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Desalination for Drinking Water

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Course Author: Mathew Holstrom

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1. Introduction

Desalination is increasingly being used to provide drinking-water under conditions of freshwater scarcity. Water scarcity is estimated to affect one in three people on every continent of the globe, and almost one fifth of the world's population live in areas where water is physically scarce. This situation is expected to worsen as competing needs for water intensify along with population growth, urbanization, climate change impacts and increases in household and industrial uses.

Desalination may be applied to waters of varying levels of salinity, such as brackish groundwater, estuarine water or seawater; in some regions, it forms the primary source of drinking-water. At its origins, desalination technology was primarily thermal, by flash distillation, but as a result of technological advances, membranes have become a more cost-effective alternative that is increasingly being selected for new systems. Many thermal plants remain in use.

Saline sources are different from freshwater sources in that they always require a substantive treatment step. However, while the desalination process usually provides a significant barrier to both pathogens and chemical contaminants, this barrier is not necessarily absolute, and a number of issues could potentially have an impact on public health. Some of these are similar to the challenges encountered in most piped water systems, but others, such as those related to stabilizing and remineralizing the water to prevent it from being excessively aggressive, are different and therefore must be addressed within the context of a site-specific health risk management plan (see section 2 below).

This course aims to:

- highlight the principal health risks related to different desalination processes;
- provide guidance on appropriate risk assessment and risk management procedures in order to ensure the safety of desalinated drinking-water.

The course introduces the concept of water safety plans (WSPs) for desalination systems, provides an overview of potential hazards in source water and describes microbial and chemical risks and other key issues associated with treatment, remineralization, storage and distribution. More detailed information is presented in a series of annexes.

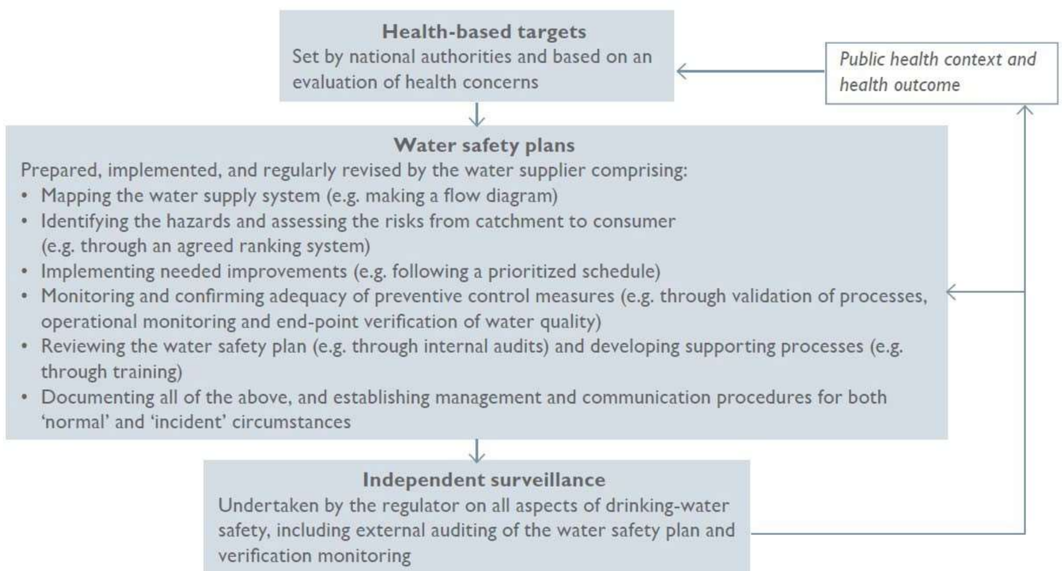
The course will be of use to health authorities, water quality regulators, operators of desalination plants and others interested in water quality and health issues.

A comprehensive examination of technical and water quality issues pertaining to desalination, such as environmental impacts, engineering considerations and equipment and processes for different desalination technologies, is provided in *Desalination technology: health and environmental impacts* (Cotruvo et al., 2010).

2. Desalination and water safety plans

As with any drinking-water supply, the development of a WSP is an essential first step in the provision of safe drinking-water (Figure 1). For any new system, development of a WSP should be initiated at the planning phase and carried through as the plant is built and commissioned. For existing plants, WSPs are equally important, as they help to identify potential risks and available barriers in their systems and support the introduction of a preventive risk management approach to problems that could have an impact on the quantity and quality of water supplied.

Figure 1. Framework for safe drinking-water (WHO, 2011)



A WSP maps the water supply system from catchment to tap to facilitate a thorough understanding of the system, including all its steps and stages, identifies the hazards that may be introduced at each stage and determines the risks associated with those hazards. Hazards are physical, microbial and chemical contaminants that could have an impact on health or adversely affect the acceptability (e.g. taste and odour) of the water to consumers.

