Chapter 2
Wastewater Treatments for the Food Industry: Physical–Chemical Systems

Abstract This chapter provides a general overview of physical–chemical wastewater remediation systems in the food industry. Water reuse systems are becoming more and more interesting and promising technologies, depending on merely quantitative estimations, physical and chemical features of pollutants and the variability of these characteristics, week after week. Different systems are available for the food industry, depending on the final destination or water effluents and peculiar chemical–physical and biological features of the fluids before treatment. Several of these remediation systems can be subdivided into different groups, depending on the desired amount of gross removed matters, or into four categories depending on the peculiar removal operation (physical, chemical, thermal or biological procedures). This chapter is dedicated to the description of physical–chemical wastewater remediation systems only. Biological procedures are not considered here, while physical–chemical techniques are discussed with the possibility of 'hybrid' solutions including biological treatments, if applicable.

Keywords Centrifugation · Evaporation · Filtration · Membrane technology · Remediation · Separation · Wastewater

Abbreviations

BOD Biochemical oxygen demand
COD Chemical oxygen demand
FAO Food and Agriculture Organization of the United Nations

2.1 Introduction to Chemical Wastewater Remediation in the Food Industry. Objectives and Conditions

At present, it may be admitted that water sources are the main concern in several economic areas. Surely, the truthfulness of this affirmation can be observed when speaking of water supplies for food/beverage production and packaging lines.

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For this reason at least, water reuse systems are becoming more and more interesting and promising technologies: generally, discharged water from processing plants can be reused by means of innovative and advanced treatments. However, the final goal can be obtained by means of different strategies, depending on merely quantitative estimations (volumes of wastewaters), chemical features of pollutants (oils, etc.), physical–chemical parameters (biological oxygen demand, solid or liquid pollutants, etc.) and the variability of these characteristics, week after week. On these bases, different systems can be now available for the food industry. Anyway, the right strategy has to be decided on the basis of chemical and biological tests carried out on initial wastewater; the final use of waters is also crucial. Moreover, different chemical systems can be used when speaking of wastewater from food industries for subsequent non-food reuses. Because of the presence of different classes of resistant pollutants, many treatments require often a preliminary adsorption stage.

Actually, the discussion about water reuse systems should take into account a peculiar distinction between technologies designed for the reduction of wastewater and methods/procedures able to reduce the contamination level of existing wastewaters. This distinction has to be taken into account as a preliminary concept or operative definition for wastewater-related treatments [1].

The first category involves preventive measures against the augment of existing wastewaters. Interestingly, these systems are relatively inexpensive (if compared with other treatments) and can easily be put in place in virtually all possible food/beverage plants without size limitations [1]. Our attention is focused on the second group of treatments, also named ‘wastewater remediation’ systems. However, it should be considered that these treatments may be further subdivided in two different categories depending on the peculiar liquid which should be treated. In fact, waters in the food and beverage industries can be either reused in different sections or subsections of the same plant (before of the final exit to the external sewage) and eliminated as wastewater (this water is directed to publicly owned treatment works) [1]. For this basic reason, the destination of wastewaters defines the best treatment, depending also on the peculiar chemical–physical and biological features of the fluids before treatment.

By a general viewpoint, food wastewaters are the best type of contaminated water when speaking of industrial activities because of the low amount of toxic compounds normally related to the industry of metals or intermediate chemicals (petroleum, plastics, etc.) [1, 2]. However, these fluids have their ‘problems’ because of their high levels of selected contaminants (minerals, ammonia salts, fats, oils, sugars, starch, etc.). Because of their notable amount of organic matters, wastewaters are also classified on the basis of two different indexes: chemical oxygen demand (COD) and biochemical oxygen demand (BOD). These parameters can give an approximate but correct idea of the state of wastewaters in terms of general contamination. Consequently, input data for wastewaters are often expressed as BOD and COD values, and the same thing is true for output generated data (in terms of BOD and COD values for ‘remediated’ waters before treatment). The choice of the best remediation treatment should take into account COD and BOD values for the entering wastewater, the level of desired removal (in terms of gross removed matters), plant costs and the desired level of BOD and COD values (with pH, close to neutrality, and analytical results for minerals and other analytes) for exiting waters [1]. With relation to the desired amount of gross removed matters, there is a simple classification which subdivides all processes in three basic categories:

(1) Primary processes. These systems are basically the separation of suspended solids from wastewaters. The aim should be an effluent with notable organic matters and remarkable BOD values
(2) Secondary treatments. These procedures aim to reduce organic loads and the remaining suspended materials in wastewaters from primary processes. As a result, average BOD values should be relatively low for effluents (not more than 30 mg/l) and similar values should be obtained when speaking of suspended solids. In general, secondary processes are based on the biological activity and degradation of pollutants
(3) Tertiary processes. These systems, also defined 'advanced treatments', aim to enhance the chemical and biological quality of effluents to a high-standard values. In other terms, the objective is to obtain water effluents with BOD values and other parameters very low if compared with waters obtained by secondary processes only.

Anyhow, the easier classification of remediation techniques may be offered when speaking of the meaning of the peculiar removal operation. Consequently, remediation systems may be subdivided in [3, 4]:

(a) Physical removal (e.g. filtration). This is a primary process
(b) Chemical systems (e.g. oxidation, coagulation)
(c) Thermal procedures (e.g. oxidation, drying)
(d) Biological removal (e.g. biomass fermentation). Basically, these systems are 'secondary treatments'.

