OPPORTUNISTIC ORGANISMS AND THE WATER SUPPLY CONNECTION*

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INTRODUCTION

The heterotrophic bacterial population in drinking water is composed of many transient organisms that never colonize the distribution system, while other associate organisms are more opportunistic, being capable of surviving on minimal nutrients, attachment to pipe sediments and becoming a participant in the developing biofilm. While these bacteria are generally of no public health significance, some opportunistic colonizers of the pipe network may, in addition, become colonizers of the human body through contact with water supply.

Opportunistic pathogens are generally understood to include those organisms which may exist as part of the normal body microflora but under certain conditions cause disease in compromised hosts. Such organisms become particularly invasive to susceptible individuals (elderly, newborns, AIDS victims, cancer patients receiving chemotherapy, burn cases, dialysis patients, trauma patients, and individuals receiving organ transplants). The route of exposure may be ingestion, inhalation or body contact with water supply during bathing, (whirlpool use, dental equipment, etc.) and indoor air climate control devices (humidification, air cooling). The purpose of this presentation is to place the subject in a more realistic aspect relative to management of water supply quality.

OCCURRENCE

Opportunistic pathogen infections are a serious public health threat anywhere there are large numbers of people in close confinement, such as nurseries, pre-schools, summer camps and in particular, hospitals and senior care facilities. At least 5 percent of patients admitted to hospitals acquire nosocomial infections and about 1 percent of the patients die as a direct result (1). Many of these organisms occur in the diverse heterotrophic flora found in water supplies (2-7). In general, these are the organisms that when found in large enough numbers and in the wrong place at the right time, have the potential to cause an infection. Some examples of nosocomial outbreaks associated with contaminated potable water are shown in Table 1.

Heterotrophic bacterial densities in most municipal water supplies are generally below 100 organisms per mL except at static water locations in buildings where densities are often one or two logs higher because of warm ambient temperatures. By contrast, the infective dose levels for a 50 percent attack rate for an opportunistic pathogen in the heterotrophic population, may range up to 10^{10} cells per dose. While the number of cells required to achieve an infective dose by ingestion may seem unlikely to occur often, the volume of water used to take a shower or bath can easily supply this density during a given exposure period.

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*Presented at the AWWA Water Quality Technology Conference, Nov. 12, 1991, Orlando, Florida

By contrast, the density of such opportunistic organisms needed to establish infection in newborn babies, post-operative or immuno-suppressed patients, the elderly and infirm is generally lower than for healthy children and adults.

An additional factor to consider is colonization by these organisms in water attachment devices used in hospitals and clinics. Acinetobacter infections have been associated with the use of ventilator spirometers (24), room humidifiers (25, 26) and moisturized Wright respirometers (27). Serratia marcescens infections have been transmitted via medical solutions (28), and peritoneal-dialysis effluents (30). While such water related systems and equipment may be amplifiers of opportunistic pathogens, the source of these organisms may be the water supply, handling of the device, or airborne contaminants, to name a few. The contribution that water supply plays in the problem has been the subject of two studies on water supply associated bacteria and patient illnesses (11, 31). Both studies suggested that water supply organisms are part of the problem but not necessarily the major source of nosocomial infections in the hospital environment.

Water supply systems in large housing projects, highrise office buildings, hotels, and large public buildings exacerbate the problem of deteriorating water quality as a consequence of static water or infrequent water demands. Static water in building plumbing networks is often at warm water temperatures that stimulate bacterial growth in the accumulated sediments. Even new building plumbing networks may present a problem of deteriorating water quality as a result of construction practices that introduce dust, dirt and excessive solder flux in the lines during pipe assembly. Solder flux can be a nutrient source as well as an attachment site for numerous heterotrophic bacteria. This type of a water quality problem was experienced by a Boston hospital after the acceptance of a new building addition to their facility complex (32). Water entering the hospital lines was of high quality (no coliforms per 100 mL and heterotrophic plate counts averaging 3 organisms per mL). As the staff began to phase in the use of the new building addition, there were numerous complaints of malaise by hospital personnel and the water supply became a prime suspect. Laboratory analyses of the water supply in this new facility revealed no detectable coliforms but heterotrophic bacterial densities ranged from 3,000 to 4,000 organisms per mL. Turning on all faucets throughout the new building for a minimum of 15 hours discharge of building water supply was successful in flushing the contaminants from the plumbing system. The bacterial densities decreased to 15 organisms per mL and by the following day averaged 7 heterotrophic bacteria per mL, thereby achieving a water quality similar to that of the municipal water supply. The ill-defined health complaints of the hospital staff declined following this action response, however, incrimination of the microbial quality of the water supply remained circumstantial.

Building water supply lines and their attachment devices have a significant impact on the microbial quality of water. Long stagnation of public water supply in the warm environment of a building water system encourages various heterotrophic bacteria, including Legionella, to colonize pipe joint packing materials, valve stem seals, vacuum breakers (used in back flow prevention) and faucet aerators (34,35).

