Pharmaceuticals and Personal Care Products (PPCPs):

Green Chemistry Solutions

Yu Chung, Veronica Becerra, and Antonio Machado
Department of Environmental and Occupational Health
California State University, Northridge

Green Chemistry in Higher Education Symposium
U.C Berkeley
October 26, 2010

PPCPs : An Increasing Environmental Concern

What are PPCPs?

Pharmaceuticals and personal care products:

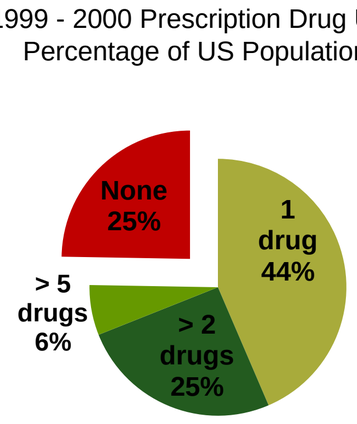
Antibiotics
Anticorrosives
Antimicrobial Disinfectants
Hormones
Antioxidants
Antipyretics
Deodorizers
Detergents
Frangrances
Insecticides
Non-Prescription Drugs
Plasticizers
Prescription Drugs
Steroids

Increased Identification of PPCPs in Water

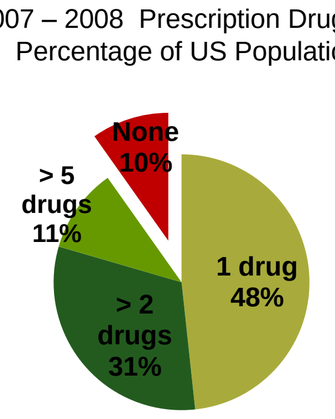
- Increased population demand has led to greater reuse of reclaimed water, which augments the risk of groundwater contamination.
- Advancements in medical science, agriculture, industry, personal care products and common household conveniences yield new contamination risks to water resources.
- Environmental persistence due to non polar molecular structures of most compounds.
- Polar PPCPs increased potential for leaching into groundwater with limited soil adsorption.
- Inability of conventional water treatment processes to remove all the PPCPs.
- Increased sensitivity of chemical assays which allow for compound identification in water