The main difference between biological systems and the other strategies (with the exclusion of separation/concentration, other technologies are substantially 'advanced' or 'tertiary' systems), is based on the degradation of contaminants by microorganisms in the first situation. Soluble and non-soluble pollutants and nutrients based on nitrogen and/or phosphorus are biologically degraded and converted in different and less hazardous compounds.

This chapter is dedicated to the description of physical–chemical wastewater remediation systems only. For this reason, biological procedures are not considered here, while physical–chemical techniques are discussed with the possibility of 'hybrid' solutions including biological treatments, if applicable.

2.2 Physical–Chemical Remediation Systems

The main technologies of wastewater remediation chemical systems in the food industry are generally listed as follows. The subsequent sections give a brief description of each system.

2.2.1 *Gravity Separation or Concentration*

Basically, these techniques aim to separate solid and semi-solid compounds and materials from wastewaters [1]. In general, this process can be performed by means of bar screens (screening system) and/or with the use of sedimentation basins (mechanical processes) [4]. The key is the density of pollutants (oils and grease are lighter than water; suspended solids are agglomerated on the bottom of basins). Chemical treatments may be also used. Anyway, the aim is to eliminate 50% or more of the total suspended solids [5], more than 60% of oils and grease, with the consequent reduction of BOD values after five testing days (also named BOD_5). Unfortunately, this treatment cannot remove colloidal and dissolved compounds, while nitrogen- and phosphorus-associated organic molecules and heavy metals can be notably reduced [5]. It should be noted that certain primary processes can be coupled with chemical and also biological treatments: in the last situation, the obtained sludge is digested anaerobically with methane production and recovery. Other solutions are also possible [5].

2.2.2 *Evaporation*

This process is a typical concentration process: it can be considered when speaking of wastewaters with inorganic salts in notable amounts. Basically, salts and other compounds including heavy metals are concentrated and recovered for other uses while distilled water is normally obtained with very good chemical and physical features, and consequently reusable. Different evaporation machines (mechanical equipment, evaporator ponds, with vertical or horizontal geometry or with forced circulation of fluids) can be used; costs may be high depending on the amount of treated fluids [1]. Anyway, these systems may require some maintenance and additional treatment systems because of possible defects (fouling is only one of possible examples).

2.2.3 Centrifugation

This separation process is useful when speaking of wastewaters with notable oil amounts and/or particle sizes under 5000 μm [1]. Basically, it is only a simple centrifugation process with different machines and costs (depending on the geometry and the amount of treated fluids). It has to be noted that wastewaters with particle sizes exceeding 5000 μm may be treated with this system on condition that high-sized bodies and compounds are previously separated.

In the sector of 'Fourth Range' (minimally processed) products various methods of water treatment systems are used in order to obtain less pollution: machinery is dealing with automatic spin dryer (such as cyclones), blowing washed and cascade washing systems.

2.2.4 Filtration and Flotation

Filtration, considered as a pre-treatment or a 'tertiary' process in certain situations, is performed by means of different filters (e.g. cartridges, membrane systems, generally used as a pre-treatment step or a final wastewater 'polishing' step before discharge. Several different types of filters exist, including granular-media, cartridge and pre-coated filters with diatomaceous earth). This system, very used in the food industry (e.g. filtration of brine solutions for cheeses), is useful on condition that particle sizes are >1 μm [1].

In some processes, such as in the production of Fourth Range foods, the intermediate processing system based on the utilisation of clean water could be treated following natural methods, like a filtration on natural sand beds. Using the equations of Darcy the flow speed and related time of transit of the fluids can be calculated in order to obtain water free from contaminants.

Another separation treatment uses the adherence of oils and grease to gas bubbles when pumped in wastewaters (dissolved or induced air flotation systems); superficial agglomerations may be eliminated by skimming [1].

2.2.5 Membrane Technologies

Actually, these systems are an emerging technology in the broader ambit of filtration treatments. Different membranes (materials: polymeric compounds such as polyamides, polycarbonates.) are used depending on the size of pollutants. In general, microfiltration is recommended if particle sizes are <10 mm (target compounds. colloidal compounds, microbial agglomerations). Ultrafiltration systems are recommended when particle sizes are <100 nm (the process is a simple diffusion method): obtained effluents are recovered, while concentrated substances are removed or incinerated [1]. Target molecules are usually colloids, proteins and different emulsions.

Should pollutant sizes be <10 nm, nanofiltration would be recommended. Naturally, this situation is expensive: with relation to wastewaters, the removal of antibiotic substances or the demineralisation of treated waters could be suggested. Finally, reverse osmosis is recommended only when particle sizes are <1 nm, and electrodialysis is used if pure water has to be obtained [1]. Naturally, exigencies of food and beverage industries cannot contemplate all these solutions.

References

1. Anonymous (1997) Wastewater reduction and recycling in food processing operations. State of the Art Report— Food Manufacturing Coalition for Innovation and Technology Transfer. R. J. Philips & Associates, Inc., Great Falls
2. Nini D, Gimenez-Mitsotakis P (1994) Creative solutions for bakery waste effluent. American Institute of Chemical Engineers. Symposium Series 300, 90:95–105
3. Henze M, van Loosdrecht MCM, Ekama GA, Brdjanovic D (eds) (2008) Biological wastewater treatment. Principles, modelling and design. The International Water Association (IWA) Publishing, London
4. Munter R (2000) Industrial wastewater treatment. In: Lundin LC (ed) Water use and management. Uppsala University, Uppsala
5. Pescod MD (1992) Wastewater treatment and use in agriculture—FAO Irrigation and Drainage Paper 95. Food and Agriculture Organization of the United Nations (FAO), Rome. Available http://www.fao.org/docrep/t0551e/t0551e00.htm. Accessed 29 Mar 2017

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