Environmental Assessment and Risk Analysis Element

Research Project Summary

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Occurrence, Distribution, and Concentration of Pharmaceuticals and Other Organic Wastewater-Related Compounds in New Jersey's Surface-Water Supplies

R. Lee Lippincott Ph.D.[1], Paul Stackelberg[2]

Abstract

The Unregulated Contaminant Monitoring Rule, which is part of the Federal Safe Drinking Water Act, directs states to develop sampling plans to identify contaminants of emerging concern that may merit future regulatory consideration as part of the USEPA's Candidate Contaminant List (CCL) process. Many of the traditional analytical methodologies used for regulatory compliance, however, lack the sensitivity and selectivity needed to detect organic contaminants of anthropogenic origin. Recently, the U.S. Geological Survey (USGS) developed analytical methods for the determination of more than 95 contaminants typically found in domestic, industrial, and agricultural wastewaters. Examples of these unregulated contaminants include pharmaceuticals, antibiotics, hormones, personal care products, and various industrial and commercial products. These newly developed analytical methods have been used by the USGS in cooperation with the N.J. Department of Environmental Protection (NJDEP) to evaluate the occurrence of contaminants of emerging concern in New Jersey's streams and drinking water supplies. Results from this study indicate that trace level organic contaminants that represent a broad suite of uses and origins can enter and persist in ambient waters and subsequently occur in finished drinking water supplies. This study provides information that will be useful for designing future monitoring efforts and for setting research and regulatory priorities.

Introduction

Increases in public awareness over recent decades have brought increasing concerns for potential contamination of water resources. Contamination can occur inadvertently during production, use, and disposal of the numerous chemicals. These multiple pathways are a direct result of modern life improvements in industry, agriculture, medical treatment, and even common household applications. Increasing knowledge of the environmental occurrence or toxicological behavior of contaminants has resulted in increased concern for potential adverse environmental and human health effects. For many contaminants, public health experts have incomplete understandings of their toxicological significance (particularly effects of long-term exposures at low-levels). The need to understand the processes controlling contaminant transport and fate in the environment, and the lack of knowledge of the significance of long-term exposures have increased the need to study environmental occurrence down to trace levels. Furthermore, the possibility that environmental contaminants may interact synergistically or antagonistically has increased the need to define the complex mixtures of chemicals that are found in our waters.

The objective of this investigation is to develop information and tools on emerging water quality issues that will be used to design and improve water quality monitoring and assessment programs of the USGS and others, and for proactive decision-making by industry, regulators, the research community, and the public.

There are two components of the activities conducted under this investigation. The first is a field synoptic study where stream segments were selected, sampled, and analyzed for the suite of target analytes. The analytical techniques developed by USGS were used to determine which organic contaminants were present in the samples and at what concentrations. The second component of the investigation involved sampling waters throughout a public community water supply. The purpose here was to examine the fate of organic chemicals from the source water through the treatment process and finally into treated, or finished, drinking water.

Methods

Analytical Methods Development: Laboratory analytical methods that enable the low-level analysis of organic chemicals in environmental samples are continually being developed. Sensitive, newly developed analytical methods at the USGS Denver laboratories were used for the study described here. The methods were able to measure the concentrations of 95 different chemicals in water.

Synoptic Field Study: Synoptic field studies are designed to provide basic scientific information related to the occurrence and potential transport of contaminants in the environment. The synoptic field study described here utilized newly developed laboratory methods at USGS to provide baseline information on the environmental occurrence of a wide range of organic wastewater contaminants in surface water used or

having the potential to be used as sources of drinking water. This is critical since preliminary results from previous field studies have shown that many organic wastewater contaminants may persist in surface waters.

Thirty stream sampling locations were selected. They are shown in Table 1. The USGS Station ID corresponds to official geographically referenced points so that follow up sampling can occur from precisely the same point in the stream. Several of these stations monitor water quality parameters on a periodic schedule. Most were located downstream of or near potential sources of human wastewaters. Figure 1 is a pictorial representation of the sampling station locations relative to the basin that influences that point. The strategic field sampling plan for this project involved a vulnerability assessment that utilized the basin hydrodynamics, land use coverage, and percent wastewater contribution to stream flow as elements. A range of 0 to 51 municipal wastewater treatment facilities are located upstream of sites selected for this survey and the estimated amount of stream flow contributed by these wastewater treatment facilities ranges from 0 to 70 percent. Each of these 30 sites was sampled once during June and July of 2001 and each sample was analyzed for organic wastewater-related compounds.

