Trace Organics in Recycled/Reclaimed Waters

The Potential Contaminants from Water Reuse Workshop
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What is Recycled or Reclaimed water?

"Municipal wastewater that has gone through various treatment processes...with the intent of being used [reused] in a beneficial manner …"
Asano et al., 2007

Why Focus on Reclaimed Water?

A potentially useful resource in providing a sustainable water supply
- re-use water instead of "throwing it away"
- reliable source
  - not susceptible to droughts
  - not dependent on upstream users

Very valuable in areas where water is scarce
- Nearly All Western states
- And Tampa, Florida!

Uses of Reclaimed Water

Established
- Irrigation of lawns, golf courses, highway medians, other landscapes
- Cooling water in industrial applications
- Fire protection

Other
- Replenishment of natural water bodies
- Irrigation of crops
- Drinking
  - Unpleasant as the thought may be, many people drink used water

Trace Organics in Wastewater Effluents

- Natural and synthetic hormones (bisphenol A, Alkylphenols, Phthalates)
- Steroidal hormones (17 β-estradiol)
- Antioxidants
- Flame-retardant chemicals (polybrominated diphenyl ethers - PBDEs)
- Pesticides and their metabolites
- Pharmaceutical and personal care products (PPCPs) and their metabolites
- Pigments & Dyes
- Perfluorinated carboxylates and sulphonates
- Disinfection by-products – organooxygen compounds such as aldehydes, carboxylic acids etc.

Examples of Sources

Trace organics	**Source**
Oral contraceptive	The Pill
Phytoestrogens	Constituents of many vegetables
Mycotoxins	Fungi that contaminate crops
OC pesticides	DDT, lindane
PCBs	Widespread industrial POPs
Alkylphenol ethoxylates	Non-ionic surfactants
PCDD/Fs	Products of combustion
Phthalate esters	Plasticizers
Bisphenol A	Component of polycarbonate plastics
PBDEs	Flame retardant compounds
PPCPs	Homes and hospitals

Pesticides	Industrial products	Unintentional byproducts
Aldrin[1]	**Polychlorinated biphenyls (PCBs)**[1,2]	Polycyclic aromatic hydrocarbons (PAHs)[3]
Chlordane[1]	Hexabromobiphenyl[1]	**Polychlorinated dibenzo-p-dioxins (PCDDs)**[3]
Chlordecone[1]		**Polychlorinated dibenzofurans (PCDFs)**[3]
DDT [1,2]		
Dieldrin[1]		
Endrin[1]		
Heptachlor[1]		
Hexachlorobenzene (HCB)[1,3]		
Hexachlorocyclohexane (HCH)[1,2]		
Mirex[1]		
Toxaphene[1]		

Substances highlighted in bold are to be included in the UNEP global POPs convention

1. Substances scheduled for elimination
2. Substances scheduled for restrictions on use
3. Substances scheduled for emission reductions

Overview: Trace Organics in the Environment

Known

- Some have been known for over 20 years to occur in the environment (e.g., caffeine, aspirin, nicotine, DDT, PCBs)
- Environmental occurrence primarily resulting from treated and untreated sewage effluent, landfills, etc.
- Domestic sewage is a major source — not just hospital sewage
- Confined Animal Feeding Operations are a major source of antibiotics

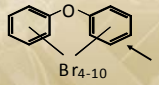
Now we have found them

- Prior discovery delayed primarily by limitations in analytical environmental chemistry

Now what do we do

- Steps have been taken to either eliminate, restrict or reduce emissions

Brominated Flame Retardants



Polybrominated diphenyl ethers (PBDEs)

Pharmaceutical and Personal Care Products (PPCPs)

Any chemical used for humans, domestic animals, or agricultural crops to:

- Treat disease
- Prevent disease or maintain health
- Serve to formulate the active ingredient
- Help in diagnosis of disease or monitoring of health
- Alter or improve physiological, cosmetic, or emotional function, appearance, or status

