E27 - Methods and available means, either simple or more elaborate, for the physical, chemical and/or bacteriological analysis of the water

20 March 2012

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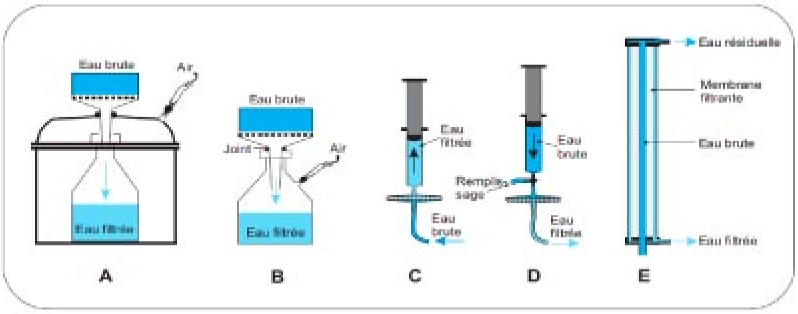
    - 

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1) What is involved ?

Seeing what are the rather simple means for analysing, in particular using kits that are rather easy to obtain and use, the physical-chemical and bacteriological parameters of water in order to check that it is safe to drink.

Safe drinking water is water that meets the standards defined by WHO for certain regions or criteria that

are specific to the region under consideration. These criteria were defined in *fact sheet E 26*.
Therefore, methods and the means for analysing water should be known that are adapted to the financial resources that are available as well as to the region concerned and to what can be found in terms of equipment.

2) Why use this means ?

The WHO has defined criteria for safe water and **recommendations** which are listed in *fact sheet E 26*.
Developed countries and most big cities apply them and constantly check the quality of the water using continuous analysers or through measurements in the laboratory in order to guarantee water that is safe to drink for consumers.
These recommendations are rather rigorous, **yet they are not always fully complied with** in some countries or in some regions as they are too restrictive for those who are lacking in means. In villages, it is usually technicians, village heads or people that have been trained beforehand who are in charge in turn of making the population aware and carrying out the tests.

3) Why ?

Because water is still one of the greatest causes of disease and even death in many countries where access to it is still very difficult or where the water is not safe to drink.
Yet, according to the United Nations, there are currently **884 million** people who do not have access to a source of water that is said to be "protected", which does not guarantee that it is safe to drink as the water from a well or from an enclosed spring is not necessarily safe to drink. Also, several international experts feel that **the number of inhabitants who do not have safe drinking water is actually about 2 to 3 billion**.
Contagious diseases caused by pathogenic bacteria, viruses and parasites are very often linked to the consumption of water that does not meet the minimum criteria for drinkability. This is for health the most common and the most widespread risk. It is therefore important **to know the standards and the indicators or devices for measuring potability and quality and above all to check that they are complied with**, especially at the water access points and if necessary adapt them with caution according to the zones and local particularities.

Finally, after studying these standards and the indicators or devices available, find the analysis method that is adapted to the country or region.

4) Who is primarily concerned ?

Young Burmese fetching water

This concerns all populations, in particular local populations, refugees and uprooted people. The poor countries are primarily concerned as only a low portion of the population is supplied via the public network. The other portion draws water directly at its source, i.e. in wells, rivers or natural rainwater reserves. It is here that the exposure to consumption of dirty water is the highest. Likewise, uprooted populations and refugees in camps need water quickly that is sufficiently safe to drink in order to not cause disease or even death. Yet the latter is often suspected.

We must be able to find a method of analysis that can provide information on :

- The **microbiological quality of the water** : this entails performing a test that gives an idea of the bacterial flora and its abundance in the water.
- The **chemical quality of the water** : this entails performing a test that provides results concerning the concentration of mineral substances that are toxic or harmful for health.

It is important to specify that **in order to be able to be consumed in a pleasant manner, the water must be clear and must not have any unpleasant taste or odour**. However, water that does not fully satisfy these criteria is not necessarily unfit to drink. So, before any physical-chemical or bacteriological test, a simple sensorial analysis can suffice in order to determine whether or not the water is drinkable and if so, if it possible to correct this.

