

Public Health Impacts of Nitrate and Other Drinking Water Contaminants: Implications for Source Water Protection

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Water Quality – a Public Health Perspective

- Longstanding issues: nutrients (nitrate), pesticides (atrazine, herbicide degradates), disinfection byproducts (DBPs: trihalomethanes, haloacetic acids)
- Emerging issues: arsenic, microcystin/cyanobacteria, neonicotinoid insecticides, Pharmaceutical compounds
- Drinking water issues and recreational water use

Drinking Water Contaminants and Health Risk Research Questions

- Is there biological plausibility?
- What about other risk factors?
 - Genetics, occupation, lifestyle, diet
- For drinking water, is there consumption data (# glasses of water per day, etc.)?
- Are positive findings corroborated by other research?

Drinking Water Contaminants and Health Studies

Iowa Resources

- University of Iowa-based Health Registries for cancer, birth defects
- CHEEC water databases: IA public water supplies, private drinking water wells
- Collaborative relationships: State Hygienic Laboratory, UI College of Public Health, county health departments, state agencies, NIH, CDC, USGS, Iowa drinking water utilities, the people of Iowa

Endogenous formation of *N*-nitroso compounds (NOCs) from ingested nitrate and nitrite

Nitrate from drinking water



Nitrate → Nitrite

Dietary nitrite/nitrate

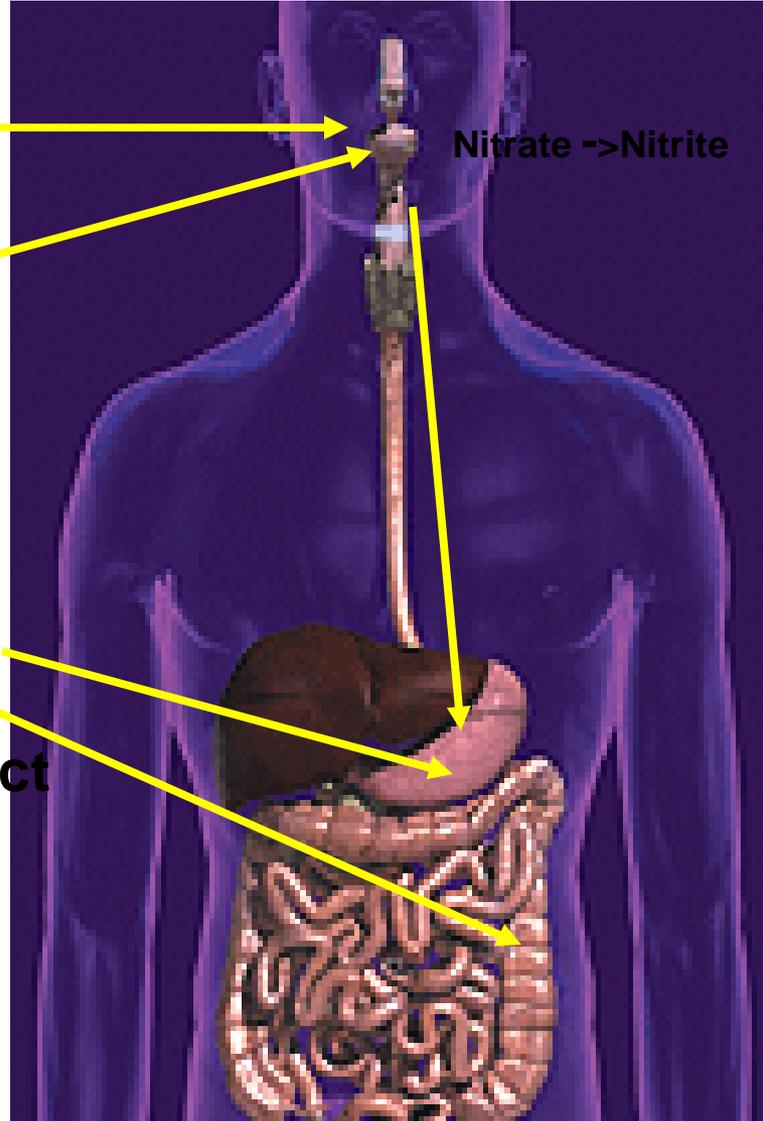


Nitrite + Amines/amides (protein)



