Understanding sources, management, and impact of Endocrine Disrupting Compounds (EDCs) in the Potomac

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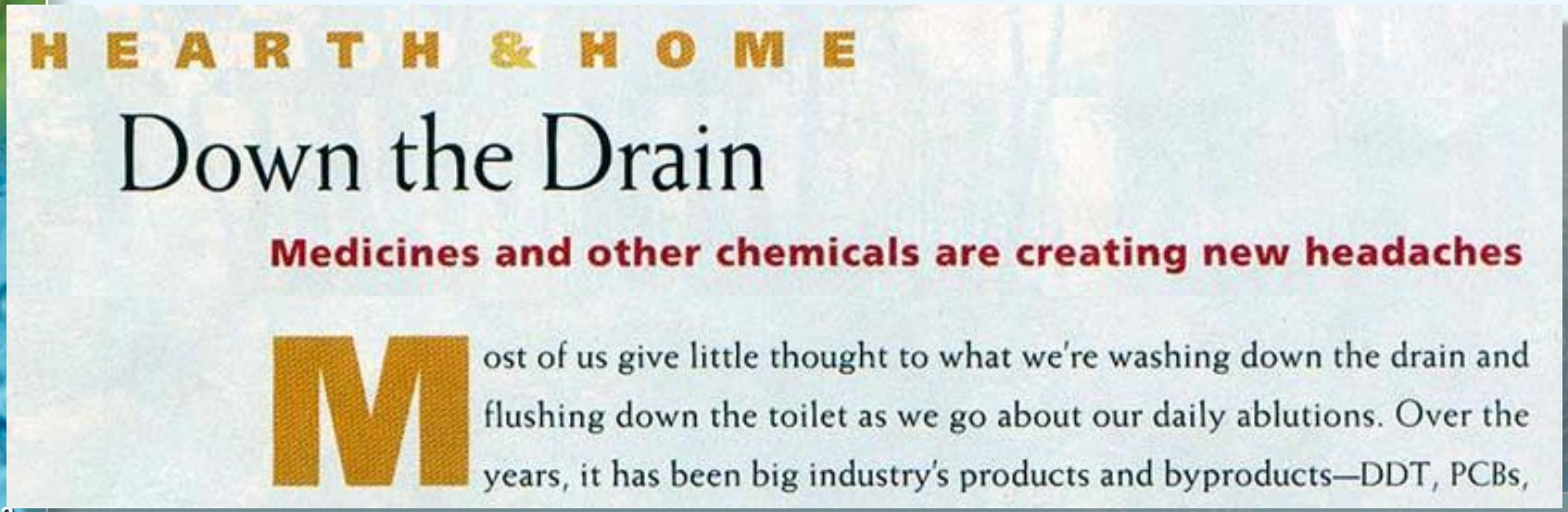
HAZEN AND SAWYER
Environmental Engineers & Scientists

Outline

- EDCs and PPCPs: What are we talking about?
- Current State of Knowledge
  - Occurrence
  - Sources
- What Can be done
  - Advanced Treatment
  - Understanding inputs?
- Proposed Research: **ASSESSING THE IMPACT OF ANTHROPOGENIC DISCHARGES OF ENDOCRINE DISRUPTING CHEMICALS IN THE POTOMAC RIVER WATERSHED**

Alphabet Soup

- Pharmaceuticals and Personal Care Products (PPCPs)
- Pharmaceutically Active Compounds (PhACs)
- Trace Organic Contaminants (TOrCs)
- Endocrine Disrupting Compounds (EDCs) – Chemicals that interfere with the function of the endocrine system
- Contaminants of Emerging Concern (CECs)



