Pharmaceuticals and Personal Care Products in Wastewater

HRSD is responsible for treating the wastewater generated in 17 cities and counties in southeastern Virginia, an area with a population of about 1.6 million. In addition to the standard waste products that are flushed down household drains, the waste stream being treated by waste water treatment plants contains traces of pharmaceuticals and the ingredients found in many personal care products, such as hand sanitizers, sunscreens and soaps.

(Pharmaceuticals and personal care products are also known as PPCPs.) Many of the personal care products reach the waste stream after being washed down the drains in sinks and showers. Pharmaceuticals can enter the waste stream in one of two ways: through bodily excretions following the ingestion of medications and through the disposal of medications down the drain (medications should never be dis-posed of in a sink or toilet, see below).

HRSD's wastewater treatment plants are highly effective facilities, engineered to treat the wastewater by reducing the concentration of biodegradable materials and pathogens before discharging it into our local waterways.

Most of these treatment plants have been further upgraded to reduce the nutrient content of this treated, discharged water (effluent).

Though our award winning treatment plants are highly effective at accomplishing these tasks, these types of wastewater treatment systems are not designed to remove PPCPs.

However, we know from research around the world and from data collected at HRSD treatment plants that the types of treatment processes we employ may incidentally re-duce the concentrations of many of the pharmaceuticals entering our treatment plants. The presence of detectable concentrations of PPCPs in treated wastewater effluent does not necessarily mean that these compounds are present at high enough concentrations to cause harm to humans or to the organisms living in the water. Detection of these compounds is attributable to the widespread use of these products and to the technological advances in analytical instrumentation that reveal the presence of trace con-taminants at the parts per trillion levels (0.000000001 g/L, roughly equivalent to one drop of water in 20 Olympic-size swimming pools). Though HRSD does not discharge treated effluent into any drinking water supplies, it is important to note that evidence to date does not indicate that exposure to PPCPs through drinking water poses a health risk to humans (WHO 2012). However, there is growing evidence from laboratory studies and from some field observa-tions outside of Hampton Roads that some PPCPs may be present at high enough concentrations to potentially cause an adverse effect on aquatic organisms. Given this concern, HRSD has been actively engaged in research on multiple fronts to better understand this issue.

Wastewater Characterization:

HRSD recently participated in a US Environmental Protection Agency (EPA) study designed to characterize the occurrence of a suite of prioritized pharmaceuticals in the treated effluent of 50 of the largest wastewater facilities in the nation.

The EPA study included a one-time sampling event at a single HRSD wastewater treatment plant. HRSD is expanding upon that study and is seeking to further characterize the occurrence of these and other PPCPs and household chemicals in the waste streams entering its treatment plants and in the treated effluent exiting them.

Leaching Potential of PPCPs from Land-applied Biosolids:

In collaboration with the University of Tennessee's Center for Environmental Biotechnology, HRSD is researching the transport of pharmaceuticals in the environment associated with the land application of biosolids. Biosolids, a product of the wastewater treatment process, are often recycled as a soil fertilizer to help stimulate plant productivity. Biosolids often contain various PPCPs; there-fore, this study is designed to help the scientific and regulatory community better understand the potential for PPCPs to leach from biosolids into the soil or surrounding water bodies.

National Partnerships

HRSD has also partnered with other researchers nationwide to further advance the science surrounding PPCPs and the broader group of emerging contaminants, which includes additional chemicals in residential and commercial use that have the potential to disrupt the hormonal activity of living organisms (i.e., endocrine disruptors). Some examples of this research include:

- Evaluating the presence of nanomaterials in biosolids. The EPA defines nanomaterials as materials that are between 1 and 100 nanometers in size in at least one dimension. These materials are used in commercial processes and products and often have unique properties that arise from their small size.
- Investigating the potential for pharmaceutical effects on bacterial activity in soil
- Developing a standardized technique for measuring the breakdown of emerging contaminants in the wastewater treatment process
- Participating in the National Association of Clean Water Agencies Emerging Contaminants Workgroup
- Providing public education on the proper disposal of unused pharmaceuticals ("My Flush Counts")

Preliminary Study Results

While much of the research is on-going, the EPA-generated data on pharmaceuticals for one HRSD plant's treated effluent is available. EPA recently released the results of their study in the journal Environmental Pollution (Kostich, et al. 2014). Table 1 provides the mean concentrations measured across all of the plants included in the EPA study in conjunction with the concentrations measured by EPA for the treated effluent of HRSD's Virginia Initiative Plant (VIP). This document will be updated with information on the other projects when the reports are available.

