Division of Science and Research

Research Project Summary

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A Reconnaissance of Contaminants of Emerging Concern in Wastewater and Sludge from Three Publicly Owned Treatment Works in New Jersey

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Abstract

The character of wastewater, landfill leachate, and sludge taken from three New Jersey regions (areas Q, X and Z) has been assessed for multiple contaminants of emerging concern to determine the likelihood of occurrence in various types of developed areas. Regions were determined based on land use and the projected character of wastewater. The distinct areas of land use that were the aim of this study consisted of residential, commercial, industrial (including two areas with pharmaceutical processing), and hospital/retirement areas. Areas contained various sub-sewersheds represented by a sampling station that was characterized by the land use type. The sampling sites selected in each of the three areas were intended to assess not only differences between the overall character of the area, but to assess the differences that may exist within the Areas, such as delineated areas with characteristics that describe residential, commercial, pharmaceutical, hospital and retirement communities and industrial sewersheds. Residential areas were found to contain the highest number and total mass of pesticides compared to other types of sewersheds and were found to have the highest number of detected hormone analytes. Among the PAH analytes in the commercial areas, phenol and p-cresol dominated the total concentration of PAHs, with the total PAH concentration in Area X being comprised of 70% p-cresol. The range of the total concentration of flavors and fragrances in residential areas was between 44 and 90 µg/L, whereas the range for all areas was between 20 and 165 µg/L. The number of flavors and fragrances detected in residential areas was also similar to other areas, having between nine and eleven compounds present. The only notable pharmaceutical group within the commercial areas were the stimulants, with the highest detection of caffeine, among all sewersheds, detected in the Area Z commercial sewershed. In all three commercial sewersheds, caffeine accounted for between 84 and 98% of the total stimulant group. The total concentration (6.034 µg/L to 272.5 µg/L) and the number of APEs (between seven and nine) detected in the Hospital and Retirement Community sewersheds were the highest among the types of sewersheds. A concentration of 260 µg/L of tri(2-butoxyethyl) phosphate (TBEB, flame retardant) was recorded in the Area Z retirement sewershed. In evaluating the results for the influent and effluent of the wastewater treatment plants, the varied detection limits attributed to interferences needs to be considered, particularly when including a value that is reported to be below the detection limit. Given the limited sample number, conclusions can only be considered preliminary.

Introduction

This study was undertaken to determine what contaminants of emerging concern (CECs) occur in raw sewage generated by different source sewersheds, in the influent and the treated waste discharge as well as in the solid wastes generated by Publicly Owned Treatment Works (POTWs). Leachate samples taken from multiple landfills were also investigated. This study was initiated to answer the following questions:

1. Do pharmaceutical processing plants, hospitals, and/or other human waste sources represent significant sources of active pharmaceutical ingredients (APIs) and other CECs to POTWs?
2. What APIs and other CECs are released at the outfalls of large POTWs?
3. What APIs and other CECs are present in biosolids (both wet and dried) produced by POTWs?

Samples were taken from waste streams in carefully selected, isolated sewersheds that included: residential communities, retirement communities, hospitals, commercial areas, and industrial areas that include pharmaceutical processing plants. These processing plants do not synthesize the APIs but create the final marketable product containing the active ingredient. Samples were also obtained from one industrial area not having a pharmaceutical processing plant and from a dormitory residency at a local university. Influent and treated outfall

water, and sludge were also sampled at three large sewage treatment plants located in New Jersey.

Seven chemical compound classes were investigated in New Jersey wastewaters and sludge for this study. The seven classes are as follows:

1. Pharmaceuticals
2. Pesticides, Insecticides, Herbicides and Fungicides
3. Sterols and Hormones
4. Flavors and Fragrances
5. Alkylphenol Ethoxylates (APEs)
6. Polyaromatic Hydrocarbons
7. Per- and Poly-fluorinated alkyl substances (PFAS)

This report summarizes the methods and results from this investigation.

