Silent Echoes on the Water: PPCPs in the Environment

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Abstract

Pharmaceutical drugs and personal care products increasingly are found in water systems all over the world. Few or no discharge standards or monitoring systems currently exist to regulate these items because the U.S. Food and Drug Administration has, in the past, focused on the direct impacts of pharmaceuticals on humans rather than after-use effects on the environment. Human waste has not been considered a toxic substance per se. As large volumes of these human-made chemicals enter the water supply on a continual and daily basis, effects can build up over time, obscuring the true ultimate toxicity and volatility of these compounds.

Human health concerns about the presence of these vast arrays of strong and unknown chemical mixtures and interactions have prompted federal agencies and people like Stephen Buhner, author of the chapter "The Environmental Impacts of Technological Medicine" in his book, "The Lost Language of Plants", to bring this topic into the mainstream for the American public. A significant but quiet corollary, echoed by few it seems, is the drastic and potential threats these endocrine disruptors and other pharmaceutical chemicals and personal care products pose to aquatic life and their surrounding ecosystems.

Introduction

Victory on the environmental front is a fleeting crown. Long-fought disputes over water usage and waste disposal in aquatic systems evolved into agricultural reclamation programs, wetland restoration projects, and revamped primary and secondary sewage treatment plants (STP). Scientific papers and conferences herald the move to sustainable development by using recycled water and link the need to conserve water with the growing needs of humans to have more, useable water for their homes, their businesses and their food (Lettinga et al. 2001).

After examining information often decades old (toxins, pathogens, etc., in the water and safe levels), it appears that little heed has been given to the presence of whole new sectors of water contaminants resulting from drugs and medical wastes, contraceptives, anti-depressents, blood pressure medication, antibiotics, perfumes, musks, soaps, cleansers, sun screens, and thousands of specific chemicals now manufactured for human use and health care . Pharmaceuticals and personal care products (called PPCPs) and both hospital and home waste discharges have invisibly entered even the most pristine streams around the world. As we continue to march forward, employing techniques thought to better the water shortage situation (like sewage sludge conversion into fertilizer and using treated wastewater for non-food needs), silent but perpetual votes about these new impacts are being cast within the waterways. Dead fish, fish and other species changing sex, and mutated invertebrates are signaling the present but invisible contents of a newly-polluted global water system.

Existing pollution standards and levels for safe water incorporate the known contaminants identified decades ago. However, no monitoring schemes exist for Prozac or Norvasc; endocrine inhibitors and lethal metabolites are not on any chart for water quality. But the move to spread around sewage sludge (now more concentrated in pollutants — known and unknown) and recycle reclaimed water for urban uses is the beginning of a potential problem that could have more far-reaching consequences than we can now conceive.

The early signs from fish and aquatic animal communities are small warning signals, echoes on the water never heard by most people. But the content of the message is clear: pharmaceuticals and their metabolites and other PPCPs may have a direct effect on many aquatic inhabitants. From habitat destruction to reproductive disruption, another assault to maintaining species biodiversity is now underway. With diminished capability to reproduce and maintain/grow populations, some aquatic species may suffer impacts from PPCPs that we are now only beginning to understand.

Clean, Pure Water?

In the end, there will never be any more water than there is now on earth. Our water will continue to circulate through soil and streams, air and atmosphere. In the future, it is conceivable that what we flush today, we will drink tomorrow. It is really that simple.

For much of geologic time, living creatures inhabited the water worlds. The Permian extinction wiped out most of the ocean's inhabitants but some survived and evolved to eventually walk on land. With most of the earth's surface still covered by water, it is easy to fall into slumber, thinking we can dump what we do not need because there is just so much water and it will cleanse itself - out of sight, out of mind.

Like the myth of Sisyphus, doomed to roll the stone up the hill, only to have it fall down the other side, we seem to discover environmental problems and build solutions, only to find the solution is not effective. For water systems, primary and secondary treatment plants initially appeared to be doing the job. However, as early as July, 1970, at the Waste Water Reclamation Committee of the American Water Works Association meeting, concerns surfaced about the use of reclaimed water, citing the presence of hormones, carcinogens, antibiotics and other materials with unknown effects on humans (Holcomb, 1970).

