

# **The Iowa Rural Drinking Water Survey: Water Quality Perceptions and Avoidance Behaviors among Rural Iowa Households**

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Among Rural Iowa Households*

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# EXECUTIVE SUMMARY

The Iowa Rural Drinking Water Survey documents drinking water sources, avoidance behavior, testing behavior, and water quality perceptions of over 8,000 rural Iowa households. The study focuses on eight rural counties with low penetration of public water systems and high susceptibility to nitrate in groundwater.

## Key findings are:

- Only 10 percent of households tested their water quality in the last year.
- Around 50 percent of households supplement their drinking water with bottled water or water coolers.
- While 70 percent of households report using water filters, just 10 percent report having a filter that can remove nitrate.
- Nearly 40 percent of households believe nitrate is a concern. More households believe nitrate is a greater concern in the state of Iowa than in their local areas.
- A third of households are at high risk of nitrate exposure due to a lack of testing, filtering, or bottled water use.

Further study is needed to identify households at the greatest risk of nitrate exposure and to devise strategies to reach at-risk households and influence their testing and avoidance behavior.

# ACKNOWLEDGMENTS

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# INTRODUCTION

The Midwestern landscape is among the world's most altered and intensively managed ecosystems. Among the greatest challenges associated with annual row crop production in the region are its impacts on water quality through the loss of nutrients into ground and surface waters. In fact, agriculture is the primary contributor to nitrate in drinking water supplies in most parts of the country. A 2007 USDA study found that agriculture was the primary source of nutrient loadings to most of the watersheds identified by the U.S. Environmental Protection Agency as impaired in the contiguous United States (Ribaudo et al., 2008). Groundwater and other water sources fed by these watersheds similarly have high nitrate concentrations. Consequently, health-based drinking water quality violations continue to affect millions of Americans annually (Allaire et al., 2018).

Public and private organizations at local, state, and federal levels have dedicated resources to mitigate this water quality degradation through programs that change on-farm practices, convert cropland to perennial species, and restore wetlands. Many Iowa farmers are adopting these practices. However, most of Iowa's more than 22 million acres of row crop agriculture remain incompletely or inadequately treated for nitrate pollution.

Most research has focused on drinking water quality in public water systems. Much less is known about pollution concentrations and exposure for households that rely on private wells, a common water source among rural Americans. Private well owners are solely responsible for testing for and treating contaminants in their drinking water. While many state public health agencies provide free or subsidized water quality testing, the services are often underused (Secchi and Cwiertny, 2019). Further, even if households properly test their drinking water, little is known about what efforts at-risk households make, if any, to avoid water pollution and its associated concerns.

The Iowa Rural Household Drinking Water Survey aims to fill this knowledge gap. The survey asks rural Iowans who rely on wells for their drinking water about their drinking water sources, filtering efforts, avoidance behavior, testing behavior, and water quality perceptions. We focus on how these behaviors relate to nitrate in drinking water, given the pollutant's prevalence in the state, its adverse health effects, and its central focus in the Iowa Nutrient Reduction Strategy.

We present data from the first two rounds of the survey covering drinking water behaviors and perceptions for over 8,000 households across eight counties in the state. We find that most households with wells rely on them for all or most of their drinking water. However, water quality testing frequency is much lower than the Iowa Department of Natural Resources recommends, and few homes report having filters capable of removing nitrate.

We use three reported behaviors in our survey to identify “vulnerable” households: whether households test their well water for pollutants, whether they have high-quality home water filter systems, and whether they supplement their drinking water with bottled water or coolers. Upwards of 33 percent of households are in our highest vulnerability group, meaning they do not regularly test, have not installed filters that can remove nitrate, and do not supplement their drinking water with alternative sources. The findings demonstrate a large potential role for policymakers to increase knowledge about nitrate in well water and help rural Iowa households avoid exposure.

# BACKGROUND

Nutrient pollution from agriculture in ground and surface water is a perennial challenge in Iowa. Statewide discussions concerning reducing nitrate and phosphorous pollution primarily focus on the downstream benefits of these efforts, namely reducing the state's significant contributions to the Gulf of Mexico Hypoxic Zone (IDALS, 2013).<sup>1</sup> Less attention is given to the in-state benefits of nitrate and phosphate reductions (Tang et al., 2018).

## NITRATE AND HEALTH

Exposure to nitrate in drinking water is a critical public health concern in many rural areas of the United States. Reducing Iowans' exposure to nitrate in drinking water is a key benefit of reducing nutrient pollution in the state. The most well-documented health impact of drinking water with high nitrate levels is methemoglobinemia, or blue baby syndrome, caused when nitrate inhibits the body's ability to carry oxygen. The condition primarily affects infants. While the condition is rare, occurrences led the EPA to set its current maximum contaminant level for nitrate (MCL) at 10 mg/L as nitrate-nitrogen (NO<sub>3</sub>-N) (Knobeloch et al. 2000). MCLs are important public health metrics in the United States, and are set as close as feasible to the level of contamination in drinking water below which there is no known or expected health risk from exposure.

Blue baby syndrome is an acute symptom; its health impacts occur soon after ingesting water with high nitrate concentrations. More recent work studies the health consequences of drinking water with elevated nitrate levels over longer periods and finds strong associations between exposure and health at all life stages. Ward et al. (2018) provide a review of this literature. The authors find the most robust evidence for a relationship between drinking water with nitrate and increased incidence of colorectal cancer and thyroid disease in adults and neural tube defects in newborns. Notably, the authors document increased risks even when nitrate concentrations are below the EPA's maximum contaminant level, suggesting this critical public health threshold may be too conservative.