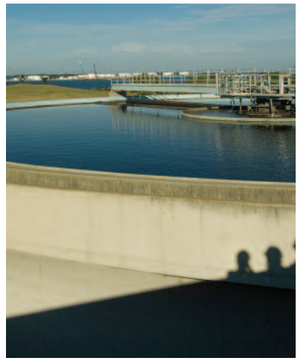
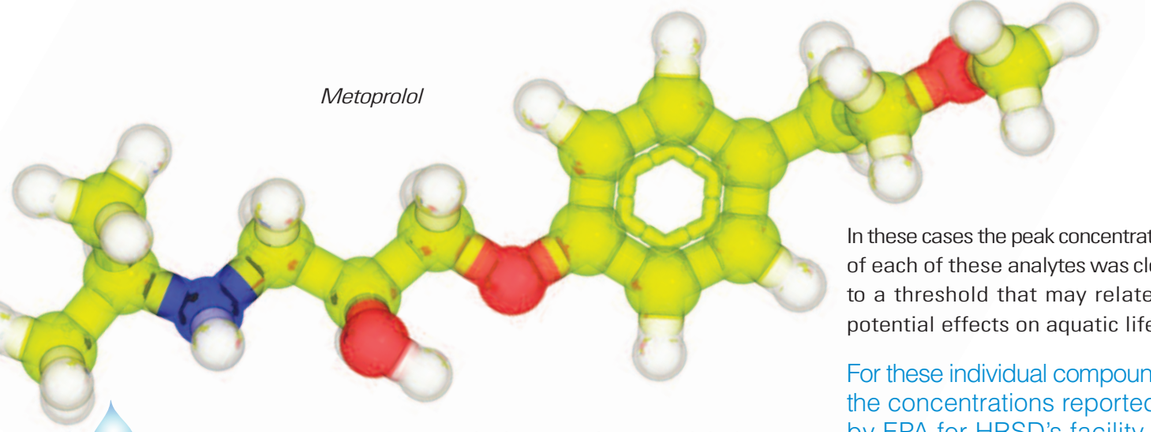


Table 1

1 The EPA study collected samples from the 50 largest wastewater treatment plants in the United States. The EPA Study Mean Concentration numbers represent an average concentration across all 50 plants.

2 ppt = parts per trillion, equivalent to one drop of liquid diluted in the water of 20 Olympic-size swimming pools. This is equivalent to nanograms per liter (ng/L).

Compound	Use	EPA Study Mean Concentration[1] (ppt, ng/L)[2]	HRSD Concentration (ppt, ng/L)
Acetaminophen	Analgesic/antipyretic	79	ND (non-detect)
Albuterol	Asthma control	14	ND
Alprazolam	Anti-anxiety	10	ND
Amitriptyline	Antidepressant	11	14
Amlodipine	Blood pressure control	7	ND
Amphetamine	Stimulant	4	ND
Atenolol	Blood pressure control	940	80
Carbamazepine	Anti-epileptic	97	80
Ciprofloxacin	Antibiotic	67	70
Desmethylsertraline	Antidepressant	10	ND
Diltiazem	Blood pressure control	85	95
Diltiazem-desmethyl	Blood pressure control	24	66
Enalapril	Blood pressure control	5	ND
Enalaprilat	Blood pressure control	14	ND
Fluoxetine	Antidepressant	9	ND
Furosemide	Diuretic	280	909
Gemfibrozil	Cholesterol control	420	ND
Hydrochlorothiazide	Diuretic	1100	1314
Hydrocodone	Analgesic/antitussive	22	33
Ibuprofen	Nonsteroidal anti-inflammatory	460	ND
Lisinopril	Blood pressure control	180	ND
Metoprolol	Blood pressure control	410	1027
Norfluoxetine	Antidepressant	8	ND
Norverapamil	Blood pressure control	6	ND
Ofloxacin	Antibiotic	160	85
Oxycodone	Analgesic	53	ND
Propoxyphene	Analgesic	17	ND
Propranolol	Blood pressure control	33	51
Ranitidine	Stomach acid control	120	ND
Sertraline	Antidepressant	21	20
Sulfamethazine	Antibiotic	12	ND
Sulfamethoxazole	Antibiotic	910	237
Triamterene	Diuretic	37	ND
Trimethoprim	Antibiotic	90	100
Valsartan	Blood pressure control	1600	539
Verapamil	Blood pressure control	26	7



Metoprolol

What do the results of EPA's study mean?