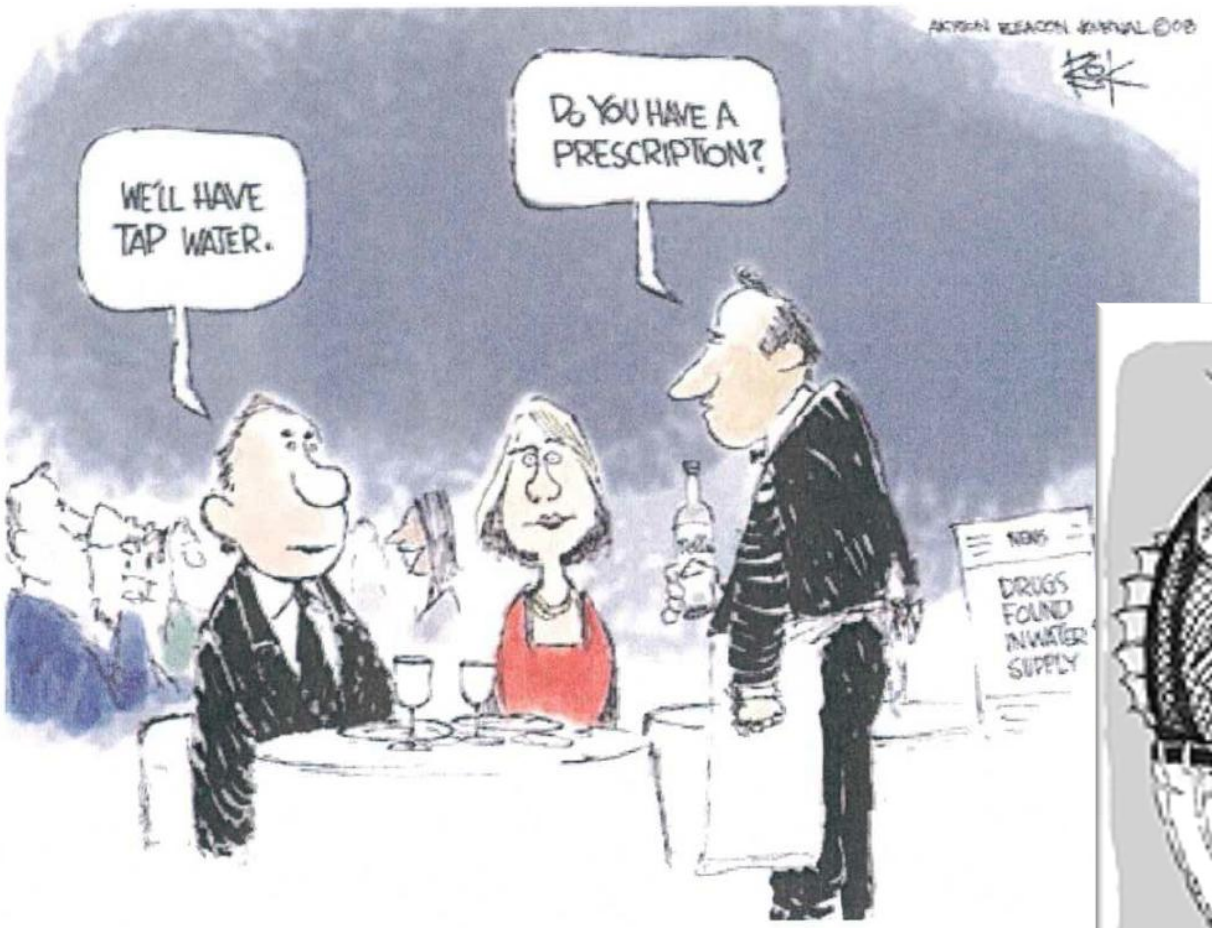
HEARTH & HOME

Down the Drain

Medicines and other chemicals are creating new headaches

Most of us give little thought to what we're washing down the drain and flushing down the toilet as we go about our daily ablutions. Over the years, it has been big industry's products and byproducts—DDT, PCBs,

Current State of Knowledge



Water
Wastewater
Water Recycling

Risks
Exposure
Regulations

Drugs In Water Report Prompts Nationwide Alarm

Hearings set for April as consumers react with shock, full scale of crisis not realized

Business

NSF Discusses Recent AP Report on Pharmaceuticals in Water and Next Steps

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AP: Drugs found in drinking water

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Women's health
Men's health
Kids and parenting
Sexual health
Mental health
Pet health

Pharmaceuticals lurking in U.S. drinking water

AP probe found traces of meds in water supplies of 41 million Americans

Jae C. Hong / AP file

Duane Moser, an assistant research professor with Desert Research Institute, collects water samples from the Las Vegas Wash in Henderson, Nev.

