## Project Number

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# *Microbiological Quality and Biostability of Reclaimed Water Following Storage and Distribution*

**Principal Investigator:** Mark LeChevallier, Ph.D., *American Water*

**Cash Contributors (in addition to the Bureau of Reclamation):** State Water Resources Control Board (CA)

**Objectives:**

The study was conducted to identify the key chemical and physical water quality parameters that influence changes in microbial water quality in reclaimed water distribution systems. A secondary objective was to evaluate a novel assimilable organic carbon (AOC) assay for analysis of reclaimed waters. The results from this study were used to develop recommendations for system operators to control microbiological growth in reclaimed water systems.

**Project Findings:**

All four treatment systems examined effectively removed bacteria in treated effluents but re-growth occurred in the distribution systems due to the (i) high AOC and BDOC levels; (ii) rapid dissipation of the disinfectant in the system; (iii) intermittent flow of water in some systems which causes stagnation of the water and depressurization of the pipeline; and (iv) the presence of open reservoirs that promoted algal growth, increasing the organic carbon levels, bacterial loading to the system, turbidity, and hydrogen sulfide – a precursor for objectionable odors. The concentration and frequency of occurrence of most of the monitored bacteria (HPC, coliforms, *E. coli*, *Pseudomonas*, *Aeromonas*, *Enterococci*, *Legionella*, and *Mycobacterium*) increased in the distribution systems. The absence of coliform bacteria and *E. coli* did not preclude the presence of potential pathogens such as *Legionella*, *Mycobacterium*, *Giardia*, *Cryptosporidum* and enteric viruses. Re-growth of bacteria was especially prevalent in systems that lacked a disinfectant residual and had high levels of AOC. Experiments performed in pipe loop systems showed that free chlorine was more effective than chloramines in controlling HPC and *Legionella* but in some instances, chlorination ironically increased AOC and BDOC levels – leading to more nutrients for downstream bacterial growth. The MBR systems showed better removal of enteric viruses possibly due to the cake development on the membrane. In the broad survey of 21 systems, membrane bioreactors consistently prodcued the lowest levels of AOC, but other technologies (like activated sludge) were also capable of achieving low levels of AOC; suggesting that there is a possibility of optimizing treatment operations to enhance AOC removal. To minimize degradation in distribution systems, utilities should: (i) maintain a constant flow in the system; (ii) control algal growth in reservoirs; (iii) routinely flush the network; (iv) evaluate treatment strategies that could improve removal of AOC, and (vi) institute post-treatment disinfection with UV, or maintain a monochloramine residual in the system.

**Recommendations**

- Examine how to optimize conventional wastewater treatment for improved removal of biodegradable organic carbon and develop design and operational criteria when various treatment processes are used to produce reclaimed water.
- Examine the risks from *Legionella* and *Mycobacterium* spp. in reclaimed water by examining specific species and serotypes prevalent in reclaimed water. Where possible, virulence determinants should be examined and the interaction of these organisms with amoebae which could increase their public health significance.
- The infectivity of *Giardia* cysts, *Cryptosporidium* oocysts, and enteric viruses should be addressed. On-going studies are examining the infectivity of cysts and oocysts in reclaimed water, but additional attention should be directed towards risks of enteric viruses.
- This study did not examine the hydraulics of reclaimed distribution systems (It wasn't needed to observe the changes in water quality). However, future studies should examine the impacts of system hydraulics on degradation in water quality.
- Because improved operation of reclaimed distribution systems would be the fastest, least-cost, mechanism to improve water quality, a project to develop best operating practices for reclaimed water distribution system management should be initiated.