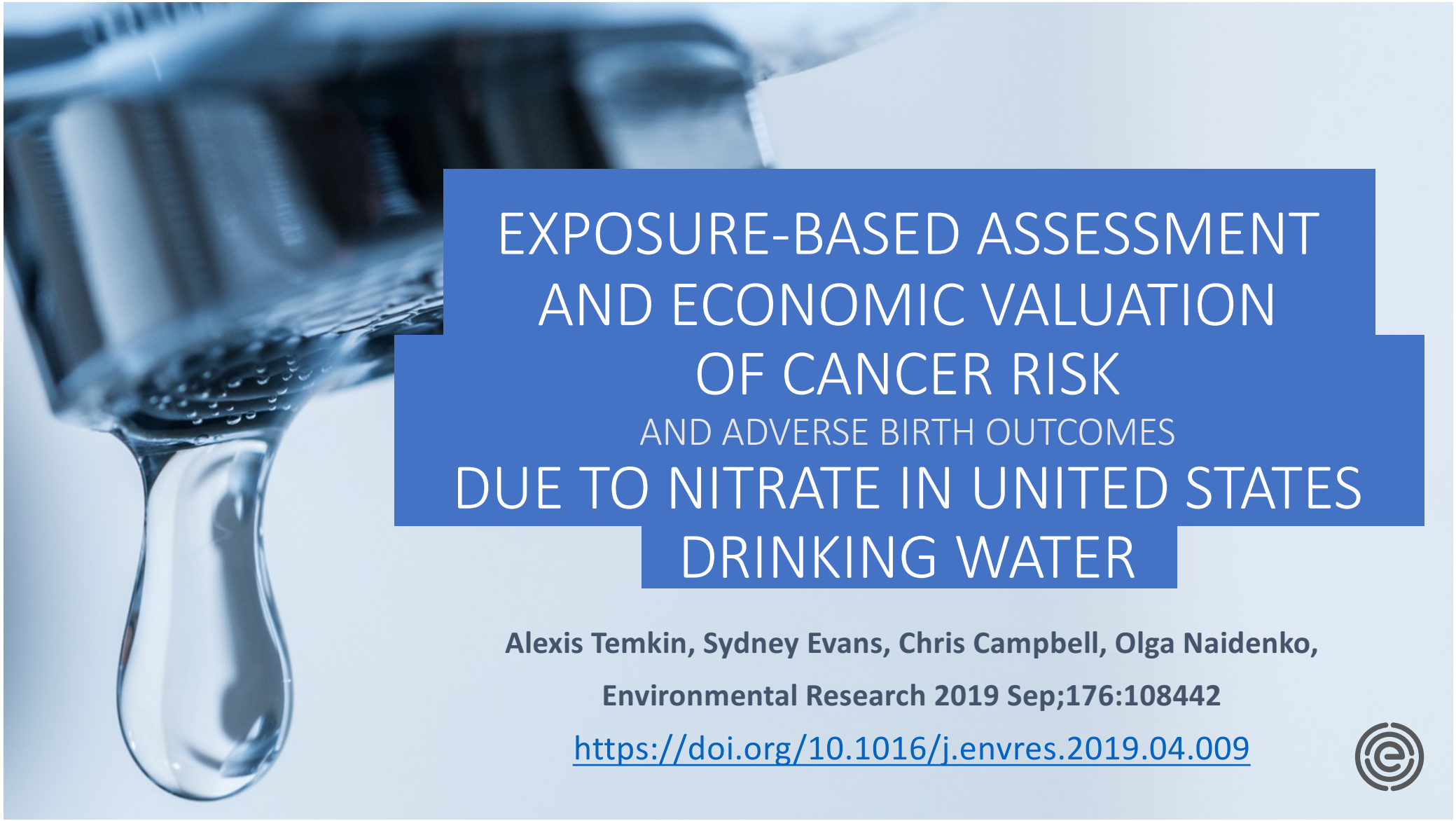

EXPOSURE-BASED ASSESSMENT AND ECONOMIC VALUATION OF CANCER RISK AND ADVERSE BIRTH OUTCOMES DUE TO NITRATE IN UNITED STATES DRINKING WATER

