turn generates interest and enthusiasm, leading to the implementation of other activities, principally educational, for the adoption of good habits of personal and home hygiene, when necessary.

In small and medium rural and periurban areas, community participation in surveillance activities can take place in a variety of ways. The community can:

- Cooperate in data collection.
- Help surveillance staff to collect water samples.
- Control quantity and quality of drinking water.
- Periodically report results to the sanitary surveillance body.
- See that the water supply is put to proper use.
- Set priorities in the implementation of corrective measures.
- Take on the maintenance of the water supply system and simple repair work.
- Request qualified staff to deal with problems which require special attention.

In order for the participation of the community's water management committee to be truly useful, it will be important to implement a simple and effective method for the identification of consumer health risks associated with the water supply, complementing it with training in the application of surveys on basic sanitation and in the identification and adoption of corrective measures. Finally, training of members of the water management committee and community health promoters should be considered, with a view to guaranteeing the sustainability of the water supply system and improved habits on the part of the service users, mainly with regard to water management and conservation.

## 2. Elements of Surveillance and Control

The WHO has defined three basic elements which every surveillance program must contain and which are perfectly applicable to the quality control of water effected by the supplier. In addition to these basic elements, there are others that can be regarded as support activities and that contribute to the execution of surveillance and control programs.

The basic elements are:

a) Evaluation of the physical, chemical and microbiological quality
b) Sanitary inspection and operational inspection
c) Institutional evaluation.

In turn, the complementary or support elements are:

a) Regulations and standards
b) Human, material and economic-financial resources
c) Training
d) Sanitary education
e) Surveys
f) Information flow.

Figure 2 shows the different elements that make up a program of surveillance and control of drinking water quality.

## *2.1 Basic Aspects*

### *2.1.1 Physical-Chemical and Microbiological Evaluation*

Physical-chemical and microbiological evaluation of water permits investigation of water quality and determines its acceptability for human consumption. In some cases it includes everything from sampling to reporting on the information obtained.

The water samples should be taken from representative locations at the supply source, at the outlet from the treatment process and at different points in the distribution system such as: storage reservoirs, distribution reservoirs, system components, primary distribution network, secondary network, and if possible in homes. Sampling in homes facilitates the development of sanitary education programs in the community served by the water supply system.

Physical-chemical and microbiological evaluation of water includes the following factors:

- Supply areas
- Selection of sampling places or points
- Indicators and parameters
- Determinations
- Sampling
- Frequency of sampling Places or points
- Analyses
- Quality of the analyses and quality control.

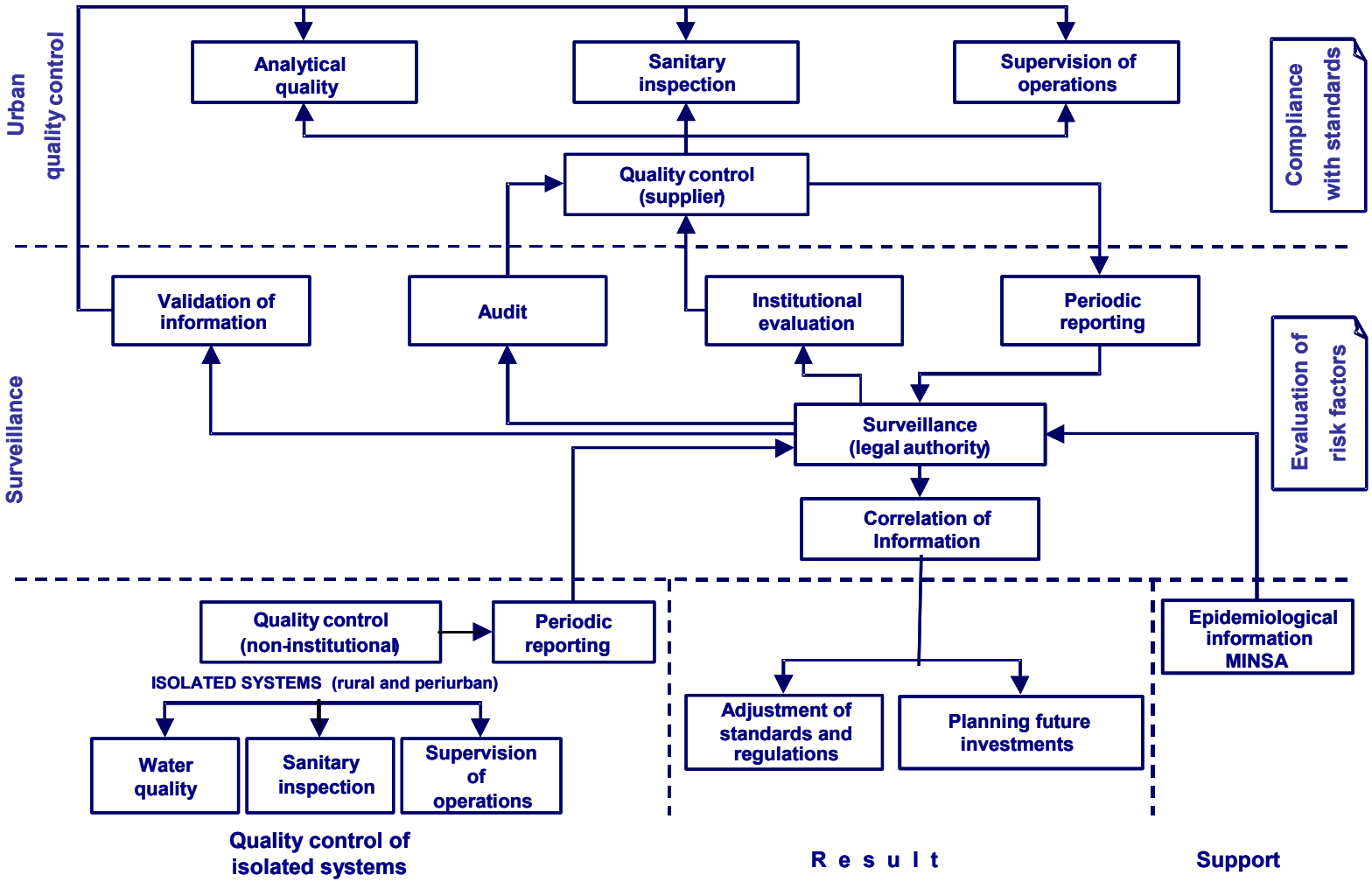


**Figure 2. Components of a Program of Control and Surveillance of Drinking Water Quality**

a) Supply areas

The WHO Guidelines (volume 3) indicate that, "in systems with more than one water source, the sampling points must be located bearing in mind the number of inhabitants served by each source."

In some countries the above concept is extended to make the quality control activities more reliable by dividing the areas served into "water supply areas," or homogeneous geographical areas in terms of (a) source; (b) components; (c) level of service and (d) quality or composition of the water.

The water supply area is considered to be "each part into which the distribution network is subdivided, considering the presence of homogeneous conditions of water quality and pressure, and/or operation related to the operation of the water treatment plant, wells, galleries, springs, reservoirs, pump chambers, or any other element pertaining to the distribution system, and in which no more than a given number of persons live, according to the supplier's estimates."

Some standards consider a population size of no more than 50,000, because this number permits a high degree of reliability in the process of quality control of drinking water. However, other numbers can be considered, but only if they reflect the true situation of water quality within the distribution system.

This zoning process requires detailed knowledge of the way in which the water supply system is operated; it must therefore be carried out in coordination with the respective technical area. The following factors need to be determined for the zoning process: the origin of the waters, the attendant components, the population being served, and the urban characteristics. This information facilitates the location of the sampling points. The frequency of sampling is then determined, as well as the number of samples required to evaluate the quality of the water supplied, at the sources, components, primary network, secondary network, and if the situation warrants it, in the customers' homes. This information can also be used in planning the corresponding sanitary inspections.

b) Selection of sampling points or places

The World Health Organization indicates the criteria to be applied in selecting sampling points. These criteria have been adapted in the present document, keeping in mind the concept of the water supply area. Thus, the sampling points must:

- Be representative of the water supply area.
- Be uniformly distributed throughout the water supply area.
- Bear a certain proportionality to the number of inhabitants in each supply area.
- Be located:

- At the outlet of the water plant, storage reservoirs, distribution reservoirs and wells.
- In the primary distribution network.
- In the secondary distribution network.
- In customers' homes in exceptional cases or to identify the content of sanitary education programs.

With reference to the characteristics of the sampling point, it has traditionally been considered that to reduce problems inherent in the *representativeness of the water sample in the distribution system*, the sampling points must be installations specifically designed for that end. However, it is recognized today that the installation of such sampling points, together with their maintenance, is an added economic burden for the supplier.

For this reason, it is now permitted to take water samples at user connections, as long as the taking of representative water samples from the distribution network is allowed, and to that effect these sampling points must be the first faucet inside the home connected directly to the distribution network, free of the influence of any type of storage within the home. In all cases, the selection of sampling points must be coordinated between the supplier and the sanitary and operational surveillance body and formally recognized by the supplier and the surveillance authorities as the only valid sampling points for any judgment regarding the quality of the water supplied.

The sampling points may be fixed or variable. The fixed sampling points are taps or faucets installed at certain points of the primary distribution network and at the outlet from the water treatment plant, wells, reservoirs, pumping stations, etc. In the case of groundwater sources (wells, springs, galleries, etc.), two sampling points must be installed, one to determine the quality of water from the source itself and the other, if such be the case, to evaluate the quality of water supplied to the population.

In the secondary water distribution network the number of sampling points per supply area must be two or three times the number of samples required, and the location of the fixed points and variable points depends on the level of risk. The fixed points are, accordingly, located in the places of greatest risk, and in each sampling campaign two thirds of the samples must be taken from these points, if possible. Areas with a history of frequent leaks, low pressure, high population density, absence of drainage, final sections of pipes, etc. are considered to be areas of greatest risk.

The variable points are located in the areas of least risk in each supply area, and in each campaign no less than a third of the required number of samples may be taken from these points.

In addition, and not necessarily forming part of the drinking water quality control program, the supplier will be at liberty to take water samples in other homes to assess the impact of storage or manipulation of the water at the intradomiciliary level. Under special circumstances the supplier may carry out quality control of the water in the customer's home at the request and expense of the customer.

c) Indicators and parameters

For surveillance of the quality of drinking water the World Health Organization recommends the evaluation of: quality, quantity, coverage and continuity of service. These criteria have subsequently been extended and today cost is also considered. In turn, the quality indicator has been divided into: (a) evaluation of water quality; and (b) sanitary inspection of the water supply system. See Table 1.

In the case of water quality control programs where the coverage, cost, continuity and quantity are known, the evaluation is normally reduced to determining the quality of the service in three aspects: analytical, physical conditions of the infrastructure, and operational conditions of the water distribution system.

d) Determinations

The determinations to be carried out by the water supplier must be in agreement with the water quality standards, with the competent authorities, and with the analytical capacity of the laboratory. Table 2 lists the principal analytical determinations that are recommended in the execution of water quality surveillance and control programs; they are grouped according to their analytical complexity, which can also be taken into account for the duly defined different levels of surveillance or control.

e) Sampling

The physical-chemical and microbiological analyses lack any value if the samples analyzed have not been properly collected, stored and identified. Although the recommendations regarding the handling of the samples depend on the parameters to be analyzed, it is recommended that the least possible amount of time be allowed to elapse between the taking of the sample and its analysis; in some cases it should not exceed six hours, and in special circumstances the analysis should be performed within 24 hours of sampling. In addition, the samples must be dispatched in cool boxes, be kept out of the sun, and be packed leaving enough space for a coolant.

Qualified staff must carry out the sampling. They will be able to ensure that the samples are representative of the water being supplied to the customers and that their composition will not be modified during the sampling and transportation. To this effect, the sampling staff must be trained to comply strictly with the prescribed procedures of sampling, preserving, packing and transportation to the laboratory, as well as to determine the content of free chlorine and pH.