## NITRATE TREATMENT COSTS: PUBLIC WATER SYSTEMS

Treating nitrate in drinking water can be costly. Tang et al. (2018) identified in-state costs of nitrate pollution to Iowans, including costs to public water systems to meet MCL requirements. The authors found that 49 public water suppliers, serving more than 10 percent of the state's population, treated their water for nitrate. These treatment costs can be relatively small—when, for example, utilities have

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<sup>1</sup> Recent estimates put Iowa's contribution to long-term nitrate loads in the Mississippi-Atchafalaya Basin, Mississippi River Basin, and Missouri River Basin as high as 52%, 63%, and 89%, respectively (Jones et al. 2018).

access to water sources with low nitrate levels and can mix water from multiple sources. For some utilities, however, reducing nitrate concentrations in drinking water sources requires installing expensive treatment systems. Tang's group found that five smaller Iowa utilities alone spent more than \$1.65 million on nitrate removal equipment. As recently as the summer of 2022, Iowa's largest water utility, the Des Moines Water Works, had to turn to an expensive nitrate removal system and implement outdoor watering restrictions in response to high nitrate concentrations in its source water (Krebs, 2022).

## **NITRATE IN IOWA WELL WATER**

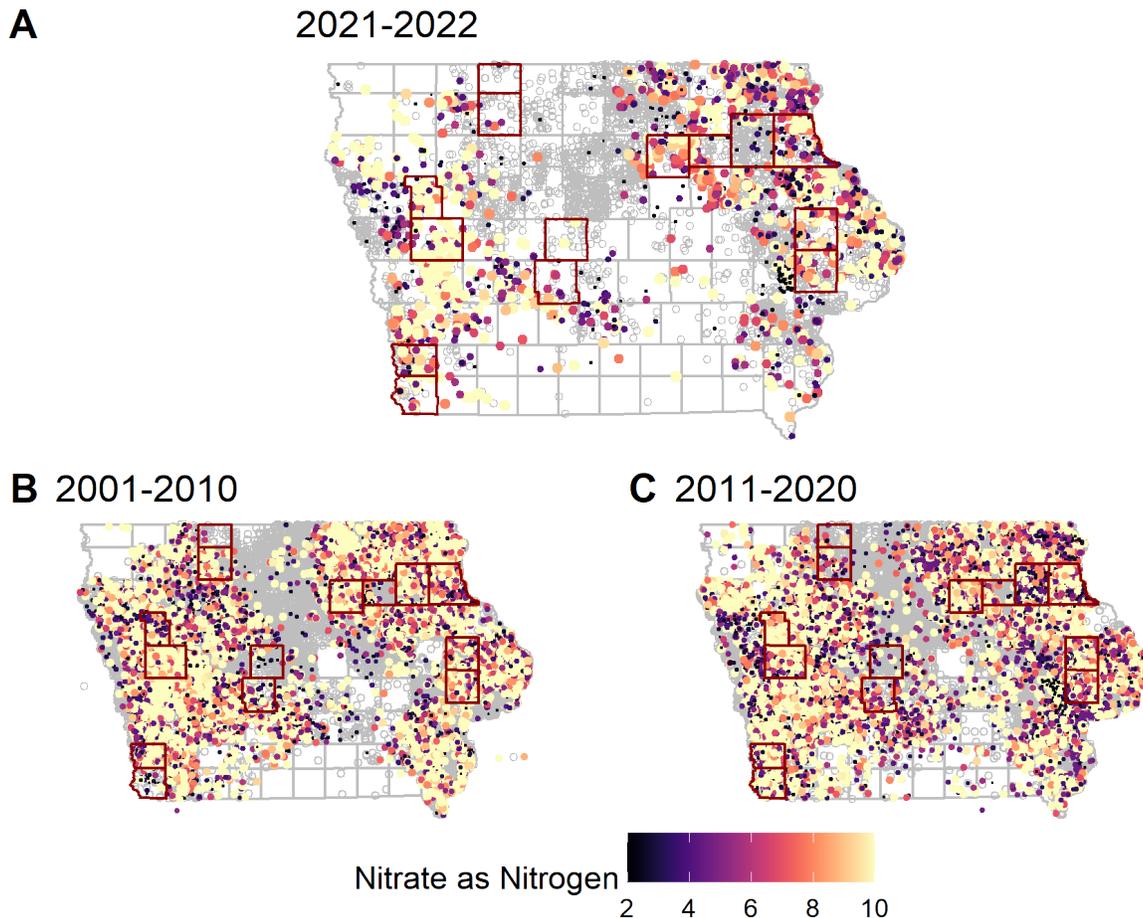
Around 7.6 percent of Iowa households—230,000 to 290,000 Iowans—rely on private well water rather than public water supplies. Nitrate levels in this well water at any given time are unknown, though several studies and state testing programs offer some information about the prevalence of the problem.

Three recent studies suggest elevated nitrate may be a concern for 1 in 10, or even 1 in 5, households. The Iowa Community Private Well Study, conducted in 2003, found that nitrate concentrations exceeded the MCL in 20 percent to 25 percent of sampled wells. The 2006–2008 Statewide Rural Well Water Survey sampled 473 private wells across 89 Iowa counties and found that nitrate levels in 12 percent of wells exceeded the EPA guideline.

The Iowa Department of Natural Resources Private Well Tracking System tracks well water quality tests conducted through state-sponsored programs. Some samples tracked in the system are voluntary, such as when owners test their water quality through the state's Grants to Counties free water-quality testing program. Most, however, are from testing required when a new well is constructed or old wells are plugged. Discussions with DNR staff suggest upwards of 40 percent of households with private wells appear in the database at least once. Using the DNR data, Tang et al. (2018) showed that, in any given year, the proportion of tested wells exceeding 10 mg/L ranged between 9 percent and 18 percent.

We updated the Tang group's analysis to understand more recent trends in nitrate concentrations in well water and their spatial distribution across Iowa. We compiled data on every nitrate test in the Iowa DNR Private Well Tracking System from 2001 to April 2022. The data include the location, date, and concentration for every nitrate test tracked by the DNR over this period. After excluding outliers—tests with concentrations exceeding 68 mg/L—the data include more than 135,000 nitrate concentration test results for more than 64,000 wells.

Figure 1 maps nitrate concentrations for every test in the data for three periods. Panel A shows results for the most recent data, tests conducted from 2021 to 2022. Panel B shows results for the first 10 years of the data (2001–2010), and Panel C shows results for the second 10 years (2011–2020). Light grey dots are wells with concentrations below 2 mg/L. Dots range from small black dots (2 mg/L) to larger yellow dots (>10 mg/L). We outline the counties included in the Rural Iowa Drinking Water Survey, described in more detail in the next section, in dark red.



