An Overview of U.S. EPA and USDA Drinking Water Treatment System Demonstrations in China

Craig L. Patterson[1], Lucille M. Garner[2], Roy C. Haught[3], and James A. Goodrich[4]

1. U. S. Environmental Protection Agency, ORD/NRMRL/WSWRD, 26 W. Martin Luther King Drive, Cincinnati, OH 45268; PH (513) 487-2805; FAX (513) 569-7052; email: Patterson.Craig@epa.gov
2. U. S. Environmental Protection Agency, ORD/NRMRL/WSWRD, 26 W. Martin Luther King Drive, Cincinnati, OH 45268; PH (513) 569-7417; FAX (513) 569-7185; email: Garner.Lucille@epa.gov
3. U. S. Environmental Protection Agency, ORD/NRMRL/WSWRD, 26 W. Martin Luther King Drive, Cincinnati, OH 45268; PH (513) 569-7067; FAX (513) 569-7185; email: Haught.Roy@epa.gov
4. U. S. Environmental Protection Agency, ORD/NRMRL/WSWRD, 26 W. Martin Luther King Drive, Cincinnati, OH 45268; PH (513) 569-7605; FAX (513) 569-7658; email: Goodrich.James@epa.gov

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Abstract

Under an interagency agreement with the U.S. Department of Agriculture, U.S. EPA has coordinated support for several water treatment research demonstrations in China. EPA has demonstrated several treatment technologies to improve water quality in small communities and has installed an immersed membrane water reuse system for a small brewery in China. U.S. EPA has also provided a water quality monitoring buoy and an automated weather station for monitoring of flood conditions (rainfall events) in a remote watershed. The weather station has been designed and built with a remote telemetry system to collect and submit real-time data on an hourly basis. This presentation will focus on interagency cooperation and cooperation between the U.S. and China during implementation and completion of these drinking water demonstrations.

Disclaimer

This paper has been reviewed in accordance with the EPA's peer and administrative review policies and approved for presentation and publication. The mention of trade names or commercial products in this paper does not constitute endorsement or recommendation for use by the authors, or by their respective employers. The trade names have been included to accurately represent the equipment used for the purpose of testing and evaluation.

Background on Rivers in North China

Viable drinking water supplies in North China are scarce compared with those in the south. Northern China contains 43 percent of China's population, but has only 14 percent of China's water resources. North China's renewable water resources are less than 1000 cubic meters per year (the international standard for water scarcity). The Yellow and Hai Rivers are heavily polluted and over-allocated with less than 50 percent of their length

ranked Level V or worse for poor water quality. A 2001 World Bank study called the Yellow and the Hai rivers the "most degraded" rivers in China.

Reservoirs in North China are facing environmental problems. Water releases from upstream reservoirs in the Yellow River to meet downstream demands have caused some reservoir levels to be at 50-year lows. These shallow reservoirs have significant eutrophication and biological contamination from untreated human and animal waste from surrounding villages, farms, fish ponds, and commercial activities.

Figure 1. Map of China Showing Tianjin and the Yellow (Huang He) River

History of Drinking Water Treatment Demonstration Projects in North China
In the mid-1990's, safe drinking water became a high environmental priority in China. The U.S. Technology for International Environmental Solutions (U.S. TIES) initiative served as the international component to promote an EPA-led technology diffusion program. The U.S. TIES program was designed to enlist greater participation of the U.S. private sector in achieving environmental objectives worldwide. In October, 1995, EPA announced U.S. TIES awards funding seven China projects, one Hong Kong project, and one Asia-wide project. As a result, drinking water treatment demonstration projects were completed at four sites in China that involved collaboration between U.S. EPA and USDA, as well as central, provincial, and local Chinese officials.

After raw water characteristics were considered, three demonstration sites were initially chosen where various treatment technology configurations would be installed. These small and packaged systems were aimed at removing high levels of industrial organic contaminants, heavy metals, hardness, iron, nitrate, fluoride, and microbial contaminants from drinking water without generating large amounts of contaminated residual (as can be found with conventional treatment approaches). Installed technologies included tray and packed tower aeration (for removal of volatile organic chemicals), granular activated carbon (for removal of organic chemicals), multimedia filtration (for removal of various

suspended solids), ion exchange (for removal of inorganic ionic species), and reverse osmosis membranes (for removal of dissolved solids).

While advancements in drinking water treatment technologies can be heralded as lifesavers throughout much of the world, municipalities in many countries can afford only the most economical water treatment technologies. Equally important, these towns and villages cannot afford to buy and operate treatment units that are inappropriate for their specific needs. In partnership with U.S. agencies and American manufacturers of cost-effective technologies, the U.S. EPA demonstrated that drinking water supplies can be made safer at a reasonable cost.

