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EPA Tools and Resources Webinar:
Cost-Effective Treatment Technologies for Small Community Drinking Water Systems

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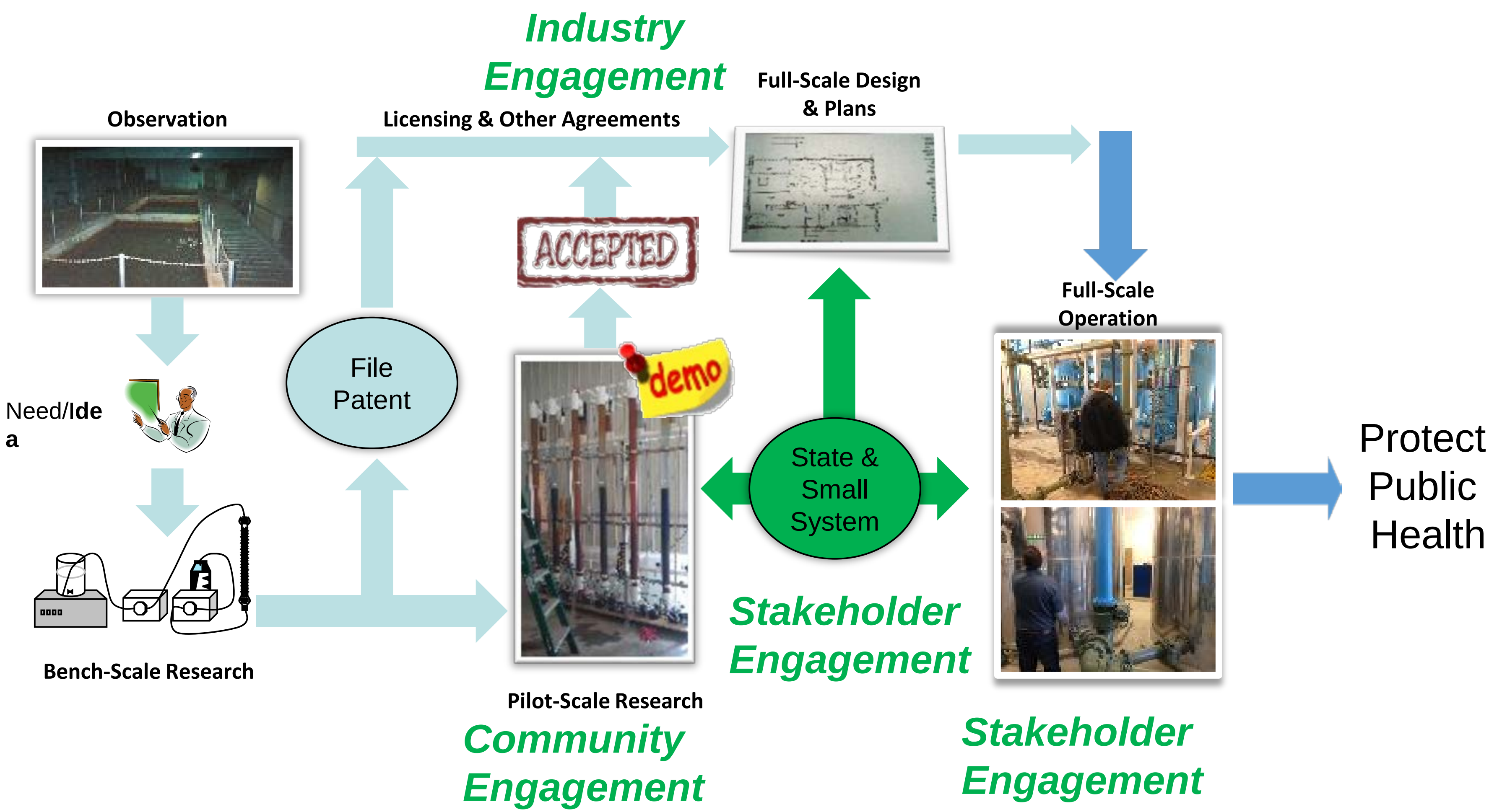
United States Environmental Protection Agency

Working with Regions, States and Communities to Bring Technology to Small Systems and Protect Public Health



Background

Drinking Water Regulations and Nitrogen (ammonia, nitrite and nitrate)

- No regulatory standard for **ammonia (NH_4^+)** in water
- **Nitrite (NO_2^-)** has Maximum Contaminant Level[1] (MCL) of 1 mg-N/L
- **Nitrate (NO_3^-)** has a MCL of 10 mg-N/L
- Drinking water standards consider concentrations entering distribution system
- Not routinely monitored in distribution system
- Ammonia is found at high levels in many agricultural areas where groundwater is the primary drinking water source
- While ammonia itself is not a regulated contaminant, it interferes with the effectiveness of some water treatment processes, such as arsenic removal
- Also, within drinking water distribution systems (pipes), it is easily converted to nitrite and nitrate, which are regulated contaminants

[1]**Maximum Contaminant Level (MCL)** - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards

Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

Nitrification

Conversion of Ammonia to Nitrate by Bacteria

Effects of Elevated Ammonia Levels in Source Water and Drinking Water

- Biological fouling of filters
- Wastewater discharge limits
- Oxidant/chlorine demand
- Difficulty complying with on disinfection requirements
- Interferes with As(III) oxidation
- Iron/manganese removal (?)