**FIGURE 1: DNR PRIVATE WELL TRACKING SYSTEM CONCENTRATIONS**

Most private wells are located in the western, north-central, and eastern portions of the state. Spatial patterns in nitrate concentrations are similar no matter which period we consider. Nitrate concentrations at wells in the north-central part of the state are primarily grey in all three maps, indicating they have the lowest nitrate levels. The greatest number of wells with nitrate concentrations exceeding 10 mg/L are found in the western and east-central portions of the state.

Consistent with prior studies, around 1 in 10 private wells in the database have elevated nitrate concentrations. More than 14,000 tests overall, around 10 percent, contain concentrations exceeding 10 mg/L. In 2021 and 2022, more than 8 percent of tests had nitrate concentrations exceeding 10 mg/L. The ratios increase to 22 percent overall and 19 percent in 2021–22 if we consider wells with nitrate concentrations exceeding 5 mg/L.

## NITRATE EXPOSURE IN RURAL IOWA

While related, high nitrate concentrations in wells do not necessarily imply high nitrate exposure in rural Iowa. Exposure depends on whether households know about nitrate in their drinking water, through testing, and then—if they find high concentrations of nitrate in the water—avoid or treat their water.

Private testing is among the most important steps well owners can take to ensure they aren't exposed to harmful pollutants in their water. The Iowa Department of Natural Resources recommends testing for bacteria and nitrate at least once a year. It also recommends testing for other pollutants like arsenic at least once in a well's lifetime.<sup>2</sup>

The best available data on testing behaviors come from the Iowa Department of Public Health's Grants to Counties Water Well Program.<sup>3</sup> The program provides financial assistance to rural Iowa residents for private well water testing and other services. However, Secchi and Cwiertny (2019) show that the service is underused. Most counties do not receive enough well water testing requests from households to spend their annual funding allocations. In 2020 and 2021, counties spent just 62 percent and 43 percent, respectively, of total water quality testing allocations from the program. While the data do not tell us how frequently households test, the low use of this free program suggests households may not be testing their water quality as often as state guidance recommends.

Households have several options to treat or avoid their water if their wells are polluted. In the short term, households can purchase bottled water or truck in water for bulk dispensers. Another option is common on-tap, pitcher, or in-refrigerator filters; however, while such filters remove many pollutants, most do not remove nitrate, limiting households' short-run options. Longer-term solutions require larger household investments. Tang et al. (2018) explored these costs. Households can install point-of-entry (POE) or point-of-use (POU) reverse osmosis filters, which do remove nitrate, for a few hundred dollars. Drilling a new well or reconstructing an existing well ranges from less than \$1,000 to over \$3,000. The most expensive option involves connecting to the pipeline network of a nearby public water system, which can cost tens of thousands of dollars. While the costs of these options are fairly straightforward to quantify, very little is known about the extent of their use.

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<sup>2</sup> See <https://www.iowadnr.gov/Environmental-Protection/Water-Quality/Private-Well-Program/Private-Well-Testing#When-is-a-good-time-to-test-my-water-supply-27>

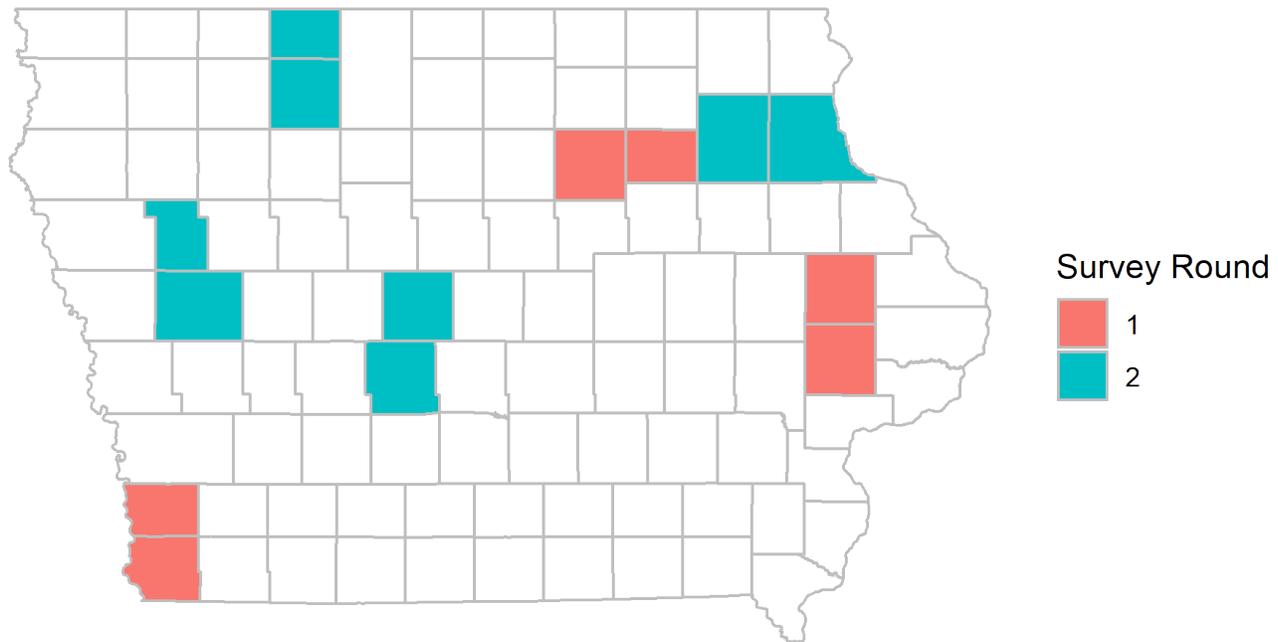
<sup>3</sup> See <https://idph.iowa.gov/Environmental-Health-Services/Grants-to-Counties-Water-Well-Program>

# SURVEY DESIGN AND IMPLEMENTATION

We designed the Iowa Rural Drinking Water Survey to fill critical knowledge gaps about rural household water sources, filtering and avoidance behaviors, testing behavior, and water quality perceptions. The survey took place over two rounds. The first round, in 2018, surveyed 8,165 residents in six counties: Bremer, Butler, Cedar, Fremont, Jones, and Mills. The second round, in 2019, surveyed 13,699 households in eight additional counties: Boone, Clayton, Crawford, Dallas, Emmet, Fayette, Ida, and Palo Alto. We selected counties based on their high prevalence of (i) households that rely on wells as their primary water source and (ii) nitrate concentrations in drinking water (Figure 1).

