Assessing the Risk of Using Reuse Water to Irrigate Turf-Covered Soil

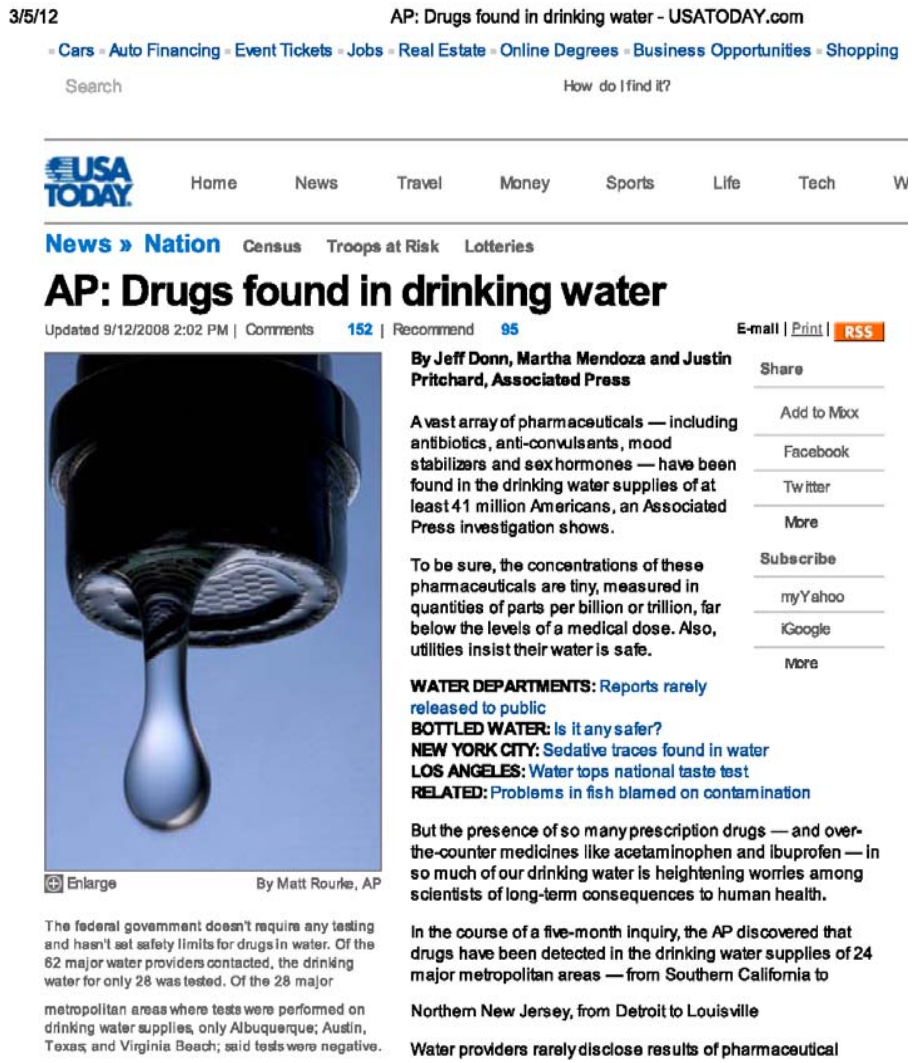
Michael H. Young[1], Robert Green[2], Jeremy Conkle[2], Michael McCullough[3], Dale A. Devitt[4], Lena Wright[4]

1 – ***University of Texas at Austin***
2 – ***University of California, Riverside***
3 – ***Monterey Regional Water Pollution Control Agency***
4 – ***University of Nevada Las Vegas***

South-Central, Geological Society of America
Austin, TX
4 April 2013

Motivation

- Reuse water is quickly becoming an accepted asset for augmenting water supplies during periods of shortages
- Lingering questions on fate and transport of PPCPs in reuse water raise issues and public concerns on long-term safety of this resource



3/5/12 AP: Drugs found in drinking water - USATODAY.com

Cars · Auto Financing · Event Tickets · Jobs · Real Estate · Online Degrees · Business Opportunities · Shopping

Search How do I find it?