**Table 1. Indicators for the Water Supply Service**

| | |
|---|---|
| **Coverage:** | Percentage of the population supplied by a specific water supply or source. |
| **Quantity**: | Volume of water used for domestic purposes in a determined time-span (usually expressed in liters per person per day) and known as "water supply." |
| **Continuity:** | Proportion of time the water is available to the customer (in a faucet or water pipe), or the proportion of days the water is distributed by other means. |
| **Quality:** | Fitness of the water for human consumption and for all domestic purposes including personal hygiene. It is verified by:<br>- analyses of the physical, chemical and biological characteristics;*<br>- sanitary inspection of the system to investigate the risk of contamination. |
| **Cost:** | Value of the water supplied for domestic use (usually expressed as a rate). |

* In areas or countries with high mortality due to diseases of fecal-oral transmission, it is more important to carry out analyses of fecal indicators (thermotolerant coliforms).

**Table 2. Recommended Analytical Determinations**

| | | |
|---|---|---|
| **a) Initial level** – Chlorine residual (total, combined and free) | | |
| **b) Basic level** | | |
| Turbidity | Odor | |
| pH value | Taste | |
| Chlorine residual (total, combined and free) | | |
| Total coliforms | Thermotolerant coliforms | |
| **c) Intermediate level (**volumetric) – In addition to the previous | | |
| Total hardness | Calcium | E. coli |
| Alkalinity | Magnesium | |
| Residual - dissolved / total | Chlorides | |
| **d) Intermediate level** (colorimetric) – In addition to the previous | | |
| Sulphates | Color | Nitrite |
| Manganese | Chromium | Nitrate |
| Fluoride | Iron | |
| **e) Advanced level** – In addition to the previous | | |
| Aluminum | Mercury | Lead |
| Arsenic | Barium | Copper |
| Cyanide | Zinc | Sodium |
| Cadmium | Selenium | Phenols |
| **f) Complete level** - Other determinations of organic and inorganic substances | | |

f) Frequency of sampling

The objective is to determine the continuity of follow-up on drinking water quality that needs to be carried out. The frequency of sampling in the distribution system should take into account the population of each supply area and its category, i.e. urban, periurban, or rural. Thus, in highly populated supply areas, samples must be taken more frequently than in less populated areas.

The WHO Guidelines are very clear with respect to microbiological quality in the system of distribution, but somewhat vague when dealing with the physical-chemical aspect as well as with regard to the evaluation of the water at the treatment plant outlet, water wells and components of the distribution system, so it is left to the judgment of the supplier to determine the frequencies of sampling, bearing in mind the quality of the source and its variability.

Tables 1 to 6 of Annex 1 can be used as a guide in this matter. The tables give suggested sampling frequencies for each type of analysis and for each type of component of the distribution system. These tables were prepared for supply areas of up to 50,000 inhabitants and for two working conditions: standard and reduced, but they can be adapted for smaller sizes and for different degrees of reliability.

The standard condition refers to the number of samples the supplier normally has to take from the supply areas in order to demonstrate compliance with the values laid down in the water quality standard for each parameter. The reduced condition is adopted by the supplier when, after a certain number of years, usually three, the parameters comply with the values required by the water quality standard. If for any reason the values stated in the standard on drinking water quality are not being complied with, the supplier must proceed to increase the number of samples according to the condition of sampling encountered. Thus, if it is in reduced condition it must be returned to standard, and if it is in standard condition the sampling frequency must be increased by 50 or 100 percent.

For supply areas or service reservoirs that supply or store a combination of groundwater and surface water, the tables for surface water are to be applied.

g) Analyses

Physical-chemical and microbiological analyses must be carried out following standardized procedures so that the results produced by the different laboratories in charge of surveillance and control are compatible and can validly be compared.

National and international agencies have published standardized methods for water analysis. It is often considered that adequate analytical accuracy can be achieved by using a particular analytical method. Experience has shown quite the contrary, since a series of different factors can influence the outcome of the tests, regardless of the analytical method used. Such factors include: the purity of the reagents, the type and the operational conditions of the equipment, the degree of

modification of the analytical method by the laboratory, the analyst's skill, and the care taken by the analyst. These factors often vary over time, even within one same laboratory.

For that reason, it is recommended that in programs for the surveillance and control of drinking water quality the analyses be carried out using universally accepted procedures in order to guarantee the results of the analyses and make sure they are comparable. Among the most well-known procedures are the methods recommended by the International Organization for Standardization (ISO) or the Standard Method for the Analysis of Water and Sewage published by the AWWA, USPH and WPCF of the United States of America.

h) Quality of the analyses and quality control

Normal methods of water analysis to be adopted by surveillance and control programs must be tried out under local conditions to test their accuracy and precision, because the use of standardized methods does not necessarily guarantee reliable and accurate results.

In the context of analytical work the terms analytical quality control and quality assurance are used. Analytical quality control occurs at two levels, internal and external, and is aimed at checking the level of reliability of a given method of analysis. Normally it is expressed in terms of accuracy. If to this internal quality control is added external quality control performed by a specialized institution other than the laboratory, it is possible to obtain the certification of the analytical procedures of one or more physical, chemical or microbiological parameters. In this case the laboratory is known as a “Certified Laboratory,” but its "certified" status refers only to the authorized determination or determinations.

Analytical quality assurance encompasses all the methods adopted by the laboratory, and guarantees to those receiving the data that the laboratory is producing valid results. Thus, the quality assurance process covers the control of analytical quality, the competence and capability of the staff responsible for carrying out the analyses, the guarantee that the laboratory has established a process of control and calibration of the equipment and analytical instruments, control of the reagents and procedures of analysis, meticulous documentation of the analytical methods, availability of the data retrieval system, proper management of data, etc. A laboratory found to comply with this procedure is commonly known as an “Accredited Laboratory.”

Finally, the laboratory must design and apply a safety policy which includes cleanliness, disinfection, control of dangerous substances, proper waste disposal, etc.

### *2.1.2 Sanitary and Operational Inspection*

a) Sanitary inspection

In most cases, sanitary inspection enables an accurate interpretation to be made of the results of laboratory tests. No laboratory result, however carefully the test has been conducted, can be a substitute for comprehensive knowledge of the physical conditions existing at the source of supply, in the treatment area and throughout the water distribution system. Unlike laboratory results, which reveal the condition of the water at a specific time and alert us to the presence of pollution when it has already occurred, sanitary inspection provides advance identification of risks that can result in water contamination or failures in the operation or maintenance of the water supply system.

Sanitary inspection should be carried out by competent staff members. By making a visual inspection of the physical conditions of the components of the water system, and observing the practices exercised throughout the system, they will detect the presence or possible presence of factors which indicate that the quality of the water for human consumption is liable to deteriorate. Especially designed "sanitary surveys" are applied for this purpose. The sanitary inspection comprises: (a) evaluation of the physical conditions of the system, and (b) evaluation of the conditions of hygiene. The "physical conditions" of the supply system refer to the structural safety and operational safety provided by each of the components that make up the water distribution system, as well as the structural and operational safety of the treatment plant, in the preservation and conservation of water quality.

Following the WHO Guidelines, Table 7 of Annex 1 contains the recommendations regarding the number of sanitary inspections to be performed per year and per component of the water supply system. The lower number of inspections will be applied when at least the three last inspections indicate an absence of sanitary defects.

b) Operational inspection

A water supply of poor quality or the deterioration of the original quality within the distribution system is common in developing countries, and this is frequently due to human error or the inexperience of the staff responsible for managing the treatment plants or production centers such as wells, springs or galleries. They are not the only culprits however: also to blame are bad conditions of the storage elements, regulation devices, and pipes of the drinking water distribution system.

The operational inspection therefore plays a relevant role. It seeks to determine the capacity or skill of those responsible for managing either whole processes or individual operations of the different elements of the water supply system. This operational inspection is an activity aimed at assessing the operational staff and identifying their capacity and competence in terms of job compliance, as a means of minimizing the risks of contamination of the water intended for human consumption. It goes without saying that the operational inspection is linked

with the training or development of human resources, because it enables us to identify gaps in the knowledge of the staff in general and of top-responsibility specialist staff in particular.

### *2.1.3 Institutional Evaluation*

One of the most significant factors in complying with water quality control tasks is the organizational structure of the supplying company itself. The institutional evaluation analyzes the entrepreneurial context in which the unit in charge of performing quality control of drinking water carries out its work, to identify any condition that may constrain or influence that unit's performance or results.

The institutional evaluation examines, among other aspects, the existing organizational model; the institution's policies on water quality control; the vision of its goals on different time horizons; the vertical and horizontal coordination relationships between the control area and the management, as well as with the other areas of the institution; decision-making mechanisms and levels; etc.

The water quality control area also needs to be evaluated on its organization, responsibilities, financial, material, technological, and human resources, experience, and relationships with other institutions, mainly with the surveillance body, etc.

## ***2.2 Support Aspects***

### *2.2.1 Regulations and Standards*

Within a country's body of legal instruments, the standard on the quality of water for human consumption can hardly be said to hold a preponderant position. However, if this standard is not well structured or is not well adapted to the conditions of the country or region in question, the whole legal structure in support of the standard will be of little value in itself, and of even less use in ensuring successful surveillance and quality control programs.

The standard provides a yardstick by which we can evaluate the operational processes, and measure their efficiency and also their cost. An over-demanding standard will imply higher or extra operational expenses for the suppliers, thereby impacting on the water rate, while an over-lenient standard is in itself conducive to sanitary risk which will directly affect the users of the water supply services.

The promulgation of the water quality standard should be the responsibility of a specific institution (usually the Sanitation Authorities). However, it should not be drawn up unilaterally; rather, it should be the product of a multi-institution and multi-sector exercise, where all the parties involved in the water supply service are entitled to express their viewpoints. Regardless of which institution has the authority to issue the standard, a water quality standard must be the result of a negotiated process involving all the stakeholders.

Since 1958, the WHO has periodically (approximately every ten years) published documents that have served as a basis for the drawing up of national standards on the quality of water for human consumption. These documents provide a series of sanitary criteria and a list of parameters with values indicative of the highest concentrations that drinking water is permitted to contain if it is to be qualified as safe for human consumption.

Volume 1 of the current WHO water quality guidelines lists a large number of possible pollutants, in an effort to respond to the needs of the different countries. However, it is unlikely that all the pollutants mentioned in those guidelines will be present in the supply water of any one given country. An attempt to follow the WHO guidelines indiscriminately could therefore lead to a situation in which the water standards adopted by a country do not address its real public health needs, and will in fact become a serious obstacle during the implementation of water quality surveillance and control programs.

It is highly to be recommended that the national drinking water standard be a realistic one; the sanitary risk to be taken must be proportionate to the cost of the prescribed measures. Consequently, those responsible for drawing up the water quality standard must take special care with the selection of parameters, taking into account the health, technological, economic, social, and cultural reality of their country, the types of human activities carried out there, as well as geological features of the country in general and of the regions in particular, and the size of the cities. In addition, in those countries where economic and human resources are limited, short- and medium-term goals should be set for the surveillance and control of water quality, in such a way to ensure that the most serious and most common risks to human health – those normally associated with microbiological contamination – will be the first to be identified and brought under control.

It should be emphasized, moreover, that there is no obligation to include relatively insignificant chemicals in the standard, or those that have little impact on the public health of a country or specific region. Normally, the inclusion of negligible chemicals results in an effort that does not draw any response from the water suppliers or even from the surveillance body itself.

In the identification and selection of the pertinent parameters, we need to evaluate the risks to which the consumers of the water will be exposed in the event that higher values than those suggested in Volume 1 of the WHO Guidelines for Drinking-Water Quality are adopted. The assessment must take into account the clinical, physiological and epidemiological considerations indicated in Volume 2 of the Guidelines (Health Criteria and Support Information) in order to adjust the values or concentrations of the selected parameters to the actual situation of the country, state, region, or province.

A procedure that has been successfully applied is the development of an "indisputable and unappealable" framework standard to be adopted in its entirety by the provinces or states of the country for the drawing up of their own local standards. However, those responsible for preparing this framework standard must bear in mind, as previously mentioned, the real conditions of the individual provinces and their different situations in terms of physical, technological, and human resources. The framework standard must be flexible enough for the standards derived from it to be

able to select their parameters and adjust their values while respecting the limits. expressed in the framework standard. This will lead to the application of differentiated standards for the different regions of the country and even for distinctions between large urban supply systems and those designed for small communities.

A good way of achieving flexibility in the values of the framework standard parameters is by classifying them under "desirable values" and "maximum permitted values" (MPV). The desirable values would be the “Guide Values” (GV) recommended in the WHO "Guidelines for Drinking-Water Quality”. The “maximum permitted values" (MPV) would define the quality of the drinking water as that which may be consumed with a greater risk to public health than that corresponding to the guide value, but which has been defined based on the efficiency of the treatment facilities and of the human, economic, and material resources of the country. In the surveillance tasks, under no circumstances may the MPVs be exceeded.

