RESEARCHING THE ENVIRONMENT AND WOMEN'S HEALTH

Emerging Contaminants in Cape Cod Drinking Water

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Overview

In October 2009, Silent Spring Institute, in collaboration with nine Cape Cod public water suppliers, tested for emerging contaminants in public drinking water supplies to learn more about how septic systems and other sources of groundwater contamination are affecting water quality on the Cape. The emerging contaminants we tested for were pharmaceuticals, hormones, personal care products, herbicides, alkylphenols, flame retardants and perfluorinated chemicals. Samples of untreated water from 20 wells and treated water from 2 distribution systems were tested for over 90 emerging contaminants altogether. Many of the target compounds, including pharmaceuticals, hormones, personal care products, herbicides, flame retardants and perfluorinated chemicals, have been found in other U.S. drinking water supplies.

Overall, a majority of samples tested contained emerging contaminants at parts per trillion levels, indicating that chemicals in household and commercial wastewater can seep from septic systems into groundwater and make their way into drinking water. Several chemicals were detected at levels that approached or exceeded the highest levels found in other studies of U.S. drinking water supplies. While there are no enforceable drinking water standards for these chemicals, health-based guideline values have been developed for three of the detected chemicals, and the levels in all samples fell below these guideline values. However, health-based guidelines are not available for most of the chemicals we detected, and the health effects of exposure to low levels of these types of compounds, especially in complex mixtures, are not yet known. Our results demonstrate widespread impact of wastewater, primarily from septic systems, on Cape drinking water supplies and highlight the need for a comprehensive strategy for protecting Cape Cod drinking water supplies.

Findings

- Three quarters of tested wells, as well as the two distribution systems, contained at least one emerging contaminant. Five wells did not contain detectable levels of any of the emerging contaminants tested.
- Of 92 emerging contaminants, 18 were detected at least once, including pharmaceuticals, an insect repellent, flame retardants and perfluorinated chemicals.
- The two most frequently detected chemicals were an antibiotic, sulfamethoxazole, and a perfluorinated chemical, PFOS, a consumer product additive used in used in stain-resistant and nonstick coatings, as well as in fire-fighting foams.
- In general, samples containing higher levels of nitrate and boron (established indicators of septic system contamination on Cape Cod) and wells located in more highly populated areas tended to have more frequent detections and higher levels of the emerging contaminants.
- While septic systems are likely the primary source of these chemicals, commercial sources also may be important. Two perfluorinated chemicals used in fire-fighting foams and aviation hydraulic fluids were found at relatively high levels in Hyannis wells downgradient of the airport. Additional testing is required to pinpoint the sources of these chemicals.
- In many cases, levels of emerging contaminants in Cape Cod wells were relatively low to moderate compared to the results of previous studies of emerging contaminants in other U.S. drinking water supplies. However, in some instances, the levels we measured were among the highest. In particular, the levels of two pharmaceuticals, sulfamethoxazole and

dilantin, as well as PFOS, were found to equal or exceed the highest levels measured in other studies, except for a few cases of industrial contamination.

The health effects of exposure to low levels of these types of compounds, especially when they occur together in complex mixtures, are not known.

- Enforceable drinking water standards have not been developed for any of the detected chemicals.
- Health based guideline values are available for three of the emerging contaminants that were detected. No samples exceeded the health-based guidelines for these chemicals, although perfluorinated chemicals were detected at levels one-half the lowest guideline value in two samples. Guideline values have not been established for many emerging contaminants.
- Detected levels of emerging contaminants ranged from 0.1 to 100 nanograms per liter (parts per trillion). By comparison, other organic chemicals, such as volatile organic compounds, are typically regulated in drinking water at the parts per billion range (1000 nanograms per liter or higher). For pharmaceuticals, even the highest levels detected in drinking water samples were many orders of magnitude lower than the amount found in a typical dose of a medicine, which is usually higher than 100,000,000 nanograms per day (a typical individual drinks about 1-2 liters water/day). For chemicals associated with household products such as perfluorinated chemicals and flame retardants, direct contact with these products would likely lead to higher levels of exposure.
- However, there are reasons to limit exposures to these chemicals through drinking water. Pharmaceuticals are biologically active in small quantities and are not intended for the general population. Exposures that occur at sensitive developmental stages (for instance, in fetuses and infants) may have effects at lower doses than exposures during other life stages. Furthermore, we have limited understanding of potential health effects of mixtures of pharmaceuticals and other chemicals at low levels.

Conclusions

While the levels of pharmaceuticals, flame retardants, and other emerging contaminants in drinking water are not currently regulated, it is prudent to find ways to prevent discharges from septic systems and treatment plants from impacting drinking water supplies. In order to build on the efforts of many Cape communities to protect drinking water quality, additional measures are needed to reduce the impacts of wastewater on Cape drinking water supplies.

- Better protection of supply wells will require additional measures to prevent contamination in Zone I and Zone II wellhead protection areas, including sewering to eliminate septic system discharges, enforcement of zoning regulations, and land acquisitions to protect open space.
- In order to reduce chemical inputs into water, Cape residents should properly dispose of unused medications and hazardous products, reduce their reliance on household products containing harmful chemicals, maintain septic systems and support local efforts to prevent contamination in wellhead protection areas.

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Introduction

Why did we do this study?

In recent years, traces of pharmaceuticals and other chemicals have been found in drinking water supplies throughout the United States. For example, in 2008 the Associated Press reported that the drinking water of 41 million Americans in 24 major metropolitan areas contained trace levels of pharmaceuticals.[1] In Philadelphia alone, the water contained 17 pharmaceuticals, including pain relievers, anticonvulsants and medications for heart conditions. Contaminants present in wastewater can make their way into drinking water after discharges from septic systems and wastewater treatment plants are released into groundwater, rivers and lakes. Some of the chemicals found in drinking water have been shown to act as endocrine disrupting compounds (EDCs), chemicals that can mimic the behavior of estrogens and other hormones in the body.

Drinking water supplies on Cape Cod are vulnerable to contamination by household wastewater. Chemicals that are not broken down in septic systems can leach into the Cape's shallow unconfined aquifer. The aquifer contains porous sandy soils with low levels of organic matter that lead to relatively fast movement of groundwater and limited breakdown of organic contaminants.[2] A 1994 U.S. Geological Survey (USGS) study estimated that up to 26% of the water pumped from public supply wells originated as discharge from septic systems.[3] In recent decades, the Cape's growing population has put increasing stress on drinking water resources.[4] Previous studies by Silent Spring Institute have found pharmaceuticals, hormones, and other chemicals in groundwater downgradient of septic systems,[5, 6] and a 2005 USGS study found pharmaceuticals and organophosphate flame retardants in several Cape Cod drinking water wells (public, semi-public and private).[7] Silent Spring Institute detected pharmaceuticals and hormones in several Cape Cod ponds, especially those downstream of more densely populated residential areas, suggesting septic systems are a source of these contaminants into groundwater.[8]

Silent Spring Institute has been studying water quality on Cape Cod for over 10 years. Our goal is to understand whether there are environmental factors linked to the Cape's elevated incidence of breast cancer. One of our questions is whether EDCs and other contaminants in drinking water play a role. Previous research has suggested that there may be a link between exposure to certain EDCs and hormonally-active diseases such as breast cancer.[9, 10] As part of Silent Spring Institute's Cape Cod Breast Cancer and Environment Study, an initial analysis used historical nitrate levels in drinking water as a tracer of contaminants from septic system or wastewater treatment plant discharge. This analysis did not show a link between more-impacted drinking water and breast cancer risk.[4] However, nitrate data were not available far into the past and we could not estimate exposure for participants who lived off Cape or used private wells. There have been few direct measurements of EDCs and other contaminants in Cape Cod drinking water supplies. A recent article by scientists at Boston University reported elevated breast cancer risk for women in the 1980s and early 1990s in Hyannis compared with other Upper Cape areas and associated this increase with contaminants in the Hyannis Water System supply.[11] These contaminants could include wastewater-related chemicals from the wastewater treatment plant in Barnstable, septic system discharges upgradient of the wells, and/or groundwater contaminants from the airport that are known to affect the Maher wells.

The goal of this new study was to measure the levels of pharmaceuticals and personal care products (PPCPs), EDCs and other emerging contaminants in Cape Cod public drinking water supplies. We wanted to know whether chemical levels are higher in wells located in more heavily populated areas and in wells that contain typical markers of wastewater contamination, such as elevated levels of nitrate and boron. The concentrations of emerging contaminants in Cape Cod water supplies were compared to studies of other U.S. drinking water supplies. Our results illustrate the importance of continued efforts to protect the Cape's drinking water supplies, and have implications for decisions about upgrading the Cape's wastewater infrastructure.

Which wells did we test?