Important Caveats

Three important caveats apply when considering the results of this study; these caveats relate to the complex nature of human wastes and the nature of flow in sanitary sewer-pipes. The first caveat is that the samples collected were grab samples and therefore not well mixed and may represent a "pulse" or "flush." In addition, the analytical methods used to quantify contaminants concentrated on the dissolved phase chemicals and therefore may not fully characterize the site conditions. Also, the sensitivity of analytical methods was impacted by matrix interference and again, may not fully characterize site conditions.

Methods

Experimental Design

Three zones within New Jersey were delineated to represent area that contributes wastewater to one of three POTWs. The characterization of these areas differed in population density, industrial concentration and urbanization. Industries included business corridors, hospitals and "industrial parks" with and without pharmaceutical processing. In addition, residential areas within these three areas consisted of mixtures of retirement communities and typical residential developments. Table 1 shows the general characteristics of the contributing wastewater area and the isolated sub-sewersheds that were sampled as a part of this study.

Field Methods

Sampling Stations

Each Area contained sampling stations located along the wastewater collection system at points that collect wastewater from delineated areas consisting of similar land use. In addition, three sampling stations within each Area included the locations where landfill leachate and sludge were collected. In addition to the landfill leachate and the sludge samples, there was a total of twenty-three sampling stations over the three Sewershed Areas (See Table 2).

Table 1: General area characteristics

				Sub-Sewersheds Classifications						
Area ID	**Overall Type**	**Area (mi^2)**	**Population Density (people per square mile)**	Hospital	Commercial	Industrial w/ Pharm	Retirement	Residential	Industrial	Other/ University
Z	Residential with small commercial areas	758	760	√	√	√	√	√		
Q	Urbanized	227	2,264	√	√		√	√	√√	
X	Urban and industrialized	323	2,508	√	√	√	√	√		√

Table 2: Sampling Stations by Area and Sewershed

Area[1]	**Sewershed**								
Z	Residential	Hospital	Retirement	Industrial w/Pharm.	Commercial	STP Inflow		STP Outflow	Sludge
Q	Residential	Hospital	Retirement	Industrial	Commercial	Industrial 2	STP Inflow	STP Outflow	Sludge
X	Residential	Hospital	Retirement	Industrial w/Pharm.	Commercial	University	STP Inflow	STP Outflow	Sludge

[1] *One landfill leachate sample was also collected from each Area. Areas are not ordered and are generally independently delineated.*

Wastewater sampling was conducted with the help of POTW personnel and USGS field crews experienced in handling and sampling raw wastes. Waste influent and treated outfall at the POTWs were 24-hour composite samples collected from the grit chamber and final outfall raceways. They were collected using an ISCO automatic sampler equipped with pre-cleaned Teflon inlet tubing and silicon pump tubing.

Analytical Methods

Seven different USGS analytical methods, many comparable to certified EPA analytical methods, were used to quantify all analytes in this study.

Results

Pharmaceuticals

Overall, in the nineteen (19) samples taken from the wastewater sampling locations, every site had a detectable level of at least nine pharmaceutical compounds. Total concentrations of these pharmaceutical compounds ranged from 50 µg/L total pharmaceuticals in the Area X University site, up to 472 µg/L in the Area Z Retirement community. The Area Z Residential sewershed showed evidence of 409 µg/L, whereas the Area Q Industrial 2 contained nine (9) compounds totaling 119 µg/L.

Upon evaluation of the treated effluent, it appears that the wastewater treatment plants reduced the number and concentration of pharmaceuticals detected. However, the "important caveats" (Section 1.3) are to be seriously considered when evaluating the data, although reporting levels between the influent and the effluent samples were reported to be similar.

