GUIDELINES FOR DRINKING WATER QUALITY STANDARDS IN DEVELOPING COUNTRIES

Felipe Solsona

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Felipe Solsona
Regional Advisor in Water Quality
PAHO/CEPIS

Pan American Center for Sanitary Engineering and Environmental Sciences
Division of Health and Environment
Pan American Health Organization
Pan American Sanitary Bureau, Regional Office of the
World Health Organization

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PREFACE

One of the most successful documents prepared by the World Health Organization in the environmental health arena, are the *Guidelines for drinking-water quality* ("WHO Guidelines").

The first WHO publication dealing specifically with drinking water quality was published in 1958 as *International Standards for Drinking Water*. It was subsequently revised and re-issued every 10 to 12 years. In 1984 the *WHO Guidelines for drinking water quality* replaced the WHO *International Standards for Drinking Water*. The change in the title of the document itself, i.e. from “Standards” to “Guidelines” was made to reflect more accurately the advisory nature of WHO recommendations so that they are not interpreted as legal standards. A second edition of the WHO Guidelines was published during 1993-1996 and, by far, these have been one of the most used sources of information on water quality and health, and as a reference document to prepare national Drinking Water Quality (DWQ) Standards.

Although very valuable, two aspects should nevertheless be mentioned regarding the Guidelines. First, the document is primarily intended to be used for the development of a list of “maximum concentration” for a number of contaminants usually found in drinking water and, as such, provides ample information on epidemiological and toxicological aspects, but does not inform on other legal aspects needed to establish drinking water standards. Second, when using the Guidelines, the health regulators and policy makers do not have a clear picture on how they should proceed from a practical point of view (making diagnosis, searching for information, establishing committees, negotiating among interested parties, etc.).

After many years of close contact with the health and water-related sectors in Latin American and the Caribbean Region, the Pan American Health Organization confirmed that the WHO Guidelines are a vital document in helping countries with their drinking water quality issues, but it was also noted that there was a lack of information on the best ways to use that tool.

To address this, the Pan American Center for Sanitary Engineering and Environmental Sciences, PAHO/CEPIS, committed his Regional Advisor in Water Quality, Mr. Felipe Solsona, to prepare a document to be used as a complement to the WHO Guidelines. The work had to be a simple and concise guidance presenting the format of a recipe book to be used as a helping hand by the countries in developing national drinking water quality standards. The result of his dedicated work is this *Guidelines for drinking water quality standards in developing countries*.

Dr. Hend Galal-Gorchev, a former WHO officer in charge of several editions of the WHO Guidelines and at present with the US Environmental Protection Agency Senior Environmental Program, was a key person in the preparation of this document. Her support, advise, and direct input are acknowledged and thanked.

Dr. Mauricio Pardón (Director of the Division of Health and Environment, PAHO), Mr. Sergio Caporali (Director of CEPIS) and Dr. Gerardo Galvis (Chief of Basic Sanitation) from PAHO, and Dr. Jamie Bartram from WHO Water, Sanitation and Health Programme provided important support to achieve the final goal.

It is with great confidence that PAHO places this Guide in the hands of every officer and expert in the water field, strongly believing that it will aid in achieving a safer water and better quality of life for many.

Presentation

This Guide is a contribution of the Pan American Health Organization, Regional Office for the Americas of the World Health Organization (PAHO/WHO), to aid developing countries in their preparation of national drinking water quality standards (DWQS).

The structure of the document is that of a pyramid, the base being the general principles and recommendations, which represents the foundation of the Guide. The second level explains the methodology suggested for developing a standard. The third level focuses on each of the components or "sections" of the standard and describes their most important features and how to apply them. The fourth level presents a case study to help visualize the use of the Guide.

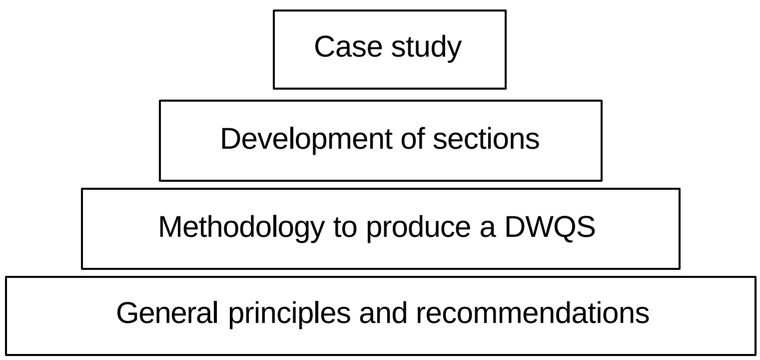

Figure 1. Structure of the Guide

Just or unjust, reality shows that developed and developing countries, with their differences in opportunities and resources, on occasions, need to take different paths. When producing a DWQS for developing countries, if the approach is to try and emulate rich countries, the result will often be failure. Therefore, drinking water quality standards that are unrealistic are in fact useless tools. In light of this, a different approach must be taken when dealing with developing countries. Using the same principles as those of appropriate technology , it is possible to produce tools and mechanisms that can bring nearly equal and, in some cases, equal benefits to those of higher technologies.

Realism and development by stages is an approach that will allow the start of a realistic process which, through time and proper management, should and could achieve the same goals developed countries have.

In order to be practical, this Guide is simple, direct, and tries to avoid as much as possible overly detailed specifications or technicalities. It should be an appropriate aid to technical staff and decision-makers confronted with the challenge of developing a DWQS.

1. Introduction, the Seven Conditions and Some Important Recommendations

The relationship between drinking water and personal health is well known. Diarrheas are the most common human disease, and there is a very strong connection between these diseases and the water consumed by those affected. Therefore, it is of obvious importance to ensure that drinking water provided to users is of good quality.

The framework against which a water sample can be considered good or “safe” is a drinking water quality standard (DWQS). By definition, a *standard* is “a rule or principle considered by an authority and by general consent as a basis of comparison. It is something normal or average in quality and the most common form of its kind”. A proper standard for drinking water quality is thus the reference that will ensure that the water will not be harmful to human health.

Two observations could be made out of the last statement:

- First, that the primary aim of a DWQS is the protection of public health. This is true.

- Second, that a very precise, complete, and detailed DWQS is preferable to a lesser detailed and complete one. This may not always be true.

Based on these statements, this Guide will provide a simple set of recommendations intended to be useful when producing a DWQS in developing countries. Too often, these countries have a multitude of problems, limitations, and restrictions. Conditions and resources may vary from season to season and from region to region within a country. Therefore, a DWQS that does not take into consideration this situation is prone to failing in its intention.

As indicated before, the production of a DWQS in a developing country needs to take a different approach to the one taken in a country with full resources. This approach should follow the road of the seven conditions.

A DWQS should be:

1. Realistic
2. Flexible
3. Comprehensive
4. Implemented by steps
5. Alive
6. Strategically supported
7. Relevant to every sector's interests.

Condition 1: Realism

The facilities, expertise, and even appropriate legislation to develop suitable drinking water quality surveillance and control programs may vary widely from country to country. Resources in developing countries are usually insufficient in quality and quantity and this reality needs to be recognized when preparing a DWQS.

It is appealing to have a standard covering all aspects of drinking water quality, even those thought of as minor or extremely specific. This may even be considered a matter of pride for high government officials and for technicians working in the drinking water field. Nevertheless, in practice, it will be found that in these countries, when a DWQS is too complex, detailed, and demanding it will inevitably lead to its non-compliance.

To have an unrealistic standard may be worse than having no standard at all. Little is achieved by establishing standards unless they can be implemented and enforced.

"Realism" means that when confronted with the task of developing a national DWQS, the officers in charge should analyze which resources are readily available and also those that are easily obtainable, without being excessively optimistic. They should weigh carefully what support they have and at what level they have it. Only then, in a rational and humble manner, can they produce a truly useful DWQS.

Condition 2: Flexibility

The same conditions prevailing in developing countries that demand realism from a DWQS, also demand flexibility. A better way to express the idea is: if a DWQS is to be realistic, then inevitably it will have to be flexible. Nevertheless, care should be taken because, although flexibility is a clever way to accept a particular reality, it carries a good amount of risk in itself.

Flexibility may give ground for transgressions or delays in the application of a DWQS and it may even be used as an excuse not to abide by the rules. Chances are that if there is too much flexibility, a DWQS will never be truly implemented.

Flexibility is a must, but it cannot be a blank check. It is important to balance a certain amount of needed and "clever" flexibility with a firm position that ensures that certain limits are not violated. This is a crucial and delicate task to be performed by people preparing the standard. There are several ways to make a DWQS flexible:

- *Flexibility in time:* A DWQS as a whole or part of it (for example, a certain substance with its limit or a certain limit for a particular substance) may be given a period of grace before it comes into effect.

- *Flexibility by clauses of exception:* A clause of exception or exclusion is the one that states that certain developing activities, technologies, parameters or limits in the drinking water quality protocol may not apply to a certain area, province, or service due to specific local problems. A typical situation is that of a water supply company asking the surveillance agency (while presenting evidence) to be spared compliance with a certain requirement due to unfavorable conditions such as raw water with high concentrations of a substance, the unavailability of proper technology, the high cost of treatment to reduce the level of a contaminant in water, or lack of resources to detect or monitor a certain substance in water. While this type of flexibility is common in developed countries, there is an element of risk involved when applying it to developing countries. This is because, in some cases, it may be too easy to obtain the exclusion while in others, no matter how the exclusion was obtained, the water supply company will not make any effort to abide by the standard once an exclusion is given.

- *Flexibility in aspects of regulation:* If a regulation covers every aspect ("comprehensiveness") but is kept simple and adheres just to the basic principles, this may represent a more relaxed standard than one that is exhaustive and too specific.

- *Flexibility by parameters chosen in the table of parameters and concentrations:* The basic support document used for developing a national standard is the *WHO Guidelines for Drinking-Water Quality* (WHO-GL). This document presents a list of over 150 parameters with their suggested guideline values. If a country selects all of these parameters for inclusion in the national DWQS then the burden may be high. Choosing a well selected but reduced list of parameters may give enough flexibility to the standard.

- *Flexibility by the limits of parameters:* This is perhaps the most visible and most commonly used way to deal with flexibility in a standard. As will be seen further down, depending on epidemiological and cultural situations, human, technical and economical resources, risk assessment, and cost-benefit evaluations, a limit in concentration imposed for a certain substance in water may be narrow or broad, giving it enough room for flexibility.

- *Flexibility by frequency of monitoring:* Monitoring is vital to ensure that the water is of adequate quality. A demanding monitoring approach is less flexible than a more relaxed one.

- *Flexibility by different set of limits:* Many countries develop a table of parameters and concentrations (TPC) with only one limit. This is normally called the *maximum permissible level*. There is an inherent flexibility depending on what value is adopted for this limit, with a higher value giving a wider flexibility. Other countries adopt another strategy that allows perhaps for a more desirable way of flexibility. They prefer to present two sets of limits or values for a certain parameter. One being the *Ideal concentration* (or *goal concentration*) and the other the maximum permissible level. This is another important issue that will be further discussed.

- *Flexibility by resources (urban and rural):* It is a reality that different areas in a country may have different level of resources. Furthermore, in almost every developing country there coexist a “First World service” with a “Third World service”. In the capital cities and most important urban centers of nearly every country, there exists good service with modern technology, human and economic resources and therefore properly run programs of drinking water quality control. Medium and small community water supply systems will lack most of the facilities and activities of their big city counterparts. A DWQS that is more demanding of services that have better facilities and less demanding for the rest, shows logical flexibility. This approach is sometimes condemned as differentiated demands on services, leading to differentiated qualities of water, which in turns implies the acceptance of “first class” and “second class” citizens. This would be true if there were no provisions made that would dictate that after a certain period of time, the rural (or small) systems should comply with the same requirements and demands as those of large towns.