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Nitrate in Drinking Water

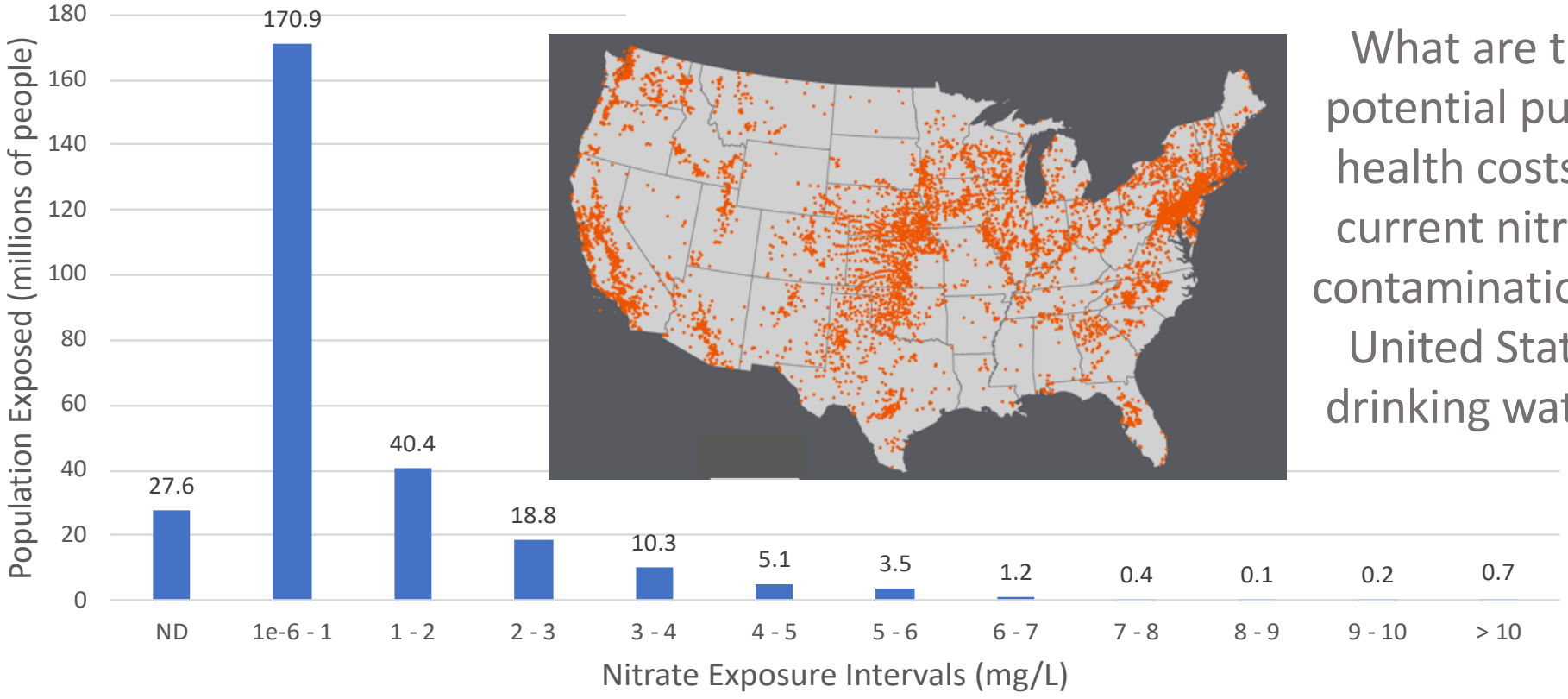
HEALTH CONCERN IDENTIFIED IN THE 1960S

Methemoglobinemia, blue-baby syndrome

HEALTH CONCERNS IDENTIFIED SINCE THE 1990S

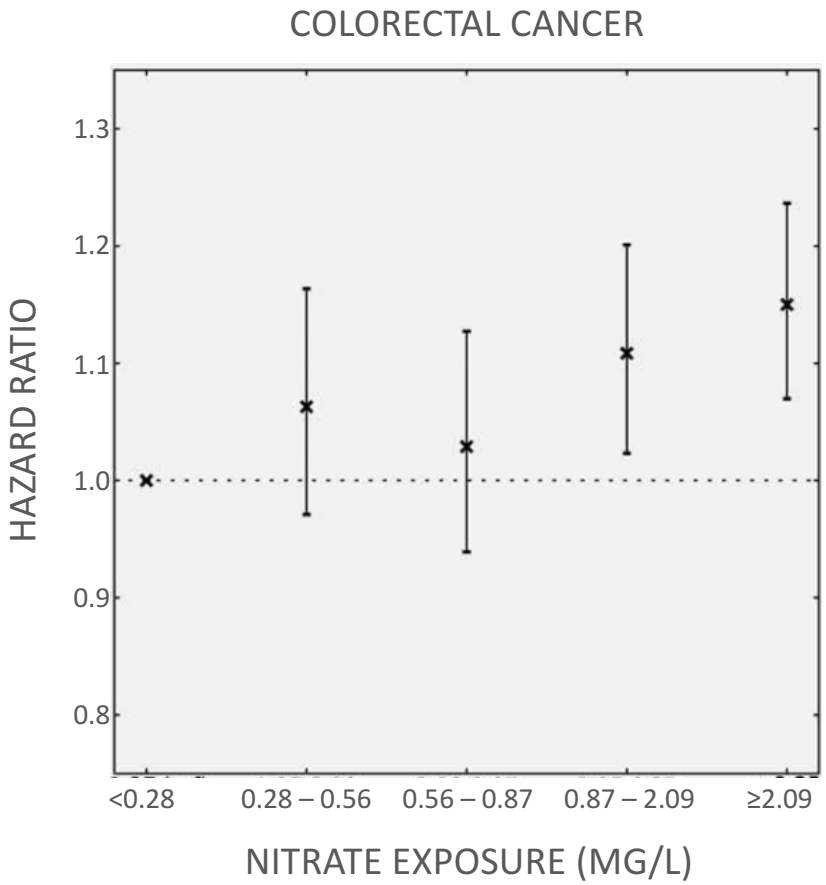
Cancer, adverse pregnancy outcomes

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**



