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EHEDG Update

Safe and hygienic water treatment in food factories

This article is an extended summary of the Guideline 28 prepared by the Process Water Subgroup of the European Hygienic Engineering & Design Group (EHEDG), originally published in December 2004. The full report prepared by A. Winkler (Chairman), R. Hopman, D. Lawrence, J.A. Milligan, D. Napper, J. O'Brien, A.M. van Buren, H.M.J. van Eijk and W.G.J.M. van Tongeren is available from CCFRA at pubs@campden.co.uk. Information about EHEDG can be found at www.ehedg.org. The production of EHEDG guidelines is supported by the European Commission under the Quality of Life Programme; project HYFOMA (QLJK1-CT-2000-01359).

Introduction

Water is a vital medium in the food industry used for many different purposes. The quality of the water used can be critical with respect to product safety in the market place, the reliability of production processes and the safety of personnel in the workplace. In many cases, treatment is necessary to bring incoming water up to, and maintaining, the required standard and therefore water treatment plants are common in most food factories.

This paper provides guidance on the control of hazards encountered by water treatment at food factories. Hazard identification is defined by CODEX as 'identification of biological, chemical and physical agents capable of causing adverse health effects'.

- Biological hazards refer to pathogenic microorganisms and microbial toxins that could be present in the water
- Chemical hazards include heavy metals, organic compounds, salts and other chemical contaminants, e.g. fertilizers.
- Physical hazards derived from incoming water are solids and foreign matter.

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Sources of water and water types

Water used in the food industry can come from different sources all of which need quality monitoring before being used in the production process.

Drinking water

Water supply companies in the European Community must supply drinking water, which meets strict quality requirements set forth in Directive 98/93/EC. The use of drinking water guarantees the water meets these strict requirements but it is expensive.

Ground/well water

Ground/well water is the water beneath the surface that can be collected with wells, tunnels, or drainage galleries, or that flows naturally to the earth's surface via seeps or springs (see Fig. 1). Some mineral contaminants such as iron, manganese, nickel, arsenic, lead occur naturally in some areas of the earth's crust. Other possible contaminants are nitrogen (nitrate, ammonia), organic material and pesticides (from agricultural use). Pathogenic microorganisms can contaminate ground/well water via surface pollution and unfavourable weather conditions, i.e. flooding, heavy rainfall.

The costs of ground water are relatively low, but the removal of certain contaminants can increase the costs significantly. Ground water taxes can also increase costs.

Bank filtered water

Bank filtered water is the ground water under the direct influence of surface water. The extraction wells, located in the vicinity of surface water bodies like rivers or lakes, withdraw groundwater with a certain amount of surface water (after filtration through the soil). The quality of the raw water is comparable to that of ground water. Costs of bank-filtered water are relatively low, but the same restrictions as for ground water apply.

Surface water

Surface water is the water from rivers, lakes, canals, etc. It is the most abundant of water sources but also the one with the highest risk of contamination from heavy metals, synthetic organic chemicals and microorganisms. The quality of surface water also depends on the weather conditions. Heavy rainfall and flooding can cause contamination with various pathogenic microorganisms. Prolonged

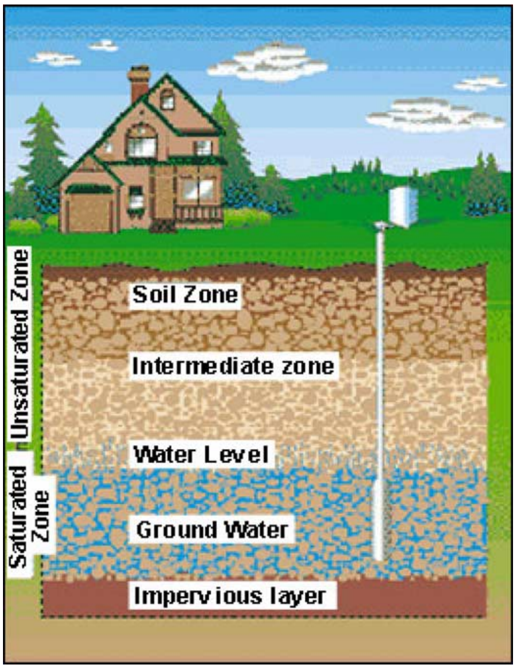

Fig. 1. Ground or well water

hot, dry weather can result in blue green algae blooming. The costs of surface water are relatively low, but the treatment is comprehensive and costly.