We tested untreated (raw) water samples from 20 public drinking water supply wells located throughout Cape Cod. All water suppliers in Barnstable County were provided the opportunity to participate in this study. Of these, the nine participating water districts were: Barnstable Fire District, Brewster Water Department, Buzzards Bay Water District, Centerville/Osterville/ Marstons Mills Water Department, Chatham Water Department, Cotuit Water Department, Dennis Water District, Falmouth Water Department and Hyannis Water System. In addition, samples were collected from the distribution systems of two of these water districts. All water samples were collected in late October 2009 by members of Silent Spring Institute's research staff. We also collected quality assurance/quality control (QA/QC) samples, including blanks and duplicates (see Appendix 3).

In selecting which wells to test, we used nitrate concentrations over the past 5 years and the level of residential development in well recharge areas as indications of wastewater impact. A well's recharge area is the area of land that potentially contributes water to that well. We prioritized wells that were most likely to be affected by wastewater; however, to get a sense of the range of impacts, we also included some wells with low to moderate levels of nitrate and some wells located in less populated areas.

We are grateful to the participating water districts for their voluntary collaboration in this project. Public water suppliers are not required to test for any of the emerging contaminants that we studied, and their participation demonstrates their commitment to learning about the condition of their water supply and their leadership in protecting water quality in the future.

What did we test for?

Based on previous studies of surface water, groundwater and drinking water on Cape Cod and throughout the U.S., we developed an initial list of chemicals that had been most frequently detected. We were particularly interested in chemicals thought to be endocrine disruptors. We used this initial list to evaluate the capabilities of several commercial laboratories and subsequently to select our final list of chemicals.

Overall, we tested for 92 emerging contaminants, including:

- 53 pharmaceutically-active compounds (over-the-counter and prescription drugs, caffeine, nicotine, and others)
- 8 hormones (naturally-occurring and synthetic)
- 4 personal care product ingredients (DEET, triclosan, 2 musk fragrances)
- 2 perfluorinated chemicals (surfactants used in non-stick and stain resistant consumer products and in industrial products)
- 5 herbicides (lawn care)
- 4 alkylphenols (breakdown products of some detergent compounds)

- 16 organophosphate flame retardants (used in many household products)

Appendix 2 provides a complete list of chemicals.

Water samples were also tested for nitrate and boron. These two chemicals occur naturally in Cape Cod groundwater at low levels, but high levels of nitrate and boron are indicative of contamination from septic systems or wastewater treatment plants. We analyzed these two chemicals primarily to investigate whether they could be useful indicators for predicting the presence of emerging contaminants. No samples exceeded the drinking water standard for nitrate (10 mg/L), and all samples were at least 100 times lower than the U.S. Environmental Protection Agency's lifetime health advisory level for boron (5 mg/L).

Chemical analyses were performed at two commercial laboratories that have the analytical capabilities to measure these types of chemicals at the parts per trillion levels typically found in drinking water. One part per trillion (ppt) is equivalent to one nanogram per liter (ng/L), or 0.0000001 milligrams per liter (mg/L). Laboratory reporting limits (the lowest concentration that we could measure) ranged from 0.1 ng/L to 1500 ng/L (0.0000001 to 0.0015 mg/L).

Results and interpretation

What did we find?

Many Cape Cod public water supplies are impacted by emerging contaminants. In most cases, the likely source of these contaminants is septic systems. Of the 20 wells and 2 distribution systems that we tested, 15 wells and both distribution systems had detectable levels of at least one of the emerging contaminants that we measured (Figure 1). Our results show a wide range in the number of emerging contaminants detected in each sample and in the measured levels of these chemicals. Table 1 provides a summary of the chemicals that were detected in at least one sample, and Appendix 1 provides the results for each individual sample.

- Of the 92 emerging contaminants that we tested for, 18 were detected in at least one water sample. These included 9 pharmaceuticals, 1 insect repellent, 2 perfluorinated chemicals, 1 alkylphenol and 5 organophosphate flame retardants. The majority (84%) of the 92 chemicals were not detected in any samples. See Appendix 2 for a complete list of chemicals included in this study.

- The number of emerging contaminants that were detected in a single sample varied from zero to 12 (Figure 2).
  - 5 samples had no detectable emerging contaminants
  - 7 samples had detectable levels of one emerging contaminant
  - 6 samples had detectable levels of 2 to 5 emerging contaminants
  - 4 samples had detectable levels of 7 to 12 emerging contaminants

In general, samples containing higher levels of nitrate and boron and wells located in more highly populated areas tended to have more frequent detections and higher levels of emerging contaminants. Tables 2, 3 and 4 and Figure 3 show the average number of chemicals detected according to nitrate and boron levels and residential density in well recharge areas.

- The average number of chemicals increased with the level of nitrate. On average, low nitrate wells contained 0.6 chemicals, moderate nitrate wells contained 3.1 chemicals, and high nitrate wells contained 6.5 chemicals.

- The average number of chemicals detected in samples containing higher levels of boron (4.4 chemicals) was around 11 times higher than in samples containing lower levels of boron (0.4 chemicals).

- In wells located in more heavily populated areas (around 20% of recharge area or more occupied by residential development), the average number of chemicals detected in each sample was 1.8 times higher (3.4 versus 1.9) than in wells located in less heavily populated areas (around 10% of recharge area or less occupied by residential development). Overall, nitrate and boron appeared to be better markers of impact than the extent of residential development alone.

- The two most frequently detected chemicals were sulfamethoxazole, an antibiotic, and the perfluorinated chemical PFOS. Sulfamethoxazole was detected in 1 of 7 (14%) low nitrate samples and in 12 of 15 (80%) moderate and high nitrate samples. PFOS was detected in 1 of 7 (14%) low nitrate samples and in 8 of 15 (53%) moderate and high nitrate samples.

- Nine pharmaceuticals were detected in at least one sample. On average, the sum of the detected concentrations for these 9 pharmaceuticals was <0.1 ng/L in low nitrate wells, 13 ng/L in moderate nitrate samples, and 87 ng/L in high nitrate samples (Figure 4).

In general, Cape Cod drinking water supplies did not contain detectable levels of hormones and alkylphenols, two classes of endocrine disrupting compounds that Silent Spring Institute previously found in Cape Cod ponds and in groundwater impacted by septic system discharge. Because of our interest in factors that might affect breast cancer on Cape Cod, Silent Spring Institute has focused our research on identifying exposure to hormones and endocrine disruptors. We did not find detectable levels of any of the 8 hormones that we tested for, and we detected trace levels of one weakly estrogenic alkylphenol, nonylphenol, in just one sample. These findings are in contrast to previous work by Silent Spring Institute and others on Cape Cod[2, 5, 6, 8] showing the persistence of these types of chemicals in Cape groundwater, although some studies on the Cape have suggested bacterial breakdown of hormones and nonylphenol can occur as they move through groundwater.[12] We will continue to look for these chemicals in private well testing on Cape Cod, beginning in the fall of 2010, to gain a better understanding of their fate in Cape Cod groundwater.

Among the chemicals that we did detect, the perfluorinated chemical PFOA and several of the organophosphate flame retardants are suspected carcinogens and the perfluorinated chemicals are endocrine disruptors that affect thyroid hormones and cholesterol metabolism. Laboratory studies show that PFOA, a perfluorinated chemical, alters mammary gland development and causes tumors in the mammary gland and other organs. Other health effects, such as neurotoxicity, have been observed from some of the organophosphate flame retardants we detected (see Table 5b). These effects have been seen in animal studies at much higher levels of exposure than are likely from drinking tap water, and the levels we detected are below available health-based guidelines.

For many chemicals, including most of the chemicals we detected, there is limited information on their ability to act as endocrine disruptors. In the past, chemicals have not routinely been screened for their ability to act as endocrine disruptors. As the importance of endocrine disruption is becoming more widely recognized, better screening tools are needed to identify which chemicals have the potential to act as EDCs.

While septic systems are likely the primary source of these chemicals, some other types of sources also may be important. In particular, the Barnstable Municipal Airport may be a source of two perfluorinated chemicals. The highest concentrations of two perfluorinated chemicals, PFOS and PFOA, were found in samples collected from two wells and a distribution system known to be contaminated by a plume of petroleum hydrocarbons and volatile organic compounds from the Barnstable Municipal Airport. Treatment of water from these two wells effectively reduces the levels of regulated contaminants, but is not effective for chemicals with low volatility, such as PFOS and PFOA. Studies in other locations have shown that groundwater downgradient of airports can be contaminated by PFOS and PFOA, which are found in some fire-fighting foams.[13] Discharges from the wastewater treatment plant in Barnstable contribute water to the Hyannisport well, as do a large number of septic systems.[3] Construction activities may also be a source of certain organophosphate flame retardants.[14]

How do Cape Cod results compare with health guidelines and other studies?