A test can be used to confirm the results obtained via a sensorial analysis.

5) What are the analysis methods and the indicators or devices for measuring that are available ? How are they used ?

a) Methods for physical and chemical analysis of water

In addition to the normal parameters, certain specific parameters must be analysed according to the region and the problems encountered. (For example, if this region is particularly affected by spillage of arsenic into its waters, such as for example in Bangladesh, an arsenic test must be favoured). Moreover, specific standards, both physical-chemical and bacteriological, have been established by the WHO for emergency and crisis situations.

Indicators of potability and of quality can be used for these analyses :

- Kits

- Portable sensors
- Test strips
- Visual : inspect the surface of the water (material in suspension, hydrocarbons, oils, colour, odour)

Physical-chemical analyses are entail primarily measuring the pH and the residual chlorine content at the outlet valves and in households. This is to ensure monitoring of the daily chlorination that is carried out in the tanks, bladders and wells with a manual pump, in order to keep the average residual chlorine content at the outlet valves between 0.4 and 0.5 mg/l.

A sampling at the treatment facility or upstream of the distribution network can suffice for the constituents for which the concentration does not fluctuate during distribution. However, for those in which the concentration can vary over the course of distribution, samples should be taken according to the behaviour and/or source of the substance in question.

Samples must in particular be taken at points that are close to the ends of the distribution network and tappings that directly serve the homes and the buildings that shelter a large number of occupants. Lead, for example, must be dosed at the tappings that supply the consumers, as the sources of lead are usually the connections or the plumbing installations in buildings.

If it is necessary to detect the presence of certain substances, there are many specific kits available :

Visual or organoleptic methods

Evaluating organoleptic parameters	Precautions
Colour. This entails visually estimating the tone, intensity and possible change over time of the coloration. Water that is safe to drink must not have any particular colour (colourless).	To do this, it is convenient to use a glass container in which the thickness of the water is at least 10 cm that is placed in front of a white surface.
Appearance of the surface. A hydrocarbon film, floating matter, the formation of foam, etc. can be observed.	
Clarity. Water is said to be clear when it is perfectly transparent and free of particles in suspension. Clarity is evaluated by examining the water is a glass container that is placed in front of a source of light.	Fine bubbles sometimes form in the water via degassing. Leave the water undisturbed for a few minutes before carrying out the evaluation again.
Turbidity. This is caused by very fine mineral or organic matter in suspension. This is evaluated in the same way as clarity (see above). Water that has the slightest amount of turbidity obviously cannot be qualified as clear. These two characteristics are mutually exclusive	Describe the colour and the degree of the turbidity by indicating for example the thickness of the water through which the shape of an object can still be distinguished. Also see above (presence of air bubbles)

Possible sediment or matter in suspension. This is matter in suspension that can be seen with the unaided eye, for example particles of organic matter or silt, as well as those that settle to the bottom of the container.	Describe the nature, colour and quantity of the suspensions and sediments. Also describe the sediments deposited at the bottom of a collection chamber, for example.
Odour. Describe the type and the intensity of the odour, for example an odour that is putrid, earthy, odours of a chemical nature that evoke chlorine, H_2S (rotten eggs), hydrocarbons, etc. Water that is safe to drink must not have any particular odour (= Odourless).	In a collection or drilling, odours that are released by the infrastructure materials can mask that of the water or give a false perception of the odour of the water. Therefore, evaluate the odour in a ventilated area without any source of special odours. As the senses quickly get used to an odour, the first impression must be retained, or else start the test again after a certain amount of time.
Taste. The type and the intensity of the taste are evaluated just as they would be evaluated by a taste tester. Drinking water must not have any particular taste.	Remain caution with water that is potentially contaminated.