USA TODAY Home News Travel Money Sports Life Tech W

News » Nation Census Troops at Risk Lotteries

AP: Drugs found in drinking water

Updated 9/12/2008 2:02 PM | Comments 152 | Recommend 95 E-mail | Print | RSS

By Jeff Donn, Martha Mendoza and Justin Pritchard, Associated Press

A vast array of pharmaceuticals — including antibiotics, anti-convulsants, mood stabilizers and sex hormones — have been found in the drinking water supplies of at least 41 million Americans, an Associated Press investigation shows.

To be sure, the concentrations of these pharmaceuticals are tiny, measured in quantities of parts per billion or trillion, far below the levels of a medical dose. Also, utilities insist their water is safe.

Share Add to Mixx Facebook Twitter More Subscribe myYahoo iGoogle More

WATER DEPARTMENTS: Reports rarely released to public
BOTTLED WATER: Is it any safer?
NEW YORK CITY: Sedative traces found in water
LOS ANGELES: Water tops national taste test
RELATED: Problems in fish blamed on contamination

Enlarge By Matt Rourke, AP

The federal government doesn't require any testing and hasn't set safety limits for drugs in water. Of the 62 major water providers contacted, the drinking water for only 28 was tested. Of the 28 major metropolitan areas where tests were performed on drinking water supplies, only Albuquerque; Austin, Texas; and Virginia Beach; said tests were negative.

But the presence of so many prescription drugs — and over-the-counter medicines like acetaminophen and ibuprofen — in so much of our drinking water is heightening worries among scientists of long-term consequences to human health.

In the course of a five-month inquiry, the AP discovered that drugs have been detected in the drinking water supplies of 24 major metropolitan areas — from Southern California to Northern New Jersey, from Detroit to Louisville

