

# **DRINKING WATER QUALITY CONTROL IDENTIFICATION OF NEEDS FOR FUTURE RESEARCH- EPAL'S PERSPECTIVE**

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## **1. Abstract**

Over 2 million people in the city of Lisbon and 21 municipalities in surrounding areas, are being supplied by EPAL, with drinking water produced from surface water and groundwater.

To ensure the safeguard of human health and the compliance of drinking water quality with the Directive's parameter values and national regulation, a systematic monitoring programme is established. To support the water quality strategy, warning stations and on-line sensors are installed, at surface water source and in the supply system.

The paper identifies the EPAL's perspective in what concerns the most relevant needs for research on monitoring of water quality.

Key words: Monitoring, on-line sensors, drinking water quality

## **2. Introduction**

Several Directives dealing with drinking water quality (75/440/EEC<sup>1</sup>, 76/869/EEC<sup>2</sup>, 80/778/EEC<sup>3</sup>) have been issued in recent years in order to safeguard the consumer. These Directives determine physical, chemical, organoleptic and microbial parameters, as well as their sampling frequency, reference methods of analysis and Maximum Admissible Concentrations (MAC). Drinking Water Directive (80/778/EEC) sets standards for 62 physical, chemical and microbial parameters. An European Commission proposal is currently under discussion within the Member States with a view to revising Directive 80/778/EEC and to including nine new parameters to be analysed. These parameters are carcinogenic and may be present in water intended for human consumption. Their origin may be the raw water, treatment by oxidation (chlorine, ozone, etc.) or treatment products.

Other international bodies, also concerned with drinking water quality, such as the World Health Organisation (WHO)<sup>4</sup> and the US Environmental Protection Agency (EPA)<sup>5</sup>, establish Maximum Concentration Levels or recommend Guidelines Values. Both these organisations, establish a significantly higher number of individual organic parameter standards than those stipulated in EC Directives: WHO has Guidelines for 77 organic compounds, while EPA establishes Maximum Concentration Level for 60 organic parameters.

The EEC Drinking Water Directive was incorporated into Portuguese Legislation in March 1990 (DL 74/90).

In order to ensure drinking water complies with the Directive's parameter values, a systematic monitoring programme has to be established by the Water Supplier. The number of sampling points and the sampling frequency is established, either according to the population served, or the volume of water produced or the volume of water distributed<sup>2,3</sup>. For this purpose, analytical laboratories need to have analytical methods capable of producing reliable, accurate and precise data, and attaining detection limits in accordance with each parametric value.

Aware that potable water is one of the most important requisites for human life, the Water Suppliers also develop and set up new structures to tackle the evolution of the water quality concept. Water quality modelling<sup>6,7</sup> and "on-line" monitoring<sup>8</sup> are tools frequently used by water suppliers.

Water quality modelling is being used to characterise, for instance, the optimum sampling location, to predict chlorine decay, bacterial re-growth and nitrate distribution, to define zones where particle deposition may occur, etc.

The importance of continuous and automatic monitoring of the water abstracted, treated and distributed by water supply companies is increasing. On-line analysers provide, from the river intake to the tap, a reliable, precise and efficient tool for drinking water production. Alarm stations, placed a few kilometres upstream from the treatment plants, permit detection of any accidental pollution. The information obtained in "real-time" allows the treatment process to be adapted to the quality at intake or to stop the intake.

In this paper it is attempted to describe the most relevant difficulties encountered during water quality monitoring undertaken by Empresa Portuguesa das Águas Livres, S.A.

### **3. Epal water quality control**

#### *3.1. Production and distribution of drinking water*

EPAL-Empresa Portuguesa das Águas Livres S.A., is a wholly state-owned corporation whose business purpose is to supply and distribute drinking water within its concession area. Two million three hundred thousand people, i.e. about a quarter of the population of Mainland Portugal, are currently being supplied by EPAL in the city of Lisbon and 21 municipalities in surrounding areas.

