

To:  
City of Raleigh  
Eileen Navarrete

Copies:  
Tom Tant, P.E.

Hazen and Sawyer,  
P.C.  
4011 WestChase Blvd.  
Raleigh, NC 27607  
919-833-7152  
Fax: 919-833-1828

From:  
Ben Stanford, PhD

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Subject:  
Interpretation of the US EPA National Municipal Effluent CEC Survey  
Pertaining to the Neuse River Wastewater Treatment Plant

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## 1. Overview

In 2011 the City of Raleigh volunteered to participate in a study conducted by the US EPA to examine the presence of trace wastewater constituents, often referred to as contaminants of emerging concern (CECs), collected from the effluents of 50 wastewater treatment plants across the US. The City of Raleigh's Neuse River Wastewater Treatment Plant, a tertiary treatment facility with full biological nutrient removal, was included as one of the facilities in the national survey with samples collected in early 2011. Data from the study were recently provided to the City by the US EPA. This document provides an overview and discussion of the data.

Of the 63 reported pharmaceutical and personal care product CECs (including duplicate measurements), only 17 were detected in Raleigh's wastewater effluent; Of the 43 reported steroid hormones, surfactants, and surfactant degradation products reported, only 3 were detected in the effluent. The data, summarized later in this report, are consistent with the concentrations of CECs in tertiary wastewater effluents observed in this and other studies from across the US and around the world. In nearly all cases, the data for the City of Raleigh are at or below the average concentration observed in the EPA occurrence study. Furthermore, 10 of the contaminants found in Raleigh's wastewater were found at concentrations well below published human health-based guideline values (based on the Australian drinking water guidelines or "DWGs" (EPHC et al, 2008)); the remaining contaminants were not included in the published DWGs.

Based on the data provided by the US EPA, the City of Raleigh's wastewater treatment facility is producing effluent consistent with national trends, and with concentrations of CECs typical of other tertiary treatment facilities.

## **2. Background**

All water on Earth contains measurable levels of various anthropogenic chemicals. The number and level of detectable contaminants depends upon the factors influencing the water, the analytical methods applied, and the intensity of monitoring programs. In the past decade, a great deal of interest and concern has been generated regarding trace pharmaceuticals, personal care products, and endocrine disrupting compounds (collectively referred to as “emerging contaminants”) in water. While this era has seen a flurry of activity related to these emerging contaminants, the earliest published manuscripts regarding emerging contaminants in North American waters date back five decades to the 1960s and 1970s. In fact, as long as humans have been on the earth, the vast majority of bioactive and medicinal compounds consumed by us have been excreted and returned to the environment.

One of the many contributors of trace emerging contaminants in the environment is wastewater discharge. Until the era of modern wastewater treatment began over a hundred years ago there was little to no treatment of those substances prior to entering the environment and our waterways. While collection, treatment, and discharge of wastewater has improved dramatically in the past 100 years, focusing on nutrient removal and pathogen inactivation, wastewater treatment plants using conventional and even advanced treatment processes still cannot remove emerging contaminants completely. Thus, even the best facilities in the country will discharge treated effluent that is expected to contain very low levels of these compounds. The types of emerging contaminants that are amenable to treatment depend on the properties of the compound and the key underlying removal pathways for a particular treatment process. Given the wide range of properties represented by these chemicals, there is not a single treatment process that provides an absolute barrier to CECs. Thus, if the objective is to minimize the presence of all CECs in treated water, a sequence of diverse yet potentially energy-intensive and expensive treatment processes is needed that are capable of tackling the wide range of compounds.

## **3. Occurrence**

Emerging organic contaminants have been measured in secondary and tertiary (advanced) treated wastewater effluent and receiving surface waters since the 1960s and 1970s, with some contaminants at levels sufficient to affect aquatic wildlife (parts per billion to parts per trillion ranges (0.000001 g/L to 0.000000001 g/L, or approximately one Tylenol tablet dissolved in 26 Olympic-size swimming pools). All wastewater effluents will contain CECs such as pharmaceuticals due to their widespread use throughout the population and their high concentration in raw (untreated) wastewater. Pharmaceuticals are largely excreted by the body shortly after ingestion and they end up in our sewers, at the wastewater treatment plant, and eventually in the environment. Compounding the issue is the practice of disposing of unused medicines down the drain which adds additional burden on wastewater treatment plants. For compounds that are

commonly used or are present at high concentrations, wastewater treatment processes that are capable of removing 99.9% of the chemical will still end up having a residual concentration that can be measured by modern analytical techniques. As an example, ibuprofen, a common anti-inflammatory drug, was present in one study at 30,000 ng/L in primary treated wastewater, was removed up to 99.8% through advanced membrane-based tertiary treatment with ozone, leaving a residual ibuprofen concentration of 50 ng/L in the effluent. (Pisarenko et al, 2012). Despite the fact that we can measure ibuprofen at concentrations this low, the concentration is so low that it would require a person to consume more than 21 million gallons of water in a single day to achieve the therapeutic dose of 400 mg.