Endogenous formation of NOC in GI tract

- Catalyzed by heme iron (red meat)
- Inhibited by antioxidants (Vitamin C)



Animal Studies of NOCs

- ~300 NOCs tested, 90% were carcinogenic (IARC, 1995)
- Carcinogenic in 39 animal species, including 6 species of primates
- Tumors in multiple organs: lung, thyroid, GI tract, bladder, kidney, ovary

Nitrate in Drinking Water and Cancer

- *Iowa Women's Health Study* (1986): National Cancer Institute-funded study of postmenopausal women, lifestyle and health outcomes
 - Info on source of water (public/private well), how long on source
 - Over 22,000 women on same water source for >20 years
 - Nitrate data from 1955-88 for municipal supplies
 - Average nitrate exposure of 33 year period
 - Cancer latency – initial exposure can be decades before diagnosis
 - Examined nitrate in diet, vitamin use, smoking, etc.
 - Follow-up through Iowa Cancer Registry since 1988

Nitrate in Drinking Water and Cancer

Iowa Women's Health Study

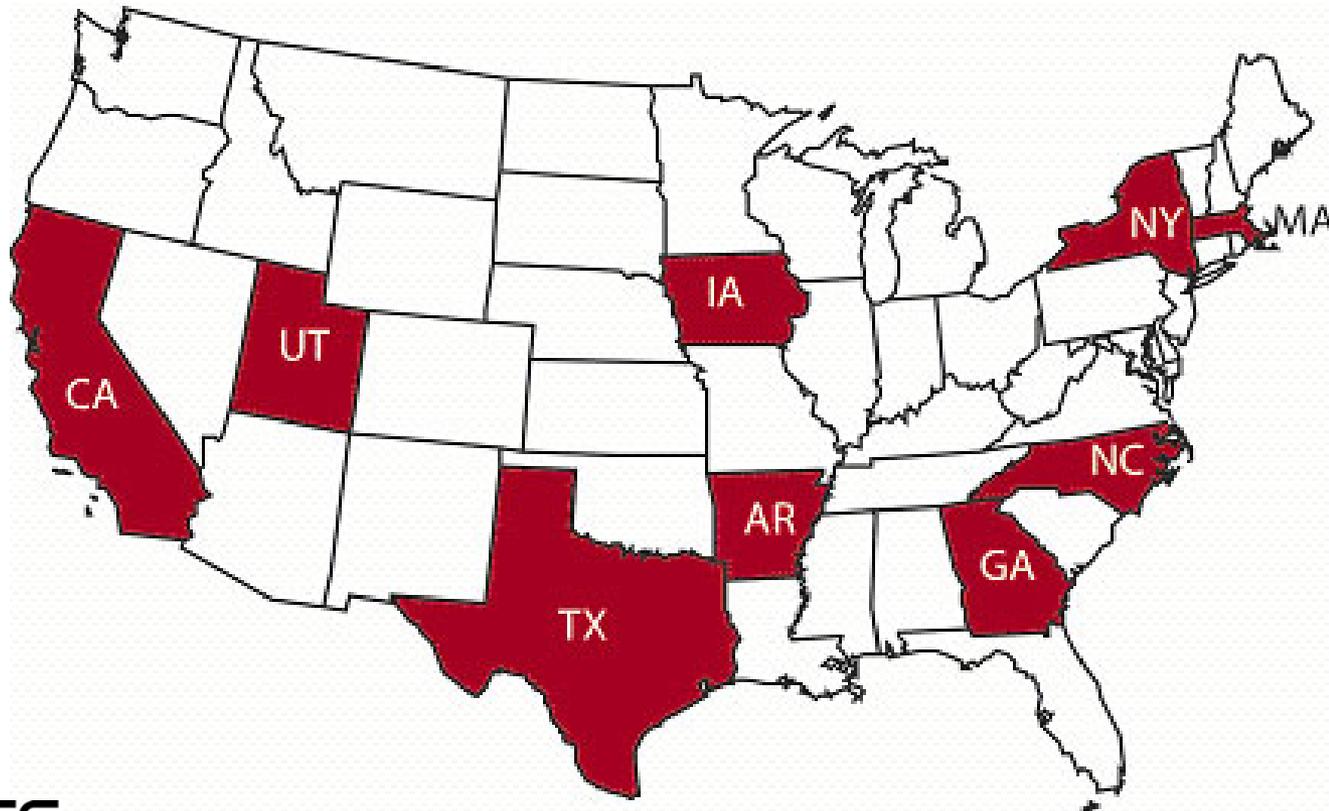
- Bladder cancer
 - 2.8 ↑ risk at >2.5 mg/L for ≥20 years on supply (Weyer 2001)
 - 1.6 ↑ risk at >5 mg/L for ≥4 years (Jones 2016)
- Ovarian cancer
 - 1.8 ↑ risk at >2.8 mg/L for ≥20 years (Weyer 2001)
 - 2.0 ↑ risk at >3.0 mg/L for ≥11 years (Inoue-Choi 2015)
- Thyroid cancer
 - Nitrate ↓ thyroid uptake of iodide → ↓ levels of T₃, T₄ hormones
→ ↑TSH → proliferative changes in follicular cells, incl. neoplasia
 - 2.6 ↑ risk at >5 mg/L for ≥5 years (Ward 2010)

