

Comparison of pesticide concentrations in streams at low flow in six metropolitan areas of the United States



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National Water Quality Assessment (NAWQA) Program



NAWQA Program

- **STATUS**—Describe the quality of the Nation’s water resources in a nationally consistent manner.
- **TRENDS**—Assess long-term trends and changes in water quality.
- **UNDERSTANDING**—Identify, describe, and explain natural and human factors that affect water quality.

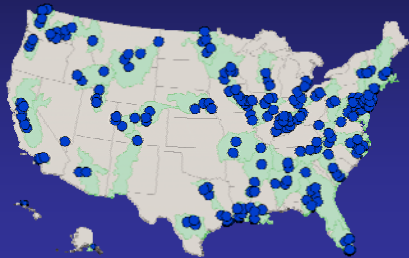


- I. Summary of NAWQA findings for pesticides, 1992–2001
- II. Pesticides in streams at low flow in six metropolitan areas



NAWQA Program: 1992-2001 results

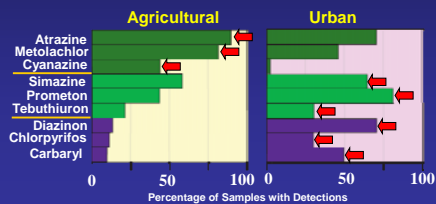
>5000 samples from 186 stream sites



USGS

Occurrence and distribution

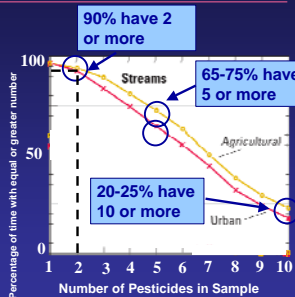
- Pesticides are detected over 90% of the time in streams in developed watersheds.
- The individual pesticides detected correspond to agricultural and non-agricultural use patterns.
- Geographic distribution depends on pesticide use patterns, pesticide p/c properties, and environmental factors.



USGS

Prevalence of mixtures

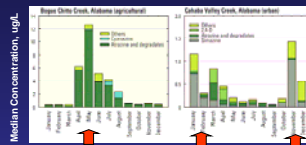
- Over 90% of the time, water from urban, agricultural, and mixed streams contain 2 or more pesticides.
- Degradates are important year-round and may exceed parent concentrations



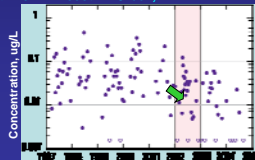
USGS

Seasonality and trends

Herbicides in 2 Alabama streams



Diazinon in Accotink Creek, VA

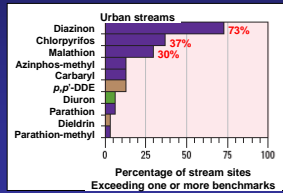


- Seasonal patterns vary with region and land use.
- Pesticide trends follow changes in use.

USGS

Potential effects on aquatic life

- Many urban (83%), agricultural (57%) and mixed land-use (42%) streams had at least 1 sample exceeding 1 or more aquatic-life benchmarks
- **Urban:** insecticides diazinon, chlorpyrifos and malathion accounted for the most benchmark exceedances.
- Potential effects are widespread but changing



USGS

II. Pesticides in streams at low flow in six metropolitan areas

- Study objectives and design
- Results for individual study areas
- National synthesis
- Potential effects on aquatic life

USGS

Effects of urbanization on stream ecosystems study



- Determine the hydrologic, chemical, habitat, and biological responses to urbanization



- Compare these responses over a range of environmental settings throughout the Nation



- Today: pesticides

USGS

Study Areas



USGS

Site Selection

- Space-for-time approach
- Environmental characteristics – homogeneous environmental framework controlled for “natural” sources of variability
- Urban intensity – sites represented a gradient of urbanization