Numerous studies have examined the presence of CECs in wastewater effluents in the US and abroad and occurrence trends tend to be fairly consistent among facilities with similar levels of advanced treatment. Table 1 presents ranges of CECs observed in previously published studies, including a 2009 EPA occurrence survey plus data from the current 2011 EPA wastewater study. The compounds shown only represent those observed in the City's wastewater effluent, not the entire suite of compounds analyzed by the US EPA.

*Table 1: Range of contaminants of emerging concern from the 2011 US EPA Study and other published sources*

<b>Contaminants</b>	<b>Use</b>	<b>2011 EPA Data Set Range (µg/L)*, <sup>1</sup></b>	<b>Range in Wastewater Effluents (µg/L)</b>	<b>Country</b>
17-α-Ethynylestradiol	Oral Contraceptive	0.00026-0.00350	0.00192-0.612 <sup>2</sup>	USA
			0.0001-0.0007 <sup>4</sup>	China
			0.0007-0.0012 <sup>9</sup>	UK
Androstenedione	Androgen, Steroid	0.00074-0.00966	0.00320-0.344 <sup>2</sup>	USA
			0.0015-0.012 <sup>4</sup>	China
Atenolol	Beta Blocker (hypertension)	0.0085-3.073	0.036-0.120 <sup>5</sup>	Canada
Diltiazem	Blood Pressure Medication	0.0125-0.3386		
Estrone	Hormone Therapy	0.00003-0.09325	0.00118-0.0309 <sup>2</sup>	USA
			0.0002-0.0086 <sup>4</sup>	China
			0.0046 <sup>6</sup>	Sweden
Fluoxetine	Anti-Depressant	0.0032-0.0312	0.0147-0.0247 <sup>2</sup>	USA
			0.0035 <sup>6</sup>	Sweden
			0.05-0.10 <sup>9</sup>	UK
Furosemide	Heart Medication	0.0525-2.0967	No Data	
Gemfibrozil	Cholesterol Medication	0.0908-2.3396	0.0189-0.259 <sup>2</sup>	USA
			0.072-0.190 <sup>5</sup>	Canada
			0.126-0.396 <sup>7</sup>	Greece
Hydrochlorothiazide	Blood Pressure Medication	0.3775-2.8302	No Data	

Metoprolol	Blood Pressure Medication	0.1077-1.1692	No Data	
Ofloxacin	Antibiotic	0.0157-0.6584	0.147-3.240 <sup>2</sup> 0.651-1.561 <sup>8</sup> 0.03-0.17 <sup>9</sup>	USA China UK
Oxycodone	Narcotic	0.006-0.3147		
Ranitidine	Gastric Reflux/Heartburn Medication	0.013-1.424	0.496-16.800 <sup>2</sup>	USA
Sertraline	SSRI Antidepressant	0.0058-0.1363	No Data	
Sulfamethoxazole	Antibiotic	0.0026-2.8725	0.00954-1.490 <sup>2</sup> 0.220-0.680 <sup>3</sup>	USA USA
Trimethoprim	Antibiotic	0.0122-0.370	0.293-0.385 <sup>2</sup> 0.210-2.4 <sup>3</sup> 0.010-0.065 <sup>5</sup>	USA USA Canada
Valsartan	High Blood Pressure Medication	0.0421-8.1841	No Data	
Verapamil	High Blood Pressure Medication	0.0053-0.0971	No Data	