Water providers rarely disclose results of pharmaceutical

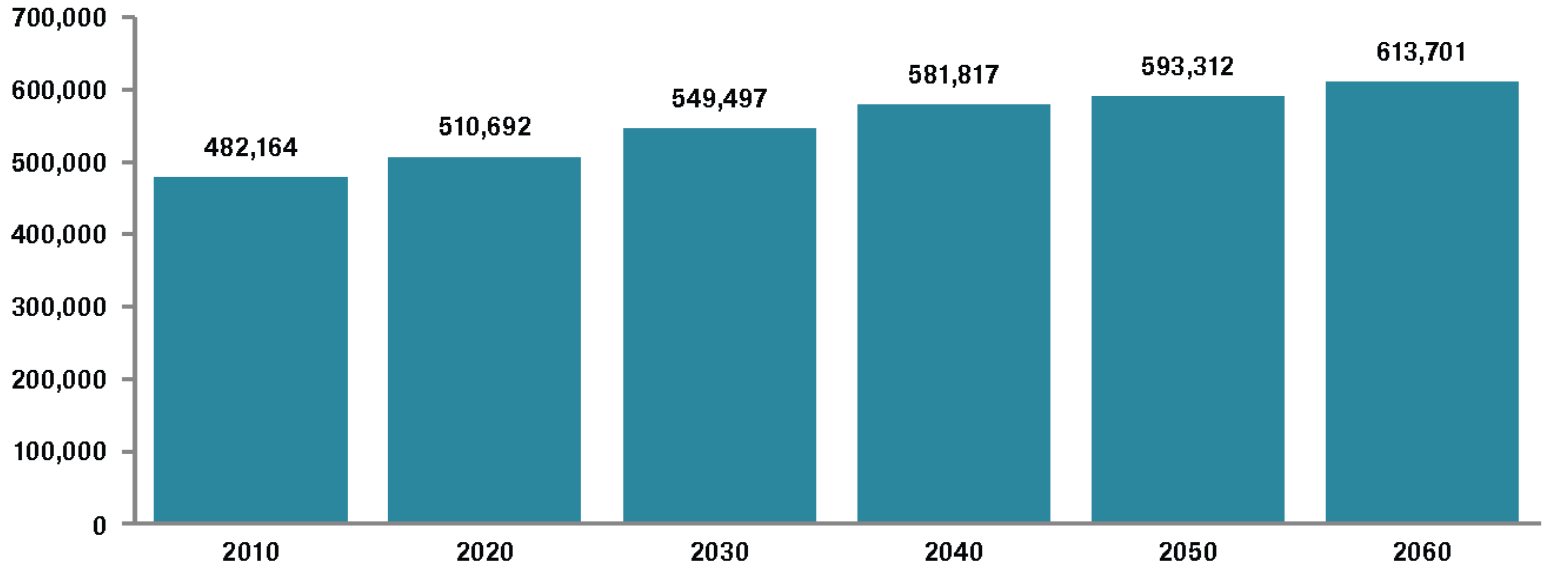
Source: USA Today, 12 Sep 2008

Water Reuse in Texas

Permits in Texas (year 2010) allow usage of 138,000 ac-ft

- 62,000 ac-ft – direct
- 76,000 ac-ft – indirect

Water availability is much higher:



Note total Austin water use: ~145,000 ac-ft

Bureau of Economic Geology
The University of Texas at Austin

Source: TWDB 2012 State Water Plan and LCRA webpage

Objectives and Hypotheses

Objectives:

- To understand fate/transport of pharmaceutical compounds in turf/soil systems with reuse water as sole source of irrigation water.
- To reduce the uncertainty of how long-term use of reuse water for irrigation may impact groundwater quality.
- To begin estimating the potential risks to humans

Hypotheses:

- Turf/soil systems can function effectively to reduce pharmaceuticals when recycled water is used as the primary irrigation source.
- Using mass flux provides a more complete picture of compound attenuation, leaching potential, environmental impact.
- Potential of pharmaceuticals to move through soil profile is a function of soil type, leaching fractions.

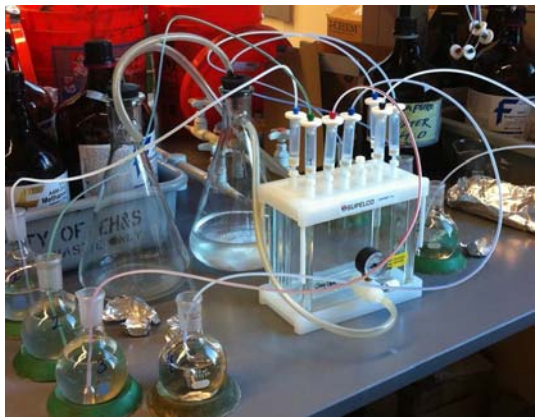
Pharmaceuticals Studied

Compound	Human Usage	Human Health Threshold*†	pKa	Log K_{ow}
Atenolol	β-Blocker; cardiovascular disease; hypertension	70,000	9.48[a]	0.16[a]
Atorvastatin	Lower blood pressure (Lipitor)	5,000	4.46[d]	6.36[b]
Carbamazepine	Anti-convulsant	1,000	<2[c]	2.30[a]
Diazepam	Sedative/anti-convulsant (Valium)	N/A	3.3[c]	2.82[a]
Diclofenac	Anti-inflammatory	N/A	4.15[b]	4.51[b]
Fluoxetine	Anti-depressant (Prozac)	10,000	9.62[a]	4.60[b]
Gemfibrozil	Lower lipid levels	45,000	4.7[c]	4.77[b]
Ibuprofen	Anti-inflammatory (Advil)	34,000	4.91[a]	3.50[a]
Meprobamate	Tranquilizer	260,000	<2[c]	0.70[a]
Naproxen	Anti-inflammatory (Aleve)	220,000	4.15[ab]	3.18[ab]
Primidone	Anti-convulsant	N/A	11.62	0.91
Sulfamethoxazole	Anti-biotic	35,000	5.7[c]	0.89[a]
Triclosan	Anti-biotic	350	7.9[c]	4.53[a]
Trimethoprim	Anti-biotic	61,000	7.1[c]	0.91[a]

a – Sangster, 2012; b – SRC PhysProp Database, 2012; c – Yoon et al., 2007; d – Wu et al., 2000
* - Monitoring Triggering Levels (Anderson et al., 2010)
† - concentrations in ng/L

