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Review

What have we learned from worldwide experiences on the management and treatment of hospital effluent? — An overview and a discussion on perspectives

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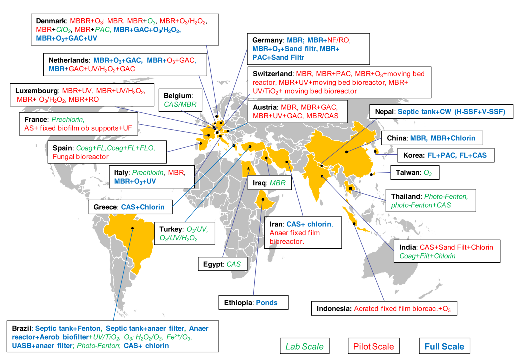
HIGHLIGHTS

- Different technologies for a dedicated treatment of hospital effluent are discussed.
- Photo-Fenton process seems to be a promising preliminary treatment. Membrane bioreactor is a proper secondary treatment for hospital effluent.
- AOPs showed a good removal efficiency for most classes of pharmaceuticals.
- UV irradiation is a promising technology in the removal of X-ray contrast media.

GRAPHICAL ABSTRACT



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ABSTRACT

This study overviews lessons learned from experimental investigations on dedicated treatment systems of hospital effluent carried out worldwide in the last twenty years. It includes 48 peer reviewed papers from 1995 to 2015 assessing the efficacy of different treatment levels (preliminary, primary, secondary and polishing) of hospital wastewater in removing a wide spectrum of pharmaceutical compounds as well as conventional contaminants. Moreover, it highlights the rationale and the reasons for each study: reducing the discharge of micropollutants in surface water, improving existing wastewater treatment technologies and reducing the risk of spread of pathogens causing endemic diseases and finally, it offers a critical analysis of the conclusions and

Abbreviations: AOP, advanced oxidation process; AOXs, adsorbable organic compounds; ARB, antibiotic resistant bacteria; ARG, antibiotic resistant genes; AS, activated sludge; BAT, best available technology; CAS, conventional activated sludge; Chlorin, chlorination; Coag, coagulation; CPCs, cancerogenic platinum compounds; CWs, constructed wetlands; D617, N-dealkylverapamil; D_{ow}, octanol water distribution coefficient; DNA, deoxyribonucleic acid; DO, dissolved oxygen; DOC, dissolved organic carbon; EE2, ethinyl estradiol or 17-α ethinyl estradiol; EQS, environmental quality standard; FL, flocculation; FLO, flotation; GAC, granular activated carbon; HDPE, high density polyethylene; HRT, hydraulic retention time; H-SSF, horizontal subsurface flow; HWW, hospital wastewater; ICM, iodinated contrast media; K_a, dissociation constant; k_{biol}, biological degradation rate; K_{ow}, octanol water partition coefficient; LP, low pressure; MBBR, moving bed biofilm reactor; MBR, membrane biological reactor; MCWO, molecular weight cut off; MP, medium pressure; NF, nanofiltration; O&M, maintenance and operation; PAC, powdered activated carbon; PhC, pharmaceutical compound; RO, reverse osmosis; SARS, severe acute respiratory syndrome; SRT, sludge retention time; T, temperature; TDS, total dissolved solids; TOC, total organic carbon; TSS, total suspended solids; UASB, upflow anaerobic sludge blanket; UF, ultrafiltration; UV, ultraviolet; UWW, urban wastewater; v_f, filtration velocity; V-SSF, vertical subsurface flow; WWTP, wastewater treatment plant.

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suggestions of each study. The most investigated technologies are membrane bioreactors equipped with ultrafiltration membranes in the secondary step, ozonation followed by activated carbon filtration (in powder and in granules) in the polishing step. Interesting research projects deal with photo-Fenton processes acting as primary treatments to enhance biodegradation before biological treatment, and as a polishing step, thus further reducing micro-contaminant occurrence. Investment and operational costs are also presented and discussed for the different treatment technologies tested worldwide, in particular membrane bioreactors and various advanced oxidation processes.

This study also discusses the need for further research to evaluate toxicity resulting from advanced oxidation processes as well as the need to develop an accurate feasibility study that encompasses technical, ecotoxicological and economic aspects to identify the best available treatment in the different situations from a global view point.

Contents

1. Introduction

In recent years, hospital effluent has been the object of study and research in various countries throughout the world facing different issues. The specific driving and inspiring force has been to improve the knowledge of the chemical and physical characterization of such wastewater for conventional parameters, namely BOD_5, COD, TSS, N and P compounds, pH and T (Sarafraz et al., 2007; Verlicchi et al., 2012a); the microbiological load of hospital effluent and also the risk of the spread of antibiotic resistant bacteria (Boillot et al., 2008; Chitnis et al., 2004); differences in composition between hospital effluent and urban wastewater (UWW) (Verlicchi et al., 2010); seasonal variation of hospital effluent compositions (Verlicchi et al., 2012a, 2012c); strategies in their management (co-treatment or dedicated treatment with UWW) (Pauwels and Verstraete, 2006; Verlicchi et al., 2010); evaluation of the adequacy of adopted treatment strategies with respect to the removal of specific contaminants (Mesdaghinia et al., 2009; Beier et al., 2010); technical and economic feasibility of dedicated treatment trains for hospital wastewater (HWW) (PILLS Report, 2012); and contribution of hospital effluent to the influent of a municipal wastewater treatment plant (WWTP) (Verlicchi et al., 2012a; Santos et al., 2013).

On occasion, the occurrence of disease outbreaks due to pathogens occurring in sewage, such as SARS (severe acute respiratory syndrome) in China in 2003, has led scientists to develop specific research projects to identify safety measures to rapidly adopt in existing WWTPs, in particular in plants receiving hospital effluent, not only to deal with the current emergency, but also to prevent further ones (Wang et al., 2005).

Quite rarely, national (or regional) legal regulations have been established to define how to manage and treat hospital effluent before its disposal (discharge in public sewage for treatment at a municipal WWTP or discharge into a surface water body) (Boillot et al., 2008; Verlicchi et al., 2010). Indeed, hospital effluent was and (still) is generally considered of the same pollutant nature as UWW and thus it is commonly discharged in public sewage systems, conveyed to an urban WWTP where it is subjected to conventional treatment, often consisting in primary clarification, activated sludge process and sometimes disinfection. This practice is very common although recent studies (Verlicchi et al., 2010; Santos et al., 2013; McArdell et al., 2011) highlighted that higher concentrations of pharmaceuticals (PhCs), disinfectants and X-ray contrast media occur in hospital effluent as well as a microbiological load exhibiting a higher resistance to treatment (Chitnis et al., 2004).