Measuring the pH

Techniques for measuring pH	Precautions

pH-meter There are many types of devices and electrodes. The conventional devices have an electrode with an internal reference which most often contains a solution of KCl 3M which needs to be replaced periodically. Before taking readings, it is indispensable to calibrate the pH-metre with two buffer solutions of known pH and which encompass the range of the pH of the waters to be measured (e.g. pH 7.0 and 10 for rather basic water or pH 7.0 and 4.0 for water that is rather acidic). The calibration procedures are specified in the instructions for use. With a conventional pH-meter, proceed as follows :

- place the selector button to "pH",
- set the "temperature" button to that of the buffers,
- rinse the electrode with demineralised water, dry it with absorbent paper, then immerse it in the pH 7 buffer and stir slowly,
- when the value has stabilised, display the actual pH with the "pH" or "ΔpH" button, according to the device,
- rinse the electrode with demineralised water, dry it with absorbent paper, then immerse it in the second buffer solution and stir slowly.
- when the value has stabilised, display the actual pH with the "slope" or "mV/pH" button, according to the device.
- rinse the electrode with demineralised water, adjust the device’s "temperature" button to the temperature of the water, and the pH-meter is then ready to be used.

If the **reading** cannot be taken in running water, a sample must be collected in a container of at least 250 ml in order to rinse the electrode and allow it to reach a thermal and chemical balance. The water is renewed in order to take the final reading. During the reading, the electrode is displaced slowly in the water. Usually 1 to 3 minutes are required for the reading to stabilise.

Check before calibration that the buffer solutions have not expired (see the supplier’s instructions). For calibration, the buffer solutions are kept in 50 ml bottles. If the device does not have any manual or automatic temperature correction device, they must be brought to the temperature of the water to be measured (allow them to soak in a bucket or in the collection area). The pH of the buffer varies according to the temperature. Therefore, the temperature of the buffer has to be measured just before calibration, read the corresponding pH value on the pH variation table according to the temperature (printed on the buffer bottle) and use it as the calibration value.

Between each series of readings, store the electrode in its sleeve with a solution specified in the instructions for the electrode, usually KCl 3M.

As pH is sensitive to the phenomena of degassing, oxidation, precipitation or changes in temperature of the sample, measuring it in a container must be carried out without delay.

The electrode must be maintained on a regular basis, then changed when the stabilisation time becomes too long. It is therefore important to consult the supplier’s instructions for each electrode. Glass electrodes are very fragile !

Current electrodes are designed for solutions with a high ionic strength, for water with low mineralisation (conductivity < 500 µS/cm), electrodes that are specifically designed for this type of medium must be used.

Warning, pH 4 standard solutions tend to store not as well as the others.

pH-meter with microprocessor. Modern devices correct automatically for the temperature and are provided with pH-temperature coupled electrodes that are protected with an anti-impact envelope. Modern electrodes have a stabilisation time of about 1 minute. The internal solution no longer has to be changed. The measurement is taken as indicated above.	Observe the same precautions as hereinabove. This type of device makes many applications possible. Follow the user's manual in order to proceed with calibration and measurement. Warning, the lifespan of an electrode is limited. It varies according to its use and the fluids measured.
Kits for measuring pH. Simple to use, they allow the pH to be determined via colorimetry with a precision of 0.2 to 0.5 units, according to the type of reagent used.	Very practical for measuring water with very low mineralisation (< 100 µS/cm).
pH paper. Provides only a vague indication that is far from being precise enough in natural water.	Not to be used.

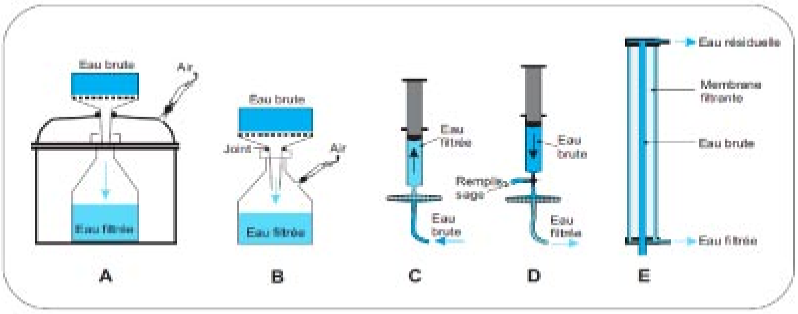
b) Bacteriological analysis methods for water

Microbiological analyses are based on searching for bacteria that are considered to be indicators of faecal contamination.

