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Review

Occurrence and fate of bulk organic matter and pharmaceutically active compounds in managed aquifer recharge: A review

Sung Kyu Maeng [a,*], Saroj K. Sharma [b], Karin Lekkerkerker-Teunissen [c,d], Gary L. Amy [e]

[a] Water Environment Center, Korea Institute of Science and Technology, P.O. Box. 131, Cheongryang, Seoul 130-650, South Korea
[b] UNESCO-IHE Institute for Water Education, P.O. Box 3015, 2601 DA Delft, The Netherlands
[c] Technical University of Delft, Stevinweg 1, 2628 CN Delft, The Netherlands
[d] Dunea, P.O. Box 34, 2270 AA, Voorburg, The Netherlands
[e] King Abdullah University of Science and Technology, Thuwal 23955-6000, Saudi Arabia

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ABSTRACT

Managed aquifer recharge (MAR) is a natural water treatment process that induces surface water to flow in response to a hydraulic gradient through soil/sediment and into a vertical or horizontal well. It is a relatively cost-effective, robust and sustainable technology. Detailed characteristics of bulk organic matter and the occurrence and fate of pharmaceutically active compounds (PhACs) during MAR processes such as bank filtration (BF) and artificial recharge (AR) were reviewed. Understanding the fate of bulk organic matter during BF and AR is an essential step in determining pre- and/or post-treatment requirements. Analysis of organic matter characteristics using a suite of analytical tools suggests that there is a preferential removal of non-humic substances during MAR. Different classes of PhACs were found to behave differently during BF and AR. Antibiotics, non-steroidal anti-inflammatory drugs (NSAIDs), beta blockers, and steroid hormones generally exhibited good removal efficiencies, especially for compounds having hydrophobic-neutral characteristics. However, anticonvulsants showed a persistent behavior during soil passage. There were also some redox-dependent PhACs. For example, X-ray contrast agents measured, as adsorbable organic iodine (AOI), and sulfamethoxazole (an antibiotic) degraded more favorably under anoxic conditions compared to oxic conditions. Phenazone-type pharmaceuticals (NSAIDs) exhibited better removal under oxic conditions. The redox transition from oxic to anoxic conditions during soil passage can enhance the removal of PhACs that are sensitive to redox conditions. In general, BF and AR can be included in a multi-barrier treatment system for the removal of PhACs.

Contents

* *Corresponding author*. Tel.: +82 2 958 6769; fax: +82 2 958 6854.
E-mail address: smaeng@kist.re.kr (S.K. Maeng).
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1. Introduction

Bulk organic matter in natural waters mainly consists of natural organic matter (NOM), derived from allochthonous and autochthonous sources. NOM does not pose a direct health threat to humans with respect to drinking water quality, but it is a precursor of organic disinfection by-products (DBP) (Siddiqui et al., 2000; Lu et al., 2009). In wastewater effluent–impacted (or wastewater effluent–dominated) surface waters, bulk organic matter is a mixture of NOM and effluent organic matter (EfOM), which originates from wastewater treatment plants. While EfOM has not been studied as extensively as NOM has, EfOM is composed of different types of organics: refractory compounds, residual degradable substrates, intermediates, complex organic compounds, and soluble microbial products (SMPs) (Barker and Stuckey, 1999). SMPs are biodegradable organic matter produced from substrate metabolism and biomass decay, and they are known as major foulants for reverse osmosis (RO), nanofiltration (NF), and ultrafiltration (UF) membranes (Jarusutthirak and Amy, 2006). Moreover, SMPs are precursor materials of nitrogenous disinfection by-products (N-DBPs) and can lead to bacterial regrowth in drinking water distribution systems (Amy and Drewes, 2007).

EfOM also consists of emerging contaminants such as pharmaceutically active compounds (PhACs), endocrine disrupting compounds (EDCs), and personal care products (PCPs). PhACs and transformation products enter surface water primarily through discharged effluent from wastewater treatment plants resulting from patient excretion in both urine and feces (Cunningham et al., 2006; Zhou et al., 2009). Previous studies conducted by Kasprzyk-Hordern et al. (2009) and Zhou et al. (2009) demonstrated the impact of wastewater effluent containing organic micropollutants (e.g., PhACs) on the quality of receiving waters. Non-point sources, such as overland flow (i.e., runoff) during rainfall or land drainage in agricultural areas, also deliver PhACs (e.g., veterinary medicines) to surface water or groundwater (Boxall et al., 2004). These situations create the possibility for the occurrence of organic micropollutants such as PhACs, PCPs, and EDCs in drinking water sources.

Currently, the total consumption of PhACs and PCPs in the world is not known because many of these compounds significantly vary with respect to application and consumption from one country to another (Cunningham, 2004). Many of them are slightly transformed or unchanged during municipal wastewater treatment (Chefetz et al., 2008). Moreover, the growing use of PhACs, EDCs, and PCPs for human and veterinary purposes has contributed to their frequent detection in the aquatic environment and in wastewater (Heberer, 2002; Tixier et al., 2003; Jjemba, 2006). Growing concern over the safety of drinking water containing PhACs, EDCs and PCPs has resulted in increased research worldwide (Mechlinski and Heberer, 2005; Kim et al., 2007; Kümmerer, 2009; Madden et al., 2009; Mompelat et al., 2009). Many water utilities in developed countries are adopting advanced water treatment processes to provide a reliable supply of safe drinking water. However, little is known about the fate of transformation products formed in drinking water treatment processes such as advanced oxidation processes (AOPs) and biodegradation (Mompelat et al., 2009).

Snyder et al. (2007) evaluated the removal of EDCs and PhACs in 13 full-scale water treatment facilities. Conventional coagulation, flocculation, and sedimentation processes were ineffective at removing most of the target EDCs and PCPs. Slow sand filtration and flocculation by iron (III) chloride were also ineffective for selected pharmaceuticals (bezafibrate, clofibric acid, carbamazepine, and diclofenac) (Ternes et al.,