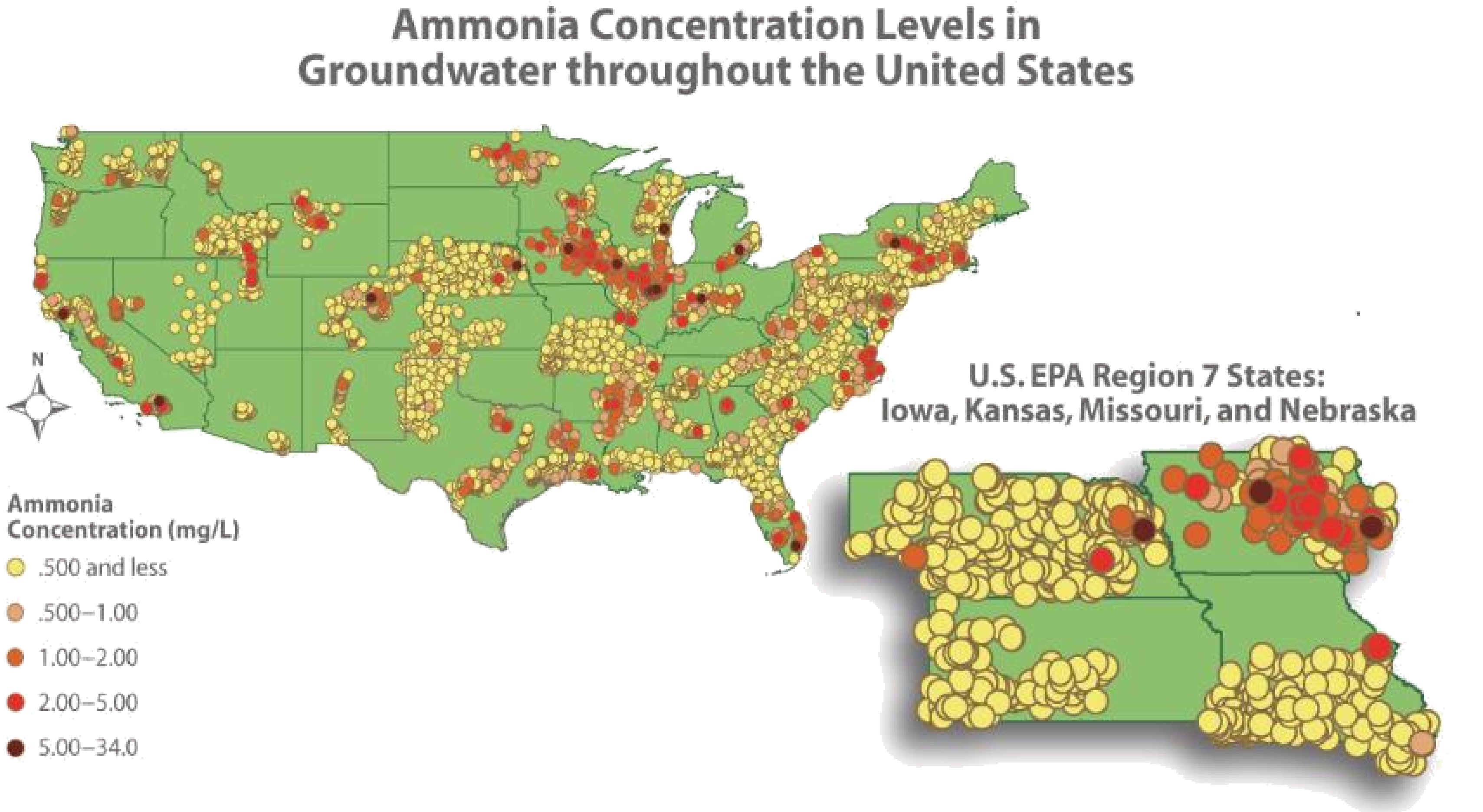
NH_4^+

Nitrification in the distribution system

- Taste and odor complaints
- Increased corrosion (pH drop)
- Iron release
- Nitrite/nitrate formation

Background

Ammonia levels in groundwater



*Map created using data from the United States Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) website. The data warehouse for this data was "built" July 7, 2011. The data is from filtered samples and are recorded as nitrogen. Map was projected using ArcGIS9 with the projection "GCS_NAD_1983."