#### 4. Human Health Implications

In terms of human health exposure, researchers generally agree that the long-term risk to humans from any single compound at sub- $\mu\text{g/L}$  levels is negligible (Schulman et al, 2002). Recently, the World Health Organization and others have stated that exposure to pharmaceuticals in water poses virtually no risk to humans (Schriks et al, 2010; WHO, 2011). In fact, the concentration of some pharmaceuticals and personal care products in water have been found to be many times lower than what humans are exposed to through food, beverages, and indoor air (Stanford et al, 2010). Recent work by Snyder et al., (2008) using an E-screen assay, showed that the amount of estrogenic activity (a surrogate for specific hormone-like compounds) found in a wastewater extract was less than that attributed to phytoestrogens present in extracts of many common foods. For example, it was concluded that a single serving of soy-based baby formula (4 oz.) contained the same amount of estrogenic activity as 44 liters of secondary wastewater effluent. This is not meant to suggest that baby formula is dangerous for infants, nor is it meant to suggest that drinking 44 liters of wastewater is as safe as 4 oz. of soy-based baby formula. Rather, it illustrates the complex relationship between trying to associate relative source inputs and risks associated with multiple exposure routes including, but not limited to water, air, and food. It also serves as a cautionary warning that simply detecting a compound or a surrogate measure of activity in water does not necessarily

equate to human health risks.

As a means to further provide context to the EPA’s data set and the City’s wastewater effluent, the concentrations observed in the study were compared to existing drinking water guideline values (EPHC et al, 2008), as presented in Table 2. The drinking water guidelines, or DWGs, were developed to provide public health protection from a lifetime of exposure to various CECs. In all cases, the observed contaminants in the wastewater were far below the drinking water guideline values. As an analogy based on information published by the WateReuse Association and available on [www.athirstyplanet.org](http://www.athirstyplanet.org), a worker exposed to such waters on a daily basis would need 8,600 years of exposure to reach a minimum health endpoint for a compound like ibuprofen and nearly 26,000 years of exposure for a compound like fluoxetine.

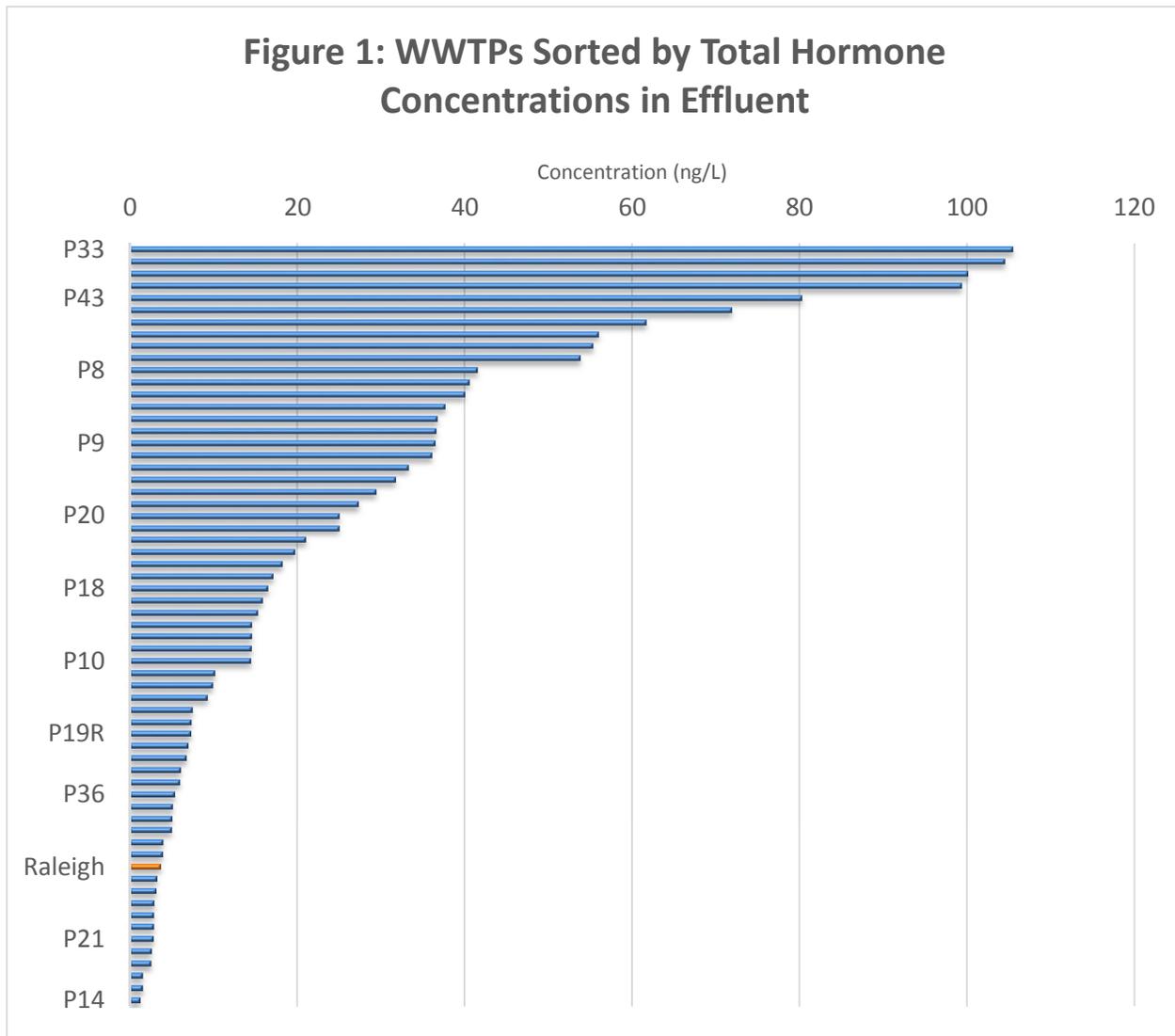
*Table 2: Mean concentrations of contaminants with Raleigh-specific data and published drinking water guideline (DWG) values from Australia.*