Cancer Type	Location and Publication Year	Nitrate-N cut-off (mg/L)	Cancer risk in exposed population
Colorectal	Spain and Italy 2016	1.7	1.49
Colorectal	Denmark 2017	0.9	1.11
Colorectal	Iowa 2003	5	1.8*
Ovarian	Iowa 2015	3	2.03
Thyroid	Iowa 2010	2.5	2.18
Kidney	Iowa 2007	5	1.7*
Bladder	Iowa 2016	5	1.61

* Above median red meat consumers

Schullehner et al. 2018. Int J Cancer

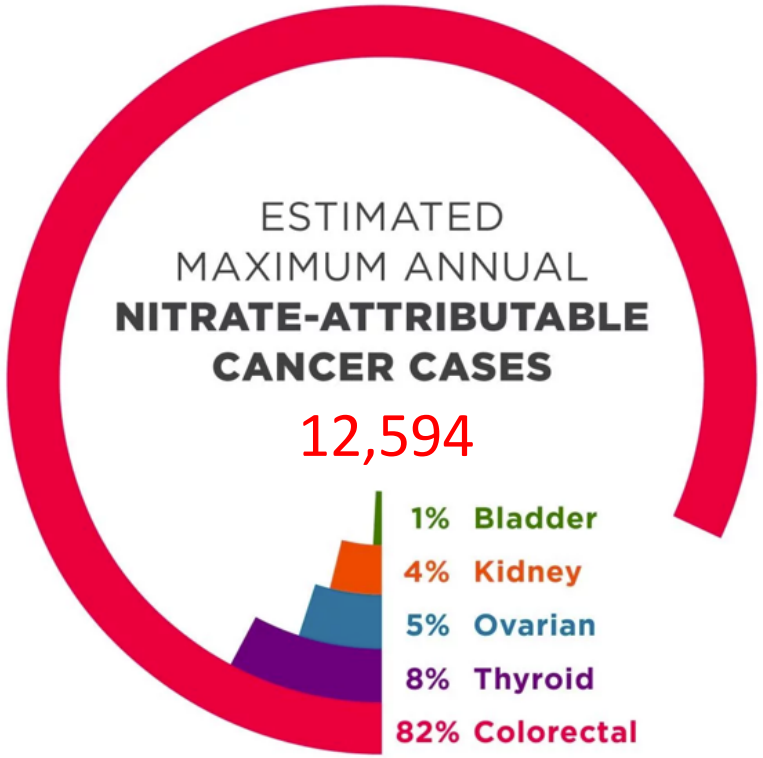
Estimate of **annual nitrate-attributable** cancer cases