Table 1. List of sites sampled in synoptic survey

USGS Station ID	Site Name
01464000	Assunpink Ck @ Trenton
01401600	Beden Bk nr Rocky Hill
01464500	Crosswicks Ck @ Extonville
01385000	Cupsaw Bk nr Wanaque
01379200	Dead R nr Millington
01463500	Delaware R @ Trenton
01465873	Haynes Ck @ Lake Pine
01391000	Ho-Ho-Kus Bk @ Ho-Ho-Kus
01391100	Ho-Ho-Kus Bk @ Mouth @ Paramus
01399780	Lamington R @ Burnt Mills
01399200	Lamington R nr Ironia
01405302	Matchaponix Bk @ Spotswood
01411800	Maurice R nr Millville
01402000	Millstone R @ Blackwells Mills
01457400	Musconetcong R @ Riegelsville
01467003	N. Branch Rancocas Ck @ Ewansville
01399120	N. Branch Raritan R @ Burnt Mills
01398260	N. Branch Raritan R nr Chester
01389500	Passaic R @ Little Falls
01381900	Passaic R @ Pine Brook
01379500	Passaic R nr Chatham
01389600	Peckman R @ West Paterson
01387500	Ramapo R nr Mahwah
01403300	Raritan R @ Queens Bridge
01381200	Rockaway R @ Pine Brook
01389100	Singac Bk @ Singac
01367620	Wallkill R @ Sparta
01367770	Wallkill R nr Sussex
01381800	Whippany R nr Pine Brook
01381600	Whippany R nr Whippany

Figure 1. Location of sampling sites for synoptic survey and associated drainage basins.

All samples were collected by USGS and NJDEP personnel in the summer of 2001 using consistent protocols and procedures designed to obtain a sample representative of the targeted raw drinking-water source.

Drinking Water Treatment Plant Investigation: A public community drinking water treatment plant using surface water as its water source and having significant upstream wastewater discharge was selected for this component of the study. The researchers sought to determine the efficiency of removal for the chemicals that were detected in the raw source water. The drinking water facility uses "conventional treatment" which consists of pre-disinfection with chlorine, flocculation/sedimentation, filtration, and post-disinfection with chlorine. Raw water, settled water, filtered water and delivered (finished) drinking water was sampled at this one facility to examine the water treatment process and measure removal efficiencies for these trace organic contaminants.

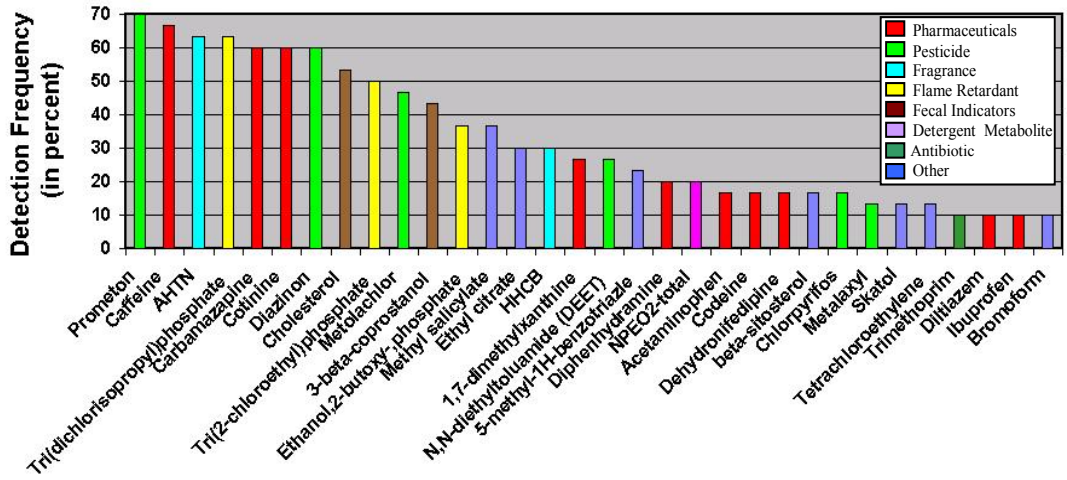
Results

Synoptic Field Study: Over 90 percent of the samples contained detectable concentrations of one or more of the target compounds. The number of compounds detected per sample ranged from 0 to 32, with a median of 11. The total concentration of these compounds per sample ranged from non-detectable to 81 ug/L, with a median of 1.7 ug/L. Compounds detected in more than 40 percent of all samples include;

- caffeine
- the pharmaceuticals carbamazepine and cotinine
- the flame retardants and plasticizers tri(dichloroisopropyl) phosphate and tri(2-chloroethyl) phosphate,
- the fragrance compound acetyl-hexamethyl-tetrahydro-napthalene (AHTN),
- the plant and animal steroids cholesterol and 3-b-coprostanol, and
- the pesticides prometon, diazinon, and metolachlor.