Occurrence

Environ. Sci. Technol. **2009**, *43*, 597–603

Pharmaceuticals and Endocrine Disrupting Compounds in U.S. Drinking Water

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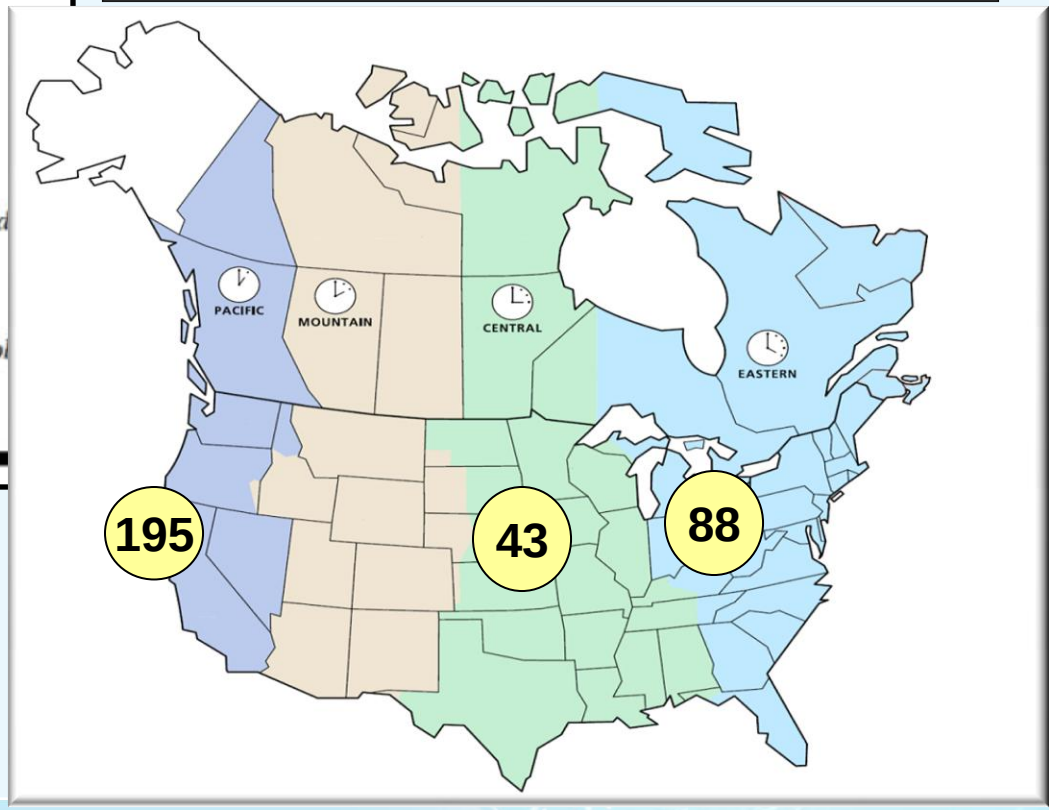
Samples collected per time zone



Pharmaceuticals (20)	Potential EDCs (26)	Steroid Hormones (5)	Phytoestrogens (11)
Atenolol	Atrazine	Estradiol	Apigenin
Atorvastatin	Benzophenone	Estrone	Biochanin A
o-Hydroxy atorvastatin	BHA	Ethinylestradiol	Chrysin
p-Hydroxy atorvastatin	BHT	Progesterone	Coumestrol
Carbamazepine	α-BHC	Testosterone	Daidzein
Diazepam	β-BHC		Equol
Diclofenac	γ-BHC		Formononetin
Dilantin	δ-BHC		Genistein
Enalapril	Bisphenol A		Glycitein
Fluoxetine	Butylbenzyl phthalate		Matairesinol
Norfluoxetine	DEET		Naringenin
Gemfibrozil	Diazinon		
Meprobamate	Dioctyl phthalate		
Naproxen	Galaxolide		
Risperidone	Linuron		
Simvastatin	Methoxychlor		
Simvastatin hydroxy acid	Metolachlor		
Sulfamethoxazole	Musk ketone		
Triclosan	Nonylphenol		
Trimethoprim	Octachlorostyrene		
	Octylphenol		
	TCEP		
	TCPP		
	Tonalide		
	Traseolide		
	Vinclozolin		

Target Compounds in Raw Water
Results from Benotti et al., 2009

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Atenolol	Atrazine	Estradiol	Apigenin
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Gemfibrozil	Diazinon		
Meprobamate	Dioctyl phthalate		
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Sulfamethoxazole	Musk ketone		
Triclosan	Nonylphenol		
Trimethoprim	Octachlorostyrene		
	Octylphenol		
	TCEP		
	TCPP		
	Tonalide		
	Traseolide		
	Vinclozolin		