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

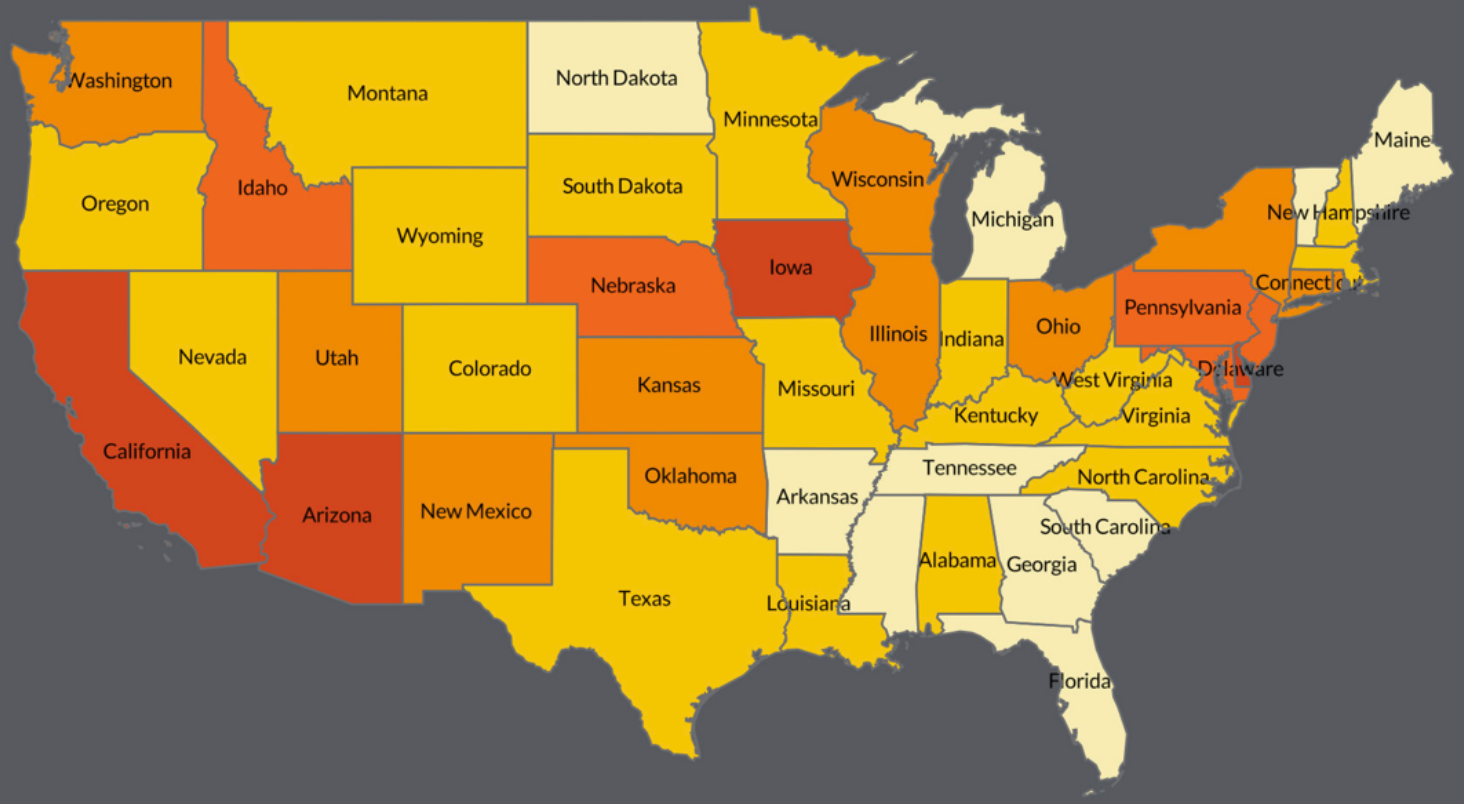
- Population exposed = # of people exposed above a given nitrate cut-off level
- Increase risk = Relative Risk (RR) in the exposed population
- Baseline Incidence = National incidence as reported by CDC