Likewise, under the authority of the law, it could be possible to establish provisional standards, authorized diversions, periods of grace, and even exemptions, as part of a national or regional policy. This would give a margin of flexibility and enable water suppliers to meet the quality goals in stages, thereby preventing local initiatives or private interests from unilaterally imposing their criteria on the quality of drinking water.

In this way the surveillance authorities and the water supplier will be able to design clear strategies for setting gradable goals on water quality. A program based on modest but realistic goals and which includes few parameters but accessible ones, and at the same time provides a reasonable degree of protection for public health, is nearly always more effective than an over-ambitious program.

### *2.2.2 Resources*

a) Human resources

The quality of the information produced by the supplier or by the surveillance body depends on the work carried out by the staff responsible for analyses, sanitary inspections, data processing, etc. It is therefore essential that staff members be trained to do their jobs properly. Good training will ensure that data are produced using standardized procedures, thereby allowing the data to be compared validly by the different persons and units involved in the surveillance and control work, and facilitating the systemizing of information at the regional and national level.

The surveillance body and the supplier should therefore design effective strategies for the ongoing development of their human resources, identifying for the different organizational levels the responsibilities, job descriptions, professional career structure, and staff motivation mechanisms.

Staff needs for the implementation of a surveillance or control program in water supply services vary a great deal and there is no reliable method of determining the number of staff members necessary to serve a given population, or the number needed for taking a given quantity of samples in different kinds of water supply systems. To estimate needs in terms of human resources, we have to take the following factors into account:

- Distance from the operational headquarters to the different sampling points or water supply systems.
- Condition of roads.
- Geomorphology of the area.
- Town development; population density.
- Size and complexity of the supply system.
- Type of vehicle used.
- Climate.
- Sampling facilities; information about the sanitary condition of the components.
- Cooperation of the community in sampling and information.
- Degree of training of the staff responsible for evaluating the water supply systems.
- Frequency of sampling.
- Types of analyses to be performed on site or in a laboratory.

b) Material resources

Under this heading we need to consider the laboratory facilities and support materials available, such as vehicles and other ancillary facilities conducive to task compliance.

As for the laboratory, whose job it is to identify the physical-chemical and microbiological characteristics of water samples obtained in the supply system in order to determine the appropriateness and safety of the treatment and distribution processes, this is the area which calls for the greatest resources – both human and financial – so laboratory work must be carried out based on a concept of efficiency and effectiveness.

In fact, the efficiency and effectiveness of the laboratory will be measured by the prompt performance of the analyses and reporting of results, as well as by the reliability of the results. To comply with this last point, a system will need to be put in place to monitor the analytical quality and guarantee the accuracy of the analytical results. The quality of the analytical information will have a direct repercussion on the identification and effectiveness of the corrective steps to be taken in order to amend defects in the supply system which have given rise to the deterioration of water quality.

With regard to equipment, the laboratory should have a variety of materials congruent with the level of surveillance or control planned for the country, region, or locality. Generally speaking, laboratory materials fall into the following categories:

- Equipment and instruments.
- Furniture.

- Reagents for physical chemical analyses and culture media for bacteriology.
- Laboratory glassware.
- Miscellaneous materials and calibration reagents.

In principle, analyses should be carried out in a laboratory as near as possible to the place from which the samples are obtained, in order to reduce to a minimum the risk of their being altered during transportation, mainly in the case of the microbiology samples. An added advantage is that the closer the laboratory, the lower the transportation costs.

Whenever it proves impossible to implement laboratories with an ample analytical capacity, modest laboratories may be used, in which a relatively small number of simple determinations are carried out, especially of critical parameters. In such cases, tests for heavy metals and organic compounds are referred to specialized laboratories. Normally, the number of determinations per year of heavy metals and organic compounds is small; besides, this type of analysis calls for sophisticated equipment and highly trained staff, very rarely found in small laboratories.

With reference to the organization of a system of surveillance laboratories, it will nearly always be necessary to have a structure based on a central laboratory, a certain number of regional laboratories, and a series of basic laboratories at the district level. This structure may be complemented with staff using portable equipment to make on-site measurements of the most important parameters, as a means of ensuring greater decentralization and coverage.

The central or referential laboratory should be an accredited one or, in its defect, one certified by an organization of recognized prestige in the region or worldwide. It should be equipped to deal with the whole series of parameters set down in the quality standard for drinking water. The central laboratory, besides complying with these tests and fully guaranteeing the quality of its own analyses through a quality assurance program, should also be responsible for performing external control on the quality of the analyses performed by the smaller laboratories.

The regional laboratories should be capable of carrying out a moderate series of physical-chemical and microbiological analyses, which must be subject to quality assurance programs to guarantee their quality. In addition they should have the capacity to offer support services to the district laboratories or to the staff carrying out tests using portable equipment. Figure 3 shows the recommended analytical capacity of the different types of laboratories entrusted with the sanitary surveillance of drinking water quality.

Another element of the utmost importance in the tasks of surveillance or control of drinking water quality is transportation. The means of transportation must be suited to the climate, terrain and local customs. The different options include using four-wheeled vehicles (normal or four-wheel drive), motor-cycles, bicycles, beasts of burden, boats, as well as going on foot. One of the criteria to determine the most suitable means of transportation is the time that will elapse between the taking of the samples and their arrival at the laboratory. The operational and maintenance costs of the different means of transportation will also have to be taken into account, as well as their service life.

In different areas a duly conditioned motor-cycle has proven highly adaptable to the requirements of programs for the surveillance and control of drinking water quality. Motor-cycles can usually carry both the portable equipment for analyses and the training material; they are a far cheaper option; they can take the staff quickly from one point to another over any kind of terrain; and, last but not least, they are less likely to be pressed into service by other departments.

The staff must also be provided with everything they need to discharge their duties, such as identification, the right kind of clothing for the climatic conditions of the work area, facilities for the preservation and transportation of water samples, and office supplies that enable them to record information *in situ*.

c) Economic and financial resources

The central or regional governments normally finance the institution responsible for sanitary surveillance at the national or regional level, as part of the country's policy to safeguard the health of the population.

In large cities, where there is a corporation responsible for the water supply, a large portion of the cost of sanitary surveillance is usually assumed by the supplier, taking advantage of the results of activities undertaken for the quality control of the water it supplies. In such cases, the cost of the sanitary surveillance is automatically passed on to the customer in the water rate.

In the surveillance and control of small and medium-sized rural water supply systems, where the cost-benefit ratio is far higher than in larger localities, strategies must be adopted to reduce surveillance and control costs to a minimum, mainly in the budget lines of laboratories, staff, and transportation, which are normally those that demand the highest expenditure. One strategy in this context is to make use of the organizational structures already existing in the communities, for example the committees responsible for managing the water supply systems, and the community health promoters.

Frequent trips to rural communities to take water samples or to inform community authorities about the condition of their water distribution infrastructure are expensive, so every effort should be made to reduce trips to a minimum. In such cases, the possibility should be evaluated of having staff spend the night in the communities, and using portable water analysis equipment in situ. In this way, before leaving the community, the staff member entrusted with the surveillance and/or control will be able to give the results of the evaluation to the community authorities right away, for them to take the necessary corrective measures to improve the quality of the water in the supply system.

Besides, an overnight stay in the community often provides a good opportunity for the surveillance staff to train the members of the community's administration committee in aspects of management of the water supply system and to train the community health promoters in aspects of health and hygiene.

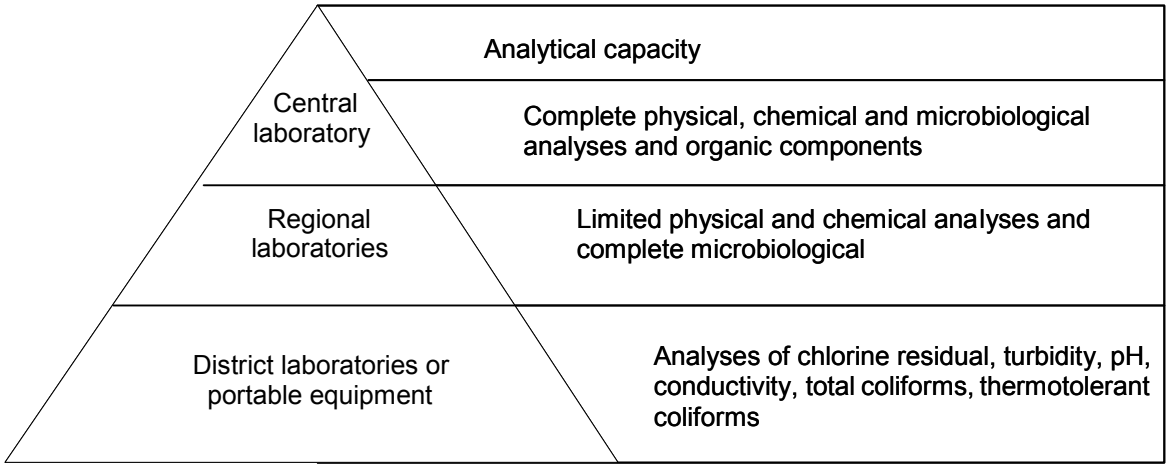


**Figure 3. Example of the Analytical Capacity of the Laboratories of the Surveillance System**

### *2.2.3 Training*

The success of programs for the surveillance and control of water quality depends on the quality and quantity of the human resources, so it is essential that ongoing training programs be designed and conducted. Training, as opposed to "education," is a non-formal process of permanent self-teaching, and therefore its objective is the growth of the individual, the development of his or her faculties, creativity, and professional and social values. This integral human growth of an individual directly benefits the institutions in which he or she works. For that reason, the training mission is to offer guidance and training to all staff members involved in surveillance and control work, as well as to community health promoters and those who carry out administrative functions in rural communities, to encourage them to support the water quality surveillance and control activities.

The training should provide the knowledge and skills required for proper compliance with the various tasks. It should enable the trainees to reach institutional objectives and meet their individual goals, teaching them to ensure a good quality of drinking water by means of planned, permanent actions. Training should also include management practices and technical skills, in keeping with the decentralization and other innovations proposed by state modernization schemes.

Keeping the surveillance and control staff updated calls for institutionalization of the training activity. Suitable premises will be required, as well as offices, a sufficient number of trained technical staff, a budget to cover the permanent organization and conduction of quality events, and a sufficient number of such events to guarantee the transfer of technology to those

responsible for surveillance and control tasks. These training programs should be planned for implementation on a continuous and repetitive basis in order to keep the present staff updated and to train new staff replacing the former as they may leave the company for retirement or other reasons, or are transferred away from the unit in charge of surveillance or control of water quality.

The areas where training should normally be given are:

- Surveillance and control
  - Basic concepts
  - Planning
  - Execution
  - Sanitary and operational inspection
- Sampling
  - Taking samples
  - Preservation
  - Identification
- Transportation
- Handling of portable equipment for analyses
- Water analysis
  - Physical
  - Chemical
  - Bacteriological
- Analytical quality control
- Processing of information
- Identification and selection of preventive and corrective measures
- Audits
  - Sampling
  - Analysis
  - Sanitary and operational inspection
  - Institutional
- Drafting of reports

### *2.2.4 Sanitary Education*

Education is a formal process whereby persons develop as human beings, individually and collectively, in a specific cultural environment. In this context, sanitary education programs are designed to create in the population the desire to have safe water supply systems and to keep them properly maintained so that they will have a long service life. This motivation is achieved by raising the people's awareness of the correct way to use, store, and handle water at the consumer level to conserve water quality and make rational use of the water. These aspects are complemented by topics of hygiene in food-handling, hygiene in the home, personal hygiene, and disposal of excreta. The main goal of sanitary education is to help reduce water-related

diseases. The fields of action of sanitary education vary according to the type of environment — urban, periurban, or rural.

In a rural environment, education on hygiene can cover many activities based on the behavior of the community, the local climate, and the diseases prevalent in the area. In planning sanitary education on the subject of hygiene, the first stage should consist of a dialogue with the community and local organizations themselves, to identify the behavior of the community with regard to hygiene, and to assess the possible impact of the sanitary education program on the previously identified behavior patterns. The team drawing up the plan of action for education on hygiene needs to obtain answers to the following questions:

How can we motivate community participation?
What is the target group to which the education is directed?
What should the contents of the education program be?
Who should impart the education on hygiene?
What teaching methods should be used?
What kind of support should be provided by the surveillance body?