We evaluated potential health effects by comparing levels of emerging contaminants detected on Cape Cod with health-based guidelines and with the results of other U.S. drinking water studies. There are currently no federal or Massachusetts drinking water regulations for any of the emerging contaminants that we detected. Water suppliers are not required to test for any of the organic compounds in our study.

In several cases, state and federal agencies have developed health-based guidelines, which incorporate information about health effects from animal and human studies. These guideline values are designed to indicate levels in drinking water that pose little to no health risk, although it is possible that there can be health effects below these guideline values because they may not adequately protect sensitive populations or account for exposures to many chemicals together. For most of the chemicals we detected, there are no health-based guidelines, so we also compared Cape Cod results with the results of previous measurements of emerging contaminants in untreated and treated drinking water throughout the U.S.

Health-based drinking water guidelines are available for several of the organic chemicals detected in Cape public drinking water. No samples exceeded the health-based guidelines for these chemicals. For the two perfluorinated compounds and one of the organophosphate flame retardants we detected, federal and regional U.S. Environmental Protection Agency (EPA) offices[15, 16] and several states[17, 18] have developed health-based guidelines, which are not enforced but provide a recommended level designed to protect human health.

- For PFOA, the highest level we detected (22 ng/L) was about one-half of the New Jersey Department of Environmental Protection's health-based guideline of 40 ng/L for PFOA, and was around 15 times lower than the Minnesota Department of Health's health-based value of 300 ng/L and EPA's short-term provisional health advisory value of 400 ng/L.
- For PFOS, the highest level we detected (110 ng/L) was about one-half of the EPA's short-term provisional health advisory value of 200 ng/L, and was about one-third of the Minnesota Department of Health's health-based value of 300 ng/L for PFOS.
- For TCEP, the highest level we detected (20 ng/L) was more than 100 times lower than EPA Region 9's drinking water screening level of 3,400 ng/L.

Compared to previous studies of emerging contaminants in drinking water supplies, in many cases the levels measured in Cape Cod wells were in the low to middle part of the range in levels measured in previous studies. However, in some instances, the levels we measured were among the highest. In particular, the levels of two pharmaceuticals and one perfluorinated chemical were found to equal or exceed the highest levels measured in other studies (see Table 1). In particular, the level of sulfamethoxazole, an antibiotic, in one sample was higher than the maximum in two other U.S. studies and the same as the maximum level in a third. In addition, two samples contained levels of dilantin, an epilepsy medication, that were higher than the maximum concentration found in a survey of 19 U.S. water supplies, many of which were thought to be impacted by wastewater. The levels of PFOS in one well and one distribution system exceeded the highest levels found in two other drinking water studies, including one that sampled wells thought to be impacted by a facilities that produced or handled perfluorinated chemicals, although they were lower than the levels found in areas known to be highly impacted by PFOS production.

The health effects of exposure to low levels of organic wastewater compounds, especially in complex mixtures, are not known. While the presence of a chemical alone does not necessarily mean that it is harmful, anticipating the effects of low level exposures to chemicals such as pharmaceuticals and EDCs in humans is difficult.

- Chemical levels that we detected were well below 1000 ng/L (1 part per billion, or ppb). Other organic chemicals, such as volatile organic compounds, are typically regulated in drinking water above 1000 ng/L. For pharmaceuticals, even the highest levels detected in well water samples were many orders of magnitude lower than the amounts found in a typical dose of a medicine. For instance, for sulfamethoxazole, a person would need to drink 80 million 8-oz cups of water from the well with our highest detected level in order to ingest the amount in a single daily dose. For chemicals associated with household products such as perfluorinated chemicals and organophosphate flame retardants, direct contact with products containing these chemicals would likely lead to much higher levels of exposure.

- However, there are reasons to limit exposures to these chemicals through drinking water. In particular, exposures that occur at sensitive developmental stages (for instance, in fetuses and infants) may have effects at lower doses than during other life stages. Furthermore, while people are exposed to complex mixtures of chemicals, most studies focus on one chemical at a time, so we have limited understanding of the potential health effects of mixtures of pharmaceuticals and other chemicals at low levels. Some preliminary studies using human cell lines have shown that mixtures of low levels of pharmaceuticals can cause effects that were not observed for these chemicals individually.[19] In addition, some pharmaceuticals can be biologically active (for instance, in fish) at very low levels -- even well below 1 ppb -- and often have side effects that are not taken into account when considering only intended doses. More information about the effects of some of these chemicals in laboratory animal studies can be found in Table 4.

Future drinking water regulations may include some of the chemicals detected in Cape drinking water supplies. The EPA currently regulates around 90 contaminants in drinking water. In the future, the EPA may include more emerging contaminants in their list of regulated chemicals in drinking water. The EPA's most recent Candidate Contaminant List (the list of chemicals being considered for future regulations) included 2 chemicals that we detected, PFOA and PFOS, as well as several hormones and an antibiotic. Drinking water regulations are established after extensive scientific studies to understand the health effects of chemicals and the levels that may be harmful. Much of this information is lacking for many emerging contaminants.

Keep in mind

Drinking water is just one pathway by which people are exposed to chemicals. Perfluorinated chemicals and organophosphate flame retardants are often found in clothing, furniture and other household products, so touching these products directly or inhaling household dust and air may potentially be much larger routes of exposure. In addition, exposure to perfluorinated compounds can occur through eating food that has come into contact with cookware and packaging containing PFOA. Based on studies in other communities, drinking water from the well with the highest PFOA concentration would be expected to increase one's total PFOA exposure by about 50%.[17] In general, household exposures to these types of chemicals are not well understood; in fact, one of Silent Spring Institute's research aims is to measure exposures to these types of chemicals and others within people's homes.

The levels of emerging contaminants in untreated well water samples may not represent the levels in tap water. Tap water in Cape Cod water distribution systems is a mixture of water from all the wells that provide water for that district. Because we chose to test mostly wells that were likely to be impacted by wastewater, the chemical levels in the wells we tested may be higher than the average levels in the distribution systems. All water districts adjust the pH of their water to prevent corrosion, and some water districts add chlorine as a disinfectant before water enters the distribution system. Previous studies have shown that chlorine can react with some of these chemicals,[20] reducing their levels but potentially leading to the formation of new, secondary chemicals, some of which are known to be harmful.

What you can do

If you are concerned about organic contaminants in your drinking water, you may wish to install a home water filtration system. In general, filtration products that contain a solid carbon block filter have been shown to effectively reduce levels of many types of organic contaminants, although results will be different for each individual chemical. Filter pitchers that contain granular activated carbon will also remove organic contaminants. Some water filters are independently tested for dozens of organic contaminants to demonstrate their effectiveness, although the specific emerging contaminants that we measured are not routinely tested. However, many water suppliers do not recommend home filtration systems. Improper use, for example not changing filters frequently enough, can lead to pathogens and other contaminants being released into the filtered water.

While some people drink bottled water as an alternative to tap water, the levels of emerging contaminants in bottled drinking water are not known, and regulatory monitoring of bottled water is less extensive than for public water supplies. There is no routine testing for emerging contaminants in bottled water and there are no published reports of measurements of PPCPs, EDCs and other chemicals in bottled water. While some bottled water comes from pristine water sources, some is simply tap water that may or may not be treated to remove chemicals. Furthermore, bottled water sits for extended periods of time in plastic containers, which may release chemicals into the water. Finally, the production of bottled water is far more resource-intensive than the sustainable use of local groundwater.

Ultimately, reducing the levels of pollutants in drinking water will require a concerted effort to reduce the amount of chemicals released into the Cape's groundwater aquifer and increased measures to protect drinking water supplies. Here are some steps you can take:

- Properly dispose of unused and expired medications. With the exception of a small number of controlled substances, most medications should not be flushed. The U.S. FDA provides guidelines (see "Additional Information" section) for consumers on proper disposal of medicines. Ask your pharmacy or town Board of Health about local programs for unwanted medications, and encourage local officials to create and publicize such programs. To reduce the potential for unwanted medications in your home, buy only what you will use and ask your doctor for trial sizes of new medications.

- Consider purchasing household products, clothing and furnishings made from natural fibers and without chemical additives such as dyes, stain-resistant coatings, antimicrobials, flame retardants, and fragrances. Avoid using harmful chemicals in your garden and lawn.

- Avoid dumping hazardous chemicals in your sink, on the ground or into storm sewers. Ask your town for information about hazardous waste collection days.

- Have your septic system regularly inspected and pumped. The Massachusetts Department of Environmental Protection (MassDEP) recommends pumping septic systems every 1-3 years.

- Support efforts to protect the Cape's shallow sole source aquifer from wastewater contamination, especially from septic systems. Installing sewers in public well recharge zones (also known as Wellhead Protection Areas or MassDEP Zone IIs) will prevent contaminants in septic system discharges from getting into drinking water. Wells with greater evidence of impacts could be considered priorities for Zone II protection efforts or reduced use.