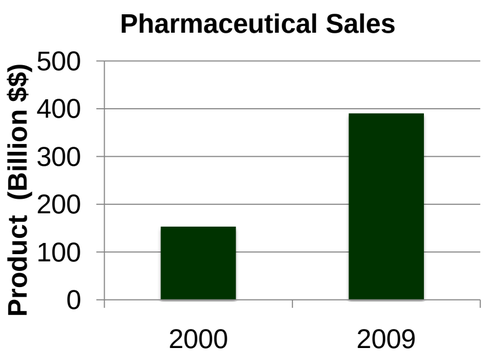
Increased Use of PPCPs

1999 - 2000 Prescription Drug Use
Percentage of US Population

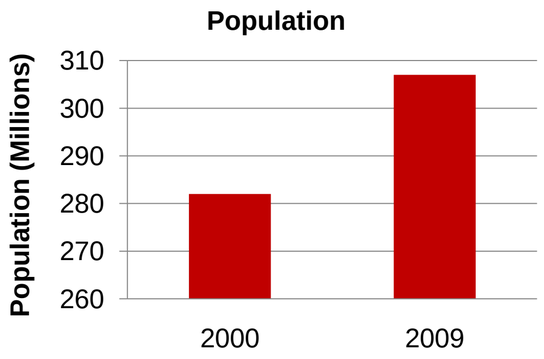


2007 – 2008 Prescription Drug Use
Percentage of US Population



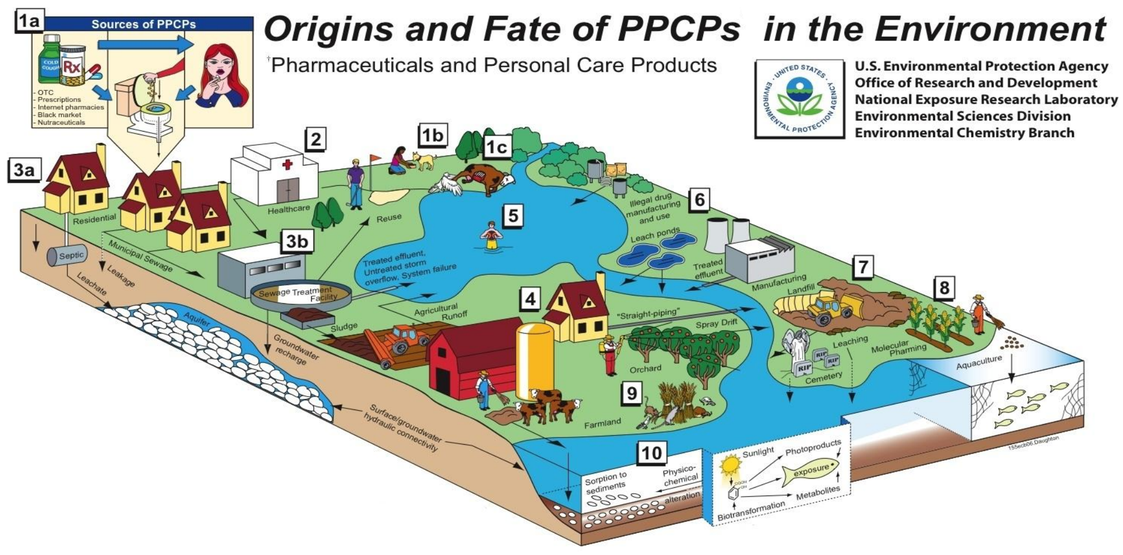


- Pharmaceuticals sales in North America have been rising nearly seven times faster then the population growth rate.
- 2009 North America sales - $390 billion [2] [3]



- U.S. Yearly population growth rate ~1.2%
- U.S compounded annual growth rate ~ 8.5%

Sources of PPCPs in Water

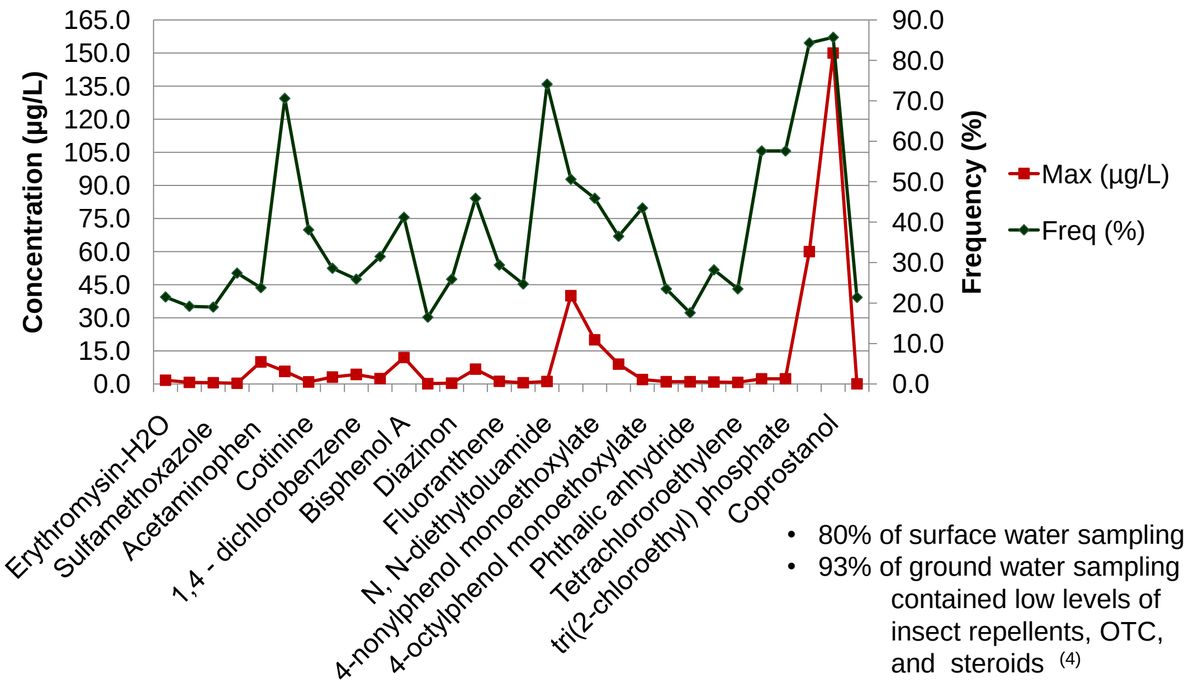


1. Excretions, disposal of unwanted medication, sewage leakage, and medicated animal carcasses used as food for scavengers.
2. Release of hospital wastes to domestic sewage systems.
3. Release of private septic/leach fields into the groundwater (3a) and (3b): over flow of the sewage system, reclaim water use, recharge into the aquifers.
4. Release from agriculture: the sludge used as soil amendment in agriculture, untreated sewage discharge, dung from medicated animals.
5. Direct release to water from swimming
6. Release from the manufacturing facilities.
7. Release and leaching from reuse or poorly engineered landfills and cemeteries.
8. Direct release into the water from aquaculture.
9. Release of drugs that serve as pest control agents.
10. Ultimate environmental transport/ fate:
    Most PPCPs are transported from terrestrial to aqueous by:
    - Phototransformation / Degradation
    - Physicochemical alteration,
    - Ultimate mineralization
    - Volatilization
    - Uptake by plants
    - Respirable particulates containing sorbed drugs

