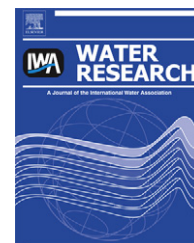


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Review

Fate of antibiotics during municipal water recycling treatment processes

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ABSTRACT

Municipal water recycling processes are potential human and environmental exposure routes for low concentrations of persistent antibiotics. While the implications of such exposure scenarios are unknown, concerns have been raised regarding the possibility that continuous discharge of antibiotics to the environment may facilitate the development or proliferation of resistant strains of bacteria. As potable and non-potable water recycling schemes are continuously developed, it is imperative to improve our understanding of the fate of antibiotics during conventional and advanced wastewater treatment processes leading to high-quality water reclamation. This review collates existing knowledge with the aim of providing new insight to the influence of a wide range of treatment processes to the ultimate fate of antibiotics during conventional and advanced wastewater treatment. Although conventional biological wastewater treatment processes are effective for the removal of some antibiotics, many have been reported to occur at 10–1000 ng L⁻¹ concentrations in secondary treated effluents. These include β -lactams, sulfonamides, trimethoprim, macrolides, fluoroquinolones, and tetracyclines. Tertiary and advanced treatment processes may be required to fully manage environmental and human exposure to these contaminants in water recycling schemes. The effectiveness of a range of processes including tertiary media filtration, ozonation, chlorination, UV irradiation, activated carbon adsorption, and NF/RO filtration has been reviewed and, where possible, semi-quantitative estimations of antibiotics removals have been provided.

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1. Introduction

Municipal water recycling for industrial, agricultural, and non-potable municipal uses is an increasingly important component of water resources management practices in many parts of the world (Exall, 2004; Vigneswaran and Sundaravadivel, 2004; Wintgens et al., 2005). In some countries, such as the USA, Singapore, Mexico and Belgium, treated effluents are intentionally used to supplement drinking water supplies, a process known as planned indirect potable reuse (planned IPR) (Drewes and Khan, 2010; Rodriguez et al., 2009). Planned IPR is rapidly emerging as an important water supply strategy for a number of Australian cities (Khan, 2009). In Windhoek, Namibia, direct potable reuse of highly treated effluents for drinking water supply has been practiced since 1969 (du Pisani, 2006) and it is possible that other countries may adopt this strategy in the future.

Pharmaceuticals including antibiotics are present in municipal sewage, largely as a result of human excretion. Many active antibiotics are not completely metabolised during therapeutic use and thus enter sewage through excretion in an unchanged form (Hirsch et al., 1999). The intentional disposal of unused drugs into the sewer (Kummerer, 2003) and veterinary use (Diaz-Cruz et al., 2003) also contribute to the quantities of antibiotics found in sewage. Discharges from veterinary clinics and runoff from agricultural applications into municipal sewers are also potential sources of veterinary antibiotics in wastewater. The reported levels of specific antibiotic drugs detected in raw sewage appear to differ between countries, possibly reflecting variable prescription practices (Miao et al., 2004) and differences in per-capita water consumption leading to various degrees of dilution (Drewes et al., 2008). Seasonal variations in sewage concentrations of antibiotics have also been reported (Alder et al., 2006).

Antibiotic drugs have been identified as a particular category of trace chemical contaminants, which warrant close scrutiny (Watkinson et al., 2007). Much of the concern regarding the presence of antibiotics in wastewater and their

persistence through wastewater treatment processes is related to concerns that they may contribute to the prevalence of resistance to antibiotics in bacterial species in wastewater effluents and surface water near wastewater treatment plants (WWTPs) (Adelowo et al., 2008; Auerbach et al., 2007; Baquero et al., 2008; Jury et al., in press). Reusing treated effluents for non-potable or potable purposes increases the range of human and environmental exposure scenarios for bacteria potentially harbouring antibiotics resistance. Accordingly, a thorough understanding of the effectiveness of treatment processes employed in water recycling schemes is warranted.

2. Analytical methods for determining antibiotics in wastewater

Many antibiotics are non-volatile with high molecular weight, which tends to render them more suited to analysis by liquid chromatography (LC) rather than gas chromatography (GC) (Choi et al., 2007a). The determination of antibiotic residues by LC with spectrophotometric detection has been reported including fluorescence and ultraviolet (UV) absorbance (Choi et al., 2007a; Esponda et al., 2009; Golet et al., 2002b; Jen et al., 1998; Li et al., 2007; Peng et al., 2008). However, a survey of literature by Hernández et al. (2007) revealed the impressive progress and focus on method development using liquid chromatography-mass spectrometry (LC-MS) and particularly liquid chromatography-tandem mass spectrometry (LC-MS/MS) to determine antibiotics in complex matrices such as municipal wastewater. This review also summarised the important factors affecting the analyses of different classes of antibiotics, such as pH adjustment, sample container materials, storage conditions, the addition of chelating agents, solvent types and matrix interference.

Sample extraction for both clean-up and enrichment is commonly undertaken with typical concentration factors in the range 100–1000 required for the necessary low limits of detection (LOD). Although a variety of techniques have been

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