Hot water tanks in homes and building water systems attachment devices should not be overlooked as a cause of water quality deterioration in home or care centers. If thermostats on hot water tanks are set below 55°C as an energy conservation measure or to prevent scalding of patients, growth of Legionella may occur in the hot water tank. In such situations legionellae densities may reach infective dose concentrations either in the hot water tank or in an attached shower head (36-41). Most residential hot water tanks are heated from the bottom, near the cold water entrance pipe so the water supply can be quickly heated to above 55°C, however, accumulating sediments at the bottom of the tank provide a heat buffered environment for Legionella colonization. Water in large institutions is often heated by internal steam coils located at mid depth in the tank, thus the cooler water in the bottom may not be heated sufficiently to kill Legionella. Recirculation of the hot water may spread the organisms to all parts of the system.

Cold water storage tanks in highrise buildings must be covered to prevent introduction of contamination from nesting birds and atmospheric dust and to reduce or prevent algae growth. Various heterotrophic bacteria may enter via this route and colonize in the accumulating bottom sediments. Algae may also be introduced by the same routes and proceed to grow in the available light from the open storage tank. Growth in an open water supply tank and subsequent release of algal toxin was the cause of one waterborne outbreak of diarrhea confined to a Chicago apartment building (42).

Increasingly, water utility customers who are dissatisfied with taste, odor or fear the potential health risks alleged to be associated with their municipal water supply are attempting to further refine the water quality at the tap. While treatment devices may be very effective initially in providing aesthetic treatment of the water, their usefulness over time may diminish because of unpredictable service capacity to adsorb a varying mixture of trace contaminants, quality characteristics of water supply and the volume of water processed over time. Poor design of attachment devices may provide recesses that do not drain. Such tiny pools of water become active sites for biofilm development that accelerates in the warm ambient environment and periodically diffuses into the interrupted flows of product water. Another aspect of bacterial proliferation is colonization in devices with carbon filters. While some organisms may pass through the device with little or no retention, others are amplified in these units and bacteria are released at densities higher than those found in the in-coming public water supply. Challenge of carbon filter devices with coliforms, opportunistic organisms and primary pathogens (bacteria anticipated in cross-connections, line breaks or backsiphonage) revealed that such treatment units do not provide an effective barrier. While Escherichia coli, Salmonella and other organisms pass through the filter, other organisms such as Klebsiella pneumoniae, Aeromonas hydrophila and Legionella pneumophila can colonize these devices. As a consequence, devices using carbon filters should not be used on an untreated water supply of questionable quality (43-45).

REPRESENTATIVE ORGANISMS

There is a variety of heterotrophic organisms that can occur in any "safe water supply." They are indeed opportunists in the broad sense, adjusting to a harsh environment and taking advantage of selected sites in the water supply system to colonize. Contacts with breaks in the human body barriers against disease result in a similar pattern of colonization of selected sites that lead to illness if natural defenses prove ineffective. While many heterotrophic organisms in water supply may be capable of colonizing the pipe network, only a few have the potential to be significant opportunistic pathogens. Such is the nature of four candidates among a variety of bacteria, fungi and yeast that are often reported to be waterborne opportunistic pathogens.

Water supply may be significant in the transport of nontuberculous bacteria that pass through treatment barriers in very low densities. Speciation of water supply isolates reveals this group of acid-fast bacteria includes M. fortuitum, M. phei, M. gordonae, M. xenopei, M. kansasii, M. avium and M. chelonae (46-51). The pathological significance of these organisms is that human colonization may occur in the lungs and lymph nodes, or cause skin lesions, septicemia, and cause post-surgery infections. Furthermore, nontuberculous mycobacterial disease is the third most common opportunistic fatal infection in patients with AIDS (46). Waterborne mycobacterial infections present the greatest risk to patients in the hospital setting, particularly those susceptible older individuals that bathe in aerosolized water during the summer months. Extensive searches for the cause of two nosocomial outbreaks of Mycobacterium infection (M. fortuitum and M. gordonae) in different hospitals revealed that these organisms were associated with ice and ice water taken from contaminated ice machines (52, 53).

Nontuberculous Mycobacteria can be isolated from human fecal material (54, 55). These organisms were isolated from 40 percent of stool samples examined from healthy subjects; the mean density was 19 acid-fast organisms per gram of feces (55). Wastes from pig farms also contained Mycobacteria (56) and waste-water effluents were reported to contain an approximate 10^4 organisms per 100 mL (57).

Raw source waters at water supply intakes have been shown to contain acid-fast bacteria (50, 58, 59). Acid-fast bacteria were found in the raw water to the Oakwood, Illinois water treatment plant at a geometric mean density of 271 organisms per liter, while at Decatur, Illinois, raw water densities were approximately one order of magnitude less. Upon passage through treatment, the most significant reductions of acid-fast bacteria occurs during sand filtration. In an 18 month study of these two water systems, reductions in the concentrations of acid-fast bacteria by rapid sand filtration ranged from 59 to 74 percent (60). In the finished water these organisms could be isolated in 36 percent of all one liter samples.