With a  $959 \times 10^3 \text{ m}^3/\text{day}$  catchment capacity and an output capacity in the region of  $700 \times 10^3 \text{ m}^3/\text{day}$ , EPAL manages and operates three supply subsystems.

EPAL currently draws water from the following sources :

- Surface water, from the Tagus river (Valada) and the Castelo do Bode reservoir-  
 $740 \times 10^3 \text{ m}^3/\text{day}$
- Groundwater :

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- from limestone soils, in the Olhos de Água springs and the Alenquer and Ota wells-  $55 \times 10^3 \text{ m}^3/\text{day}$ ;
- from alluvium in the river Tagus, in boreholes in the Valada, Azambuja and Carregado areas-  $160 \times 10^3 \text{ m}^3/\text{day}$ ;
- from Miocene layers, in the Valada and Lezírias boreholes

Two treatment plants located at Asseiceira and Vale da Pedra treat water drawn from the surface water sources.

Asseiceira water treatment plant includes pre-chlorination, correction of aggressivity by addition of diluted lime and carbon dioxide, chemical coagulation with liquid aluminium sulphate, rapid gravity filtration in a double layer of anthracite and sand and final disinfection with gaseous chlorine.

Vale da Pedra water treatment plant includes pre-chlorination, chemical coagulation with liquid aluminium sulphate, flocculation and settling, using polyelectrolic, rapid gravity filtration in a layer of sand, adsorption on activated carbon and final disinfection with gaseous chlorine.

The distribution network in the City of Lisbon is divided into five zones bounded by distinct topographical levels. It has a length of approximately 1 450 km and consists of 50 to 1 250 mm cast iron, ductile cast iron, reinforced concrete, fibro-cement, fibreglass and high density polyethylene pipes. There are also 18 storage reservoirs having a total storage capacity of  $556 \times 10^3 \text{ m}^3$ .

### *3. 2. Water quality management*

The water abstracted, treated, distributed and delivered by EPAL is regularly and systematically analysed to ensure water quality and compliance with quality parameters defined in Portuguese legislation and by the European Community.

In order to attain these goals, an "off-line" sampling programme is established for the complete supply system, which includes about 220 different sampling points :

- Surface water: 12
- Ground water: 28
- Treatment plant: 13
- Transport and delivery to the municipalities: 102
- Lisbon distribution network: 68

Samples are collected daily for microbial, physical and chemical analysis at the EPAL laboratories.

This periodic check is reinforced by the operation of two alarm units installed upstream of the intake point on the Tagus River. Continuous analysis units are also installed at various points in the supply system. To support its Water Quality strategy, EPAL has the PICCOLO network hydraulic software and chlorine decay modelling in the distribution network is being developed.

Awareness of the risk of contamination derived from the chemicals and materials used in contact with water means that quality checks are carried out regularly to ensure compliance with the agreed specification or CEN standard.

### 3.3. Laboratory analysis

At the treatment plants, EPAL has two laboratories, which are responsible for daily water quality monitoring at the intakes and at the treatment plants for process control. Another central laboratory located in Lisbon undertakes all of the analyses in the water quality monitoring programme established within the Supply System, for example at intakes, water treatment, pipelines, points of delivery to the municipalities, reservoirs, etc. These laboratories are prepared to carry out routine analysis of 122 microbial and chemical parameters. They analyse some 20 000 samples each year, requiring around 510 000 individual determinations.

EPAL laboratories are provided with a wealth of sophisticated analytical equipment, which is largely automated and includes :

- High performance liquid and gas chromatography;
- High performance gas chromatography, combined with mass spectrometry;
- Atomic absorption spectroscopy with electrothermal atomisation;
- Segmented flow system (autoanalyser);
- Ion chromatography

The use of electronic sample logging and labelling equipment (optical mark recognition), combined with computerised laboratory information management systems, enables samples to be traced and controlled from the point of reception to the issue of the final report. This system allows rapid and accurate sample processing and reporting of results.