Pesticides

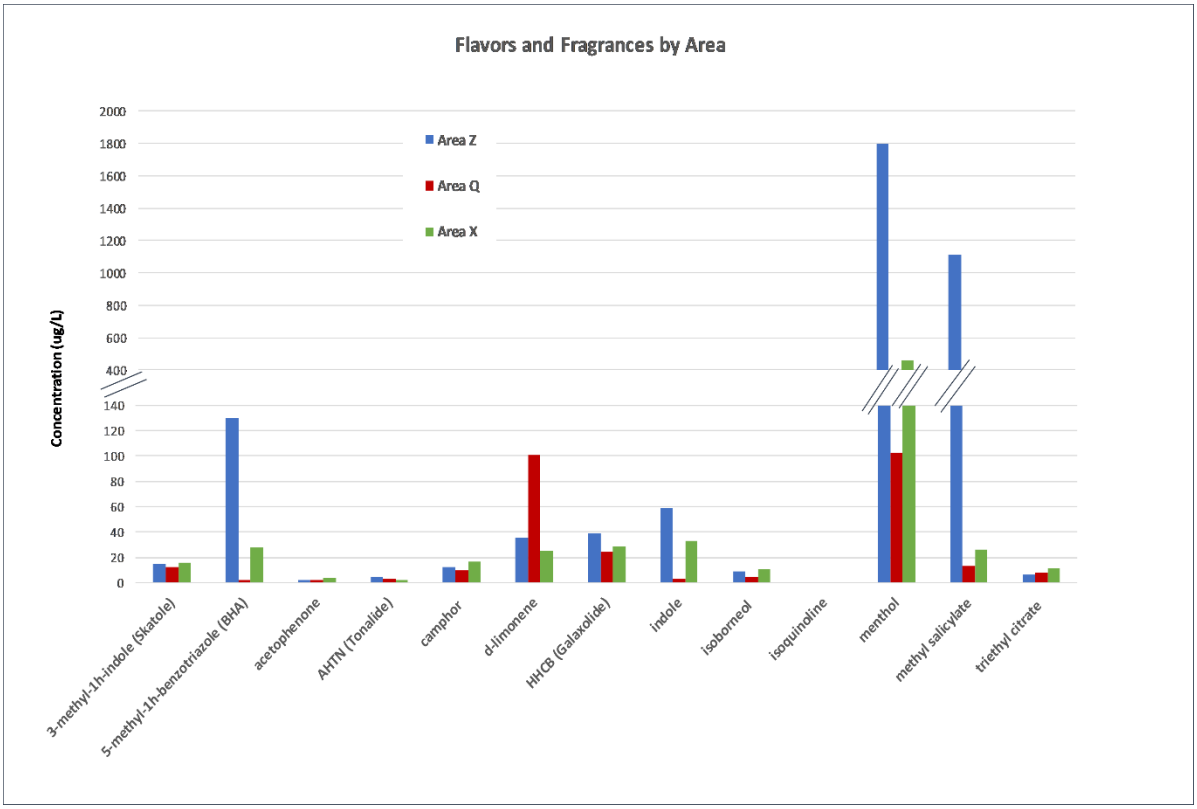
The analysis detected only five of the twelve compounds across the twenty-six wastewater sampling stations, including the landfill leachate. DEET was found in nineteen of the twenty wastewater samples, with concentrations ranging from 0.04 to a high of 21 µg/L found in the Area X residential station sample.

Sterol and Hormones

Twenty water samples were collected at the various points of interest in the three sewersheds. Of the seventeen hormones, all sites had detectable levels of at least four compounds (the lowest being Area Z POTW inflow), but many of the sampling sites had detectable levels of nine or more compounds. Area Q Hospital sub-sewershed showed thirteen compounds, with a total mass of hormones equaling 6.2 µg/L (6,233 ng/L).

Flavors and Fragrances

The wastewater, treated water, and landfill leachate were analyzed for thirteen compounds that were classified as flavors and fragrances. The wet and dried sludge samples were analyzed for ten of these compounds (See Appendix B, Table 4). These compounds include 3-methyl-1h-indole (Skatole), camphor, and menthol. Many of these compounds can occur naturally or can occur in wastewater due to the synthetic manufacture and use of these compounds. For instance, indole is found naturally in coal tar and feces, and is also synthetically manufactured to be a malodorant for the military. The twenty wastewater sites each contained detectable levels of between eight and twelve of the compounds that were quantified. The number of flavors and fragrances, as well as the magnitude of the detection was reduced in the treated effluent.



Flavors and Fragrances in Wastewater by Area

Note: Those parameters with no bars were below the reporting limit.