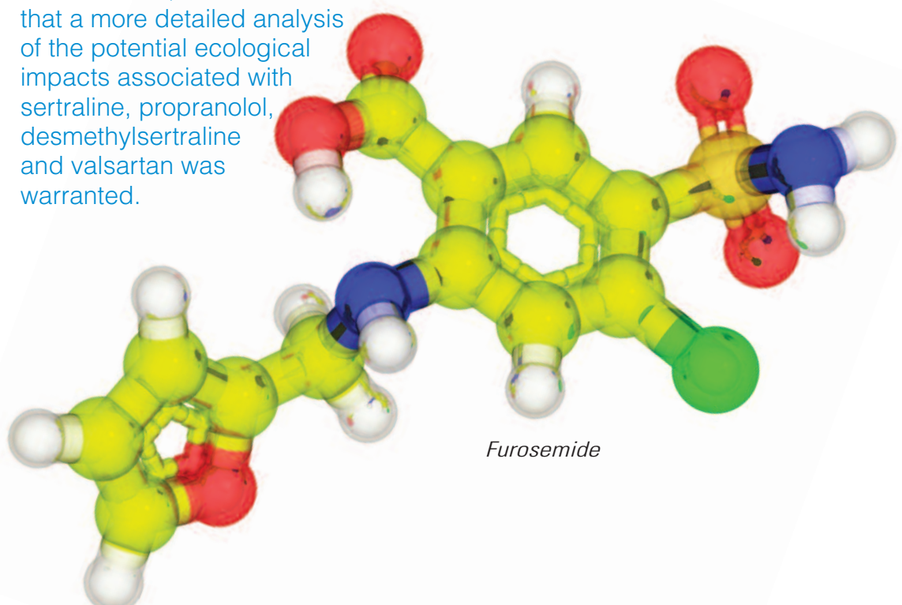
When comparing the EPA data for HRSD's facility to the national averages, it seems that treated effluent quality at HRSD's facility is generally consistent with or better than that produced by the other wastewater treatment plants involved in the study for the compounds studied.

Conclusions based on a single sample (as exists in the EPA study for the VIP) are tentative given the many variables that can affect the data, but were not addressed in the study (season, service area characteristics, treatment performance, etc.). The VIP concentrations of two compounds, metoprolol and furosemide, were reported by EPA as more than double the national average. Since the concentrations entering each of the wastewater treatment plants was not measured, it is unclear if these differences from the national average are a result of variability in the patterns of use of these medications in the HRSD service area or due to differing removal efficiencies among the plants included in the study. Though the concentrations in the VIP treated effluent for these two compounds were reported to be higher than the national average, the concentrations of these compounds in VIP effluent were well below any known toxicity threshold.

In the case of metoprolol, the concentration in the VIP effluent was more than 8000 times less than the lowest concentration reported to be toxic to aquatic organisms in several studies (Huggett, et al. 2002; van den Brandhof and Montforts 2010; Sun et al., 2013). Similarly, the concentration of furosemide in the VIP effluent was thousands of times less than the concentrations reported to be toxic in a study examining multiple species of aquatic organisms (Isidori, et al. 2006).

EPA's evaluation of the peak concentrations observed in this study indicated that the risk to aquatic life from these pharmaceuticals was low. However, EPA indicated that a more detailed analysis of the potential ecological impacts associated with sertraline, propranolol, desmethylsertraline and valsartan was warranted.

Pharmaceutical	Max Result from EPA Study (ppt)	VIP result (ppt)
Desmethylsertraline	24	ND
Propranolol	260	51
Sertraline	71	20
Valsartan	5300	539



Furosemide

In these cases the peak concentration of each of these analytes was close to a threshold that may relate to potential effects on aquatic life.

For these individual compounds the concentrations reported by EPA for HRSD's facility were well below the peak concentrations of the study and thousands of times less than the concentrations reported to be toxic to aquatic organisms (propanol: Huggett, et al., 2002; van den Brandhof and Montforts 2010; Sun et al., 2013; sertraline and desmethylsertraline: Connors, et al., 2009; Valenti, et al., 2009; valsartan: Zielinski, F. 2004).