Reused water

Reused water refers to water that is used in or obtained from a food processing operation and is subsequently reused in a food processing operation as reclaimed and/or recycled water. This water requires appropriate treatment in order to fulfil respective quality criteria for its intended purpose.

Precipitation

Precipitation is the generic term for rain, snow (including meltwater), hail, dew and mist. Possible contaminants are heavy metals from roof surfaces and tiles and microorganisms from birds and other animals. This is not a reliable source of water; in periods of drought, another water source should be available as back up.

Common treatment techniques and main hazards

The choice of water treatment depends on the water source and the intended application of water. Often a combination of techniques will be necessary.

See Table 1 for an overview of the most common treatment techniques and their purposes.

There are three main sources of hazards in relation to water treatment techniques:

- Hazards in relation to design and building;
- Hazards during the normal operation (including stops);
- Hazards introduced by external factors;

To prevent design and building hazards, the general rules for hygienic design for installation in the food industry are important. For some techniques, there are specific design considerations, which are discussed below. Hazards during normal operation and due to malfunctioning can be minimized by good hygienic practice and adequate preventative maintenance. Examples of external hazards are: incoming water, used chemicals and materials, lack of water supply or inferior utilities (energy, cooling water, air). A good monitoring and guarding system will decrease these hazards.

Filtration

Filtration is a separation process that consists of passing a solid and liquid mixture through a porous material (filter) that retains the solids and allows the liquid (filtrate) to pass through. Filtration is used for the removal of suspended solids from the water.

Table 1. Common treatment techniques and their purpose

Hazardous agent	Treatments						
	Filtration	Membrane filtration	Ion exchange	Chlorination/ ozonisation	UV radiation	Neutralisation	Activated carbon
Solids	X	X					
Salts, including hardness		X	X				
pH correction						X	
Other chemical contaminants, e.g. organic residues	X	X	X				X
Bacteria		X		X	X		
Viruses		X		X (depending on virus species)	X		
Protozoa		X		X (Cryptospori-dium)	X (Cryptos-poridium)		
Algae bloom (toxin)							X (option if contamination detected)

There are three types of filtration:

- Filtration on a support (micro straining, filtration with cartridges and candles);
- Filtration with a filter cake;
- Filtration through a granular solid material filter bed (e.g. sand and anthracite).

For the treatment of process water, filter cartridges and granular filtration are generally used.

Filtration hazards

Damaged or badly designed filters can lead to fine sand passing into the downstream pipe work.

Pressure drop over a filter is a good indication that a filter is saturated. Replacing or back-washing the filter is necessary. For the removal of iron and manganese, sufficient aeration and right pH are of importance. It takes some time after the start up of a new installation before filtration works effectively.

Growth of microorganisms is a problem when the installation is out of operation. Recirculation of water over the filter during these periods can be a solution.

Another risk is the breakthrough of material to be filtered due to:

- Too long running time
- Insufficient back-wash program;
- Wrong installation of cartridges in pressure vessel.

Ion exchange processes

Ion exchange processes modify or reduce the ionic content of waters and include de-alkalising, softening and de-mineralising.

Hygienic aspects of ion exchange processes

During normal operation of ion exchange processes for product water, the following precautions should be taken:

- Recirculate water over the beds to avoid stagnant water.
- Pre-rinse the unit when the operation starts.
- If the unit has been out of operation for longer than 6 h, drain two bed volumes before starting to use the water for process purposes.

Ion exchange plants must be disinfected if they become infected with microorganisms. Disinfection agents such as sodium hypochlorite must be approved for food application.

