Fate of Wastewater-Derived Organic Contaminants in Engineered and Natural Systems

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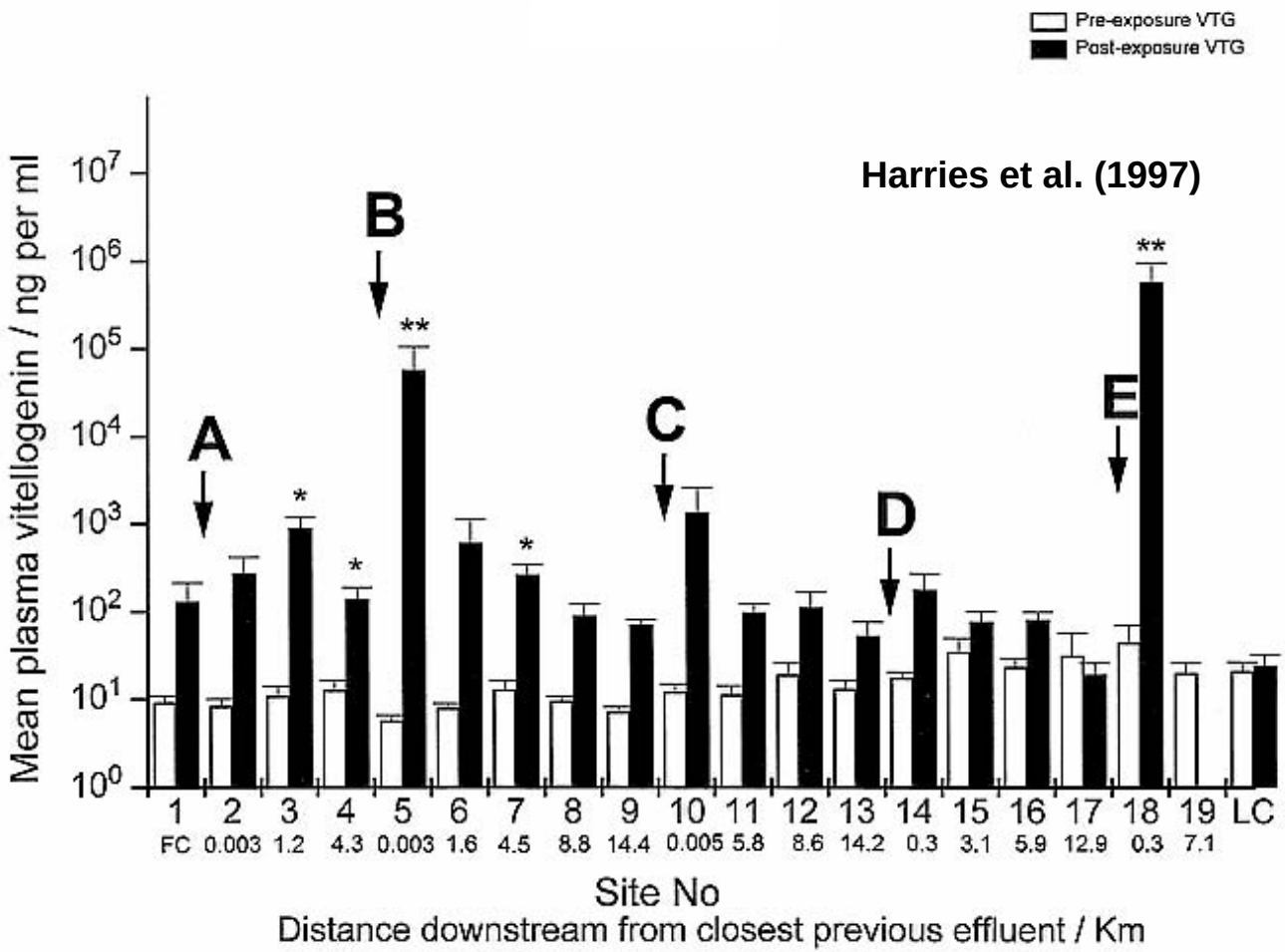
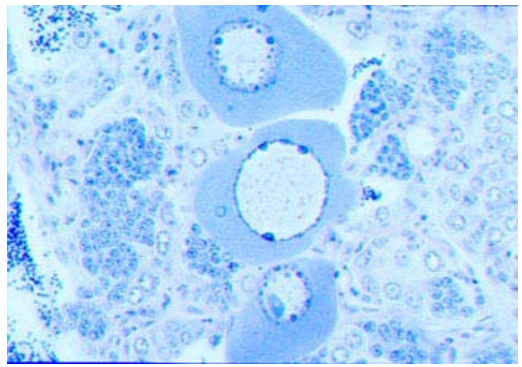
Overview

- What compounds should we be concerned about?
- Where should we look for effects?
- How can we reduce concentrations?
- When should we take action?

Endocrine Disruption Concerns

- Observations of feminized wild fish
- Feminization of trout by wastewater effluent

