Innovative Biological Ammonia Treatment for Small Systems: Pilot Study to Full-Scale Water Treatment Plant

Darren Lytle, Dan Williams, Maily Pham., Colin White, Jonathan Popovici, and Brenda Groskinsky*
U.S. Environmental Protection Agency NRMRL, WSWRD; * Region 7

Project Overview

Prior to extensive flooding to the region in 2008, the small city of Palo, Iowa did not have a centralized water treatment or drinking water distribution system. Support to build the necessary infrastructure to supply the community with potable drinking water was put into place. The Iowa Department of Natural Resources (DNR) requested assistance from EPA's Office of Research and Development (ORD) to develop an appropriate treatment system to address the source water ammonia concerns (**Figure 1**). Specifically, ORD's experience in applying biological water treatment to remove ammonia from water was requested, as the treatment system needed would be required to address elevated levels of both iron and ammonia in the source water.

As a result, the Iowa DNR, EPA ORD and EPA Region 7 began a pilot study to evaluate the impact of biological water treatment on ammonia oxidation. Specifically, the pilot was based on an EPA-patented approach to address elevated levels of ammonia and iron in source water (Patent No. US 8, 029,674). The treatment system relies on bacteria for the conversion of ammonia to nitrate; provided the raw ammonia levels are lower than the nitrate MCL of 10 mg N/L, the approach can be effective and relatively simple. The pilot system was designed and built by EPA staff, and installed in March 2011. In a collaborative effort, EPA and pilot site staff coordinated system operation and maintenance, as well as water sample collection and analysis.

The pilot study demonstrated the ability of biological treatment to effectively remove ammonia and iron from the source water. It was also valuable in identifying key reasons for data discrepancies, and more importantly, potential engineering and design improvements. The success of the pilot study in Palo paved the way for the community to design, build and as of January 2014, operate a new full-scale water treatment plant (**Figure 2**).

Technology Description

The pilot system consisted of three pairs of 3-inch (7.62 cm) diameter columns in series built from clear PVC and other common plumbing materials (**Figure 3**). Each pair consisted of one column, or "contactor," filled with 30 inches (76.2 cm) of gravel in series with a second column, or "filter," filled with anthracite (20 inches [50.8 cm] deep) over sand (10 inches [25.4 cm] deep). Each contactor contained different sized gravel (**Figure 4**) : ¼ inch (6.35 mm), ½ inch (12.7 mm) and 1 inch (25.4 mm), as seen in **Figure 3**. The contactors were aerated from the bottom, such that air bubbles flow upward countercurrent to the water flow (downflow) using a diffuser connected to a gas pump at a rate of 2.5 L/min (0.66 gpm).

In this configuration, the water in the contactor is always saturated with respect to dissolved oxygen throughout the gravel media bed despite the demand from the nitrification process and iron oxidation. The gravel in the contactor serves solely as a growth support for nitrifying bacteria where nitrification occurs. The gravel allows bacteria attachment and growth, yet eliminates the potential for "clogging" of the media. It also allows air bubbles to move through the contactor. Oxidation of ferrous iron in the source water also occurs in the contactor, but no iron removal should occur. Various flowrates were considered during pilot evaluations. The filter is intended to remove iron particles and potentially bacteria. IT can also provide biological oxidation of excess ammonia and/or nitrite that exits the contactor as a result of incomplete nitrification. With regards to the latter, the filter serves as a polishing step and safeguard against disruption in operation of the contactor which could result, for example, in excess nitrite formation. Effluent water from the filter is routed to a clear well, that when full, can be used to backwash the filters or overflow to the sanitary sewer.

