Pharmaceuticals in the Environment

by M. Roth

Stephen Harrod Buhner presents a terrifying summary of how pharmaceuticals and other chemical agents are affecting the environment in the chapter, "The Environmental Impacts of Technological Medicine," from his the book, The Lost Language of Plants - The Ecological Importance of Plant Medicines to Life on Earth (2002). His information is so dramatic that at times it appears to be false or exaggerated. Pharmaceutical drugs (e.g., pain killers, contraceptives, anti-depressants, cancer drugs, hormone therapies, blood pressure medicines) are ingested and personal care products (PCPs) (e.g., skin creams, antibacterial soaps, shampoos, sun screens, perfumes, musks) are used by many people throughout the day, everyday, and these products are eventually rinsed off or excreted and wash down the drain. The individual rarely gives a second thought about where those products are going. Who would have imagined that estrogen from birth control pills could eventually wind up in drinking water and potentially contribute to young girls to entering puberty early? At first reading, Buhner's arguments appear to be slightly farfetched. How could health care drugs and personal care products harm the environment? Therefore, it was necessary to conduct my own thorough research in scholarly and scientific journals to evaluate the accuracy of the information provided in his text which is clearly designed for a popular audience.

Articles I explored in peer-reviewed scientific journals on the topic of pharmaceuticals and personal care products in the environment supported almost all of the information presented by Buhner. This result quickly surprised me because it seems as though little publicity has been given to this extremely significant environmental issue.

Human use of pharmaceutical drugs and personal care products has increased to extremely high levels. Several kilotons of nonsteroidal anti-inflammatory drugs, such as ibuprofen, alone are produced annually worldwide (Cleuvers 2003). Pharmaceuticals and PCPs eventually get washed from the body and enter water systems, ultimately winding up in the effluent of wastewater treatment plants and aquatic environments. Since medical substances are developed with the intention of performing some sort of biological function, they have a tendency to bioaccumulate and induce effects in aquatic and terrestrial ecosystems (Halling-Sorensen et al. 1998).

Every journal article I reviewed acknowledged that pharmaceuticals and PCPs are being released into the environment. Not only are these products being released after usage, but also during manufacturing and disposal of unused or expired drugs (Breton and Boxall 2003). Millions of prescription and nonprescription drugs are purchased and ingested by or applied on individuals. Ingested drugs are eventually excreted from individuals through urine or feces. Buhner (2002) states that high percentages of many pharmaceuticals can be excreted from the body unmetabolized and enter wastewater as biologically active substances. A specific example that supports this claim is provided in a study published in the scientific journal, *Chemosphere*, by Klaus Kummerer (2001), which states that 90% of the drug, propofol found in anesthesia, is excreted unmetabolized. This is a very high percentage and it illustrates that large amounts of various unmetabolized pharmaceuticals are being released into wastewater where their environmental impacts are not well known.

Unmetabolized pharmaceuticals are often the most non-biodegradable substances in the environment (Stuer-Lauridsen et al. 2000). Their intrinsic medicinal properties give them the tendency to bioaccumulate in other organisms besides humans and thereby potentially provoke effects on the biota of aquatic and terrestrial ecosystems (Halling-Sorensen 1998). Many pharmaceuticals are often persistent and lipophilic - able to pass through cell membranes, which allows them to carry out specific biological functions. Many pharmaceuticals are relatively stable to avoid being biologically inactivated before carrying out their intended pharmaceutical effects in the body.