Ammonia Treatment

Source Water Ammonia Treatment Options

- Monochloramine formation
  - Formed when chlorine is added
  - Difficult to manage
- Breakpoint chlorination (Disinfection by-products concerns)
- Biological treatment
- Others:
    - Ion exchange
    - Reverse osmosis
    - Chemical oxidation

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Nitrification

Oxidation of Ammonium to Nitrite

$$NH_4^+ + 1.5\,O_2 \rightarrow NO_2^- + H_2O + 2\,H^+$$

Oxidation of Nitrite to Nitrate

$$NO_2^- + 0.5\,O_2 \rightarrow NO_3^-$$

Complete Nitrification Reaction

$$NH_4^+ + 2\,O_2 \rightarrow NO_3^- + 2\,H^+ + H_2O$$

- In order to have complete nitrification, ***4.57 mg O_2 must be consumed per mg NH_4^+,*** which at higher concentrations of ammonia requires a constant O_2 feed
- Nitrifying bacteria consume CO_2 to build new cells. The total consumption of alkalinity by nitrification is ***7.1 mg as $CaCO_3$ per mg NH_4^+- N*** oxidized

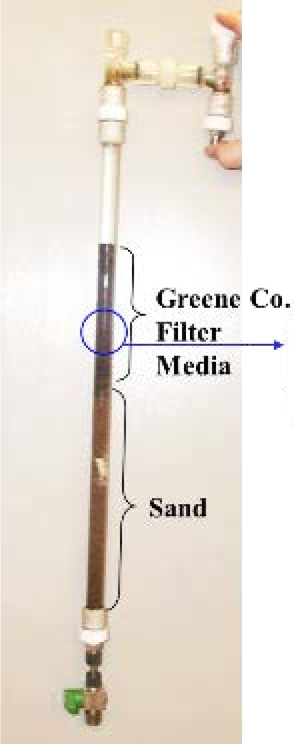
Ammonia

Biological Ammonia Treatment Configurations

- Aeration-Filtration configuration (<1.4 mg N/L)
  - Common iron removal design
- Nitrification contactor (<1.4 mg N/L)
  - Retrofit to existing plant
  - Follows aeration
  - Gravel (or other large media) vessel
- Aeration contactor (1.4 to 10 mg N/L)
  - Combines aeration with nitrification contactor

Laboratory Bench-Scale Studies

- Prove concept/technology
- Establish engineering and operating parameters
- Identify limitations
- Build pilot-scale system and evaluate technology under controlled conditions



