Trends in Pesticide Concentrations in Corn-Belt Streams, 1996-2006

Skip Vecchia, Dan Sullivan, Bob Gilliom, Jeff Martin, Dave Lorenz

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Topics

- Study background
  - Trend assessment technique
  - Summary of atrazine and metolachlor concentration trends
  - Relation between concentration trends and pesticide use

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USGS Report
By
D.J. Sullivan
A.V. Vecchia
D.L. Lorenz
J.D. Martin
R.J. Gilliom

Study Objectives

1) Evaluate the performance and applicability of statistical trend-assessment methods for pesticide data.

2) Assess trends in concentrations of commonly occurring pesticides in selected Corn Belt streams.

3) Assess the relative influences of pesticide use patterns and other potential factors, such as changes in management practices, on pesticide trends.
31 USGS pesticide sampling sites in Cornbelt (culled from a national network of 201 NAWQA sites)
Topics

• Study background

➢ Trend assessment technique

• Summary of atrazine and metolachlor concentration trends

• Relation between concentration trends and pesticide use
Acetochlor data for Mad River and Platte River

Trend-Method Requirements

- Repeatable
- Unbiased
- Efficient
- Robust:
  - Censoring
  - Sparse and changing sampling
  - High variability
  - Changing flow
Acetochlor data for Mad River and Platte River

**SEAWAVE-Q**

"seasonal wave w/streamflow adjustment"

Statistical model for concentration with:
- Seasonal variability
- Flow-related variability
- Trend
- Error
SEAWAVE-Q Model

“Seasonal wave with streamflow adjustment”

\[ \log(\text{Conc}) = \text{SWAVE} + \text{FLRV} + \text{TND} + \text{ERR} \]

- SWAVE = \( \gamma_0 + \gamma_1 W(t) \)
  - \( W(t) \) is a periodic function (period=1 yr)
  - \( (d/dt) W(t) = \lambda(t + s) - \phi W(t) \)
  - \( \lambda(.) \) is a pulse input with \( \lambda(.) > 0 \) during the “application season(s)” and \( \lambda(.) = 0 \) otherwise
  - \( s \) is a seasonal shift
  - \( \phi \) is a “decay rate”
Seasonal wave for acetochlor – Illinois River at Ottawa, IL (2000-2006)

2-Month Application Season (Apr-June)

Decay rate too fast

Decay rate “just right”
Seasonal wave for simazine - Ohio River at Cannelton Dam (2000-2006)

6-month application season (Dec-June)

Two, 2-month application seasons (Oct-Dec and Apr-June)

Poor fit – model rejected

Optimum fit – model accepted
SEAWAVE-Q Model

\[
\text{Log(Conc)} = \text{SWAVE} + \text{FLRV} + \text{TND} + \text{ERR}
\]

- \(\text{FLRV} = \gamma_2 \text{LTFA}(t) + \gamma_3 \text{MTFA}(t) + \gamma_4 \text{STFA}(t)\)
  - "Flow-related variability"
    - Flow anomalies computed using log-transformed daily flow for USGS streamgage
    - \(\text{LTFA}(t)\) “long-term flow anomaly”
      - Low-frequency (annual) flow variability
    - \(\text{MTFA}(t)\) “mid-term flow anomaly”
      - Mid-frequency (seasonal) flow variability
    - \(\text{STFA}(t)\) “short-term flow anomaly”
      - High-frequency (day-to-day) flow variability
Acetochlor for Platte River at Louisville, NE

Without FLRV

Significant (p=0.006) upward trend (28 percent per year)

With FLRV

No significant flow-adjusted trend
SEAWAVE-Q Model

\[
\text{Log(Conc)} = \text{SWAVE} + \text{FLRV} + \text{TND} + \text{ERR}
\]

- **TND** = $\gamma_5 \, t$
  - Log-linear trend
  - “Flow-adjusted trend” (adjusted for FLRV)