- Support land conservation and efforts to limit development near public supply wells, for example through land trusts and programs like the Cape Cod Land Bank. Support enforcement of state and local laws that prohibit or limit potentially detrimental land uses within public well recharge zones.

- Support efforts to promote more thorough testing of chemicals before they go into production. Chemicals are present in wastewater because they are present in consumer products. However, many of these chemicals have not been thoroughly tested to understand their health effects.

If you want more information, contact your local water district or Silent Spring Institute at info@silentspring.org or call 617-332-4288.

Next steps

Compared to public wells, private wells may be even more vulnerable to septic system impacts. Past work has shown higher nitrate levels in private wells than in public wells. Silent Spring Institute plans to test for a similar list of emerging contaminants in 20 Cape Cod private wells in fall 2010.

While septic systems are likely the primary source of emerging contaminants in Cape drinking water supplies, our results showed that there may be other types of sources. Additional testing in the vicinity of the airport may help identify sources of the elevated levels of perfluorinated chemicals found in two of the Hyannis wells.

Previous Silent Spring Institute research demonstrated the presence of hormones and pharmaceuticals in Cape Cod ponds due to high density of septic systems upgradient of the ponds. Additional studies of fish populations in Cape ponds, which are fed almost entirely by groundwater, could evaluate whether these chemicals are causing endocrine disruption in these fish populations.

Additional information

Silent Spring Institute

- Cape Cod water studies: http://silentspring.org/our-research/water-research

General information about PPCPs:

- U.S. Environmental Protection Agency: http://www.epa.gov/ppcp
- MA Dept. of Environmental Protection: http://www.mass.gov/dep/toxics/stypes/ppcpedc.htm
- U.S. Geological Survey: http://toxics.usgs.gov/regional/emc/

Associated Press series on pharmaceuticals in drinking water

- Main story: http://hosted.ap.org/specials/interactives/pharmawater_site/
- Results for 28 cities: http://hosted.ap.org/specials/interactives/pharmawater_site/

Proper disposal of medications:

- White House Office of National Drug Control Policy: http://ww.whitehousedrugpolicy.gov/publications/pdf/prescrip_disposal.pdf
- U.S. Food and Drug Administration (FDA): http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm101653.htm

Chemical testing policies:

- Safer Chemicals, Healthy Families: http://www.saferchemicals.org

General information about the Cape Cod Aquifer:

- http://www.capecodgroundwater.org/Cape_Cod_Aquifer.html

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TABLES AND FIGURES

Table 1. Summary of emerging contaminants detected in 20 Cape Cod public supply wells and 2 distribution systems.

Chemical name	Reporting limit (ng/L)	Number of times detected (out of 22)	Maximum level detected (ng/L)	Health-based guideline values* (ng/L)	Maximum levels found in other drinking water studies (ng/L)	
					Raw (untreated)	Finished (treated)
Pharmaceuticals and personal care products						
Antipyrine	1	1 (5%)	1	n	n	n
Atenolol	0.1	1 (5%)	0.8	n	36[b]	18[b]
Carbamazepine	1	6 (27%)	72	n	4.7[i], 51[b], 190[c]	18[b]
DEET	5	1 (5%)	6	n	74[i], 110[b], 410[c]	93[b]
Dilantin	2	5 (23%)	66	n	29[b]	19[b]
Gemfibrozil	0.5	1 (5%)	1.2	n	<13[i], <15[c], 24[b]	2.1[b]
Meprobamate	0.1	5 (23%)	5.4	n	73[b]	42[b]
Sulfamethizole	1	1 (5%)	1	n	<50[c]	n
Sulfamethoxazole	0.1	13 (59%)	113	n	>23[c], 58[i], 110[b]	3[b]
Trimethoprim	0.1	1 (5%)	0.7	n	<13[i], 11[b], 20[c]	<0.25[b]
Organophosphate flame retardants						
TEP	10	6 (27%)	20	n	1[a]	23[h]
TCPP	10	5 (23%)	40	n	720[b]	510[b]
TDCPP	10	1 (5%)	10	n	<500[c], 170[d], 240[i]	23[h], 5500[d]
TBEP	50	1 (5%)	50	n	300[i], 400[d], 960[c]	560[d], 560[h]
TCEP	20	3 (14%)	20	3400	<500[c], 110[i], 260[d], 530[b]	220[d], 470[b], 52[h]
Perfluorinated chemicals						
PFOA	10	3 (14%)	22	40, 300, 400	2.9[e], 31[g], 35[f]	2.9[e], 30[g], 39[f]
PFOS	1	9 (41%)	110	200, 300	8.6[e], 19[f], 29[g]	9.7[e], 14[f], 57[g]
Alkylphenols (9 samples tested)						
4-nonylphenol	250	1 of 9 (11%)	20 J	n	<5000[i], 130[b], >5000[c]	100[b]

Definitions and abbreviations

- Reporting limit = The lowest level of a chemical that can be quantified using a chemical testing method
- ng/L = nanograms per liter, also parts per trillion. A nanogram is one-trillionth of one gram.
- J = chemical was detected above the detection limit but below the reporting limit. This concentration should be considered an estimate.
- n = no data available
- TEP = triethyl phosphate
  TCPP = tris(chloropropyl) phosphate
  TDCPP = tris(1,3-dichloro-2-propyl) phosphate
  TBEP = tris(2-butoxyethyl) phosphate
  TCEP = tris(2-chloroethyl) phosphate
  PFOA = perfluorooctanoic acid
  PFOS = perfluorooctane sulfonate
- n = no data available
- * = see text for references for health-based guideline values

References for Table 1

[a] **Bacaloni A and others, 2008**. Occurrence of organophosphorus flame retardant and plasticizers in three volcanic lakes of central Italy. *Environmental Science & Technology.* 42:1898-1903.

This study tested water from three lakes and nine groundwater wells in Italy for a range of organophosphate flame retardants. All of the locations tested in this study were remote, with possible impacts from nearby small towns, agricultural activities, and tourism. Only the results for TEP in groundwater are presented for these comparisons.

[b] **Benotti MJ and others, 2009.** Pharmaceuticals and endocrine disrupting compounds in U.S. drinking water. *Environmental Science & Technology*. 43:597-603.

This study included 19 large drinking water treatment plants serving 28 million people, including 18 surface water sources and 1 groundwater source. Raw (untreated), finished (treated) and distribution system samples were tested for 51 organic wastewater compounds.

[c] **Focazio MJ and others, 2008.** A national reconnaissance for pharmaceuticals and other organic wastewater contaminants in the United States--II) Untreated drinking water sources. *Science of the Total Environment*. 402:201-216.

This study tested 74 water supplies that ranged in size from very small to very large and included 49 surface water sources and 25 groundwater sources. Samples were tested for 100 organic wastewater compounds. This study included results for raw water samples only.

[d] **Kingsbury JA and others, 2008.** *Anthropogenic organic compounds in source water of nine community water systems that withdraw from streams, 2002–05*. U.S. Geological Survey Scientific Investigations Report 2008–5208.

This study included multiple samples collected from 9 water supplies drawing upon surface water sources. These supplies served 3,000 to 2,000,000 people. Samples were tested for 134 organic wastewater chemicals. This study included results for raw and treated water samples.

[e] **Loos R and others, 2007**. Polar herbicides, pharmaceutical products, perfluorooctanesulfonate (PFOS), perfluorooctanoate (PFOA), and nonylphenol and its carboxylates and ethoxylates in surface and tap waters around Lake Maggiore in Northern Italy. *Analytical and Bioanalytical Chemistry*. 387:1469-1478

This study tested raw water samples from eight locations in a lake in Italy that provides drinking water, as well as samples from the lake's tributary streams and finished tap water from nearby cities. The lake is downstream of domestic and industrial activities, although no known production facilities are mentioned. These samples were tested for 30 organic wastewater compounds. Results are presented for lake samples only.

[f] **NJ DEP, Division of Water Supply, 2007.** *Determination of Perfluorooctanic Acid (PFOA) in Aqueous Samples: Final Report.* Trenton, NJ.

This study measured PFOS and PFOA in raw and finished drinking water samples from 23 systems, at least one in nearly every New Jersey county. Of the 22 drinking water samples reported here, 10 were from locations close to facilities that manufactured or handled PFOS or PFOA, one was intended as an unimpacted control, and the remainder were from areas with previous detections of high levels of organics in drinking water.

[g] **Quiñones O and SA Snyder, 2009**. Occurrence of perfluoroalkyl carboxylates and sulfonates in drinking water utilities and related waters from the United States. *Environmental Science & Technology*. 43:9089-9095.

This study examined eight perfluorinated chemicals at seven drinking water treatment plants with varying levels of wastewater impact. While only results for raw water samples were used for comparison to Cape water supplies, the study also included treated water samples. For each treatment plant, multiple samples were collected over the course of a year, which were averaged in these comparisons.