Free chlorine or any other oxidising agent may substantially harm the resin bed. For this reason, the disinfectant should be compatible with the particular resin being used. As a general guide, disinfection frequency should not exceed once a month.

Ion exchange plants can also become fouled with iron and suspended solids. Any chemicals used to remove such materials must be approved for food factory use.

After disinfection and/or cleaning, the ion exchange unit must be thoroughly rinsed with at least four bed volumes of water.

Resin replacement

Ion exchange resins will last on an average for about 5 years. An annual resin analysis should be used to indicate when a replacement needs to be installed.

Membrane filtration

Membrane filtration is a pressure-driven technology using a broad range of pore sizes.

Membranes can be characterised as given in Table 2.

Membrane filtration can be applied with both cross-flow and dead-end filtration. With cross-flow filtration, the inlet feed is pumped over the membranes with a turbulent high flow velocity. The pressure differential across the membrane forces part of the fluid through the filter membrane, while the remainder flows over the membrane and removes residues, whereas dead-end filtration forces all of the fluid through the filter membrane by pressure. This technology is generally used for fluids with a low solid content.

Hygienic aspects of membrane filtration

Cleanability depends on both the type of membrane and material it is made of. In general, tubular membranes are easier to clean than other types. Ceramic is ideal for sanitary applications as well as for products with extremes in pH, temperature or solvents. Stainless steel is effective for applications with aggressive process conditions.

Table 2. Membrane characterisation

Technology	Pressure (bar)	Porosity (cut-off)	Retention
Microfiltration	1–2	0.02–10 μm	Solid particles, yeast, bacteria, colloids
Ultrafiltration (UF)	<5	20–200 nm (5000–500,000 D)	See above and polysaccharides, proteins
Nanofiltration (NF)	5	1–10 nm (200–10,000 D)	See above and sugars, amino acids, hardness (calcium salts), multiple charged ions (e.g. sulphates, phosphates), virus
Reverse osmosis (RO)	15–50	<2 nm (50–300 D)	See above and salts

UF-membranes can be cleaned by either enzymatic or chemical processes.

Membrane fouling is one of the main problems during operation. It is most frequently caused by build-up of colloidal material, but metal oxides can also cause fouling.

To prevent bacterial growth through the filter, appropriate cleaning schedules and monitoring (e.g. turbidity, conductivity, pressure differential measurement) of the treated water should be established. Working conditions (e.g. velocity) of the filtration should be chosen in a way to minimize the risk of fouling.

Water produced by reverse osmosis may have corrosive properties due to the removal of minerals. Consequently, for some applications, a degree of re-mineralisation might be required.

Chlorination and ozonation

Chlorination and ozonisation are oxidation techniques used to degrade organic chemicals and for disinfection.

General hazards of the application of oxidation techniques are:

- the reaction with other compounds and formation of toxic agents,
- the occurrence of residues of chemicals,
- damage to personnel by inhalation or skin contact.

Chlorine

Chlorination has for many years been the most commonly used procedure for the control of microbiological contamination in both potable and utility water. Chlorination can either be done with NaOCl or with chlorine gas. In the food industry, NaOCl is used in most cases.

Depending on the reliability of purchased water supply, it may be required to chlorinate the incoming water. In many cases, this is then unsuitable as ingredient water because of taste. In this case, a combined chlorination/dechlorination process is required, dechlorination usually taking place via activated carbon treatment.

Chlorine exhibits a broad spectrum of anti-microbial activity. For effective disinfection, there should be a residual concentration of free chlorine of 0.5 mg/l or greater for at least 30 min contact time at pH <8.0. It is extremely cost effective in use and has a rapid killing action. However, disadvantages include:

- Increasingly reduced effectiveness at pH >8.
- Reacts with nitrogenous compounds to give chloramines, which are poor biocides and can give rise to unpleasant odours.
- Reactive with other organic materials and may yield environmentally unacceptable compounds, e.g. trihalomethanes.
- Reacts with naturally occurring phenolic compounds to form chlorophenol taint materials.
- Easily quenched by organic matter and turbidity in the water.
- Highly corrosive.

