Water Research 87 (2015) 237–270

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Review

Spoilt for choice: A critical review on the chemical and biological assessment of current wastewater treatment technologies

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ARTICLE INFO

Article history:
Received 2 June 2015
Received in revised form
2 September 2015
Accepted 11 September 2015
Available online 14 September 2015

Keywords:
Wastewater quality assessment
Conventional and advanced treatment
Sewage
Environmental chemistry
Ecotoxicology
Toxicity

ABSTRACT

The knowledge we have gained in recent years on the presence and effects of compounds discharged by wastewater treatment plants (WWTPs) brings us to a point where we must question the appropriateness of current water quality evaluation methodologies. An increasing number of anthropogenic chemicals is detected in treated wastewater and there is increasing evidence of adverse environmental effects related to WWTP discharges. It has thus become clear that new strategies are needed to assess overall quality of conventional and advanced treated wastewaters. There is an urgent need for multidisciplinary approaches combining expertise from engineering, analytical and environmental chemistry, (eco)toxicology, and microbiology. This review summarizes the current approaches used to assess treated wastewater quality from the chemical and ecotoxicological perspective. Discussed chemical approaches include target, non-target and suspect analysis, sum parameters, identification and monitoring of transformation products, computational modeling as well as effect directed analysis and toxicity identification evaluation. The discussed ecotoxicological methodologies encompass *in vitro* testing (cytotoxicity, genotoxicity, mutagenicity, endocrine disruption, adaptive stress response activation, toxicogenomics) and *in vivo* tests (single and multi species, biomonitoring). We critically discuss the benefits and limitations of the different methodologies reviewed. Additionally, we provide an overview of the current state of research regarding the chemical and ecotoxicological evaluation of conventional as well as the most widely used advanced wastewater treatment technologies, *i.e.*, ozonation, advanced oxidation processes, chlorination, activated carbon, and membrane filtration. In particular, possible directions for future research activities in this area are provided.

Contents

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http://dx.doi.org/10.1016/j.watres.2015.09.023
0043-1354/

1. Introduction

The access to clean and safe water has become one of the major challenges of our modern society, due to the growing imbalance between freshwater availability and consumption (Jackson et al., 2001). Water scarcity often results from the increasing use for agricultural irrigation, industry, and domestic purposes (Jackson et al., 2001). Additionally, the quality of freshwater is threatened by a large number of pathogens (Rizzo et al., 2013) as well as anthropogenic chemicals entering the urban and rural water cycle (Schwarzenbach et al., 2006). Discharges from municipal and industrial wastewater treatment plants (WWTPs) have been identified as one of the major sources of aquatic pollution in industrialized countries (Reemtsma et al., 2006). Considering the predicted growth rate of the global population and constantly increasing number of people that are connected to WWTPs, the amount of treated wastewater (WW) is likely to increase in the future. Water shortages currently necessitate indirect non-potable and even potable reuse of treated WW. Advances in WWTP technologies are crucial to limit the burden of WW-originated contaminants, due to the importance of WWTPs as point sources for microbial and chemical contaminants entering surface waters. To date, one of the main challenges is to appropriately evaluate the different treatment technologies regarding their potential to minimize the toxicological risks for both, biota and human health.

In the past, advances in WW treatment in high-income countries have strongly improved the quality of wastewater discharged into the aquatic environment as well as minimized wastewater