Parameters	OMS guidelines	Interpretation
Thermotolerant coliforms	0/100 ml	Faecal pollution indicators
Faecal streptococci	No standard	Faecal pollution indicators
Total coliforms	0/100 ml in 95% of the samples of water treated	Treatment effectiveness indicators (disinfection) ; do not necessarily report faecal pollution

Microbiological quality standards for drinking water set by the WHO and repeated by RéFEA
Note : According to WHO, the most precise indicator for estimating faecal pollution is in fact Escherichia coli, a member of the group of thermotolerant coliforms
The most useful indicator is indeed the Escherichia coli bacterium as it is abundant in human faeces and persistent enough to be detected (its detection time in water at 20°C varies from 1 week to 1 month). It is difficult to identify it however in the field and requires specific devices or the use of the "membrane filtration" method.
In routine analyses, detection is carried out for bacteria referred to as thermotolerant, with E. coli being a member of this group.
In the field, **the membrane filtration method is relatively easy** to implement :
- It consists in **filtering** a known volume of water **over a porous membrane**, calibrated to retain the bacteria (0.45 µm).
- This membrane is then placed into conditions that allow thermotolerant bacteria to develop, but not other bacteria : for this, incubation is required for 24 h at 44°C (this is where the name "thermotolerant" bacteria comes from), as the other coliforms do not develop in principle above 37°C) on a favourable nutritive medium.
- After 24 hours, the bacteria present have formed **bacteria colonies that can be identified with the**

unaided eye.
- The results are expressed in number of colonies per 100 ml of water filtered.



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Detecting total coliforms is done according to the same procedure but the incubation conditions are modified : temperature of 37°C only and another culture medium.
In practice, the use of indicators of pollution of a faecal origin are used as a basis for obtaining a bacteriological idea of the quality of the water. The germs tested are faecal coliforms. They are quite good representatives of the quality of the water and are easily detected.

6) Special difficulties and precautions to be taken

a) Difficulty

Finding the device or indicator at a low cost that can measure these parameters.
- Taking into account the situation of each country or region and favouring the most suitable method that makes it possible to determine whether or not the water is safe to drink.
- Ensuring that this method is easy, can be repeated and is safe. Sampling should normally be random, but there will have to be more samples in epidemic periods, floods or crises, or in the event the supply is interrupted or repair work.

The aspects to be taken into consideration in perfecting the chemical verification include :
- the availability of suitable means for analysis
- the cost of the analyses
- possible degradation of the samples
- stability of the pollutant
- likely presence of the pollutant in the various supplies
- the most suitable point for monitoring and the sampling frequency.

b) Precautions to be taken

For a given chemical, the location and the frequency of sampling will be determined according to its main sources and according to the variability of its presence. Substances for which the concentration does not vary notably over time require less sampling than those for which the concentration fluctuates substantially.
In many cases, sampling spring water once a year, or even less frequently, especially for stable underground water, can suffice when the concentrations of substances of natural origin that are the sources for concern change very slowly over time. Surface water has a tendency to have more variable characteristics and requires a large number of samples, according to the pollutant present and how much of it there is.

The sampling points will depend on the characteristics in terms of the quality of the water examined.
The precautions to take are multiple during the analysis :
- **Before sampling** : check that the stream is not polluted downstream of the sampling point, which would render the samples useful. Also check that all of the containers are clean and are not contaminated, and preferably sterilised (chlorine tablets can be used).
- **During the sampling** : follow the sampling protocol well (correctly calibrated sensors, significant quantity of the sample, etc.), or in vivo analyses (temperature measurement, etc.).
- **After sampling** : avoid contaminating the sample : either by the container, or by the appearance of bacteria during storage. Carry out the various analyses in situ according to a well-defined experimental protocol.
- **During the results** : interpret the results obtained correctly using the instructions or a model.