Detected in Raw Water (24 / 62)
In at least 20% of samples
Results from Benotti et al., 2009

Pharmaceuticals (20)	Potential EDCs (26)	Steroid Hormones (5)	Phytoestrogens (11)
Atenolol	**Atrazine**	Estradiol	Apigenin
Atorvastatin	Benzophenone	Estrone	Biochanin A
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Naproxen	Galaxolide		
Risperidone	Linuron		
Simvastatin	Methoxychlor		
Simvastatin hydroxy acid	**Metolachlor**		
Sulfamethoxazole	Musk ketone		
Triclosan	Nonylphenol		
Trimethoprim	Octachlorostyrene		
	Octylphenol		
	TCEP		
	TCPP		
	Tonalide		
	Traseolide		
	Vinclozolin		

Detected in Drinking Water (11 / 62)
In at least 20% of samples
Results from Benotti et al., 2009

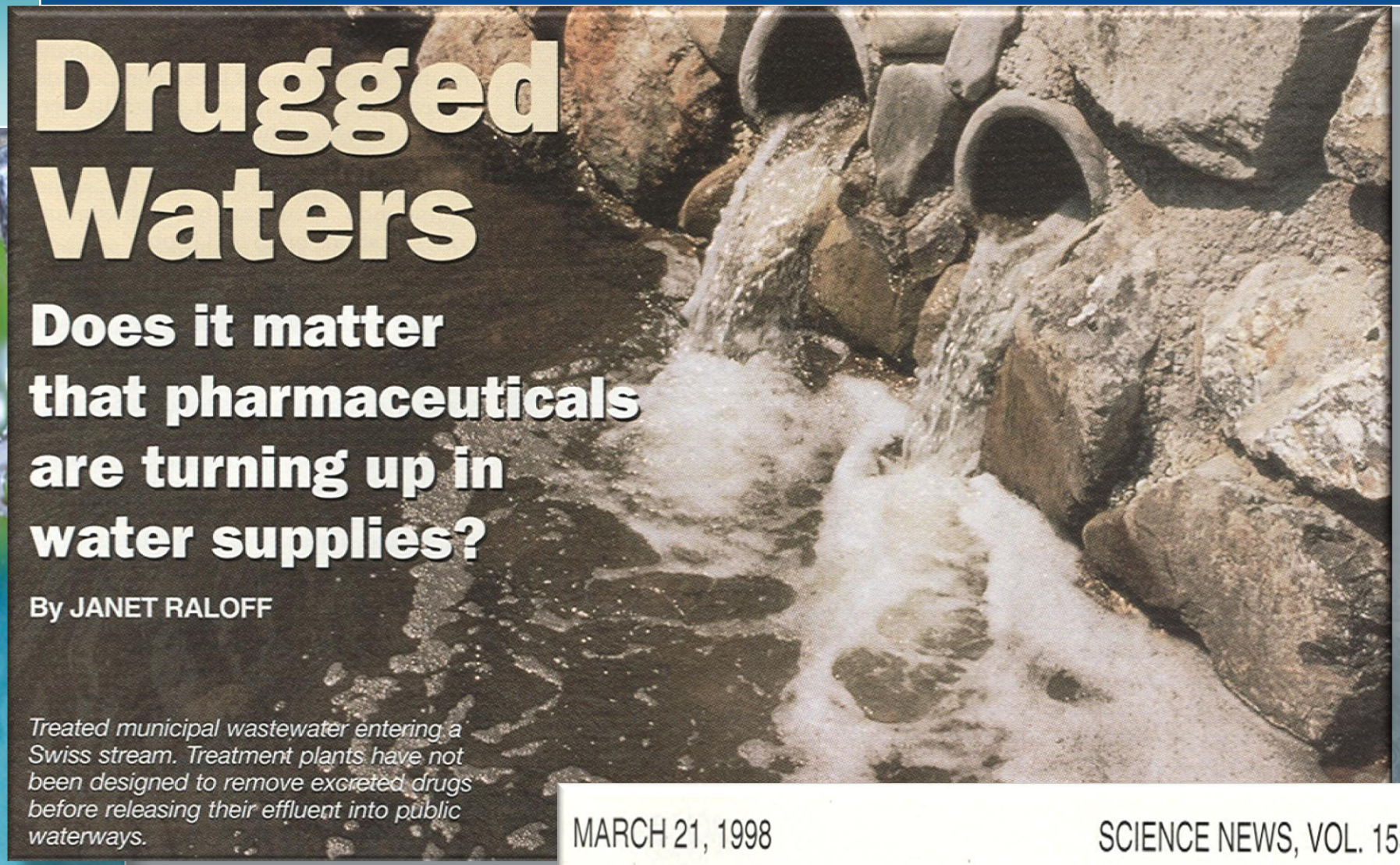
Finished Water for Drinking Water Facilities (n = 15)