Multiple Research Approaches

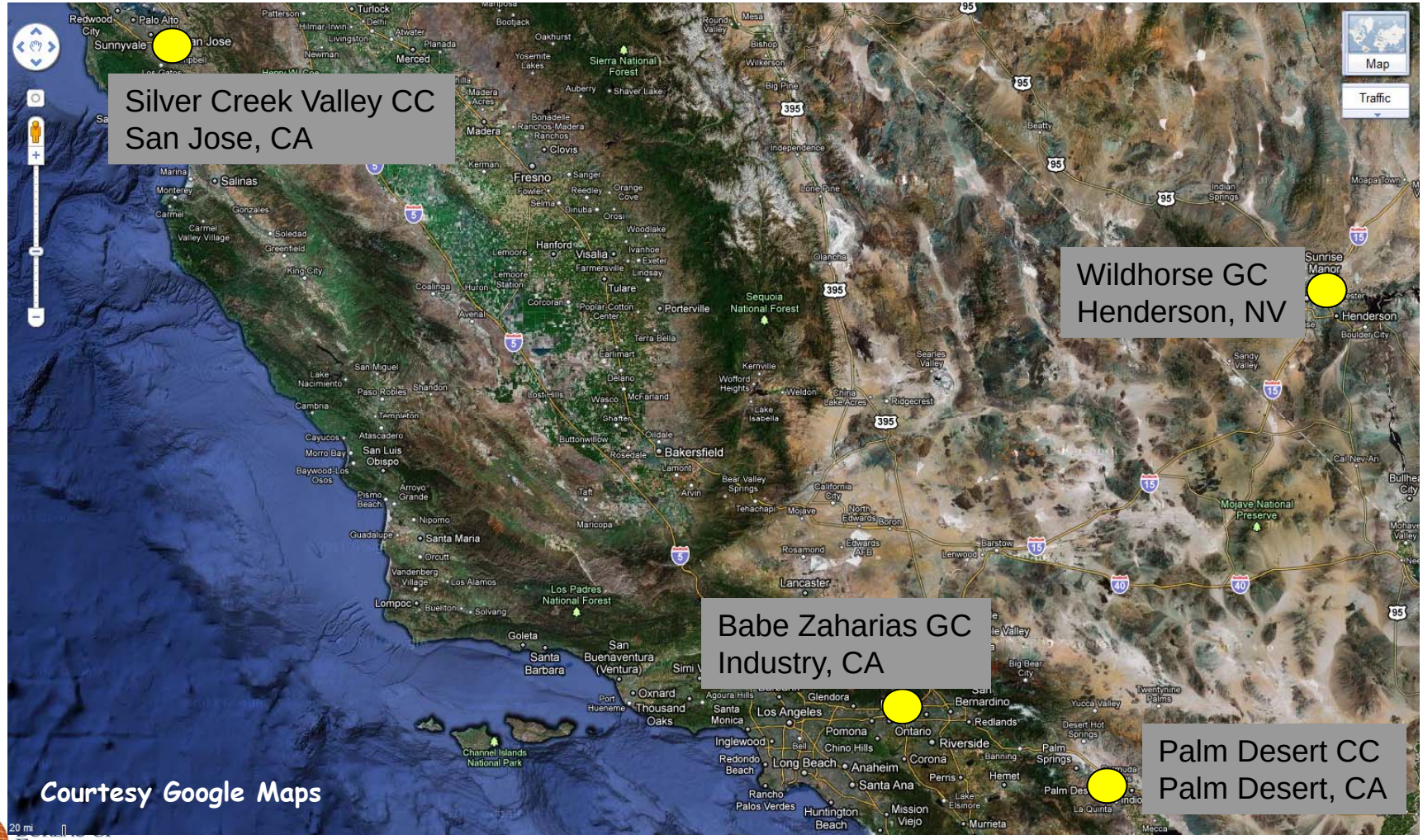
- Laboratory Experiments
- **Lysimeter Experiments**
- Controlled Field Plot Experiment
- **Golf Course Experiments**