During educational campaigns in rural areas, we need to bear in mind that hygiene-related behavior patterns are particularly difficult to change for three reasons: they are linked with routine daily activities, they are common to the whole community, and they form part of the local culture and traditions. It must be realized that the improvement of the water supply service, and of sanitation and hygiene form part of an integral process of community development. It is therefore important to work with all members of the community, and in particular with the schoolchildren. The whole community should be urged to participate in all phases of the education campaign. If effective didactic methods are used, the people will be sufficiently motivated by the training to assimilate and adopt new habits of hygiene and sanitation.

Hygiene education should focus on the following behavior patterns:

- Preservation of water sources
- Water collection
- Water storage
- Protection of the water for human consumption
- Use and conservation of water in general
- Handling of food
- Disposal of excreta
- Disposal of sewage

However, it is sometimes more effective to focus on a minimal number of behavior patterns, rather than attempting to improve all those listed above at one time. Behavior patterns should be selected for attention based on the probable benefits that their modification or improvement will contribute to public health or the health of the community. In all probability, the greatest benefit to the health of users of rural and periurban water supply services will be

achieved by having the education activities focus on those habits of hygiene that the surveillance work has revealed to require priority attention.

### *2.2.5 Surveys*

Surveys are applied to determine the physical, administrative and operational conditions of the water supply systems. They enable us to identify risk factors, both material and human, that have an impact on water quality, water treatment and distribution processes, administrative and institutional aspects, and levels of hygiene — with particular emphasis on sanitation-related habits of hygiene.

Surveys are made up of several sections designed to evaluate each of the physical parts of the water supply system or the relevant institutional or administrative aspects, for either the surveillance or the control program. The survey designers should take care that the questions to be asked are as few as possible and that they are directly related to the objective of the surveillance or control activities. Moreover; each question on the survey should be examined to check its relevance to the objective of the work. The attempt is often made to take advantage of the surveys to obtain additional information, of doubtful value, and this merely hinders the act of gathering of information, with the consequent loss of reliability of the answers or results obtained. Finally, the questions must be precise and worded in such a way as to minimize misinterpretations on the part of the surveyor.

The types of survey forms usually applied in the drinking water surveillance and control programs are outlined below:

- Basic data on the water supply system and physical characteristics of each of the components it comprises;
- Referring to each of the components, its physical aspects that jeopardize or may jeopardize the conservation of the quality of drinking water. These characteristics are listed on the sanitary inspection form;
- Indicators designed to evaluate the quality of the water and of the supply service. These cover the aspects of physical, chemical and microbiological quality of the drinking water at the outlets from treatment plants and at supply sources (surface or ground), intake components of the distribution system and the distribution network.
- If possible, evaluation of the water quality in customers' homes and surveys, to determine the habits of hygiene of the beneficiary population. The latter point will probably be of greater relevance in the case of low-income sectors of the population and in small and medium rural communities.
- Indicators of the operational management of the different components of the water supply system; and indicators of the administrative management of the water quality control program.

## *2.3 Information*

### *2.3.1 Application of the Surveillance Information*

Not only is the information obtained by the surveillance body useful in assuring the quality of drinking water by protecting the consumer from the presence of harmful pathogenic, physical and chemical agents in the water; but in addition the processing of all the surveillance information produces complementary benefits. Among the most useful are the ability to identify the need for a) expansion of the basic sanitation infrastructure, b) rehabilitation of the water supply system, c) training requirements for the staff involved in the operation, maintenance and administration of the water and sanitation services, d) measures to prevent and mitigate pollution of water sources, e) updating the regulations, standards and codes of practice relating to the preservation and conservation of drinking water quality. Also, a regional or national data base facilitates the identification of needs in the water and sanitation sector and can therefore be a valuable tool in planning the country's future investment in extension of coverage, improvement and rehabilitation of water supply services, training, etc.

- **Improving the service:** The permanent monitoring of water quality helps ensure that the distribution system as a whole is working satisfactorily and providing a product that complies with drinking water standards.

- **Rehabilitation of the system:** As in the above case, both the surveillance and control of water quality lead to the identification of any physical areas of the supply system where there may be deficiencies that normally necessitate corrective measures. This identification will subsequently be translated into the execution of projects for the repair or reconstruction of the water supply system.

- **Investing in water supply:** The information obtained from the surveillance and control activities can also be used in planning projects for the extension, improvement and rehabilitation of the water supply services, as well as in determining the respective investment required at the national and regional level.

- **Training:** The recontamination of water for human consumption is a consequence of activities carried out by the supplier, mainly during the operation of the water supply system or routine maintenance work. This recontamination of water is usually associated with the use of wrong procedures, owing to insufficient knowledge on the part of the staff responsible for applying sanitary procedures to conserve and preserve the quality of water within the distribution system.

- **Updating the drinking water quality standards:** The goal of the quality standards for drinking water, is to ensure the removal – or reduction below levels harmful to human health – of harmful microorganisms and substances, for the well-being of the community. Surveillance has as one of its objectives the revision and periodic adjustment of these quality standards to guarantee that the public will be supplied with safe water, free from any danger,

harm or risk to human health. The surveillance information can also be used to revise and update the regulations and codes of practice for the conservation and preservation of drinking water quality in the aspects of design, construction, operation and maintenance of the water supply systems, including the building materials and chemicals that can be used in the implementation and operation of water services.

- **Preservation of water courses and bodies:** As in the above case, the information obtained on drinking water quality can help in the definition and adoption of national policies for the protection or the contamination of water courses and bodies.

Figure 4 shows how the surveillance and control information can be used in the improvement of the quality of water and water supply services.

### *2.3.2 Information Flow*

Communication between the water supplier and the surveillance body must be completely fluent and unrestricted; there must be permanent dialogue. The water supplier is under the obligation to report to the local, regional or national office of sanitary or operational surveillance, as the case may be, all the information obtained in the execution of its water quality control program in the supply system it administrates. For its part, the sanitary or operational surveillance body must perform strict follow-up, in particular on the procedures used for obtaining information in the field, sampling, analytical methods used on the water samples, data management, among others, in order to verify the accuracy of the results and their compliance with the regulations set by this body.

There should be a mechanism in place to allow information to flow faster in cases of emergency and/or force *majeure*, to ensure effective coordination so that corrective measures may be taken jointly and opportunely. Such an impact is highly beneficial for both institutions because the population attended to will see for themselves that joint efforts are being made by the water supplier and the surveillance body to safeguard the people's health and well-being. Figures 5 and 6 show models of information flows originated by the supplier and by the surveillance body.

At all times the supplier must be careful not to conceal information and the surveillance body must refrain from acting as an inquisitor, because this could lead to a strained or conflictive relationship between the two institutions. Worse still, if the two belong to different sectors, it may lead to problems of a political nature, which could seriously tarnish the water supplier's image.

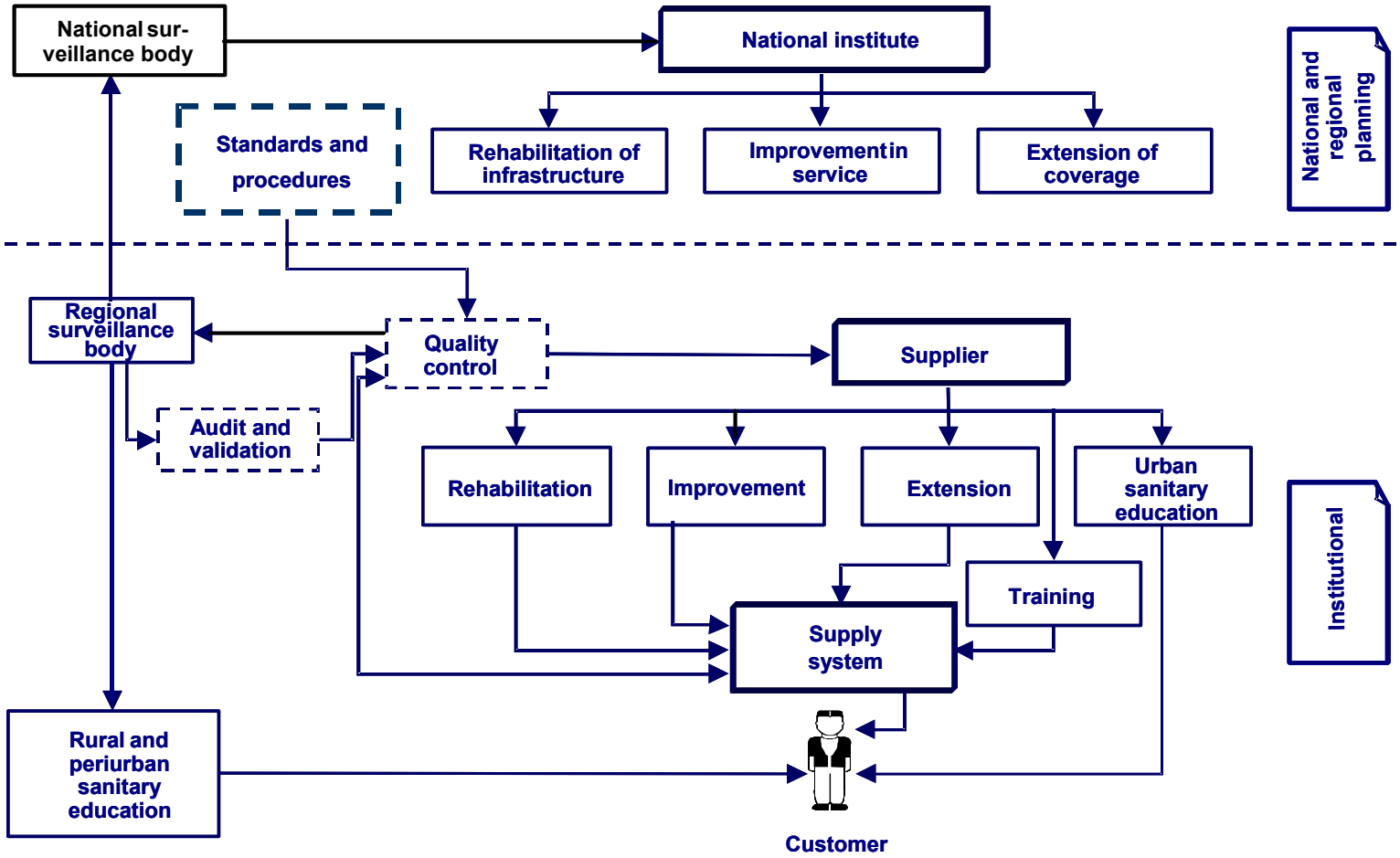


**Figure 4. Use of Information Obtained from Control and Surveillance of Drinking Water Quality**

### *2.3.3 Data Processing and Reports*

The processing of data produces information and it is the use of this information generated by the surveillance and/or control program which enables rational improvements to be made to the water supply systems, the term **rational** implying that the human and economic resources available are used with maximum efficiency for the benefit of public health.

The information obtained by the supplying company on the quality of the water it supplies and any defects that may have been encountered in its water supply system (information resulting from the sanitary inspection) must be properly validated to make sure that the data to be processed reflect as faithfully as possible the quality of the water supplied and the condition of the infrastructure. In the validation process, information that is immaterial or inconsistent from an analytical point of view (physical-chemical or microbiological analyses) may be discarded, as well as data inconsistent from a qualitative or appreciative point of view in the case of validation of sanitary inspections; so that the information to be processed and analyzed will be completely reliable. The process of validation of analytical information is carried out by means of quality assurance and quality control tests, while the validation of the sanitary inspections is performed by means of random re-inspection of a percentage of the facilities assessed.

The acceptable or reliable results should be stored in a data base, and special programs will be used to classify the information and correlate it in order to identify problems and their causes. This will make it possible, in turn, to identify the pertinent corrective measures.

In addition, the water supplier should classify the validated information per main component of the water supply system, namely: water source, outlet from the treatment plant and/or sources of groundwater, outlet from components of the distribution system, distribution network and user connections. The information should be processed at different levels: scientific, professional, management and public, each of which has a clearly defined individual focus.