Study Areas

Milwaukee-Green Bay

Portland



Minimally developed



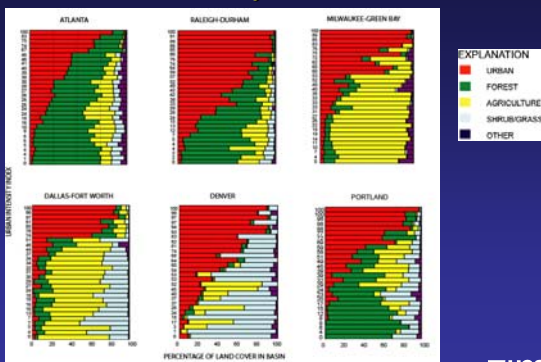
Moderately developed



Highly developed



Study Areas



Data Collection



- Samples collected twice during low flow conditions



- QA/QC included blanks, replicates, and spikes



61 Pesticides analyzed

16 HERBICIDES

- 7 Triazine
- 3 Acetanilide
- 3 Dinitroaniline
- 3 Miscellaneous

20 INSECTICIDES

- 14 Organophosphate
- 3 Pyrethroid
- 1 Carbamate
- 2 Miscellaneous

22 DEGRADATES

2 FUNGICIDES

1 NEMATOCIDE



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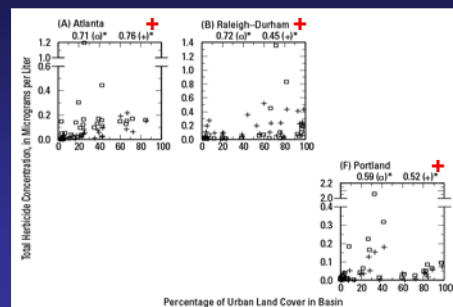


Patterns of response to urbanization

- Total herbicide and total insecticide concentrations calculated as the sum of their respective components
- Spearman's rank correlation used to assess the strength of the relationships between concentrations and urban land cover ($\alpha=0.05$)
- High and low base-flow conditions were evaluated separately