Experimental Design – Lysimeter Study

- Non-weighing lysimeters
  - 127 cm deep by 60 cm diameter
- Monitored for Eh, pH, water content and temperature
- Irrigated with reuse water for 745 days
- Varied by soil type, leaching fraction (LF), and cover
- 24 total systems (8 combinations)

Golf Course Field Locations (Focus on SW US)



Field Setup at Golf Course Sites

- Three passive capillary drain gauges (model G2, Decagon Devices, Inc., Pullman WA) at each site
  - Top of gauge ~15 cm below ground surface
  - Installed on active fairway irrigated with reuse water
  - Water samples collected from lower/upper chambers when available and needed to obtain sufficient volumes
- Temp, Water Content and Bulk EC (model 5TE, Decagon)
  - Installed at 15 and 75 cm depths at Babe Zaharias and Palm Desert
- Field site monitored for ~2 years

Lysimeter Studies – Summary of Results

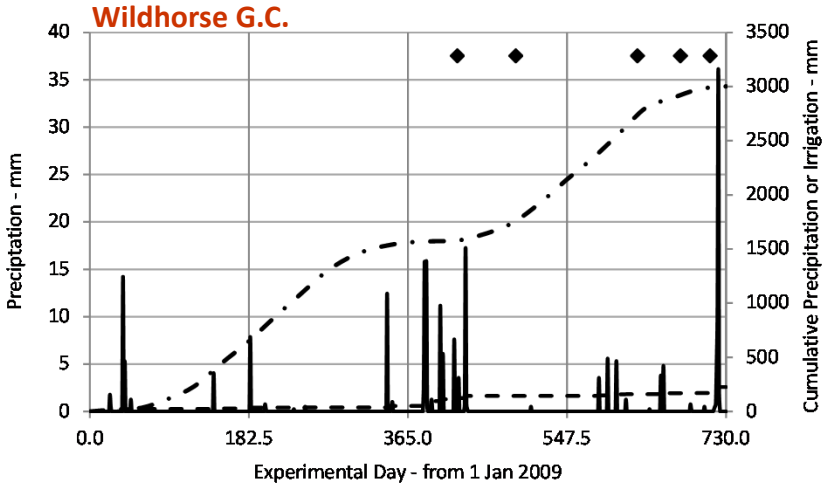
Most compounds were strongly attenuated

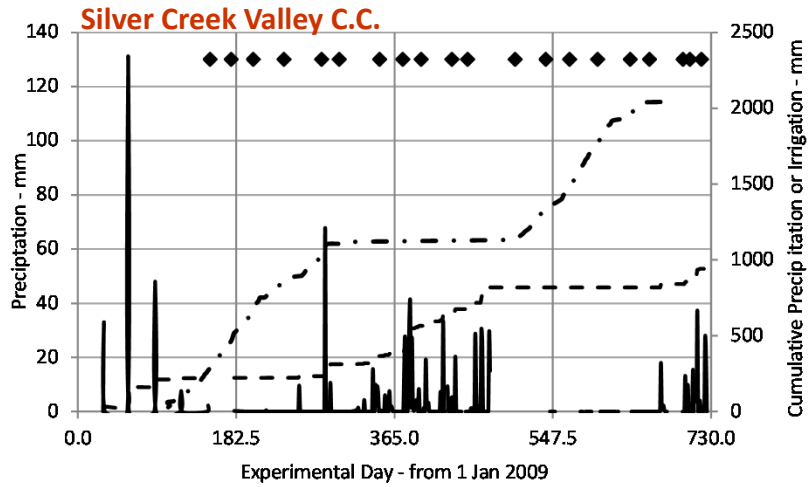
	Lysimeter Experiments			
	Loamy Sand	Sandy Loam	Loamy Sand	Sandy Loam
	Low LF	Low LF	High LF	High LF
Atenolol	X	X	X	X
Atorvastatin	X	X	X	X
Carbamazepine	X	X	X	X
Diazepam	X	X	X	X
Diclofenac	X	X	X	X
Dilantin	X	X	X	X
Fluoxetine	X	X	X	X
Gemfibrozil	X	X	X	X
Meprobamate	X	X	X	X
Naproxen	X	X	X	X
Primidone	X	X	X	X
Sulfamethoxazole	X	X	X	X
Triclosan	X	X	X	X
Trimethoprim	X	X	X	X