Normally, the scientific level has the whole data base at its disposal, and work at this level consists mainly of using the information to find explanations for cases or phenomena that are difficult to interpret. Information at the professional level is mainly operational, since it facilitates prompt identification of defects or problems in the water supply system. Management level, as its name indicates, is information used by top management of the company to define the strategies and actions that will lead to an improvement in the water supply service. Finally, public-level information is directed to making the customers aware of the quality being provided by the supplier. The report containing public-level information should be considered a support tool for the Public Relations area.

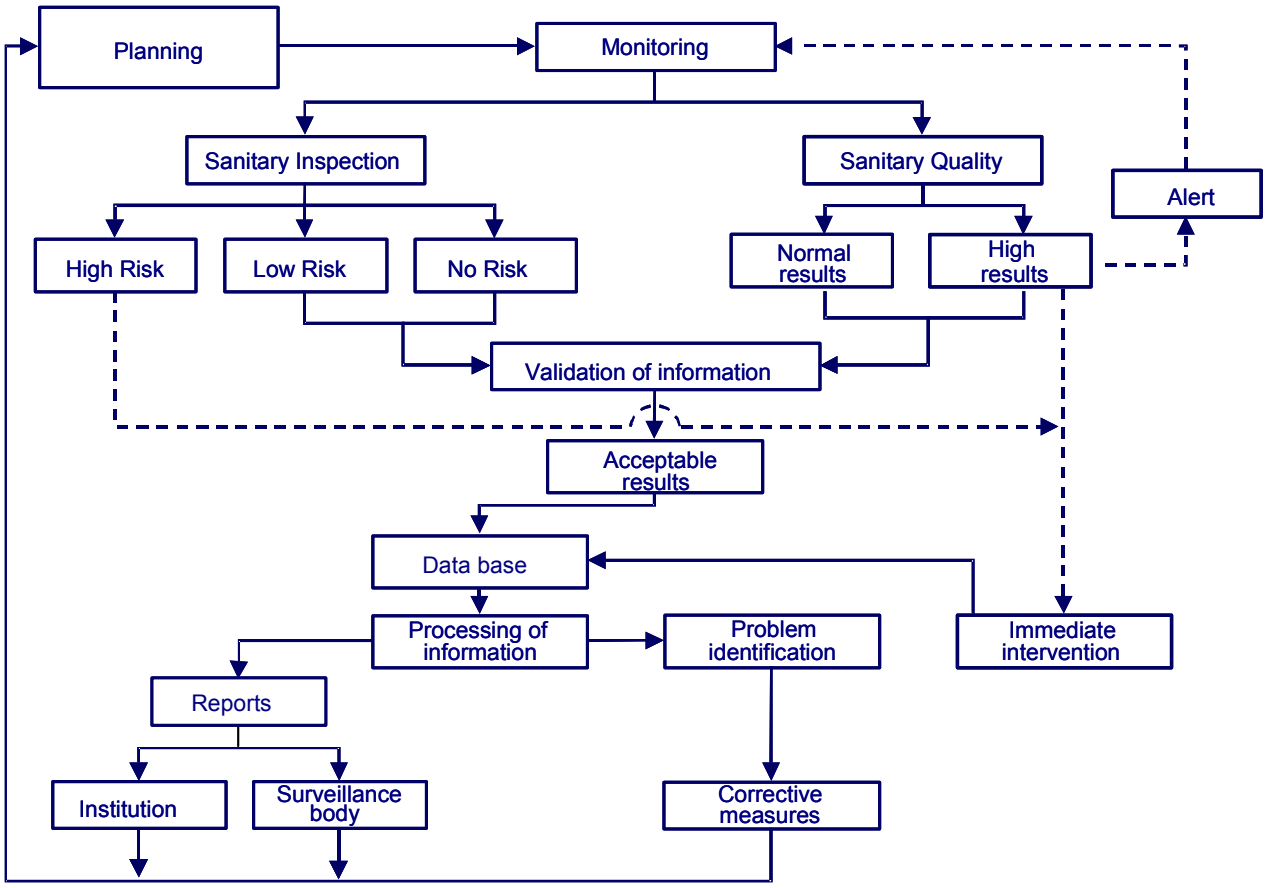


**Figure 5. Information Flow-Supplier**

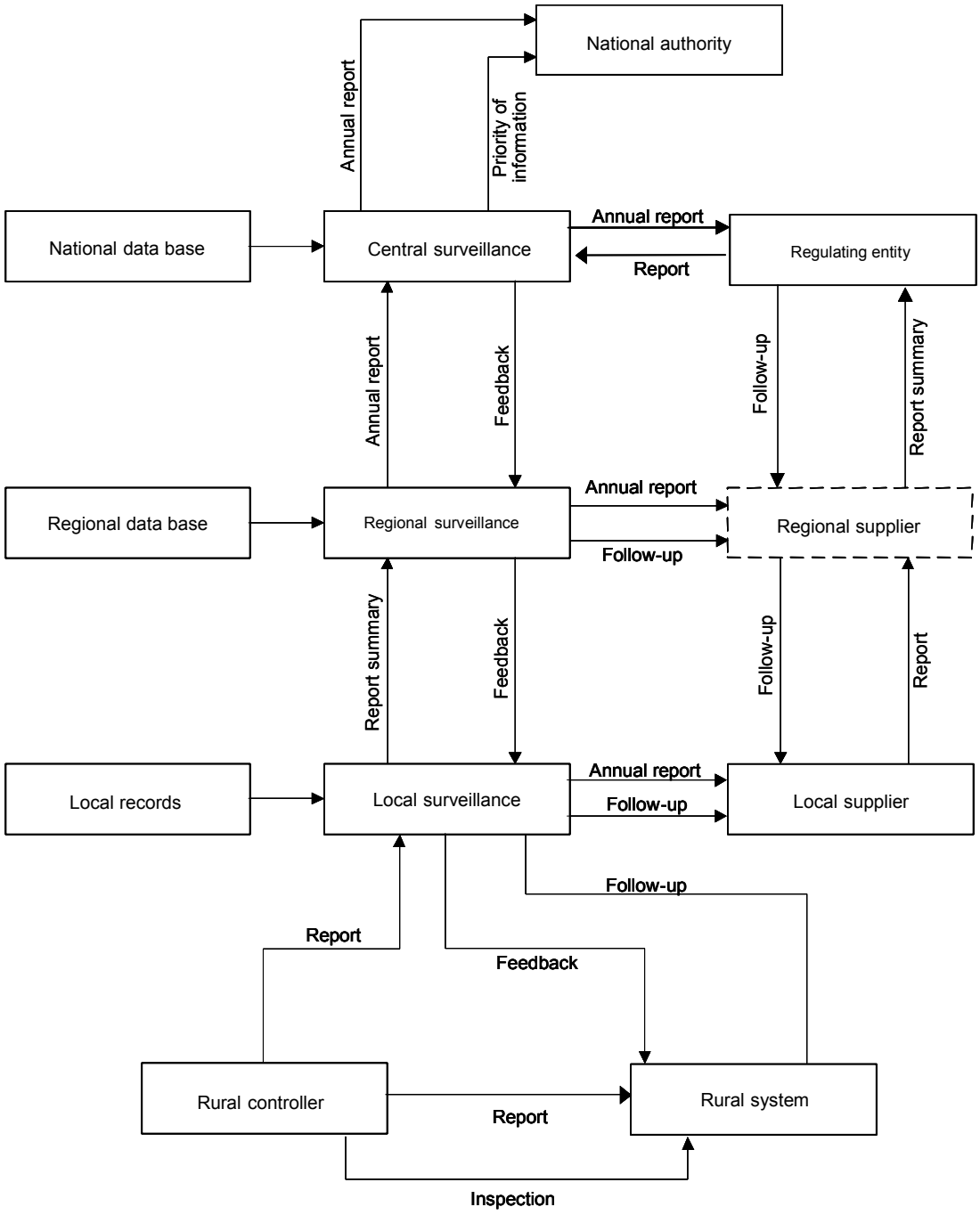


**Figure 6. Information Flow Surveillance of the Quality of the Water Supply Services**

### *2.4 Sanctions*

The surveillance function should essentially be one of support, notification and caretaking, and only in the last resort a function of sanctioning of failure to comply with standards. Nevertheless, the legal framework must specify penalties, including fines for isolated and repeated infringements, and it must clearly state that the administrators or directors of the water supply institution will be held personally responsible for serious offenses causing a negative impact on the health of the consumers, in cases where it is demonstrated that the deterioration in water quality was due to acts of negligence or mismanagement on the part of the staff responsible for managing the water supply system.

Although the scope of the surveillance program is to assure the quality of the water supplied and the adoption of measures required to correct any deficiencies observed, thereby safeguarding consumers' health, sanctions should also include the protection of suppliers in the event that they are unjustly held responsible for supplying water of an inferior quality.

Finally, the sanctions should also consider cases in which the suppliers refuse to submit periodic reports to the surveillance body, or to notify the population of certain measures to protect their health when emergency situations arise, as in the event of accidental contamination with bacteria or chemicals.

## 3. Methodologies

### *3.1 General*

#### *3.1.1 Surveillance and Control Levels*

When drawing up sanitary or operational programs for the surveillance or control of water quality, the program designers must take existing resources into account: laboratories, network of laboratories, qualified staff, financial support, transportation facilities, etc. The availability of these resources, and the legal devices already in place relating to water quality (standards or regulations) help to define the level of quality control that the water supplier can undertake in its area of service, and what the sanitary surveillance body can demand in the country, or in a given region or community.

To begin with, sanitary surveillance and control programs can be simple, low-cost and high-impact programs executing only the sanitary inspections on the physical works that make up the water supply system. This type of inspection makes it possible to identify the main defects of the components, which represent a risk for the preservation and conservation of drinking water quality within the supply system. Subsequently, they can be complemented with determinations of chlorine residual and other basic operational parameters such as turbidity, pH, etc. These last mentioned determinations can be started at the intake reservoirs, to continue afterwards with the different components of the distribution system, and subsequently cover the primary networks as far as the secondary network level.

Once the basic parameters mentioned above have been started and consolidated, the inspection can then proceed with total and thermotolerant coliforms in the same sequence indicated above, and if there is a laboratory for physical and chemical analyses, the volumetric analyses and some simple colorimetric ones can be effected, until eventually the more complex analytical determinations, such as heavy metals and organic compounds, can also be covered.

Bearing in mind the above, we can establish five levels of surveillance or control ranging from an "initial" level, applicable in the countries, regions or communities where there is very little experience in these types of programs, to a "complete" one, similar to those implemented in developed countries or regions, where water-related diseases have been brought under control.

It is important, when defining the level of surveillance and control, to take into account the real situation of the control programs available to each of the water supply services, and the capacity of response of the institution responsible for surveillance at the national and regional levels, so as not to exceed their capacities of response. Once efficiency and effectiveness have been achieved at the level of work adopted, it will then be possible to move up to the next level, but under no circumstances should an attempt be made to go on to levels beyond the capacity of response of the institutions involved; such attempts nearly always result in failure. The competent authorities' scheduling and rescheduling of levels as described above should be repeated until the desired goal is met.

Table 3 shows a matrix linking the institutional situation and the levels of surveillance proposed above, and Table 4 identifies the main activities undertaken for surveillance and control of drinking water quality at each of the five levels. Table 5 shows the main requirements to be met for each level of surveillance or control.

**Table 3. Proposed Levels Based on the Institutional Situation of The Country or Region**

| Level | | Situation of the country or region |
|---|---|---|
| I | Initial | No formal program and no pertinent authorities |
| II | Basic | Minimal program with seriously limited scope and efficiency |
| III | Intermediate | Program applicable to large cities |
| IV | Advanced | Program applicable to large and medium-sized cities and, with some constraints, to rural communities |
| V | Complete | Programs similar to those employed in the countries or regions where water-borne diseases have been brought under control |

**Table 4. Activities per Level of Intervention for the Surveillance or Control of Drinking Water**

| Activity | Level | | | | |
|---|---|---|---|---|---|
| | **I** | **II** | **III** | **IV** | **V** |
| Sanitary inspections in components of the distribution system | X | X | X | X | X |
| Elementary analytical parameters in components and primary networks | X | X | X | X | X |
| Elementary analytical parameters in secondary networks* | | X | X | X | X |
| Quantification of indicators of microbiological quality in components and primary networks | | X | X | X | X |
| Quantification of indicators of microbiological quality in secondary networks | | | X | X | X |
| Quantification of indicators of microbiological quality in sources and homes | | | X | X | X |
| Basic physical and chemical analysis | | | X | X | X |
| Intermediate physical and chemical analysis | | | | X | X |
| Complete physical and chemical analysis | | | | | X |

* Elementary analyses refer to pH, turbidity, chlorine residual and organoleptic characteristics.