Estimated annual nitrate-attributable **cancer cases**

Cancer Type	Estimated **MINIMUM** number of cancer cases	Estimated **MAXIMUM** number of cancer cases
Colorectal	1233	10,379
Ovarian	110	580
Thyroid	369	1,047
Kidney	454	454
Bladder	134	134



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*

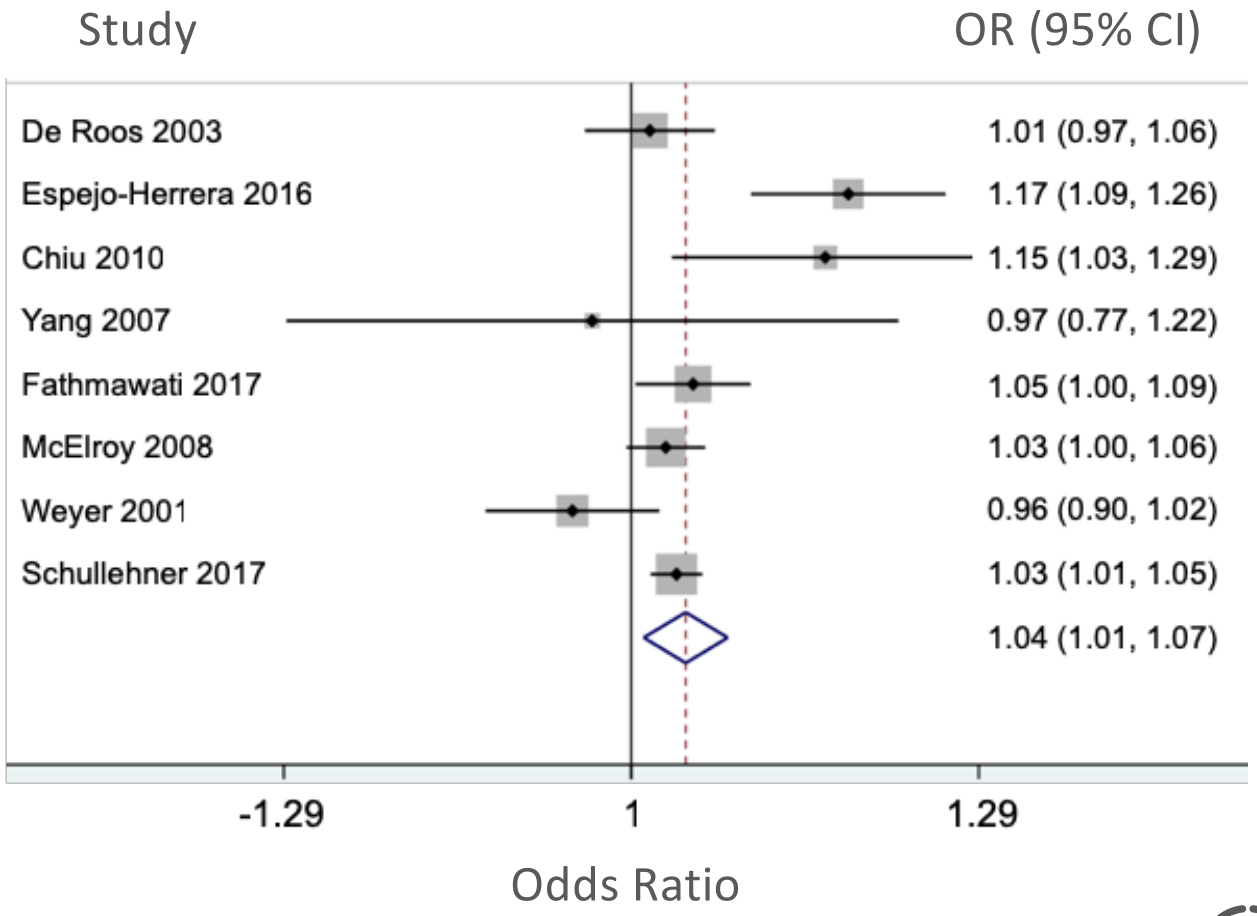
*DALYs = Nitrate-attributable cases * (YLL + YLD)*

