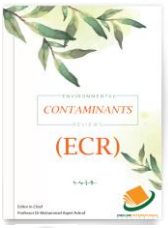
ZIBELINE INTERNATIONAL PUBLISHING

Environmental Contaminants Reviews (ECR)

DOI : http://doi.org/10.26480/ecr.01.2018.01.12



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REVIEW ARTICLE

STUDY OF FATE AND TRANSPORT OF EMERGENT CONTAMINANTS AT WASTE WATER TREATMENT PLANT

Mesmire Wilson, Muhammad Aqeel Ashraf

Department of Environmental Science & Engineering, School of Environmental Studies, China University of Geosciences 430074 Wuhan, China
Corresponding Author Email: chemageel@gmail.com

ARTICLE DETAILS

Article History:

Received 13 November 2017
Accepted 16 December 2017
Available online 01 January 2018

ABSTRACT

Contaminants of emerging concern such as pharmaceuticals, personal care products, bacteria, viruses, and pesticides are frequently found in waste water, groundwater, and surface waters. The search to find the sources of these compounds has routinely led to wastewater treatment plants (WWTPs) as an entry point of contaminants into the natural environment. The unknown effects of low concentrations of emerging contaminants in the aquatic ecosystem require scientists to study the occurrence, sources, fate, and transport of these compounds in wastewater treatment, to better understand and possibly identify mitigation opportunities. Reducing the contaminant levels in WWTP effluent helps minimize the contamination in lakes and rivers, which are both WWTP receiving waters as well as drinking water sources. Emerging contaminants end up in wastewater through several pathways including the disposal and use of consumer products, farm runoff, toxic spills, and excretion via the urine and feces of those consuming pharmaceuticals. The human body only metabolizes a percentage of each drug taken, expelling the rest into the municipal wastewater system. Another source is from consumer products such as soap, shampoo, disinfectant washes, and toothpaste which contain biologically active compounds that, when used, release these contaminants into the sewer system where they are then transported to a wastewater treatment plant (WWTP). Municipal wastewater treatment plants are not specifically designed to deal with the trace levels of emerging contaminates found in wastewater and many compounds pass through conventional treatment systems without removal. From the WWTP effluent, emerging contaminants are discharged into surface waters where they may have measurable effects on aquatic life at low concentrations. Once in surface waters, pharmaceuticals have been shown to interrupt the natural biochemistry of many aquatic organisms including fish and algae. Many of the problems associated with the removal of emerging contaminants from municipal wastewater stem from their low concentrations and chemical diversity, which make detection and analysis difficult. Low concentrations require extremely sensitive analytical equipment while the wide range of distinct chemical compounds necessitates techniques to identify many chemicals at once. Only recently have scientists become aware of the presence of some emerging contaminants in wastewater because analytical techniques able to detect them at the ng/l have only recently been developed. As laboratory procedures are developed and emerging contaminants can be accurately quantified, scientists are becoming increasingly able investigate the sources, removal pathways, and fate of pharmaceuticals in municipal wastewater. In addition to emerging contaminants, the potential entrance of prions into the wastewater system and their fate in wastewater treatment is an area of concern and a topic of interest in this study. A sampling program will implement to monitor the sources and fate of emerging contaminants in municipal wastewater treatment system. Laboratories will test for twelve different classes of emerging contaminants ranging from pharmaceuticals to flame-retardants. Hospitals, funeral homes, slaughterhouses and residential neighborhoods will monitor to determine possible point sources of contaminants into municipal sewer systems. Multiple locations within each wastewater treatment plant will monitor to trace the fate of each emerging contaminant class through the wastewater treatment process in an attempt to understand the fate removal pathways of each contaminant.

KEYWORDS

Contaminants, waste water, treatment plant, natural environment.

1. BACKGROUND

Emerging contaminants (ECs) such as pharmaceuticals, endocrine disruptors, pesticides, x-ray contrast media, and personal care products have been found in wastewater, groundwater, and surface waters [1-2]. These compounds can enter the environment through leaky sewers and septic systems, which can allow contaminants to infiltrate into the groundwater, and pass through wastewater treatment plants to discharge contaminants into receiving waters. The fate and concentrations of many EC's in the environment are mostly unknown, making the design of treatment strategies difficult. One class of EC attracting particular attention is known as endocrine disrupting compounds (EDCs). These natural or synthetic compounds mimic biological hormones disrupting an organism's natural processes. EDCs have been shown to be biologically active down to concentrations as low as the ng/L level and have been linked to significant change in wildlife including the feminization of fish [3-4]. Pharmaceuticals and personal care products (PPCPs) are another group of emerging contaminants gaining recent attention. These include x-ray media, analgesics, antiseptics, antibiotics etc. This class of contaminants often contains polar functional groups making the detection and removal process more difficult.