- **ERR**
  - Random error
  - Assumed normal, uncorrelated

Model parameters estimated using maximum likelihood with censored data (“Survival” or “Tobit” regression)
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  ➢ Summary of atrazine and metolachlor concentration trends
• Relation between concentration trends and pesticide use
31 Pesticide Sampling Sites on Corn-Belt Streams
<table>
<thead>
<tr>
<th>Ohio Basin</th>
<th>Great Lakes Basins</th>
<th>Upper Mississippi Basin</th>
<th>Missouri Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MAD</td>
<td>8. DUCK</td>
<td>14. LCOBB</td>
<td>27. MIZZ-OM</td>
</tr>
<tr>
<td>2. OHIO-CA</td>
<td>9. MILW</td>
<td>15. MSSP-HA</td>
<td>28. MAPLE</td>
</tr>
<tr>
<td>3. LBUCK</td>
<td>10. CLINT</td>
<td>16. MSSP-CL</td>
<td>29. PLATTE</td>
</tr>
<tr>
<td>4. SUG-NP</td>
<td>11. STJOS</td>
<td>17. WAPS-TR</td>
<td>30. MIZZ-HE</td>
</tr>
<tr>
<td>5. WHITE</td>
<td>12. AUGL</td>
<td>18. IOWA-ROW</td>
<td>31. MSSP-TH</td>
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<tr>
<td>6. WABASH</td>
<td>13. MAUM</td>
<td>19. SFIOWA</td>
<td></td>
</tr>
<tr>
<td>7. OHIO-GRCH</td>
<td></td>
<td>20. IOWA-WAP</td>
<td></td>
</tr>
</tbody>
</table>

**AVERAGE DAILY FLOW, 1996-2006 (m³/s)**

- <80
- 800
- 8,000

**AVERAGE ANNUAL FLUX, 1996-2006 (kg/yr)**

- <4,000
- 40,000
- 400,000

**FLOW-ADJUSTED TRENDS IN CONCENTRATION**

- Estimated value
- 90-percent confidence limits
- Non-significant (p>0.1)
- Significant (p<0.1)
- Highly significant (p<0.01)

**1996-2002**

- TREND, IN PERCENT PER YEAR

**2000-2006**

- TREND, IN PERCENT PER YEAR

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**ATRAZINE TRENDS FROM SEAWAVE-Q**

- Ohio Basin
- Great Lakes Basins
- Upper Mississippi Basin
- Missouri Basin

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**USGS**

Science for a changing world
METOLACHLOR TRENDS FROM SEAWAVE-Q

Ohio Basin

Great Lakes Basins

Upper Mississippi Basin

Missouri Basin

Flow-adjusted trends in concentration

Estimated value

90-percent confidence limits

nonsignificant (p>0.1)

significant (p<0.1)

highly significant (p<0.01)

Average daily flow, 1996-2006 (m^3/s)

Average annual flux, 1996-2006 (kg/yr)

90-percent confidence limits

nonsignificant (p>0.1)

significant (p<0.1)

highly significant (p<0.01)

Average annual flux, 1996-2006 (kg/yr)

Average daily flow, 1996-2006 (m^3/s)

90-percent confidence limits

nonsignificant (p>0.1)

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highly significant (p<0.01)

Flow-adjusted trends in concentration

Estimated value

90-percent confidence limits

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Questions

- How do pesticide trends in corn-belt rivers compare to changes in agricultural use?

- Are there other factors (land use changes, management practices, non-ag use, etc.) that may be contributing?
Metolachlor and Atrazine Use
12 States, >80% Corn and Soybean Acreage

Pounds of active ingredient

2000-2006
1996-2002

S-metolachlor introduced

Graphic by USGS based on data provided by Dmrkynetec, Inc.
Focus on 11 sites on major rivers

- 3 sites in Ohio Basin
- 3 sites in Missouri Basin
- 4 sites in Upper Mississippi Basin
- 1 site on Mississippi downstream of Missouri (but upstream of Ohio)

Annual pesticide use estimates for each basin obtained from GIS coverage of crop data and pesticide application rates

Large basins ~ more accurate use estimates
Metolachlor Concentration and Agricultural Use Trends
Wabash River: 1996-2002

SUT = -11.9 (-14.3 to -9.4) pct/yr
SCT = -16.8 (-21.6 to -11.6) pct/yr
Concentration and Use Trends for Metolachlor

1996-2002

2000-2006

Ohio Basin
- OHIO-CA
- WABASH
- OHIO-GRCH
- MSSP-CL
- IOWA-WAP
- ILLI-VC
- MSSP-GR
- MIZZ-OM
- PLATTE
- MIZZ-HE
- MSSP-TH

Upper Miss. Basin

Misso. Basin

Trend, in percent per year

90-pct confidence bounds for agricultural use trend

90-pct confidence bounds for concentration trend

Estimated concentration or agricultural use trend
Implications for major agricultural herbicides in large Cornbelt rivers

- A multi-year trend in watershed use intensity generally produces a similar trend in river concentrations.
- Changes in non-use management practices during 1996-2006 have not had a statistically discernable effect on concentrations.
- Large-scale effectiveness of non-use management practices will be difficult to evaluate without improved information on implementation of practices.
Thanks!

For more Information and copies of publications:

USGS
National Water Quality Assessment Program
Pesticide National Synthesis Project
http://water.usgs.gov/nawqa/pnsp/
or
avecchia@usgs.gov