The surveys asked households about their well characteristics (age and depth), their well water uses (drinking, cooking, laundry, etc.), whether they used alternative drinking water sources (bottled water, water coolers), whether they filtered their water, whether and when they tested their well, their water quality perceptions, and simple demographic information.<sup>4</sup>

Figure 2 shows the location of the surveyed counties.



**FIGURE 2: SURVEYED COUNTIES**

<sup>4</sup> The Appendix includes the full survey for both rounds. Questions differ slightly from the first to second survey round based on feedback received on the first survey.

Response rates were high. In the first round, 4,027 surveys were returned, a 49 percent response rate. In the second round, 6,396 surveys were returned, a 47 percent response rate, though the returns included many households whose primary water source was not a private well. In total, we have 4,174 valid second-round surveys. For this report, we excluded households that did not report any demographic information, leaving a final sample of 8,140 households across the two rounds.

# SURVEY RESULTS

We now turn to our survey results. We begin with household demographics. We compare our survey demographics to those from recent census data, showing respondent households are similar to the broader population in their counties. We then highlight information collected on the depth and age of their wells, both important factors affecting contamination risk. We then turn to the uses, avoidance, treatment, and testing of well water in respondent households. Last, we describe respondents' perceptions about their water quality and water quality in their local area, county, and state.

## HOUSEHOLD CHARACTERISTICS AND REPRESENTATIVENESS OF THE SURVEY PANEL

Table 1 shows the characteristics of households that responded to the surveys. For this and all subsequent tables, we report the question of interest in the first column, responses in the second column, and the number of households that answered the question in the third column. Unless otherwise indicated in the first column, responses are the percent of households that responded yes to the question.

**TABLE 1: SURVEY RESPONDENT DEMOGRAPHICS**

|   | Response | Number |
|---|----------|--------|
| <b>Home Ownership</b>   |          |        |
| Own Home  | 94%      | 8121   |
| Rent Home   | 6%       | 8121   |
| <b>Household Income</b>                                       |          |        |
| <\$25,000   | 8%       | 6920   |
| \$25,000-\$50,000   | 26%      | 6920   |
| \$50,000-\$100,000  | 42%      | 6920   |
| \$100,000-\$200,000   | 20%      | 6920   |
| >\$200,000  | 4%       | 6920   |
| <b>Head of Household Education</b>                            |          |        |
| High School or Less   | 60%      | 7556   |
| Associates Degree or Higher                                   | 40%      | 7556   |
| <b>Household Size (Number of Adults and Children/Infants)</b> | 2.50     | 8098   |
| <b>Infants or Children (Number)</b>                           | 0.48     | 8098   |

Most survey respondents (94 percent) own their homes, and most households have incomes around or above the state median income of just over \$60,000 in 2020.<sup>5</sup> Household size averages to 2.5 adults and children.

Table 2 compares the demographics of our survey respondents to data from the 2020 American Community Survey (ACS) for the 14 counties in our sample. Our sample contains a higher proportion of households with incomes in the \$50,000 to \$100,000 income range (42 percent) than the average household in the 14 treatment counties (35 percent). This overrepresentation comes from the undersampling of households with incomes less than \$25,000. Along other dimensions, though, the ACS data suggest households that responded to our survey are reasonably representative of those in their home counties. On average, 36 percent of individuals 25 and older have an associate's degree or more in the ACS, compared to 40 percent of heads of households in our sample. The average household size is 2.38 according to the ACS, compared to 2.5 in our sample.

**TABLE 2: AMERICAN COMMUNITY SURVEY DEMOGRAPHICS (14 COUNTIES)**

|                             | Response |
|-----------------------------|----------|
| <b>Household Income</b>     |          |
| <\$25,000                   | 17%      |
| \$25,000-\$50,000           | 23%      |
| \$50,000-\$100,000          | 35%      |
| \$100,000-\$200,000         | 21%      |
| >\$200,000                  | 4%       |
| <b>Education</b>            |          |
| High School or Less         | 64%      |
| Associates Degree or Higher | 36%      |
| <b>Household Size</b>       | 2.38     |

<sup>5</sup> See <https://www.census.gov/quickfacts/IA>

## WELL CHARACTERISTICS

Table 3 reports key well characteristics. We focus on well age and depth, two important features affecting nitrate concentrations in well water. Older wells are more susceptible to cracking, making them more vulnerable to nitrate and other contaminants. Shallower wells draw from shallower water sources, which may be more susceptible to nitrate contamination from the surface.

Many households are unaware of their well's age (10 percent) or depth (20 percent). Most of those who knew—almost 70 percent—reported having wells more than 20 years old. Only 7 percent of wells were built in the last 10 years, suggesting that many of Iowa's private wells are aging infrastructure. Well depths vary more. Only 10 percent of reported wells are less than 50 feet deep, 32 percent are between 50 and 150 feet deep, and around 40 percent of households have wells more than 150 feet deep.

**TABLE 3: WELL CHARACTERISTICS**

|                   | Response | Number |
|-------------------|----------|--------|
| <b>Well Age</b>   |          |        |
| 0-5 years         | 3%       | 8074   |
| 6-10 years        | 4%       | 8074   |
| 11-20 years       | 14%      | 8074   |
| Over 20 years     | 68%      | 8074   |
| Don't Know        | 10%      | 8074   |
| <b>Well Depth</b> |          |        |
| 0-50 feet         | 9%       | 7922   |
| 51-150 feet       | 32%      | 7922   |
| Over 150 feet     | 40%      | 7922   |
| Don't Know        | 19%      | 7922   |

## WELL WATER USES, TESTING, AND AVOIDANCE BEHAVIORS

Table 4 turns to well water uses. Nearly all households use their well water for drinking (90 percent) and cooking (97 percent), and most households use their well all or most of the time for those purposes. The higher incidence of reported cooking use may indicate that householders believe that boiling water reduces harmful contaminants. However, this is not the case with nitrate, which does not boil off. In fact, boiling water may increase nitrate concentrations as water evaporates (CDC, 2016).

