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Wastewater treatment and water reuse

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Abstract
To implement tariffs and regulations on sanitation and wastewater treatment, as well as for disposal or reuse of treated effluents, it is necessary to know the treatment technologies, which one would be best adapted to the present circumstances of any site and finally if the treated wastewater can be disposed of, legally or reused complying the rules and regulations, in a safe way.
Wastewater treatment has been evolving at different pace along the history, according to the increasing concentration of people in towns and cities. With the increasing pressures on water resources, concerns on how to find new resources capable to help reaching equilibrium within demand and offer arise. In this context, one of the main possibilities to cope with water scarcity is wastewater reclamation and reuse.
The main features of wastewater treatment and several of the characteristics of reclamation and reuse are developed in this chapter.

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Introduction

To understand wastewater management in present days is worth to describe how the problems associated with wastewater have been dealt with in the past centuries. This was done by Angelakis and Zheng [1]; which described wastewater management in the Bronze Age (*ca* 3200–1100 BC) in Crete, Aegean Islands and Indus Valley civilizations as the first known places were wastewater has received “technical” attention. The authors also explain that later in the Archaic (*ca* 750–480 BC) and Classical (*ca* 480–336 BC) Old Greek civilisation periods, historical sources and archaeology provide evidences that wastewater technologies existed and were widespread in the area.

Romans inherited Greek technologies and further developed them in its Empire. Afterwards, Islamic cultures on the periphery of Europe introduced religious mandates, through which personal hygiene and adequate sanitation systems were developed. Sometimes, the remnant old Greek and Roman facilities were used.

During millennia, untreated wastewater was discharged into water bodies, and alternatively was applied to fields to dispose of it or maintain soil fertility, thus obtaining vegetables with magnificent aspect. The application, with or without crops, remained active until well into the 20th century and is still practiced in countries under development or where water is scarce and health management is underdeveloped.

Along the “dark ages” wastewater management nearly disappeared in the west of Europe, but was maintained in other places of the world. In medieval times, wastewater in those European cities was disposed of by the citizens in the middle of the streets or retrieved using sewage carts and finally reached water bodies. Thus, bad odours and illnesses were present in crowded towns, prone to suffer epidemics, like the bubonic plague or typhoid fever, which decimated towns’ populations during the Middle Age.

Scientists observed finally that there was a real relationship among wastewater disposal and population health. Diseases were spread all along the river basins from upstream towns to the mouth. All the indicated boosted the implementation/recovery of sewerage systems and wastewater treatment plants in many parts of the world. By the end of the 19th century the present concept of sanitation started to be implemented. Later on, other types of wastewater were also treated, e.g. from industries.

The “classical” activated sludge treatment technique, secondary and biological, celebrated its centenary during 2014. This wastewater treatment technology became the treatment of reference all over the world from 1930 on. Right nowadays, activated sludge technology still has full success, but there are also several new technologies based on the activated sludge principle, like membrane bioreactors (MBR); and also other “hard” techniques have also found their niche in the market.

In parallel, the "soft" or extensive technologies, some of them older than the activated sludge, evolved from land application and from the simple lagoons, to the more sophisticated infiltration-percolation or wetland systems. Comparatively, soft technologies use a reduced amount of energy but a lot of space, and are gaining momentum in the small facilities for wastewater treatment. In this context, the relationship or nexus water-energy should be considered for both types of treatment.

There are two main purposes when treating wastewater. The first and most common is the sanitation of the main number possible of cities and towns, and the consequent need of safe disposal of the gathered wastewater into the environment after treatment, complying at the same time with the disposal regulations. In environmental terms, in most arid and semiarid areas the main amount of water flowing in a river could be treated wastewater, especially in the lower part of the basin.

The second purpose, wastewater reuse in its modern form, is a relatively new concept in many communities of the world, even though it has been practiced in an empiric way for more than 5000 years and is a *de facto* phenomenon in nature and along river basins throughout the world [2]. It can be indicated that reuse of treated/reclaimed wastewater as technology-based practice appeared during the 20th century, after the implementation of wastewater treatment at a big scale all over the developed world, and following also the increase of population living in cities. There are right now large amounts of treated wastewater available for reuse, which is expected to increase in the next future.

Rationale of the wastewater treatment processes: water line

Wastewater treatment systems tend to copy natural processes, biological, physical and chemical. The differences between facilities are based on the type of technology used and its intensity, as well as on the possible combinations of technologies. Then, quite all processes can be defined in terms of physico-chemistry, biochemistry (including microbiology) and speed of the process. The processes can also be classified in terms of the type of microbiological culture: suspended or fixed. Fixed technologies (i.e. the culture is growing over a solid material) are usually more efficient than suspended ones. The suspended technologies require more energy to maintain the contact between the microorganisms and the nutrients.

Extensive "soft" systems use biochemical reactions at a comparative low speed and the efficiency rate is usually improved by increasing the hydraulic residence time and occupying great surfaces. On the contrary, intensive systems reach high biochemical reaction speeds by forcing reactions with the addition of oxygen, reactive or applying agitation (mechanical or by air/oxygen under pressure), and one of its main advantages is a good relationship efficiency/space occupied.

Before deciding which technology should be implemented for a given site or use, it is necessary to know and compare the characteristics of all possible useful techniques (Table 1). The external needs (sewerage, pipelines…) are not indicated in the paper.

Apart from the secondary treatment technologies, there is usually a need for additional ones for disposal in sensible places (could be mandatory) or for reuse. Those are known as tertiary, advanced or reclamation technologies. Those technologies have the purpose to further reduce nutrients, suspended solids, microorganisms or other pollutants still present. The technologies used can be, like in secondary wastewater treatment, chemical, physical or biological (Tables 2 and 3) alone or in combination. It is to consider that the purpose of nutrient elimination is to finally dispose of legally treated wastewater complying with the regulations, and for reclamation is to guarantee that reclaimed water has enough quality to be safely and legally reused.

There are three main types of reclamation treatment considered:

a) Secondary treatments capable of obtaining water suitable for reuse
b) Tertiary treatments without disinfection, with an end-product allowing reuse
c) Full tertiary treatments, including pre-treatment for disinfection and disinfection;

In all cases, reclamation and reuse must follow the standards or recommendations issued at different administrative levels, but new preventive approaches are appearing, as indicated later on in this chapter, based on risk assessment.

When reusing reclaimed water, disinfection (Table 3) is basic since one of the main legal, compulsory limitations of this practice is the microbiological quality. The technologies previously employed (Table 2) are mainly used for preparing the water to be easily disinfected. For example, for using UV with good results is necessary to previously reduce turbidity/presence of suspended solids.

For disinfection, the main objective is to maximize the elimination of pathogens while creating a minimum amount of disinfection by-products. This can be also achieved by the combination of two technologies being usually the last one chlorination which allows that a