Nitrate in Drinking Water and Cancer

- *Iowa Case-Control Study of Cancer and Drinking Water Contaminants* (1987: NCI, EPA)
 - Colon and rectum (DeRoos 2003)
 - Bladder (Ward 2003)
 - Brain (Ward 2005)
 - Pancreas (Coss 2004)
- Additional research on cancer is in progress
 - Looking at mixtures of water contaminants

National Birth Defects Prevention Study Sites

Centers for Birth Defects Research and Prevention



Nitrate in Drinking Water and Birth Defects

- *National Birth Defects Prevention Study (NBDPS)*: NIEHS funded study of mothers' lifestyle and birth defects risk
 - 10 sites across U.S.
 - Nitrate in drinking water, diet, and “nitrosatable” drugs
 - Iowa and Texas: PWS nitrate data
 - Also tested bottled water in both states
 - Mom's exposure one month pre-conception through 1st trimester
 - Geocoded Mom's residence(s) during B1-P3, linked to PWS data
 - Water consumption information at home, work
 - Information on water filter use

Nitrate in Drinking Water and Birth Defects

NBDPS Study Results (Brender 2013)

- Spina bifida: Moms 2x as likely to ingest ≥ 5 mg nitrate daily from drinking water than control mothers
- Limb deficiencies: 1.8 x as likely to ingest ≥ 5.42 mg nitrate daily
- Cleft palate: 1.9 x as likely to ingest ≥ 5.42 mg nitrate daily
- Other drinking water nitrate studies report positive associations with neural tube defects
 - Arbuckle 1988 (Canada); Croen 2001 (California); Brender 2004 (Texas)