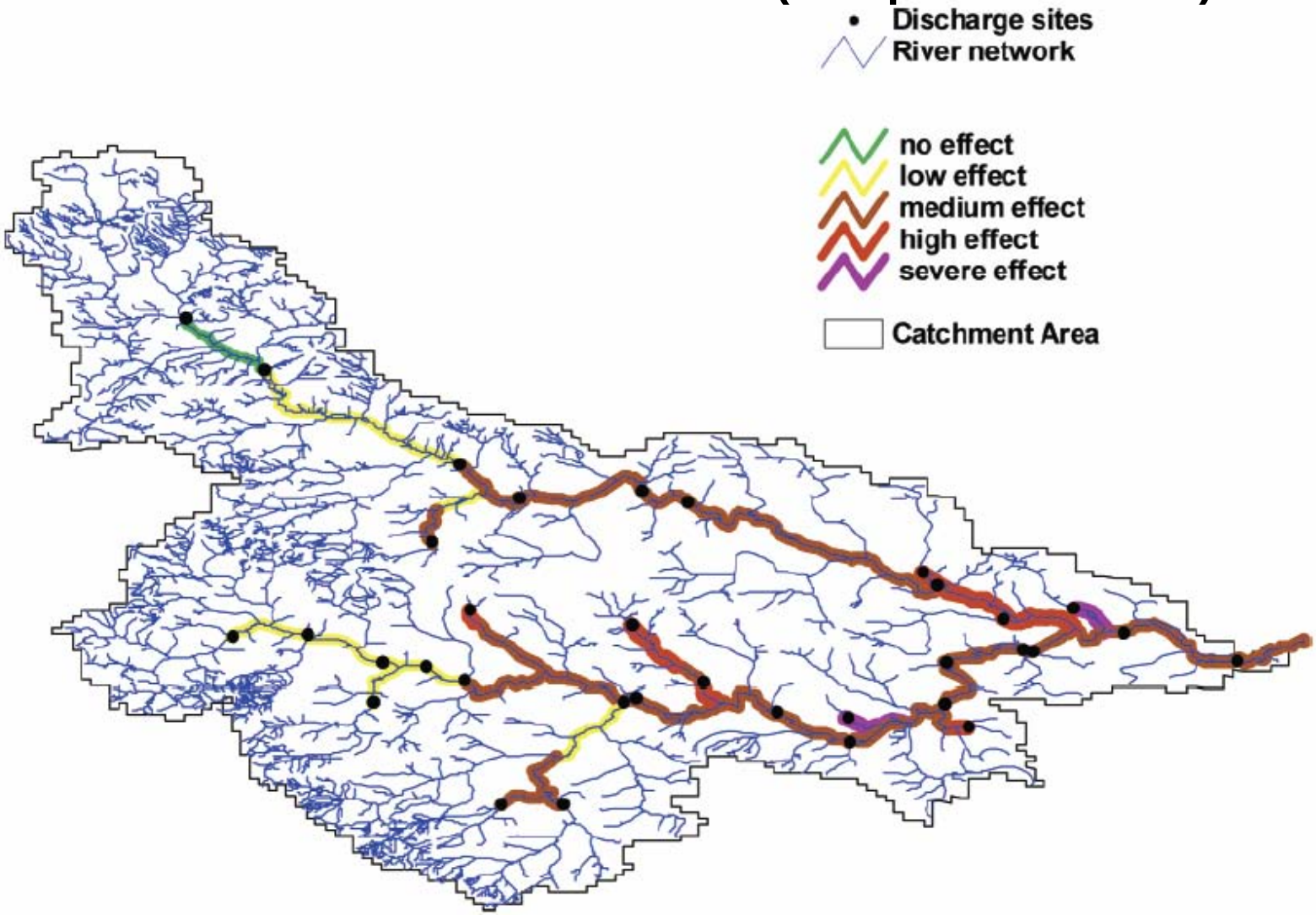




Gonad of feminized male

Causes of Endocrine Disruption

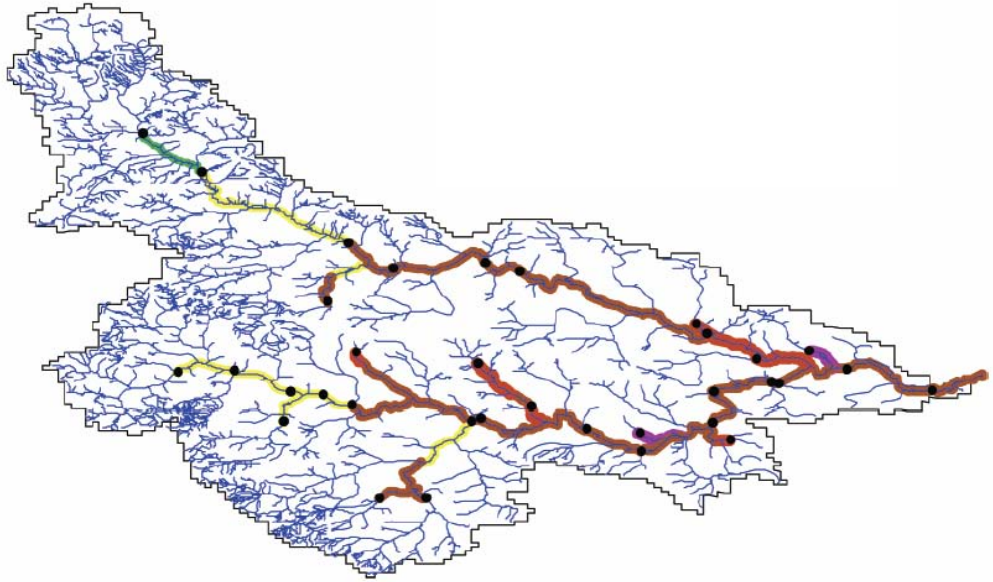
- E_2, E_1, EE_2 and NP thought to be main causes
- Aire River catchment models (Sumpter et al. 2006)



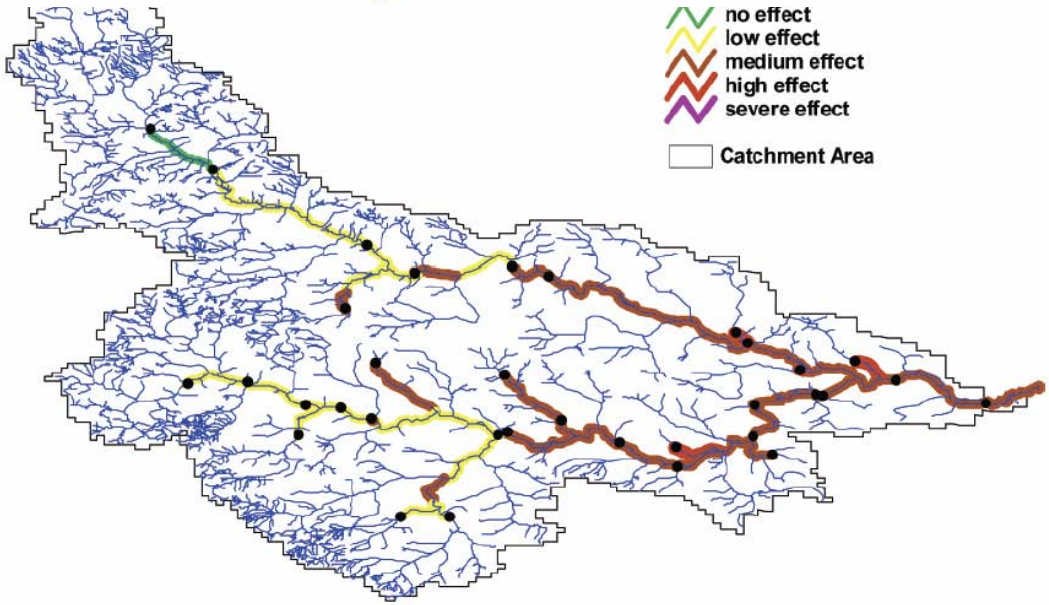
Potential for Source Control

- **NP reduction could reduce impacts**

Current



Low NP



Other Potential Concerns

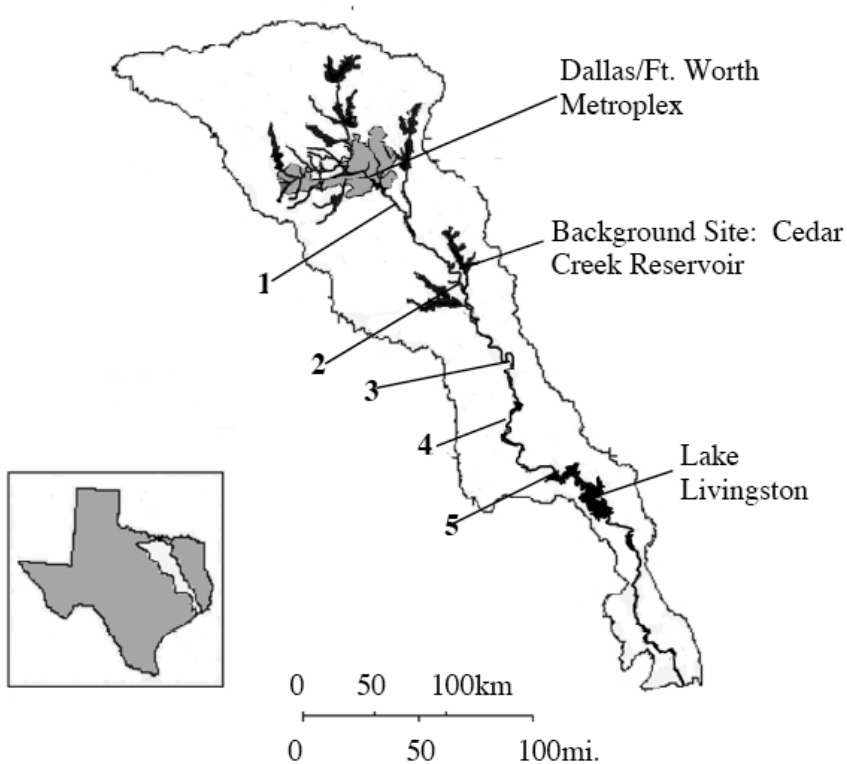
- **Carbamazepine in sediments (Knacker et al. 2005)**

Table 4b.7: Risk characterisation (RC) – EMEA (2005) Phase II Tier B – sediment: Effect concentrations for sediment organisms in long-term toxicity studies as derived by own studies and literature search. PNECs are derived by using the respective assessment factor (AF) to be applied according to the TGD (EC 2003). Phase II Tier B assessment was not required for SMX. [a]) Oetken *et al.* (2005); [b]) 90-percentile, measured data (Ternes, pers. com., 2005); [c]) own studies with *Lumbriculus variegatus*; [d]) measured data (Ternes *et al.* 2002); [e]) derived from measured concentration in suspended matter (van de Plassche and Balk 1997).