Figure 2 illustrates the distribution of the detected contaminants with their respective detection frequencies from the NJ study. Findings from this survey are similar to a USGS National Reconnaissance of organic wastewater contaminants in streams across the country. In the national study, a variety of organic wastewater-related compounds was detected at low-level concentrations in streams that receive effluent from wastewater treatment plants.

Figure 2. Compounds detected in 10 percent or more of samples from the synoptic survey.



The strategic field sampling plan for this project involved a vulnerability assessment that utilized the basin hydrodynamics, land use characteristics, and percent wastewater contribution to stream flow as elements. This information was used to determine if there was an indication of primary source and to assess the fate and transport of the detected chemicals in the environment. The total number and concentration of target compounds detected per sample seems to correlate somewhat with the percentage of streamflow contributed by sewage treatment plants, indicating, that the likely primary source for many of these compounds is effluent from the wastewater treatment process.

Utilizing spatial information from a geographical information system (GIS), distance information from end of pipe point source discharge can be determined. This information is presented in the top graphic in Figure 3. This graph shows the distance to the nearest upstream sewage treatment plant discharge for each of the 30 sampling locations; sites with no apparent upstream discharge are indicated in red. As we move across the bottom graph from left to right, the total concentration (circles) decrease and the total number of organic contaminants (triangles) decreases significantly.

These results indicate that distance from the point source discharge is a factor that effects both the concentration and the number of compounds detected. Contaminants may also be influenced by the hydrodynamics of the system, some type of chemical or microbial degradation and/or adsorption process in the environment. Nonetheless, the continuous discharge of effluent into streams results in continuous exposure for aquatic organisms and humans.

Drinking Water Treatment Plant Investigation: Part of the preliminary assessment of water treatment efficiency is presented in Figure 4. Figure 4 shows the concentrations

Figure 3. Total concentrations and number of compounds in increasing distance to nearest upstream STP discharge