[h] **Williams DT and others, 1981**. A national survey of tri(haloalkyl)-, trialkyl-, and triarylphosphates in Canadian drinking water. Bulletin of Environmental Contamination and Toxicology. 27:450-457.

This study tested finished drinking water in 29 cities and towns throughout Canada in summer and winter.

[i] **Zimmerman MJ, 2005.** *Occurrence of Organic Wastewater Contaminants, Pharmaceuticals, and Personal Care Products in Selected Water Supplies, Cape Cod, Massachusetts, June 2004*. USGS Open-file Report 2005-1206.

This study tested 8 wells on Cape Cod: 3 public, one semi-public and 4 private wells. Samples were tested for 85 organic wastewater compounds. Results are provided for raw water samples only. This study also included measurements of these chemicals in monitoring wells impacted by a wastewater treatment plant, in a septic system leachfield and in a recirculating sand filter system.

Table 2. The average number of chemicals detected in low, medium and high nitrate samples. The range of values is provided in parentheses. Groundwater with nitrate less than 0.5 mg/L is considered near background quality, and groundwater with nitrate between 0.5 and 2.5 mg/L is considered moderately impacted.[21]

Nitrate	**number of samples**	**average no. of compounds (range)**
low (< 0.5 mg/L)	7	0.6 (0 to 3)
medium (0.5 to 2.5 mg/L)	11	3.1 (1 to 8)
high (> 2.5 mg/L)	4	6.5 (1 to 12)

Table 3. The average number of chemicals detected in samples with relatively low and high boron levels. The range of values is provided in parentheses.

Boron	**number of samples**	**average no. of compounds (range)**
low (≤ 10 µg/L)	8	0.4 (0 to 1)
high (> 10 µg/L)	14	4.4 (1 to 12)

Table 4. The average number of chemicals detected in wells located in lower and higher residential density areas. The results are categorized according to the percent of land use in a well's recharge area[a] that is used for residential land use. The range of values is provided in parentheses.

% residential land use in well recharge area	**number of samples**	**average no. of compounds (range)**
low (around 10% or less)	8	1.9 (0 to 5)
high (around 20% or more)	12	3.4 (0 to 12)

[a] A well's recharge area refers to the entire land area that potentially contributes water to that well.

Table 5a. Uses and typical daily doses for the pharmaceuticals detected in Cape Cod public drinking water.

Notes:

Pharmaceuticals are biologically-active chemicals intended for use in targeted populations. Publicly-available toxicity data are currently limited and insufficient as a basis for setting health-based guidelines for the general population.

Pharmaceutical	Major uses	Typical daily dose[a]		Maximum level detected (ng/L)[c]
		milligrams[b]	nanograms	
Antipyrine (phenazone)	Analgesic for relieving pain of ear infections	not applicable		1
Atenolol	Beta blocker	50	50,000,000	0.8
Carbamazepine	Anti-convulsant (treatment for epilepsy), anti-depressant	100	100,000,000	72
Dilantin (phenytoin)	Anti-convulsant	50	50,000,000	66
Gemfibrozil	Lipid regulator (lowers cholesterol)	1,200	1,200,000,000	1.2
Meprobamate	Anti-anxiety	200	200,000,000	5.4
Sulfamethizole	Antibiotic	500	500,000,000	1
Sulfamethoxazole	Antibiotic	400	400,000,000	113
Trimethoprim	Antibiotic	80	80,000,000	0.7

[a] Adult doses unless doses for children are available.
[b] A milligram is 1,000 micrograms, or 1,000,000 nanograms
[c] Drinking water concentrations from this study are reported in nanograms per liter (ng/L). A common assumption for drinking water consumption is 1-2 liters per day.
Source: www.drugs.com

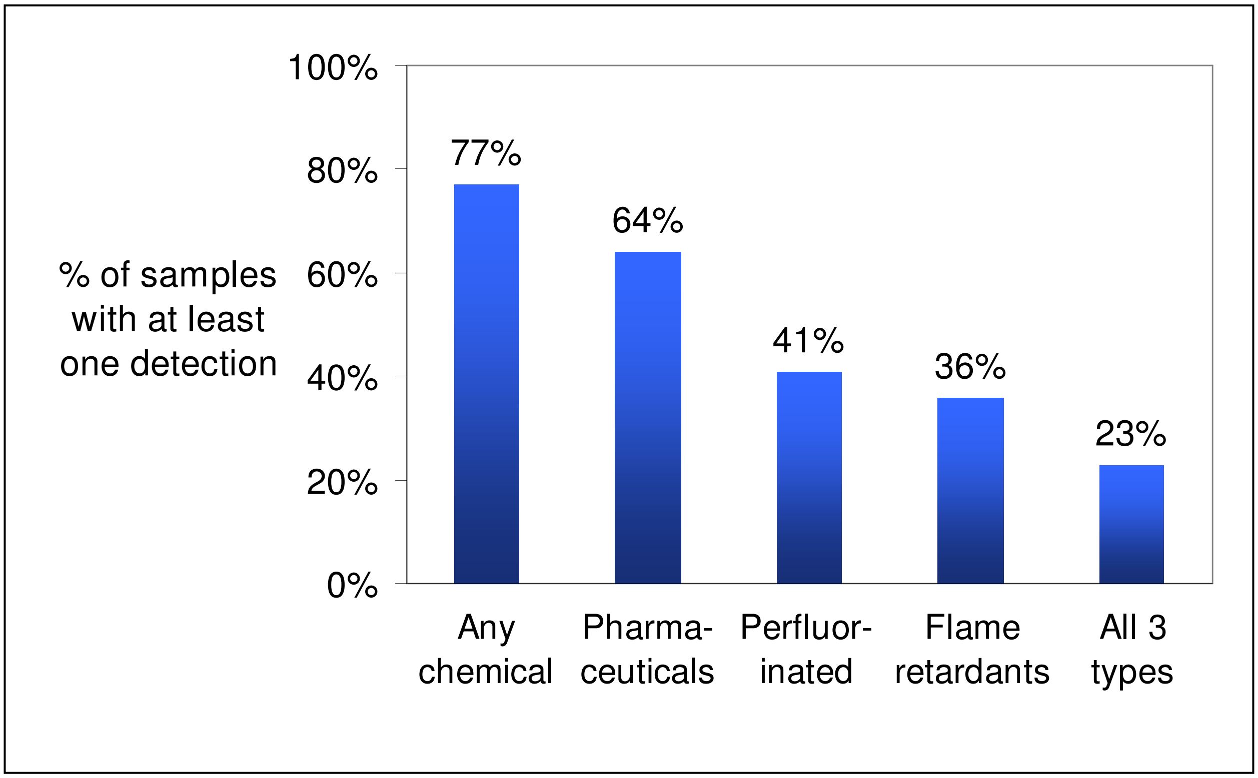
Table 5b. Major uses and health effects[a] (based on laboratory animal studies) of consumer-product chemicals detected in Cape Cod public drinking water. Note that exposure to these chemicals in consumer products is likely much greater than exposure via the detected concentrations in drinking water.

See Table 1 for full chemical names.

Chemical	Health concerns
Perfluorinated chemicals: used in stain resistant and nonstick surfaces in many household products, metal plating industries, fire-fighting foams	
PFOA	Drinking water health advisories of 40-400 ng/L developed by various regulatory agencies based on effects on liver, blood, and immune systems in animal studies. Effects on mammary gland development have been observed, and there is some evidence of carcinogenicity. Effects on cholesterol metabolism and growth and development have also been observed.
PFOS	Drinking water health advisories of 200-300 ng/L developed by various regulatory agencies based on effects on thyroid and liver in animal studies.
Organophosphate flame retardants: used in furniture foam, textiles, and electronics, some organophosphates have non-flame retardant uses as well, for example as plasticizers	
TEP	Possible neurotoxicity; limited data; Proposed DWAL[b] of 700,000 ng/L for leaching from drinking water supply pipes.
TCPP	Structural similarity to probable carcinogens, such as TDCPP
TDCPP	Carcinogenic, neurotoxic, general toxicity; Consumer Product Safety Commission ADI[c] of 5000 ng/kg-day
TBEP	Possible neurotoxicity; liver toxicity
TCEP	Carcinogenic, neurotoxic; EPA Region 9 drinking water screening level 3,400 ng/L.
Alkylphenols: breakdown products of surfactants used in detergents, some alkylphenols (including 4-nonylphenol) are also used as plasticizers	
4-nonylphenol	Weak estrogen mimic; kidney toxicity
Other chemicals	
DEET (insect repellent)	Approved by EPA for application directly to skin; limited evidence of toxicity.