**TABLE 4: WELL WATER USES**

|                                     | Response | Number |
|-------------------------------------|----------|--------|
| <b>Uses Well for Drinking Water</b> | 90%      | 8191   |
| <b>How much?</b>                    |          |        |
| All                                 | 66%      | 8191   |
| Most                                | 14%      | 8191   |
| Some                                | 10%      | 8191   |
| <b>Uses Well for Cooking</b>        | 96%      | 8191   |
| <b>How much?</b>                    |          |        |
| All                                 | 87%      | 8191   |
| Most                                | 5%       | 8191   |
| Some                                | 4%       | 8191   |

While well water use is high among households in our sample, a key question for public health is whether households test, treat, and avoid their water, especially if their water contains contaminants. Table 5 presents our survey results on testing behaviors. When asked if they ever tested their water quality, most households (78 percent) said yes. However, just 9 percent of households followed safety recommendations from the EPA and DNR and tested in the last year. Less than a third of households (27 percent) reported any testing in the previous two years.

We expanded our testing questions in the second survey round to include testing providers. Approximately half reported using Iowa's Grants to County Program, with the remainder testing through private companies and other sources.

**TABLE 5: TESTING BEHAVIORS**

|                                    | Response | Number |
|------------------------------------|----------|--------|
| <b>Ever Had Well Tested?</b>       |          |        |
| Ever Tested for Water Quality      | 78%      | 7897   |
| Never Tested for Water Quality     | 21%      | 7897   |
| Unsure if Tested for Water Quality | 3%       | 7897   |
| <b>Testing Frequency</b>           |          |        |
| Last Year?                         | 9%       | 7897   |
| Last Two Years?                    | 27%      | 7897   |
| <b>If tested, who provided?</b>    |          |        |
| County/Grants to County            | 50%      | 3886   |
| Private Company                    | 12%      | 3886   |
| In-Home Test                       | 8%       | 3886   |
| Other                              | 6%       | 3886   |

Table 6 presents avoidance behavior responses. Over half of the respondent households reported supplementing their drinking water by purchasing bottled water or using water coolers that dispense filtered water. Nearly 70 percent of households filter their water, though just 40 percent filter all or most water. While 40 percent of households have whole-home filters, only 9 percent have reverse osmosis systems known to remove nitrate.

The findings suggest that avoidance behaviors are common but not ubiquitous. Further, households' motivations are not clear. Households avoid using well water for various reasons, including convenience, taste, or contamination concerns. While we gathered responses related to households' avoidance behaviors, we did not ask respondents to clarify the reasons for avoiding their well water. Further, the survey did not distinguish between in-home versus out-of-home bottled water purchases. Both of these issues suggest our survey results may overstate the amount of avoidance behavior due to nitrate contamination.

**TABLE 6: AVOIDANCE BEHAVIORS**

|                                  | Response | Number |
|----------------------------------|----------|--------|
| <b>Use Bottled Water</b>         | 51%      | 8199   |
| <b>Use Water Cooler</b>          | 6%       | 8199   |
| <b>Filter Water</b>              | 67%      | 8200   |
| <b>How much?</b>                 |          |        |
| All                              | 29%      | 8200   |
| Most                             | 11%      | 8200   |
| Some                             | 17%      | 8200   |
| <b>What type?</b>                |          |        |
| Pitcher                          | 10%      | 8200   |
| On-Tap                           | 7%       | 8200   |
| In-Fridge                        | 29%      | 8200   |
| Whole Home                       | 38%      | 8200   |
| <b>If whole home, what type?</b> |          |        |
| Reverse Osmosis                  | 9%       | 8200   |
| Activated Carbon                 | 6%       | 8200   |
| Water Softener                   | 32%      | 8200   |

## WATER QUALITY PERCEPTIONS AND CONCERNS

Water quality perceptions and concerns can drive and be affected by the aforementioned behaviors. Baseline sentiments are critical to understanding both the appetite for policy among rural lowans and the need for informational campaigns. Our survey asks households about their perceived water quality, concerns about the broader water quality in their local area, region, and state, and concerns about nitrate in their local area, region, and state.

Table 7 presents responses to sentiment questions. Over three-quarters of households believe their drinking water quality is good or great, with only 7 percent reporting poor water quality. Less than half of households have heard news about water quality issues in the last year. Of those, most report hearing of drinking water concerns in the state rather than in their local area or home county. Similarly, around 40 percent of households believe nitrate is a concern. Again, most believe it is a concern at the state level, with fewer (25 percent) believing it is a concern for their local area.

**TABLE 7: DRINKING WATER PERCEPTIONS**

|   | Response | Number |
|---|----------|--------|
| <b>Rating of Well Water Quality</b>                     |          |        |
| Great   | 37%      | 8111   |
| Good  | 40%      | 8111   |
| Neutral   | 10%      | 8111   |
| Poor  | 7%       | 8111   |
| Unsure  | 5%       | 8111   |
| <b>Heard News Related to Water Quality in Last Year</b> |          |        |
| Yes   | 44%      | 8112   |
| No  | 42%      | 8112   |
| Unsure  | 6%       | 8112   |
| <b>If yes, for what area?</b>                           |          |        |
| Local   | 14%      | 8112   |
| County  | 17%      | 8112   |
| State   | 40%      | 8112   |
| <b>Believe Nitrate is a Concern</b>                     |          |        |
| Yes   | 39%      | 8110   |
| No  | 17%      | 8110   |
| Unsure  | 31%      | 8110   |
| <b>If yes, for what area?</b>                           |          |        |
| Local   | 25%      | 8110   |
| County  | 26%      | 8110   |
| State   | 34%      | 8110   |

The findings reflect relatively low concerns about water quality, particularly locally. They also suggest that households believe water quality and nitrate contamination are a more significant concern outside their local areas, with more households responding that they had heard about water quality or nitrate concerns in the state than in their local area or county. These beliefs suggest that lack of awareness of the risks of nitrate contamination in well water may be a key reason households do not regularly test or avoid well water.