What can be done to reduce the concentrations of pharmaceuticals in the waste stream?

One of the easiest things for individuals to do is to properly dispose of any unused medications.

Unused medications should not be flushed down toilets or sinks as this increases the potential for unacceptable environmental exposure of these medications.

Drug Enforcement Agency (DEA) medication take-back events occur locally twice per year. Many local pharmacies are willing to accept unused medications for proper disposal although they are currently restricted from accepting controlled medications that have already been dispensed to patients. DEA restrictions regarding the handling of controlled drugs are being reconsidered in order to allow individuals to return controlled medications to their local pharmacies or through mail-back programs.

HRSD has prepared a leaflet describing disposal options in the absence of a take-backprogram (http://www.hrsd.com/pdf/MyFlushCountsBrochure.pdf).

The pharmaceutical loading to HRSD facilities is largely due to bodily excretions. Individuals can help reduce this loading by following the dosing guidelines provided with the medication.

Literature Cited:

Connors, D.E., E.D. Rogers, K.L. Armbrust, J-W Kwon, and M.L. Black. 2009. Growth and development of tadpoles (Xenopus laevis) exposed to selective serotonin reuptake inhibitors, fluoxetine and sertraline, throughout metamorphosis. Environmental Toxicology and Chemistry. 28:2671-2676.

Huggett, D.B., B.W. Brooks, B. Peterson, C.M. Foran, and D. Schlenk. 2002. Toxicity of select beta adrenergic receptor-blocking pharmaceuticals (-blockers) on aquatic organisms. Archives of Environmental Contamination and Toxicology. 43:229-235.

Isidori, M., A. Nardelli, A. Parrella, L. Pascarella, and L. Previtera. 2006. A multispecies study to assess the toxic and genotoxic effect of pharmaceuticals: furosemide and its photo product. Chemosphere. 63:785-793.

Kostich, M.S., A. L. Batt, and J. M. Lazorchak. 2014. Concentrations of prioritized pharmaceuticals in effluents from 50 large wastewater treatment plants in the US and implications for risk estimation. Environmental Pollution. 184:354-359.

Sun, L., L. Xin, Z. Peng, R. Jin, Y. Jin, H. Qian, and Z. Fu. 2013. Toxicity and enantiospecific differences of two -blockers, propranolol and metoprolol, in the embryos and larvae of zebrafish (Danio rerio). Environmental Toxicology. doi:10.1002/tox.21867.

Valenti, T.W., P. Perez-Hurtado, C.K. Chambliss, and B.W. Brooks. 2009. Aquatic toxicity of sertraline to Pimephales promelas at environmentally relevant surface water pH. Environmental Toxicology and Chemistry. 28:2685-2694.

van der Brandhof, E.J., and M. Montforts. 2010. Fish embryo toxicity of carbamazepine, diclofenac, and metoprolol. Ecotoxicology and Environmental Safety. 73:1862-1866.

WHO. 2012. Pharmaceuticals in Drinking-water. World Health Organization, Geneva, Switzerland.

Zielinski, F. 2004. Environmental Assessment and Finding of No Significant Impact for Diovan® (valsartan) tablets. Report for the Food and Drug Administration Center for Drug Evaluation and Research, Division of Cardio and Renal Drug Products. NDA21-283/S-011.

For further information:

Drug Enforcement Agency website on Prescription Drug Take-Back Events:
http://www.deadiversion.usdoj.gov/drug_disposal/takeback/

EPA's website on nanotechnology:
http://www.epa.gov/nanoscience/

EPA's website on PPCPs:
http://www.epa.gov/ppcp/

EPA's website on PPCPs in wastewater
http://www.epa.gov/eerd/research/pharmaceuticals.html

HRSD's My Flush Counts brochure:
http://www.hrsd.com/pdf/MyFlushCountsBrochure.pdf

Water Environment Federation website on Microconstituents
http://www.wef.org/AWK/pages_cs.aspx?id=1066

Water Environment Research Federation, Research on nanomaterials in biosolids
(https://www.werf.org/a/ka/Search/ResearchProfile.aspx?ReportId=U1R10)

Water Environment Research Federation, Research on the breakdown of emerging contaminants in wastewater
http://www.werf.org/a/k/Search/ResearchProfile.aspx?ReportID=U3R10)
Literature