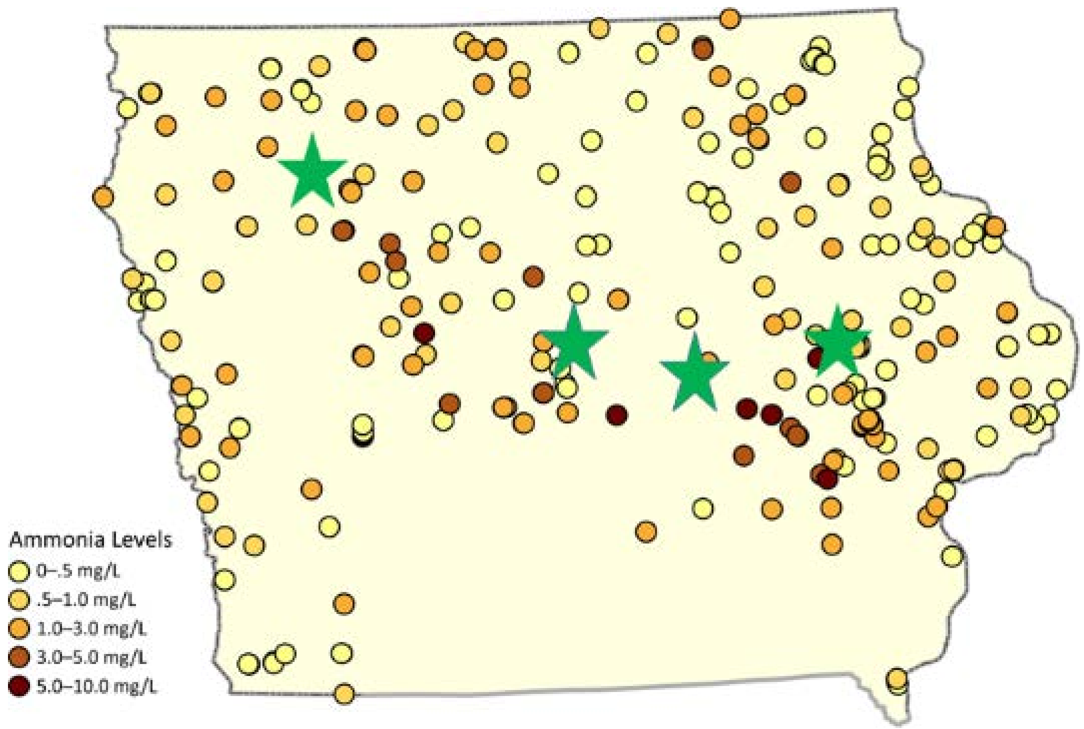
Bench-scale studies

In-house pilot studies

Collaborating with States/Communities

Iowa Pilot Study

- Iowa Department of Natural Resources (DNR) approached EPA about ammonia concerns in community water sources and strategies to reduce ammonia
- This allowed EPA to evaluate its ammonia treatment strategy in the State using real ammonia-containing waters
- Iowa DNR connected EPA with small water systems with a treatment need and interest to operate a pilot



Partner: Iowa DNR
Challenge: High ammonia levels in drinking water
Resource: Innovative small drinking water systems treatment

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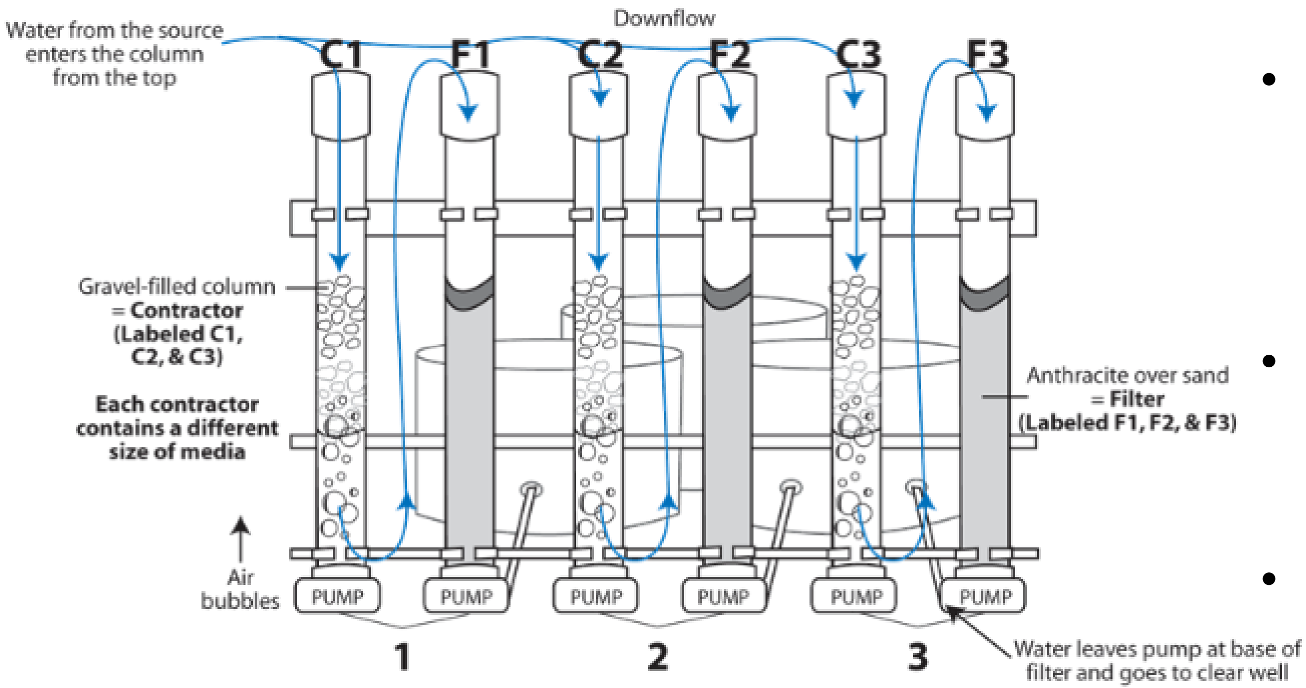
Aeration Contactor: Pilot to Full-Scale

City of Palo, Iowa

- 2010 census population was 899 people
- No city-wide public drinking water system
- Individual wells
- Shallow sand point wells contaminated during 2008 flood
- Awarded Community Development Block Grant (CDBG) for public water system

Aeration Contactor Configuration

EPA Technology[1]



- Saturated oxygen levels maintained throughout contactor
- Minimal backwashing needs
- Granular filter follows in series