# ANALYSIS AND CONCLUSIONS

## HOW MANY HOUSEHOLDS MAY BE DRINKING NITRATE-CONTAMINATED WATER?

This first and second round of the Iowa Rural Drinking Water Survey suggest that most households use their well water for drinking, cooking, and other common uses. However, many households may not test, treat, or avoid their water. The survey did not collect well water samples from households, so it is impossible for us to determine how many of these households are exposed to high nitrate concentrations in their well water. However, the survey does allow us to determine the proportion of households that are vulnerable to nitrate exposure through their reported activities.

We developed a risk metric based on three key survey responses. First, do households test their well water? Second, do households treat their well water? Third, do households supplement their drinking water with alternative sources? We classify a household as susceptible to drinking nitrate-contaminated water if they a) use well water as their primary drinking water source, b) don't regularly test their water quality, c) don't filter their well water using an RO system, and d) don't use other drinking water sources like water bottles or coolers. Susceptibility is not zero for households that do not meet all listed conditions. Different combinations of use, testing, filtration, and avoidance still pose varying degrees of risk. Nonetheless, the metric gives us a conservative measure of households at most risk.

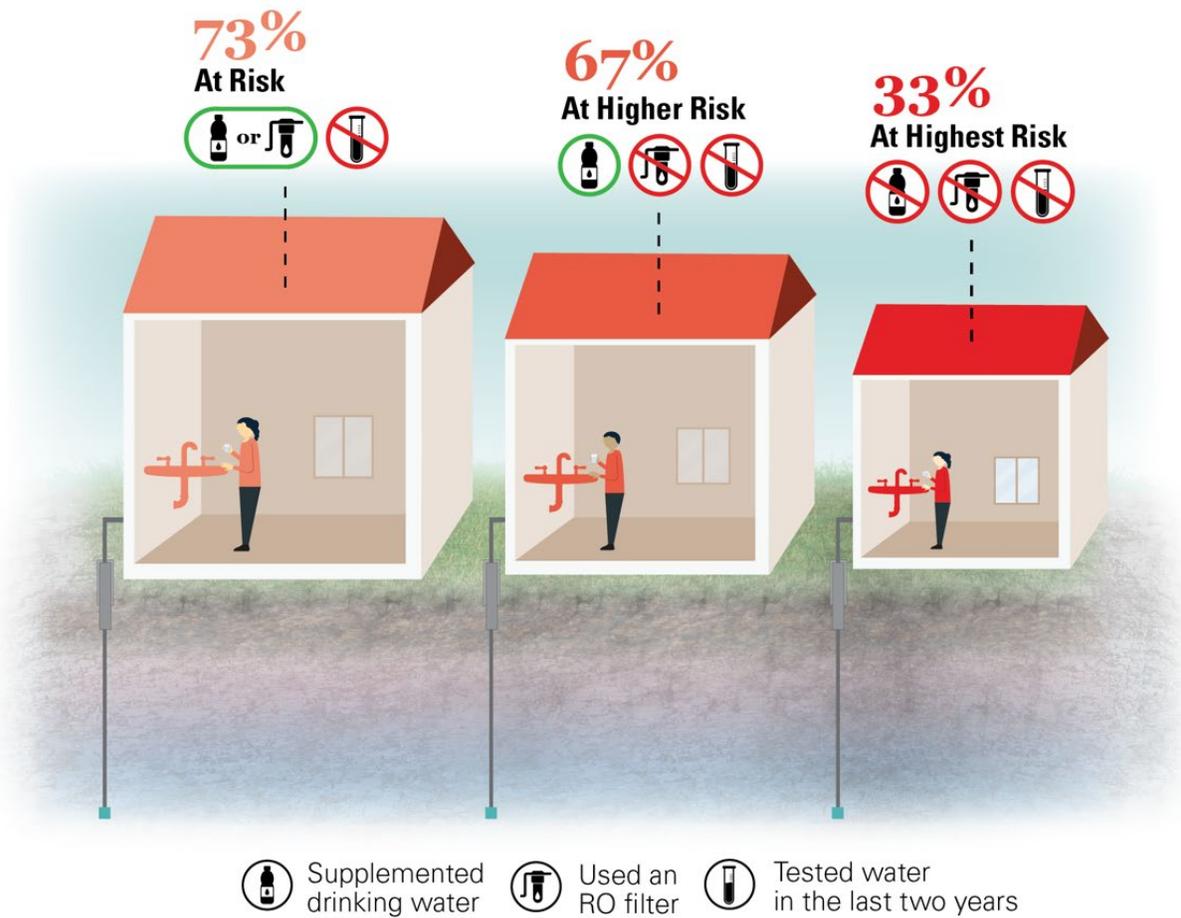
Figure 3 depicts our results. We limited our survey sample to 7,100 households that reported using their well water for drinking water and responded to survey questions on their testing behavior, filter type, and bottled water or cooler use. Of those, 73 percent are at risk of nitrate exposure since they did not test their water quality in the previous two years. Of those, 67 percent are at higher risk since they did not test in the last two years and do not have a whole-home filter that can remove nitrate. A third (33 percent) of households are in our highest risk category. These households have not tested their water quality in the last two years, do not have a whole home filter that can remove nitrate, and do not supplement their drinking water with bottled water or water coolers.<sup>6</sup>

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<sup>6</sup> If we instead characterize households at highest risk if they have never tested their water quality, our highest-risk sample remains high, at 10 percent of the population.

## Reported behaviors and risk of nitrate exposure

n=7,100



### FIGURE 3: REPORTED BEHAVIORS AND RISK OF NITRATE EXPOSURE

The analysis suggests a large portion of the population is at high risk for nitrate exposure. What lessons can we take from this work? First, we need more research in this area. Surveys are a useful tool but have natural limits. Our risk metric characterizes households that are *likely* at risk of nitrate exposure. Our findings are naturally limited if households misinterpreted our questions or the underlying respondent sample is unrepresentative of broader rural Iowa households.

Nonetheless, we suggest three key steps to improve water quality testing and awareness around nitrate issues among rural households in Iowa:

1. **Identify** at-risk households.
2. **Inform** households of the risks of nitrate exposure and benefits of yearly testing through greater programming and easing access to testing.
3. **Incentivize** households to test, filter, and avoid nitrate in drinking water. Offer funding and programs for mitigation and replacement if appropriate.