Compound	Max (ng/L)	Median (ng/L)	Frequency (> 50%)
Atrazine *	870	8.4	80
Meprobamate	42	6.2	73
Dilantin	19	5.8	60
Diethylhexyl phthalate	120	66	53

** Atrazine is the only regulated compound*

Results from Benotti et al. – different data analysis

Sources


Drugged Waters
Does it matter that pharmaceuticals are turning up in water supplies?
By JANET RALOFF
Treated municipal wastewater entering a Swiss stream. Treatment plants have not been designed to remove excreted drugs before releasing their effluent into public waterways.
MARCH 21, 1998
SCIENCE NEWS, VOL. 153

Industrial / Urban Inputs:

- Medical Waste
- Surfactants
- Industrial Pollutants
- etc.

Agricultural Inputs:

- Pesticides
- Hormones
- Antibiotics
- etc.

Human Inputs:

- Pharmaceuticals
- Hormones
- PPCPs
- etc.

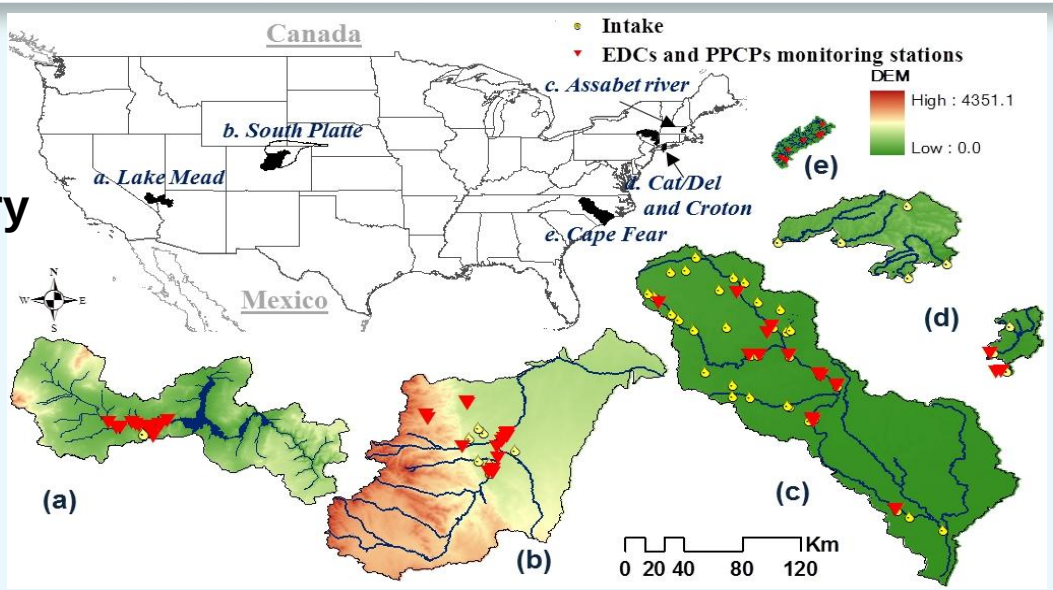
PD-Sw075.ppt

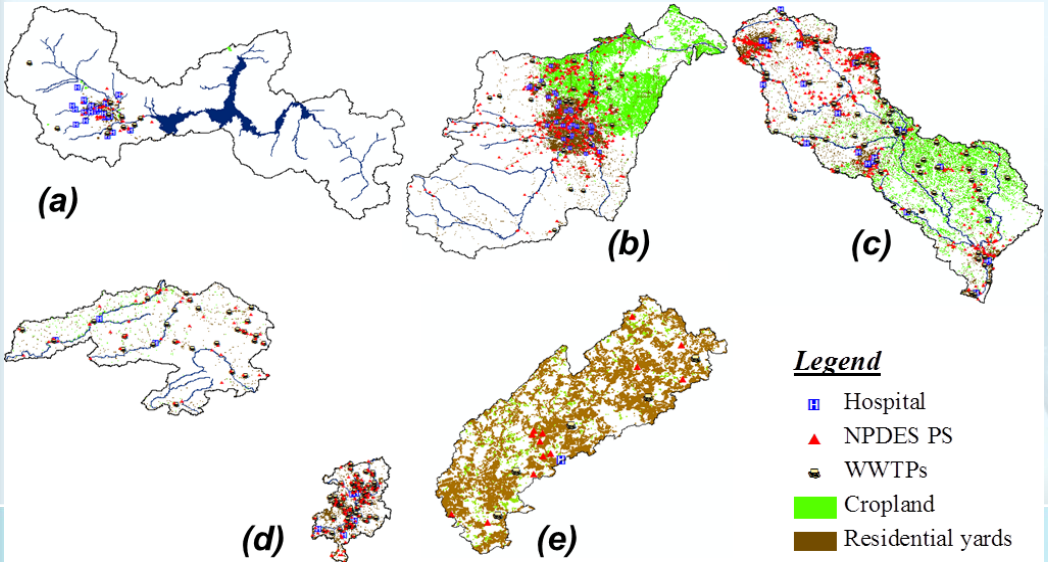
http://www.jointheevolution.ca/blog/wp-content/uploads/2009/06/water-cycle-urban-4-www.pacificwater.org.jpg

WaterRF 4260: Benchmarking EDCs in Watersheds

Watersheds of Interest from Across the Country

- Assabet River
- Cat/Del andCroton
- Cape Fear
- South Platte
- Lake Mead