### 3.4. "On-line" analysis

3.4.1. The Tagus river receives a large quantity of domestic and industrial discharge, causing a high variability in the quality of the raw water, as well as the occurrence of serious contamination problems. This situation can have a critical effect on the treatment plant located at Vale da Pedra. EPAL has two alarm units, located at the river basin, around 6 Km and 15 Km upstream of the Valada intake. These stations permit the treatment plant to receive, in "real time", information on the following parameters: turbidity, pH, oxygen dissolved, conductivity, temperature, alkalinity, ammonium nitrogen, cyanides, nitrates, chloride, dissolved organic carbon and phosphates.

3.4.2. The surface water intake points are equipped with analysers allowing the control of the treatment process:

- Castelo de Bode reservoir: temperature, turbidity, pH, total hardness, alkalinity and dissolved oxygen.
- Valada - Tagus river: temperature, turbidity, pH, conductivity, dissolved oxygen, Total Organic Carbon and ammonium nitrogen.

3.4.3. Different analysers have been installed for quality control during treatment processes, focused mainly on the monitoring of basic parameters.

- Asseiceira Water Treatment Plant - analysers have been installed in order to control remineralisation and filtration processes and treated water. These analysers permit the detection of pH, conductivity, turbidity, total hardness, aluminium and chlorine;
- Vale da Pedra Water Treatment Plant - analysers have been installed in order to control pre-chlorination, settling and filtration processes and treated water. These analysers permit the detection of temperature, turbidity, pH, dissolved oxygen, total organic carbon, aluminium and chlorine

3.4.4. A network of 60 residual chlorine analysers has been installed along the transport pipelines, points of delivery to the municipalities and Lisbon distribution system. Taking into account the fact that the distribution system is fed with water from different sources, analysers for the control of turbidity and conductivity have been installed at a few selected points in the distribution network.

#### **4. Identification of research needed for water quality management**

Daily distribution system management involves coping with changes in water quality in the customer's tap, associated either with the raw water, the treatment plant or the distribution network. In fact, water passing through the distribution system is subject to a number of processes which may affect its chemical and microbial composition :

- Degradation and leaching reactions at the pipe surface
- Changes in chemical species present
- Precipitation and biofilm formation
- Resuspension and film interaction
- Corrosion and degradation in distribution
- Disinfection by-products formation

Considerable attention is being given to these processes. However, the present approach followed by EPAL is based on comparing measurements of the quality in the distribution system with defined criteria and standards. This approach is centred on consumer safety, taking into account parameters that can or cannot be detected directly by the human senses :

- Taste and odours
- Bacterial growth
- Chlorine decay
- Disinfectants-by-products (DPBs)
- Toxic micropollutants

Organoleptic and aesthetic properties of water are the main elements immediately evident to the consumer on appraising water quality. Taste and odours can be produced during the disinfection processes, using namely chlorine, ozone, chloramines or dioxide chlorine. The molecules responsible for the organoleptic properties of water can be mineral elements (metals, dissolved salts) or organics. Some of these organic compounds are the result of

biotransformation, while others ones are the result of chemical reactions. At the moment the identification and quantification of odour and flavour causing compounds in water call for a systematic and efficient combination of chemical and sensory methods<sup>9</sup>. Two different procedures for sensory analysis are used: the threshold Odour Number Test (TON) and the Flavour Profile Analysis Method (FPA). However, these tests need to be supported by very expensive identification techniques such as GC-MS and MS-MS. For this purpose it is important to select sensorial standard methods that may be easily applied to water quality control.

Much attention is also focused on the management of the free chlorine present in the distribution network, taking into account the risks represented by microbial re-growth while minimising the risks of taste and odours and the formation of disinfection-by-products (DBP). The efficacy of chlorination is assessed by periodically measuring the free and combined chlorine, using either manual photometer or "on-line" analysis. However, in order to have a better knowledge of chlorine decay within the network and to contribute to the validation of the chlorine quality model, it is necessary to have, amperometric micro-sensors available in the market, at a low cost, easy to maintain and to install, with low detection limit and reproducibility.