Hazards may also be substances or circumstances that threaten the operation of the desalination plant. The risks may be the potential for a particular hazard to reach the consumer in numbers (pathogens) or concentrations (chemicals) that will result in illness or the water becoming unacceptable. This may include the risk of exceeding the current drinking-water standards in a given country. In addition to technical considerations, a WSP also entails essential management components, such as training, maintaining records, documentation and periodic review of operating procedures to enhance the operation and management of the water supply system. Table 1 illustrates the key elements of a WSP for desalination.

Table 1. Elements of a water safety plan for desalination

Component	Action
Description of the system, including the water source and sources of hazards.	Thoroughly understand and document the system from the source to the tap.
Assess the risks of hazards reaching consumers in numbers or concentrations of concern, and ensure that steps are in place to mitigate the risks.	Determine the pathogens or chemicals that could be introduced at each stage, and ensure that barriers or operational procedures are in place to reduce the risks to meet health-based targets.
Ensure that the barriers are working efficiently at all times, and develop procedures for responding when efficiency starts to fall.	Develop operational monitoring to demonstrate that processes are working efficiently and an alert system to warn upon a decrease in effectiveness. Develop management procedures to ensure that all of the procedures are followed.
Verification that the WSP is working adequately and that a safe and acceptable supply of drinking-water is delivered.	Analyse key indicators of water quality and safety, and assess against appropriate standards and guidelines.
Develop supporting programmes.	Activities in such programmes are tailored to the specific needs and priorities of the water supply system and may vary from consumer education and community engagement to workforce training programmes.
Periodically review the WSP, and update the WSP in the wake of problems or emergencies.	Ensure that operation and management procedures are kept up to date and revised to incorporate lessons learnt.

Specific hazards and risks are considered in the following sections. Hazards may be present in source waters or may arise during treatment or other drinking-water production processes, during distribution and in consumer premises. Once the hazards have been identified, the associated risks need to be mitigated by removing or reducing their influx into the source using specific treatment barriers and sound operation and management procedures. A key step is operational monitoring of processes or barriers to ensure that they are working optimally at all times. However, all monitoring should be used to provide information that can be applied to ensure the proper management of the system and safe water quality. The WSP will also include procedures to ensure that chemicals and materials used in the system comply with requirements and will not introduce hazards. Appropriate emergency plans that would cover all aspects of the system, from a contamination incident in the raw water source to a breakdown in treatment and distribution (e.g. in final disinfection or damage to the distribution system), are also important components. In addition, WSPs for desalination systems should take into account the process of remineralization or stabilizing the treated water before distribution.

Detailed information on WSPs can be found in the World Health Organization's (WHO) *Guidelines for drinking-water quality* (WHO, 2011) and supporting WHO guidance documents, such as the *Water safety plan manual: step-by-step risk management for drinking-water suppliers* (WHO, 2009).

3. Source water and potential hazards

Source water for desalination can be marine or brackish surface water or highly mineralized groundwater. By definition, this water has a significant content of naturally occurring inorganic ions, and the objective of treatment is to reduce the concentration of, or remove, these substances. These naturally occurring substances include some that would be of potential concern if present in sufficient concentrations after treatment. Like all surface water sources and some groundwater sources, there can be contamination by pathogenic viruses, bacteria and parasites and by a variety of chemical contaminants from human activities.

There are notable differences between freshwater sources and brackish or saline sources. In particular, the survival of many microbial pathogens is significantly reduced in saline waters, especially in combination with a high level of solar radiation. However, some pathogens, such as *Vibrio cholerae*, do survive well in saline waters. There are also many marine algae that can produce toxins of concern to human health. These issues are covered in detail in *Desalination technology: health and environmental impacts* (Cotruvo et al., 2010).

Chemical constituents of interest include boron (borate), bromide, iodide, sodium and potassium; they may require additional actions for removal (boron) or are present in such concentrations as to leave significant residues. While natural organic matter (NOM) varies significantly, there are a number of organic substances, coming from both natural and anthropogenic sources, that are of particular interest. Individual and groups of chemicals that are of concern for desalination processes are considered in more detail in Annex 1.

Understanding the hazards that are likely to be present in the source water is a critical condition for the proper design of the desalination process; it highlights the need for pretreatment steps and the removal of contaminants in treatment or the need for additional treatment barriers. In the case of potential problems from contaminants, either chemical or microbial, the first step in reducing the associated risks is to try to prevent or reduce inputs at source. In some cases, this may be possible; in other cases, siting of the raw water intake may help to minimize the intake of contaminants into the desalination plant. However, thermal plants, in particular, are often co-located with power plants, and there may be limited options in terms of suitable locations for the intake. Where source water quality is highly variable, some form of monitoring will help to provide information in managing water abstraction to minimize the intake of constituents or contaminants. For example, some estuarine-based desalination plants abstract water only at a particular tide level to reduce the salinity in the source water and the concentrations of possible anthropogenic

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