Huantai Village
In a small agricultural village outside Zibo City, a system with shallow wells was chosen as a demonstration site. Although no medical data were available, the drinking water was found to have high fluoride and nitrate levels with trace levels of volatile organic contaminants. Low levels of ingested fluoride are beneficial. The extremely-high fluoride levels found in the drinking water source for this community, however, had caused poor dental conditions and skeletal problems. While microorganisms were not found to be a significant risk in this aquifer, residents disinfected their drinking water by boiling it. Many residents transported their drinking water from a less contaminated aquifer nearby with a limited water supply. To ensure the safety of drinking water drawn from the local groundwater supply, a 10 gallon per minute (gpm) treatment train was installed; treatment processes included tray aeration, multimedia filtration, granular activated carbon (GAC), and reverse osmosis. The system began operating in July, 1997.

Beijing's First Bottled Water Plant (Haidian District)
This government owned facility had problems producing contaminant-free bottled water. The existing treatment train included six steps. The plant draws water from a deep well with low levels of industrial contaminants, moderate hardness and nitrate concentrations. Bottled water production, marketed by the Chinese government as a safe alternative to potentially contaminated well water, had suffered because of treatment difficulties. Source water was hard and moderately contaminated with natural and man-made contaminants such as formaldehyde, nitrates, chromium, and strontium. A three-step pilot scale treatment train was installed and began operating in September, 1997. This technology, employing multimedia filtration, ion exchange, and GAC, had an output of 10 gpm.

Zibo City Water Supply and Wastewater System, Dawu Aquifer
This demonstration was aimed at improving drinking water distributed to 2.5 million city residents. The pilot-scale demonstration technology operated at 10 gpm. The groundwater had been contaminated by oil refinery and plastics industry wastes. High hardness and iron levels made treatment of the organic contaminants very difficult. Volatile organic contaminants included benzene, toluene, and xylene in the milligrams per liter range. Contaminant levels had proven to be extremely variable. Because of the extremely variable contaminant levels, substantial modifications were made to the original treatment train, as well as repair to the system following a typhoon. The system included

two iron filters, multimedia filtration, packed tower aeration, GAC, and reverse osmosis membranes.

Due to the success of these demonstrations (e.g., significant reductions in contaminant levels in the treated drinking water) and relationships developed between the government partners, a fourth system was installed in July 1997. The 20 gpm system was purchased by Zibo City's Water Supply and Wastewater Utility to further treat water for a new housing complex in Zibo City, China. The system is composed of GAC, cartridge filtration, UV pre-disinfection, reverse osmosis membranes, and ozonation. This purchase gave testimony to the effectiveness of the earlier-demonstrated technologies. Also significant is that Zibo City purchased the technology from an American vendor without U.S. government mediation – fulfilling a long-range objective of the U.S. Technology for International Environmental Solutions program.

Throughout these demonstration projects, U.S. EPA served as a catalyst for expanding the drinking water technology market and gained valuable performance data for a variety of drinking water contaminants. In turn, China gained knowledge regarding the use of effective new technologies as well as improved public health (access to solutions for widespread acute and chronic environmental problems).

Interagency Agreement between U.S. EPA and USDA

In June of 2001, EPA and USDA initiated a joint demonstration research project at two different sites in China. The first demonstration project involved the installation and operation of an innovative membrane system to treat industrial wastewater for reuse at a brewery located in Jinan, Shandong Province. The wastewater membrane treatment system, shown in Figure 2, was installed and successfully demonstrated at the brewery.

Figure 2. Packaged Wastewater Treatment System

The second demonstration project entitled "Real Time Watershed Management" involved the installation and operation of a solar-powered buoy (water quality monitoring system) on the Yellow River, at Huayuankou, 20 miles north of Zhengzhou, the capital of Henan Province as simulated in Figure 3.

Figure 3. Solar Powered Buoys

The weather station with remote telemetry (Figure 4) was shipped to Tianjin to be an integral part of a watershed management project for the Yuqaio Reservoir (Tianjin's principal source of drinking water serving five million people).