Chlorine dioxide

The first reported use of chlorine dioxide treatment of drinking water was in the 1940 s in the USA. Chlorine dioxide can be prepared by acidification of sodium chlorite or by its reaction with chlorine gas. Only when sodium chlorite became commercially available, the industrial use of chlorine dioxide was made possible.

Chlorine dioxide is extremely reactive and cannot be stored in its active state. It must therefore be generated on site, close to the point of use. The process is usually designed to ensure that the chlorine dioxide produced is delivered as a dilute solution. Recently ClO_2 can also be generated directly converting sodium chlorite to chlorine dioxide via a patented electrochemical process, which is safer to use than the traditional generators.

Chlorine dioxide has a number of advantages over chlorine and bromine, as follows:

- Broad spectrum anti-microbial activity at lower concentrations.
- Maintains its effectiveness up to pH 10.
- Does not react with nitrogenous compounds.
- Does not react readily with organics so does not produce environmentally unfriendly compounds.
- It is more effective in the presence of organic matter.
- It is approved for use in potable water.
- It is considerably less likely to produce taint compounds.

It does also have some disadvantages:

- It is much more expensive than chlorine.
- It has to be generated at the point of use.
- With some generation processes, significant levels of chlorine may be produced which cancels out some of the advantages.
- As it is a gas dissolved in water, some will be lost to atmosphere in processes, which involve spraying under pressure or high agitation of heated water.
- Generators have a high capital cost, are complex to install, and may require frequent servicing.
- Due to higher volatility than chlorine or bromine, it may demonstrate a greater corrosion potential, e.g. in vapour spaces of hydrostatic sterilizers.

Ozone

Ozone has many potential applications for oxidation and disinfection. It has to be generated on site by means of a silent electrical discharge. For disinfection of water for potable supply, a concentration of 0.4 mg/l should be maintained for 5 min and for sporicidal activity, 2 mg/l is needed. Apart from water disinfection, ozone is increasingly being applied in cooling tower systems and before sand or active carbon filtration for the removal (oxidation) of certain dissolved organic compounds, e.g. phenols, turbidity, iron, manganese and colour.

The main advantages of ozone include:

- It can be generated easily as and when it is required, thereby not requiring any storage facilities.
- It does not form carcinogenic organic residues.
- It has a broad spectrum of activity and is an excellent viricide.
- Microorganisms do not develop resistance towards ozone.
- It breaks down easily to oxygen so is unlikely to pose any risk of taint.

The main disadvantages of ozone include:

- Discoloration, bleaching.
- Easily quenched by organic matter in the water.
- Possible formation of by-product, for instance bromate in the presence of bromide.
- Generating has a high energy demand.
- Capital and maintenance costs of generators can be high.
- Because of its high volatility, ozone is not recommended for evaporative cooling systems.

Ultra violet radiation

Ultraviolet (UV) radiation has been used for years in many industries for inactivation or destruction of microorganisms for disinfection purposes. Ultraviolet light is the name given to electromagnetic radiation lying in the wavelength band immediately beyond the violet end of the visible spectrum but preceding the X-ray radiation band. The spectral band is, by definition, between 100 and 400 nm. The UV spectrum is arbitrarily subdivided into three bands:

	Wavelength (nm)
UV-A (long-wave)	320–400
UV-B (medium-wave)	280–320
UV-C (short-wave)	100–280

Microorganisms like bacteria, moulds, yeasts, and protozoa can be inactivated by short-wave UV radiation. UV treatment should ensure a 4 log reduction of test organisms proven by biodosimetry. The UV radiation used should be comparable to 400 J/m^2.