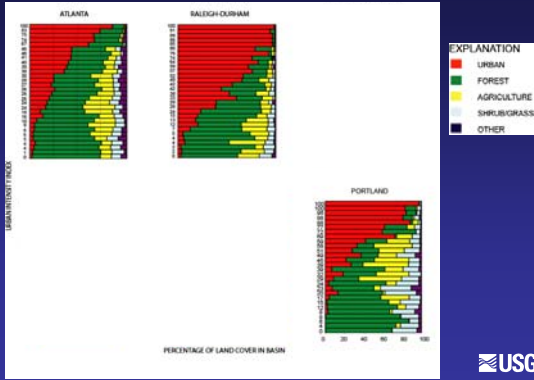
Response to urbanization: Herbicides



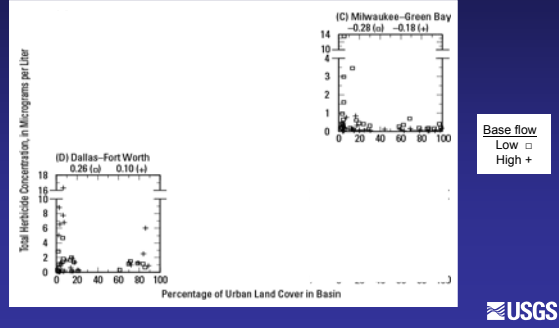
Base flow
Low □
High +



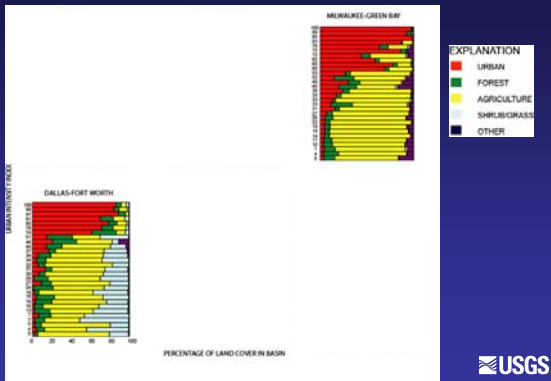
Study Areas



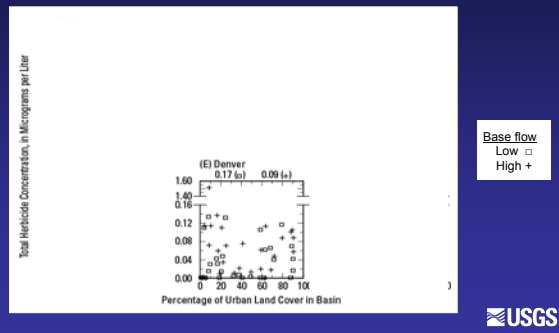
Response to urbanization: Herbicides



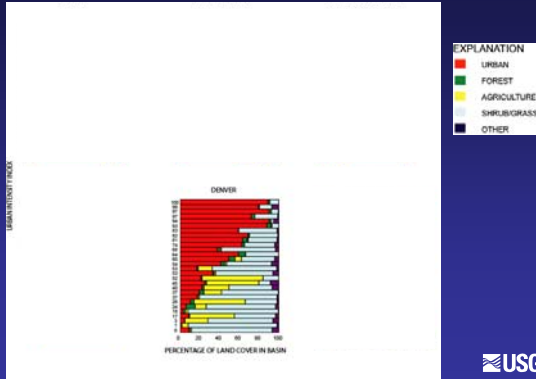
Study Areas



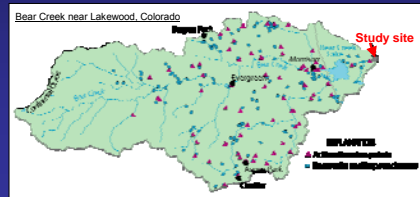
Response to urbanization: Herbicides



Study Areas

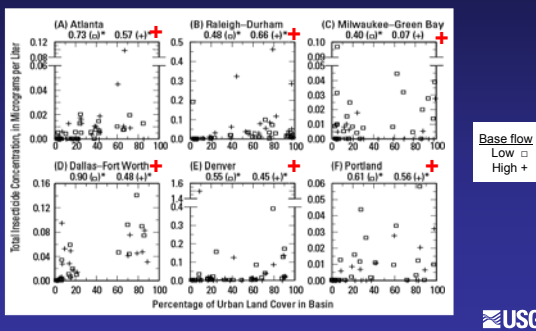


Water management



Photos from <http://bcn.boulder.co.us/basin/gallery>

Response to urbanization: Insecticides



Patterns of response to urbanization

- Urbanization of forest or other undeveloped (natural) land may increase concentrations of herbicides and insecticides in streams
Atlanta, Raleigh-Durham, and Portland
- Urbanization of agricultural land
- May increase insecticide concentrations in streams
- May not increase herbicide concentrations, but the types of herbicides present may change
Milwaukee-Green Bay and Dallas-Fort Worth
- Other factors such as water management could complicate the link between land use and pesticide occurrence
Denver

USGS

II. Pesticides in streams at low flow in six metropolitan areas

- Study objectives and design
- Results for individual study areas
- **National synthesis**
- Potential effects on aquatic life



National-scale patterns of response

All six study areas combined:

Objective:

To evaluate the importance of urbanization compared to other (non-urban) environmental characteristics

Statistical techniques:

- Factor analysis
- Multiple linear regression

Base-flow condition	Regression coefficients					R _L ²
	Factor 1 (urban)	Factor 2 (forest, elevation)	Factor 3 (slope)	Factor 4 (soil permeability)	Factor 5 (temperature)	



National-scale patterns of response

All six study areas combined:

Base-flow condition	Regression coefficients					R _L ²
	Factor 1 (urban)	Factor 2 (forest, elevation)	Factor 3 (slope)	Factor 4 (soil permeability)	Factor 5 (temperature)	
Total Herbicide Concentration						
High	--	--	-0.97	-0.73	-0.25	42%
Low	--	--	-0.96	-0.64	0.46	39%



National-scale patterns of response

All six study areas combined:

Base-flow condition	Regression coefficients					R _L ²
	Factor 1 (urban)	Factor 2 (forest, elevation)	Factor 3 (slope)	Factor 4 (soil permeability)	Factor 5 (temperature)	
Total Herbicide Concentration						
High	--	--	-0.97	-0.73	-0.25	42%
Low	--	--	-0.96	-0.64	0.46	39%
Total Insecticide Concentration						
High	0.33	--	--	--	--	71%
Low	0.32	--	--	--	--	70%