- *Flexibility by combining some of the previous ones:* Obviously, there is the possibility of being flexible by combining two or more of the options described above.

Condition 3: Comprehensiveness

A reason for failure in the application of DWQS in developing countries is that, in some cases, a standard is too detailed, too complex, and too demanding. This characteristic could be called *"completeness".*

There is a difference between "completeness" and "comprehensiveness". The former means that *nothing* is left aside or behind. The latter means to cover a wide spectrum; to be inclusive and to take into consideration all the important aspects of a major field or study. Briefly, the first could be described as “all” and the second, as “the most important things from every area”.

It is undesirable to have many professionals and even authorities and decision-makers believe that a standard is just the table giving the list of parameters and their respective concentrations (TPC). Very often, this mere list is called “the standard” as if there were nothing else beyond it. Even though the TPC is the most visible section, by no means is it the most important part of the standard.

In a developing country, if a DWQS is not complete, it should try to cover every important and relevant aspect of drinking water quality. A comprehensive standard should cover at least these sections:

- Introduction
- General clauses
- Definitions
- Institutional framework
- Table of parameters and concentrations (TPC)
- Frequency of sampling
- Approved analytical methods for analysis
- Sanitary surveys
- General requirements
- Good water practice recommendations
- Violations and penalties
- Information, record keeping, and reporting
- Surveillance and control programs.

Each section is discussed in greater detail further down.

Condition 4: Development by Steps

A DWQS is a tool closely related to and a part of the national program of drinking water quality surveillance and the water supply companies' programs of drinking water quality control. The implementation of a DWQS or the revision of an existing standard may occasionally require investing new and sometimes important resources. These are needed to comply with the demands involved in the application of the new standard and the drinking water quality surveillance and control programs.

One rational way of achieving the program goals and the requirements of the DWQS is to implement both the program and the standard in a stepwise manner. It is more practical to have a modest standard at the beginning and, through consecutive steps of growing complexity, reach a complete and thorough coverage at a later stage.

For example, in a developing country where it would probably be very difficult to deal with all the contaminants that may occur in drinking water, the DWQS should be set first for contaminants that occur frequently and at significant concentrations in drinking-water and that have the greatest health impact. Microbiological contaminants belong to this category while pesticides, which are of a lesser immediate health hazard and more resource-intensive in terms of equipment needed for their monitoring, may be left for a future revision of the standards. Another possibility is that such pesticide standards may be included in the standards but enough time may be given before their implementation.

The US EPA has adopted this approach when setting the new standard of 10 :g/L for arsenic in drinking water; sufficient time (five years) is allowed for modifying or installing new treatment techniques before the standard is implemented. The European Union adopted a similar approach in setting interim values for its lead standard, with the final standard of 10 :g/L to be implemented 15 years from enactment of the EU Drinking Water Directive. A table with levels of complexity, steps, or time intervals to proceed with compliance should be included in the standard.

Condition 5: Aliveness

We live in a changing world. General and technical knowledge accumulates and changes continually. A DWQS cannot be static and fixed. As epidemiological evaluations change, toxicological information increases, and laboratory know-how on substance identification improves, it will be necessary to adapt the standard to the changing environment.

Let us consider the framework that supports the establishment of a national DWQS: the *WHO Guidelines for Drinking Water Quality*. The WHO-GL is a document that shows a high degree of aliveness. In fact the WHO is so conscious of the changing conditions that since 1994 it has started a process called “The rolling revision of the GL". A national DWQS should have a similar degree of alertness and liveliness, and be continually reviewed and fed with new information, while being periodically updated. Five to eight years seems to be an appropriate interval of time for new editions.

Condition 6: Support

A country, government, ministry, or an institution may have a perfect standard, which is a wonderful tool. But if the appropriate social forces do not support this, it may not be used at all. It may be left aside or ignored. Amongst politicians, government officers, technicians, and the public there is a need for strong sustenance.

This may be external to the DWQS itself. Nevertheless, the support to ensure that the standard will be produced, validated, and enforced is vital to its implementation. If there is no support, then there will be no application. All representatives of the different sectors dealing with the DWQS should work hard to ensure that the higher ranks of their sectors see this tool as important to them in order to assure strong and continuous support.

Condition 7: Wide Participation

One reason for success in the implementation and respect of the DWQS is that when well prepared and executed, every sector dealing with drinking water is represented. This full participation gives force and support to the standard.

Even when the responsible agency for the DWQS may be a specific institution (in most countries this falls in some department under the Ministry of Health), it is of the utmost importance that during the production, development, and validation of the DWQS, all sectors dealing with drinking water have an active participation. In this case, aside from the "legal ownership" of the standard, every sector will feel that this standard represents their interests. This issue is of utmost importance when assembling the DWQS Committee (see further down).

Besides the seven conditions, this section will also present some important suggestions:

- It is important to note that when establishing national standards, consideration must be given to the practical measures that will need to be taken. These measures include finding new sources of water supply, instituting certain types of treatment, and providing for adequate laboratory facilities, monitoring, and enforcement. National standards will therefore, by necessity, be influenced by national priorities and economic factors.

- A DWQS is not a simple rule or regulation but a rather complex one, where, as previously mentioned, there is plenty of room and need for flexibility. Since flexibility is a major component, in preparing a

DWQS care should be taken to consider various factors such as lack of information and information availability, technological components, resources (in general), differences between the urban and the rural environment, risk-benefit and cost-benefit analysis, cultural and social constituents, and the interests of the sectors involved.

- As flexibility and multiple factors are to be considered, and as a great variety of sectors (all having their own needs and interests) will take part in the production, implementation, and use of the standard, it is important to produce the DWQS through an honest and valid process of negotiation. This is also another important point for success.

2. Methodology for Developing a DWQS

The best method to start the process of preparing or renewing a DWQS is to follow this path:

2.1 *Identification of the "Lead Institution" Responsible for Developing the DWQS*

As its name implies, the lead institution will be the one to conduct the process, convene meetings and distribute tasks, support research, and process the information. This institution will be the one to present the DWQS proposal to the legislative authority for its approval as law or regulation. Once the standard is validated, most probably this institution will also have the ability and responsibility of enforcing it. The lead institution is a key element in the whole process.

2.2 *Creation of a DWQS Committee*

The lead institution will convene the creation of a DWQS Committee. This committee should comprise representatives from all sectors related to the drinking water field. The committee will be composed of professional and technical staff. Nevertheless, it would be convenient to have government representatives or advisors working in close contact with decision-makers. It is also advisable to incorporate one or two lawyers or legal advisors in the group.

Since a DWQS Committee should be representative of the drinking water sector, it will have a considerable number of members. However, from the practical point of view, it is recommended that no more than 15 participants be included in the Committee. This does not prevent wide participation. If each member represents one institution, most probably that number would easily cover the most important organizations dealing with drinking water in the country.

One important request to the institutions is that their representatives do not change frequently. Recurrent change of members from the same institution is disturbing and time consuming, as the newcomers are normally not well informed of the steps already taken and will need sufficient time to grasp the whole picture and be active. Aside from their particular professional expertise, all members of the Committee should know the drinking water quality arena and its characteristics and, if working under the suggestions of these *Guidelines for national drinking water quality standards in developing countries*, they should all be very familiar with it.

2.3 *Obtaining Official Recognition of the Committee*

The appropriate authorities should officially recognize the Committee and its members for the mission they will carry out.

2.4 *Selection of a Group of Advisors*

It is always important to invite a selected group of professionals with experience in drinking water issues and related legislation to act as external advisors and provide support. Their task would be to accompany and to suggest modifications or corrections to the work developed by the Committee. A group of three to five advisors is suitable. These advisors may not necessarily be locals. They may reside in other towns or other countries.

Even though some may be paid for their work (if resources are available), some may not. International organizations or organizations with international activities may accept to have some of their personnel supporting a national and official DWQS Committee. PAHO through CEPIS, the US Environmental Protection Agency through several of its departments, and several universities around the world fall under this category. With electronic mail connections, very important advisory support can take place today without the need for time and money for travel.

2.5 *Distribution of Responsibilities and Setting the Rules for the Work of the DWQS Committee*

Once the process has started, it is important that the different members or institutions of the Committee be assigned duties and responsibilities. Simple and clear rules like when, where, and how to meet responsibilities should be established.

2.6 *Gathering of Base Line Information for Diagnosis*

The first important task of the Committee is to gather base line information to start working on. The information should be divided into six areas:

- Resources
- Water quality
- Epidemiological data
- Industrial activity
- Pesticides imports
- Cultural habits.

Resources will be important in setting goals and in defining how thorough and complete the DWQS can be. They are related to the flexibility that the Committee will have to maintain.

Water quality is the data and information available, as recorded by the water companies, the ministry of health, the ministry of agriculture and others. Water quality information should be obtained for raw (surface and underground) water and for drinking water as delivered to the population. This information will be vital when developing the TPC.

Epidemiological data will help to identify the most important water-related diseases, and this in turn will identify substances that are present in drinking water and that have an impact on public health. Epidemiological information is the support for the "health hazard-occurrence" exercise, as will be seen in the TPC section 3.5.

Industrial activity will help identify contaminants that may be found in raw waters. The presence and concentrations of these substances (mostly organic) are also related to the technology needed to treat water to make it potable.

A list of *pesticides* and amounts imported annually is very important when selecting the pesticide parameters. There are too many agrotoxics that can be present in water and to monitor all of them would be too costly and too difficult. An approach of health hazard-occurrence analysis is important for selecting a few but representative substances. This list can usually be obtained from the ministry of agriculture or the ministry of industry and will be a crucial piece of information in that analysis.

Although not vital, *cultural habits* of the population may also lead to a selection of certain parameters and to specific management of their limits.

2.7 *Task Development and the Production of the Final Draft*

Once the information is available, the real work will start. Tasks should be divided. It is practical to create sub-committees and to give each one different tasks to be accomplished. Sub-committees should work on the development of the different sections (introduction, definitions, TPC, sampling, sanitary surveys, etc.).

It is good to have clear goals and precise deadlines. Deadlines should be respected and there should also be a serious monitoring of the products delivered by each sub-committee. Full and wide discussions should be allowed and encouraged in each session, but the lead institution should also be a time manager in order that the discussions and negotiations do not take extraordinary time or lead to dead ends. It is good to have the sessions decisions recorded.

The goal for a final draft should be established after the first sessions and its deadline should be adhered to as far as possible. Depending on the characteristics of the country, its institutions and the available information, the period of time from the starting point to the production of the final draft may vary. Nevertheless, it is considered that an appropriate time for this process should be between 6 and 12 months.

2.8 *Peer Reviewing*

Once the final draft is ready, it is advisable that this draft be reviewed and revised by additional national and international experts. This peer review is fundamental, as several important suggestions, commentaries, and the identification of errors will be received. Depending on the amount of suggestions or commentaries received, the analysis and inclusion in the document may be done by a sub-committee or by the whole committee working together. This exercise will add focusing, clarity, and strength to the document.

2.9 *Production of the DWQS Proposal*

The final draft, once it has incorporated the relevant suggestions, will be analyzed and discussed by the DWQS Committee and a new document will be produced. This approved new document is the DWQS proposal.