Over the last decade, researchers have found a surprising variety of drugs, medicines, oils and other human-based products in water supplies. To identify pathways of contamination and categories of new, human-based contaminants, the United States Geological Survey (USGS) conducted a survey of 139 rivers and streams across

America to measure and identify the presence and levels of antibiotics, prescription and nonprescription drugs, organic wastewater contaminants (OWCs), steroids and hormone compounds. Streams were selected based on the likelihood of the presence of some OWC contaminants, as the results proved with over 80% of the streams registering one or more OWCs (Barnes et al, 2002).

The danger of such a variety of unknown contaminants can be magnified by further unknown interactive effects with identified existing pollutants such as PCBs (as evidenced in a study of PCB-contaminated fish fed to mink) that affect offspring, causing lower birth weights and increased infant mortality (Knopper, 2003).

Although much of the comments in this paper have been directed toward human-based contaminants, about 70% of the antibiotics streaming back into water supplies comes from livestock farming. In addition, manure that has been composted is also spread back onto the soil, now putting a much more toxic (in the sense of antibiotics) and concentrated contaminant into the soil system, eventually able to reach into ground water supplies (Kummerer, 2003).

Hospital wastewater and effluents also contain high concentrations of pathogenic microbes and antibiotics. Salmonella is a common pathogen found in sludge (Tsai and Lin, 1999). Disinfection with chlorine compounds can clean the pathogens from the water but the antibiotics and the residual chlorine compounds pass directly into water discharge or sewage systems.

Growing Drug, Hormone, and Biocide Use

When Time magazine has a cover story on a topic, you know it's now main-stream. I read, with interest, the November 3rd issue that focused on drugs and children, asking, "Are we giving kids too many drugs?" An interesting question given the increased volumes of drugs now being prescribed for treating symptoms, not healing diseases. Before the human genome project, there were 500 sites in the human body that drugs could affect (Buhner, 2002). Current estimates range from 3,000 to 10,000 new sites providing many new drug targets and a great new market for pharmaceutical companies!

However, drug purchasing and drug use are two different things. Although millions more dollars are spent each year on PPCPs, many of these products are never used or only partially used and end up thrown out in the trash or dumped down the drain (Daughton and Ternes, 1999).

Hormones and steroids are also showing up in greater quantities in wastewater. Although the DES growth hormone was eventually banned in the United States in the mid-1970's, other livestock and poultry growth hormones are increasingly used as their effectiveness can bring a cost savings of $40 or more per head.

The pervasive use of biocides in consumer products to improve hygiene and destroy bacteria creates another set of chemical contaminants that pass readily into water supplies as they are usually associated with cleaning and are dumped directly into household or industrial drains. In addition, the increasing presence of antibiotics and other biocides can create resistant bacteria in environments where such use is truly not needed (Gilbert and McBain 2003). What remains is either a more sterile environment, devoid even of "good germs," or an altered bacterial community with stronger, more resistant bacteria.

Which brings us back to wastewater treatment…

Even today, over one million homes in the United States do not have sewage systems and dump raw sewage into waterways or outside detached outhouses (Daughton and Ternes, 1999). Considering population growth in the United States, and average annual excrement volumes of 1,300 pounds per person (Buhner, 2002), wastewater treatment has changed over the last thirty years when a third of the population lived in areas without sewers (Holcomb, 1970). Sludge handling was identified then (as now) as one of the most difficult processes in sewage treatment.

Substance removal can happen either with the use of microbes to break molecules and mineralize contaminants or by creating filterable solids that end up forming sludge. PPCPs are not trapped in sludge, for the most part, but are continually discharged into water systems as a result of perpetual or daily use. Some transformations can occur in STPs but most of these chemical compounds survive further breakdown and pass back, unaltered or as a metabolic conjugate, into surrounding water systems (Daughton and Ternes, 1999).

Currently, chlorine additives and anaerobic processes are added to oxygenation and other methods to separate, treat and precipitate out designated toxins, chemicals, minerals, additives, and other substances from wastewater. Still, no urgent concern or discharge control has been voiced and established for human-based PPCPs. Establishing standards for this new class of contaminant will be a first step. On-site monitoring will eliminate the excessive blending (and almost impossible sorting) that can occur at the point of collection as all effluents collide at the STP gate.