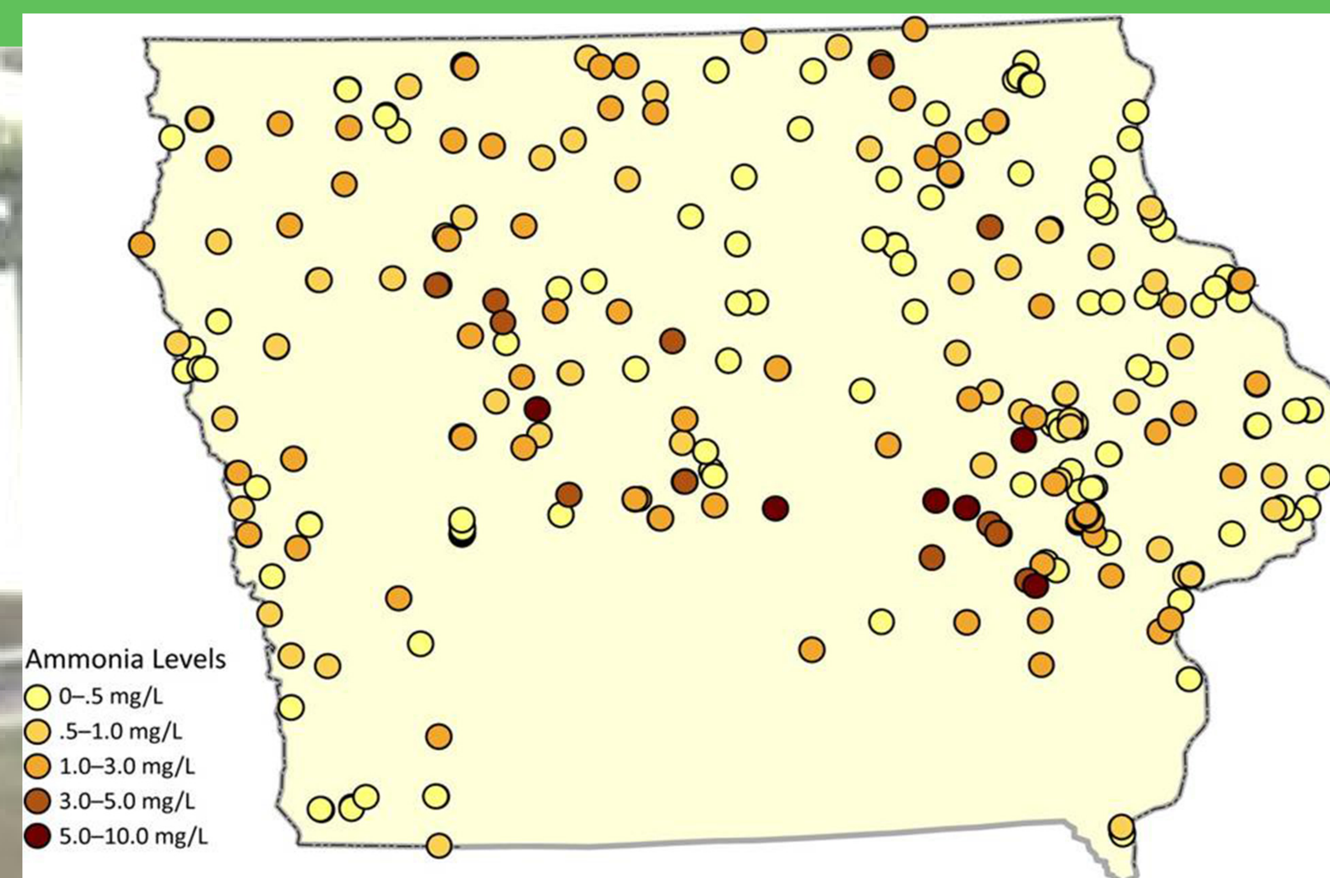

Figure 1. Map of ammonia levels in Iowa based on groundwater well analyses (1998–2012) provided by the state of Iowa.

Project Conclusions

- Ammonia is found in groundwater across the U.S.
- Ammonia is not regulated, but can cause serious problems in distribution systems and treatment processes
- Biological treatment is a relatively simple approach to ammonia removal from water
- Media size, loading rate, nutrient addition and oxygen levels are important design factors
- Biological ammonia oxidation is robust
- Biological ammonia removal is a reliable and cost-effective treatment technology

City Profile

- Population: 899 people (2010 U.S. Census)
- No city-wide public drinking water system at start-up
- Utilizes individual wells
  - Shallow sand wells that contain elevated levels of ammonia
- Awarded million Community Development Block Grant (CDBG) for a full-scale public water system