The first step, **identifying at-risk households**, should target all households on a private well. However, higher-risk households could be pinpointed if county or state officials have limited budgets. This latter approach can be readily achieved using the Iowa DNR Private Well Tracking System. Because wells must be tested when they are constructed, reconstructed, or plugged, most private wells in the state show up in the database at some point. The data can help county public health officials identify areas with high nitrate concentrations. Officials can then identify households on wells in those high-risk areas, particularly those that have not tested using the Grants to Counties program in recent years.

**Informing households** can involve relatively simple information campaigns. Dubuque County provides a promising case study. Dubuque County Health Department staff actively promoted their water quality testing program in 2022 in local newspapers and through community outreach. Program participation increased from 114 tests in 2021 to over 240 tests in 2022 (Fisher, 2022).

**Incentivizing households** may involve simply continuing to support free water quality testing through the Grants to Counties program. As the Dubuque County experience shows, however, informing households may substantially increase demand for the program. Dubuque currently has a waiting list after using all its grant resources for the 2021–22 fiscal year. Officials may also consider increasing support for households to mitigate contamination after testing.

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# APPENDIX

## ROUND 1 SURVEY (2018)

**IOWA STATE  
UNIVERSITY**

### Iowa State University Rural Water Use Survey

Please complete each item below by circling the number that best represents your response.

1. Do you rent or own your home?

|      | Yes | No |
|------|-----|----|
| Own  | 1   | 2  |
| Rent | 1   | 2  |

2. What is the primary source of water for your household?

|                         | Yes | No | Not Sure |
|-------------------------|-----|----|----------|
| Municipal supply        | 1   | 2  | 3        |
| Rural piped water       | 1   | 2  | 3        |
| Private Well            | 1   | 2  | 3        |
| Other (please describe) |     |    |          |

3. If your primary water source is a well, what is its approximate age and depth?

|     | 0-5 years | 6-10 years | 11-20 years | More than 20 years | Not Sure |
|-----|-----------|------------|-------------|--------------------|----------|
| Age | 1         | 2          | 3           | 4                  | 5        |

|       | Less than 50 feet | 51-150 feet | More than 150 feet | Not Sure |
|-------|-------------------|-------------|--------------------|----------|
| Depth | 1                 | 2           | 3                  | 4        |

4. For the following uses, how much of the time do you use your primary source of water?

|                           | All | Most | Some | None |
|---------------------------|-----|------|------|------|
| Drinking water            | 1   | 2    | 3    | 4    |
| Cooking                   | 1   | 2    | 3    | 4    |
| Laundry and dishwashing   | 1   | 2    | 3    | 4    |
| Landscaping and gardening | 1   | 2    | 3    | 4    |
| Showering/bathing         | 1   | 2    | 3    | 4    |

5. Beyond your primary source of water, what other sources of water does your household use?

|                                | Yes | No | How many gallons do you estimate your household uses in a week? | Year you started using this source |
|--------------------------------|-----|----|---|------------------------------------|
| Bottled water                  | 1   | 2  |   |                                    |
| Water coolers (e.g., Culligan) | 1   | 2  |   |                                    |
| Other:                         | 1   | 2  |   |                                    |
| Please List                    |     |    |   |                                    |

6. Do you use any of the following water filters?

|                                    |     |    | If yes, how much of your drinking water do you filter from this source? |      |      |             |
|------------------------------------|-----|----|---|------|------|-------------|
|                                    | Yes | No | All   | Most | Some | Very Little |
| Pitcher filters (e.g., Brita, Pur) | 1   | 2  | 1   | 2    | 3    | 4           |
| On-tap filters (e.g., Brita, Pur)  | 1   | 2  | 1   | 2    | 3    | 4           |
| In-Fridge filters                  | 1   | 2  | 1   | 2    | 3    | 4           |
| Whole home filtration system       | 1   | 2  | 1   | 2    | 3    | 4           |

## 7. Have you ever had the quality of your primary source of water tested? If so, when?

|                              | Yes | No | Not Sure |
|------------------------------|-----|----|----------|
| Primary water source tested? | 1   | 2  | 3        |
| Did you test for nitrates?   | 1   | 2  | 3        |

## If so, when?

|           | In the last year | In the last two years | More than two years ago | Never |
|-----------|------------------|-----------------------|-------------------------|-------|
| Last test | 1                | 2                     | 3                       | 4     |

## 8. How would you rate the quality of your drinking water from your primary water source?

|                        | Poor | Neutral | Good | Great | Unsure |
|------------------------|------|---------|------|-------|--------|
| Drinking Water Quality | 1    | 2       | 3    | 4     | 5      |

## 9. Over the last year, have you read or heard news of drinking water quality concerns in your:

|            | Yes | No | Not Sure |
|------------|-----|----|----------|
| Local Area | 1   | 2  | 3        |
| County     | 1   | 2  | 3        |
| State      | 1   | 2  | 3        |

## 10. Do you believe nitrates in drinking water are a problem in your:

|            | Yes | No | Not Sure |
|------------|-----|----|----------|
| Local Area | 1   | 2  | 3        |
| County     | 1   | 2  | 3        |
| State      | 1   | 2  | 3        |

## 11. Please provide the following demographic information for all members living full time in the home.

|  | 1                                | 2                                 | 3                       | 4                    | >5                        |
|--|----------------------------------|-----------------------------------|-------------------------|----------------------|---------------------------|
| Number of infants (<1 year)                      | 1                                | 2                                 | 3                       | 4                    | >5                        |
| Number of children (1-18 years)                  | 1                                | 2                                 | 3                       | 4                    | >5                        |
| Number of adults (19-65 years)                   | 1                                | 2                                 | 3                       | 4                    | >5                        |
| Number of retirement eligible adults (>65 years) | 1                                | 2                                 | 3                       | 4                    | >5                        |
| Highest level of education (head of household)   | No formal educational credential | High school diploma or equivalent | Some college, no degree | Bachelor's degree    | Master's degree or higher |
| Household income                                 | <\$25,000                        | \$25,000 - \$50,000               | \$50,000- \$100,000     | \$100,000- \$200,000 | >\$200,000                |

*Thank you for your feedback and your assistance!  
Please return this completed survey in the enclosed postage-paid envelope.*

## ROUND 2 SURVEY (2019)

IOWA STATE UNIVERSITY  
OF SCIENCE AND TECHNOLOGY

## Rural Drinking Water Survey

ID#

Please circle the number that best represents your response or fill in the blank.