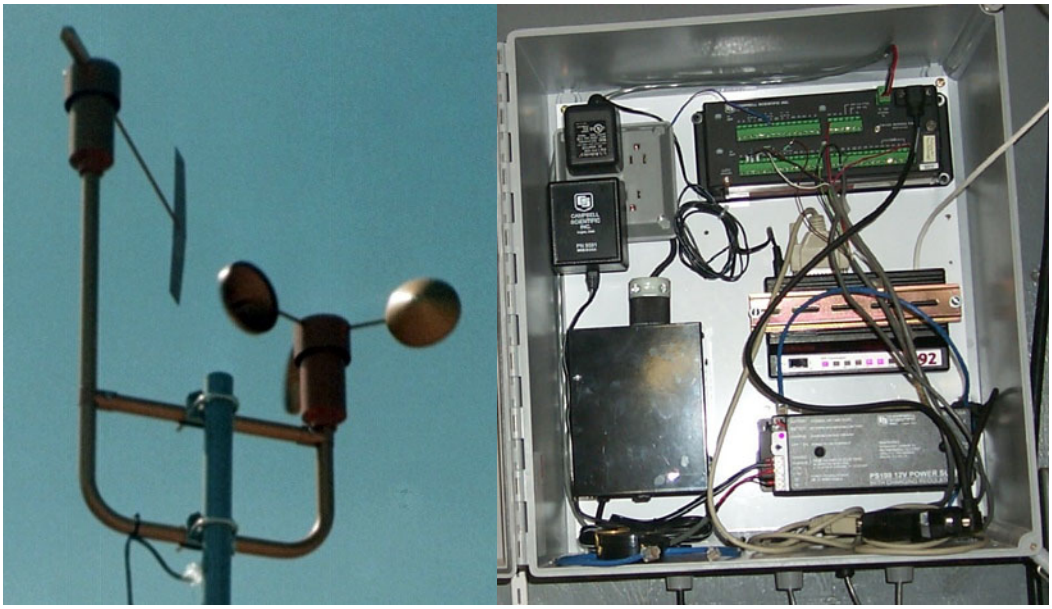

Figure 4. Weather Station and Modem for Remote Real-Time Data Transfer

The projects were managed by EPA's Office of Research and Development, USDA's Foreign Agricultural Service, and several Chinese partners including the China Environmental Protection Foundation, Shandong Environmental Protection Bureau, Shandong Environmental Protection Production Group Company, and the Zhengzhou Environmental Monitoring Center. Lessons learned from collection of water quality monitoring data from the solar-powered buoy on the Yellow River are currently being transferred to the Hai River Watershed Project described at the end of this paper.

Memorandum of Understanding between EPA and SEPA
On December 8, 2003, the U.S. EPA and the State Environmental Protection Administration of the People's Republic of China (SEPA) signed a Memorandum of Understanding (MOU) on scientific and technical cooperation in the field of the environment. The MOU establishes a Joint Committee on Environmental Cooperation (JCEC) that will provide guidance to all working groups pertaining to environmental protection established under the Science and Technology Agreement.

The MOU sets a framework for scientific and technical cooperation on water pollution. Project activities include work on drinking water quality; water quality surveillance and control; sanitation and wastewater management; watershed management, including source water and wetlands protection; water resources conservation and pollution prevention; compliance and water quality policies and standards; and other areas as determined by the parties. The MOU designates the Deputy Assistant Administrator for the EPA Office of International Affairs as the Management Official for the United States. The MOU and lessons learned during the Jinan wastewater reuse demonstration resulted in greater research coordination between EPA's National Risk Management Laboratory and the Office of International Affairs.

Hai River Watershed Project
The U.S. EPA, USDA, and the Civil Engineering Research Foundation (CERF) are working with Chinese authorities and Non-Governmental Organizations to protect scarce water resources along North China's Hai River. Initiated in 2003, the Hai River Basin project focuses on "Clean Water for Sustainable Cities." The objectives of the project are to improve drinking water quality, reduce industrial wastewater pollution, reduce industrial water consumption, increase mechanisms for financing water-related infrastructure, and promote development of a watershed management plan. This implementation process is running simultaneously with a public awareness campaign and a financial analysis of Tianjin's water sector infrastructure.

Enhancing the performance of drinking water plants and wastewater treatment plants is a major part of EPA's technical plan for the Hai River Basin. EPA has noted problems there including encroachment by agriculture, a lack of wastewater treatment of household waste, and discharges from hotels, restaurants and light manufacturing. EPA is helping to assess and improve management of Yuqaio Reservoir near Tianjin. The shallow reservoir has significant eutrophication and biological contamination from untreated human and animal waste from surrounding villages, farms, fish ponds, and commercial activities. The project provides an opportunity to gather and disseminate data from the pilot facilities to other facilities and is making technical, policy, and financial recommendations.

U.S. EPA is also demonstrating the capabilities of an automated weather station for monitoring of flood conditions (rainfall events) in the Hai River Basin watershed. The weather station has been designed and fabricated with a remote telemetry system to collect, store, and transmit real-time weather data (rainfall, temperature, relative humidity, wind direction and velocity) across telephone lines on an hourly basis.

To date, the Hai River Basin watershed project has conducted assessments of the Yuqaio Reservoir and identified possible sources of contamination, implemented a sampling and monitoring plan, provided sampling and monitoring equipment and conducted training, developed a digitized map of the reservoir and its surrounding watershed; and is producing a simple model of the reservoir's water quality. Future work will develop and implement pollution control strategies for the village of Yaobaizhuang to be used as a model for best management practices.

Future International Collaboration

U.S. EPA's National Risk Management Research Laboratory continues to assist nations with drinking water source water, treatment and distribution system problems. The Water Supply and Water Resources Division is working with private companies in the U.S. to assist India and Bangladesh with treatment solutions for arsenic in well water. EPA is collaborating with Mexico, Central and South America to improve water quality monitoring and compliance. EPA's Office of International Affairs is working with Asia, Africa, and the Middle East to ensure adequate and safe water supplies. In 2006, EPA will continue the Yuqaio Reservoir source water protection project in China.

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