EXPOSURE-BASED ASSESSMENT AND ECONOMIC VALUATION OF CANCER RISK AND ADVERSE BIRTH OUTCOMES DUE TO NITRATE IN UNITED STATES DRINKING WATER

Alexis Temkin, Sydney Evans, Chris Campbell, Olga Naidenko,
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Nitrate in Drinking Water

HEALTH CONCERN
IDENTIFIED IN THE 1960S
Methemoglobinemia, blue-baby syndrome

HEALTH CONCERNS
IDENTIFIED SINCE THE 1990S
Cancer, adverse pregnancy outcomes
National contamination of nitrate in drinking water

What are the potential public health costs of current nitrate contamination in United States drinking water?
Nitrate in drinking water and cancer risk

Schullehner et al. 2018. Int J Cancer
**Estimate of annual nitrate-attributable cancer cases**

Population exposed $X$ increased risk in the exposed population $X$ baseline national incidence = Nitrate attributable cancer cases

- Population exposed = # of people exposed above a given nitrate cut-off level
- Increase risk = Relative Risk (RR) in the exposed population
- Baseline Incidence = National incidence as reported by CDC
Estimated annual nitrate-attributable cancer cases

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Estimated MINIMUM number of cancer cases</th>
<th>Estimated MAXIMUM number of cancer cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorectal</td>
<td>1233</td>
<td>10,379</td>
</tr>
<tr>
<td>Ovarian</td>
<td>110</td>
<td>580</td>
</tr>
<tr>
<td>Thyroid</td>
<td>369</td>
<td>1,047</td>
</tr>
<tr>
<td>Kidney</td>
<td>454</td>
<td>454</td>
</tr>
<tr>
<td>Bladder</td>
<td>134</td>
<td>134</td>
</tr>
</tbody>
</table>

ESTIMATED MAXIMUM ANNUAL NITRATE-ATTRIBUTABLE CANCER CASES

12,594

1% Bladder
4% Kidney
5% Ovarian
8% Thyroid
82% Colorectal
Estimated nitrate-attributable cancer cases for each state per 100,000 people
Estimate of **economic cost** of nitrate-attributable cancer cases

*Direct Medical Costs = Initial Cost + Continuing Costs each Year + Cost for the Last Year of Life*

*Indirect Economic Loss = Total DALYs * VOLY*

\[ \text{DALYs} = \text{Nitrate-attributable cases} \times (\text{YLL} + \text{YLD}) \]

- DALY = disability-adjusted life years
- VOLY = value of a life year
- YLL = years of life lost (avg life expectancy – median age death for disease)
- YLD = years lived with disease (years lived with disease * disease-specific disability weight)
Estimated economic cost of nitrate-attributable cancer cases

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Estimated MINIMUM number of cancer cases and DALYs</th>
<th>Estimated MAXIMUM number of cancer cases and DALYs</th>
<th>Range of Medical Costs in 2014 USD (billions)</th>
<th>Range of Indirect economic loss in 2014 USD (billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorectal</td>
<td>1,233 and 10,083</td>
<td>10,379 and 84,901</td>
<td>$0.16 to $1.33</td>
<td>$0.58 to $4.9</td>
</tr>
<tr>
<td>Ovarian</td>
<td>110 and 1,558</td>
<td>580 and 8,188</td>
<td>$0.02 to $0.11</td>
<td>$0.09 to $0.47</td>
</tr>
<tr>
<td>Thyroid</td>
<td>369 and 5,718</td>
<td>1,047 and 14,695</td>
<td>N/A</td>
<td>$0.30 to $0.85</td>
</tr>
<tr>
<td>Kidney</td>
<td>N/A</td>
<td>454 and 4,310</td>
<td>$0.06</td>
<td>$0.25</td>
</tr>
<tr>
<td>Bladder</td>
<td>N/A</td>
<td>134 and 535</td>
<td>$0.01</td>
<td>$0.03</td>
</tr>
</tbody>
</table>
Meta-analysis of Colorectal Cancer Risk and Nitrate in Drinking Water
Summary and Conclusions

• 2,300 to 12,594 cancer cases, costing $1.5 to $8 billion, annually in the U.S. may be attributable to nitrate, of which 54-82% are colorectal cancer cases.

• States with estimated greater than 10 nitrate-attributable cancer cases per 100,000 people are Delaware, Arizona, California and Iowa.

• Meta-analysis of eight studies assessing nitrate in drinking water and colorectal cancer finds a statistically significant linear positive association

• **Substantial public health impacts are likely occurring at current nitrate levels in tap water**
Acknowledgements

CO-AUTHORS and COLLEAGUES

• Sydney Evans, Tatiana Manidis, Chris Campbell, Olga Naidenko
• Tasha Stoiber and David Andrews
# Nitrate in drinking water and adverse birth outcomes

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Location and Publication Year</th>
<th>Nitrate-N cut-off (mg/L)</th>
<th>Disease risk in exposed population</th>
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</thead>
<tbody>
<tr>
<td>Neural Tube Defect</td>
<td>Brender 2013</td>
<td>4.5</td>
<td>1.43</td>
</tr>
<tr>
<td>Very low birth weight</td>
<td>Stayner 2017</td>
<td>1</td>
<td>1.17</td>
</tr>
<tr>
<td>Very preterm birth</td>
<td>Stayner 2017</td>
<td>1</td>
<td>1.08</td>
</tr>
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</table>
## Estimated annual nitrate-attributable adverse birth outcomes

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<tr>
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<th>Location and Publication Year</th>
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</thead>
<tbody>
<tr>
<td>Neural Tube Defect</td>
<td>Brender 2013</td>
<td>4.5</td>
<td>1.43</td>
<td>41</td>
</tr>
<tr>
<td>Very low birth weight</td>
<td>Stayner 2017</td>
<td>1</td>
<td>1.17</td>
<td>2939</td>
</tr>
<tr>
<td>Very preterm birth</td>
<td>Stayner 2017</td>
<td>1</td>
<td>1.08</td>
<td>1725</td>
</tr>
</tbody>
</table>
Estimated economic cost of nitrate-attributable adverse birth outcomes

• Lifetime direct costs of neural tube defects (spina bifida) are $577,000 to $791,900 per case (National Center on Birth Defects and Developmental Disabilities)
  • 41 cases = $24 to 32 million

• Premature Births medical cost estimate of $67,022 per case (Institute of Medicine)
  • 1725 cases = $116 million

• Indirect cost due to Loss IQ points associated with very low birth weight (Malits et al. 2018)
  • 2939 cases = $11,745 to $15,883 per IQ point loss