Because many scientific journal articles clearly documented that pharmaceuticals and PCPs are being released into the environment, I then evaluated Buhner's (2002) statements regarding the toxicity of various pharmaceuticals and PCPs. One of the drugs mentioned by Buhner is clofibric acid, which is a highly persistent drug that has been discovered in wastewater treatment plant effluents and in aquatic ecosystems, as well as in tap water of some areas (Halling-Sorensen et al. 1998). Clofibric acid is a metabolite of a blood lipid regulator used to lower blood cholesterol levels. Numerous studies support Buhner's statements regarding the relatively nonbiodegradable nature of this pharmaceutical (Halling-Sorensen et al. 1998, Webb et al. 2003). However, a study by Ferrari et al. (2003) that appeared in *Ecotoxicology and Environmental Safety* claims that clofibric acid does not pose a potential hazard to aquatic environments or humans. Ferrari et al. (2003) investigated the pharmaceutical residues in sewage treatment plants throughout France, Greece, Italy, and Sweden, and determined that the concentrations of clofibric acid present in effluents are so low that they cause no effects on nontarget organisms.

Estrogen

One aspect of Buhner's paper for which it was difficult to find legitimate scientific support was the section on estrogen. Buhner presented a great deal of information regarding the effects of estrogen compounds on the environment and on humans. Many literature sources were encountered that supported his statements about the negative effects of increasing aquatic estrogen levels on fish (Christensen 1998, Webb et al. 2003). However, it was more difficult to find support for Buhner's statements regarding the effects of estrogen on humans. Buhner (2003) insinuates that the increasing levels of estrogen in the environment, via pharmaceuticals for purposes such as menopause symptom relief and birth control pills, could be causing adverse effects on humans, such as reduced male sperm counts and sperm motility and younger ages of puberty in girls. This is one aspect of Buhner's paper that does not appear to have sufficient support, because my review found no experimental studies that have actually linked these symptoms with increasing levels of estrogen in the drinking water or environment.

F.M. Christensen (1998), a scientist at the Danish Toxicology Center in Harsholm, Denmark, published a study that tested the human exposure and risks of higher estrogen levels in the environment. He claims that many forms of estrogen are produced and excreted naturally by humans and other organisms and therefore occur naturally in the environment. He acknowledges that there are synthetic forms of estrogen currently being produced, which is increasing the level of this hormone in the environment. He also acknowledges that these circumstances are resulting in adverse effects on fish. The increasing occurrences of hermaphrodite fish in natural waterways are attributed to the higher estrogen levels from wastewater treatment plant effluent. After examining the degree of human exposure to this hormone and the way in which estrogen reacts in the body, Christensen concludes that the human exposure to estrogen via drinking water and foodstuffs does not pose a significant risk.

A study conducted by Webb et al. (2003) supports Christensen's claim. They conducted an experiment that examined the degree of human exposure to various pharmaceutical compounds in drinking water. Based on their results it was determined that the average daily intake of estrogen from drinking water is negligible. They assert that humans naturally produce and intake various forms of estrogen. The level of this natural exposure to estrogen is approximately two orders of magnitude greater than the potential levels of exposure to synthetic estrogen from pharmaceuticals. Therefore, they suggested that current increased levels of estrogen in the environment will not cause harmful effects on humans.

Antibacterial Resistance

One negative environmental effect of pharmaceuticals and PCPs in the environment that is not readily discussed by Buhner (2003) is the issue of antibacterial resistance. Halling-Sorensen et al. (1998) discuss various instances in which antibacterial agents present in waterways and sediments have allowed bacterial flora to develop antibacterial resistance to those particular agents. In locations surrounding fish farms, many sediment bacteria were found with antibiotic resistance. This resistance is attributed to the high number of antibiotics utilized as feed additives in fish farms. Bacterial resistances to erythromycin, tobramycin, chloramphenicol, and tetracycline were discovered in effluent from slaughterhouses. The development of resistance to antimicrobial agents makes treatment of infections very difficult to cure, therefore this issue is an important consideration for the treatment of wastewater, especially that which is discharged from hospitals, veterinary clinics, or other locations where large amounts of antibiotics are used.

Another synthetic chemical found in the environment are quaternary ammonium compounds (QACs). Klaus Kummerer (2001), a scientist in the Institute of Environmental Medicine and Hospital Epidemiology in Freiburg, Germany, describes the negative effects that QACs are having on the environment. QACs are cationic microbidical compounds that are important ingredients in disinfectants, which are used in hospitals as well as households. They are known to inhibit the proper functioning of aquatic microorganisms, and they have a low biodegradability. Inhibitory effects have also been found against denitrifying bacteria in very low concentrations of QACs.