### *3.1.2 Scope*

Since there is a considerable difference between integral planning for surveillance in general and the control of water for human consumption, and between urban and rural surveillance work, in this document we define the methodological procedures for each type.

Generally speaking, in the planning of surveillance and control activities, the following aspects must be taken into account:

- Identification of the basic characteristics of the water supply system
- Water quality standards, with emphasis on analyses to be effected, frequency of sampling, sampling points, etc.
- Execution
  - Evaluation of the water quality
  - Sanitary and operational inspection
  - Institutional inspection
  - Assurance of quality of the information
- Processing of the information
- Identification of corrective measures
- Reports

## Table 5. Principal Requirements per Level of Intervention

| Activity | Level | | | | |
|---|---|---|---|---|---|
| | **I** | **II** | **III** | **IV** | **V** |
| **Laws and regulations** | Elementary | Basic | Intermediate | Advanced | Complete |
| **Scope of water quality standards** | Sanitary risk | Sanitary risk and bacterial parameters | Sanitary risk, bacterial parameters, and basic physical-chemical | Sanitary risk, bacterial parameters, and intermediate physical-chemical | Sanitary risk, bacterial parameters, and advanced physical-chemical |
| **Staff responsible for surveillance and control** | Untrained Basic | Basic | Trained Basic | Intermediate | Intermediate to highly trained |
| **Operators of water installations** | Untrained Basic | Basic | Trained Basic | Intermediate | Intermediate to trained |
| **Application of sanitary surveys** | Large cities | Main cities | Main and medium cities | All urban cities and some rural towns | All urban cities and rural towns |
| **Approval of sources of water** | None | Main cities | Main and medium cities | All urban cities and some rural towns | All urban cities and rural towns |
| **Sampling** | Main cities | Main cities | Main and medium cities | All urban cities and some rural towns | All urban cities and rural towns |
| **Standardized methods*** | Residual Chlorine | Bacterial and Residual chorine | Basic bacterial, physical chemical | Intermediate microbial physical chemical | Complete microbial and physical chemical |
| **Laboratories**** | Analysis kits | Portable laboratories | Basic non-specialized laboratories | Basic specialized laboratories | Regional specialized laboratories |
| **Standards for the design of water systems** | None | Basic | Elementary | Intermediate | Complete |
| **Standards for building materials** | None | Basic | Elementary | Intermediate | Complete |
| **Complementary regulations (water tanks, bottled water, etc.)** | None | Basic | Elementary | Intermediate | Complete |

* Bacterial determinations include mainly total and thermotolerant coliforms, and microbiological determinations include the identification of protozoa, helminths and other aquatic microorganisms

** From intermediate level upward it is required to have a Central ("Reference") Laboratory.

The methodologies proposed normally aim at:

- Determining the quality of the drinking water supplied by the companies or institutions providing the water supply service.
- Identifying any sanitary defects in the different components of the supply system that may represent a risk to the conservation and preservation of drinking water quality.
- Evaluating the effectiveness of the treatment plant's processes for surface water or groundwater.
- Identifying the corrective procedures for the re-establishment and/or improvement of the drinking water quality.
- Evaluating the institutional capacity of the supplier to carry out the water quality control.
- Identifying the localities and areas of supply that are the most vulnerable and pose the highest risk to the health of the users of the water supply services.
- Planning the sampling programs of the surveillance body to validate the information provided by the supplier.
- Auditing the activities of the supplier in connection with the quality control of the water supplied to the population and other aspects of the operation and maintenance of the service.
- Supervising the application of corrective measures.
- Improving the water quality standards, and regulations relating to building processes and materials employed in the building of the water supply systems.
- Certifying the quality of the water consumed by the population served by the supplier.
- Processing the information provided by the supplier.
- Planning investments for the extension, improvement or rehabilitation of water supply services.

### *3.1.3 Fields of Action*

The fields of action for the surveillance and control of drinking water quality, in both urban and rural areas, are the following:

- **Source:** Depending whether the water is of surface or ground source and on the natural or artificial factors affecting its quality, the source of water supply can have an impact on the health of the consumers and special attention should be paid to protection, quality, and treatability. The sources are mostly raw waters of rivers, lakes, dams, wells, filtration galleries, and springs.

- **Treatment plant:** The treatment plant's efficiency in removing the compounds that affect the acceptability of the water for human consumption and human health is influenced by the quality of the raw water and, in particular, by the operation, maintenance and control of the treatment processes, which need to be more rigorous in the case of highly contaminated sources. At this level, consideration can also be given to the treated water that is supplied to the distribution network by wells, filtration galleries and springs.

- **Water distribution system:** The water treated and distributed through the supply system should be preserved and conserved until it is delivered to the customer, to ensure that it complies with physical, chemical and microbiological standards, that it is safe for human consumption, and that it therefore represents no danger to the health of the customers.

- **Consideration is given to the evaluation of:**
  - components of the distribution system (reservoirs, pumping chambers, supply pipes, etc.), and
  - the distribution system itself.

- **Intradomiciliary:** In urban areas this aspect is not usually considered in quality control programs, since the responsibility of the supplier goes no further than the limits of the customer's property. However, it is often to the supplier's advantage to carry out evaluations in the home, to clarify liabilities.

In rural areas, mainly in those places where water quality is evaluated only very sporadically and the evaluating institution plays the double role of surveillance body and controller, sampling should be carried out in people's homes as a routine part of the evaluation, as this will help identify the reach of the sanitary education programs.

In addition, in the specific case of surveillance, the following aspects should be considered:

- **Audit**: To be able to accept unconditionally the information obtained by the supplier, the surveillance body will have to implement a mechanism to verify the information and the degree of compliance with surveillance regulations regarding frequency of sampling, parameters and number of determinations, types of sampling stations, analytical quality control and validation of all the information obtained by the supplier.

- **Validation**: Periodically the surveillance body should make an operational and sanitary inspection of certain components and take samples at certain fixed points of the water supply system in order to verify that the operation and maintenance activities, the sanitary inspection and the analytical results do not differ materially from the data reported by the supplier.

- **Epidemiology**: The surveillance body should gather and process the information from the epidemiological surveillance obtained by the pertinent authorities, and identify and select all those diseases related with water quality.

- **Investigation**: The surveillance body should process the information provided by the supplier and the epidemiological data supplied by the competent authorities, and determine whether there is any link between the water quality and reported cases of waterborne diseases. If such a link is detected, the surveillance body must proceed to recommend corrective measures to be applied by the supplier and, if deemed appropriate,

these measures may be incorporated into the standards, regulations or specifications for the design, operation, and maintenance of water supply systems.

- **Control of water quality in areas under communal management**: In places that are not served by a water supplier, the Health Authorities assume responsibility for carrying out control of the quality of drinking water and act through the administrations, community leaders, or municipalities, for the execution of corrective actions. To prevent interference and misunderstanding within the Health Authorities, the institution that carries out the control activity must act independently from the organization responsible for sanitary surveillance, thereby reducing to a minimum the subjective influence of a two-fold antagonistic function.

## *3.2 Surveillance Plan*

A surveillance plan usually consists of a series of programs, sub-programs, activities and tasks to be implemented in execution of a project or development. The plan does not provide a detailed description of the contents of each activity identified; rather, it is more like a set of ideas, properly justified, that give a clear notion of the sequence to be followed in order to achieve the desired goal, the benefits to be obtained, and an estimate of the cost involved.

The drawing up of a Surveillance Plan should consider four aspects: a) diagnosis; b) the plan itself; c) intervention possibilities; and d) investment.

### *3.2.1 Diagnosis*

The diagnosis seeks to obtain an understanding of the geographic, economic, cultural, and health scenario of the country, and to present the legal framework with respect to the laws, regulations, standards, etc., associated with surveillance and control activities. This chapter could be structured in the following way:

- The country:
  - Population and its distribution
  - Populated centers
  - Population growth
  - Situation of water supply services
- The health situation:
  - Health indicators
  - Prevalence and incidence of diseases related to the quality of drinking water and sanitation; their impact on the country's economy
  - Attention by the Ministry of Health
- Preventive health programs:
  - Health programs
  - Investment in preventive health

- Surveillance and control:
  - Legal framework (laws, regulations, standards, etc.)

- Prevention of transmissible diseases by providing an adequate supply of drinking water:
  - Surveillance and control programs
  - Evaluation of the surveillance and control system

### *3.2.2 The Plan*

The field of action of surveillance and control is defined in detail. This chapter could have the following contents:

- General (summary of the plan itself)

- Main goal and specific objectives

- Strategies

- Hoped-for results

- Fields of action:
  - Sources of supply
  - Production
  - Distribution network
  - Operational and institutional evaluation
  - Etc.

- Scope of the surveillance and control program
  - Levels of surveillance:
    - Water supplied by distribution networks (urban and rural)
    - Water supplied by public faucets, tank trucks, or individual sources
  - Analytical determinations:
    - Outlet from treatment plant
    - Components of the distribution system and primary network
    - Distribution system
    - User connections
  - Frequency of sampling:
    - Bacteriology
    - Physical and chemical
    - Sanitary inspections

- Programs
  - Operational

1. Water analysis
   - Quality standard
   - Laboratories
     - Minimum equipment
     - Quality control
   - Sampling
     - Procedures
     - Sampling points
   - Analysis procedures
2. Sanitary inspection
   - Populated centers (with and without supply systems)
     - Urban
     - Rural
   - Inventory of treatment facilities and of components of the distribution system
   - Risk evaluation procedures (sanitary inspection)
3. Institutional evaluation
   - Institutional organization
   - Operational capacity

- Support

4. Information
   - Information Flow
   - Data base
   - Evaluation
     - Water quality
     - Level of service
     - Level of risk
5. Institutional development
   - Institutionalizing the surveillance system
   - Follow-up and notification system
   - Strengthening the institutions responsible
6. Legal bases
   - Revision and updating of legal standards to adjust them to the scope of the surveillance plan
7. Development of human resources
   - Identification of staff engaged in the surveillance and control of drinking water quality
   - Quantification of staff requirements
   - Training needs
   - Development of training material
   - Design of the training program
8. Environmental education
   - School education
   - Community education

9. Epidemiological surveillance
    - Notifiable diseases
    - Correlation of water quality information and epidemiological information
10. Community surveillance (rural and periurban level)
    - Surveillance Committees

### *3.2.3 Intervention Possibilities*

Technically viable intervention possibilities must be identified, based on the following considerations: the objectives of the sanitary surveillance intervention, range or scope of the operational and support programs, capacity of existing laboratories, number of professionals and their degree of qualification, economic resources, situational status of the surveillance and control programs and, above all, the standards and regulations currently in force on drinking water quality.

### *3.2.4 Investments*

Each of the previously identified alternatives should be quantified to determine its cost and inherent benefits. For this purpose, the following investment and cost aspects need to be examined for each alternative:

- Sanitary inspections
- Analyses
- Equipping of laboratories
- Transportation
- Salaries and wages
- Others.

Based on the technical, economic and political analysis, the alternative most advantageous to the interests of the country or region is selected. Subsequently a more detailed analysis of the selected alternative and its scope and benefits is made. For this purpose it is recommended to analyze the following aspects:

- Characteristics of the selected alternative (detailed description)

- Investment and implementation cost of the selected alternative:
  - Sanitary inspections
  - Analyses
  - Equipping of laboratories
  - Transportation
  - Salaries and wages
  - Others.

- Origin and application of the financial resources to comply with the selected alternative:
  - Origin of the funds
  - Use of the funds.

- Execution of the plan (Implementation timeframe)

## *3.3 Water Quality Control in Urban Environments*

### *3.3.1 Planning*

Since the control of drinking water quality is a fundamental part of sanitary and operational surveillance in urban areas, the guidelines issued by the sanitary surveillance body and the regulating entity should take into account, besides current legislation, the following factors: operational capacity of the suppliers, laboratory and transportation facilities, and the availability of human and financial resources.