2.10 *Decision Makers Involvement*

Even though there may be an important meeting to present the DWQS proposal to all decision makers (ministers, directors, chiefs of department, advisors, etc.) of institutions dealing with drinking water, from a strategic point of view it is highly important that prior to that eventual gathering, each of the Committee members present the proposal to their own institutions decision makers.

Being an in-house exercise, the member can speak openly with their superior(s), support the different aspects of the standard, and clarify the institutional doubts they may have. This has been shown to be a good tactic to get the full support of the institutions involved.

2.11 *Legislative Involvement*

Having the support of the heads and directors of the institutions dealing with drinking water and with the DWQS proposal in hand, the lead institution through its highest level representative, should contact the legislative authority and present it for its adoption as law or regulation. Once the DWQS is adopted, then the DWQS Committee should maintain follow-up activities.

2.12 *Follow-up Activities*

As indicated previously, a DWQS should be alive. The aliveness of this tool will depend on the vital energy that the DWQS Committee gives it. Two main activities should be carried out on a continuous basis:

- Monitoring of the implementation
- Gathering of new information related to water quality data, epidemiology, laboratory analysis, treatment technologies, etc.

Monitoring is vital to see how the standard is doing, how it is used, whether it is being abided by or not, and whether it is too demanding or too flexible. As with any activity, it is important to check work performance to correct flaws and drawbacks when making revisions for future editions of the DWQS.

In the search of a successful (useful and usable) DWQS, the final product will most probably be simple and modest. The gathering of new information is important because it will prepare the field for increasing the level of complexity in the next up-grading process.

As a summary for these two conditions, it can be stated that information gathering is important to make the standard more complete and comprehensive, while monitoring will allow the fine polishing of the standard. It is advisable to keep the DWQS Committee active and to ensure constant communication by holding frequent meetings.

3. How to Work out Each Section

This point is directed to the core of the Committee's task: the development of the standard. As previously suggested, there should be a minimum of thirteen sections which will comprise the final standard. While all sections add to the importance and comprehensiveness of the standard, not every section will have the same weight and length. Some of the sections are crucial and are so important that they may demand more time, dedication, and resources to develop. One example is the TPC. Due to its importance and to the visibility it gives to the whole DWQS, it will require more effort from the Committee and, accordingly, this section is discussed in more detail in this Guide. In the pages to come, a series of examples will be given. They are presented as a guide or recommendation. By no means do they represent the total possible list and in some cases, the Committee may find some of them unnecessary.

3.1 *Introduction*

As its name indicates, this is the entrance door to the DWQS. Although it does not need to be excessively long, it should address at least the following:

- *The importance of a DWQS:* Mentioning of the relationship between drinking water and health.

- *Precedents:* A very brief history of the standards if there were other previous editions in the country.

- *Aim of the DWQS:* Importance of the standard in providing day-to-day operational values to ensure that there are no health risks to the consumer, to serve as a basis for the design and planning of water supply augmentation, and to provide a benchmark for assessing long-term trends in the performance of the system.

- *Principles:* Clean and safe water access for everyone, the economic value of water and the costs of treating water to make it potable, the need for sustainability of the services and the protection of the environment while producing drinking water, are among the possible recommendations based on codes and principles.

3.2 *General Clauses*

This section will incorporate all miscellaneous aspects that do not belong to a specific area. Among these can be mentioned:

- *Mandate:* Statement that assures that all drinking waters delivered to the population will respect the values as presented in the TPC.

- *Scope of the DWQS:* Presents the exclusions for waters that will not be covered by the standard, like some special types of water (mineral water, soda water, or water intended for other uses including medicinal waters). Another exclusion is the number of users to which the actual DWQS will not be applied (in some countries this number varies from 25 or 50 people). Exclusions can also be applied to a minimum flow of water for common or individual use. As an example, the European Community establishes that a flow of less than 10 m^3/day is not subject to control.

- *Technical approach:* Brief description of technical issues, such as the approach that will be taken to prepare frequency of sampling tables and considerations in the selection of parameters and their concentrations. This will be covered in more details in section 3.5.

- *The point of use (POU):* The point of use is where the DWQS will be applied, for example, outside the water treatment plant, in a reservoir, in the distribution network, etc.

- *Exception clauses:* Exception to the enforcement of certain parameters, their concentration or time exemption, if any, may be included in this section.

- *Revisions:* Recommended period of time between revisions or up-dating of the DWQS.

3.3 *Definitions*

In order to know the full meaning of technical terms, it is important to have these very well defined. Every DWQS has a list of such expressions and its extent is related to the length of the document but it is mostly dictated as input from the Committee members. Definitions should be clear, short, and use as few technical words as possible.

It is not necessary to have a very long list of definitions but, at the very least, the list should be comprehensive, cover the most common expressions, and terms that the public and authorities not involved in the drinking water technical field may not be familiar with.

In this regard, attention should be given to terms such as: “control” and “surveillance”; “drinking”, “potable”, “safe” and “mineral” water; “aesthetic” and “organoleptic” parameters; “maximum tolerable” and “ideal” concentration; to some parameters or group of substances like “organic”, “agrotoxics”, “pesticides”, “disinfection by-products”, "trihalomethanes" (THM), etc; biological water components like “protozoa” “coliform”, "thermotolerant coliform bacteria" and "virus"; and institutional terms like "service", "surveillance agency", "regulatory agency", etc.

3.4 *Institutional Framework*

This section may well be called "roles, rights, and responsibilities". Mention should be made in this section of the actual legislation dealing with drinking water matters and to the extent of the regulation. If the regulation is thorough, it will be easy to identify the key institutions and their role in the drinking water field. If there is no such identification and role designation, then this section should clearly establish both. Once this is done, one practical way of dealing with the section is to list those institutions and under each one of them, describe the rights and responsibilities they should have. For example:

Rights and obligations of the Ministry of Health:

- Produce the DWQS and deliver it to the regional (provincial or state) institutions for their implementation.

- Promote and support the drinking water quality surveillance programs developed by regional health institutions.

- Develop national water quality reference laboratories to support the surveillance activities developed by regional institutions.

- Approve sampling and sanitary inspection programs proposed or developed by regional institutions.

- Maintain drinking water surveillance activities to complement regional drinking water surveillance activities.

It is in this section where it should be stated the way of managing and implementing the DWQS depending on the type of legislative structure the country has. Depending on that structure, the DWQS may fall either into a system (sometimes called *unitary*) where, emanated from a central level (for example the Ministry of Health), it has to be adopted exactly as it was validated, or it may fall into a system (sometimes called *federal*) where a state or a region may modify it prior to its local implementation. The last option is what happens in some developed countries like the European Union or the United States of America. In the second case it is the norm that no regional or provincial DWQS can be more flexible than the one coming from the central level.

It is customary in the unitary system to consider the list of parameters and concentrations (TPC) presented by the central level as a "standard"; while in the federal system it is usually called "guidelines" (because it is a guide for the provinces or states to produce their own standards).

3.5 *Table of Parameters and Concentrations (TPC)*

"Parameter" is the usual term used for a substance that can be present in raw or treated water. In drinking water, a parameter in itself is not totally relevant, unless it is coupled with its concentration. This is highly important, because, as the toxicologists like to express: “It is not the substance that may be dangerous, but its concentration” or better paraphrased: "It is the dose that defines the poison".

This explains why a certain parameter at a certain concentration can be considered normal or even desired, while at other concentrations, it is a contaminant. The typical case being fluoride. Concentrations of fluoride of around 1 mg/L in drinking water may be optimal for good dental health, while higher doses may give rise to several diseases (dental fluorosis, skeletal fluorosis, etc.).

When dealing with this section, the final product will be a list of parameters with their linked concentrations. Although different DWQS use the terminology "quality criteria", "potability standard", "table of limits", "technical standard", "parameters of water quality" and others, this document will use the term "table of parameters and concentrations" or "TPC".

The TPC is the most visible part of the DWQS. In fact, many professionals even think that the TPC is the standard itself. This stems from the fact that the TPC is one of the most consulted part of the standard. It is one of the most important tools in any program of drinking water quality surveillance and control, and it has an obvious relationship with the treatment demands.

The parameters and their concentration limits will not only pose precise requirements on the technical side of the equation, but also on the economic side. A stricter limit will require more strict treatment, and simply stated, this will involve money. It is here that the already mentioned flexibility should be very carefully managed and balanced in order to make a water system economically (and technically) viable, while not compromising the health of the consumers.

Activities the DWQS Committee has to perform to develop the TPC are:

- Selection of parameters.
- Assignment of concentration limits to the selected parameters.

3.5.1 Selection of Parameters

It is well known that thousands of substances have been identified in water. For practical reasons, it would be obviously impossible to monitor all these substances in routine drinking water quality surveillance or control programs. A DWQS should then focus on a clearly set number of parameters. While the WHO-GL present a list of over 100 parameters, most of the DWQS of different countries around the world have a far smaller number of parameters.

How to do that selection? What criterion should the experts in the DWQS Committee follow?

The route this Guide suggests is the following:

(a) Make a classification of the substances in water.
(b) Individualize the most conspicuous substances in that classification.
(c) Develop a diagram of health hazard-occurrence.
(d) Select the parameters by drawing the line.

Classification of the Substances in Water

Substances in water can be classified according to their chemical characteristics (inorganic, organic, radiological, etc.) or according to other characteristics associated with their uses, functions, or physical condition. A number of classification systems are therefore possible.

One possible classification is that used in the Brazilian standard and is as follows:

- Microbiological
- Turbidity

- Chemical substances with implications in human health
  - Inorganic
  - Organic
  - Agrotoxic
  - Cyanotoxins
  - Disinfectants and disinfectant by-products
- Radiological
- Aesthetics.

A classification where the focus is on the alteration the substances produce to the water, is the one used in the DWQS of France:

- Aesthetics
- Physical-chemical related to the natural condition of waters
- Undesirable parameters
- Toxic substances
- Microbiological
- Pesticides.

The classification recommended here is widely used and is the one adopted in the WHO-GL:

- Microbiological
- Chemicals (health-related)
  - Inorganics
  - Organics (other than pesticides)
  - Pesticides
  - Disinfectants and disinfectant by-products
- Radiological
- Aesthetics.

Individualization of the Most Conspicuous Substances

This individualization could be considered the first (or rough) selection of parameters. As an example, it can be pointed out that while the available information shows that there are no important health-related problems with the consumption of tin at the concentrations normally found in raw or treated water, this is not the case for arsenic. The first selection may well leave tin aside, while it should incorporate arsenic to be evaluated in the second and final selection.

The Committee doing this pre-selection should also bear in mind that not only individual parameters may have different weight, but also groups of parameters may be of different importance. Discussion of these groups and most important parameters will be done in the following paragraphs.

The first important group to be considered, is the group of *microbiological contaminants*. These constituents can have a huge impact on public health since diarrheas due to gastroenteritis and cholera are major problems in developing countries. WHO publishes every year the *World Health Report*, where epidemiological statistics show that diarrheas have the highest morbidity rates for the human race.

Ensuring that drinking water is free of microbiological hazard is perhaps the most important priority. In other words, in order to decrease the risk of waterborne diseases in any country, standards for the microbiological quality of drinking water should be developed and implemented as a first priority.

While there are a vast number of microbiological organisms ranging from nematodes to protozoa to bacteria to virus, and since it would be almost impossible to check for all of them, one or two "indicators" are normally selected. These indicators have such characteristics that their presence means a very high probability that other microbes may be present, while their absence is a good evidence of the microbiological safety of the water tested.