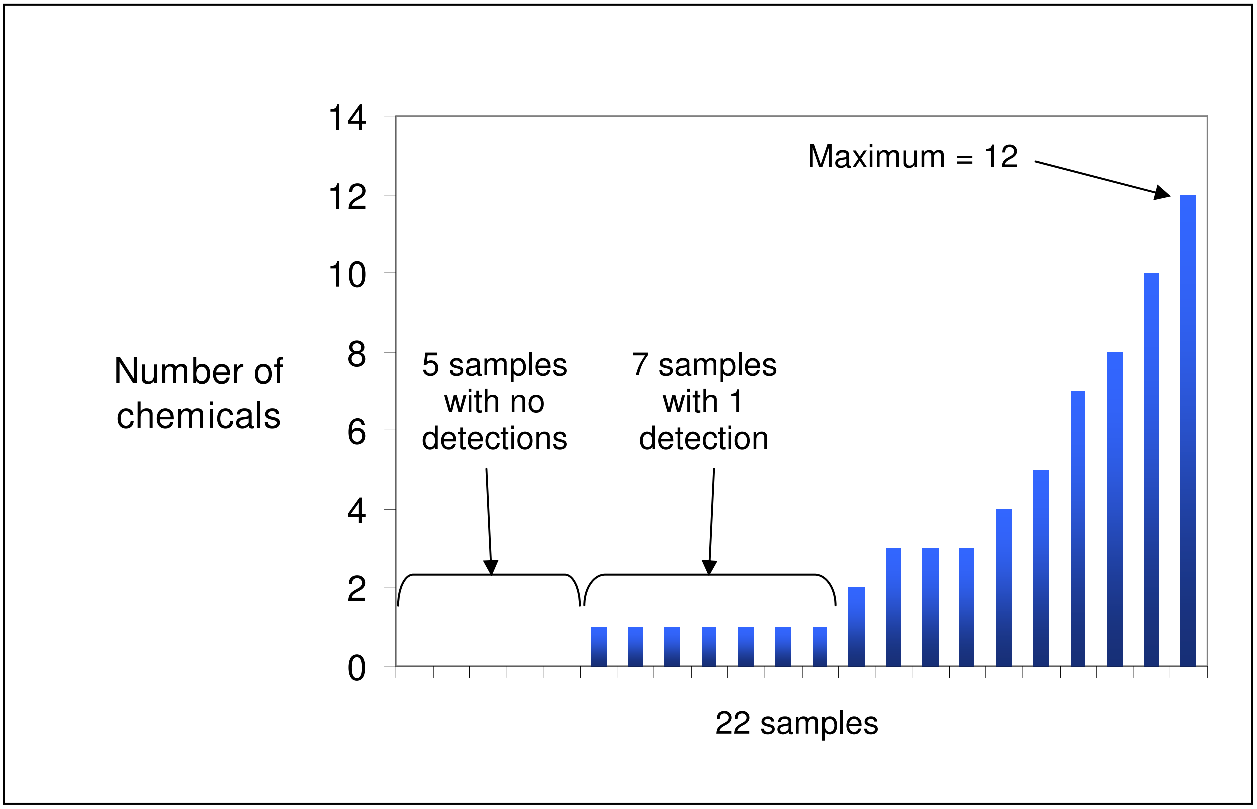
[a] Additional information on the toxicological effects of these chemicals is available from Silent Spring Institute.
[b] DWAL = Drinking water action level for use in water distribution pipes
[c] ADI = Acceptable daily intake, expressed in units of chemical amount per unit body weight per time

Figure 1. Frequency of detection of three categories of emerging contaminants.



Number of drinking water samples (raw and distribution system) that contain at least one emerging contaminant; at least one of chemical classified as a pharmaceutical, organophosphate flame retardant or perfluorinated chemical; and all 3 types of chemicals.

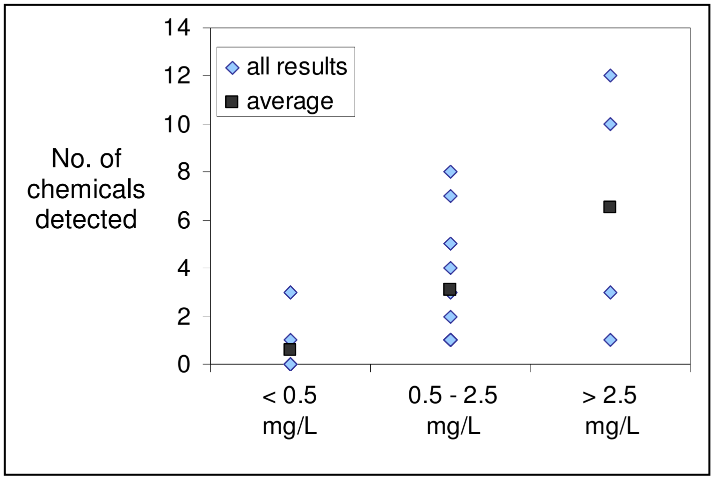
Figure 2. Number of emerging contaminants detected in drinking water samples.



Number of emerging chemicals detected in each of the 20 public supply well samples and 2 distribution system samples.

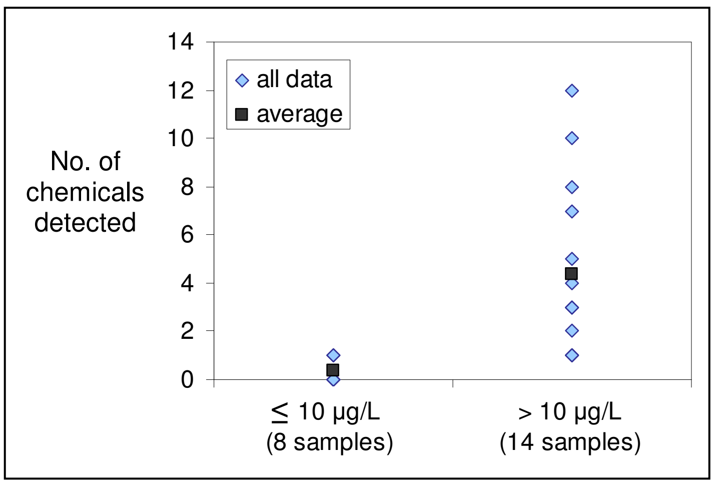
Figure 3. Number of emerging contaminants detected according to levels of nitrate, boron and extent of residential development in well recharge areas.

a) Nitrate



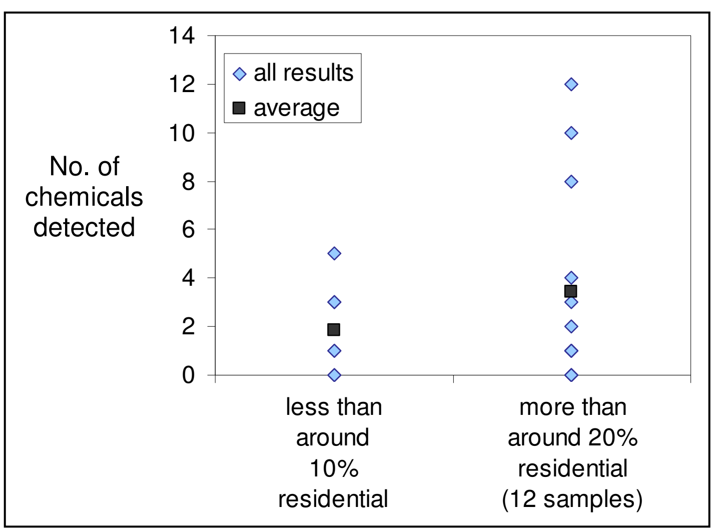
Number of emerging contaminants detected according to levels of nitrate. Groundwater with nitrate less than 0.5 mg/L is considered near background quality, and groundwater with nitrate between 0.5 and 2.5 mg/L is considered moderately impacted.[21]