PPCP	NOEC	AF	$PNEC_{sediment}$	$PEC_{sediment}$	$RC_{sediment}$
CBZ	< 140 ng/g dw [a]	50	< 2.8 ng/g dw	42 ng/g dw [b]	> 15
EE2	31.6 µg/g dw [c]	100	316 ng/g dw	0.9 ng/g dw [d]	0.003
AHTN	50 µg/g dw [c]	100	500 ng/g dw	480 ng/g dw [e]	0.96

Where Should We Look?

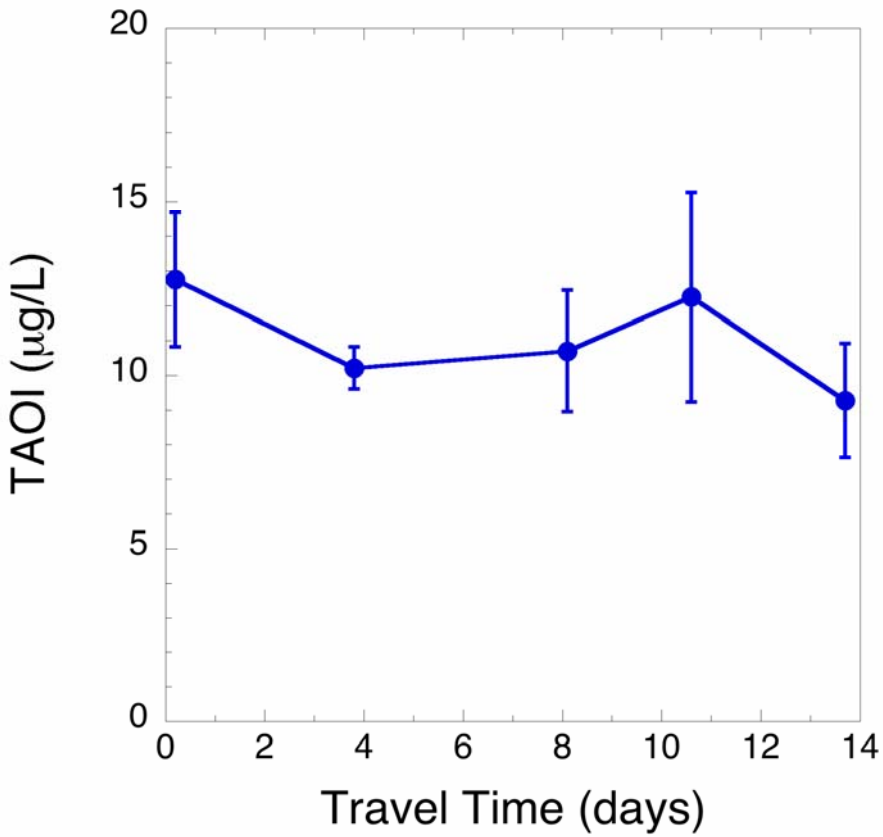
- **Effluent-Dominated Waters (Fono et al. 2006)**