WHO microbiological guidelines have been adopted worldwide and they recommend as indicators of microbiological quality the adoption of the following parameters:

- *Escherichia coli or thermotolerant (faecal) coliform bacteria:* These must not be detectable in any 100-mL samples of any water intended for drinking.

- *Total coliform bacteria:* These must not be detectable in any 100-mL samples of treated water entering the distribution system. Allowance can be made for the occasional occurrence in the distribution system of coliform organisms in up to 5% of samples taken over any 12-month period, provided *E. coli* is not present.

The group of *inorganics (health-related)* normally address the most commonly found parameters in raw and treated waters. It is not a very extensive group and the most important parameters to be considered are described below.

- *Arsenic:* Arsenic is naturally present in several areas in the world. Ground water may have high arsenic concentration as has been found in Bangladesh, Mexico, Argentina, and the USA. Arsenic can be released into the environment from natural sources (volcanic eruptions, erosion of rocks, forest fires) or human activities (paint industry, wood preservation, metal production, drugs, semi-conductors, etc.). Long-term exposure to arsenic in drinking water has been linked to cancer of the bladder, lungs, skin, kidney, liver, and prostate.

- *Barium:* Barium occurs in a number of compounds in the earth's crust and is also used in a number of industrial activities. Although the evidence is weak, barium is associated in some epidemiological studies with adverse cardiovascular effects in humans.

- *Chromium:* Chromium is widely distributed in the earth's crust and exists in valences states of +2 to +6. Of these, the most important from the ingestion point of view is the +6 state as it is the most easily absorbed from the gastrointestinal tract and it is also the one to be able to penetrate cellular membranes. Although there is no clear evidence of the relationship between chromium +6 ingestion and disease, inhaled chromium causes lung cancer.

- *Fluoride:* Fluoride is present naturally in the earth’s crust in minerals such as fluorspar (calcium fluoride). Ground water in many areas of the world may have high concentrations of fluoride. Levels between 0.5 and 1 mg/L are beneficial to health, providing substantial protection against dental caries. WHO Oral Health Program supports fluoridation of water supplies as a cost-effective method for reducing dental caries in children. However, for fluoride, the margin between beneficial and toxic effects is rather narrow. Higher concentrations of fluoride (1.5 - 2 mg/L) may lead to dental fluorosis. At 3 - 6 mg/L, skeletal fluorosis may be observed, and crippling skeletal fluorosis can develop where drinking water contains more than 10 mg/L.

- *Lead:* Lead is present in drinking water as a result of its dissolution from natural sources or from household plumbing containing lead. The most significant health effect from lead is its association with reduced intelligence quotient (IQ). Infants and children are particularly susceptible to the adverse effects of lead.

- *Mercury:* Although natural sources of mercury exist in the environment, such as mineral deposits, hot springs and volcanoes, increased amounts of mercury have entered the biosphere from anthropogenic sources. These are gold mining, medical incinerators, and coal and oil combustion. Gold mining is considered to be the largest single source of mercury pollution to the environment in the world. It has been estimated that between 100 and 150 tons of mercury are released in the Amazon basin per year. Mercury affects the brain, the nervous system, and the kidneys.

- *Nitrate and nitrite:* Sources of nitrate in water include geological formations containing soluble nitrogen compounds, agricultural fertilizers, decaying plants, manure, and domestic sewage. Nitrate is highly mobile in soil and migrates readily into groundwater. Under anaerobic conditions, nitrate may be reduced to nitrite. High levels of nitrates in drinking water may lead to serious, even fatal, consequences in bottle-fed infants less than three months of age. Nitrate is reduced to nitrite in the gastrointestinal tract, and combine with blood hemoglobin to form methahemoglobin, which is unable to transport oxygen to the tissues. The result is cyanosis ("blue baby" syndrome) and eventual asphyxia. Young infants are more susceptible to methahemoglobin formation than older children and adults.

Two conditions should orient the selection of *health-related organic* compounds to be included in the TPC of the DWQS. First, many of these organic substances are carcinogenic, mutagenic or both. However, at the concentrations usually found in drinking water, a prolonged period of exposure (e.g., 20 years or more) is needed to produce such impact on human health. That is to say, the risk organic chemicals pose to human health has not the same weight as the risk derived from microbiological contaminants. Second, and contrary to the inorganic substances, there is a wide range of compounds in the organics group.

These two conditions make it necessary to adopt a very careful selection procedure if the standard is to be realistic. A convenient way of dealing with such a large number of substances is to divide the organic group into sub-groups:

- Organics related to health
- Pesticides
- Disinfectant and disinfectant-by-products (DBP).

The first sub-group of organics related to health can be further divided into a few categories:

- Chlorinated alkanes
- Chlorinated ethenes
- Aromatic hydrocarbons
- Chlorinated benzenes
- Miscellaneous.

The WHO *Guidelines for Drinking Water Quality* (WHO-GL) (version 1993) includes five chlorinated alkanes; five chlorinated ethenes; six aromatic hydrocarbons; five chlorinated benzenes, and nine miscellaneous compounds.

Pesticides include all the substances that are used in agriculture to eliminate undesirable pests. These include insecticides, acaricides, nematocides, fungicides, and herbicides. The WHO-GL includes 36 such pesticides.

The last group of health-related chemicals consists of the disinfectants and disinfectant by-products (DBP). DBPs are the products disinfectants produce after their use in the treatment of water.

Although there are several disinfectants, very few are used in developing countries. By far, the most popular disinfectant, covering more than 98% of the systems is chlorine. A few systems may use other disinfectants such as chloramines and chlorine dioxide. Two methods that are slowly gaining importance in water treatment, ultraviolet radiation and ozone, do not pose any direct health risk (as disinfectants) because ultraviolet radiation does not leave a chemical residual and ozone has a very short half-life.

Even though a guideline value for chlorine is given in the WHO-GL (5 mg/L), this limit is unlikely to be reached and most probably there would be a rejection by the consumers before reaching this level because of unpleasant taste and odor.

As for the disinfectant by-products, chlorine is not the only disinfectant producing undesirable substances after its use. Chloramines, ozone, and chlorine dioxide also produce DBPs of potential risk to human health. Since DBPs are normally found in treated water, it is important to consider their inclusion in the DWQS. Nevertheless, a very important point will be made here and it is suggested that a similar cautionary comment be made in the standard. DBPs are a risk when disinfecting water. However, the elimination of this risk by means of suppressing the disinfection that produces them may give rise to microbiological contamination, a much higher health hazard.

The WHO-GL is very clear in this respect: "Where local circumstances require that a choice must be made between meeting either microbiological guidelines or guidelines for disinfectants or DBP, the microbiological quality must always take precedence. Efficient disinfection must never be compromised". The WHO-GL gives guide values for 24 DBP. The most commonly found are the groups of chlorophenols, trihalomethanes (THM), and chlorinated acetic acids.

The aesthetics is a group which calls for different standards: "organoleptic", "acceptability parameters", "substances not health-related" or "substances and parameters in drinking water that may give rise to complaints from consumers". If it is true that the first aim of a DWQS is to provide the framework for "safe" water, a second but also important goal is to assure that the water will also be pleasant to the consumer. Consumers may not be able to judge if the water they are drinking is harmful or not to their health but, through their senses, they may perceive it as being pleasant or not. A colored, turbid, smelly, or tasty water may give place to rejection. This in turn may lead to complaints and possibly to the use of water from less safe sources or from more expensive ones (bottled water).

There is a number of this type of constituents. The standard may or may not include a sub-classification for these substances, but if desired they can be divided into:

- Physical
- Inorganic
- Organic
- Disinfectant and DBP.

The most common ones and their main characteristics (the ones that give rise to complaints) are given in Table 1.

Table 1. Aesthetic Parameters and Their Effects

Physical	
Color	Raises suspicion by the user of foreign undesirable matter.
Taste and odor	Indicate *per se* some type of pollution.
Temperature	High temperature not only is not agreeable to the palate, but may offer good conditions for microorganisms to grow.
Inorganic	
Aluminum	Produces turbidity (flocs of aluminum hydroxide).
Chloride	Bad taste.
Copper	Increases corrosion of galvanized iron and steel fittings. Produces stains in laundry and in sanitary ware.
Hardness	Causes scale deposition in tubes and steam boilers, and results in excessive soap consumption. Bad taste.
Hydrogen sulfide	Odor and bad taste.
Iron	Ferric iron gives reddish-brown color to the water. Iron stains laundry and plumbing fixtures. Promotes growth of "iron bacteria" which produce deposits in piping.
pH	Important operational parameter, as the effectiveness of disinfection with chlorine depends on its value.
Sulfate	Depending on the associated cation, may give bad taste to the water.
Total dissolved solids	Has effect on taste.
Organic	
Dichlorobenzenes	Odor.
Ethylbenzene	Odor.
Monochlorobenzene	Odor and bad taste.
Styrene	Odor.
Synthetic detergents	Odor and bad taste. Production of foam.
Toluene	Odor.
Trichlorobenzenes	Odor.
Xylene	Odor and bad taste.
Disinfectants and DBP	
Chlorine	Odor and bad taste.
Chlorophenols	Odor.

Radiation in the environment originates from a number of natural and human activities. Even though natural sources are responsible for most of the radiation humans are exposed to, there is a risk that radionuclides may contaminate the water from nuclear wastes, nuclear power plants, and nuclear weapons testing. Exposure to ionizing radiation has different effects on humans, depending on the organ and the type of tissue. The radiological parameters are rarely monitored in developing countries.

Development of a Diagram of Health Hazard-Occurrence

With the broad view the previous sections have provided, the time has arrived for a more focused intervention in the selection of parameters that will be included in the DWQS. This is done by means of the *Diagram of Health Hazard-Occurrence.* As its name indicates, one axis (the y-axis) is used for the rate of occurrence of each parameter in the water (both raw and treated) and the other axis is for the health risk associated with the consumption of such substance.

The graphic is built by placing each and every possible parameter with its occurrence value and its health hazard value.

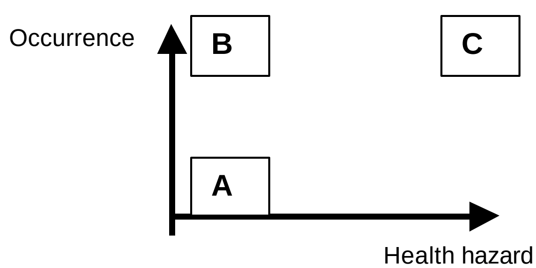

Figure 2. Diagram of Health Hazard-Occurrence

A substance with low occurrence and low health hazard will be placed on the lower left side of the graph (A).
A substance with high occurrence but low health hazard will be placed in the upper left side of the graphic (B).
A substance with high occurrence and high health hazard will appear in the upper right corner of the graph (C).

How to identify the health hazard information?

The WHO-GL provides detailed information on the health effect of approximately one hundred chemicals (Volume 2: Health criteria and other supporting information). This information is summarized in Volume 1: *Recommendations*.

The International Programme on Chemical Safety (IPCS) is a joint venture of the United Nations Environment Program, the International Labor Organization, and the World Health Organization. It produces a series of documents called *Environmental Health Criteria* (EHC) where the effects of chemicals on human health and on the environment are described. The EHC monographs have information on over 200 chemicals.

The US Environmental Protection Agency Integrated Risk Information System (IRIS) is an electronic database containing information on human health effects that may result from exposure to various chemicals in the environment. It has information on more than 500 substances.

These (and others) are tools that provide hazard identification and dose-response assessment information. It should be noted that the information in WHO-GL, the EHC monographs, and IRIS is easily available through the web (see References).