Phenols and Alkylphenol Ethoxylates (APEs)
Fourteen APE compounds were quantified during this study. These compounds include alkylphenols, alkylphenol ethoxylates, phosphates, and bisphenol A and are used in the manufacture of resins, polymers, fire-retardants and surfactants. Across the three areas, each sample of untreated wastewater contained detectable levels of between five and ten of the fourteen compounds considered under the APE classification. The sum of all APEs ranged from 6.51 μg/L from the Area X residential station to 272.52 μg/L from the Area Z retirement community. The most commonly detected analytes included benzophenone, a UV-blocker, and tris(2-butoxyethyl) phosphate (TBEP), a flame retardant, which were found in all wastewater samples and had concentrations ranging from 0.23 μg/L to 3.3 μg/L for benzophenone and 1.3 to 260 μg/L for TBEP. Of the eight compounds entering the Area Z POTW, only three were detected in the effluent, and at lower levels than was measured in the influent. The three samples of landfill leachate contained between four and nine detectable APE compounds.

PAHs
Seventeen (17) PAH compounds were quantified in the wastewater, while fifteen compounds were quantified in the sludge for this study. These compounds include anthracene, benzo(a)pyrene, phenol, and naphthalene and can be formed during the incomplete combustion of coal, oil, gas, and garbage as well as emanating from manufacturing of the intermediates of dyes, solvents and mothballs. Detectable levels of at least three of the PAH compounds were found in all wastewater samples, with an Area Q commercial area detecting up to thirteen of the compounds.

Perfluorinated Alkyl Acids
Perfluorinated compounds in the wastewater, sludge, and finished water were analyzed in samples from Area Z only. Eight perfluorinated carboxylic acids, with carbon chains from 5 to 12 carbons, and two sulfonic acids, PFBS and PFOS, were quantified in samples taken from six wastewater sampling stations. The two stations with detectable levels of one perfluorinated compound included the Area Z industrial with pharmaceutical processing station (PFBA= 26.6 ng/L) and the Area Z retirement community station (PFNA=117 ng/L). Each of the three samples taken of the influent and treated water at the Area Z wastewater treatment plant contained detectable levels of one perfluorinated compound. The levels in the influent were not always very different than the levels in the effluent. One reason this may be true is that traditional wastewater treatment has not been found to remove perfluorinated compounds. The results of the three sampling events and the perfluorinated compounds detected in those samples can be found in the table below.

Perfluorinated Compound Concentrations in the Influent and Effluent at Area Z POTW (ng/L)

	PFBS (ng/L)		C8 Acid (PFOA) (ng/L)	
Date	Influent	Effluent	Influent	Effluent
February 2010	94.5	88.2	ND	ND
March 2011	ND	ND	26.0	27.9
August 2011	ND	ND	82.3	49.2

Note: ND=non-detect

Conclusions

The sampling sites selected in each of the three areas were intended to assess not only differences between the overall character of the area (Area Z as residential with small commercial areas, Area Q as urbanized, and Area X as urban and industrialized), but to assess the differences that may exist within the Areas, such as delineated areas with characteristics that describe residential, commercial, pharmaceutical, hospital and retirement communities and industrial sewersheds.

The results of this study provide an initial insight into the many manmade compounds that can be found in our wastewater. Human consumption and human use leads to the presence of many of these compounds in the wastewater system and often in the treatment plant effluents, sludge and landfill leachates. Typically, many of the compounds studied here were greatly reduced in concentration before the water was discharged to the environment. However, given their status as “emerging contaminants”, there is a need for an increased understanding of the concentrations and loads that the human population is contributing and that the public treatment works can treat.

The results comparing the various sewersheds characterized by the nature of the land use did not provide evidence of a signature chemical profile. The results evaluated on a sample basis did provide information on chemical profiles that were common to wastewater impacted by any human activity.
Although multiple compounds were detected in many of the samples taken for this study, there are many more compounds that originate from human consumption or use that could enter the environment through the wastewater treatment system. It is through additional studies that knowledge will be gained on the prevalence and the significance of those compounds.

References

U.S. Environmental Protection Agency (EPA) Office of Water, Occurrence of Contaminants of Emerging Concern in Wastewater from Nine Publicly Owned Treatment Works, August 2009.

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RESEARCH PROJECT SUMMARY

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