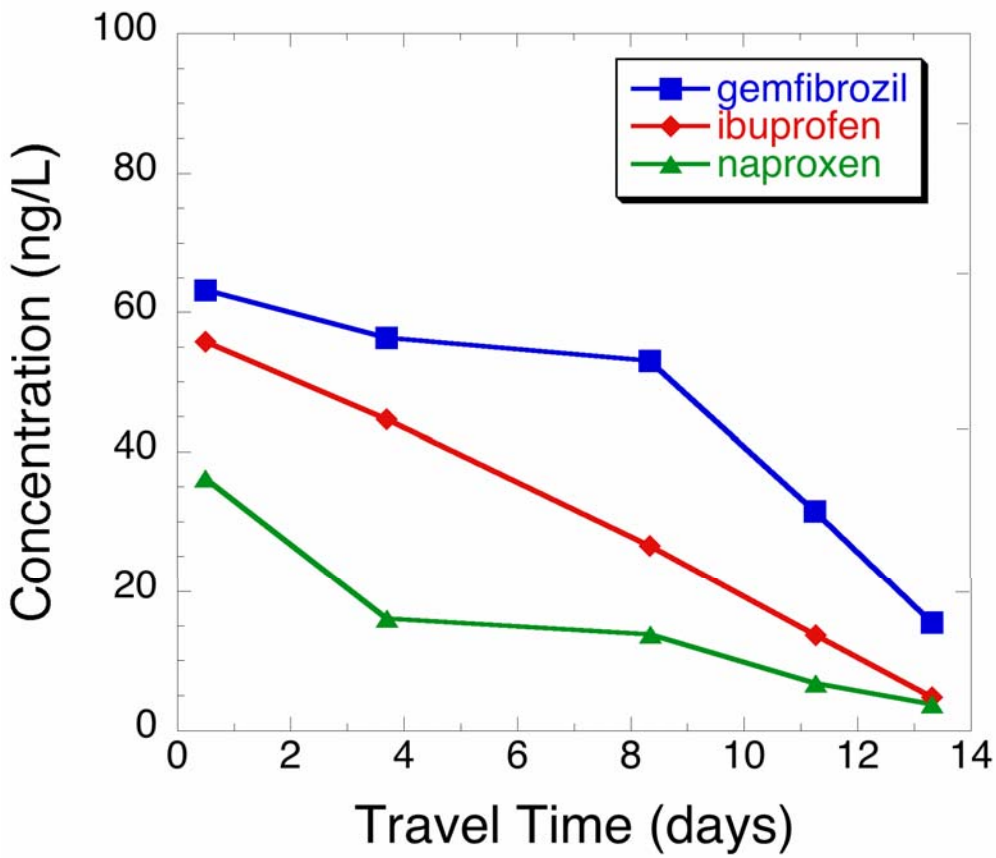
Trinity River, Texas

Slow Attenuation in Surface Waters

Organic I: Wastewater tracer

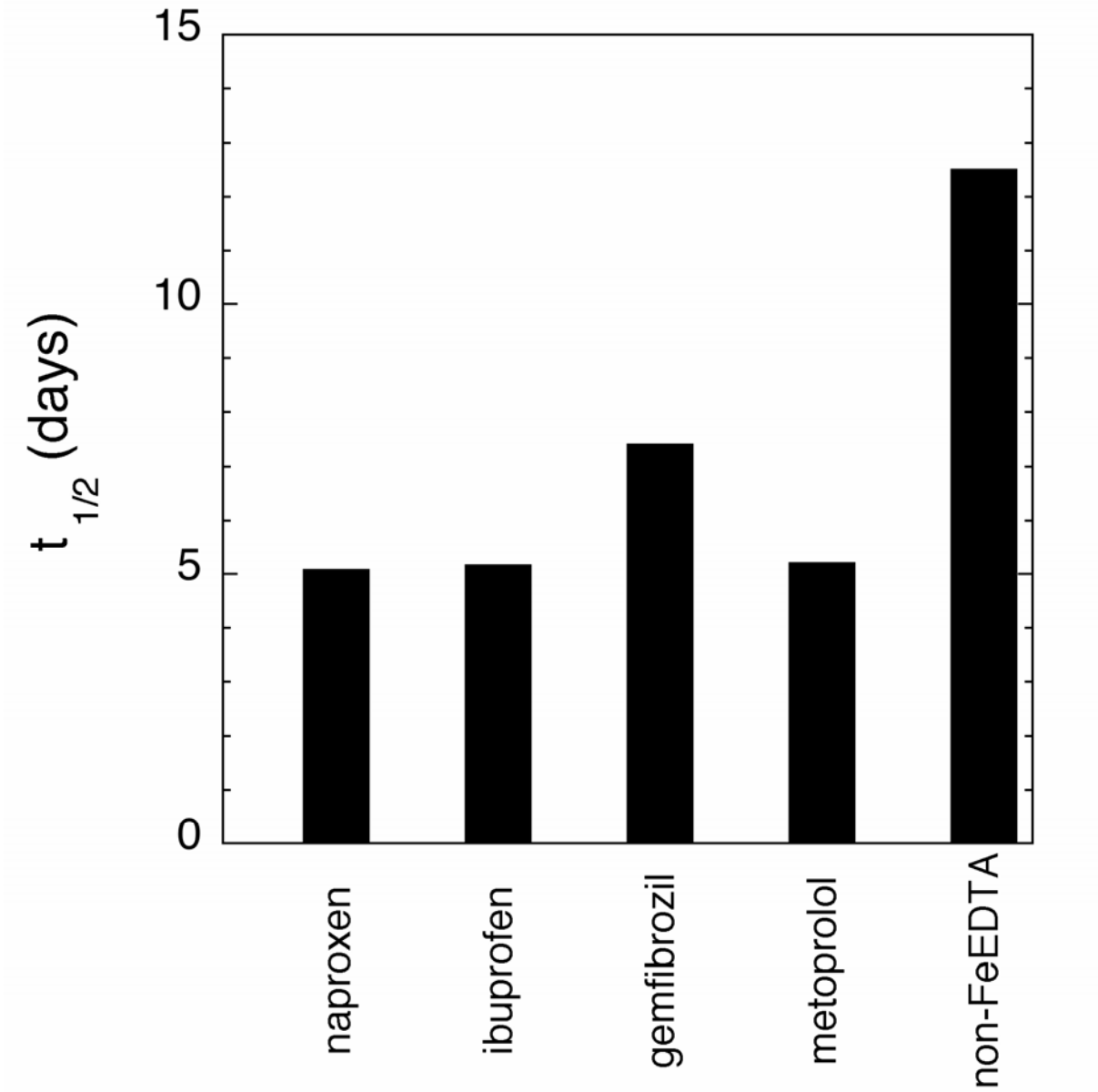


Reactive compounds

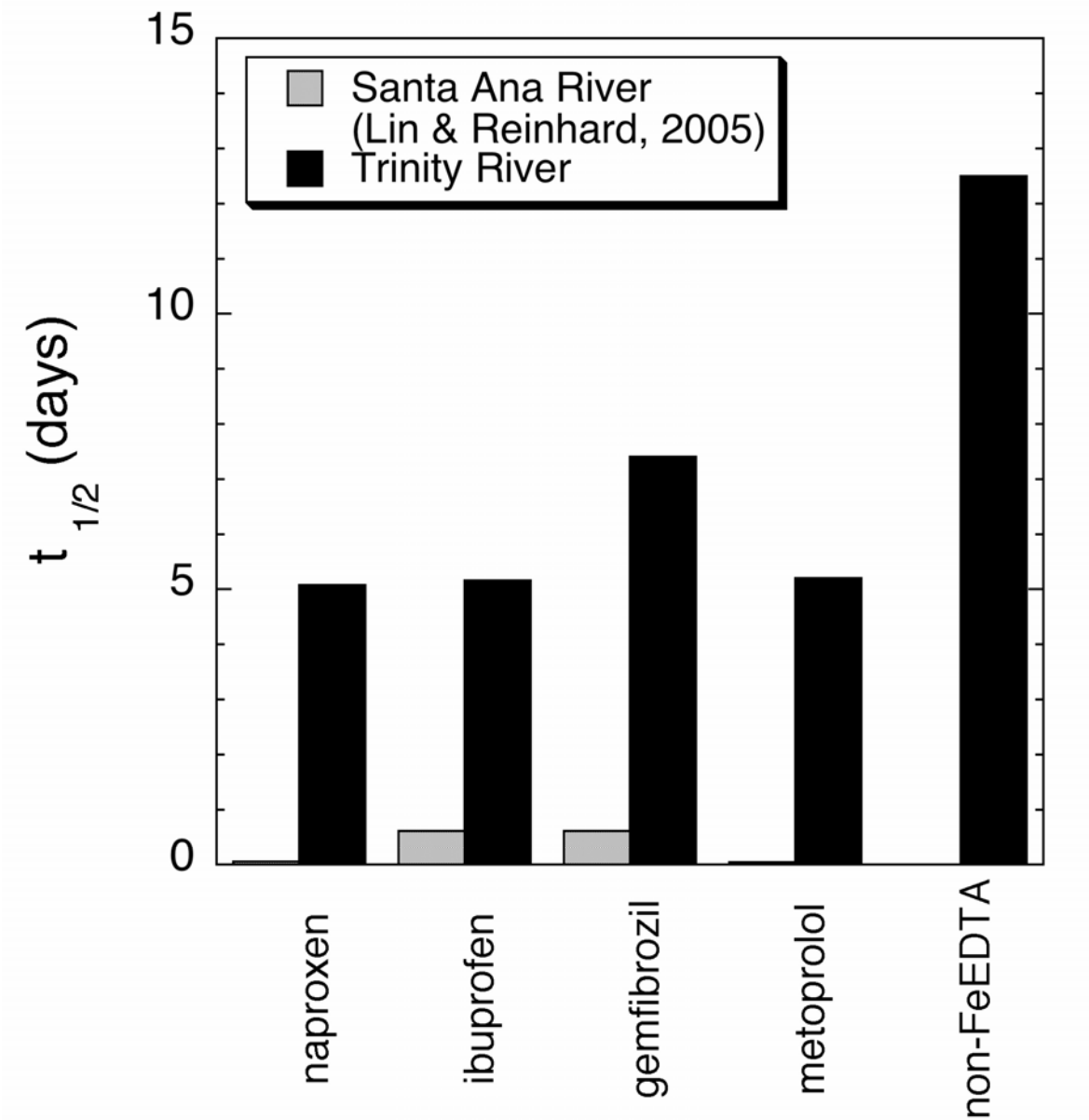


(Fono et al. 2006)