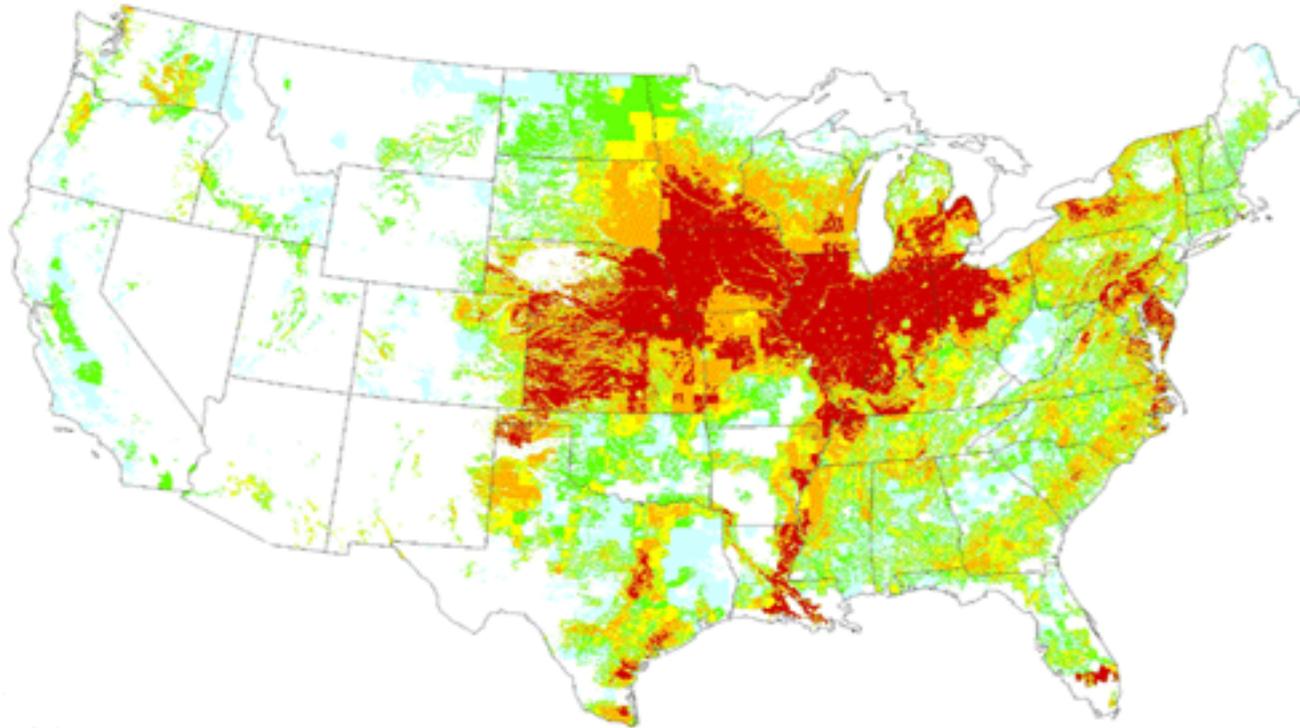
Drinking Water Disinfection Byproducts (DBPs)

- Chlorine, interaction with natural organic material in source water can form DBPs
- Trihalomethanes (THMs) and Haloacetic acids (HAAs) carcinogenic, teratogenic in some animal studies
- EPA drinking water standard for Total THM = 80 ppb, MCL for HAA5 is 60 ppb (annual average)

Drinking Water Disinfection Byproducts and Health Iowa Studies

- Iowa small towns (1-5k pop.) reproductive health study (Kramer 1992)
 - 1.8 ↑ risk of IUGR (low weight for gestational age) at chloroform ≥ 10 ppb
- Bladder, rectal cancers (Cantor 1998)
 - ↑ risks with longer duration on chlorinated surface water
- *Iowa Women's Health Study*
 - No association of TTHM with bladder cancer (Jones 2016)
 - No association of TTHM with ovarian cancer (Inoue-Choi 2015)

Atrazine Use in the United States



Average annual use of
active ingredient
(pounds per square mile of agricultural
land in county)

- no estimated use
- 0.001 to 0.307
- 0.308 to 1.91
- 1.911 to 9.32
- 9.321 to 34.596
- ≥ 34.597

Map: U.S. Geological Survey

Exposure to Atrazine in Drinking Water

- Atrazine – common use herbicide on corn, other crops
 - 7.8 M Iowa corn acres had atrazine applied; total of 6.7 M pounds in 2014 (National Agricultural Statistics Service)
 - Restricted use pesticide due to potential for GW contamination
- ~ 8% private well water samples have detectable atrazine; 11% desethylatrazine (SWRL2: 2006–08)
- EPA drinking water standard of 3 ppb; possible human carcinogen