b) Boron



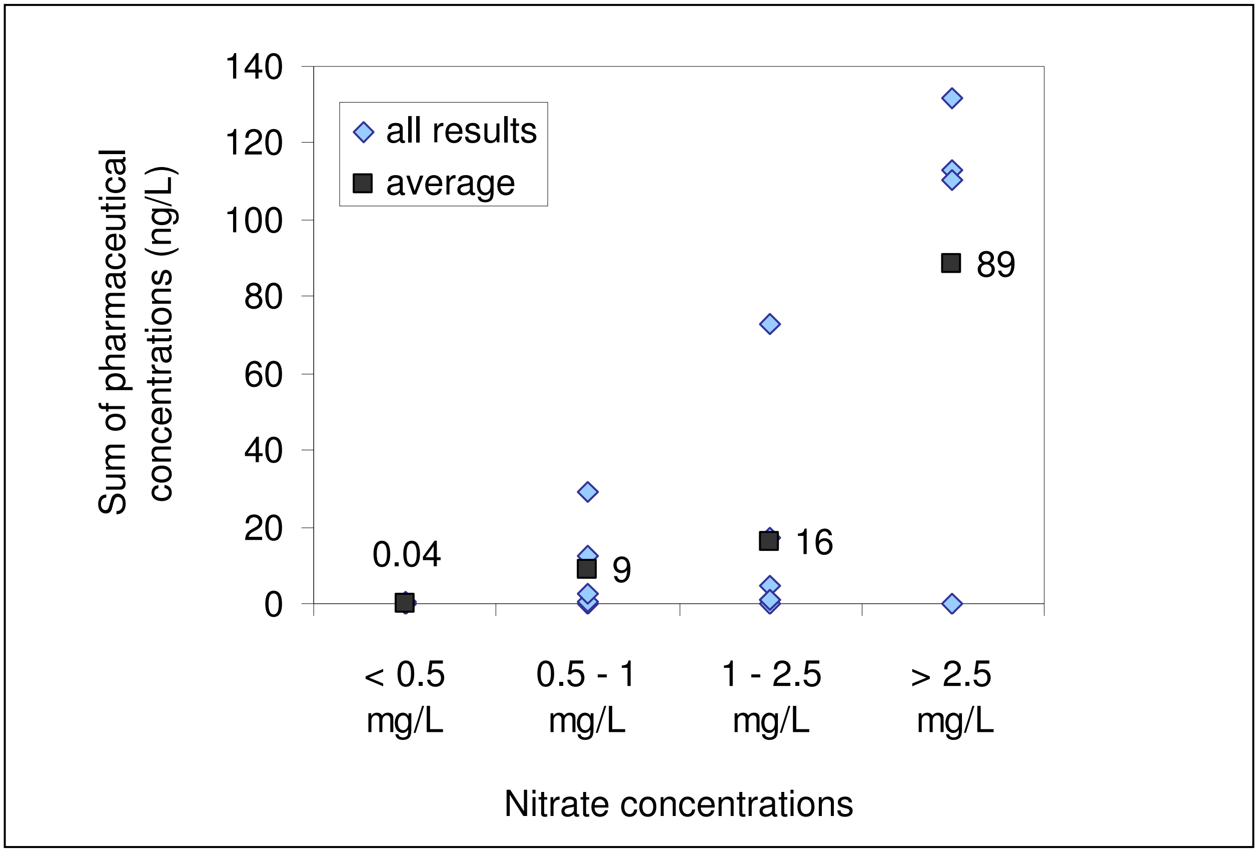
Number of emerging contaminants detected according to boron levels. Boron is present in some laundry detergents, and may be a more specific marker of wastewater impact than nitrate, which can come from fertilizers. However, wells impacted by saltwater intrusion will also have elevated boron levels.

c) Residential land use



Number of emerging contaminants according to the fraction of land use in well recharge areas (Zone IIs) that is attributed to residential development.

Figure 4. Sum of pharmaceutical concentrations in samples according to nitrate concentrations.



APPENDICES

APPENDIX 1

Concentrations of emerging contaminants, nitrate and boron detected in individual Cape Cod drinking water wells

Notes:
We used nitrate and boron as indicators of impact from septic systems. No samples exceeded drinking water standards or guidelines for these two chemicals. Nitrate and boron are naturally occurring, so low levels of these two chemicals are expected even in areas without septic systems or other human impacts. Groundwater with nitrate less than 0.5 mg/L is considered near background quality, and groundwater with nitrate between 0.5 and 2.5 mg/L is considered moderately impacted.[21]

Sample	Chemical name	Concentration detected	
Barnstable Fire District			
Old Barnstable Rd Well 2 (4020000-02G)	Emerging contaminants		
	Sulfamethoxazole	0.2	ng/L
	Perfluorooctanesulfonic acid (PFOS)	2.5	ng/L
	Tris(2-butoxyethyl) phosphate (TBEP)	50	ng/L
	Inorganic indicators of septic systems		
	Nitrate	0.7	mg/L
	Boron	0.016	mg/L
GP Well 4 (4020000-04G)	Emerging contaminants		
	Perfluorooctanesulfonic acid (PFOS)	13	ng/L
	Inorganic indicators of septic systems		
	Nitrate	1.1	mg/L
	Boron	0.010	mg/L
Brewster Water Department			
Freeman's Way Well 1 (4041000-01G)	Emerging contaminants		
	None detected		
	Inorganic indicators of septic systems		
	Nitrate	0.2	mg/L
	Boron	0.0093	mg/L
Freeman's Way Well 3 (4041000-03G)	Emerging contaminants		
	None detected		
	Inorganic indicators of septic systems		
	Nitrate	0.1	mg/L
	Boron	0.0058	mg/L

Buzzards Bay Water District

Dry Cedar Swamp Road Well 1 (4036001-01G)	Emerging contaminants		
	None detected		
	Inorganic indicators of septic systems		
	Nitrate	0.1	mg/L
	Boron	0.0068	mg/L
Kettle Lane Well 2 (4036001-02G)	Emerging contaminants		
	Sulfamethoxazole	0.3	ng/L
	Inorganic indicators of septic systems		
	Nitrate	0.8	mg/L
	Boron	0.010	mg/L

Centerville-Osterville-Marstons Mills Water Department

Arena Wells 3 & 4 (4020002-02G)	Emerging contaminants		
	Sulfamethoxazole	113	ng/L
	Triethyl phosphate (TEP)	10	ng/L
	Tris(chloropropyl) phosphate (TCPP)	20	ng/L
	Inorganic indicators of septic systems		
	Nitrate	3.2	mg/L
	Boron	0.014	mg/L
Lumbert Mill Well 9 (4020002-05G)	Emerging contaminants		
	Atenolol	0.8	ng/L
	Carbamazepine	5.5	ng/L
	Dilantin (phenytoin)	66	ng/L
	Meprobamate	0.8	ng/L
	Sulfamethoxazole	37.1	ng/L
	Perfluorooctanesulfonic acid (PFOS)	1.7	ng/L
	Triethyl phosphate (TEP)	15	ng/L
	Tris(chloropropyl) phosphate (TCPP)	~7.5	ng/L
	Tris(1,3-dichloro-2-propyl) phosphate (TDCPP)	10	ng/L
	Tris(2-chloroethyl) phosphate (TCEP)	20	ng/L
	Inorganic indicators of septic systems		
	Nitrate	4.6	mg/L
	Boron	0.028	mg/L
Harrison GP 19 (4020002-16G)	Emerging contaminants		
	None detected		
	Inorganic indicators of septic systems		
	Nitrate	None detected	
	Boron	None detected	

Chatham Water Department			
Indian Hill Well 1 (4055000-04G) note: this well is currently off-line	Emerging contaminants		
	Perfluorooctanesulfonic acid (PFOS)	2.2	ng/L
	Inorganic indicators of septic systems		
	Nitrate	2.6	mg/L
	Boron	0.032	mg/L
Town Forest Well 9 (4055000-09G)	Emerging contaminants		
	None detected		
	Inorganic indicators of septic systems		
	Nitrate	None detected	
	Boron	0.006*	mg/L
Distribution System Sample	Emerging contaminants		
	Sulfamethoxazole	0.3	ng/L
	Inorganic indicators of septic systems		
	Nitrate	0.4	mg/L
	Boron	0.012	mg/L
Cotuit Water Department			
Electric Station Well 1 (4020003-02G)	Emerging contaminants		
	Carbamazepine	20	ng/L
	Dilantin (phenytoin)	47	ng/L
	Meprobamate	2.5	ng/L
	Sulfamethoxazole	3.2	ng/L
	Inorganic indicators of septic systems		
	Nitrate	2	mg/L
	Boron	0.015	mg/L
Station 5 (4020003-06G)	Emerging contaminants		
	Sulfamethoxazole	0.9	ng/L
	Inorganic indicators of septic systems		
	Nitrate	1.6	mg/L
	Boron	0.065	mg/L

*Corrected value

Dennis Water Department			
Bakers Pond Well 14 (4075000-15G)	Emerging contaminants		
	Sulfamethoxazole	1	ng/L
	Inorganic indicators of septic systems		
	Nitrate	1.8	mg/L
	Boron	0.019*	mg/L
GP 21 (4075000-21G)	Emerging contaminants		
	Sulfamethoxazole	17.1	ng/L
	PFOS	1.4	ng/L
	Inorganic indicators of septic systems		
	Nitrate	2.5	mg/L
	Boron	0.020	mg/L
Falmouth Water Department			
Fresh Pond Well (4096000-02G)	Emerging contaminants		
	Carbamazepine	1	ng/L
	Sulfamethoxazole	2.9	ng/L
	Trimethoprim	0.7	ng/L
	Tris(2-chloroethyl) phosphate (TCEP)	20	ng/L
	4-Nonylphenol	20[J]	ng/L
	Inorganic indicators of septic systems		
	Nitrate	1.2	mg/L
	Boron	0.012	mg/L
Crooked Pond Well (4096000-05G)	Emerging contaminants		
	Sulfamethoxazole	2.8	ng/L
	Inorganic indicators of septic systems		
	Nitrate	0.9	mg/L
	Boron	0.015	mg/L

* Corrected value

[J] Estimated value; concentration detected between the detection limit and reporting limit. See Appendix 3 for additional QA/QC information about this sample.