As for the *occurrence* of the different contaminants, this will be related to the type of treatment the water undergoes prior to distribution, and obviously, intimately related to the quality of the raw water. Therefore, it will be necessary to identify the type and concentration of those contaminants in the water sources. There are many ways of doing this.

- The first one is to analyze the information already available related to drinking water and raw water. The Ministry of Health, the Ministry of Agriculture, and the water supply companies may have this information.

- The second one is to search data from other agencies. Customs and the agriculture authorities may have lists with the most widely used pesticides in the country. Water companies and the National Institute of Standards may have ample information on the chemicals and materials used in water treatment and distribution. The Department of Industry may have facts and figures about industrial discharges, which is a good way to find out what foreign substances are added to the raw water. Finally, short but broad sampling programs may also give information on the occurrence of contaminants in water both at the sources and at the distribution systems.

At this point, and with the information gathered, the next step is the:

Selection of the Parameters by "Drawing the Line"

Once the health hazards have been identified and the occurrence established, the graph is plotted and the different parameters will be distributed. Three zones can be identified: high, medium and low priority.

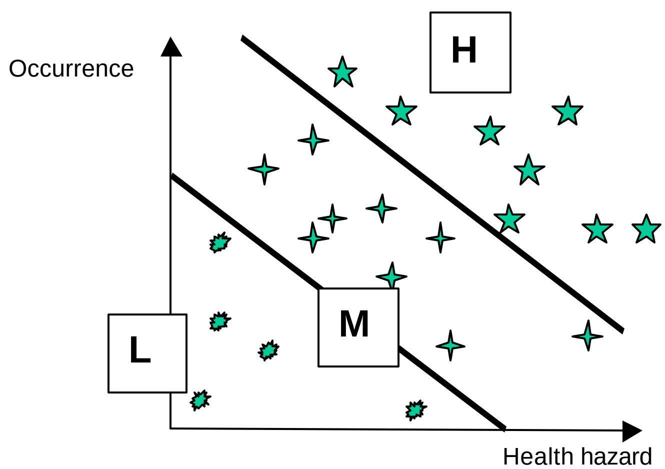

Figure 3. "Drawing the Line" to Select Parameters

Figure 3 depicts a qualitative prioritization scheme for setting the DWQS. Depending on the resources of the country the standard may have a small or large number of parameters and their selection should be done taking into consideration their position in the graph.

It is clear that standards should be set at first for those contaminants that occur frequently and at significant concentrations in drinking water and that have the greatest health impact. In the graph, these are the parameters in the "high" section (the five-point stars). Microbiological contaminants belong to this category. As indicated before, information on the water contaminants and the resources the country has will influence the selection of contaminants in the "medium" zone, while the ones in the "low" zone could be considered only if there are plenty of resources.

3.5.2 Assignment of Concentration Limits to the Selected Parameters

This is the second part of the activity: preparing the TPC. Countries may adopt either of two approaches: a table with one limit or a table with two or more limits. As stated in the Introduction, two important conditions are "reality" and "flexibility", and these are very important when setting limits. If a limit is too demanding, with no flexibility at all, then the standard is unrealistic. It will not be abided by and to have such a standard is worse than not to have a standard at all. If a TPC is to have only one limit, then this inevitably has to be flexible. Australia, France, Mexico, and most of the Caribbean countries are examples of countries having standards with only one limit.

Italy, Nicaragua, Spain, and the United States are examples of countries with two-limit standards. In this case, one of the limits is referred to as the ideal value the water should have. In fact this is a goal that the water industry should aim for, and a level to achieve with time and the improvement of technology. These limits are usually named: "ideal value", "recommended value", "guide value", "maximum contaminant level goal" or "desired concentration".

The second limit or maximum concentration allowed for the different parameters is less strict but may still achieve an adequate margin of safety for the users. The names these limits usually have are: "maximum limit", "maximum admissible concentration", "maximum contaminant level" or "upper limit".

In a few cases some countries have even gone further and adopted three different limits. In this case the limits will address: (a) the ideal value; (b) a concentration that while not being the goal, is still well balanced and presents a wide safety margin, and (c) the absolute maximum level, sometimes provisional or having a deadline after which the parameter should achieve level 2. One example is Colombia (INCOTEC, 1979) where the limits are called: (a) suggested; (b) acceptable, and (c) maximum admissible.

In the case of the European Community, the EC in 1989 proposed three limits: (a) the guide level; (b) the maximum admissible concentration, and (c) the minimum required concentration. The concentration in each case is obtained by a process called "risk management action".

As previously explained, the information taken into account when selecting the parameters using the health hazard-occurrence diagrams, came from the WHO-GL, IRIS, the EHC, etc. This information is useful in selecting the parameters through the graph exercise, but it is also useful to develop the process that will produce the limits for the selected parameters. In fact, these documents will allow the preparation of a risk assessment (or at least a part of such risk assessment).

A risk assessment is the characterization of the potential adverse health effects of human exposures to environmental hazards, and it is used in the risk management process.

A risk assessment consists of four steps:

- Hazard identification
- Dose-response assessment
- Exposure assessment
- Risk characterization.

Hazard identification involves the gathering and evaluation of data on substances that may cause disease in humans. It identifies the manner in which these substances cause disease and quantifies the contribution of the different routes of exposure to the overall human exposure.

Dose-response assessment analyses the quantitative relationship between the extent of the toxic effect or disease and the amount of exposure to a substance. Both hazard identification and dose-response analysis can be done using IRIS and other documents previously mentioned.

As for "exposure", while "occurrence" is a relatively simple concept and was used to select the parameters in the health hazard-occurrence diagram, *exposure assessment* goes a step further beyond the mere fact of determining the occurrence of a substance. Exposure is not only the determination of the presence and concentration of the substance but also the frequency of its occurrence in water, its ubiquity, abundance, and persistence. It is also the estimation of the dose or level of the substance to which individuals or populations are exposed. The evaluation could concern past or current exposures, or even exposures in the future.

Risk characterization involves the integration of the data and analysis of the first three components of the risk assessment process and determination of the likelihood that humans will experience any of the various forms of toxicity associated with a substance.

Finally, risk management is the process by which an action is taken to develop measures to prevent potential dangers and threats to the public health. It is by a risk management process that the concentration limit of a certain hazardous substance is allocated. Or, in other words, a concentration of a parameter in water is set according to a certain risk that the public health authority has decided to accept.

What is the level of risks? And what are the risks that are normally taken when setting DWQ Standard limits in the TPC?

If in epidemiology a risk of 10^{-1} to 10^{-2} is considered "clinical", then it is from 10^{-3} upwards (in fact, downwards) that the risks for both morbidity (cases) and mortality (deaths) are of importance in setting DWQ standards.

Most of the Guideline values for the listed parameters suggested in the WHO-GL are estimated for a very low risk. This is the case of compounds considered to be genotoxic carcinogens, where the concentrations in drinking water were established assuming a daily consumption of 2 liters of water by a 60-kg adult, and after a life-long of 70 years. The values for these consumers under those conditions were associated with a risk of 10^{-5}; which means that in a certain population there will be one additional case of cancer per 100,000 of the population ingesting drinking water (2 liters/day) containing the contaminant substance at the guideline value for 70 years.

Some of the parameters may be allowed to be present in concentrations associated with lower risks than others which are associated with higher risks. In any case, from the public health point of view and also from a practical point of view, a risk range from 10^{-6} to 10^{-3} should be considered.

It is here where flexibility will be applied as the DWQS Committee will have to adjust the concentrations and their associated risks, depending on the technical resources of the water treatment facilities, the economical factors of such treatments, the chemical laboratories know-how, and equipment availability to detect very low concentrations of certain substances. It is also obvious that if a TPC has one limit or two limits, the values of the concentrations will have to reflect such flexibility in a different way. An example will clarify this:

Single limit TPC:

Table 2. Single Limit TPC, Risks, and Associated Concentration

Parameter	Risk assessment	Concentration associated with such risk
A	10^{-5}	C1
B	10^{-3}	C2
C	10^{-4}	C3
D	10^{-4}	C4

Double limit TPC: Where one limit may be called the "ideal value" and the second the "maximum admissible concentration".

Table 3. Double Limit TPC, Risks, and Associated Concentrations

Para-meter	Risk (1) assessment for ideal values	Concentration associated with risk (1) (ideal value)	Risk (2) assessment for maximum admissible concentration	Concentration associated with risk (2) (maximum admissible concentration)
A	10^{-6}	C1	10^{-4}	C5
B	10^{-5}	C2	10^{-3}	C6
C	10^{-5}	C3	10^{-4}	C7
D	10^{-6}	C4	10^{-3}	C8

As seen, in the first case (Table 2) there is only one limit and this has to show as much flexibility as possible, but the values cannot be so loose as there should be a compromise between the maximum risk and the ideal value. In the second case (Table 3), while one limit is very strict, the second one, being looser by definition, is where a greater flexibility can be introduced.

The WHO has produced in 2002 the *Chemical Monitoring Protocol*; a document highly recommended when dealing with this section, as it has been specially developed to cope with the way to prepare a precise and useful TPC. In fact, this document was produced to assist developing countries to determine which chemicals should be considered as priorities for the purpose of developing risk management strategies, including standard setting and monitoring, in the context of drinking water quality surveillance and control.

A final recommendation derived from this section is the one related to a practical and reasonable condition, which many DWQS do not address. If distributed water from a particular system shows a compliance with the DWQ standard for years and suddenly one sample shows a deviation from the value of the standard, does this mean that the service is doing things wrongly? Or that it should be disciplined, fined, or the water distribution halted even if the deviation is a slight one?

Common sense says this is not advisable. But how to overcome this?

Many DWQS associate an acceptable margin of non-compliance of the standard with certain parameters (for example microbiological ones). The WHO-GL suggest that for treated water in the distribution system: "Total coliform bacteria: must not be detectable in any 100-mL sample. In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period".

The Australian DWQS establishes that: "95% of scheduled samples should not contain any coliform organisms in 100 ml" and adds a very specific flexibility clause: "Up to 10 coliform organisms may be occasionally accepted".

The DWQS for Brazil presents a standard for turbidity where there is a similar allowance, depending on the type of source or treatment. Similar flexibility could be considered for other parameters.

Table 4. Accepted Deviations from the Standard for Turbidity (Brazil)

Source/treatment	Maximum admissible value for turbidity unit (TU)
Ground water (with disinfection)	1 TU in 95% of samples
Rapid filtration (after complete treatment)	1 TU
Slow sand filtration	2 TU in 95% of samples

3.6 *Frequency of Sampling and of Sanitary Inspections*

When dealing with a program of drinking water quality surveillance or control, the microbiological and physical-chemical analysis on one side and the sanitary inspections on the other are relevant activities that should be carried out by the surveillance agency and by the water supply company.

Both sampling for analysis and the sanitary inspections should recognize a program that considers the selection and visit of the most important points in the water system, like the treatment plant, reservoirs, low pressure points, stand pipes, special connections, etc. These visits should also recognize a frequency pattern.

The establishment of such frequencies of sampling for water analysis and of visits to water systems for sanitary inspections, depend on:

- The quality of the source water
- The number of water sources
- The treatment the water receives
- The risks of contamination in various parts of the system
- The particular type of system
- The previous history of water quality
- The size of the population supplied with water.

In developing countries, all of the above conditions should also be balanced with the availability of personnel, transport, and laboratory facilities. That is, the resources available to both the water companies and the public health service will dictate what may be assigned to these activities.

As in the case of the TPC, where a lower limit may require a more demanding treatment, which in turn means better equipment and higher operational costs, a higher frequency both of analysis and of sanitary inspections in the drinking water quality surveillance and control programs implies higher costs and greater resources.