[1] Patent: US 8,029,674 B2 awarded on 10/2/2011

EPA Pilot Team

- Pilot built at EPA
- Pilot transported to field location
- Re-built at site
- Utility staff trained

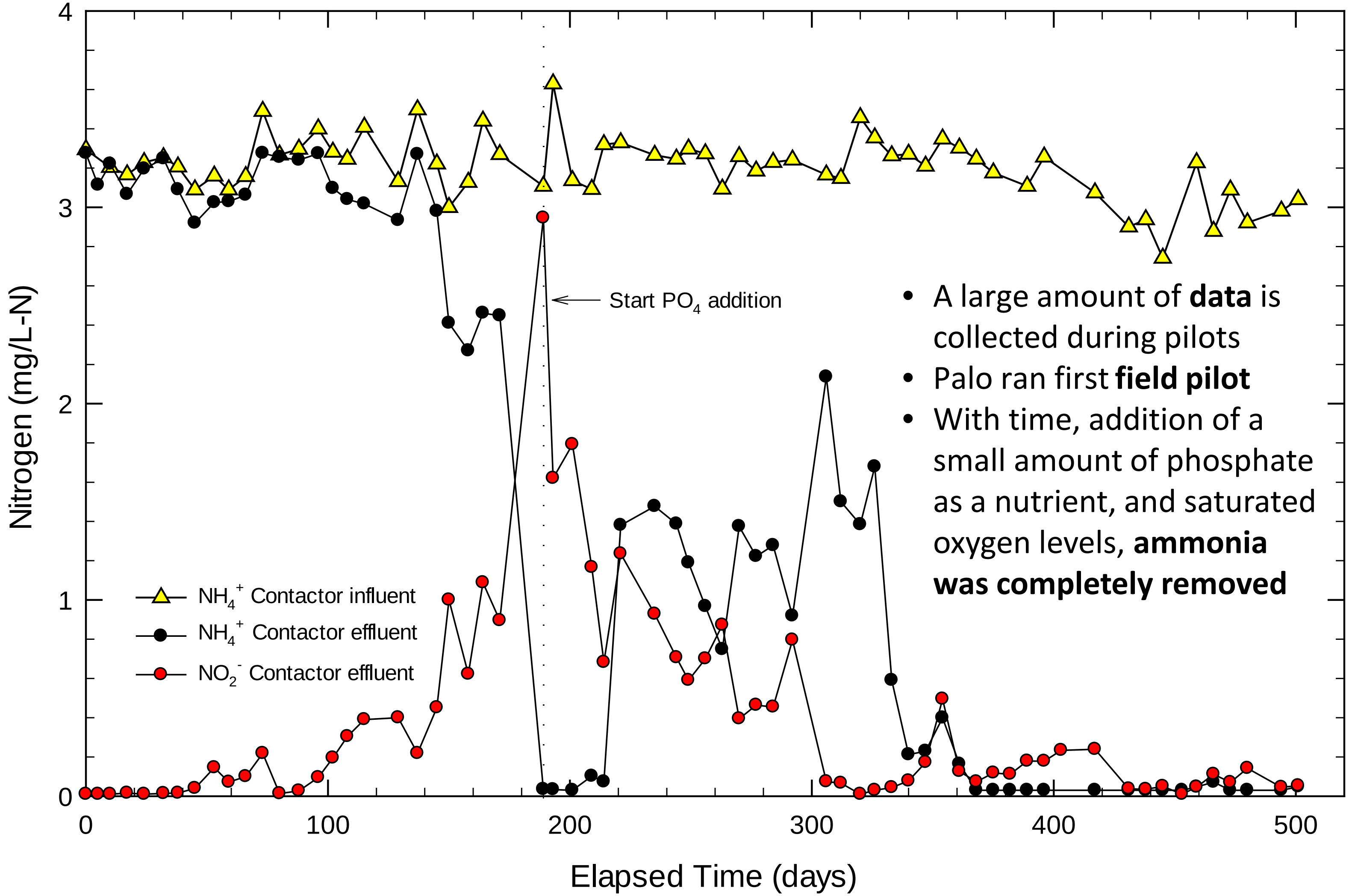
Keystone, Iowa

Pilot Study – Palo, IA

- Aeration contactor approach (addresses ammonia levels 1.4 to 10 mg-N/L)
- Saturated oxygen levels maintained throughout contactor
- Meets the stoichiometric oxygen needs in high-ammonia waters
- Minimal backwashing needs
- Granular filter follows in series

Pilot Data Example

Ammonia, nitrite and orthophosphate



- A large amount of **data** is collected during pilots
- Palo ran first **field pilot**
- With time, addition of a small amount of phosphate as a nutrient, and saturated oxygen levels, **ammonia was completely removed**

Pilot Findings

- Orthophosphate addition was necessary to provide nitrification completeness
- Maintaining oxygen saturation was critical
- Nitrite spiking during acclimation period must be watched
- Design parameters for full-scale system were defined
- Pilot report was submitted to Iowa DNR
  - Lytle, D.A., White C., Williams, D., Koch, L., and E. Nauman. Summary Report: Results from the Pilot Study of an Innovative Biological Treatment Process for the Removal of Ammonia from a Small Drinking Water System in Iowa. U.S. EPA, Office of Research and Development, Cincinnati, Ohio, EPA/600/R-12/655 (2012).