Spatial and Statistical Analysis to find:

- Hotspots
- Inputs
- Sampling Frequency
- Compounds of Concern

State of Knowledge Summary

- Ubiquitous
- Persistent
- Link between climate change/drought and concentration
- Diverse sources
- Environmental impacts clear
- Human impacts???

World Health Organization

WHO/HSE/WSH/11.05

Pharmaceuticals in Drinking-water

Analysis of the results indicated that appreciable adverse health impacts to humans are very unlikely from exposure to the trace concentrations of pharmaceuticals that could potentially be found in drinking-water. Concentrations of pharmaceuticals in drinking-water are generally more than 1000-fold below the MTD, which is the lowest clinically active dosage. The findings from these three case-studies are in line with the evidence published over the past decade, which suggests that appreciable risks to health arising from exposure to trace levels of pharmaceuticals in drinking-water are extremely unlikely.

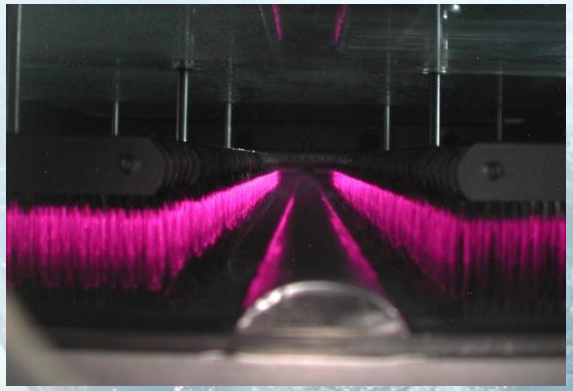
Given Enough Energy (and Money) Input, Any Chemical Can Be Removed From Water…

Is The Benefit Worth The Impact?

And

Is There a Better Approach?