It is then important that both the public health institution and the water supply companies evaluate their resources and work towards the goal of having realistic, although not health-compromising, frequencies of sampling and sanitary inspections. In any case, important approaches should be taken to satisfy the last statement.

First, the different parameters (for example: microbiological, physical-chemical, aesthetic), should have a differentiated treatment. Due to higher risks the microbiological parameters pose to human health when compared with the aesthetic parameters, the microbiological parameters should have a higher frequency of sampling.

Second, it is always advisable to have at least a basic standardization for such frequencies. Which is to say that the DWQ standard should establish a minimum number of samples and sanitary inspections to be carried out for different types of systems.

Finally, the standard may also present a table indicating increasing numbers of interventions, according to the increasing level of implementation of the drinking water quality surveillance or control programs. This is another way to show flexibility in the standard.

Some examples will clarify these approaches. Let us consider initially, the sampling frequency for laboratory analysis. A DWQ Standard could consider the sampling for microbiological analysis on one side and the physical-chemicals on the other. Even these, could be divided into two or more clusters of parameters.

When preparing a table of frequency for microbiological parameters the simple fact should be considered that relatively simple tests done with a reasonable frequency are of more value in monitoring the quality of a supply than occasional exhaustive tests. A standard analysis for total coliforms and an analysis for *Escherichia coli* or thermotolerant coliform bacteria would suffice. The frequency for microbiological sampling can be linked to the size of the population using the particular service.

Examples:

Table 5. Frequency of Sampling for Microbiological Analysis

Population supplied with water	Minimum number of samples/month
WHO (Guidelines)	
< 5,000	1
5,000 – 100,000	1/every 5,000 population
> 100,000	10 + 1/every 10,000 population
Australia	
< 2,000	1
2,000 – 10,000	1/every 2,000 population
10,000 – 100,000	3 + 1 /every 5,000 population
> 100,000	13 + 1/every 10,000 population
Argentina (COFES)	
< 10,000	1
10,000 – 100,000	4
> 100,000	30

It is obvious that if a certain system is to be visited to take 20 samples in a month, the quality of the monitoring is not the same if all these samples are taken in one visit or if they are distributed over a one-month period.

It is then appropriate for the standard to present another table with the intervals between samples, as the example shown from the US Environmental Protection Agency.

Table 6. Intervals Between Samples for Microbiological Analysis

Minimum number of samples / month	Maximum period between consecutive samples
< 5,000	1 month
10,000 – 20,000	1 month
20,000 – 45,000	2 weeks
45,000 – 100,000	4 days
100,000 – 300,000	2 days
> 300,000	Daily

The following tables are from the England and Wales Drinking Water Regulation. They are interesting as they not only give a different weight to different sets of parameters (thus presenting different clusters), but they also recognize three different levels of sampling complexity: reduced, standard and increased. The first one is divided into water from underground source (GW), and water from surface source (SW).

Table 7. Clusters of Parameters for Sampling Purposes

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Conductivity or pH	Odor (quantitative)	Trihalomethanes	Chloride
Odor (qualitative)	Taste (quantitative)	Carbon tetrachloride	Sulfate
Taste (qualitative)	Turbidity	Trichloroethene	Calcium
	Temperature	Tetrachloroethene	Magnesium
	pH	Copper	Sodium
	Nitrate	Lead	Potassium
	Nitrite	Zinc	Dry residues
	Ammonium	Pesticides	Oxygen demand
	Iron	Polycyclic aromatic	Total organic carbon
	Aluminum	Hydrocarbons	Boron

Table 7. Clusters of Parameters for Sampling Purposes (Continuation)

Cluster 1	Cluster 2	Cluster 3	Cluster 4
	Manganese		Surfactants
	Color		Phosphate
			Fluoride
			Barium
			Silver
			Arsenic
			Cadmium
			Cyanide
			Chromium
			Mercury
			Nickel
			Antimony
			Selenium
			Total hardness
			Alkalinity

Table 8. Sampling Frequencies at Supply Points

Population	Sampling frequency (number/year)							
	Cluster 1				Cluster 2			
	Reduced		Standard	Increased	Reduced		Standard	Increased
	GW	SW			GW	SW		
< 500			4	12			4	12
500-5,000	4	4	6	12			4	12
5,000-10,000	4	6	12	24			4	24
10,000-20,000	6	12	24		4	4	6	24
20,000-50,000	15	30	60		4	5	10	60
50,000-100,000	30	60	120		5	10	20	60
100,000-150,000	45	90	180		8	15	30	60
150,000-300,000	90	180	360		15	30	60	120
300,000-500,000	90	180	360		30	60	120	
500,000-1,000,000	90	180	360		30	60	120	

Table 8. Sampling Frequencies at Supply Points (Continuation)

Population	Sampling frequency (number/year)								
	Cluster 3				Cluster 4				
	Reduced		Standard	Increased	Reduced		Standard	Increased	
	GW	SW			GW	SW			
< 500	1	2	4	12			1	12	
500-5,000	1	2	4	12			1	12	
5,000-10,000	1	2	4	12			1	12	
10,000-20,000	1	2	4	12			1	12	
20,000-50,000	1	2	4	12			1	12	
50,000-100,000	2	3	6	24	1	1	2	24	
100,000-150,000	2	3	6	24	1	2	3	24	
150,000-300,000	2	3	6	24	2	3	6	24	
300,000-500,000	3	5	10	24	3	5	10	24	
500,000-1,000,000	5	10	20	36	5	10	20	36	

Finally, another approach is shown in Tables 9 to 11 presenting a compact list of parameters with the frequency of required sampling according to the type of source and to the point of use. The tables are from Peru's SUNASS.

Table 9. Sampling Frequencies at Points of use (Distribution Network) for a System Using Underground Water Source

Parameter	Frequency of sampling (samples/year)		
	Water flow produced		
	< 50 L/s < 4000 m^3/day	50-100 L/s 4000-8000 m^3/day	100-400 L/s 8000-40000 m^3/day
Total coliform	12	26	52
Thermotolerant coliforms	12	26	52
Chlorine residual (a)	4	4	4
Color	1	2	4
Conductivity	4	4	4
pH	4	4	4
Turbidity	4	4	4
Aluminum	-	-	-
Arsenic	1	1	1
Cadmium	1	1	1
Chloride	1	1	1
Chromium	1	1	1
Copper (b)	1	1	1
Total hardness	1	1	1
Iron	1	2	4
Lead (b)	1	1	1
Manganese	1	2	4
Mercury	1	1	1
Nitrate	1	2	4
Sulfate	1	1	1

Notes:
(a) The numbers correspond to daily sampling.
(b) Only if the material in the distribution network may deliver Cu or Pb.

Table 10. Sampling Frequencies at Points of Use [Outside Water Treatment Plant and at Reservoirs]

Parameter	Frequency of sampling (samples/year)			
	Water flow produced			
	< 50 L/s < 4,000 m^3/day	50-100 L/s 4,000-8,000 m^3/day	100-400 L/s 8,000-40,000 m^3/day	>400 L/s >40,000 m^3/day
Total coliforms	12	26	52	104
Thermotolerant coliforms	12	26	52	104
Chlorine residual (a)	4 (1)	4 (1)	4 (1)	4 (4)
Color	4	6	6	12
Conductivity	12	26 (12)	52 (12)	365 (26)
PH	12	26 (12)	52 (12)	365 (26)
Turbidity	12	26 (12)	52 (12)	365 (26)
Aluminum (b)	4	6	6	12
Arsenic	4	6	6	12
Cadmium	4	6	6	12
Chloride	4	6	6	6
Chromium	4	6	6	12
Copper (c)	4	6	6	12
Total hardness	4	6	6	6
Iron	4	6	6	12
Lead (c)	4	6	6	12
Manganese	4	6	6	12
Mercury	4	6	6	12
Nitrate	4	6	6	6
Sulfate	4	6	6	6

Note:

(a) The numbers correspond to daily sampling and up to 300,000 people. A bigger system needs special chlorine residual frequency sampling programs.

(b) Only when the treatment uses aluminum sulfate.

(c) Only if the material in the distribution network may deliver Cu or Pb.

If no bracket is present the same number of samples are taken for both the treatment plant and the reservoir. When there is a bracket, the number corresponds to samples to be taken in reservoirs.

Table 11. Sampling Frequencies at Points of Use (Distribution Networks)

Parameter	Frequency of sampling (samples/year)			
	Water flow produced			
	< 50 L/s < 4,000 m^3/day	50-100 L/s 4,000-8,000 m^3/day	100-400 L/s 8,000-40,000 m^3/day	>400 L/s >40,000 m^3/day
Chlorine residual (a)	1	1	1	1
Color	2	2	2	18
Conductivity	12	26	26	236
pH	12	26	26	236
Turbidity	52	52	52	472
Aluminum (b)	2	2	2	18
Arsenic	-	-	-	-
Cadmium	2	2	2	18
Chloride	2	2	2	18
Chromium	-	-	-	-
Copper (c)	2	2	2	18
Total hardness	2	2	2	18
Iron	2	2	2	18
Lead (c)	2	2	2	18
Manganese	2	2	2	18
Mercury	-	-	-	-
Nitrate	2	2	2	18
Sulfate	2	2	2	18

Notes:
(d) The numbers correspond to daily sampling and up to 300,000 people. A bigger system needs special chlorine residual frequency sampling programs.
(e) Only when the treatment uses aluminum sulfate.
(f) Only if the material in the distribution network may deliver Cu or Pb.

A useful consideration can be made at this point. As presented, the previous tables are the minimal frequencies of samples to be taken for the different parameters to be monitored. By being minimal, if resources allow it, the minimal frequencies of samples can be considerably increased while establishing the standard, and the drinking water quality surveillance and control programs should start complying with these numbers.

Nevertheless, it is possible that after a few years (two to four) the continuous monitoring show no variance in some parameters. If these parameters are not the ones intimately related to public health, then their monitoring frequency could be reduced.

As an example, the DWQS of Italy states that: "If after two years the concentration values of the samples taken for aesthetic parameter analysis, show constancy at levels significantly lower than those of the limits, and there is no known or foreseeable factor that may diminish the quality of the water; then the public health authority may allow for the reduction in the number of samples to be analyzed. Nevertheless, the minimal frequency should not be lesser than 50% of the established original frequency".

In any case, under no circumstance, should the sampling frequency for microbiological analysis be compromised or modified below the frequency originally established in the standard.

Very similar considerations can be made for the frequency of sanitary inspections. Resources as well as the characteristics of the systems, the treatment, and the population served all should determine the number of visits for this important activity. As an example, Table 12 presents one such frequency. It is taken from the *Guide for Surveillance and Control of Drinking Water Programs* (CEPIS-PAHO/WHO). The table makes reference to an amount of water treated by the individual system both urban and rural, and also recognizes two different levels of complexity.

Table 12. Frequency of Sanitary Inspections

Area	**Volume of water treated (m^3)**	**Frequency of sanitary inspections**	
		Reduced	**Normal**
Urban	< 2,000	--	3
	2,000 – 6,000	3	6
	6,000 – 12,000	6	12
	> 12,000	12	24
Rural	Any	--	2

Table 13 presents a program guideline for sanitary inspections by surveillance agencies. This is an excerpt from WHO *Surveillance of Drinking Water Quality* (1976). It recognizes four levels of implementation.