With the planning guidelines issued by the respective authority and the physical characteristics of the water supply system, the supplier can then proceed to draw up the strategy and define the activities required to implement the program for the control of drinking water quality. The activities or tasks to be executed at this stage are the following:

- Identification of the limits of the water supply areas.
- Definition of sampling points and establishment of sampling criteria.
- Selection of the analytical determinations to be executed in each of the components of the water supply system.
- Determination of sampling frequency and of the number of analytical determinations.
- Determination of the frequency of sanitary inspections.
- Definition of staff needs.
- Identification of complementary laboratory material.
- Standardization of sampling and analysis procedures.
- Training of the staff responsible.
- Design or adaptation of the different forms to be filled out in the water quality control program.
- Identification of sampling routes.
- Establishment of the information flow.
- Creation of data base for processing information.
- Definition of data-processing method.
- Definition of contents of regular reports.
- Definition of sanitary education programs.

A guideline list in Annex 2 shows the main activities to be considered at this stage.

### *3.3.2 Execution*

Once the planning stage is over, the program moves into the implementation stage. The first step is to verify the physical characteristics of each of the components of the water supply system. The facilities for obtaining water samples can then be installed. The sampling points in the water distribution network are identified. When this stage has been completed, permanent monitoring of the water quality begins in: a) sources and treatment plants; b) components; and c) distribution network; in addition to sanitary inspections effected in each of the components of the water supply system. All the resulting data start forming a core body of information for the water quality control program and will be made full use of by the bodies responsible for sanitary surveillance of the water.

This procedure can be applied in large, medium, and small urban centers, as well as in rural or periurban areas, by merely making a selection of the information deemed necessary for the particular type of program envisaged.

### *3.3.3 Data Processing and Reports*

Once validated, the results of the laboratory analyses and sanitary inspections are processed in order to determine the quality of the water supply service provided by the supplier and to identify both the problems affecting water quality and their causes. This processing will make it possible to determine the most pertinent corrective measures.

The information must be classified in such a way as to afford an overall vision of the quality of the service based on the main components that make up the water supply system, such as: sources of water, outlets of treatment plants, outlets of components, distribution network and user connections if necessary. In turn, information processing must be carried out at the scientific, professional, managerial and public level, each one having a clearly defined characteristic.

Figure 7 shows in diagram form how to classify the input information, composed of data collected at the levels of office, supply installations, distribution network and laboratory, as well as the types of reports and results that need to be obtained as output information. This information should be managed automatically as far as possible and must reflect the most important aspects for the different levels targeted.

***Executive report***: This is a report in which global results are presented as well as results from each of the regions into which the water supply administration is divided, if such be the case. The report should contain the following:

- Percentage of positive samples – total and thermotolerant coliforms.
- Percentage of doubly positive samples in components and supply areas – total and thermotolerant coliforms.
- Percentage of samples that exceed the limits established for chemical substances in the standards on drinking water quality – surface sources and ground sources

- Sanitary condition of the components.
- Main defects in the components of the water supply system.
- Percentage of samples that comply with the minimum concentration of disinfectant.

***Technical report:*** In addition to the executive report containing an overview of the situation of the whole water supply system, the results from each administrative region must be reported, clearly indicating points and areas where deficiencies have been detected, complemented by a representation of the historic behavior of each supply area. The contents of this report could be the following:

- Percentage of positive samples – total and thermotolerant coliforms.
- Percentage of doubly positive samples in components and supply areas – total and thermotolerant coliforms.
- Percentage of samples exceeding the limits established for chemical substances in the standards on drinking water quality – surface and ground sources.
- Sanitary condition of the components
- Condition of the supply areas with respect to water quality and continuity.
- Main defects in the components of the water supply system.
- Percentage of samples that comply with the minimum concentration of disinfectant.

***Public report:*** This purpose of this document is to make known to the users of the water supply service the general characteristics of the service and the quality of water they are being supplied with. The information to be given at this level could be the following:

- Percentage of positive samples – total and thermotolerant coliforms.
- Percentage of samples exceeding the limits established for chemical substances in the standards on drinking water quality – surface sources and ground sources.
- Corrective measures taken.

### *3.3.4 Corrective Measures*

The final result of the several tasks involved in drinking water quality control permits the identification of risks the water supply system can present and leads to a determination of the corrective measures that need to be taken to remedy the defects identified in operational and administrative aspects and in the infrastructure of the water supply system, from the treatment plant to the user connection, and in some cases (mainly in periurban or rural areas) inside the customers' homes.

Operational and administrative corrective measures will be translated into training programs, while at the customer level, the work is of a citizen education nature. Training is directed toward improving the skill of the staff responsible for performing the services; while the objective of the social outreach is to improve the habits and customs of the consumers by means of sanitary education campaigns.

Corrective measures at the level of the water supply infrastructure should be directed toward improving the quality of the water service by taking timely action to ensure the conservation and preservation of the water service in general and drinking water quality in particular.

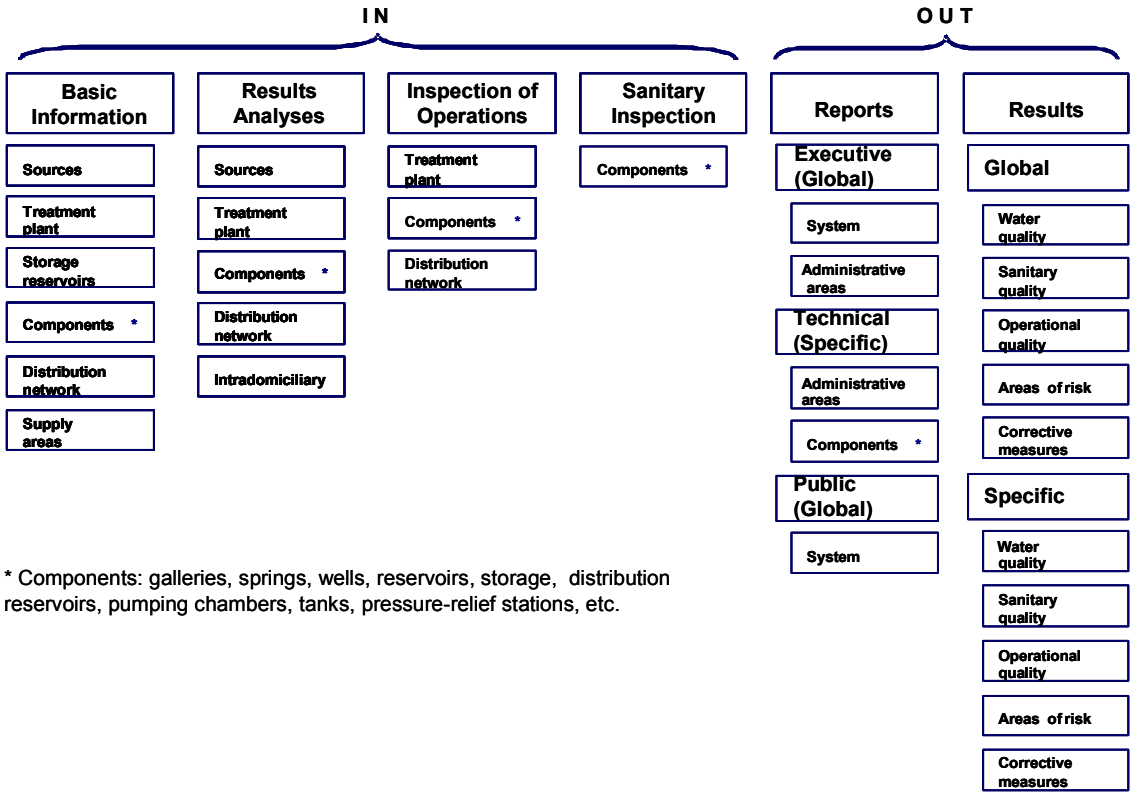


**Figure 7. Processing Information**

### *3.3.5 Preventive Measures*

It is possible that at the beginning of the water quality control program the activities resulting from recommendations will be of a corrective nature, and these corrective measures will continue until a sanitary consolidation of the water supply system has been achieved. Later, the control work will include follow-up to verify the conservation and maintenance of drinking water quality. It will establish the exact frequencies of application of preventive measures, mainly concerning the conservation and cleanliness of the supply system's infrastructure, but also with reference to preventive measures to be adopted in operational and administrative aspects, training and public relations.

## *3.4 Water Quality Control in Rural Areas*

### *3.4.1 Introduction*

Activities in rural areas are more complex than in urban ones, mainly because of the lack of a responsible supplier and the scanty supervision of water supply services by competent authorities. For this reason, on each inspection visit it is necessary to collect as much information as possible on the quality of the water service, the disposal of excreta and solid waste, and the habits of hygiene, among others, in order to evaluate the sanitary situation and identify the principal defects with a view to introducing the corresponding improvements.

Normally, water quality control in rural areas is aimed at the evaluation of the service as a whole. The following main aspects need to be considered:

a) Quality of drinking water
b) Standard of service of water supply to the community
c) Deficiencies in the components of the water supply system which can lead to deterioration in water quality
d) Management of the water supply system
e) Degree of sustainability of the water supply service
f) Sanitary conduct of the customers;
g) Programs of sanitary education leading to improvement in the health of the members of the community served
h) Prevalence of diseases
i) Economic impact.

### *3.4.2 Evaluation of Water Supply Services*

The evaluation of the quality of the rural water supply service could include the identification of the following characteristics:

a) General
   - Introduction
     - Geographic location
     - Population
     - Accessibility
     - Source

   - Type of system
     - Conventional
       - Gravity without treatment
       - Gravity with treatment
       - Pumping without treatment
       - Pumping with treatment
     - Non-conventional
       - Community

        - Artesian wells
        - Protection of springs
        - Others
    - Individual
        - Artesian wells
        - Springs
        - Rainwater catchment
        - Home filters
        - Others

b) Water quality
    - Concentration of coliforms
    - Concentration of chlorine residual
    - Turbidity
    - pH

c) Quality of service
    - Quantity of water supplied (Waste)
    - Continuity of service
    - Coverage

d) Management situation
    - Administration
    - Operator (permanent, part-time, none)
    - Operators' and others' pay
    - Commercialization (rate, extra charges)
    - Punctuality in payment

e) Level of sanitary conduct of the customers
    - Personal hygiene
    - Hygiene in the home
    - Handling of water inside the home
    - Presence of animals in the home

f) Prevalence of diseases (basic epidemiology)
    - Diarrheas
    - Skin and eye infections

g) Level of deficiencies in the installations
    - Collection
    - Surface water
    - Groundwater
        - Presence of people and animals
        - Condition of the structure (cracks, leaks)
        - Foreign elements inside the storage reservoirs

- Contamination of surface water upstream (latrines, dumping of solid waste, mining activity, etc.)
- Treatment
- Storage
  - Access by people and animals
  - Condition of the structure (cracks, leaks)
  - Foreign elements in the interior
- Adduction/Conduction
  - Access of persons and animals to pressure-relief boxes
  - Condition of pipes (leaks and cracks)
- Distribution
  - Access of persons and animals to pressure-relief boxes
  - Condition of pipes (leaks and cracks)
  - Condition of public sources
- In the home
  - Condition of user connection (faucet, drainage of domestic sewage)
  - Gray water disposal.

## *3.5 Surveillance*

### *3.5.1 General*

The surveillance methodology proposed in these guidelines is feasible only if there is political support and a legal framework with clearly specified rules of the game enabling surveillance activities to be supported by the control activities of the supplier, and the two parties to coordinate work in conjunction.

In this way, the surveillance methodology described on the following pages is complemented by the methodology described above for drinking water quality control. In the case of rural or periurban localities not under the administration of a supplier, the surveillance body will have to identify an outside institution or an office independent from the sanitary surveillance work of its sector, to perform the quality control of the service. As far as possible, the surveillance body must abstain from carrying out the quality control of water of public or communal water supply services.

The responsibilities of the surveillance body are to: a) validate the sampling; b) audit the supplier; c) evaluate epidemiological information; d) manage information, investigation and risk evaluation; and e) follow up and develop the quality of the services.

### *3.5.2 Validation of Data*

To validate the sampling carried out by the supplier, the surveillance body can apply the frequency values recommended in Charts A to E, Annex 1, affected by a factor that could be between 15 and 25 percent and which, according to sampling theory corresponds statistically to a

reliability level of no less than 95%. The surveillance body can accept, question, or reject the information provided by the supplier depending on the extent to which its own results coincide with those reported by the supplier. The analytical capacity of the surveillance body's laboratory does not need to be very great nor do large quantities of money need to be invested for it to discharge this responsibility.

