
Introduction

In the 1990s, microbiological contamination was a major concern, in particular due to the contamination of drinking water sources by cysts and oocysts (*Giardia* and *Cryptosporidium*), as well as by bacteria and viruses. The rise in living standards, the rapid extension of urbanization and ever-increasing industrialization not only contributed to the increase in the demand for water but also to the degradation of receiving environments. In some cases, not even well-protected groundwater was spared. At some point, it became necessary to face the facts and to design an array of technical solutions to revitalize surface water and groundwater to reach their expected properties and qualities in relation to health regulation. On the other hand, the new millennium brought a series of new challenges. Research into the health effects of several inorganic contaminants, such as arsenic and lead, encouraged the reduction of their respective concentrations in water. Lead and water chemistry problems are often related to the corrosion of pipes and other equipment, to such an extent that the focus should not only be on water stability but also on distribution systems. Currently, new pathogens such as new viruses (H₅N₁, H₅N₅, Ebola, Covid-19, etc.) have appeared in our environment, and their treatability in drinking water plants is being tested and monitored. Other concerns are related to the possible health effects of many organic micropollutants. Not only do these include the categories of compounds emanating from our modern way of life – such as pharmaceutical compounds, endocrine-disrupting compounds, and personal care products – but also solid micropollutants, such as microplastics. The appearance of all these physical, organic and biological contaminants in water raises fears of contamination, which may require a more complex treatment. This leads to increased attention on the conditions for protecting water resources, plant performance optimization and a proper management of recycling flows through the implementation of new technologies: high- and low-pressure membrane techniques, a more formalized use of powdered activated carbon, controlled ozonation and ultraviolet radiation. Terrorist attacks place greater emphasis on the security of water

infrastructure and risk management, namely, on the transport of dangerous chemicals. Relatedly, regulations are increasingly shifting the point of quality control from factory-produced water to the customer's tap. Considerable media attention has brought these categories of pollutants into the spotlight. It is also true that over the past few years, analytical methods have improved in such a way that trace amounts can now be systematically detected. Even though their toxicity effects on humans, as well as their impact on the environment, are continuous for some of these substances, little is known about their actual effects. The reuse of municipal wastewater as a drinking water resource is also the subject of increased attention and requires the serial use of several high-level techniques.

The microbiological quality of drinking water makes the news every day. At present, customers are increasingly involved in the quality of the water supply and share their concerns about chemical disinfection and its by-products, as well as the presence of lead and legionella in water distribution systems.

For this reason:

- the challenges of drinking water treatment are diverse, making it one of the most interesting fields in civil engineering: new contaminants are under scrutiny, as well as perfluorinated compounds in groundwater and algal toxins that are detectable due to a proliferation of cyanobacteria in surface water;

- alternative resources are being contemplated to profitably recover rainwater, deep brackish groundwater, and fossil water and to directly or indirectly reuse wastewater.

Over the past two decades, there has been a continuous development of new water treatment technologies, and older technologies have also been improved. Thus far, progress has been made in:

- the development and maturation of membrane technologies: microfiltration and ultrafiltration are often used instead of media filtration for particle removal. Nanofiltration and low-pressure reverse osmosis are increasingly used for water softening and the removal of heavy metals, organic carbon and organic micropollutants. High-pressure reverse osmosis is experiencing significant development for desalination applications and for removing organic and mineral contaminants;

- the use of powdered activated carbon (PAC) or micrograin carbon in specific reactors for the removal of humic substances and organic micropollutants;

- the use of biological processes for ordinary applications such as iron and selenium removal from groundwater;

- the development of new and improved advanced oxidation processes for increasing the formation of hydroxyl radicals, therefore inducing the decomposition of many worrisome organic contaminants;

- improvement in the performance of UV disinfection systems to such a point that the currently applied dose is higher than the one required during the 1980s and 1990s.

What about the future?

Nowadays, engineers in charge of designing water treatment processes are confronted with many challenges. In fact, not only are there new challenges, but past challenges are cumulative and still need to be overcome. Some challenges are even contradictory, such as the need for more effective disinfection contrasted with the urge to reduce disinfection by-products. The major challenge is to develop and implement more effective methods for the removal of disinfection by-product (DBP) precursors from raw water or to reduce the risk of protozoa-related contamination without significantly increasing the formation of by-products.

The science of drinking water continues to make progress, and knowledge about the public health risks entailed by emerging contaminants and pathogens is closely monitored.