Technology Evaluations



Contaminant Removal by Process (From Draft 2012 US EPA Water Reuse Guidelines)

Table 6-5 Indicative percent removals of organic chemicals during various stages of wastewater treatment

Treatment	Percent Removal										
			Pharmaceuticals					Hormones			
	B(a)p	Antibiotics[1]	DZP	CBZ	DCF	IBP	PCT	Steroid[2]	Anabolic[3]	Fragrance	NDMA
Secondary (activated sludge)	nd	10–50	nd	–	10–50	>90	nd	>90	nd	50–90	–
Soil aquifer treatment	nd	nd	nd	25–50	>90	>90	>90	>90	nd	>90	>90
Aquifer storage	nd	50–90	10–50	–	50–90	50–90	Nd	>90	nd	–	–
Microfiltration	nd	<20	<20	<20	<20	<20	<20	<20	nd	<20	
Ultrafiltration/ powdered activated carbon (PAC)	nd	>90	>90	>90	>90	>90	nd	>90	nd	>90	>90
Nanofiltration	>80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	
Reverse osmosis	>80	>95	>95	>95	>95	>95	>95	>95	>95	>95	25–50
PAC	>80	20–>80	50–80	50–80	20–50	<20	50–80	50–80	50–80	50–80	
Granular activated carbon		>90	>90	>90	>90	>90		>90		>90	>90
Ozonation	>80	>95	50–80	50–80	>95	50–80	>95	>95	>80	50–90	50–90
Advanced oxidation		50–80	50–80	>80	>80	>80	>80	>80	>80	50–80	>90
High-level ultraviolet		20–>80	<20	20–50	>80	20–50	>80	>80	20–50	nd	>90
Chlorination	>80	>80	20–50	–<20	>80	<20	>80	>80	<20	20–>80	–
Chloramination	50–80	<20	<20	<20	50–80	<20	>80	>80	<20	<20	

(Sources: Ternes and Joss, 2006; Snyder et al., 2010)

B(a)p = benz(a)pyrene; CBZ = carbamazepine, DBP = disinfection by-product; DCF = diclofenac; DZP = diazepam; IBP = ibuprofen; NDMA=N-nitrosodimethylamine; nd = no data; PAC = powdered activated carbon; PCT = paracetamol.

[1] erythromycin, sulfamethoxazole, triclosan, trimethoprim

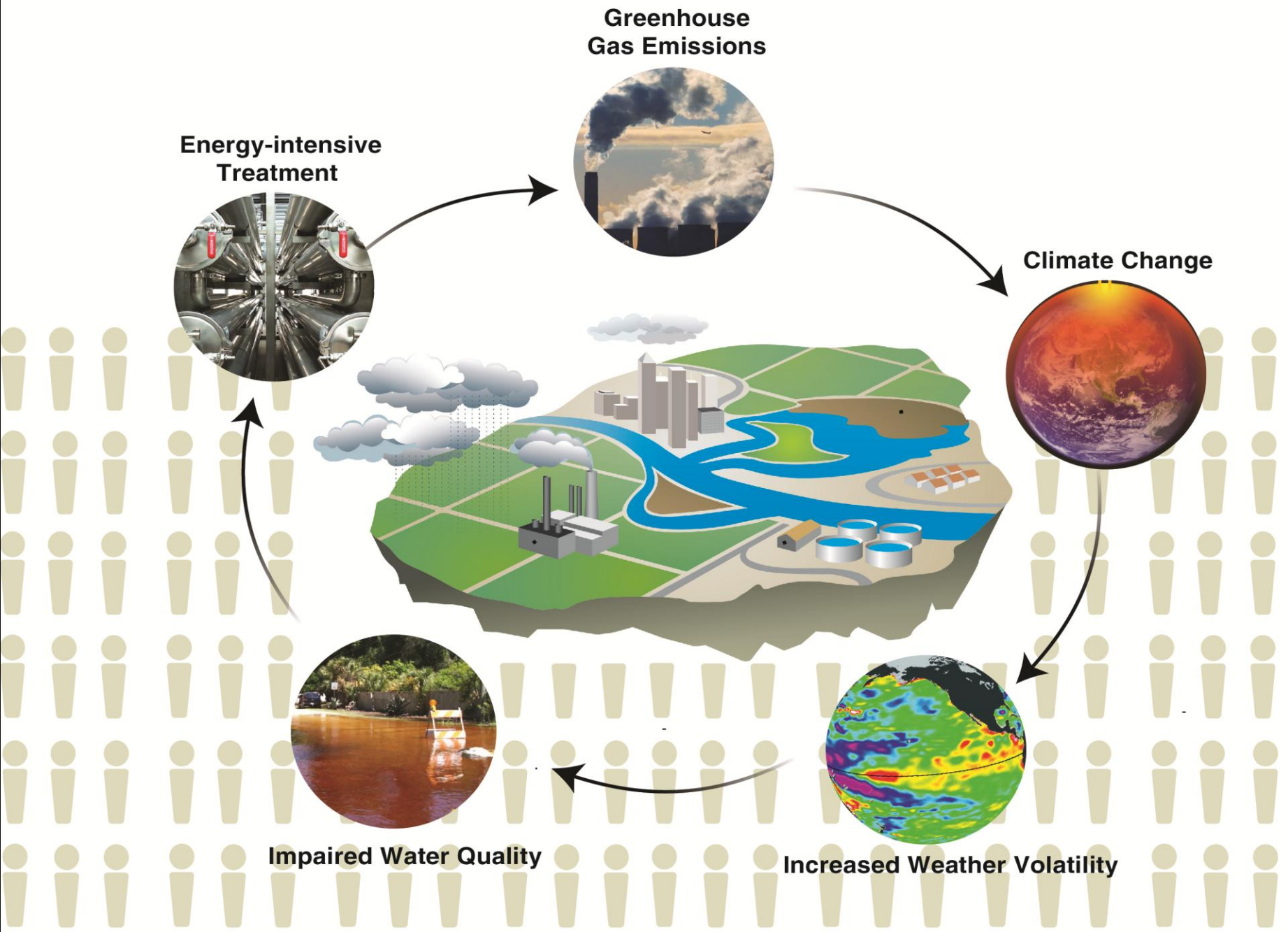
[2] ethynylestradiol; estrone, estradiol and estriol