Because denitrifying bacteria are important constituents of wastewater treatment plants, QACs are a synthetic chemical that disturbs the wastewater purification process in these facilities.

The environmental effects of nonsteroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen, diclofenac, naproxen, and acetylsalicylic acid have also been tested. Michael Cleuvers (2003) from the department of General Biology at Aachen University of Technology in Aachen, Germany, conducted a study to determine the ecotoxicity of NSAIDs in dilutions of single substances and in mixtures. NSAIDs are one of the most widely used pharmaceuticals worldwide and have reached detectable concentrations in the environment, including, in some instances, drinking water. Cleuvers acknowledged the importance of testing the effects of mixtures of pharmaceuticals because drug residues often occur as mixtures and not as single contaminants after entering wastewaters and the environment. This mixing of substances results in overall higher concentrations of drug residues.

Cleuvers (2003) determined that NSAIDs have inhibitory effects on certain functions in non-mammalian vertebrates and invertebrates (2003). The function of NSAIDs in humans is basically to inhibit the enzymes that catalyze the biosynthesis of prostaglandin, which is partially responsible for causing pain and inflammation. Prostaglandins are also present in organisms such as fish, amphibians, birds, corals, sponges, and marine algae, where they carryout various functions, including defense mechanisms. Another effect specific for ibuprofen was growth inhibition of certain gram-positive bacteria when exposed to low concentrations of the drug in the environment (Halling-Sorensen et al. 1998). Buhner (2003) did not discuss the effects of NSAIDs in the environment in the assigned chapter, but many studies concerned with this particular group of drugs have been published in scientific journals. The negative affects associated with these drugs supports Buhner’s general argument that pharmaceuticals are having impacts on the environment.

Human Health

Webb et al. (2003), claim that the concentrations of many drug and synthetic chemical residues in potable drinking water are so low that they do not pose high risks to humans. These researchers created a framework in which to measure the indirect exposure of various drugs from drinking water. They then examined the possible daily intake and exposure to 60 different compounds from drinking water in Germany and compared those values to the actual therapeutic dosages of each medication. In most cases the difference between daily possible intake via drinking water and the therapeutic dosage differed by a factor of at least 150,000. They claim that this indicates that the estimated indirect exposures are extremely low and below doses that would actually cause pharmacological effect. This study demonstrates that there is a low potential for negative impacts on humans from pharmaceutical residues in drinking water.

Webb et al. (2003) claim that the pharmaceuticals known as genotoxins are excluded from the category of nontoxic pharmaceuticals in drinking water. Genotoxins are antineoplastics, which are extremely toxic because they are carcinogenic, mutagenic, embryotoxic, or teratogenic. There is no threshold dose of this drug in which no significant effects may be induced through indirect exposure. This information also supports the statements made by Buhner when he explains that antineoplastics are extremely toxic substances.

Treatment Facilities

In his text, Buhner (2003) discusses the various methods in which pollutants are removed from wastewater. A study from, *Science News*, describes how older wastewater treatment plants do not remove many of the pharmaceuticals and synthetic hormones, such as those present in modern birth control pills and other prescription drugs, that enter through water effluent (Harder 2003). Modern wastewater treatment plants now have multiple tank systems that contain different types of bacterial and chemical conditions that work to break down contaminants present in the wastewater, whereas older facilities consist of single tanks that remove primarily phosphates and nitrates from the sewage sludge. Many facilities continue to utilize this older, less efficient technique. This is a significant issue because pharmaceuticals and other synthetic chemicals continue to be released from wastewater treatment facilities that have not yet been upgraded to a multiple tank purifying system (Breton and Boxall 2003).

