

# Pharmaceuticals in Drinking Water: An Analysis of the Problem in the Charleston Area and Finding a Solution Through Awareness

Emily Bauer, Lauren Davis, Colin Crowe, Heather Leisy, William Marshall, Khaled Moussawi, Jamie Rudisill, Joe Vuthiganon



Presidential Scholars Program, Medical University of South Carolina, Charleston, SC

## INTRODUCTION

Recent studies have shown contamination of drinking water by pharmaceuticals in 24 metropolitan areas around the US. These drugs exist in minimal concentrations and the impact on human health is uncertain. While some officials think alerting the public about this issue is unnecessary at this time, others have started programs to raise public awareness and prevent water contamination through multiple intervention strategies.

- Goals of our project**
- Comprehensive literature review to evaluate the potential harm of pharmaceuticals in the water system
  - Determine how Charleston Water System is addressing the issue locally
  - Evaluate and promote public awareness through questionnaires, interviews with local pharmacies, and the creation and distribution of an educational flyer on the proper disposal of medications

## Defining the Problem

The impact of water contamination by pharmaceuticals on human health and ecological stability are uncertain. The recently developed advanced analytical detection techniques allow scientists, more than any time before, to detect minute amounts of different chemicals and pharmaceuticals in the environment around us (Ternes, Joss et al. 2004, Dove 2006). Therefore, while these drugs might have always been in the environment, we have recently acquired the tools to detect them. This is a new challenge we were not ready to cope with as evidenced by the guidelines for waste- and drinking water treatment plants, which do not require clearance of pharmaceuticals. This problem is complicated by the tremendous rise in pharmaceutical consumption as evidenced by the rise of sold prescription in the US from 2.9 billion in 2000 to 3.4 billion in 2005 (U.S. census 2007), and the rise of pharmaceutical sales from \$79 billion in 2005 to \$116 billion in 2005 (U.S. census 2007). These numbers and facts along with the recent scientific studies are alarming and indicate that the problem can only get worse if ignored.

Due to the recent awareness of the problem, the scientific evidence documenting the impact of waterbodies contamination by pharmaceuticals is rapidly starting to accumulate. Several studies so far suggest that some of the detected drugs are already harming the ecological system. Natural and synthetic estrogens contributed to the appearance of new fish phenotypes near waste water effluent areas. These fish show gender-blending with feminized male fish that lay eggs and/or have lost their reproductive abilities (Sumpter 1995; van Aerle, Nolan et al. 2001; Jobling, Coey et al. 2002; Jobling and Tyler 2003). In addition, the widespread presence of antibiotics in the environment has been linked to emerging antibiotic resistance (Kummerer and Henninger 2003; Kummerer 2004), as well as interference with beneficial identifying bacteria in the environment (Halling-Sorensen 2001; Amin, Zilles et al. 2006).

In the Charleston area, dolphins carry drug resistant bacteria (The Post and Courier 2008) and "thirty-nine percent of these dolphins had multiple antibiotics in their bodies," Geoff Scott, director of the biomedical research center, in a presentation to the S.C. Natural Resources board. In addition, other studies showed flame retardants in dolphins fats (The Post and Courier 2008).

There is no direct evidence yet linking the water pharmaceuticals to human health especially that the concentrations of drugs detected in surface as well as drinking water are much lower than concentrations indicated to cause side effects upon acute exposure to these drugs. Current data from human toxicology studies rely on comparisons of a single drug to its therapeutic or lethal dose (Webb, Ternes et al. 2003; Harvey and Everett 2006). However, these single drug studies ignore the major risk of the synergistic effects of the cumulative chronic exposure to a mixture of different drugs (Daughton 2002); this risk is very difficult to predict at this point (Daughton 2003; Ternes, Joss et al. 2004). For example, it has been shown that synergy of various chemicals in the environment increases individual effect by up to six folds (Aroni and McLachlan 1996; Daughton 2003), (study from Italy). More relevant to human health, Francesco Pomati recently published some reports studying the effect of a mixture of 13 drugs at concentrations found in the environment (ng/L) on development of human embryonic kidney cells. These drugs included anti-cholesterol, seizure, hypertension, cancer, pain and infection medications (atenolol, bezafibrate, carbamazepine, cyclophosphamide, ciprofloxacin, furosemide, hydrochlorothiazide, ibuprofen, lincocmycin, ofloxacin, ranitidine, salbutamol, and sulfamethoxazole) (Pomati, Casigliotti et al. 2006). The mix inhibits growth of embryonic kidney cells up to 30% through an ERK signaling pathway. He showed a possibility of synergistic and antagonistic effects of different combinations of these drugs, like promoting or inhibiting cell growth (Pomati, Orlandi et al. 2008).