7) Main advantages and drawbacks

a) Advantages

- **Provides information** on the quality of the water and makes it possible to know if it is acceptable or unfit for human consumption.
- **Makes it possible to prevent diseases** due to the presence of chemical or bacteriological substances that are harmful for humans when the water is consumed.
- **Makes it possible to determine the treatments** that would be necessary in order to deliver safe drinking water ; chlorination in general is used.
- For households for which the analysis of the samples confirms the presence of faecal coliforms, generally due to the manipulation of the water in dirty containers and an unsuitable storage system, hygiene promoters can organise **door-to-door awareness campaigns and in meetings** on the good practices of collecting, transporting and storing water in homes.

b) Disadvantages

Analyses only provide information on a one-off basis. They only indicate the quality of the water at the time the sample was taken. These analyses must therefore be carried out on a regular basis in order to detect any degradation in quality.
- This work **only provides information** on the state of the water, you still have to be in a position to treat it.
- Studying **faecal indicators** combined with a count of the viable bacteria is a sensitive method, but it is not rapid. This requires a laboratory equipped to create bacteriological cultures and trained personnel. The minimum delay for obtaining the results is **3 days**.
- The **sampling conditions** can play a **major role** in the results, and the latter can be misleading if the sampling and the analysis are not carried out correctly.
- The quality of the water can become degraded in the network or between the spring and the point where it is used by the consumer. **A single measurement** at the spring can therefore be insufficient if the water is not kept in good conditions.
- **The equipment can be expensive** and need to be easy to use and reliable.

8) Achievement example : The WHO training workshop in Chad

In the East of Chad, with the concentrations of populations **in the refugee camps** and in the sites with uprooted people, the risks of epidemics of water-borne diseases are real. Several cases of acute watery and bloody diarrhoea have been reported.

Epidemics of hepatitis E, which is a faeco-oral or waterborne disease by excellence, have been observed every year since 2004 in the rainy season. 4,600 cases were as such recorded in the years 2007 and 2008 alone.

The WHO has suggested to the Water Sanitation and Hygiene (WASH) Cluster 3 concrete actions :

(1) Recruit a water and sanitation specialist, the main leader of the workshop

(2) Order state-of-the-art equipment to monitor the quality of the water in the East of Chad

(3) Organise this training workshop on the use of this equipment.

Moreover, special attention was given to the system for checking the quality of drinking water aiming to minimise the risks of contamination in faeco-oral diseases in vulnerable populations, mentioning that the priorities for control in terms of water quality, which are able to provide a maximum amount of benefit from a health standpoint, vary according to the locations.

For example, iron, arsenic and fluorides were not a problem everywhere, but could be a major health problem when they appeared.

The WHO then extended the monitoring and the control of the quality of the water at the water points and households **around the perimeter of the refugee camps and sites with uprooted people** and recommended that, using all of the data collected by the various organisations, bulletins be established concerning the indicators for monitoring the quality of the drinking water which it then analysed.

At the end of the workshop, WHO distributed portable Kits with a total value of €32,000. These were offered by the European Community and the government of Finland.

9) Where to obtain further information

- **OXFAM water quality monitoring kit**

http://www.who.int/hac/crises/tcd/c...

- **Drinking water quality directive, THIRD EDITION, Volume 1, Recommendations, WHO Geneva 2004**.

www.who.int/water_sanitation...

- **OFEFP, Federal Office of the Environment**, Forests and Landscape (2000) : Methods for analysing solid and aqueous samples coming from polluted sites and excavation materials. L'environnement pratique, April 2000, 53 pp.

- **USEPA** (1991) Ground water monitoring, chap 11 of SW-846 U.S. Environmental protection Agency, Washington, D.C.

http://www.epa.gov/osw/hazard/corre...