Conclusion

Pharmaceuticals and PCPs are being released into water systems, yet inadequate federal and state regulations are implemented to monitor or control them, even though water quality standards are enforced in countries throughout the world. The water quality standards in the United States are enforced by the Environmental Protection Agency (EPA), which executes over 170 drinking water standards, but none of these standards currently apply to pharmaceuticals (Webb et al. 2003). Pharmaceuticals are excluded from water quality standards in other countries as well. Nevertheless, numerous analyses have determined that pharmaceuticals and PCPs have potential adverse human and environmental effects from indirect exposure (Cleuvers 2003, Halling-Sorensen et al. 1998, Harder 2003, Webb et al. 2003). Just as pesticides are highly regulated by means of rigorous pretesting to demonstrate no adverse environmental effects of the chemicals, new pharmaceutical and PCPs manufacturing requirements might be required of industry as a possible solution to preventing further environmental pollution by such products.

Pharmaceuticals and synthetic chemicals from personal care products are being released into the environment in extremely large quantities on a regular basis – of that there is no doubt. The exact effects that each drug is having on ecosystems, biota, and humans, however, are still are not completely understood. Therefore more research is critically needed. The information in Buhner's book chapter may not all be completely supported by work published in peer-reviewed, scientific journals. His text does present an alarming issue that deserves considerable attention and exploration. Buhner's (2003) paper is clearly meant as a means of gaining greater public awareness of this increasingly important subject, and it does a fine job of doing so.

Literature Cited:

Buhner, Stephen Harrod. 2002. The Lost Language of Plants- The Ecological Importance of Plant Medicines to Life on Earth. Chelsea Green Publishing: White River Junction, Vermont.

Boxall, Alistair, and Roger Breton. 2003. Pharmaceuticals and Personal Care Products in the Environment: Regulatory Drivers and Research Needs. QSAR and Combinational Science 22(3): 399-409.

Christensen, F.M. 1998. Pharmaceuticals in the Environment- a Human Risk? Regulatory Toxicology and Pharmacology 28(3): 212-221.

Cleuvers, Michael. 2003. Mixture Toxicity of the Anti-Inflammatory Drugs Diclofenac, Ibuprofen, Naproxen, and Acetylsalicylic Acid. Ecotoxicology and Environmental Saftey. Online: http://dx.doi.org/10.1016/S0147-6513(03)00141-6

Kummerer, Klaus. 2001. Drugs in the Environment: Emission of Drugs, Diagnostic Aids and Disinfectants into Wastewater by Hospitals in Relation to Other Sources- a Review. Chemosphere 45(6-7): 957-969.

Stuer-Lauridsen, F., M. Birkved, L.P. Hansen, H.C. Holten Lutzhoft, and B. Halling-Sorensen. 2000. Environmental Risk Assessment of Human Pharmaceuticals in Denmark After Normal Therapeutic Use. Chemosphere 40(7): 783-793.

Kummerer, K., T. Erbe, S. Gartiser, and L. Brinker. 1998. AOX-Emissions from Hospitals in Municipal Waste Water. Chemosphere 36(11): 2437-2445.

Halling-Sorensen, B., S. Nors Nielsen, P.F. Lansky, F. Ingerslev, H.C. Holten Lutzhoft, and S.E. Jorgensen. 1998. Occurrence, Fate, and Effects of Pharmaceutical Substances in the Environment- a Review. Chemosphere 36(2): 357-393.

Harder, Ben. 2003. Extracting Estrogens. Science News 164(5): 67-68.

Webb, Simon, Thomas Ternes, Michel Gilbert, and Klaus Olejniczak. 2003. Indirect Human Exposure to Pharmaceuticals via Drinking Water. Toxicology Letters 142(3): 157-167.

Ferrari, Benoit, Nicklas Paxeus, Roberto Lo Giudice, Antonino Pollio, and Jeanne Garric. 2003. Ecotoxicological Impact of Pharmaceuticals Found in Treated Wastewaters: Study of Carbamazepine, Clofibric Acid, and Diclofenac. Ecotoxicology and Environmental Safety 55(3): 359-370.