DISINFECTION AND FLUSHING OF AIRCRAFT DRINKING WATER SYSTEMS

Background

The goal of this project was to better understand how aircraft drinking water systems become contaminated with bacteria and to investigate remedies. Under the Aircraft Drinking Water Rule, drinking water systems in commercial United States flagged aircraft are categorized as Transient Non-Community Water Systems. As such, airline employees collect total coliform bacteria samples and conduct disinfection and flushing of the water system on a routine, approved schedule. Generally, coliform bacteria are not harmful, but, when detected in water systems, they indicate that other potentially harmful fecal bacteria could be present. National data indicate that the drinking water systems in some aircraft models have experienced more positive total coliform water samples from the aircraft lavatory than from the galley location, even though both taps are served by the same onboard water tank. The presence of coliforms in these tap water samples suggests either cross contamination via aerosols from the lavatory wastewater disposal system or bacterial colonization of the water system during normal passenger use of lavatory facilities. This project focused on identifying the bacteria that are the potential sources of these positive total coliform assays, on locating potential hotspots for bacterial colonization within aircraft plumbing materials, and on investigating the effectiveness of the airline industry's current disinfection and flushing procedures.

Approach

A Materials Cooperative Research and Development Agreement was signed by the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development (ORD), Boeing Commercial Airplanes, and air carriers in EPA Region 6 to share equipment and technical expertise. This Regional Applied Research Effort (RARE) project, part of the ORD program to respond to the high-priority, near-term research needs of EPA's regional offices, consisted of two phases. Phase 1 was focused on isolating coliform bacteria from commercial aircraft. EPA Region 6 and ORD scientists worked with regional air carriers and their contract water testing laboratories to have positive total coliform water samples shipped overnight to the EPA's ORD laboratory in Cincinnati for concentration and isolation studies. Aliquots of the media were cultured on solid nutrient media to recover isolates, which were then identified to the species level using both biochemical testing and DNA sequencing methods.

Figure 1: Mock aircraft water system constructed at EPA's Test and Evaluation Facility in Cincinnati, Ohio.

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In Phase 2 of the project, a mock up of a Boeing 737 aircraft water system was constructed (Figure 1). The coliform strains isolated and identified in Phase 1 were used to conduct seeding studies in the mock system to understand the possible locations within the aircraft drinking water plumbing system that were susceptible to bacterial colonization. Once the mock system had been contaminated with coliform bacteria, researchers tested the effectiveness of various decontamination procedures used by the air carriers to disinfect any residual coliforms.

Results and Impact

With assistance from the project's air carrier collaborators, 38 positive total coliform samples from 35 different aircraft were received. Most of the positive samples were from lavatories with one sample from a galley location. A total of 161 bacterial isolates were recovered by ORD. The isolated bacteria are commonly found in the environment. Aliquots of these isolates were incubated in sections of the plumbing material that makes up the aircraft water systems (Figure 2), and the ability of the microorganisms to form biofilms (i.e., to stick and grow on the pipe wall) was assessed. The three isolates with the greatest biofilm forming potential were used to inoculate the mock system.

Aircraft water systems are commonly disinfected and flushed using disinfectants such as chlorine dioxide or ozone. These disinfectants, along with a novel mixed oxidant solution, were then used separately to disinfect the mock aircraft water system after inoculation with the coliforms isolated in Phase 1. Results showed that while some of the coliforms colonized water tube sections under laboratory conditions, isolates were not observed to persist on or to colonize water system tubing and fittings in dechlorinated water in the mock system. This suggests that coliforms do not readily form biofilms or persist in airplane drinking water systems. The only place that coliforms were detected after disinfection and flushing were on lavatory faucet aerators when ozone or mixed oxidant solutions had been used for disinfection. Standard aircraft procedures for disinfecting individual aerators (using Glyco-San® [Celeste Inc., Easton, MD] or Lysol® [Reckitt Benckiser LLC, Parsippany, NJ]) were tested. After disinfection, no coliforms were detected on the aerators. Overall, coliforms were not detected on tubing, fittings or in the water phase after disinfection and flushing with chlorine dioxide, ozone or mixed oxidant solutions. The disinfection and flushing procedures with chlorine dioxide and ozone appear adequate when coupled with further disinfection (or replacement) of faucet aerators, which is standard practice for US based commercial air carriers.

Figure 2. Sections of aircraft water system tubing.

The project further investigated how one commercial product called Purogene® (Bio-Cide International, Inc., Norman, OK) performed in the creation of chlorine dioxide (ClO_2). Purogene is a blend of chlorine compounds containing purified sodium chlorite, which, when activated, produces chlorine dioxide. Laboratory scale analyses indicated that, over time, active chlorine dioxide increases significantly. As the concentration of chlorine dioxide increases, chlorite is consumed (Figure 3). Once the active Purogene® is added to water in the aircraft water tank, the reaction degrading chlorine dioxide is quenched such that more active chlorine dioxide is present, but less chlorite is available to maintain the chlorine dioxide concentration.

These data can be used by air carriers to understand how long to let a Purogene® solution activate in order to achieve the appropriate chlorine dioxide concentration in the aircraft water system during disinfection and flushing.

Data from the project was shared with the air carrier community at EPA's 2016 National Aircraft Drinking Water Conference and at the 2016 EPA International Decontamination Research and Development Conference. Results will also be published in the journal *Water Science and Technology: Water Supply* (in-press).

This project allowed EPA Region 6 Aircraft Drinking Water Rule staff to better comprehend the mechanics involved in aircraft water systems. In addition, this RARE project has fostered greater trust between the air carrier industry and EPA offices by allowing EPA's regional and ORD staff to interact with aircraft manufacturers, air carrier maintenance teams, and air carrier environmental staff throughout the research effort.

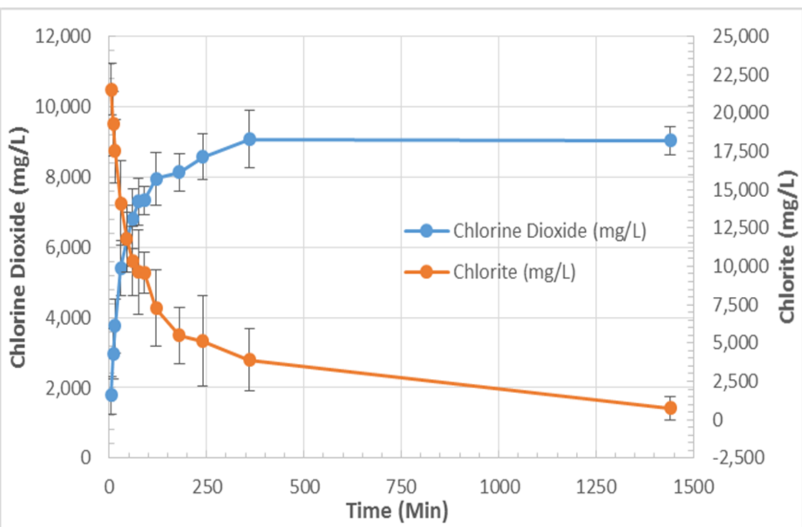

Figure 3: Increase in Purogene® chlorine dioxide concentration and decrease in chlorite over time.

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For more information, go to: https://intranet.ord.epa.gov/regional-science/regional-applied-research-effort-rare

Disclaimer

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