Pomati also studied the effects of this 13 drug mixture on zebrafish liver cells. This mixture inhibited ZFL cells proliferation (Pomati, Colaspas et al. 2007). Using DNA-microarray, he showed a transcriptional repression of primary metabolism and cell cycle genes, and an upregulation of protein kinase signaling pathways and DNA repair mechanisms (Pomati, Colaspas et al. 2007).

**Pharmaceuticals in drinking water** An investigation by The Associated General Contractors of South Carolina  
 1. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 2. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 3. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 4. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 5. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 6. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 7. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 8. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 9. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 10. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 11. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 12. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 13. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 14. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 15. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 16. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 17. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 18. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 19. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 20. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 21. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 22. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 23. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 24. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 25. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 26. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 27. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 28. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 29. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 30. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 31. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 32. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 33. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 34. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 35. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 36. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 37. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 38. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 39. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 40. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 41. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 42. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 43. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 44. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 45. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 46. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 47. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 48. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 49. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 50. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 51. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 52. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 53. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 54. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 55. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 56. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 57. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 58. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 59. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 60. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 61. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 62. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 63. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 64. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 65. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 66. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 67. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 68. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 69. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 70. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 71. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 72. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 73. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 74. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 75. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 76. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 77. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 78. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 79. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 80. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 81. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 82. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 83. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 84. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 85. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 86. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 87. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 88. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 89. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 90. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 91. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 92. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 93. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 94. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 95. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 96. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 97. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 98. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 99. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina  
 100. [Pharmaceuticals in drinking water](#) An investigation by The Associated General Contractors of South Carolina

## METHODS

The environmental and pharmaceutical drug study was created and brought together by various literature reviews, interviews, surveys, and data collection tactics to increase the awareness and ability for each pharmacy to take back expired and/or unused prescriptions. The methods include:

- **Literature Reviews:** Over the course of 6 months, vigorous literature reviews were retrieved and compiled to build an array of background information.
- **Environmental Blog:** An internet website was created on behalf of the committee to organize and observe questions of the general public and environmental committee.
- **Public Support:** Networked amongst public support groups and agencies to classify expired or unused prescription drugs.
- **Interviews:** Mr. Andy Fairley, Chief Operating Officer of the Charleston Water System was interviewed and asked to serve as the Environmental Liaison for the Presidential Scholar Environmental Committee. Mr. Fairley was interviewed by the committee to gather additional information as to policy and procedures the water system implements to avoid pharmaceutical drugs into the water system, the awareness of the water system, and ways to begin educating the public of the long-term effects.
- **Pharmacy Informative Interviews:** Each member of the committee informally interviewed an employee of CVS, Target, Walgreens, and Wal-Mart to gain information as to the pharmacy's involvement and awareness of pharmaceutical drugs in the water system.
- **Educational Flyer:** An educational and informative flyer was designed to teach the average American how to properly dispose of one's pharmaceutical drugs. This was published across the Medical University of South Carolina campus to create awareness. In addition, an ad was placed in the Catalyst.
- **Questioning:** Surveys were conducted throughout the City of Charleston to gain a new prospective as to public's knowledge and awareness on how to properly dispose of one's pharmaceutical liquids/pills. The survey was available to a diverse population.

## RESULTS

Figure 1

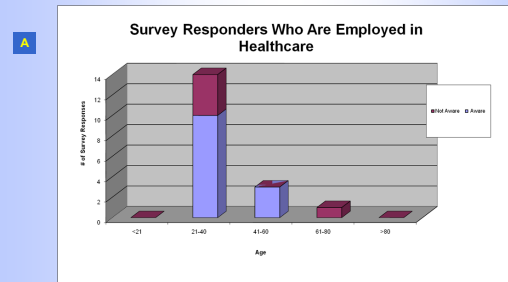


Fig. 1A. Those responders who answered that they had no prior knowledge of traces of medications being found in Charleston's water supply are coded in pink. Those responders who answered that they did have prior knowledge are coded in blue. Of those responders who are employed in healthcare, 72% (13 of 18) had prior knowledge of the issue.

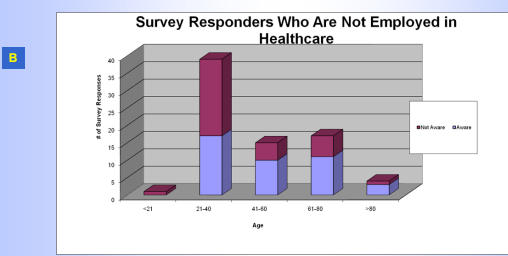


Fig. 1B. Those responders who answered that they had no prior knowledge of traces of medications being found in Charleston's water supply are coded in pink. Those responders who answered that they did have prior knowledge are coded in blue. Of those who are not employed in healthcare, 54% (41 of 76) had prior knowledge of the issue.