Most Common PPCPs Identified in Water

Compounds and Concentration of PPCPs

Contaminants were measured in 139 streams in the United States.



- 80% of surface water sampling
- 93% of ground water sampling contained low levels of insect repellents, OTC, and steroids [4]

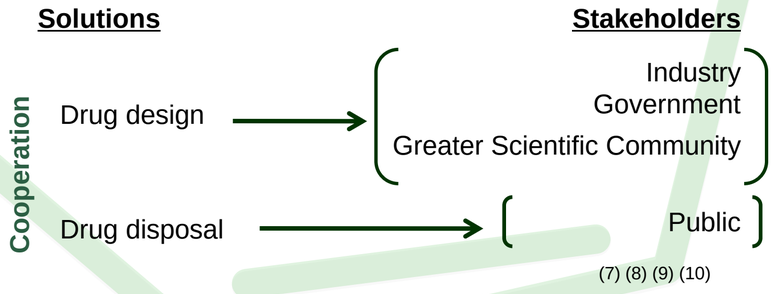
An Interdisciplinary Green-Chemistry Approach

Department of Toxic Substances Control Goals

1. Expand the pollution prevention and product stewardship program
2. Develop the green chemistry workforce
3. Create an online product ingredient network
4. Create an online toxics clearinghouse and online database
5. Accelerate the search for safer products
6. Move toward a cradle-to-cradle economy [5]

Knowledge Gaps

1. Centralized, standardized and consistent information
2. Accurate methods to quantify, identify and trace sources
3. Fate and transport
4. Toxicology
5. Risk assessment, communication and regulation
6. Economic impacts
7. New research support [6]
8. International pharmaceutical industry management



Activation of a Green-Chemistry Interdisciplinary Solution

1. **Engage experts in chemistry, biology, engineering, toxicology, risk analysis, risk communication, risk management, environmental and occupational health, policy analysis, and all other applicable areas.**
2. **Increase partnerships among agencies, universities, industry, and other stakeholders.**
3. **In consultation with partners, develop interdisciplinary education through green chemistry majors, existing majors with an emphasis in green chemistry, and minors.**
4. **Expand the international network for collaboration in standardization and regulation of PPCPs.**

References

1. Khetan et al. 2007. Human pharmaceuticals in the aquatic environment: A challenge to green chemistry. *Chem. Rev*. 107:2319-2364.
2. Santos et al. 2010. Ecotoxicological aspects related to the presence of pharmaceuticals in the aquatic environment. *Journal of Hazardous Material.* 175: 45-95.
3. Prescription Drug Use Continues to Increase: U.S Prescription Drug Data for 2007-2008. Available from: http://www.cdc.gov/nchs/data/databriefs/db42.htm
4. Kolpin et al. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance. *Environ. Sci. Technol*. 36, 1202-1211.
5. California Green Chemistry Initiative. Final Report. Available at: http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/GREEN_Chem.pdf
6. Daughton. PPCPs in the Environment: Future Research. Available at: http://www.epa.gov/nerlesd1/bios/daughton/researchneeds-chapter.pdf
7. A Healthy Future Pharmaceuticals in a Sustainable Society. Available at: http://www.epa.gov/esd//bios/daughton/Pharmaceuticals-Sustainability-2009.pdf
8. Daughton et al. Pharmaceuticals in the Environment. 2010. Available at: http://www.iwapublishing.com/template.cfm?name=isbn9781843393146
9. Daughton. 2003. Cradle-to-cradle stewardship of drugs for minimizing their environmental disposition while promoting human health. *Environmental Health Perspectives*. 111: 757-774.
10. Daughton. PPCPs in the Environment: Future Research. Available at: http://www.epa.gov/nerlesd1/bios/daughton/researchneeds-chapter.pdf

For more information:
email: amachado@csun.edu
pdf of this poster: http://www.csun.edu/~vchsc006/solutions.pdf
CSUN EOH Department: www.csun.edu/hhd/eoh