Impact

This pilot study demonstrated the ability to effectively remove ammonia and iron from the community's source water, while keeping nitrite and nitrate levels below their MCL in the treated water.

Following the pilot's success, Palo's engineering consultant designed a full-scale plant that was approved by the State and constructed by the city, and has been successfully in operation for several years.

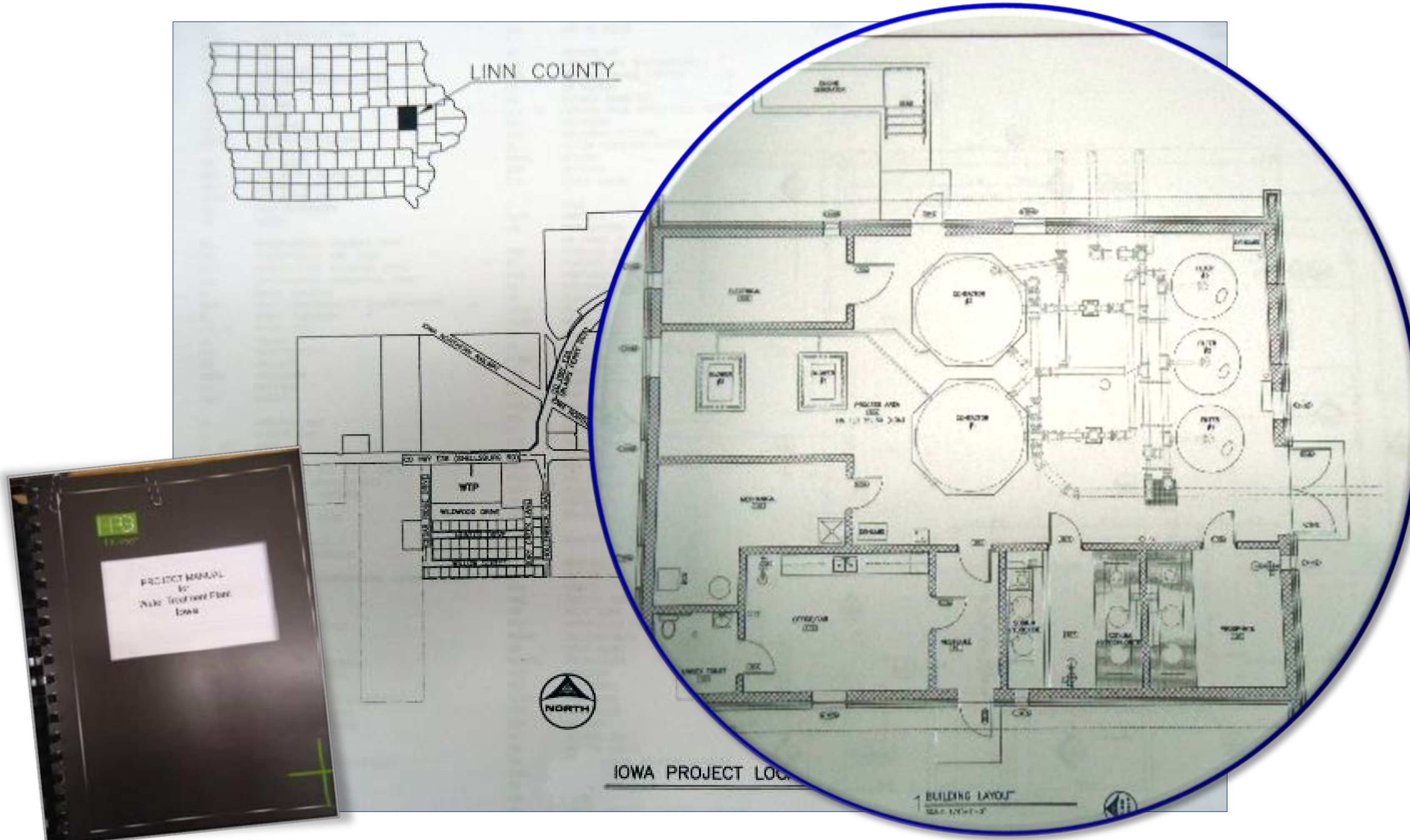
This cost-effective and easily implementable treatment technology provides a solution option for small drinking water systems in areas with high groundwater ammonia levels.