Hyannis Water System

Maher Well 2 (4020004-02G)	Emerging contaminants		
	Carbamazepine	9	ng/L
	Dilantin (phenytoin)	10	ng/L
	Meprobamate	3.8	ng/L
	Sulfamethoxazole	6.1	ng/L
	Perfluorooctanoic acid (PFOA)	22	ng/L
	Perfluorooctanesulfonic acid (PFOS)	97	ng/L
	Triethyl phosphate (TEP)	10	ng/L
	Tris(chloropropyl) phosphate (TCPP)	30	ng/L
	Inorganic indicators of septic systems		
	Nitrate	0.9	mg/L
	Boron	0.016	mg/L
Hyannisport Well (4020004-03G)	Emerging contaminants		
	Antipyrine	1	ng/L
	Carbamazepine	72	ng/L
	DEET	6	ng/L
	Dilantin (phenytoin)	4	ng/L
	Gemfibrozil	1.2	ng/L
	Meprobamate	5.4	ng/L
	Sulfamethizole	1	ng/L
	Sulfamethoxazole	41	ng/L
	Perfluorooctanesulfonic acid (PFOS)	15	ng/L
	Triethyl phosphate (TEP)	10	ng/L
	Tris(chloropropyl) phosphate (TCPP)	~13	ng/L
	Tris(2-chloroethyl) phosphate (TCEP)	20	ng/L
	Inorganic indicators of septic systems		
	Nitrate	5.3	mg/L
	Boron	0.037	mg/L
Airport Well 1 (4020004-10G)	Emerging contaminants		
	Perfluorooctanoic acid (PFOA)	14	ng/L
	Perfluorooctanesulfonic acid (PFOS)	16	ng/L
	Triethyl phosphate (TEP)	10	ng/L
	Inorganic indicators of septic systems		
	Nitrate	0.3	mg/L
	Boron	0.011	mg/L

Hyannis Water System (continued)

Distribution System Sample	Emerging contaminants		
	Carbamazepine	3	ng/L
	Dilantin (phenytoin)	7	ng/L
	Meprobamate	2.7	ng/L
	Perfluorooctanoic acid (PFOA)	22	ng/L
	Perfluorooctanesulfonic acid (PFOS)	110	ng/L
	Triethyl phosphate (TEP)	20	ng/L
	Tris(chloropropyl) phosphate (TCPP)	40	ng/L
	Inorganic indicators of septic systems		
	Nitrate	0.9	mg/L
	Boron	0.017	mg/L

APPENDIX 2

Complete list of chemicals measured (detected and not detected) in Cape Cod public supply wells

RL = laboratory reporting limit (lowest level quantified by the laboratory)
** = chemicals detected in at least one sample

Chemical	RL (ng/L)
Pharmaceuticals – antibiotics	
azithromycin	5
bacitracin	1000
carbadox	5
chloramphenicol	5
chlorotetracycline	50
ciprofloxacin	50
doxycycline	50
enrofloxacin	50
erythromycin	1
lasalocid	1
lincomycin	0.1
monensin	1
narasin	1
norfloxacin	50
oleandomycin	1
oxytetracycline	500
penicillin	2
roxithromycin	1
salinomycin	0.1
sulfachloropyridazine	5
sulfadiazine	1
sulfadimethoxine	0.1
sulfamerazine	1
sulfamethazine	1
sulfamethizole**	**1**
sulfamethoxazole**	**0.1**
sulfathiazole	1
trimethoprim**	**0.1**
tylosin	1
virginiamycin	1

Chemical	RL (ng/L)
Pharmaceuticals – prescription	
antipyrine**	**1**
atenolol**	**0.1**
bezafibrate	0.5
carbamazepine**	**1**
clofibric acid	0.5
diclofenac	0.5
dilantin (phenytoin)**	**2**
diltiazem	0.1
fluoxetine (Proxac)	1
gemfibrozil**	**0.5**
levothyroxine	2
meprobamate**	**0.1**
naproxen	2
prednisone	2
simvastatin	5
theophylline	5
Pharmaceuticals – non-prescription	
acetaminophen	5
caffeine	10
cotinine	1
ibuprofen	50
nicotine	5
paraxanthine	5
theobromine	50

(continued)

Chemical	RL (ng/L)
Hormones	
17-alpha-estradiol	0.5
17-beta-estradiol	0.5
17-alpha-ethynylestradiol	0.5
diethylstilbestrol (DES)	0.5
estriol	0.5
estrone	0.5
progesterone	0.1
testosterone	0.1
Perfluorinated compounds	
perfluorooctanoic acid (PFOA)**	**10**
perfluorooctane sulfonate (PFOS)**	**1**
Personal care product ingredients	
DEET**	**5**
galaxolide (HHCB)	10
tonalid (AHTN)	10
Triclosan	50
Alkylphenols *(analyzed in a subset of samples)*	
4-nonylphenol**	**250**
4-nonylphenol mono-ethoxylate	1500
4-nonylphenol diethoxylate	1500
Octylphenol	250

Chemical	RL (ng/L)
Phosphate flame retardants	
diphenylcresyl phosphate	10
2-ethylhexyldiphenyl phosphate	10
tributyl phosphate	10
tri-m-cresyl phosphate	10
tri-o-cresyl phosphate	10
tri-p-cresyl phosphate	10
triethyl phosphate**	**10**
trimethyl phosphate	10
tripentyl phosphate	10
triphenyl phosphate	10
tris(2-butoxyethyl) phosphate**	**50**
tris(2-chloroethyl) phosphate**	**10**
tris(chloropropyl) phosphate**	**10**
tris(2,3-dibromopropyl) phosphate	100
tris(1,3-dichloro-2-propyl) phosphate**	**10**
tris(2-ethylhexyl) phosphate	10
Herbicides	
2,4-D	5
dicamba	50
dichlorprop	5
MCPA	5
triclopyr	5

APPENDIX 3

Summary of quality assurance/quality control (QA/QC) samples

Blanks: Two field blanks were collected over the course of our sampling. Field blanks were collected by pouring analytical-grade water that we received from the laboratory into sampling bottles at two of the field sites. When analyzing our samples, the laboratory did not know which samples were field blanks. No chemicals were detected in any of our field blanks.

For the alkylphenol analysis, there was one laboratory blank that contained trace levels of 4-nonylphenol. A laboratory blank is a blank that is the laboratory analyzes along side the actual samples. 4-nonylphenol was only detected in one sample, and the estimated concentrations in the sample and the laboratory blank were both below the reporting limit, but above the detection limit. For this sample, the estimated concentration in the sample was approximately 3 times higher than the concentration present in the laboratory blank.

Duplicates: Two samples were collected in duplicate over the course of our sampling. Duplicate samples were collected at the same location into separate collection bottles. When analyzing our samples, the laboratory did not know which samples were duplicates.

In general, the results of the duplicate analyses showed very good reproducibility (see Table A3).

- For pharmaceuticals and personal care products, the average percent difference was 3% (range: 0% to 18%). Four chemicals were detected in both of the duplicate samples.
- For PFOS, which was detected in both duplicate samples, the results were identical (percent difference was 0%).
- For 4 organophosphate flame retardants detected in at least one of the duplicates, there was more of a range in the reproducibility. We attribute these differences in part to the fact that the analytical laboratory only reported one significant figure for these results, so some differences may appear artificially large. For 4 detections, the duplicate results were identical (0% different), and for 3 detections, the difference was >50%.

Table A3. Percent difference between duplicate analyses. Two well water samples were collected in duplicate. The percent difference is determined as the difference between the two values divided by the average of the two values. For organophosphate flame retardants, the percent difference appears higher in part because concentrations were only reported to one significant digit. See Table 1 for full chemical names.

-- not detected in either duplicate
** percent difference could not be calculated because one duplicate was above the reporting limit and the other was below the reporting limit

	Pharmaceuticals								
	antipyrine	atenolol	carbamaze-pine	DEET	dilantin	gemfibrozil	meproba-mate	sulfamethi-zole	sulfameth-oxazole
Sample 1	--	0%	18%	--	3%	--	0%	--	3%
Sample 2	0%	--	3%	0%	0%	0%	11%	0%	1%

	Perfluorinated chemicals	Organophosphate flame retardants			
	PFOS	TEP	TCPP	TDCPP	TCEP
Sample 1	0%	67%	**	0%	0%
Sample 2	0%	0%	**	--	0%