A place for all science writing

One of the questions we were asked to address in this paper based on the book chapter, "The Environmental Impacts of Technological Medicine," is the validity of the argument and its credibility and stature among science reviewers. Is the thesis of potential PPCP impacts in the environment confirmed among peer-reviewed science journals? To answer this question, I read publications from the EPA, studies from USGS, on-line articles from Science Daily and Science News magazines. I found study after study published in medical, microbiology and water journals that document the statements in Mr. Buhner's popular book chapter. If anything, the tone of his chapter only hints at the pervasive findings now being uncovered any time scientific research is completed identifying water content and examining local aquatic inhabitants (Raloff, J. 2000). The difficulty is in converting the scientific results into a useful form for public and governmental action.

For me, schooled in scientific formats ad nauseum, it is easy to discredit writing about science not presented in a scientific format of continual citations and small-step conclusions. I often forget that most published material is general media writing. At my first reading of the book chapter, I noticed an overall lack of direct citations and a more explanatory method of detailing the over-arching statement in the paragraphs that followed. This approach would have surely fallen under the scientific peer-reviewers cutting knife. However, reading the article for a second time, I realized how progressively simple the premise is: we are putting things into the water that are harming the inhabitants and the future quality of the water itself. Citations were used after major sections and the prose-like style made for a very easy read. The biggest hurdle in reviewing this chapter was to then find my own independent set of documentation among science journals and to confirm or refute this simply stated hypothesis.

Drugs and water: what can we do?

If water is the gold of the future, as the fortunes and success of nations are written in water currency, efforts should begin immediately to clean and protect this most valuable natural resource. It is the lifeline for all living things: it keeps habitats thriving and supports miraculous levels of biodiversity.

Past practices, identifying each contaminant, its risk levels and approved dosages, may no longer be the approach for a sustainable future. There is an alternative to the traditional risk model: its called the ecological paradigm, recognizing the interconnectivities of all systems and the fact that the introduction of elements, no matter how small, can alter and impede the natural development of the ecosystem and the reproductive success of its inhabitants (Crews, 2001). Using risk as the model, every chemical has a safe level; using the ecological paradigm, chemicals with any known toxicity are considered a threat and must be worked out of the system. The healing process can begin in a slow but directed way.

The process of identifying what is in the water (as shown in the USGS survey) sets the foundation for knowledge, monitoring and treatment. Understanding the continual and fluid nature of PPCPs can form a new environmental policy to develop an ecological paradigm approach to chemical regulation. Pollution controls and coal filters installed in manufacturing facilities will stop the outflows at the source, before they enter a general and more complicated water system.

New methods of bacteria processing in sewage treatment plants can be developed and implemented to keep the sugar molecule on the estrogens from birth control pills ---now currently eaten by bacteria in STPs—keeping the estrogen inactive as it is passed through to the water system (Knopper, 2003).

Conducting literature searches on this topic unveiled many studies and findings expressing concern over OWCs, PPCPs, and pharmaceuticals in our water supplies. A Seattle City Councilwoman had also been reading some reports when she wrote to over-zealous utility managers to go slowly and cautiously in evaluating the requests to use reclaimed water in the Seattle area. Citing research documenting sex changes in some species and the findings of female-only species, her concern for the future of the aquatic populations was correctly targeted (Pageler, M. 2002).

But time, in this case, is really a two-edged sword. For humans, it takes time (sometimes moving at glacial speeds!) to induce and implement changes in social and political structures. For the bacterial world, time gives many generations of resistance to develop quickly. For fish and animals, time can speed by, producing holes in species populations that set an irreversible course towards extinction. For population sustainability, reproduction is the number one priority. The presence of metabolites and other harmful pharmaceutical by-products in waters strikes at the heart of the reproductive process. The evidence for potentially serious environmental impacts from PPCPs is clear from studies of teleost fish and changes in reproductive development due to exposure to endocrine disruptors (Rolland, 2000), and more recently in Baylor University studies (Science Daily, 2003) looking at the behavioral changes in fish from fluoxetine in water or reproductive inabilities due to estrogen. We are damaging our most valuable resource and possibly dooming some resident aquatic species to extinction through unpredictable consequences of PPCP contamination.

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