This biological treatment technology has been pilot-scale tested in IL, IN and OH for its ability to remove ammonia and reduce elevated iron, manganese and arsenic levels.

EPA's patented technology was recently licensed to a private company for full-scale development.

"Ammonia residual in the distribution system can cause nitrification and other operational 'nightmares.' This EPA ORD supported pilot project in Palo is successful and the use of biologically active filters is an innovative, emerging drinking water technology that can be a viable option for certain other systems." **–** Iowa DNR Environmental Services Division Director Bill Ehm

Pilot to Full-Scale



Matthew J. Wildman, P.E.
Project Manager
HR Green, Inc.

Palo Project Schedule

Engineering Report	August 2010
Pilot Plant	March 2011-April 2012
Bid – Well, Watermain, Tower	December 2011
Well Construction	Jan 2012-Aug 2012
Watermain Construction	Jan 2012-Nov 2013
Tower Construction	March 2012-July 2013
Bid – Water Treatment Plant	January 2013
Iowa DNR Approval of Pilot	April 2013
Water Treatment Plant Construction	April 2013-Jan 2014

Full-Scale Design Conditions

- Design Population = 1,139 people
- Average Day Demand = 0.115 Millions of Gallons per Day (MGD)
- Peak Day Demand = 0.23 MGD
- Design flow rate = 300 gallons per minute

Plant run time

- Average day demand – 6.4 hours/day
- Peak day demand – 12.8 hours/day

Pilot versus Full-Scale

Condition	Pilot	Full-Scale
Hours of Operation	24 hours/day, 7 days/week	*January to late April:* 4-5 hours/day, 5 days/week *Late April to Present:* 6-7 hours/day, 7 days/week
Phosphate	Orthophosphate: 0.3 mg PO_4/L	Total phosphate: 0.3 mg PO_4/L (blended phosphate)
Air/Water Flow Direction	Counter-current	Co-Current
Filter Backwash Water	Non-chlorinated	Chlorinated

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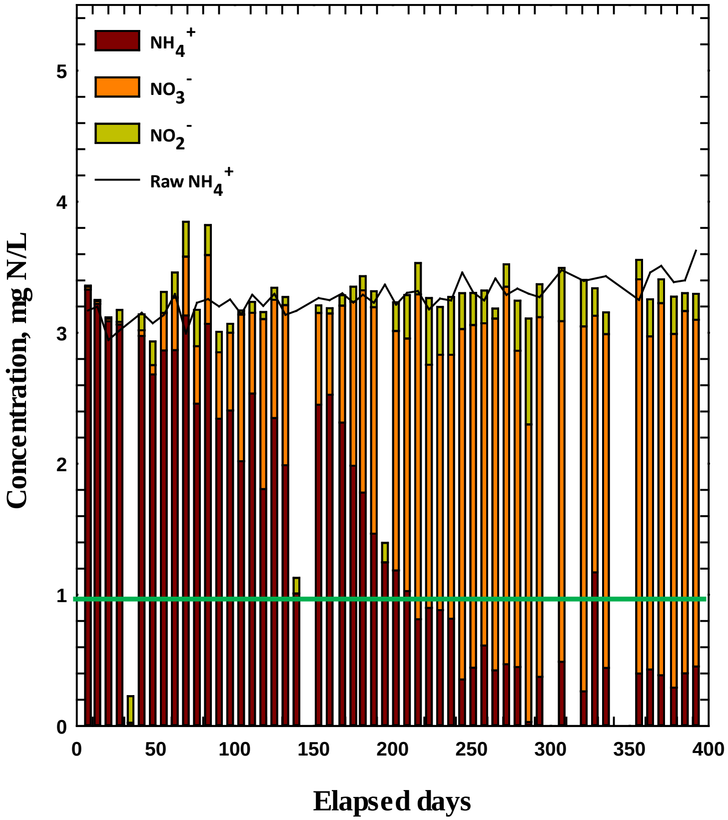
Contactors