Half-Life Estimates



Comparison w/ Santa Ana River



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  - **-takeback programs**

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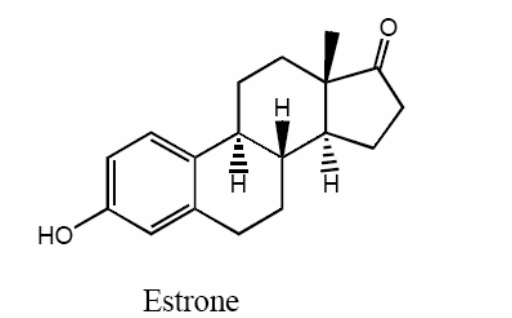
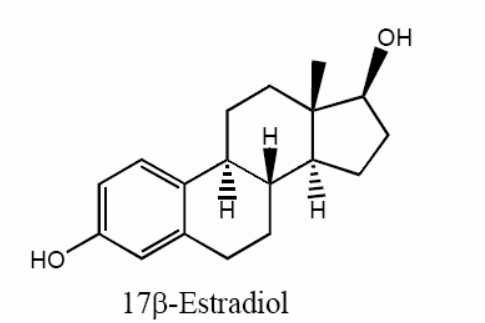
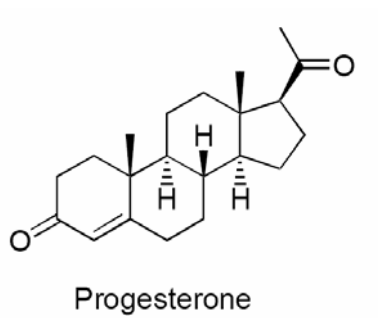
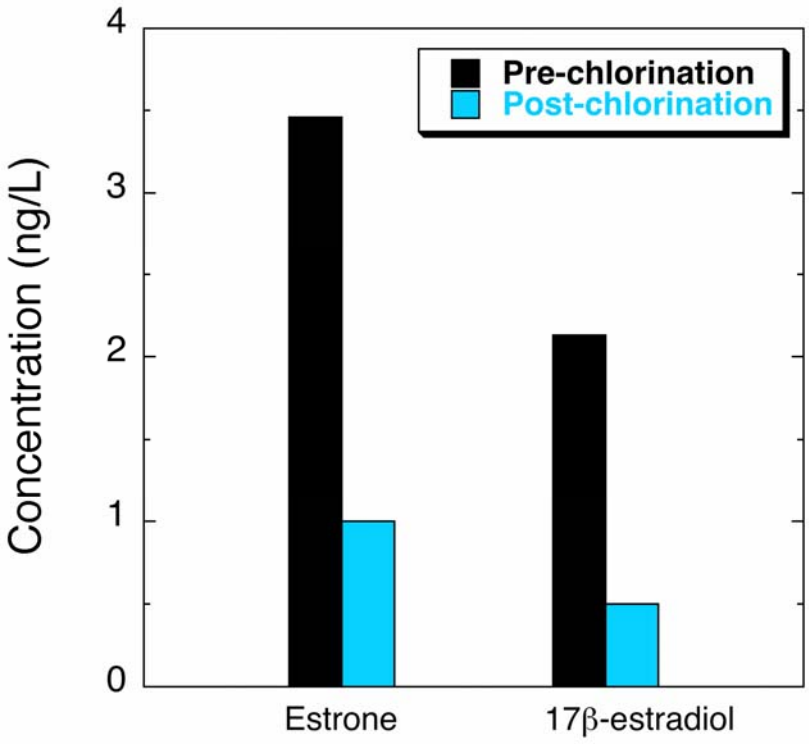
  - -free chlorine
  - -ozone