Table 13. Program Guidelines for Sanitary Inspection Frequency by Surveillance Agencies

Level of surveillance program	Population water system under survey	Source		Treatment		Storage and distribution
		Groundwater	Surface water	Groundwater	Surface water	
I	Rural areas	-	-	-	-	-
	Towns	-	-	-	-	-
	Cities	3 years	2 years	3 years	2 years	3 years
	Major cities	2 years	1 year	2 years	1 year	1 year
II	Rural areas	-	-	-	-	-
	Towns	-	3 years	-	3 years	-
	Cities	3 years	1 year	3 years	2 years	2 years
	Major cities	2 years	1 year	2 years	1 year	1 year
III	Rural areas	Irregular	Irregular	-	-	-
	Towns	5 years	3 years	5 years	3 years	5 years
	Cities	3 years	2 years	3 years	1 year	2 years
	Major cities	2 years	1 year	2 years	1 year	1 year
IV	Rural areas	Irregular	Irregular	Irregular	Irregular	Irregular
	Towns	3 years	2 years	3 years	3 years	2 years
	Cities	1 year	1 year	1 year	1 year	1 year
	Major cities	1 year	6 months	1 year	6 months	6 months

3.7 *Approved Analytical Methods for Analysis*

Water analysis is one of the most important tools to monitor water quality and to ensure its compliance with the standard. While all the practical aspects related to water analysis will have to be considered in great detail in the drinking water quality surveillance and control programs, a few but important points should be addressed in the DWQS.

It is a matter of common sense that if the quality of an analysis is not reliable, very little value could be obtained from this important resource. In addition, if different laboratories use different standardised procedures, then, it will be difficult to compare results from different sources.

Taking these points into consideration, the first conclusion is that a DWQS should present a clause enforcing the establishment of a system of quality control and quality assurance. At the "standard level" it is not important to establish the extent of such QC or QA, or even the order of magnitude of limit of detection or the target accuracy inherent to any of these actions. What is important is that any drinking water quality surveillance and control program should consider these issues. And this has to be stated in the standard.

The second conclusion is that even if the use of a common standard may not imply by itself the achievement of analytical accuracy, it is by all means, the best way to achieve it. Furthermore, the use of a common method will allow comparison of results between laboratories and facilitate the flow of information.

As for "standard" methods of analysis, there are several sets of techniques belonging to international or national agencies. The most used and recognized ones are the *Water quality series* from the International Organization for Standardization (ISO); *Standard Methods for the examination of water and wastewater* from the American Public Health Association; *Report 71* from the British Public Health Service and the *Methods for chemical analysis of water and wastes* from the USEPA.

As a functional and useful orientation for the professionals dealing with drinking water quality surveillance and control programs, some DWQS are prodigal in presenting overly detailed information on how the analytical procedures should be conducted. It is not uncommon to see a standard with a table including parameters, methods to be used, the description of the analytical technique, volume of sample, time between sampling and the start of the analysis, conditions of sampling (for example the addition of preservatives, etc.), and several other features that are too technically specific for a DWQS.

It is better to present such a table, but including only the parameter, analytical method, and the technique to be used. An example with only a few parameters is shown in Table 14.

Table 14. Approved Analytical Methods

Parameter	Method	Technique
Turbidity	Standard Methods - 2130B	• Nephelometry
Calcium	Standard Methods - 3500CaB Standard Methods - 3500CaD	• Atomic absorption spectrophotometry • EDTA titrimetry
Nitrite	Standard Methods - 4500NO_2B Standard Methods - 4500NO_2C	• Colorimetry • Ion chromatography
Fluoride	Standard Methods - 4500F-C Standard Methods - 4500F-D	• Ion-selective electrode • SPADNS
Phenols	Standard Methods - 6420B	• Liquid-liquid extraction gas chromatography

3.8 *Sanitary Surveys*

For any drinking water quality surveillance or control program, the importance of the laboratory analysis may only be matched with another important tool: the sanitary survey.

A sanitary survey is an on-site review of the water source, facilities, equipment, operation and maintenance of a public water system, for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water.

It provides a comprehensive and accurate record of the components of water systems, assesses the operating conditions and adequacy of the water system and determines if past recommendations have been implemented effectively.

A sanitary survey means the evaluation of the water source and intake structure, the treatment and conditioning process, the facilities and components, and also an evaluation of the distribution system. During an inspection, operation and maintenance practices, records, and communication flows are reviewed.

A sanitary survey is a very useful tool because it can give first hand information and it can do so in real time. As in the case of the analytical procedures, it is not mandatory that the DWQS present extremely detailed information or conditions related to sanitary inspections. Nevertheless, it is very important that the issue be addressed, as an obligation for the surveillance and control programs to develop and incorporate clear, extensive, and resourceful sub-programs of sanitary inspections. The frequency of sanitary surveys has been discussed in section 3.6.

3.9 *General Requirements*

If the general clauses were the place to include all miscellaneous aspects that do not belong to a focused area, the general requirements may be used to state or to highlight a few conditions that are expected to be considered by any of the actors, institutions, or sectors in drinking water quality production, provision, surveillance, and control.

Examples of points to be included here are:

- Need of approval from the public health service to use a certain water source.
- Need of approval from the public health service to use certain process or technologies.
- Obligation of the water service to disinfect water regardless of whether the source is surface or ground water.
- Obligation of the water supply company to protect water sources and watersheds.

- Obligation of the water service to operate the systems with certified or trained operators.
- Obligation of the water service to disinfect mains and distribution networks every time repairs have been completed.
- Obligation of the water service to monitor with a fixed frequency (e.g., monthly) the quality of the chemicals used in water treatment.

3.10 *Good Water Practice Recommendations*

As previously mentioned, making drinking water quality compliant with the DWQS is the aim of the surveillance and control programs. Nevertheless, these programs and the measuring rod (the DWQS), are merely the mechanisms by which the quality of water will be monitored.

Another important part of the equation is how the drinking water will be produced (treated to become potable or safe), the technology through which this can be achieved, and the proper way of operating that technology. While a DWQS has little to do with particular equipment, methods, or technology to be used in engineering process, it is nonetheless important to stress the need of good practice to minimize the risks of producing unsafe or not so good water. Applying good practice means to manage the quality of water from catchment to consumer.

The DWQS should then encourage the concept and use of water quality management by means of the good practice approach.

Typical clauses that are related to specific treatment of water include disinfection and associated conditions (e.g., concentration of disinfectant, contact time, pH and turbidity), reduction of risk of contamination (e.g., lead from pipes), use of materials and chemicals (additives), removal of organic substances prior to disinfection to reduce the formation of DBP, need to always have positive pressure in the distribution network, etc.

The DWQS may also address the "multiple barrier" approach, which is a typical good-operation concept. If the fundamental purpose of water treatment is to protect the consumer from unsafe water, an urban water system is by definition a four-stage barrier: the storage reservoir; chemical treatment (coagulation, flocculation, and sedimentation); filtration; and the final disinfection. Each stage represents a concrete obstacle or barrier to the passage of the contaminants. If these stages are properly managed, then the quality of the water may be secured in a far better way.

3.11 *Violations and Penalties*

A DWQS is prepared as a set of conditions to be observed and complied with by specific agencies and persons. How, where, when, to what extent, etc., has to be clearly established and regimented. Similarly, the consequences of any non-compliance should also be clearly stated.

Although the surveillance authority should ideally be capable of achieving its objectives through counseling and cooperation rather than through legal enforcement, it will almost certainly be necessary on occasion to use legal sanctions against an individual or organization in the public interest. While such powers should be used sparingly, they should be available for immediate use during an emergency.

These articles should first describe different violations, such as the failure to comply with the DWQS or failure to notify the public health authority whenever any situation develops within the distribution system or treatment plant that can impact on the health of the users. Violations may also include failure to comply with monitoring requirements, failure to use approved analytical methods, or failure to maintain the approved communication flow to the surveillance authorities.

This section should also give empowerment to the surveillance agency to forbid the distribution of water unsafe for human consumption and to discipline the water supply company through notification, fines, cancellation of permit of operation, or other.

3.12 *Information: Record Keeping and Reporting*

If the idea behind a drinking water quality surveillance or control program is to detect faults in the production of drinking water, and when detected, to react by solving the problem, it is obvious that proper information should be available for these important goals.

Unfortunately, information is not data. For too long and in many countries, drinking water surveillance and control programs have just been gathering data such as laboratory protocols, and sanitary inspection forms.

Data is only the raw material, while figures, statistical calculation, comprehensive graphing, and appropriate reporting are the needed mechanisms to produce the pursued information.

A DWQS should have a section with instructions not on how to produce the information, but on how to manage it, and on how to respect the communication channels and flows since record reporting is an important part of every program of surveillance and control. Record keeping and its availability is another issue to be addressed by a standard.

3.13 *Surveillance and Control Programs*

On several occasions, this Guide has mentioned the importance of the drinking water surveillance and control programs. A DWQS is the reference against which water will be safe for human consumption. It is a goal and also a permissible limit dependent upon capabilities and resources.

The drinking water quality surveillance and control programs are the mechanisms by which such tool (the standard) will be used and, as previously mentioned, they are the means of detecting problems and monitoring their solutions. Even if concise, a DWQS should mention the importance of surveillance and control programs and how to carry them out.

The European Community DWQS asks its Member States to monitor their compliance and determine the motives of any non-compliance, making clear reference to the need to develop surveillance and control programs.

The Italian DWQS establishes the need for both the water service and the surveillance agency to maintain proper drinking water quality monitoring programs. It goes further mentioning even the time (five years) during which the reports should be readily available for any inspection by the surveillance agency.

Although the Brazilian DWQS set conditions for the control program activities the water supply company should develop, it divides the responsibility of surveillance to three levels of governmental organization: while the municipal level will implement the drinking water quality surveillance, the federal and state levels should promote and support the activities of such surveillance.

The DWQS should describe a series of conditions that both the government and the water supply company will have to honor in their programs. As an example, the section on municipal responsibilities could establish that municipalities should:

- Implement the drinking water quality surveillance program according to the guidelines provided by the Ministry of Health.
- Implement and maintain a drinking water quality surveillance program.
- Analyze the information presented by the water service.
- Have the proper laboratories facilities to develop their surveillance activities.
- Assess systematically the human health risk by monitoring the water source, the physical characteristics of the water systems (sanitary inspections), and the drinking water quality history and trends.
- Audit the drinking water quality control programs.
- Inform the public about drinking water quality and associated risks.
- Maintain records on drinking water quality characteristics.
- Maintain open resources for the public to express their complaints and concerns.
- Inform the water service of anomalies detected in the water system and demand the needed corrective actions.
- Approve the sampling programs as presented by the water service.

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Annex

LULAND CASE STUDY

Application of the principles and procedure suggested in the Guide to develop a national drinking water quality standard in a fictional republic

1. Introduction

This case study describes, in a simplified way, how a DWQ standard was produced in a fictional country in Latin America named Luland. Because Luland is small, has a modest infrastructure, lacks important economic assets, and has few highly qualified human resources, the DWQS Committee produced a very simple standard. The realistic and flexible approach so strongly suggested in the Guide, was used here to prepare what would be a first step of implementation or the basic level of a DWQS.

2. Formation of a Committee

The Ministry of Health of Luland decided to develop realistic standards appropriate to the country situation, and committed its Public Health Bureau (PHB) to lead a National Drinking Water Standards Committee (NDWSC). The PHB invited all stakeholders involved in drinking water quality to participate in the work of the Committee. Members of the Committee with defined responsibilities included representatives from the Public Health Bureau, Bureau of Standards, the private Water Supply Company, Public Utilities Commission and the Rural Water Supply and Sanitation Unit. Others participating in the work of the Committee included the Department of the Environment, Water and Sewerage Authority, Agricultural Health Authority, Pesticide Control Board, the Institute of Coastal Zone Management, Luland Brewing Company, the Pan American Health Organization, and UNICEF.