The biggest challenges in our days are related not only to the treatment processes themselves but also, most importantly, to the choice of treatment route and water supply development.

The water deficit observed in many regions, as well as an increased competition for available water resources, prompts a desire to use every water resource at hand.

There is also an increasing focus on the choice of the most effective water processes. Wastewater is being recycled for various applications, even for drinking water. In fact, in some countries, the supply from groundwater has become common.

In addition, there is an emphasis on the design and supply of more sustainable facilities. Engineers today are called upon to:

- make an optimal use (or reuse) of existing infrastructure and materials;
- limit or reduce the physical and environmental footprint of a facility;
- conserve and recover energy;
- minimize the use of chemicals and the production of solid sewage sludge;

- assess and maybe incorporate sources of alternative energy, in particular those capable of producing a net reduction in greenhouse gas emissions; and
- consider various environmental management benchmarking and accounting procedures, such as the carbon footprint.

Climate change concerns are closely related to water resource challenges and the need to provide sustainable water plants. However, considering that the impacts of climate change are difficult to predict, various questions remain:

- Will the frequency of rainfall be sufficient?
- Will the region see an increase in average temperatures, or will they be more extreme?
- To what extent should the engineer modify treatment routes and make provisions for potential changes, recognizing that these may lead to an increase in the cost of water?

To date, the main discharge-related concerns have focused on the future of sewage sludge, but the environmental impact of liquid discharges through the use of concentrates (high-pressure membrane plants and desalination procedures) and eluates (resulting from water softeners based on ion exchange resins) is now receiving particular attention.

Until recent decades, new water treatment projects and the resulting quality of drinking water have not particularly attracted public attention. Media attention to water issues and the explosion of social media communication are now inviting a larger public engagement in drinking water. As a result, engineers are expected to share certain aspects of a project with the audience in further detail. For this, engineers must take into account a variety of novel requirements related to public perception or values that do not strictly correspond to technical issues. By way of example, this could be the claim that an aluminum residual in the water (even if below standard) could lead to Alzheimer's disease, although there currently is no scientific evidence proving that it constitutes a threat to public health. The audience also expects public services to pay more attention to the esthetic quality of the water delivered. This may include the reduction of taste, odor and color, for example. On the other hand, the reduction of iron, manganese and water hardness is related to comfort parameters rather than potential toxicity effects. In addition to meeting current drinking water standards, engineers are now required to anticipate potential future needs. A water system designed today must be conceived with enough flexibility so that it can be modified to meet potential future requirements. Engineers must also account for other environmental concerns, such as waste management practices, chemical supplies and storage operations, energy conservation, occupational health and safety, and general safety.

Since water treatment engineering is a global market, engineers must adapt to the local context and to the ideas, practices, products and services exchanged. The French water school has always been the subject of particular interest due to its practices, references, technology and services. Building information modeling (BIM) is one element of new practices and technologies that provide the designer, builder and operator with outstanding features, such as:

- the ability to create 3D visualizations throughout the different design stages;
- the possibility of sharing various project aspects between the designer, equipment suppliers, contractors and operators;
- the ability to integrate asset and maintenance management needs.

This book provides a thorough presentation of techniques for producing drinking water, including conventional and unconventional surface water, as well as groundwater. The first chapter presents the diverse physical and chemical constituents most frequently analyzed in drinking water and those requiring reduction. Regardless of whether the resource is surface water (river, lake, dam, ocean, sea) or groundwater, the physicochemical composition of raw water presents many physical, chemical and bacteriological parameters. Contaminants are many and varied. They can be of natural origin, such as humic substances (resulting from plant decomposition), calcium hardness and magnesium, heavy metals (iron, manganese, arsenic, nickel, antimony, etc.). Alternatively, they can be of industrial origin, such as pesticides, nitrates and emerging micropollutants (drug residues, endocrine-disrupting compounds, industrial waste). Contaminants can be of biological origin, with the discharge of wastewater into receiving environments and the concomitant presence of pathogenic germs. Then, there is a presentation of the standards and qualities of drinking water and a discussion about the risks generated by the presence of mineral or organic compounds above standard thresholds. In France, water fit for consumption includes all the water intended for drinking, cooking, food preparation or other domestic purposes, as well as the water used by food companies for manufacturing, processing, preserving or marketing products or substances intended for human consumption, including water-origin ice cream.