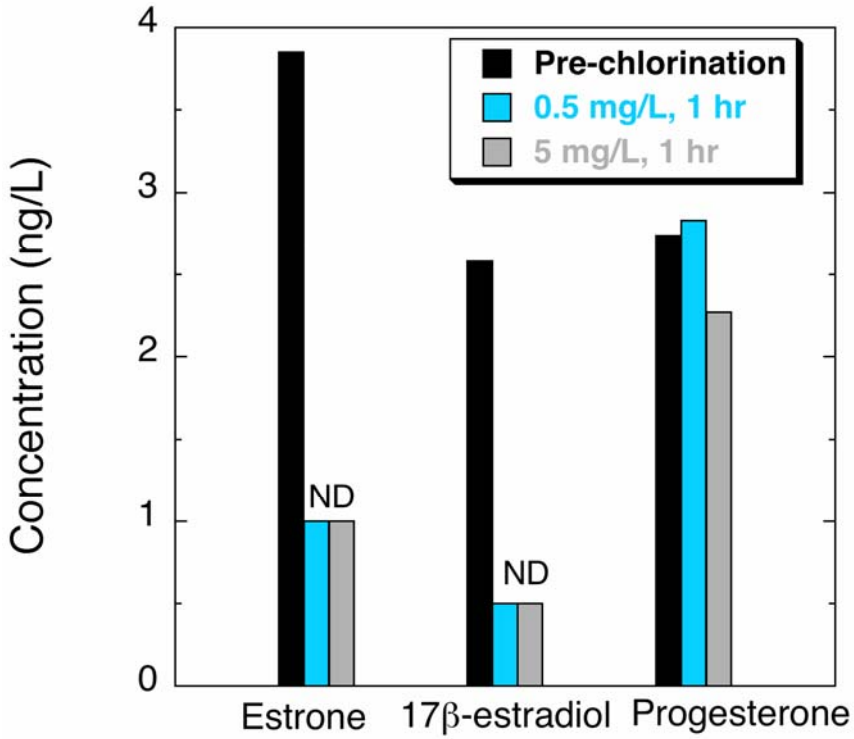
Steroids and Chlorine Disinfection







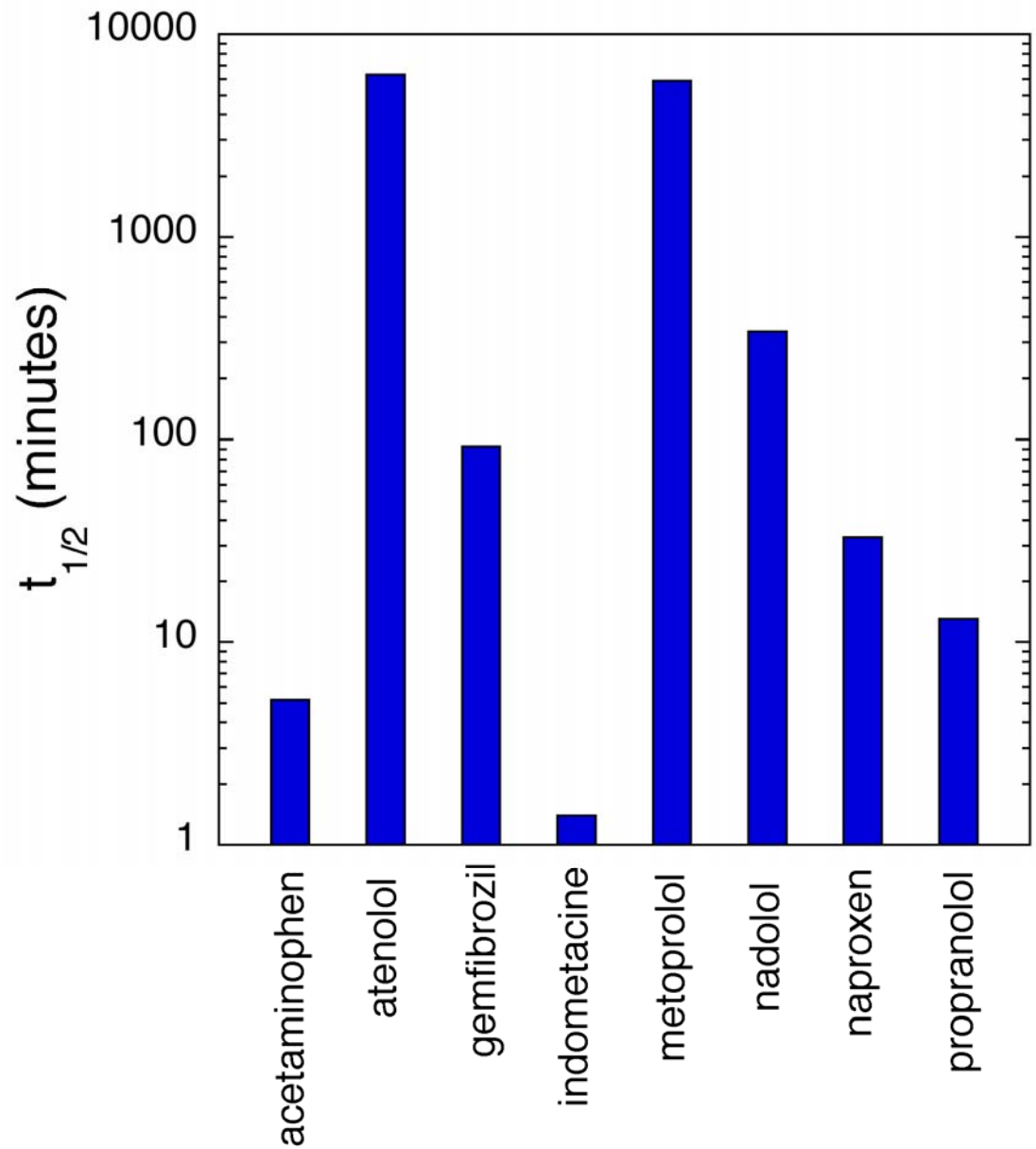




Treatment Plant

Laboratory Study

Chlorine and Pharmaceuticals



10 mg/L, 1 hr

Pinkston and Sedlak
ES&T,38,4019-4025, 2005

Ozone and Pharmaceuticals

Huber et al. ES&T, 37, 1016-1024, 2003

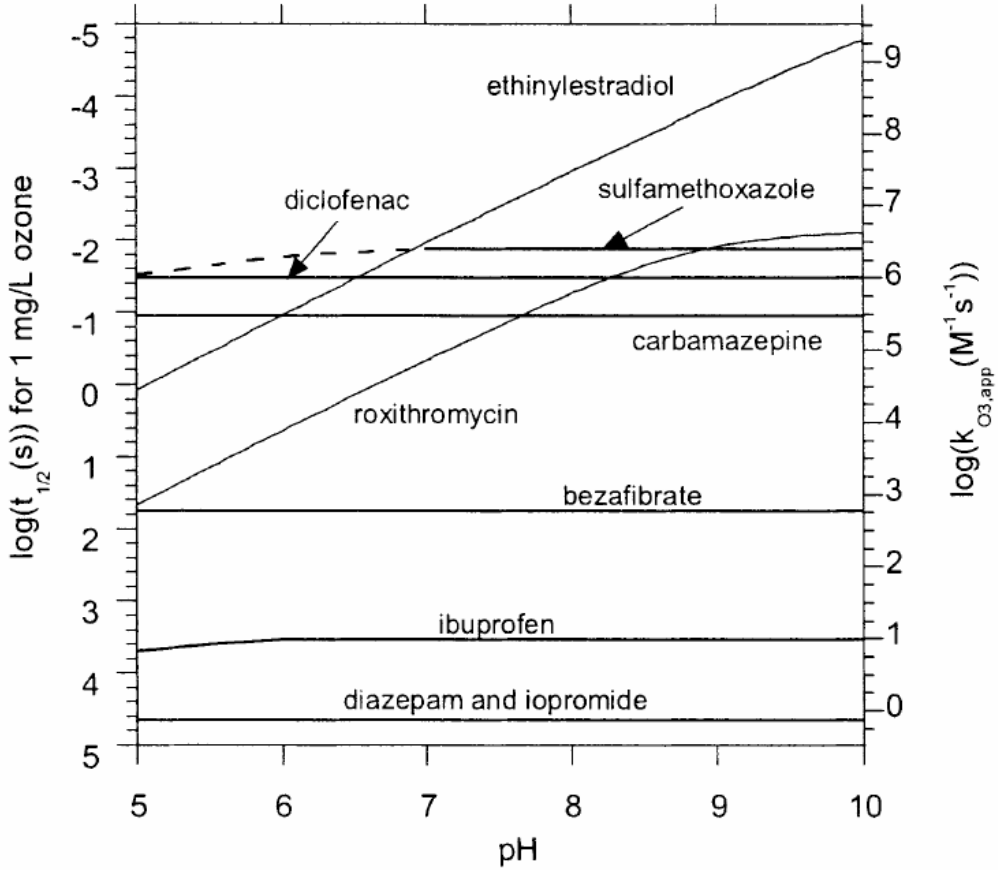


FIGURE 1. Half-lives and apparent second-order rate constants for the reactions of the investigated pharmaceuticals with ozone as a function of pH at 20 °C. The half-lives are calculated for an ozone concentration of 1 mg/L (20 μM) neglecting reactions with OH radicals.

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- Transformation During Disinfection
  - -free chlorine
  - -ozone
- Enhanced Natural Attenuation
  - -engineered wetlands
  - -soil aquifer treatment

Wetland Treatment

Prado Wetland

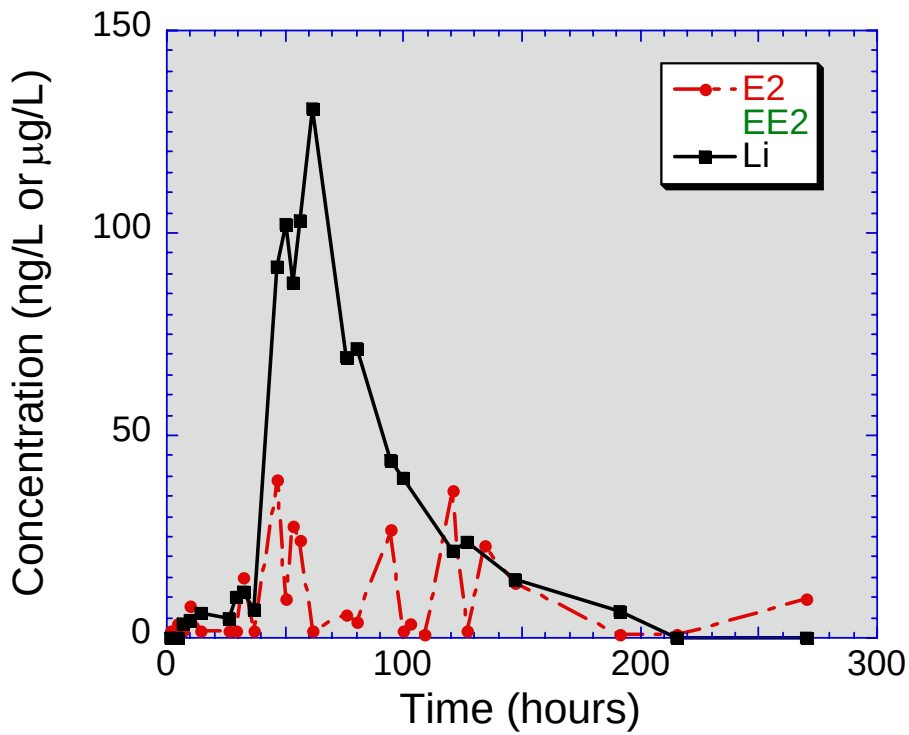
Prado Test Cell Spiking Study

Gray and Sedlak (2005)

-1 wetland cell (HRT~4 days)

-Pulse: 30 mg Estradiol, ethinyl estradiol
50 gm Li^+

-Result ~35% removal



Should We Take Action?