- 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**

Cancer Type	Estimated **MINIMUM** number of cancer cases and DALYs	Estimated **MAXIMUM** number of cancer cases and DALYs	Range of Medical Costs in 2014 USD (billions)	Range of Indirect economic loss in 2014 USD (billions)
Colorectal	1,233 and 10,083	10,379 and 84,901	$0.16 to $1.33	$0.58 to $4.9
Ovarian	110 and 1,558	580 and 8,188	$0.02 to $0.11	$0.09 to $0.47
Thyroid	369 and 5,718	1,047 and 14,695	N/A	$0.30 to $0.85
Kidney	N/A	454 and 4,310	$0.06	$0.25
Bladder	N/A	134 and 535	$0.01	$0.03

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**

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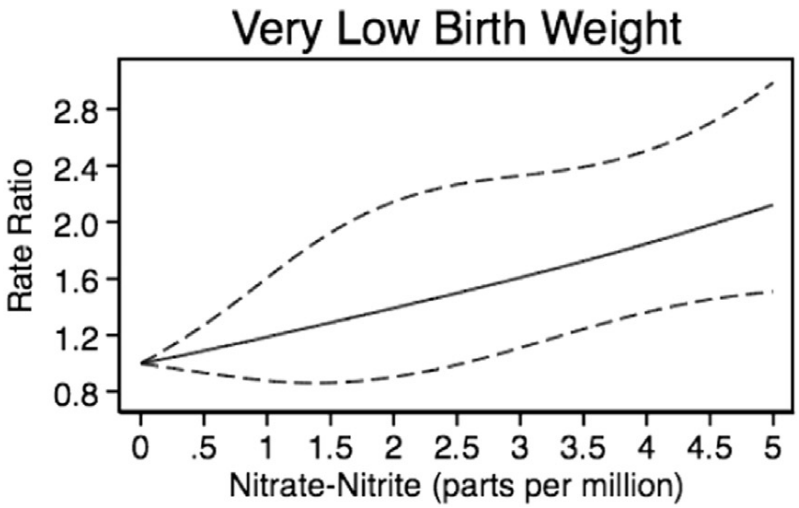
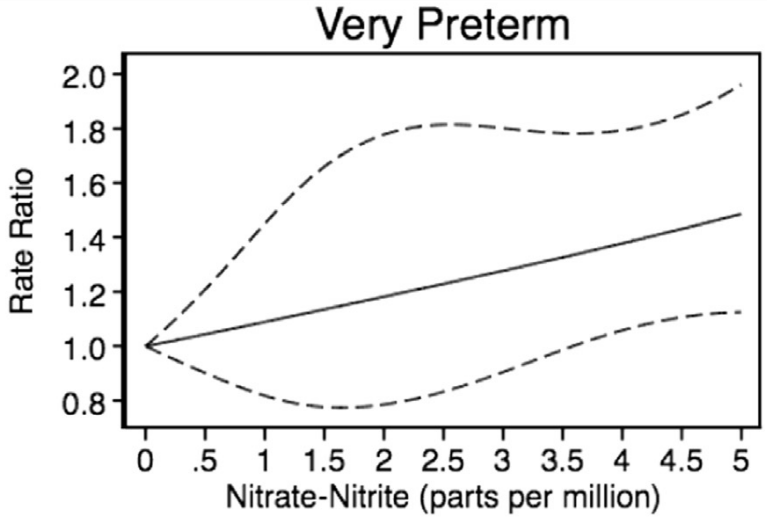
- Tasha Stoiber and David Andrews

Nitrate in drinking water and **adverse birth outcomes**

Cancer Type	Location and Publication Year	Nitrate-N cut-off (mg/L)	Disease risk in exposed population
Neural Tube Defect	Brender 2013	4.5	1.43
Very low birth weight	Stayner 2017	1	1.17
Very preterm birth	Stayner 2017	1	1.08





Estimated annual nitrate-attributable **adverse birth outcomes**

Cancer Type	Location and Publication Year	Nitrate-N cut-off (mg/L)	Disease risk in exposed population	**Estimated number of nitrate-attributable cases**
Neural Tube Defect	Brender 2013	4.5	1.43	**41**
Very low birth weight	Stayner 2017	1	1.17	**2939**
Very preterm birth	Stayner 2017	1	1.08	**1725**

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