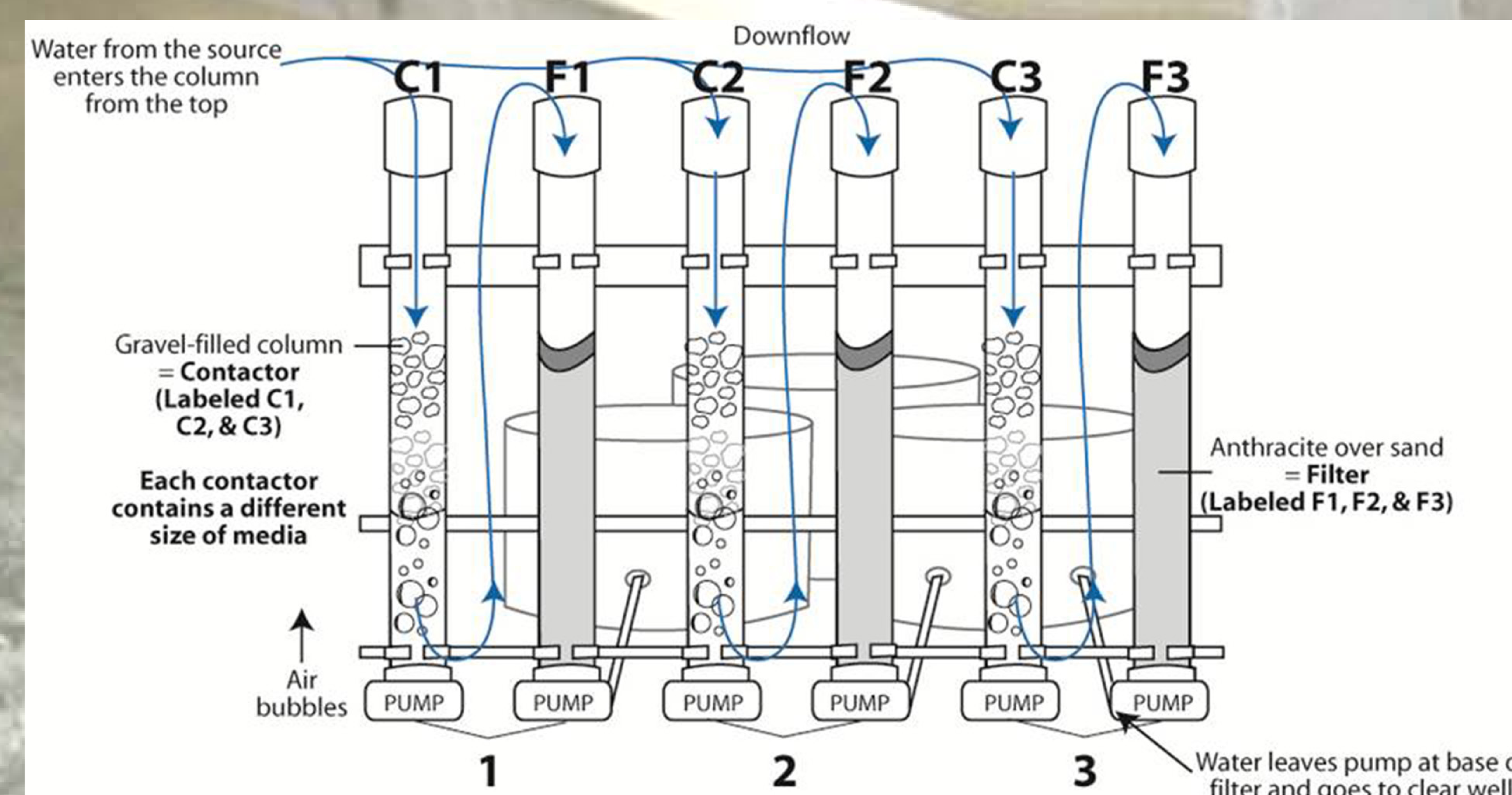

Figure 3. Schematic of the pilot biological ammonia removal treatment technology system.

Figure 5. Pilot biological water treatment system for ammonia removal at the Iowa study site.

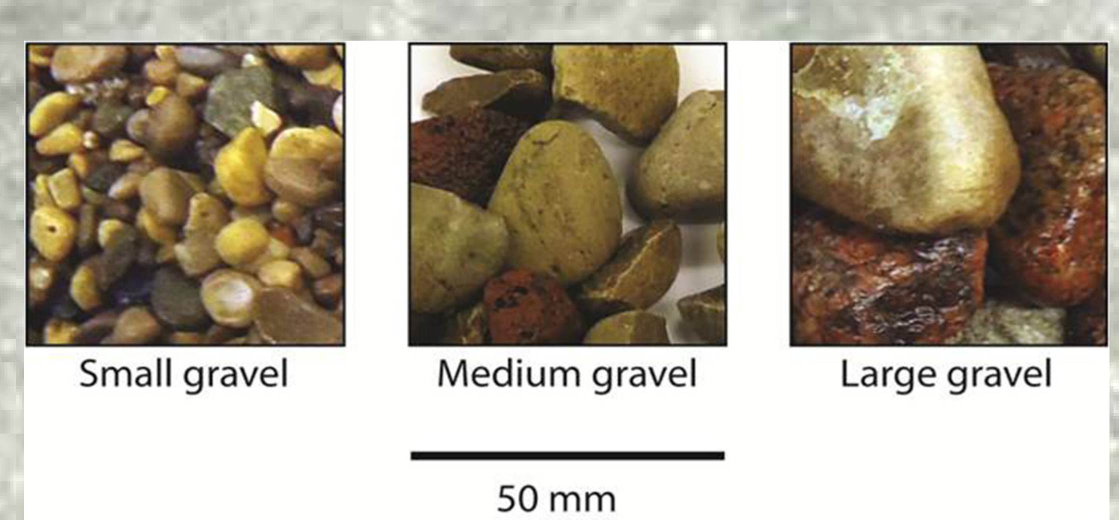

Figure 4. Three gravels used in the contactors of the piloted biological ammonia removal treatment technology system.

Figure 2. The new, full-scale water treatment plant and tower in Palo, Iowa.

Background Image: Aeration process in one of the contactors.