Reproductive outcomes at changing PFAS exposures in Minnesota
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Gina Waterfield
The Nature Conservancy, Washington DC
gina.waterfield@tnc.org
Background

- Production and disposal of PFAS at multiple locations in Minneapolis East Metro Area beginning in 1950s
- High levels of PFOA (0.07 to 0.70 μg/L) and PFOS (ND to 1.04 μg/L) detected in Oakdale municipal wells in 2005
- Almost all 27,000 Oakdale residents served by municipal water
- Granular activated charcoal (GAC) filtration installed for municipal supply in 2006
- PFAS detected in other surrounding communities but less consistent exposure, no large-scale intervention
• All singleton birth records in all zip codes in Washington County 2002 to 2011 (MDH)
  • Birth weight
  • Gestational age
  • Sex

• Individual-level maternal characteristics (MDH)
  • Age
  • Residence zip code
  • Marital status
  • Educational attainment
  • [Drug use and Medical risk factors]

• Zip code-level characteristics (ACS)
  • Income
  • Racial/ethnic composition
## Summary of Selected Characteristics

<table>
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</thead>
<tbody>
<tr>
<td>Number of Births</td>
<td>1,685</td>
<td>1,715</td>
<td>9,017</td>
<td>8,600</td>
<td>13,811</td>
<td>14,237</td>
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<tr>
<td>Maternal Characteristics</td>
<td></td>
<td></td>
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<tr>
<td>Age</td>
<td>Mean (SD)</td>
<td>28.5 (5.7)</td>
<td>28.1 (5.5)</td>
<td>30.0 (5.5)</td>
<td>29.8 (5.4)</td>
<td>28.6 (5.8)</td>
</tr>
<tr>
<td>Marital Status</td>
<td>% Married</td>
<td>70.5%</td>
<td>63.2%</td>
<td>82.7%</td>
<td>78.6%</td>
<td>70.9%</td>
</tr>
<tr>
<td>Educational Attainment</td>
<td>% No HS Diploma</td>
<td>5.7%</td>
<td>6.2%</td>
<td>3.7%</td>
<td>3.4%</td>
<td>7.3%</td>
</tr>
<tr>
<td></td>
<td>% College Degree</td>
<td>38.7%</td>
<td>35.9%</td>
<td>53.6%</td>
<td>56.0%</td>
<td>38.9%</td>
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<tr>
<td>Newborn Characteristics</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Sex</td>
<td>% Female</td>
<td>47.4%</td>
<td>50.3%</td>
<td>48.5%</td>
<td>48.2%</td>
<td>48.8%</td>
</tr>
<tr>
<td>Birth Weight (grams)</td>
<td>Mean (SD)</td>
<td>3,390 (573)</td>
<td>3,360 (542)</td>
<td>3,445 (545)</td>
<td>3,409 (538)</td>
<td>3,419 (551)</td>
</tr>
<tr>
<td></td>
<td>% &lt; 2,500g</td>
<td>5.7%</td>
<td>4.7%</td>
<td>3.8%</td>
<td>4.2%</td>
<td>4.3%</td>
</tr>
<tr>
<td></td>
<td>% &lt; 1,500g</td>
<td>1.0%</td>
<td>0.7%</td>
<td>0.7%</td>
<td>0.7%</td>
<td>0.8%</td>
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<tr>
<td>Gestational Age (weeks)</td>
<td>Mean (SD)</td>
<td>38.8 (2.0)</td>
<td>39.0 (1.8)</td>
<td>38.9 (1.7)</td>
<td>38.9 (1.9)</td>
<td>38.9 (1.9)</td>
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<tr>
<td></td>
<td>% &lt; 37 Weeks</td>
<td>7.2%</td>
<td>5.9%</td>
<td>6.3%</td>
<td>6.4%</td>
<td>6.4%</td>
</tr>
<tr>
<td></td>
<td>% &lt; 32 Weeks</td>
<td>1.1%</td>
<td>0.8%</td>
<td>0.7%</td>
<td>0.9%</td>
<td>0.8%</td>
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<tr>
<td>Zip Code Characteristics</td>
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<tr>
<td>Household Income ($)</td>
<td>Median</td>
<td>73,588</td>
<td>70,040</td>
<td>99,082</td>
<td>96,002</td>
<td>77,474</td>
</tr>
</tbody>
</table>
Identification Strategy

- Compare outcomes in affected communities, and changes in outcomes in Oakdale, to control communities without known PFAS contamination of drinking water supplies
  - Implicitly controls for fixed differences in community characteristics
  - Implicitly controls for changes over time common to all communities

Individual level regressions with explicit controls for maternal characteristics and additional zip code level controls:

\[
Birth \ Outcome = f(\alpha + \beta_1 Oakdale_{2002-2006} + \beta_2 Oakdale_{2007-2011} + \beta_3 Other \ Affected \\
+ \beta_4 Maternal \ Characteristics + \beta_4 Zip \ Code \ Characteristics \\
+ \gamma Birth \ Years + \theta Birth \ Months + \epsilon)
\]
Reducing PFAS exposure had a small impact on birth weight and gestational age.
Reducing PFAS exposure substantially and significantly reduced the odds of adverse birth outcomes in Oakdale.
Reducing PFAS exposure appears to have had a positive effect on the general fertility rate in Oakdale but the response is slower.
Conclusions

- Reduced exposure to PFAS in drinking water was associated with slightly higher birth weight and gestational age on average.
- PFAS filtration significantly reduced the odds of low birth weight and preterm birth in Oakdale relative to other communities.
- Response in general fertility rate was slower but appears to be positive.
- Caveats and limitations:
  - Exposures in Oakdale and other affected communities not known.
  - Cannot disentangle effects of PFOA, PFOS and other PFAS.
  - Cannot rule out confounding factors, despite “quasi-experimental” study design.
- Continued need for follow-up and monitoring of outcomes; additional studies of PFAS interventions.