Proper maintenance is of utmost importance to ensure reliable operation. UV treatment will never produce sterile water, but it is capable of significantly reducing the number of microorganisms. For water sources with a high initial contamination level, UV treatment may not be sufficiently effective to obtain potable quality water. Some bacteria, particularly micrococci, protozoa, algae and moulds, exhibit varying levels of resistance and may need higher doses for inactivation.

A decision to install a UV system should be based on a thorough investigation of the water source, since the effectiveness of UV is strongly dependent on the composition of water (turbidity, adsorption, concentration of organic material).

The main advantages include:

- No chemicals used.
- A clean process.
- It can be used synergistically with ozone and can be used to remove ozone residues in water.
- It has a broad spectrum of activity.

The main disadvantages include:

- It is only effective in non-turbid water.
- Particulates can protect organisms in shadows.
- Contact times required may limit flow rates.
- Lamps need regular maintenance and quite frequent replacement.
- No residual activity requiring a high level of hygiene after UV treatment in order to maintain water quality.

Neutralisation

After treatment, particularly using one of the above processes, it may be necessary to bring pH back into the desired range using acid or alkali dosing as appropriate. Care must be taken to ensure that this introduction of ions will not cause damage, for example, sulphates in concrete and chlorides on stainless steel are a particular problem. The plant should provide proper protection against overdose of chemicals.

Activated carbon

Adsorption refers to the ability of certain materials to retain molecules on their surface in a more or less reversible way. The main applications of adsorption are the removal of micro pollutants from water in a concentration area of less than one milligram to some tens of milligram per litre. The most applied adsorbent is the activated carbon. The adsorption capacity of the material depends on the specific surface area of carbon, the particle size, the contact time, the type of carbon and the nature of adsorbance–adsorbent bond. A good pre-treatment by sand filtration is necessary to prevent the pollution of carbon bed with suspended solids.

For the treatment of water, granular activated carbon is used with an internal surface area of 500–1500 m^2/g. The GAC can be reactivated with steam or at high temperatures (800–900 °C).

Growth of microorganisms also is a serious risk. In carbon filters, a strong biological activity is possible. This can result not only in microbiological risks, but also in the production of hazardous compounds such as toxins and lipopolysaccharides.

Chemical coagulation

Coagulation is suitable for the removal of certain heavy metals and low solubility organic chemicals such as certain organochlorine pesticides. It is generally ineffective for other organic chemicals.

Chemical coagulants are dosed to the raw water under controlled conditions to form a solid flocculent metal hydroxide. The flocculant is removed from the treated water by subsequent solid–liquid separation processes such as sedimentation or flotation, and/or rapid gravity filtration.

Typical coagulant doses are 2–5 mg/l as Al or 4–10 mg/l as Fe. The compounds used are various salts of aluminium (e.g. alum) or iron (ferric sulphate). In some countries local law defines maximal values than can be used. Consideration must be taken of residual chemicals that are in the water after it has been processed.

Electrolytic treatments

There are a few companies on the market that offer electrolytic treatment for water. Generally, in a separate small water circuit, a high electric tension is used to produce radicals. These compounds exhibit bactericidal actions due to their unpaired electrons.

The value of the electrolytic process depends on a number of factors. No general statement can be made in support of the technology as only a careful analysis of the reactions that occur can determine if the technology is of an advantage without creating harmful by-products.

Definitions

For definitions of generic terms used in this summary, see www.ehedg.org/glossary.pdf.

Normative references

The following reference texts underpin this EHEDG guideline. At the time of this publication, the editions listed below were valid. Please check for more recent versions.

- Codex Alimentarius – Food Hygiene – Basic Texts – Second Edition, FAO/WHO, 2001: http://www.fao.org/documents
- EN 1278:1998/prA1: Chemicals used for treatment of water intended for human consumption— Ozone
- EU Council Directive 98/83/EC of November 1998 on the quality of water intended for human consumption
- WHO document ‘Current edition of the WHO Guidelines for Drinking-Water Quality’ (http://www.who.int/water_sanitation_health/dwq/guidelines2/en/)

Please refer to the original document for a more detailed reference list.