PPCPs in Our Everyday Life






Examples of PPCPs

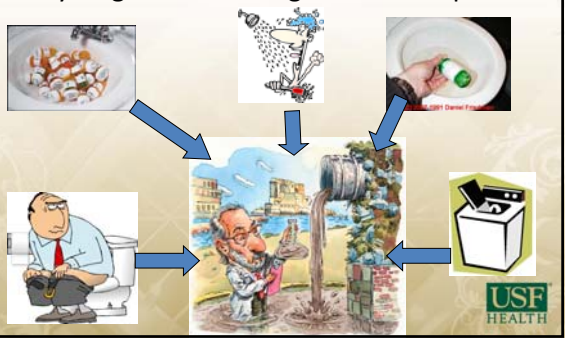
Pharmaceuticals

- pain killers
- antibiotics
- contraceptives
- anti-depressants
- cancer drugs
- hormone therapies
- impotency drugs
- blood pressure medicines

Personal Care Products

- skin creams
- antibacterial soaps
- shampoos
- sun screens
- perfumes
- musks

They all go to the sewage treatment plant!



Contaminants in Municipal Wastewater

General Concerns (1)

All drugs are designed to have biological effects

Poisoning from overdose

Certain drug combinations result in unexpected side effects

Drugs are often taken in controlled amounts
- Non-target organisms do not have these luxuries
- They are exposed continuously to a cocktail of drugs

General Concerns (2)

Medical practitioners are sometimes very “generous” in prescribing/dispensing medication

Recent survey have found unwanted medication at homes

Some people dispose of unused medication in trash and some even flush down drains

Very little knowledge on potential effects

Troubling Scenario?

Uses for which PPCPs were designed differ from those of industrial and agro-chemicals

Intended biological targets (receptors) are numerous and frequently exquisitely specific and sensitive

Receptors in non-target species could differ from those in humans

Possible interactive effects

Effects of Trace Organics on Non-Target Organisms (1)

Endocrine disruption (e.g. 17 a-ethinylestradiol)
- Feminization of male fish

Effects on brain activity

Effects on sexual differentiation

Immunosuppression (e.g. antidepressants like prozac)

Effects of Trace Organics on Non-Target Organisms (2)

Reproductive Effects
- Disrupts development of sex organs
- Induction of intersex or ova-testes

High Toxicity of Antibiotics to Algae and Bacteria

Profound effects on development, spawning, and other behaviors in shellfish, ciliates, and other aquatic organisms by tricyclic antidepressants

Dramatic inhibition of sperm activity in certain aquatic organisms by calcium-channel blockers.

Effects of Trace Organics on Non-Target Organisms (3)

Decline of Gyps spp. vultures in Pakistan & India – Possible Link with Diclofenac

Massive decline in alligator population in Lake Apopka in 1980 due to dicofol (pesticide)

Discovery of hermaphrodite roach in stretches of UK rivers close to sewage outlets

Skewed sex ratios in bird populations - Western Gull population on Santa Barbara Island, California (1968-1978)

Is Reclaimed Water "Safe"?

PBDE Levels in a Waste Water Treatment Facility

Location	Concentration (pg/mL)
Influent	247.04
Primary sedimentation	<DL
Carbonaceous sedimentation	<DL
Nitrification	2.99
Denitrification	2.40
Secondary sedimentation	1.15
Final effluent	1.05
Reclaimed water	<DL

Antiviral Drugs in Influents and Effluents of Sampled WWTPs

Analyte	WWTP1 (grab samples) elimination [%]	WWTP2 (24 hr composite samples) elimination [%]
ribavirin		
acyclovir	98	97
penciclovir	>94	>87
lamivudine	>76	>93
stavudine	>78	>89
abacavir	>99	>99
oseltamivir carboxylate	59	59
zidovudine	68	none

Prasse et al; ES&T ASAP

The good News …

Even though most of these trace organics have existed in the environment for as long as they have been used commercially. Now …

- Good analytical techniques to measure them
- Detected at very low concentrations
- There are new technologies to effectively remove them although they are expensive
- Reclaimed water could be a viable option to solve our water problem

To Summarize …

1. Trace organics have been in the environment for a long time ... since they were first used
2. They are being detected in many waters only recently as detection limits are becoming more refined
3. The number of substances (contaminants) entering water is growing rapidly … far greater than we can collect data on biological (pollution) effects

Thank you for your attention