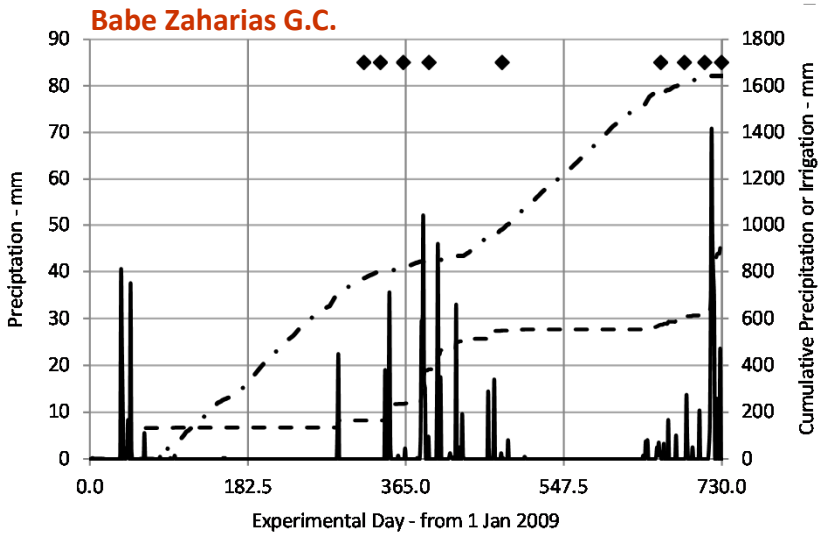
Bureau of Economic Geolog
THE UNIVERSITY (

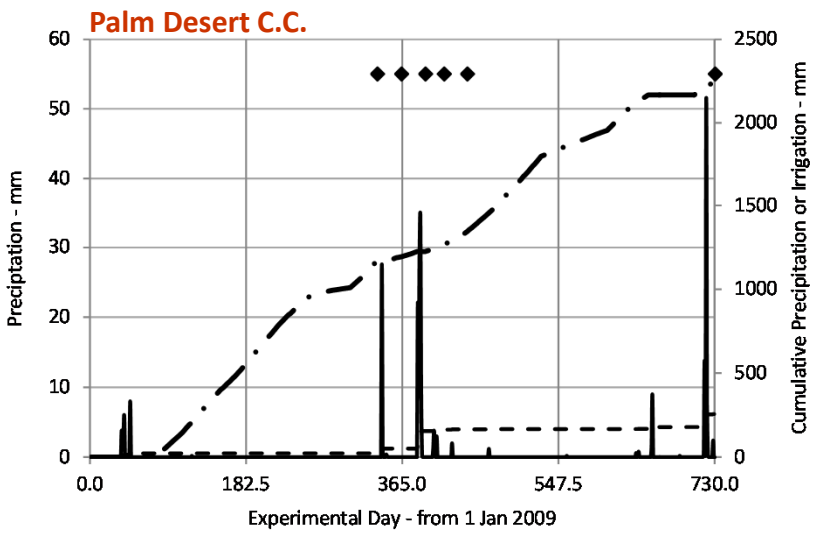
Green cell - >98% attenuation; Yellow cell – 85 - 98% attenuation; Red – 84 - 80% attenuation