Atrazine in Drinking Water and Health Iowa Studies

- *Iowa Women's Health Study* (Inoue-Choi 2016)
 - Atrazine not associated with ovarian cancer risk
- Southern Iowa study (Munger 1997)
 - Rathbun communities had higher risk of IUGR associated with triazine herbicides atrazine, cyanazine
- *National Birth Defects Prevention Study* (Winston 2016)
 - Atrazine not associated with risk for hypospadias

Arsenic in Groundwater

- Arsenic is naturally occurring; geologic conditions, subsurface chemistry, well use are important factors
- Drinking water standard is 10ppb in public water systems
- Health concerns from exposure in drinking water
 - Lung, bladder, skin cancers
 - Cardiovascular disease
 - Cognitive/immune effects

Arsenic in Private Drinking Water Wells

Iowa Surveillance Activities

- IA Community Private Well Study (2002–03)
 - 232 wells in 54 incorporated communities without PWS
 - 23% As detected; ~ 5% had As ≥ 10 ppb; max 130 ppb
- IA Statewide Rural Well Water Survey Phase 2 (2006–08)
 - Total of 473 wells sampled in 91 counties
 - 48% As detected; ~ 8% had As ≥ 10 ppb, max 75 ppb
- Grants to Counties Program includes arsenic testing since July 1 , 2015

Arsenic?

Get your well water tested.



Visit:
www.cghealth.com



*Cerro Gordo County
Department of Public Health*

Harmful Algal Blooms

Blue-Green Algae/Cyanobacteria

- Phosphorous, nitrogen loading of lakes, reservoirs, rivers
- Cyanotoxins: 25-75% of blooms are toxic (Blahova 2008)
- Most common: Microcystin, Nodularin, Anatoxin, Cylindrospermopsin
- Potential health impacts: stomach or liver illness, respiratory problems, neurological effects (EPA)



Microcystin

Recreational Water Exposure

- Lake Macbride, Coralville Reservoir, June-August 2005
- Enrolled 261 beach-goers
- Composite water samples collected daily
- Follow-up for 4 weeks on self-reported GI illness and skin irritation/rash
- Positive correlations
 - Microcystin & skin rash
 - Enterococci & diarrhea
 - Enterococci & skin rash



Neonicotinoid Insecticides

- Replacing OP and carbamate insecticides; seed coatings
- Adverse ecological effects: immune suppression in insects, affects pollinators
- Highly water soluble; aqueous half-life in months
- 2013 USGS survey detected neonicotinoids at all 9 sampling sites in Iowa

Pharmaceuticals in Water



Pharmaceutical Compounds in Water

- IDNR, USGS surveillance activities
 - Surface water monitoring in Iowa; municipal well (groundwater) sampling
- Compounds commonly found in U.S. rivers, streams
 - Conventional drinking water treatment does not completely remove compounds
- EPA strategy: Improve science/public understanding, identify partners, take regulatory action if needed

Implications for Source Water Protection in Iowa

- Surface water sources
 - Des Moines Water Works provides for ~500,000 customers
 - High nitrate in Raccoon River: ag sources?
- Groundwater sources for PWS, private wells
 - Arsenic, radionuclides?
- Water quality debate: who/what is to blame? What are costs and approaches to fix problems?
 - Iowa Nutrient Reduction Strategy
 - Iowa Watershed Approach: reduce flood risks, improve water quality

IDNR Ambient Water Monitoring Strategy for Iowa: 2016-2021

- Seeks to provide comprehensive monitoring of all groundwater and surface water
 - Biological, chemical and physical characteristics
- Opportunities to improve Program's effectiveness in
 - Monitoring objectives
 - Sampling design
 - Data management
 - Products and services
 - Program evaluation and coordination

Collaborators in Iowa Drinking Water Research

Iowa Municipal Water Utilities
Iowa County Health Departments
Iowa Department of Public Health
Iowa Department of Natural Resources
Centers for Disease Control and Prevention
National Birth Defects Prevention Study Centers
National Cancer Institute
National Institute of Environmental Health Sciences
U.S. Geological Survey
Iowa State University
Texas A&M University
University of Minnesota
University of Iowa College of Public Health
University of Iowa College of Engineering
State Hygienic Laboratory at the University of Iowa