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Review

Emerging contaminants of public health significance as water quality indicator compounds in the urban water cycle

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ABSTRACT

The contamination of the urban water cycle (UWC) with a wide array of emerging organic compounds (EOCs) increases with urbanization and population density. To produce drinking water from the UWC requires close examination of their sources, occurrence, pathways, and health effects and the efficacy of wastewater treatment and natural attenuation processes that may occur in surface water bodies and groundwater. This paper researches in details the structure of the UWC and investigates the routes by which the water cycle is increasingly contaminated with compounds generated from various anthropogenic activities. Along with a thorough survey of chemicals representing compound classes such as hormones, antibiotics, surfactants, endocrine disruptors, human and veterinary pharmaceuticals, X-ray contrast media, pesticides and metabolites, disinfection-by-products, algal toxins and taste-and-odor compounds, this paper provides a comprehensive and holistic review of the occurrence, fate, transport and potential health impact of the emerging organic contaminants of the UWC. This study also illustrates the widespread distribution of the emerging organic contaminants in the different aortas of the ecosystem and focuses on future research needs.

Contents

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1. Introduction

The most significant factors affecting the availability and distribution of water in urban settings are population growth and the migration of rural populations to urban areas, resulting in urban sprawl and the rapidly growing number of mega-cities. Urbanization presents a host of technical, ecological and social challenges, most critical ones being supplying fresh water to cities and disposing wastewater without jeopardizing water resources and the environment. Traditionally, fresh water has been extracted from local surface water or groundwater or imported from distant watersheds, and wastewater has been discharged to downstream surface water bodies or the ocean. However, with growing competition among cities for water resources, importing water from distant watershed has ceased being an option in most cases. As a consequence, water planners are forced to develop new supplies from impaired sources, such as wastewater effluent, effluent bearing rivers, brackish estuaries, and stormwater runoff. Implementing water recovery schemes created the UWC (Fig. 1) in which used water is reused directly after advanced treatment or indirectly after discharge to local surface water bodies or groundwater aquifers and cycling the treated water back into the water supply.

While water quality investigations have traditionally focused on nutrients, bacteria, heavy metals and priority pollutants (compounds with known health effects such as pesticides, industrial chemicals, petroleum hydrocarbons) recent research has revealed the occurrence of hundreds of organic contaminants in wastewater and impacted urban surface waters. These novel contaminants belong to diverse compound classes and are typically detected at concentrations in the range 1 ng/L–1 μg/L although concentrations range up to 100 μg/L in some cases. Their toxicological significance is difficult to assess and generally accepted concentration limits for drinking water and discharge limits for wastewater effluent have not yet been established. Collectively, these compounds are referred to as "Emerging Organic Contaminants" (EOCs). Representative compound classes include hormones, antibiotics, surfactants, endocrine disruptors, human and veterinary pharmaceuticals, X-ray contrast media, pesticides and metabolites, disinfection-by-products, algal toxins and taste-and-odor compounds (Richardson, 2003; Shannon et al., 2008). EOCs comprise recently developed industrial compounds that have been newly introduced to the environment; compounds that have been prevalent for some time but are only now being routinely detected owing to improved detection techniques; and compounds that have been prevalent for a long time but have only recently been shown to have harmful eco-toxicological effects (Houtman, 2010).

Environmental contamination of EOCs has been reviewed from several perspectives, including developments in analytical techniques (Dirtu et al., 2012; Farré et al., 2012; Lepom et al., 2009; Richardson, 2012), occurrence of EOCs in surface waters (Houtman, 2010; Pal et al., 2010; Schriks et al., 2010; Thomaidis et al., 2012), ground water (Jurado et al., 2012; Lapworth et al., 2012), sludge (Clarke and Smith, 2011; Tadeo et al., 2012) and drinking water (Delgado et al., 2012a; Delgado et al., 2012b; Houtman, 2010; Post et al., 2012), and (eco)

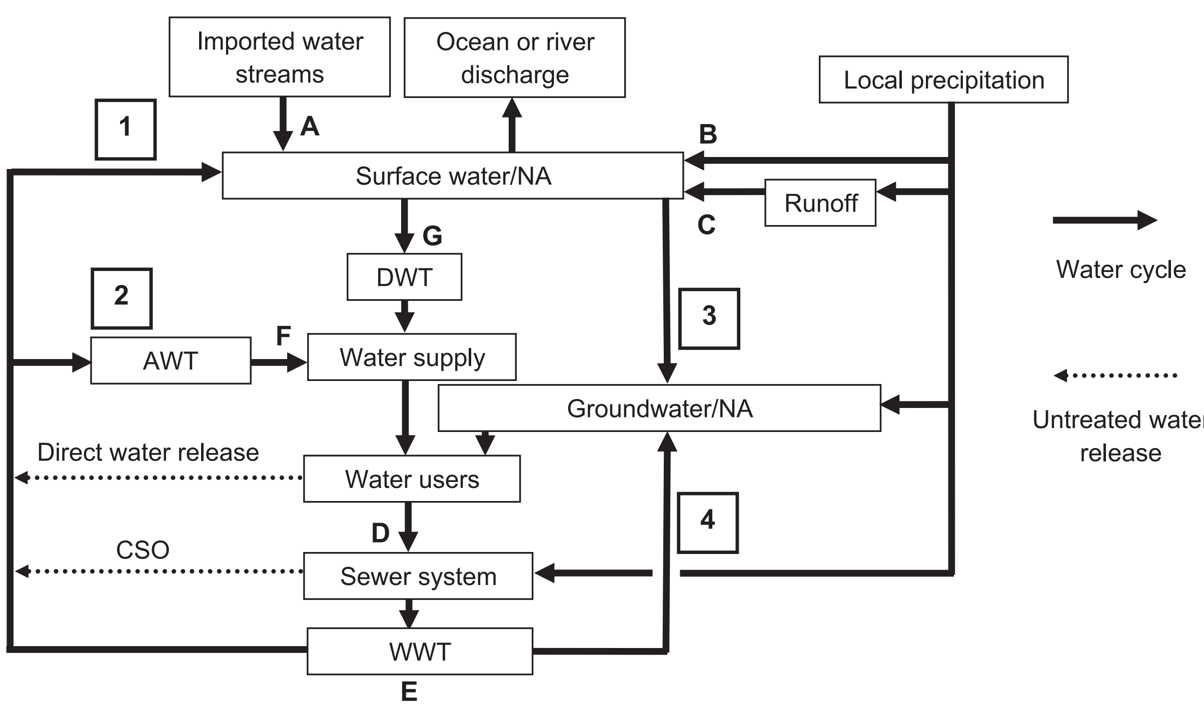

Fig. 1. Schematic of generic urban water cycle: (1) indirect reuse via surface water; (2) direct reuse by advanced wastewater treatment (AWT); (3) recharge of effluent bearing river water (bank-filtration); (4) artificial recharge of aquifers with effluent, referred to as soil-aquifer treatment (SAT). A–F: Entry points of EOCs: A: upstream effluent discharge; B: wet (rainwater) and dry deposition; C: runoff; D: wastewater discharge from sources including domestic, industrial and hospitals, clinics and medical centers; E: treated effluent; F: disinfection by-products produced during AWT; G: *in situ* produced algal toxins and taste and odor compounds.