Water Flux – All Golf Course Sites









BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

cumulative precipitation
cumulative irrigation
fluid sampling event

Instances of Compounds Above Reportable Limits

	Wildhorse G.C.	Silver Creek C.C.	Zaharias G.C.	Palm Desert C.C.	Total
Atenolol	0	0	0	0	0
Atorvastatin	0	0	0	0	0
Carbamazepine	**1**	**20**	**8**	**5**	**34**
Diazepam	0	0	0	0	0
Diclofenac	1	1	1	0	3
Fluoxetine	0	0	0	0	0
Gemfibrozil	0	6	0	0	6
Ibuprofen	1	0	0	0	1
Meprobamate	**2**	**20**	**7**	**2**	**31**
Naproxen	0	1	1	2	3
Sulfamethoxazole	**1**	**16**	**3**	**3**	**23**
Triclosan	2	3	1	3	9
Trimethoprim	0	1	0	0	1
Total	8	68	21	15	112

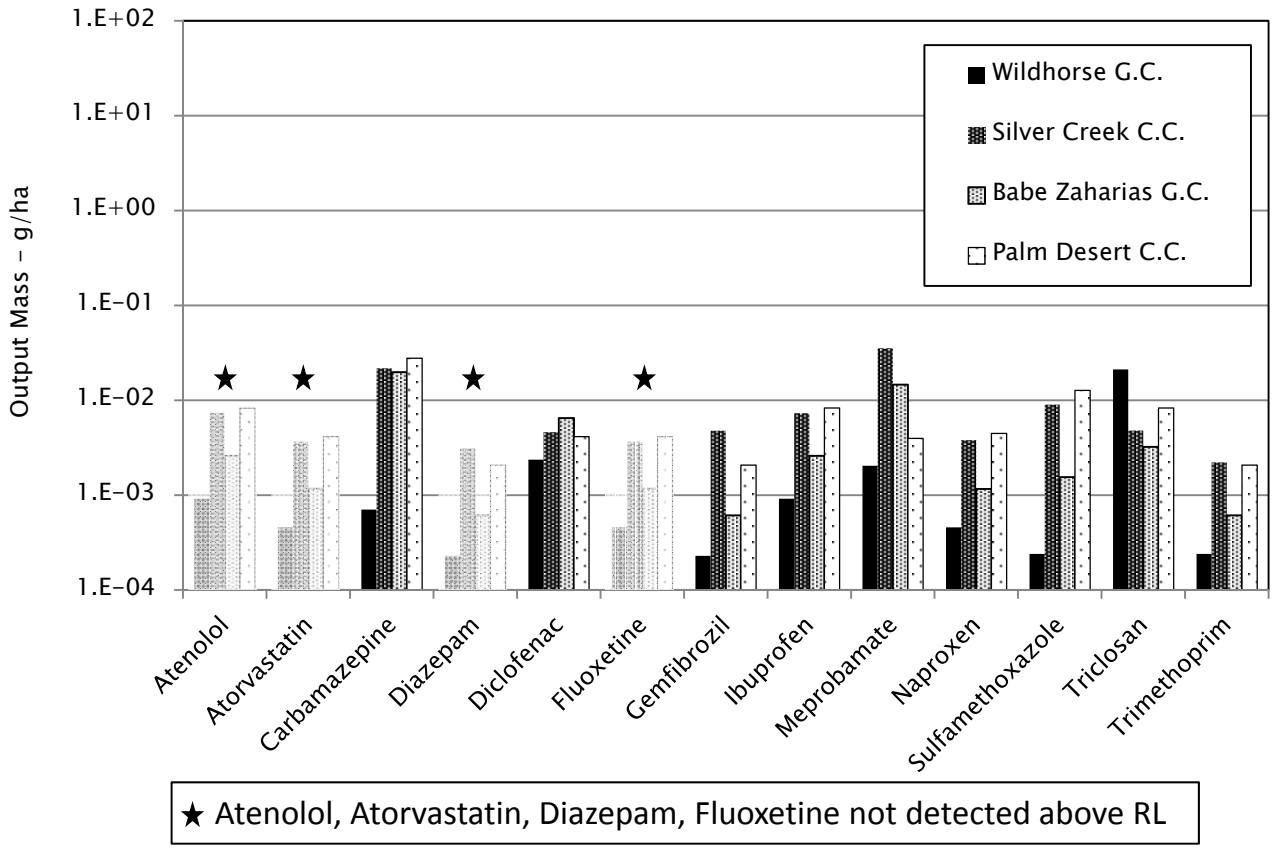
Concentration Ranges (ng/L)† and Trigger Levels