II. Pesticides in streams at low flow in six metropolitan areas

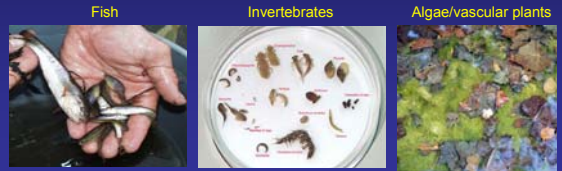
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Potential aquatic toxicity 1

Comparison to aquatic-life benchmarks

- Described in Gilliom et al. (2006) USGS Circular 1291
- Listed at: http://www.epa.gov/oppefed1/ecorisk_ ders/aquatic_life_benchmark.htm



Potential aquatic toxicity 2

Pesticide Toxicity Index (PTI)

- To evaluate relative potential toxicity of pesticide mixtures to aquatic organisms
- Normalize measured concentrations by aquatic toxicity (additive toxicity)
- Taxa: fish, cladocerans, benthic invertebrates

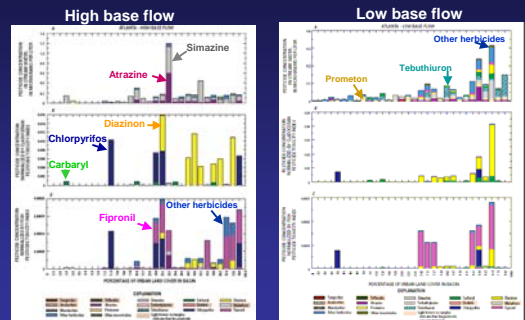


$$PTI_T = \sum_i \left(\frac{\text{Concentration}_i}{\text{Toxicity}_{iT}} \right)$$

Munn et al., 2006, <http://pubs.usgs.gov/sir/2006/5148/>



Atlanta

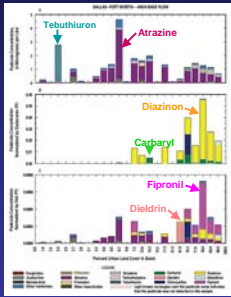


Background: Forest

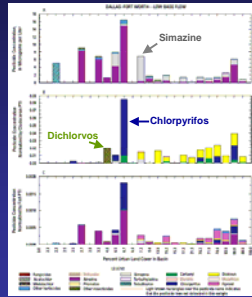


Dallas-Fort Worth

High base flow



Low base flow

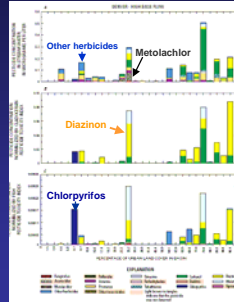


Background: Agriculture

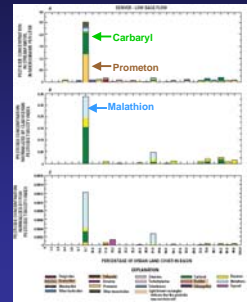


Denver

High base flow



Low base flow



Background: Shrub and grassland



Conclusions

- Urbanization increased insecticide concentrations in streams in six metropolitan areas with widely different environmental settings.
- For herbicides, the response to urbanization depended on the environmental setting and other factors.
- Pesticides with the greatest potential to adversely affect aquatic life were not necessarily the pesticides detected at the highest concentrations.
 - Potential toxicity was higher for insecticides than herbicides.
 - Potential toxicity was higher towards invertebrates than fish.
- Managing insecticides will be an important pesticide issue in urbanizing areas.



Acknowledgements... Many, many people



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Jerry McMahon
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Kevin Richards
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For Further Information:

Publications, effects on stream chemistry:

<http://water.usgs.gov/nawqa/urban/pdf/Sprague-Comp-2008.pdf>

<http://pubs.usgs.gov/sir/2007/5083/>

NAWQA, Effects of Urbanization on Stream Ecosystems:

<http://water.usgs.gov/nawqa/urban/>

NAWQA, Pesticide National Synthesis:

<http://water.usgs.gov/nawqa/pnsp/>

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