Drinking Water/Human Exposure

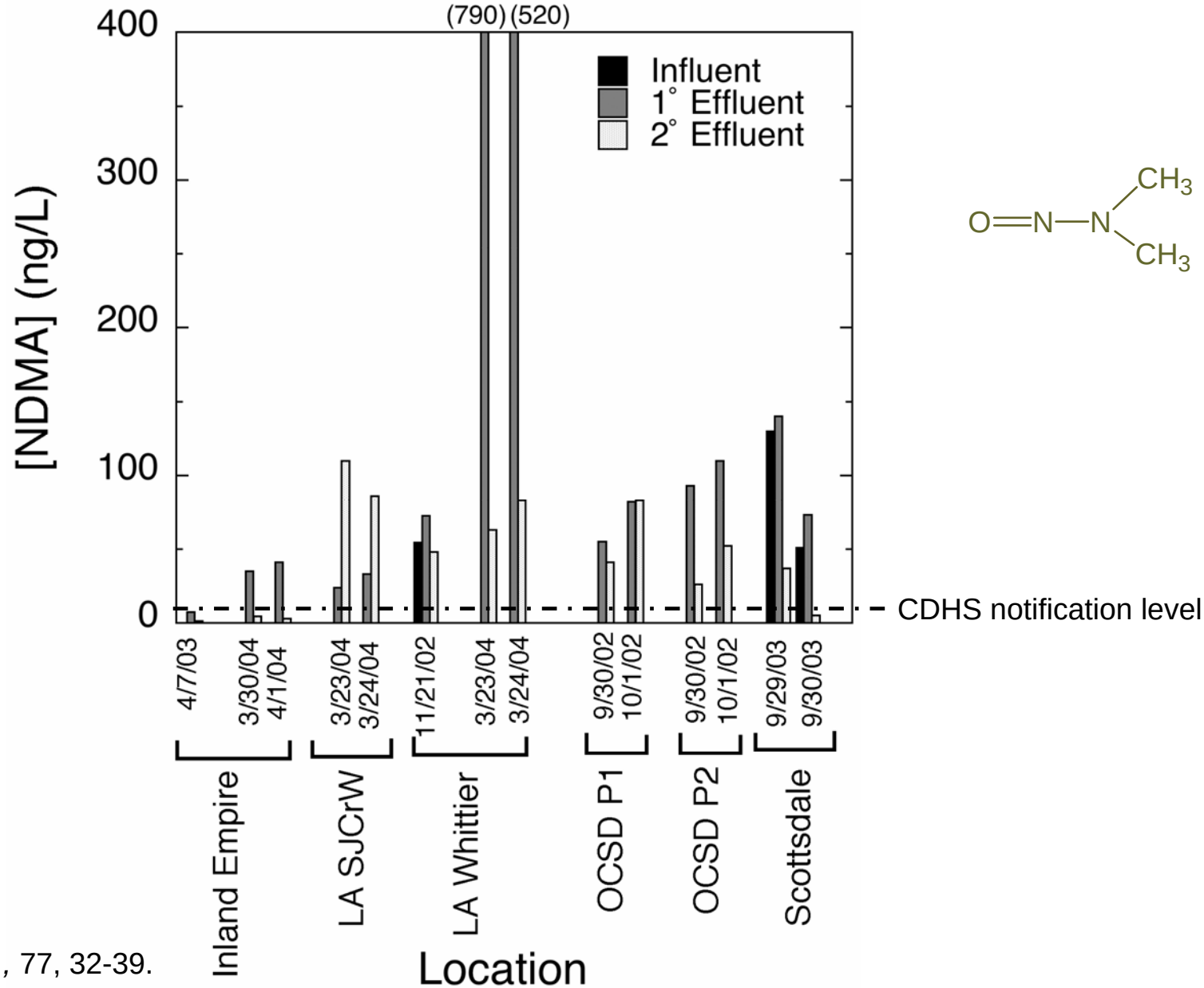
Most likely exposure:

- **unplanned indirect potable reuse**
- **planned indirect potable reuse**

Compare risks to other chemical contaminants:

- **nitrate**
- **DBPs**
- **NDMA**

NDMA in Wastewater



Sedlak et al. (2005)
Water Environ. Res., 77, 32-39.

Should We Take Action?

Endocrine Disruption in Surface Waters

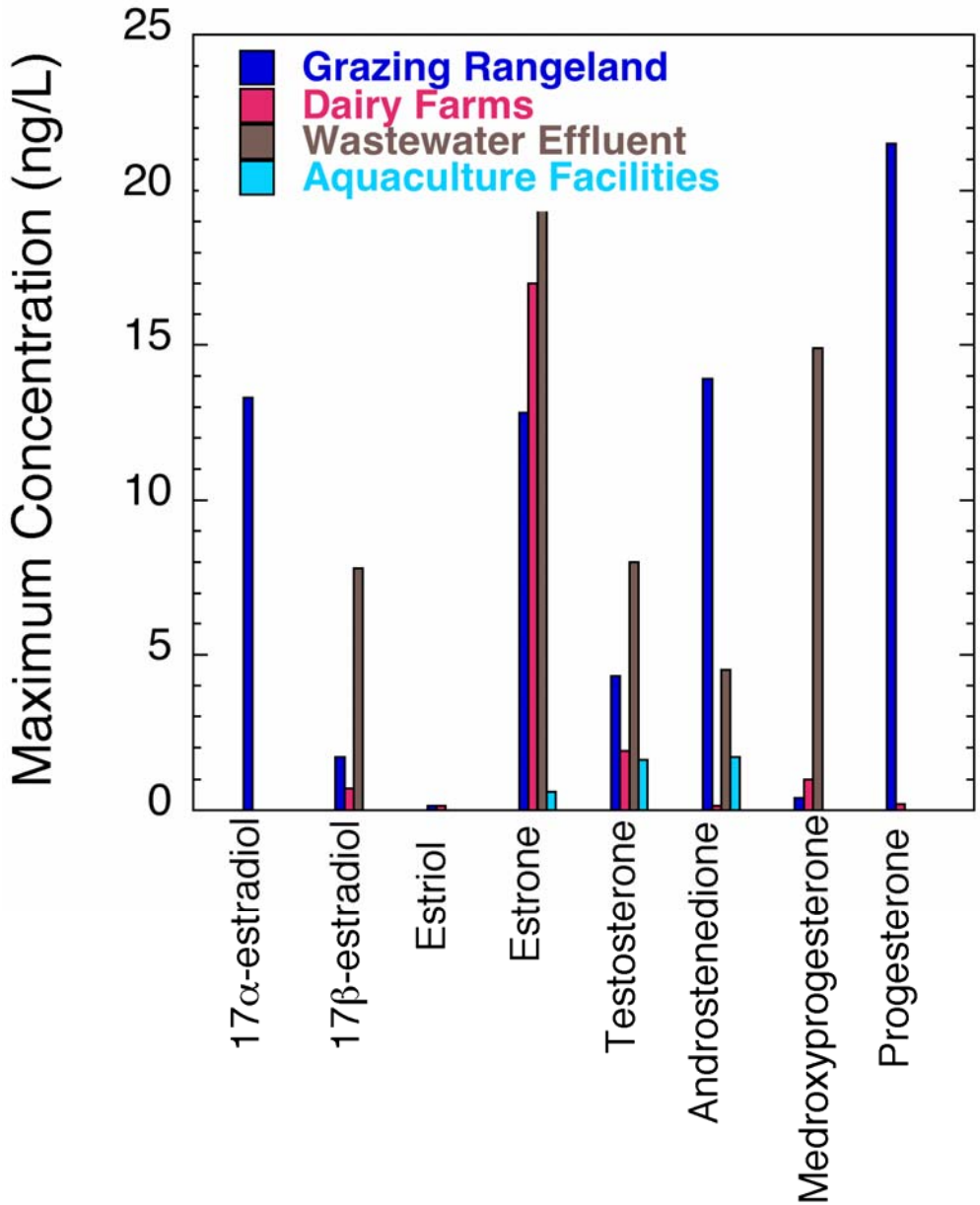
Most likely exposure:

- **effluent-dominated surface waters**
- **sources unrelated to municipal wastewater**

Examples of other sources:

- **CAFOs**
- **Grazing Rangelands**
- **Agricultural Runoff**

Wastewater vs Agriculture



Beef Cattle Feed Lots

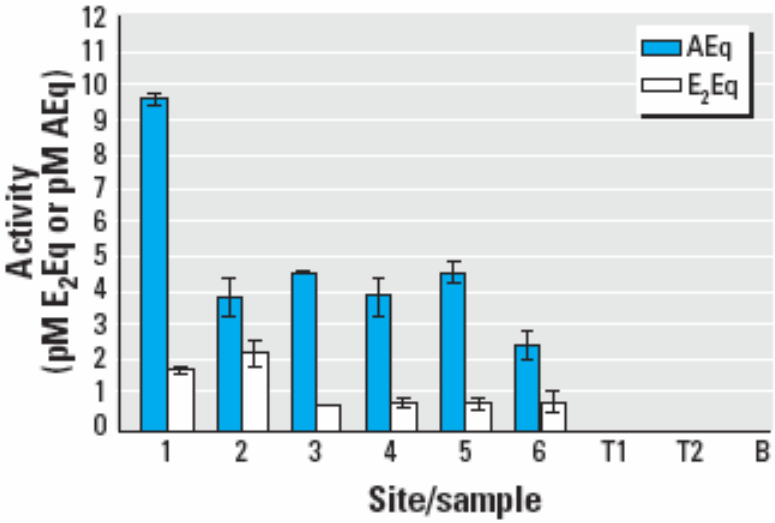
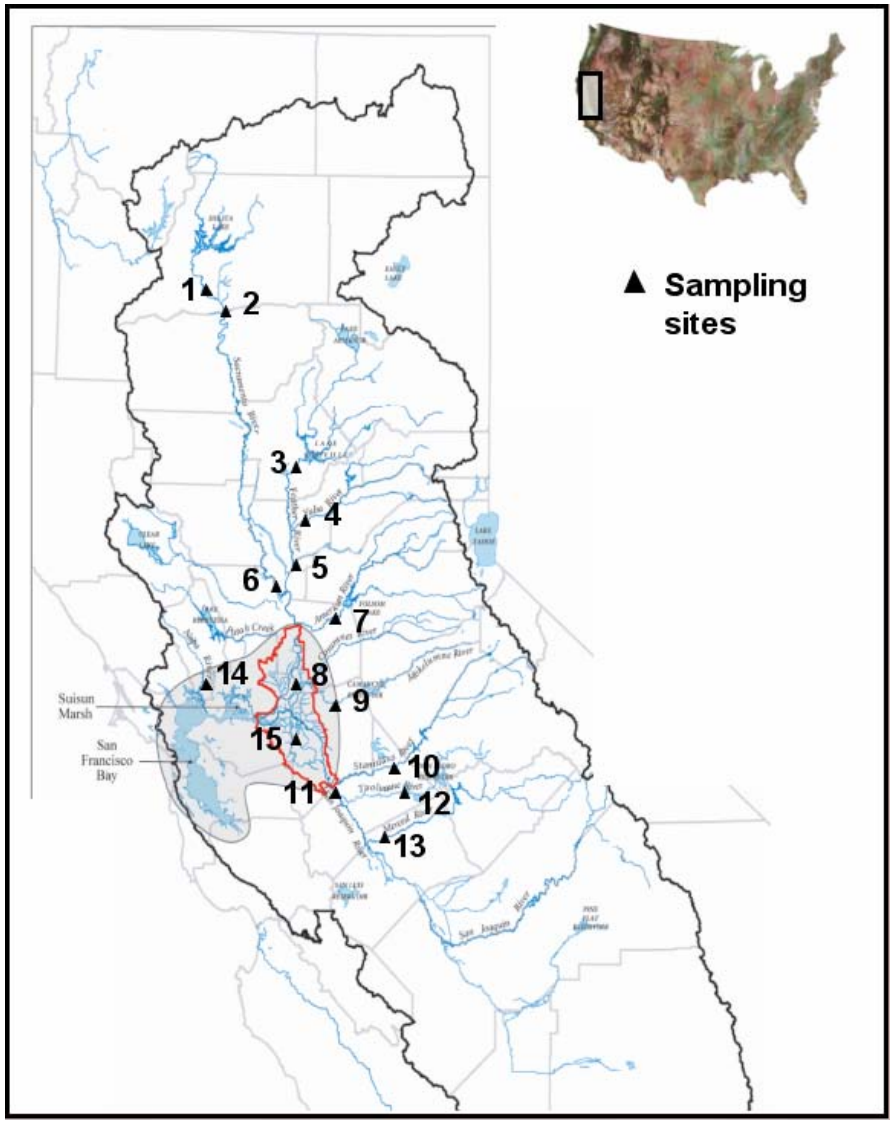


Figure 1. Map of eastern Nebraska showing the six collection sites where water was obtained in June 1999 (sites 1–6). During September 2000 and July 2001, water was collected only at sites 1 and 6 and at sites 1, 3, and 6, respectively, because of drought conditions at the other sites.

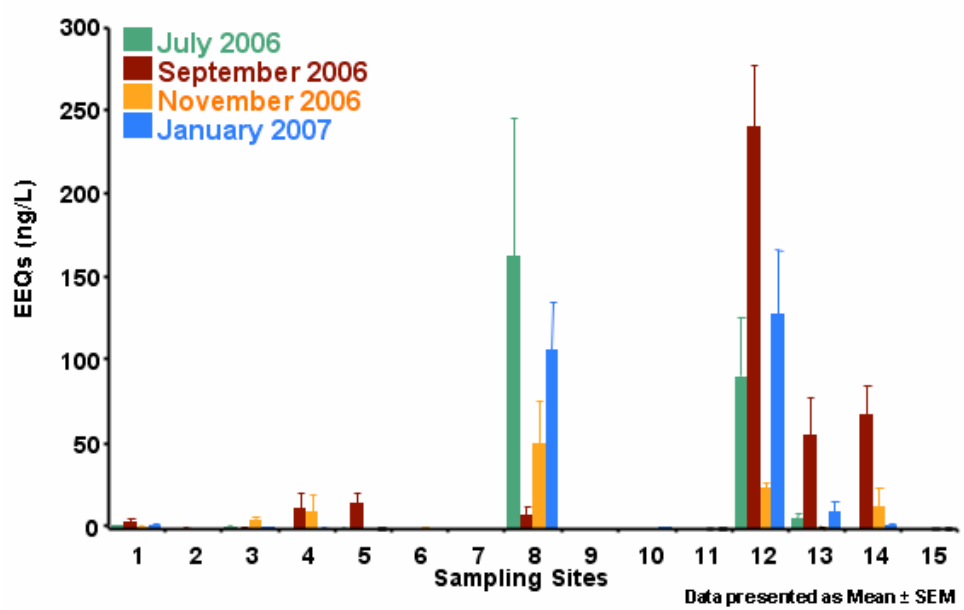
Soto et al. (2004)

Endocrine Disruption in Inland Waters



Trout liver hepatocyte assay

- **C-18 water extracts**
- **Steroids, NP below effect levels**
- **In vivo assay also shows activity**



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  - -improved wastewater treatment
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- **Control Options Available**
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- **Need for additional research**
  - -endocrine disruption in surface waters
  - -wetlands and aquifer treatment

Acknowledgments

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