	Feed Water	Drain Gage	Human Health Threshold*
Atenolol	14-1300	<RL**	70,000
Atorvastatin	<RL-0.64	<RL	5,000
Carbamazepine	**3.4-240**	**<RL-81**	**1,000**
Diazepam	<RL-7.3	<RL	N/A
Diclofenac	<RL-120	<RL-74	N/A
Fluoxetine	<RL-44	<RL	10,000
Gemfibrozil	3.9-2100	<RL-15	45,000
Ibuprofen	<RL-320	<RL-13	34,000
Meprobamate	**160-1700**	**<RL-300**	**260,000**
Naproxen	<RL-100	<RL-98	220,000
Sulfamethoxazole	**8.1-600**	**<RL-75**	**35,000**
Triclosan	<RL-140	<RL-170	350
Trimethoprim	<RL-220	<RL-1.8	61,000

† - All sites combined
* - Monitoring Triggering Levels (Anderson et al., 2010)
** <RL = below reportable limits

Bureau of Economic Geology
The University of Texas at Austin

Output Mass Flux of Pharmaceuticals – all sites



Health Thresholds – what do they mean?

$$Monitoring\ Trigger\ Level(MTL) = \frac{ADI \times body\ mass \times RSC}{fluid\ intake/day}$$

where:

ADI = Acceptable Daily Dose (mg/kg/day)

Body mass - Default 60 kg adult body weight

RSC = Relative Source Contribution from drinking water (default is 20% of total daily exposure)

Fluid intake/day = Default 2 L/day intake for a 60 kg adult

$$Acceptable\ Fluid\ Intake = \frac{ADI \times body\ mass \times RSC}{Max\ Measured\ Env\ Conc\ (MEC)}$$

Max MEC/MTL > 0.1 => include in monitoring program

Source: Anderson et al., 2010

Consumption and Environmental Monitoring

Compound	Max Measured Concentration	Acceptable Daily Intake	Acceptable Fluid Intake	(max MEC) / MTL
	mg/L†	mg/kg/day‡	L/day	--
Atenolol	<RL	0.002	--	--
Atorvastatin	<RL	0.00054	--	--
Carbamazepine	**8.1E-05**	**0.00034**	**252**	**8.10E-05**
Diazepam	<RL	0.001	--	--
Diclofenac	7.4E-05	0.067	54324	7.40E-05
Fluoxetine	<RL	0.00097	--	--
Gemfibrozil	1.5E-05	0.0013	5200	1.50E-05
Ibuprofen	1.3E-05	0.0114	52615	1.30E-05
Meprobamate	**3.0E-04**	**0.0075**	**1500**	**3.00E-04**
Naproxen	9.8E-05	0.57	348980	9.80E-05
Sulfamethoxazole	**7.5E-05**	**0.51**	**408000**	**7.50E-05**
Triclosan	1.7E-04	0.075	26471	1.70E-04
Trimethoprim	1.8E-06	0.19	6333333	1.80E-06

Bureau of Economic Geology
The University of Texas at Austin

† - Values grouped across all four golf course sites; <RL is below reportable limits

‡- Snyder et al. (2008, AwwaRF) for all compounds, except Ibuprofen (Environment Protection and Heritage Council et al., 2008)

Implications

- Mass fluxes in drainage water reduced by 100-fold or lower for most compounds, after transport through 60 cm of soil
- Nearly all mass flux occurred during overseeding or winter rains. Deficit irrigation reduced downward mass flux
- Acceptable daily fluid consumption often orders of magnitude higher than needed for humans.
- Results indicate that routine monitoring is not needed in these environments
- "Riskiest" condition occurs in sandy soils with shallow water tables (travel time is shortest)

Acknowledgements

This research was supported by Water Environment Research Foundation, WaterReuse Research Foundation, 28 water and sanitation agencies in California and other regions, and Northern California Golf Association.

Bureau of Economic Geology
The University of Texas at Austin