[3] progesterone, testosterone

Costs Associated with Reduction Technologies (WTP, Internal H&S Documents)

Plant Capacity (MGD)	Ozone/BAC		MF/RO		GAC		UV AOP	
	CAP ($M)	O&M ($M/yr)	CAP ($M)	O&M ($M/yr)	CAP ($M)	O&M ($M/yr)	CAP ($M)	O&M ($M/yr)
10	8.9	0.6	34	4.8	6.1	0.7	2.2	0.4
50	31	3.0	120	19	25	3.2	10	2.2
80	44	4.0	180	29	37	5.1	16	3.5

Big Costs Associated with Advanced Treatment Options


Greenhouse
Gas Emissions
Energy-intensive
Treatment
Climate Change
Impaired Water Quality
Increased Weather Volatility

What's our Job?

- Provide high quality water that is safe
  - Human Health
  - Environmental Health
- Understand the implications of EDCs/PPCPs, and other contaminants of emerging concern
  - Human Health
  - Environmental Health
- Evaluate the best ways to protect water resources from EDCs/PPCPs/CECs
- Prepare for Uncertainty of Future EPA Regulatory Actions

A Holistic View of EDC Control

Option	Environmental Exposure	Human Exposure	Cost	Energy
Advanced Drinking Water Treatment	-	+	$$	
Source Water Protection	+	+	?	?
• Wastewater Treatment	+	+	$ - $$	
• Agriculture Runoff	?	?	?	?
• Urban Runoff	?	?	?	?

- Negative or No Impact
+ Positive Impact
? Unknown Impact

There are Many Unknowns About Source Water Protection Methods

Providing an Initial Evaluation

- **Assessing the Impact of Anthropogenic Discharges of Endocrine Disrupting Chemicals in the Potomac River Watershed**
- Research Project Designed to:
  - Understand Relative Source Impact of EDCs *and* biological activity in the Potomac
    - WWTP
    - Agriculture
    - Urban Runoff
  - Evaluate Impact of Nutrient Best Management Practices
- Approach:
  - Collect Samples from the river and at BMP locations
  - Evaluate (and examine correlations):
    - Advanced Biological Activity Assays (USGS)
    - Advanced Analytical Techniques (USDA)
    - Advanced "Fingerprinting" Techniques
      - UMD - Nutrients
      - Hazen and Sawyer - NOM

The DC/VA/MD/WV Team Assembled is Second to None

- Sudhir Murthy, Ph.D., P.E., DC Water
- Erik Rosenfeldt, Ph.D., P.E., Hazen and Sawyer
- Luke Iwanowicz, Ph.D., USGS, Leetown, WV Science Center
- Cliff Rice, Ph.D., USDA – Agricultural Research Service Center
- Sujay Kaushal, Ph.D., University of Maryland Dept. of Geology & Earth System