All these waters must simultaneously fulfill three conditions:

- they have to be free from any number or concentration of microorganisms and parasites or from any other substances constituting a potential danger to human health; they must comply with the predefined quality values (French Government Resolution of January 11, 2007 on the limits and quality references for raw water and water intended for human consumption, as mentioned in articles R. 1321-2, R. 1321-3, R. 1321-7 and R. 1321-38 from the Public Health Code), which are mandatory values;

– they must satisfy quality references following indicative values (French Government Resolution of January 11, 2007).

Compliance with the quality reference values is assessed at “the point of compliance”, that is, the consumer’s tap (for water supplied by a distribution network).

To produce drinking water that meets existing standards, Veolia has a large number of tools and technologies displayed on thousands of sites where it operates worldwide. The following chapters further explain the various drinking water production techniques included in a global water treatment system. Each process is accompanied by its fundamental and theoretical underlying principles. All cases include a presentation of the required elements for their design, implementation and operation. These technological elements have been designed to remove particulate pollution through coagulation–flocculation–settling and filtration mechanisms, which all represent ineluctable stages for a drinking water plant treating surface water. Settling based on processes such as Cyclofloc[®], Actiflo[®], Multiflo[®] or flotation using Spidlow[®] or Spidflow[®] Filter are described in terms of their operating parameters, efficiency and associated chemical reagents. The supplementary treatment of filtration through various materials (sand, anthracite, pumice stone) is detailed with the Filtraflo family, for which the diversity of available techniques (gravity and pressure filters) makes it possible to treat each type of water in accordance with the local context and final water quality goals.

In addition to the removal of particulate pollution, that of dissolved pollution is of great importance for many surface waters. The removal of nitrates has an exclusively dedicated chapter because this compound continues to be relevant in our days. Using either a biological process (Biodenit) or ion exchange resins (Ecodenit), Veolia has developed two processes that have been successfully applied throughout Europe. Particular attention is given to the removal of natural organic matter (humic and fulvic substances) whose residuals in the water produced are known to contribute to the formation of carcinogenic by-products after disinfection. The use of granular activated carbon in Filtraflo GAC, or powdered activated carbon, with the development of many PAC reagents in recent years (Actiflo[®] Carb, Multiflo[®] Carb, Opacarb[®] MG and Opacarb[®] MF), makes it possible to meet the needs of users for the various organic molecules present in water.

Similarly, an entire chapter is devoted to the removal of emerging organic micropollutants (drug residues, endocrine-disrupting compounds, industrial waste) due to the use of activated carbon (powdered, granular and micrograin) or high-pressure membranes (nanofiltration and reverse osmosis). This chapter illustrates the importance Veolia gives to this type of contaminant and describes their removal processes based on micrograin carbon, such as Opacarb[®] FL, Filtraflo[®] Carb or

Contact[®] Carb. This is done in addition to and/or in combination with other conventional processes for the removal of organic matter.

These fundamental stages of water treatment plants need to be supplemented with other no less important phases providing water with the required calcium-carbon balance to prevent it from being too aggressive (concrete destructuring) or corrosive (alteration of metals). Mechanisms and chemical reactions are properly explained, and many Veolia processes are described by means of saturators, remineralization processes in line or in tanks, or limestone filters (FiltrFlo limestone).

Similarly, chemical decarbonation (Actiflo[®] Softening, Multiflo[®] Softening, Saphira[®], Actina[®]), ion exchange or nanofiltration is well detailed, since the problem of excess limestone is an ongoing consumer concern. Metal removal (iron, manganese, arsenic, antimony, selenium, nickel) is presented and described under the light of acquired experience. Low-pressure membranes (microfiltration and ultrafiltration) intended to remove particulate and bacteriological pollution are presented through Veolia's know-how and the many references it has built and/or operates. Because of the expertise and feedback gained from the operations of multiple membrane-based plants, Veolia has built an excellent reputation for its know-how and is often consulted by manufacturers to give an opinion on the membranes being developed.

For high-pressure membranes (nanofiltration, low-pressure reverse osmosis, reverse osmosis), Veolia has a rich and varied database on the use of these membranes in conventional surface water and for the desalination of sea water. Many references are explained in this work, together with the technical justification for their choice.

Chemical disinfection and ultraviolet radiation are detailed in depth as the final stage before the distribution of the water produced, emphasizing the technical recommendations to be implemented to obtain the best disinfection results.

This book is intended as a guide for engineers in charge of the design of drinking water plants, driving them through the different processing goals and helping them with the choice and design of physical, chemical and biological facilities. The book is also intended to aid plant operators by giving them access to the fundamental principles of the processes involved in water treatment plants.