Figure 2



Figure 3

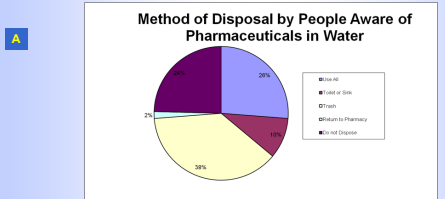


Fig. 3A. Of the responders who indicated they had prior awareness of traces of medications being found in Charleston's water supply, 10% dispose of their medications in the Toilet or Sink, thus exacerbating the problem. 37% dispose of them via the EPA- and ONDCP-preferred method (if no recycling program exists), the trash. Only 2% of responders take their medications back to their pharmacies for recycling or disposal, despite this being the federal guideline for personal medication disposal. This is most likely due to limited availability of these programs in our area.

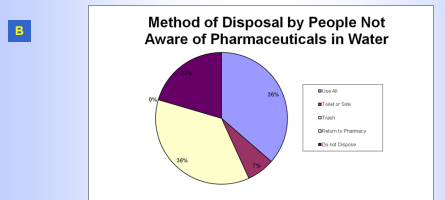


Fig. 3B Of the responders who indicated they had no prior awareness of traces of medications being found in Charleston's water supply, 36% already employ the trash as a means of disposal (as recommended by the EPA and ONDCP if there is no recycling program available). However, more studies should be done to determine the exact method of disposal and whether it involves the recommended technique of crushing, mixing with coffee grounds, and then disposing.

## SUMMARY

The short and long term risks associated with pharmaceuticals in our drinking water are unknown. The current risk is perceived to be small, but what effects will years of exposure have? We must also think about the marine ecosystems, where studies have already shown damage from pharmaceuticals.

This problem that affects everyone regardless of race, education, religion, or economic status. Raising awareness of the problem is the first step. The simple act of disposing of unwanted/unused medications in the trash instead of flushing them down the toilet could make a huge difference in years to come.

- Several ways that we have worked to raise awareness in our local community include:**
- Submitted an article about the problem for publication to the City Paper Skirt, Catalyst, West Of, Sierra, and Co/C.
  - Posted "Crush Don't Flush" fliers around the MUSC campus and distributed to students and patrons, as well as local pharmacies.
  - Collaborated with Mt. Pleasant Water Works to have results distributed within their community
  - Received invitation from Lowcountry Environmental Education Program (LEEP) to speak in public schools about problem.

- Interprofessional Collaboration:**
- Every medical professional can play an important role in addressing this issue
  - Physicians, Dentist, Physician Assistants, and Nurse Practitioners should be aware of the problem so they can properly educate their patients on disposal of unused medications. Also, being careful not to overprescribe is important so that the patient doesn't have extra medication to dispose of.
  - Pharmacists can organize medication take back programs and also educate their clientele about proper medication disposal.
  - Nurses should also be aware of the problem since part of their job involves medication disposal. Nurses can also petition for hospitals to come up with a safer way to dispose of medication.
  - Continuous research is vital in order to better understand the magnitude of this problem, the potential risks, and how to best deal solve the problem.

- Lessons Learned:**
1. There is not much known about the magnitude and long term effects of this problem. However, there are a number of studies that extracted a shocking number of pharmaceuticals in our drinking water.
  2. In addition, water treatment plants are not currently capable of screening for or removing these pharmaceutical agents.
  3. Studies have shown that this problem has already begun to affect marine life.
  4. Our interviews with pharmacists and survey of the general public showed that few people are aware of this problem or of how to properly dispose of medications.

- Questions that remain unanswered:**
- What are the long term risks associated with continuous exposure to pharmaceuticals in the drinking water?
  - Are there any risks associated with ingesting multiple pharmaceuticals in combinations that were never intended?
  - How do we efficiently screen for all the pharmaceuticals in the water?
  - What is the most efficient way to remove pharmaceuticals from drinking water?
  - What is the most effective way to convey proper medication disposal to health care professionals and the general public?

- Recommendations for continued work:**
- Continue increasing public awareness via flyers, articles, etc.
  - Collaborate with pharmacies to organize medication take back programs
  - Petition government officials at the local, state, and national level to act on this problem.

## ACKNOWLEDGEMENTS

Support provided by **Andy Fairley** (Charleston Water System); **Betty Bear** (Mentor); **Mary Mauldin** (Mentor)