3. Organization of the Committee and Assignment of Tasks

The first task of the NDWSC was to obtain its accreditation through formal recognition by the Ministry of Health. Upon receiving this official support, the Committee set to work as a whole in the preparation of a diagnosis. After completing this diagnosis, the whole set of experts was divided into two sub-committees with responsibilities to: (a) write the General Articles; (b) produce the table of parameters and concentrations (TPC). This last sub-committee was also in charge of writing some issues related to the TPC like the approved analytical methods and the frequency of sampling. The sanitary inspections section was also their responsibility.

The lead institution also invited two professors from the Sanitary Engineering Department of the University of Luland, as well as one epidemiologist, one chemist, and one legal consultant to act as external advisors. Two more experts from PAHO and the USEPA were invited to offer international counsel via the Internet.

A plan of action, a timetable, and precise deadlines were set at the very beginning of the process.

4. Diagnosis

The baseline information was produced in a conveniently short time by the NDWSC. Its main findings were:

- Luland is a tropical country and even though there are no complete epidemiological studies, diseases related to lack of access to safe drinking water and sanitation services are common in rural areas, with diarrheal diseases being major problems. Recently, the Ministry of Health acknowledged several cholera outbreaks.
- Agriculture is the most important economic sector of Luland with sugarcane, citrus, and bananas being the main crops. Pesticides and fertilizers are extensively used. Information is available on the nature and quantities of the most commonly used pesticides. There are no manufacturers of pesticides in Luland and all pesticides are imported.
- In addition to pesticides, certain chemicals were found to be of potential importance in drinking water. Nitrates were found to be of some concern in certain villages served by groundwater and very high concentrations of fluoride were found in some wells in the northern area of the country. Lead pipes are not used in the country, however, anomalous values for lead have been reported in stream waters, probably as a result of its dissolution from natural sources; cadmium, a common contaminant of fertilizers, could be of potential importance in drinking water. In addition, arsenic was considered a potential contaminant of drinking water given that Luland is bordering on a country where arsenic from natural geological formations was found to be a problem in groundwater.
- There are no chemical industries of any significance in Luland.

5. General Articles

Following the suggestion of the Guide, the Sub-committee on General Articles set down to produce a short but very concise list of Articles.

The Sub-committee decided to further divide preparation of the various Articles among its members.

In the *Introduction*, the Committee set the precedents of the present NDWSC, its aims, and the principles guiding the document.

In the *General Clauses*, it described the scope of the NDWSC, the exception clauses (mineral water and soda water), the exclusion (number of users to which the NDWSC would not be applied), and established a period of five years between revisions (up-dating).

In the *Definitions*, the experts listed a very short number of the most commonly used terms in the standard.

In the *Institutional Framework*, the Sub-committee described the roles, rights, and responsibilities of the major actors, like the Surveillance Agency (PHB), the Water Supply Company and others.

The *General Requirements* article was very short and due to the problems encountered in Luland, the Sub-committee stressed protection of the water sources and watersheds and the need for prior approval by the PHB to use certain water sources.

The *Good Practice* article stressed the need to provide wide and sound disinfection for every water system and to apply the “multiple barrier” approach.

The article on *Violations and Penalties* described a list of different possible violations giving strong and clear empowerment to the surveillance agency when any of those violations were found.

In the *Information* article, a brief description on how to proceed with the information flow was described.

Finally, in the *Surveillance and Control Programs* article, reference was made to the approach the surveillance agency and the water supply companies should take to apply consistent programs of monitoring and how these programs should be coordinated and communicated.

5.1 *Table of Parameters and Concentrations*

The Sub-committee for the table of parameters and concentrations (TPC) worked on the most visible and used section of the NDWSC. The experts of this committee divided their duties and proceeded to analyze three different components: bacteriological aspects, health-related chemicals, and the aesthetics component. The work they produced is described below.

Bacteriological Standards

Because of the high incidence of waterborne diseases, the Sub-committee determined that the first priority was the establishment of strict bacteriological standards, namely:

- Absence of thermotolerant coliform bacteria in any 100-mL samples of drinking water.
- Absence of total coliform bacteria in any 100-mL sample of treated water entering the distribution system.
- Absence of total coliform bacteria in 95% of 100-mL samples taken over any 12-month period.

In addition, to ensure the absence of virus and protozoa, minimum treatment conditions were specified for faecally contaminated sources of drinking water. These are:

- Filtration must achieve a median value of turbidity value of not more than 1 nephelometric turbidity unit (NTU) and single samples must not exceed 5 NTU.
- Disinfection conditions must achieve a minimum of 0.5 mg/L residual free chlorine, and 30 minutes contact time, at pH less than 8.0.

Health-Related Chemical Contaminants

Given the limited resources in the country, the NDWSC decided to establish maximum acceptable concentrations (MACs) for a limited number of high priority chemical contaminants. Where it was known that the human and analytical resources were not immediately available to monitor contaminants of potential importance, interim maximum acceptable concentrations (IMAC) were established, to be implemented five years from the adoption of the national drinking water standards. MAC and IMAC values included in the national drinking water standards are given in Table 1.

Inorganic Chemicals

Based on the environmental profile and the baseline information of Luland, MACs were established for cadmium, fluoride, lead, nitrate, nitrite, and chlorine, the only disinfectant used in Luland (Table 1). These MACs are the same as the WHO guideline values (GVs).

WHO recognized that the stringent GV of 0.01 mg/L for lead might not be achieved immediately because of the difficulty in controlling dissolution of lead from lead pipes. However, the Committee decided that such a value could be realistically achieved because lead pipes are not used in the country and lead is present in water from natural sources.

Analytical capability is not available in Luland for the determination of arsenic. In addition, the value recommended by WHO of 0.01 mg/L is based on hypothetical cancer risk estimates that are far from certain. For these reasons, the Committee adopted an IMAC range of 0.01 to 0.05 mg/L, to be attained within five years from the date of adoption of the standards.

Disinfectant by-Products

With the limited analytical capabilities available in Luland, an IMAC of 0.1 mg/L was established for total trihalomethanes to be attained within five years from the date of adoption of the standards.

Pesticides

A large number of pesticides are used in Luland and it was necessary to select a few that could potentially be present in drinking water. Analytical capability is not available in Luland to monitor pesticides in water and no such survey, with or without outside assistance, was ever conducted. However, information is available from the Pesticide Control Board (PCB) on the nature and quantity of pesticides imported in the country. Using information on the most widely used pesticides, coupled with PCB knowledge of the persistence of certain pesticides in water and their use near water bodies, the following pesticides were selected for inclusion in the standards:

Aldicarb	Mancozeb
Atrazine	Methomyl
2,4-Dichlorophenoxyacetic acid	Pendimethalin
Diuron	Propanil
Glyphosate	Terbufos
Malathion	

Luland does not have the capability to conduct risk assessment of pesticides. Therefore, where available, WHO GVs for pesticides were adopted as IMACs, to be implemented five years from adoption of the Standards.

WHO Guideline values are not available for the following pesticides of high priority in Luland: Diuron, Malathion, Mancozeb, Methomyl and Terbufos. With PAHO's assistance, information was obtained on risk assessments available for these pesticides and conducted by the Joint FAO/WHO Meeting on Pesticide Residues or the US Environmental Protection Agency. Based on these risk assessments and using the methodology described in the WHO *Guidelines for drinking-water quality*, IMACs were derived for these pesticides (Table 1).

The major source of exposure to pesticides is generally from food and in the occupational setting rather than from drinking water. For this reason, and in order to prevent the potential presence of pesticides in drinking water, Luland has implemented a very active program to promote the safe use of pesticides in the agricultural sector. Prevention is always better than cure.

Aesthetic Considerations

Recommendations, rather than enforceable standards, were established for aesthetic parameters (e.g. chloride, iron, total dissolved solids). These are given in Table 2. The Sub-committee considered that recommendations for aesthetic parameters were important, but wanted to leave some flexibility in their implementation.

Table 1. Maximum Acceptable Concentration (MAC) and Interim Maximum Acceptable Concentration (IMAC) for Health-Related Chemical Contaminants

Chemical	MAC, mg/L	IMAC, mg/L
Inorganics		
Arsenic		0.01 - 0.05
Cadmium	0.01	
Fluoride	1.5	
Lead	0.01	
Nitrate (as NO_3^-)	50	
Nitrite (as NO_2^-)	3	
Disinfectants and disinfectant by-products		
Chlorine	5	
Total trihalomethanes		0.1
Pesticides		
Aldicarb		0.01
Atrazine		0.002
2,4-Dichlorophenoxyacetic acid		0.03
Diuron		0.01
Glyphosate		1
Malathion		1
Mancozeb		0.1
Methomyl		0.1
Pendimethalin		0.02
Propanil		0.02
Terbufos		0.001

Table 2. Aesthetic Parameters - Values Recommended not to be Exceeded

Parameter	Value
Colour	15 true colour unit
Taste and odour	Acceptable
Turbidity	5 nephelometric turbidity unit (NTU)
Aluminum	0.3 mg/L
Chloride	400 mg/L
Total hardness	500 mg/L as calcium carbonate
Iron	0.4 mg/L
Manganese	0.5 mg/L
PH	6 -8
Sulfate	500 mg/L
Total dissolved solids	1000 mg/L

5.2 *Frequency of Sampling*

5.2.1 Frequency for Bacteriological Analysis

Population-based minimum monitoring frequencies for bacteriological quality in the distribution system were also specified. These are:

Table 3. Frequency of Bacteriological Analysis

Population served	Minimum number of samples/month
< 5,000	4
5,000-100,000	One/5,000 population, plus 3 additional samples
> 100,000	One/10,000 population, plus 10 additional samples

It should be noted that small systems serving less than 5,000 people are where problems occur in Luland. For this reason, sampling frequency was increased from one sample/month (given in the WHO *Guidelines for drinking-water quality*) to four samples per month.

5.2.2 Frequency for Health-Related Chemicals and Aesthetic Parameters

As aesthetic parameters are in general subject to more variations than health-related inorganic chemicals and therefore require more frequent monitoring to avoid consumers' complaints, the NDWSC produced a simple and fixed standard for sampling frequency of those parameters.

Table 4. Frequency of Analysis of Aesthetic and Health-Related Inorganic Substances

Parameters	Sampling frequency in any system
Aesthetic	Monthly
Health-related inorganic (MACs)	Quarterly

5.3 *Approved Analytical Methods*

The Sub-committee also specified analytical methods for health-related MACs, i.e. total coliforms or thermotolerant coliforms, cadmium, fluoride, lead, nitrate, and nitrite. Methods specified included those described in *Standard Methods for the Examination of Water and Wastewater* (last edition) and HACH rapid analysis techniques.

5.4 *Sanitary Surveys*

Being important in any program of surveillance or control, the sanitary inspections were addressed as an obligation imposed to those programs. A standard of frequency of surveys was also presented. It belonged to the first level (modified) of the surveillance program taken from Table 13 of the Guide.

Table 5. Frequency of Sanitary Surveys

Population water system under survey	Source		Treatment		Storage and distribution
	Ground water	Surface water	Ground water	Surface water	
Rural areas	--	Irregular	--	Irregular	Irregular
Towns	--	3 years	Irregular	3 years	Irregular
Cities	3 years	2 years	3 years	2 years	3 years
Major cities	2 years	1 year	2 years	1 year	1 year