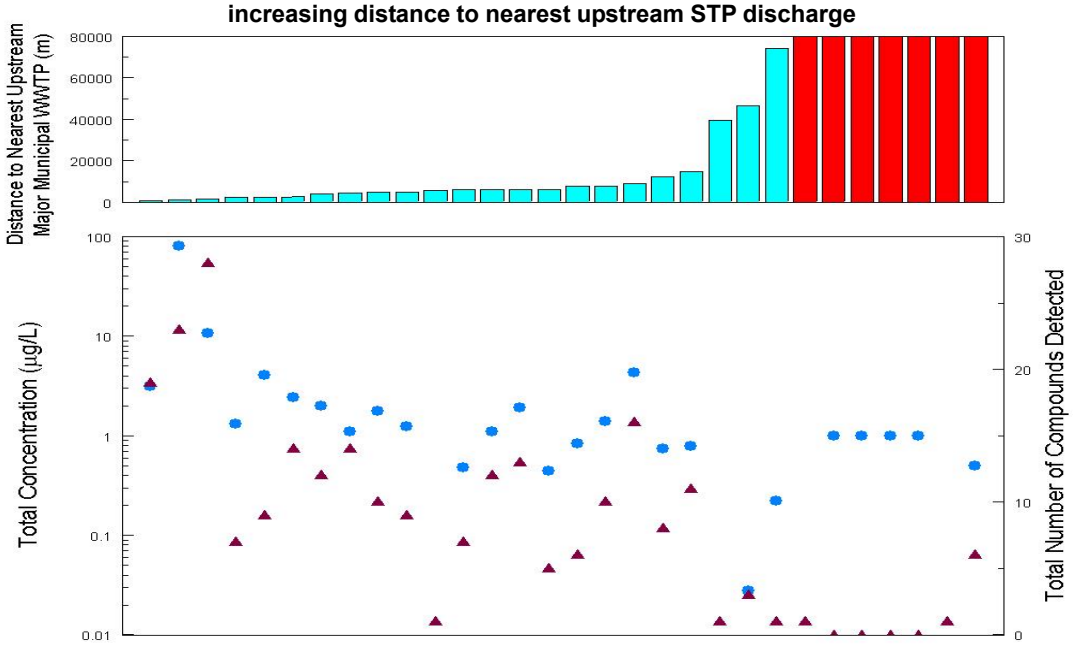
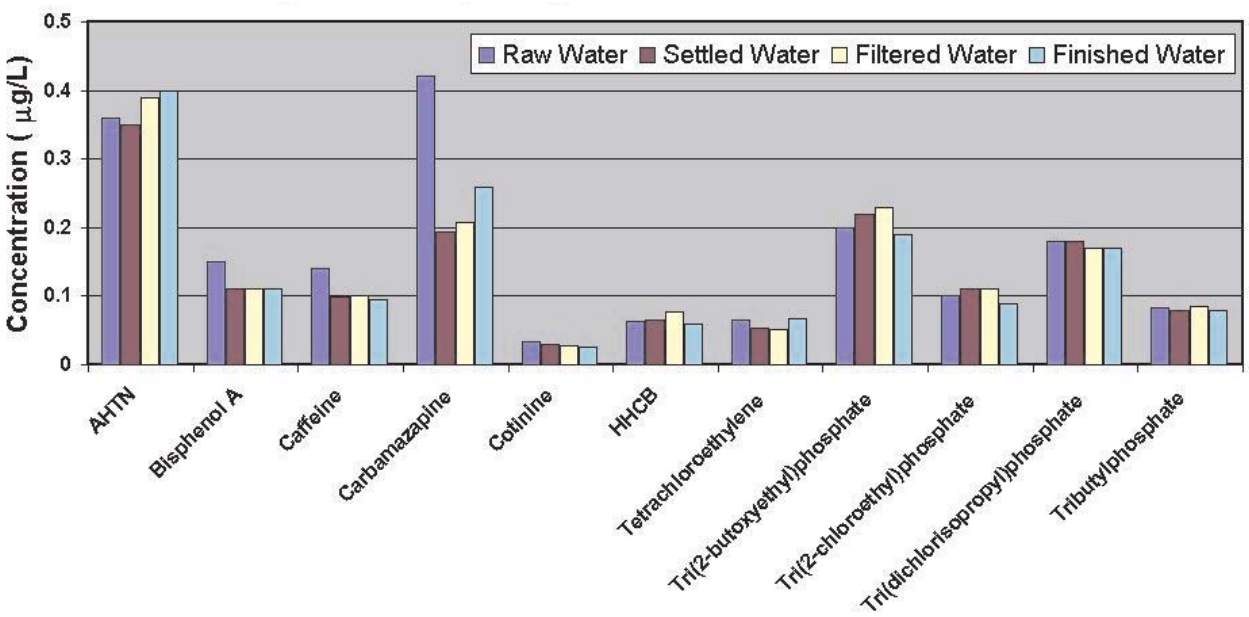


Figure 4. Concentration of select compounds in raw, settled, filtered, and finished water.



of 11 contaminants as they move through the treatment process. Tetrachloroethylene is a New Jersey regulated contaminant with a maximum contaminant level (MCL) of 1 part-per-billion (ppb). The level detected in this research project was well below the MCL at approximately 0.05 ppb.

Discussion and Conclusions

The Unregulated Contaminant Monitoring Rule, which is part of the Federal Safe Drinking Water Act, directs states to develop sampling plans to identify contaminants of emerging concern that may merit future regulatory consideration as part of the USEPA's Candidate Contaminant List (CCL) process. In New Jersey there are three considerations used for state drinking water regulations to protect public health; 1) human health and risk assessment; 2) analytical capability; and 3) availability of treatment technology. The human health effects of these unregulated chemicals are unknown. The preliminary analytical data indicates their presence at extremely low levels in the raw and finished drinking water.

Utilizing advanced analytical techniques to identify suspected organic wastewater contaminants is a necessary first step in determining the vulnerability of source water. These analytical tools provide a glimpse into the trace level organic background matrix and are a measure of human impact to the overall source water quality. The analytical methods provide the sensitivity and selectivity needed to assess water treatment limitations at these low concentrations. Determining the hydrodynamics of the area under study is critical to understand the contribution from wastewater facilities so that point source impact can be assessed.

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Prepared By

[1]R. Lee Lippincott Ph.D., New Jersey Department of Environmental Protection, Division of Science, Research and Technology

Principal Investigator

[2]Paul Stackelberg, U.S. Geological Survey, Water Resources Division, New Jersey District

STATE OF NEW JERSEY
James E. McGreevey, Governor

Department of Environmental Protection
Bradley M. Campbell, Commissioner

Division of Science, Research & Technology
Dr. Eileen Murphy, Director

Please send comments or requests to:
Division of Science, Research and Technology
P.O.Box 409, Trenton, NJ 08625
Phone: 609 984-6070
Visit the DSRT web site @ www.state.nj.us/dep/dsr

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