Bacteriological monitoring is essential for hygienic control of the water. This is carried out by test methods which only provide an answer 24 hours after sampling the water. If water is contaminated with bacteria, this is far too long to wait without reacting with the requisite water treatment and warnings to the public. Accordingly, a rapid screening technique is necessary to assess the presence/absence of bacteria and/or enumeration of coliform bacteria<sup>10</sup>. To this aim, instruments need to be developed either for laboratory or "on-line" monitoring.

As mentioned above, a systematic monitoring of drinking water quality has to be designed for each individual "supply zone", according to EC Directives and national regulation. For this purpose Water Companies need to have, within their bodies, analytical laboratories able to produce reliable accurate and precise data. Moreover, results have to be quickly available, in order to allow, for adequate corrections within the distribution system as and when necessary.

Analytical laboratories have nowadays access to techniques for inorganic parameters, which have proved to give reliable and accurate results, such as Ion Selective Methods, Inductively Coupled Plasma (ICP), Ion Chromatography (IC), Atomic Absorption Spectrometer (AAS), etc. The problems arise when the detection limit is too close to the Guide Value, the measurements being made in a concentration range of great variability and uncertainty (for example, lead and arsenic). Research should be strengthened for the development and validation of the multi-element analysis, namely by atomic absorption spectrometry, improving their sensitivity. The development of "on-line" sample pre-treatment with final detection technique is also necessary.

During the last decade legal requirements have become increasingly demanding in what concerns the presence of organic compounds in drinking water. The problems of analysing organic micro-pollutants in water relate mainly to their large variety and very low concentration levels.

Analyses of organic compounds are generally performed with sophisticated equipment, need knowledgeable operators, are very expensive and the results are not quickly available.

There are currently several potential “priority” organic compounds, namely pesticides, for which there is no available method capable of monitoring samples at the limit level of 0.1 µg/L. In addition, many methods are inadequately tested at this concentration and are not accurate enough for the purpose of monitoring compliance. Systems should be developed and made available commercially, regarding “on-line” extraction and clean-up with final detection.

Regarding “on-line” analysers, the sensors commercially available are dealing mainly with inorganic compounds like anions (nitrate, nitrite, phosphate, cyanide, ammonium) and heavy metals (lead, copper, zinc). For organic compounds, it is necessary to develop sensors with sensitivity and specificity. As a rule, it is recommended to put more effort into developing and validating “on-line” analysis for the concentration level of standards and guidelines. For these analysers, it is also essential to guarantee a representative and constant flow of the sample water in order to obtain accurate and reliable results.

## **5. Conclusions**

Several areas where research should be increased are identified :

- Rapid screening techniques to assess the presence/absence of bacteria and/or enumeration of coliform bacteria, for laboratorial and “on-line” purposes;
- Development of sensorial standard methods for taste and odour, which may be easily applied in water quality control;
- Chlorine micro-sensors to install in the distribution network;
- “On-line” analysers for disinfecting by-products (THM’s, bromate)
- Fast toxicity tests for drinking water purposes;
- The research needed on the analysis of organic micro-pollutants can be summarised:
  - Lower detection limits
  - More accurate analysis at low concentration values
  - Development of low cost and rapid methods
  - Development of fully automated analysis (sample pre-treatment and final detection technique)
  - Development of sensors with sensitivity and specificity
- Research on inorganic analysis:
  - Development and validation of the multi-element analysis, improving their sensitivity.
  - Development of “on-line” sample pre-treatment with final detection technique is also necessary
- Development of fast methods for assessing biological stability:
  - Assimilable organic carbon (AOC)
  - Biodegradable Organic Carbon (BDOC)
- Development of reliable test procedures to assess effects of distribution materials on water quality

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