Analyte	Number of measurements	Number of detections	Mean (µg/L)	Raleigh (µg/L)	DWG* (µg/L)
atenolol	50	48	0.94	0.36	Not Listed
diltiazem	49	41	0.085	0.093	60
fluoxetine	48	18	0.0087	0.022	10
furosemide	50	45	0.28	0.26	Not Listed
gemfibrozil	50	38	0.42	0.14	15
hydrochlorothiazide	50	50	1.1	1.5	Not Listed
metoprolol	50	49	0.41	0.57	25
ofloxacin	49	44	0.16	0.059	Not Listed
oxycodone	50	30	0.053	0.04	Not Listed
ranitidine	50	19	0.12	0.16	Not Listed
sertraline	50	32	0.021	0.024	Not Listed
sulfamethoxazole	50	40	0.91	2.2	150
sulfamethoxazole	49	44	0.33	0.94	150
trimethoprim	43	37	0.17	0.37	95
trimethoprim	49	40	0.09	0.15	95
valsartan	41	40	1.6	1.3	Not Listed
verapamil	49	39	0.026	0.017	Not Listed
Estrone	63	61	0.013	0.002	0.03
17-α-ethynylestradiol	63	55	0.00081	0.0004	0.0015
Androstenedione	63	62	0.0033	0.0015	49

\* Drinking Water Guideline, based on Australia’s EPHC, NHRMC, and NRMMC 2008 guidelines

## 5. Aquatic Species

In 1996, the first known North American report of endocrine disruption in fish below wastewater outfalls was published (Bevans et al, 1996). Since this time, there have been many other reports also documenting endocrine type effects on fish and other aquatic species exposed to wastewater effluents and mixtures of natural waters (Hemming et al, 2001a; Sole et al, 2003; Snyder et al, 2004; Gagne et al, 2007). Many studies have identified impacts on wildlife species from short- and long-term exposure to sewage effluents and/or compounds present in sewage effluents (Hemming et al, 2001b; Aerni et al, 2004; Brion et al, 2004; Balch & Metcalfe, 2006; Brian et al, 2007; Gagne et al, 2007). However, wastewater is not the only source of contaminants that impact aquatic species. While wastewater effluents certainly contribute to the overall loading of contaminants into our waterways, it is important also to consider the myriad other sources including runoff from agriculture, lawns and landscape, urban areas, industrial sources, septic systems, to name a few. As such, studies that have investigated impacts to aquatic wildlife in natural environments find it difficult to conclude that either (a) wastewater is the sole contributor to impacts among fish and other aquatic species or (b) elimination of CECs from wastewater effluents would solve the problem of the observed aquatic impacts. In the case of Raleigh, the City's wastewater is among the lowest having measurable concentrations of some of the more potent hormones (estrone, 17 $\beta$ -estradiol, estriol, 17 $\alpha$ -ethinylestradiol, progesterone, androstenedione, testosterone, and dihydrotestosterone; see Figure 1)



## 6. Conclusions

Based on the data presented, the Neuse River Wastewater Treatment Plant appears to be producing a high-quality effluent that is consistent with or better than national trends for CECs. There appear to be no major anomalies in the data that would indicate problems in the treatment process or operation of the facility. One possible mechanism of further control of CECs in the wastewater would be to curb the practice of disposing of unused medication down the drain from homes, hospitals, retirement centers, and other locations where large quantities of medicines are stored, distributed, and eventually disposed of. Thus, the issue must be examined holistically and considered from a “cradle-to-grave” perspective in addition to evaluating not just the *presence* of the compounds, but the potential human and environmental health implications.

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