## 1. Do you rent or own your home?

|      | Yes | No |
|------|-----|----|
| Own  | 1   | 2  |
| Rent | 1   | 2  |

## 2. Is your primary source of water a private well?

|                         | Yes | No | Not Sure |
|-------------------------|-----|----|----------|
| Private Well            | 1   | 2  | 3        |
| Other (please describe) |     |    |          |

## 3. If your primary water source is a well, what is its approximate age and depth?

|     | 0-5 years | 6-10 years | 11-20 years | More than 20 years | Not Sure |
|-----|-----------|------------|-------------|--------------------|----------|
| Age | 1         | 2          | 3           | 4                  | 5        |

|       | Less than 50 feet | 51-150 feet | 150-300 feet | More than 300 feet | Not Sure |
|-------|-------------------|-------------|--------------|--------------------|----------|
| Depth | 1                 | 2           | 3            | 4                  | 5        |

## 4. For the following uses, how much of the time do you use your well water?

|                   | All | Most | Some | None |
|-------------------|-----|------|------|------|
| Drinking water    | 1   | 2    | 3    | 4    |
| Cooking           | 1   | 2    | 3    | 4    |
| Showering/bathing | 1   | 2    | 3    | 4    |

## 5. Beyond well water, what other water sources does your household use?

|                                | Yes | No | If YES, how much does your household typically spend on this source per week? |
|--------------------------------|-----|----|---|
| Bottled water                  | 1   | 2  | \$_____ per week  |
| Water coolers (e.g., Culligan) | 1   | 2  | \$_____ per week  |
| Other (Please specify)         |     |    | \$_____ per week  |

## 6. Do you use any of the following water filters?

|                                    | If YES, how much of your drinking water do you filter from this source? |    | If YES, how much of your drinking water do you filter from this source? |      |      |             |
|------------------------------------|---|----|---|------|------|-------------|
|                                    | Yes   | No | All   | Most | Some | Very Little |
| Pitcher filters (e.g., Brita, Pur) | 1   | 2  | 1   | 2    | 3    | 4           |
| On-tap filters (e.g., Brita, Pur)  | 1   | 2  | 1   | 2    | 3    | 4           |
| In-fridge filters                  | 1   | 2  | 1   | 2    | 3    | 4           |
| Whole home filtration system       | 1   | 2  | 1   | 2    | 3    | 4           |

## 6.1 If YES to whole home system, what type of system?

|                        | Yes | No | Unsure | Installation Date |
|------------------------|-----|----|--------|-------------------|
| Reverse osmosis        | 1   | 2  | 3      |                   |
| Activated carbon       | 1   | 2  | 3      |                   |
| Water softener         | 1   | 2  | 3      |                   |
| Other (Please specify) |     |    |        |                   |

### 7. Have you ever had your well water quality tested?

|                            | Yes | No | Don't Know |
|----------------------------|-----|----|------------|
| Well water quality tested? | 1   | 2  | 3          |

#### 7.1 If YES, who provided the test?

|   | Yes | No | Don't Know |
|---|-----|----|------------|
| County Environmental Health Office/Sanitarian or Grants-to-County | 1   | 2  | 3          |
| Private company (please specify below)                            | 1   | 2  | 3          |
| In-home kit   | 1   | 2  | 3          |
| Other (Please specify)  |     |    |            |

#### 7.2 If YES, how frequently do you test your well water quality?

|                        | Yes | No | Don't Know |
|------------------------|-----|----|------------|
| More than once a year  | 1   | 2  | 3          |
| Once a year            | 1   | 2  | 3          |
| Every 2-5 years        | 1   | 2  | 3          |
| Only once              | 1   | 2  | 3          |
| Other (Please specify) |     |    |            |

### 8. How would you rate the quality of your drinking water from your well?

|                        | Poor | Neutral | Good | Great | Unsure |
|------------------------|------|---------|------|-------|--------|
| Drinking Water Quality | 1    | 2       | 3    | 4     | 5      |

### 9. Over the last year, have you read or heard news of drinking water quality concerns in your:

|            | Yes | No | Not Sure |
|------------|-----|----|----------|
| Local Area | 1   | 2  | 3        |
| County     | 1   | 2  | 3        |
| State      | 1   | 2  | 3        |

### 10. Do you believe nitrates in drinking water are a problem in your:

|            | Yes | No | Not Sure |
|------------|-----|----|----------|
| Local Area | 1   | 2  | 3        |
| County     | 1   | 2  | 3        |
| State      | 1   | 2  | 3        |

### 11. Please provide the following demographic information for all members living full time in the home.

|  |                                  |                                   |                         |                       |                       |                           |
|--|----------------------------------|-----------------------------------|-------------------------|-----------------------|-----------------------|---------------------------|
| Number of infants (<1 year)                      | 0                                | 1                                 | 2                       | 3                     | 4                     | >5                        |
| Number of children (1-18 years)                  | 0                                | 1                                 | 2                       | 3                     | 4                     | >5                        |
| Number of adults (19-65 years)                   | 0                                | 1                                 | 2                       | 3                     | 4                     | >5                        |
| Number of retirement eligible adults (>65 years) | 0                                | 1                                 | 2                       | 3                     | 4                     | >5                        |
| Highest level of education (head of household)   | No formal educational credential | High school diploma or equivalent | Some college, no degree | Associate's degree    | Bachelor's degree     | Master's degree or higher |
| Household income                                 | <\$25,000                        | \$25,000 - \$50,000               | \$50,000 - \$100,000    | \$100,000 - \$200,000 | \$200,000 - \$500,000 | >\$500,000                |

Thank you for your feedback and your assistance!  
Please return this completed survey in the enclosed postage-paid envelope.