### *3.5.3 Auditing*

In addition to the previous task, it is necessary that activities carried out by the supplier to comply with its water quality control program be audited by an external institution appointed by the surveillance body. The audit will include an examination of the processes of collecting field information and water samples, and the procedures used for analyzing the water samples, to check whether the results and their records are reliable and whether they conform to the regulations of the surveillance authority.

It is considered essential that strict control be exercised over two basic aspects: a) analytical evaluations and b) results of sanitary inspections.

### *3.5.4 Epidemiological Evaluation*

Epidemiology is a basic public health science which has as its objective the study of medical issues (health/disease) concerning the population as a whole and known as mass phenomena. These mass phenomena link the physical, chemical and biological environment with the human community and its environment. In the specific case of the sanitary surveillance of water quality, epidemiology helps to determine the causes of water-related diseases and leads to the identification and implementation of corrective measures.

From the epidemiological information provided by the specialized Ministry of Health department, the body responsible for sanitary surveillance of drinking water must select the diseases related exclusively to water in order to correlate them with the water quality records.

### *3.5.5 Management of Information, Risk Investigation and Identification*

Surveillance has two main components: (a) the permanent and systematic examination of information on water quality to verify that the supply system is complying with established objectives and regulations; and (b) the correlation of physical, chemical and microbiological water quality with diseases related to drinking water quality, to determine the impact on customers' health.

Since surveillance is an activity of investigation, it must be directed toward identifying and evaluating risk factors associated with water supply systems so that any corrective action required can be taken before health problems occur in the population. Surveillance also makes it possible to determine the causes or origins of outbreaks of diseases related to water quality in order to take the necessary measures to prevent them from spreading.

The procedure consists of a detailed examination of the basic information available, namely the results of analyses and epidemiological evaluation. The information will later be classified and grouped, taking into account the "cause and effect" aspect for further analysis.

Once classified, the information must be correlated with water-borne diseases. In this way relationships can be discovered between the diseases and water quality, sanitary defects, chemical products used in treatment and building materials used in the construction of the different elements of the water distribution system, in order to determine the supposed or possible impact of some of these factors on the consumers' health. In the processing of information, especially of bacteriological results, the many causes of transmissible diseases must be taken into account, paying particular attention to those originating in the food and the soil, so as to identify only those relating exclusively to water quality.

Based on the results of the correlation of risk factors with the quality of the water and the diseases relating to drinking water, we will be able to contribute criteria for improving the existing standards: standards on water quality, on the chemical products or substances used in water treatment, on building materials used in the construction of water supply systems, as well on the building procedures themselves, among others.

### *3.5.6 Follow-Up and Development*

In addition to verifying compliance with the water quality standards, the surveillance body must observe, record and examine the information about water quality, chemical products used in water treatment, and operation and maintenance procedures. Also, it must continually follow up water quality to check for changes that may occur over time, and determine whether projections of these changes imply any impact on consumers' health.

### *3.5.7 Periodic Reports*

The systemized information on drinking water quality provided by the different suppliers must be distributed to all public and private institutions involved in public health, management of water resources and sanitation.

The report, normally published once a year, should give a summary of the water quality in the geographic area under the jurisdiction of the surveillance body, complemented with information from the smallest areas, which could coincide with the geopolitical divisions of the geographic area of intervention. The information at the level of the smallest areas will be a summary of the physical, chemical and bacteriological characteristics of the water provided by the different water suppliers.

The report should also contain general remarks on the quality of the drinking water, as well as a list of the programs to be implemented by the suppliers to improve drinking water quality. If possible, it should also identify the most urgent investigations that need to be made in the short term, as a way of contributing criteria for establishing the pertinent policies for the sector.

## 4. Bibliography


1. CEPIS (Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente). (1992). Control de Calidad del Agua de Lima. SEDAPAL.
2. European Community (1980/778/EC). The EC Directive relating to the quality of water intended for human consumption. DoE Circular 25/84.
3. Feachem, R. (1977). Water supplies for low-income communities in Water, Wastes and Health in Hot Climates. London, Willey.
4. Feachem, R. *et. al.* (1978). Water, health and development: Tri-Med Books Ltd., London.
5. Galal-Gorchev, H. (1986). Water Quality and Health. In Course on Surveillance & Control of Drinking Water Quality. Arusha, Nov. 1990. Centre for Developing Countries. Technical University of Denmark. WHO/DANIDA, 1990.
6. Geldreich, EE; Fox, K.R.; Goodrich J.A. et al (1992). Searching for a water supply connection in the Cabool, Missouri disease outbreak of *Escherichia coli* O157:H7. Water Res 26:1127-1137.
7. ITINTEC. Instituto de Investigación Tecnológica Industrial y de Normas Técnicas. Norma Técnica Nacional. Agua Potable - Requisitos. ITINTEC 214.003. June, 1987.
8. ITINTEC. Instituto de Investigación Tecnológica Industrial y de Normas Técnicas. Norma Técnica Nacional. Agua Potable - Toma de muestras. ITINTEC 214.005. June, 1987.
9. Lloyd, B. (1982). Water Quality Surveillance. Waterlines, 1, (2), 19-23.
10. Lloyd, B.; Wheeler, D. & Pardón, M. (1984). Safe Water in the Third World. Dept. of Microbiology, University of Surrey, U.K.
11. Lloyd, B.; Pardón, M. & Bartram, J. (1987). The Development & Implementation of a Water Surveillance and Improvement Programme for Peru. American Society of Civil Engineers. International Conference on Resource Mobilisation for Drinking Water Supply & Sanitation in Developing Nations. Puerto Rico.
12. Lloyd, B. & Bartram, J. (1990). Drinking Water Microbiology in Developing Countries. Proceedings of the International Association on Water Pollution Research and Control. International Symposium on Health-Related Water Microbiology. Tubingen, Germany.
13. Lloyd, B. & Helmer, R. (1990). Surveillance of Drinking Water Quality in Rural Areas. WHO/UNEP Published by Longman Scientific & Technical, UK. ISBN 0-582-06330-2.
14. Lloyd, B. & Suyati, S. (1990). A pilot Rural Water Surveillance Project in Indonesia. Waterlines, 7, (3), 10-13.
15. Lloyd, B.; Bartram, J.; Rojas, R.; Pardón, M.; Wheeler, D. & Wedgwood, K. (1991). Surveillance and Improvement of Peruvian Drinking Water Supplies. Robens Institute, DelAgua. A project supported by the UK Overseas Development Administration as part of a technical cooperation programme for the Government of Peru.
16. Ministerio de Salud. Perú. Reglamento de los requisitos oficiales (físicos, químicos y bacteriológicos) que deben reunir las agua de bebida para ser consideradas potables. December, 1946.
17. PAHO (Pan American Health Organization. Organización Panamericana de la Salud - OPS). (1990a). Declaración de Puerto Rico; Abastecimiento de Agua, Saneamiento y Salud. Puerto Rico, 4-6 September.

18. PAHO (Pan American Health Organization. Organización Panamericana de la Salud - OPS). (1996). La Calidad del Agua Potable en América Latina. Ponderación de los riesgos microbiológicos contra los riesgos de los subproductos de la desinfección química.
19. PAHO (Pan American Health Organization. Organización Panamericana de la Salud - OPS). (1990b). Conferencia Regional sobre Abastecimiento de Agua y Saneamiento. Evaluación del Decenio Internacional del Abastecimiento de Agua Potable y Saneamiento 1981-1990 y Proyecciones hacia el año 2000. Puerto Rico, 4-6 Setiembre. Volumen 1.
20. Rojas, R. (1994). SANIPLAN. Programa de control de la calidad de agua de consumo humano. Trujillo, Ica y Pisco.
21. Rojas, R. (1993). Quality Control of Lima's Water Supply. University of Surrey, Department of Civil Engineering.
22. Rojas, R. (1992). Quality Control of Piped Urban Water Supplies.
23. Rojas, R. & Bartram, J. (1990). Manual del Supervisor. Vigilancia de los Servicios de Agua de Consumo Humano. Secciones I al VIII. Ministerio de Salud. Lima, Perú.
24. Rojas, R; Vargas, C. (1998) Control y Vigilancia de la Calidad del Agua de Consumo Humano.
25. APHA-AWWA-WPCF Standard Methods For the Examination of Water and Wastewater. 14th Edition, 1975.
26. SEDAPAL. (1992). Lima Water Authority. Anuario Estadístico.
27. Seligmann, R.; Reitler, L. (1965). Enteropathogens in water with low Escherichia coli titer. Journal AWWA 57:1572-1574.
28. Society of Applied Bacteriology Symposium on Microbiological Aspects of Water Management. SAB Summer Conference. Lancaster, 16-20th July 1984.
29. Statutory Instruments, 1989/1147. Water England and Wales. The Water Supply (Water Quality) Regulations 1989.
30. Stenström, T.A. Community Education and Involvement. In Course on Surveillance & Control of Drinking Water Quality. Arusha, Nov. 1990. Centre for Developing Countries. Technical University of Denmark. WHO/DANIDA, 1990.
31. Thames Water Utilities. (1991). Drinking Water Quality, 1990.
32. UN. (1977). Informe de la Conferencia de las Naciones Unidas sobre el Agua. Naciones Unidas. Mar del Plata, 14-25 March.
33. UNEP. (1990). Consultación Mundial sobre Abastecimiento de Agua Potable y el Saneamiento Ambiental para los años de 1990. Declaración de Nueva Delhi, 10-14 September.
34. UNEP/WHO. (1989). Project on Control of Drinking-Water Quality in Rural Areas. Report of a Review Meeting at the WHO Collaborating Centre for the Protection of Drinking-Water Quality and Human Health. Robens Institute. Guildford.
35. Vargas, C. Mejoramiento de la calidad del agua de la ciudad de Lima y el Callao. CEPIS, 1995.
36. Vargas, C. (1995) Control de la calidad del agua de la ciudad del Cuzco. CEPIS.
37. Ward, C. (1990). Groundwater Quality Monitoring in Relation to on-site Sanitation. Waterlines, 8, (4), 11-14.
38. Walsh, J. & Warren, K. (1979). Selective Primary Health Care: An interim strategy for disease control in developing countries. New England. J. Med 301(18), 967.

39. Wheeler, D. & Bartram, J. (1988). Surveillance Planning. In Course on Surveillance & Control of Drinking Water Quality. Arusha, Nov. 1990. Centre for Developing Countries. Technical University of Denmark. WHO/DANIDA, 1990.
40. Wheeler, D. & Bartram, J. (1990). Sanitary Inspection. In Course on Surveillance & Control of Drinking Water Quality. Arusha, Nov. 1990. Centre for Developing Countries. Technical University of Denmark. WHO/DANIDA, 1990.
41. WHO. (1976). Surveillance of Drinking Water Quality. WHO Monograph Series No 63. WHO, Geneva.
42. WHO. (1978). Conferencia Internacional sobre Atención Primaria de la Salud. Alma Ata 6-12 Setiembre 1978. OMS, Geneva.
43. WHO. (1983). GEMS/WATER Report of the Inter-Regional review meeting on water quality monitoring programmes. Burlington (Ontario) 17-21st October.
44. WHO. (1984). Guidelines for Drinking Water Quality. Vol 1, Recommendations. WHO, Geneva.
45. WHO. (1985). Guidelines for Drinking Water Quality. Vol 3, Drinking Water Quality Control in Small Community Supplies. WHO, Geneva.
46. WHO. (1986). Guiding Principles for National Monitoring of the Water Supply and Sanitation Sector. WHO, Geneva, June, 1986.
47. WHO. (1995). Guías para la calidad del agua potable. Recomendaciones. Segunda edición. WHO, Geneva, 1995.
48. WHO. (1997). Guidelines for drinking-water quality. Surveillance and control of community supplies. WHO, Geneva, 1997.
49. WHO. (1991). Revision of the WHO Guidelines for Drinking-Water Quality. Report of the Review Meeting on Pathogenic Agents and Volume 3 on Surveillance of Community Supplies. Harare, Zimbabwe, 24-28 June, 1991.
50. World Water. (1981). "D-Day for the Water Decade". Liverpool, p. 3.