Contactors/Blowers

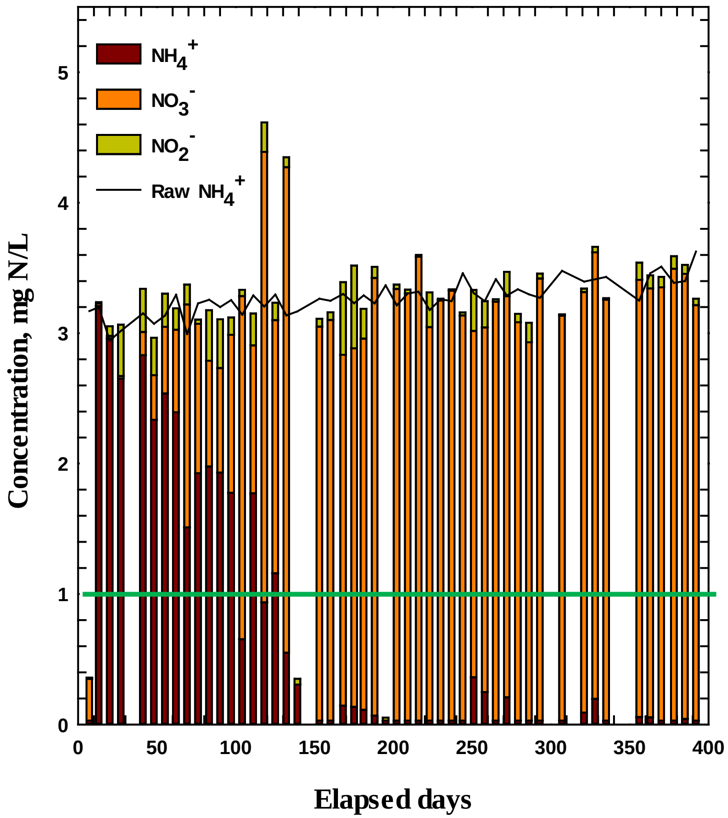
Contactor Aeration

Pressure Filters

Full-Scale Results



Contactor 1



Filter 2

Federal Technology Transfer

Cooperative Research and Development Agreements (CRADAs)

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AdEdge water technologies

Home Company Contamii

ADEDGE TREATMENT PRODUCTS

NOMONIA BIOLOGICAL FILTRATION SYSTEMS

NoMonia

Ammonia is an increasing concern for many communities throughout North America. While it is currently unregulated by the USEPA, the World Health Organization (WHO) set a recommended maximum contaminant level of 0.2 mg/L in drinking water. Concerns, however, related to water contaminated by ammonia should not be taken lightly. If ammonia-generated nitrification occurs in the distribution network, it may lead to pipe corrosion, biofilm generation, poor taste and odor, and elevated nitrate levels. Additionally, ammonia commonly interferes with the removal of contaminants that require oxidation including arsenic, iron, and manganese.

Legacy ammonia treatment approaches such as ion exchange, reverse osmosis, breakpoint chlorination, and air stripping often struggle to meet the recommended guideline of 0.2 mg/L set by WHO. These processes require chemicals and extensive operator attention and are not environmentally sound due to the generation of concentrated waste water.

NoMonia is a sustainable, cost-effective, and robust biological treatment approach and an alternative to legacy treatment approaches. NoMonia was developed and patented by the USEPA (EPA Patent # US 8,029,674, October 4, 2011). NoMonia relies on naturally occurring bacteria already present in groundwater to enhance the natural nitrification process during which, in the presence of oxygen, ammonia is converted to nitrite and then nitrate.

Benefits of choosing NoMonia include:

https://adedgetech.com/nomonia-biological-filtration/

Ammonia Work

Current to Future

- Piloted at 4 locations in Iowa, each with a unique challenge
- License agreement with industry partner, AdEdge (small business, Atlanta)
- Just completed a pilot in Gilbert, IA (November 2017)
  - Water contains ammonia as well as Mn, As and Fe
  - Successful pilot
  - Iowa DNR approved full-scale plans submitted by AdEdge
  - Groundbreaking for the treatment plant construction (Spring 2018)
- ORD technical assistance continues
- Examining wastewater applications
- Papers, design criteria document

Nitrate Work

Current to Proposed Future

- Applying approach for engaging EPA regions, states and communities (as followed in the ammonia treatment project) to address nitrate problems
- Working in-house on biological treatment process pilot to develop and refine technology
- Identify community with a need to remove nitrate from water where a pilot can be performed
  - Build pilot for field testing

Conclusions

- Arsenic, iron and manganese have primary or secondary MCLs Ammonia is not regulated, but can cause problems in distribution systems
- Aerobic biological treatment can be relatively simple approach and was shown to remove multiple **contaminants** (ammonia, Fe, Mn, As)
- Media size, loading rate, nutrient addition, and oxygen levels are important design factors
- Biological aerobic treatment was robust
- Biological aerobic treatment is a **viable** and **cost-effective** treatment technology that can be suitable for small systems
- Success of such efforts are dependent on **partnerships** with states and communities, beginning from the planning stages of the project

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Information on the Safe and Sustainable Water Research (SSWR) program:
https://www.epa.gov/aboutepa/about-safe-and-sustainable-water-resources-research-program