1.1 Personal Care Products

Personal Care Products are a class of chemicals found in wide ranging consumer products from toothpaste to soap, to kitchen utensils. They are

generally used for their antimicrobial and antifungal properties. In this study, wastewater samples were analyzed for triclosan (TCS) and triclocarban (TCC) concentrations. TCS and TCC are both anti-bacterial and anti-fungal agents commonly used in consumer products such as soaps, disinfectants, toothpastes, body washes, and medical disinfectant of which these products contain between 0.1% and 2% of TCS or TCC by 15 weight [5]. Approximately 96% of the triclosan is used in consumer goods, which are disposed of to the sewer system [6]. They have both been used since the 1970's and have been detected in wastewater treatment plant effluent and surface waters [7-8]. TSC and TCC interact with bacteria by binding to the enoyl-acyl carrier protein reductase enzyme (ENR) found in their cell membrane inhibiting fatty acid synthesis [9]. Bacteria need these fatty acids to build new cell membranes and without them they do not have enough material to build new cells and thus cannot reproduce. The following table outlines some triclosan and triclocarban concentrations found in other wastewater treatment plants.

Table 1: Selected Literature Concentration Values for Personal Care Products in WWT

Compound	Influent ng/L	Effluent ng/L	Removal efficiency	Location	Source	Treatment Type
Triclosan	1900	114	94%	Ontario	Lishmen et al.,2006	Activated Sludge Process
Triclosan	5200	260	95%	Columbus, Ohio	McAVoy et al., 2002	Activated Sludge Process
Triclosan	2500	625	75%	United Kingdom	Thompson et al., 2005	Rotating Biological Contactor as Secondary
Triclocarban	6100	170	97%	-	Heidler at el, 2007	-

The above papers report removal efficiency of 75 to 97% and suggest that an activated sludge process may remove more triclosan than a rotating biological contactor process though detailed comparisons are not possible without detailed operating conditions.

1.2 Antidepressants

Antidepressants are a class of pharmaceuticals that affect neurotransmitters, the chemicals that nerves within the brain use to communicate with each other. Examples of neurotransmitters include serotonin, dopamine and norepinephrine. Antidepressants are believed to work by inhibiting the release or affecting the action of neurotransmitters. The antidepressant compounds in this study are venlafaxine, O-desmethylvenlafaxine, citalopram, and desmethylcitalopram. Venlafaxine is a serotonin-norepinephrine reuptake inhibitor (SNRI) prescribed for the treatment of depression, depression with associated symptoms of anxiety, generalized anxiety disorder, social anxiety disorder and adult panic disorder. O-desmethylvenlafaxine, a major active metabolite of venlafaxine, also functions as an SNRI. It is also synthetically produced (desvenlafaxine) and was approved by Health Canada in 2009 for treatment of depression. Citalopram is a selective serotonin reuptake inhibitor (SSRI) prescribed for the management of depression as well as treating obsessive-compulsive disorder, panic disorder, premenstrual dysphoric disorder, anxiety disorder and posttraumatic stress disorder. Desmethylcitalopram, an active metabolite of citalopram, also functions as an SSRI. The following table outlines the concentrations of Citalopram and Venlafaxine found in other wastewater treatment plants.

Table 2: Selected Literature Concentration Values for Antidepressants

Compound	Influent ng/L	Effluent ng/L	Removal efficiency	Location	Source	Treatment Type
Citalopram	52	46	11%	Montreal, Canada	Lajeunesse et al.,2008	Primary Treatment Only
Venlafaxine	195	175	10%	Montreal, Canada	Lajeunesse et al.,2008	Primary Treatment Only
Venlafaxine	540	300	44%	Spain	Gracia-Lor et al., 2005	Not Specified

The removal rate for the wastewater treatment plant in Montreal, Canada was reported as 10 to 12% [10]. This low removal efficiency suggests that antidepressants are difficult to remove, however, the wastewater treatment plant in Montreal, Canada is only equipped with primary treatment and municipalities with secondary or tertiary treatment would likely expect a higher removal efficiency. The researcher does not specify the treatment type used in their study [11].

1.3 Pharmaceutical (Acid/Basic/Natural)

Pharmaceuticals can be divided up into acidic, basic, or neutral compounds and can be used to treat pain, inflammation and a variety of other conditions. They range in prevalence from Naproxen, which is a prescription drug, to caffeine, which is found in coffee, tea, and chocolate among other goods. The following table outlines examples of the WWTP concentrations found in literature for some of the compounds in this study.