Reported findings of acid-fast bacteria in finished water demonstrate that these organisms are resistant to the usual chlorine disinfectant C•T values applied to inactivate coliforms and viruses (61). Experiments using recent Mycobacterium isolates from chlorinated water supply (M. fortuitum, M. gordonae and M. avium) plus clinical isolates of M. chelonae, M. kansasii and M. intracellulare revealed that chlorine levels of less than 1.0 mg/L may not be adequate for effective inactivation of these opportunistic pathogens (62). Even the presence of a free chlorine residual (<0.2 mg/L) at a low water pH (5.9 to 7.1) did little to reduce acid-fast bacteria in the distribution system. Mycobacterium were also reported to be more resistant than E. coli to inactivation by inorganic chloramines (63) and by ozone (64).

While densities of mycobacteria entering the distribution system may be only a few organisms per liter, this density may change significantly during warm water periods in the static sections of the distribution network. Regrowth may also be intensified in older portions of the pipe network where corrosion is a problem and water pH is elevated to combat corrosivity. The trade-off is less effective disinfectant action of free chlorine at higher pH. Some regrowth was also noted in dead end areas where chlorine residuals disappeared and total organic carbon concentration and turbidity were higher.

Devices attached to building plumbing systems may also be amplifiers of mycobacteria. Mycobacteria are among the first organisms to colonize reverse osmosis membranes used in producing reagent grade water, reuse water systems and medical devices. For example, nontuberculous mycobacteria were detected in water from 95 of 115 hemodialysis centers that reused disposable hemodialyzers (artificial kidneys) for the same patient (65). Increased incidence of patient infections caused by acid-fast mycobacteria prompted an investigation that concluded water was the source of these opportunistic pathogens.

The water tap may also be a source of mycobacteria with the organisms colonizing the sediment accumulations in the device itself. Apparently, the presence of these organisms can invariably be found in scrapings or swabbings from the cold and hot water taps (66). In a study involving three hospitals, M. xenopei was recovered from 61 of 111 pairs of hot and cold water taps, 20 of 74 tap pairs in another hospital, but from only 3 of 61 pairs of taps in the third hospital. Positive findings were more often reported from the hot water tap, an observation which is not surprising since the optimum growth temperature for acid-fast bacteria is 42 to 44°C.

FECAL KLEBSIELLA

The sanitary significance of the klebsiellae group of coliform bacteria can be perplexing. Most of these organisms are of environmental origin without sanitary significance while other strains of the same genus have their source in the intestinal tract of warm-blooded animals (67-69). The genus includes K. pneumoniae, K. oxytoca, K. ozaenae, K. planticola, K. terrigena and K. rhinoscheromatis. Most of these species have been detected in coliform contaminated public water supplies (70-79). K. pneumoniae and K. oxytoca have often been reported to be the predominant organisms in distribution biofilm occurrences. These occurrences in water supply pose the questions: are these klebsiellae of fecal origin; can they be a potential opportunistic pathogen to susceptible individuals in the community?

In response to the first question, approximately 30 to 40 percent of all warm-blooded animals, humans included, have Klebsiella in their intestinal tracts, with individual densities ranging up to 10^8 Klebsiella per gram of feces (70-82). An estimated 60-85 percent of all Klebsiella isolated from feces and clinical specimens were positive in the fecal coliform test were identified as K. pneumoniae (83-86).

K. pneumoniae, particularly antibiotic resistant serotypes, can cause human infections of the respiratory system, genito-urinary tract, nose and throat, and occasionally meningitis and septicemia (87, 88). Klebsiella-caused infection is sometimes of apparent primary etiology, but more often is found in mixed infection or as a secondary invader (89). In the hospital environment, the nosocomial infection rate for pathogenic K. pneumoniae was 16.7 infections per 100 patients from 94 hospitals (90). Klebsiella pneumoniae was the cause of 1.1 percent of all nosocomial hospital deaths during the same period. Infections of the urinary system, lower respiratory tract and surgical wounds were the most frequent cause of Klebsiella associated illnesses or deaths. The lack of evidence of increased illness in a community during a coliform biofilm event may relate to difficulties in gathering reports of water related illness cases among susceptible people at home or in the work environment vs. patients in the hospital setting.

Most of the Klebsiella waterborne occurrences are not of fecal origin. In those infrequent situations where the laboratory analyses reveal fecal Klebsiella in the distribution system, there should be a high priority effort to destroy the colonization sites because of the concern for more frequent releases of this opportunistic pathogen at higher densities into the water supply. Infective dose (ID_{50}) values for environmental and clinical isolates of Klebsiella have been reported to be between 3.5×10^1 to 7.9×10^5 cells per mL (91). Therefore, ingestion of 100 mL of drinking water (approximately one glass of water) containing 3.5×10^1 Klebsiella per mL could present a risk to susceptible individuals. Inhalation of moisture from vaporizers using drinking water contaminated with Klebsiella should also be considered a risk to some individuals.

LEGIONELLA

Legionella pneumophila is an important waterborne opportunistic pathogen that causes Legionnaire's disease in susceptible individuals exposed to contaminated aerosols from shower baths and air conditioner heat exchanges. The respiratory disease results in a complex colonization of the body that is responsible for pneumonia with significant mortality rates among senior citizens. Pontiac fever, another illness caused by legionellae, is a non-pneumonic, non-fatal and self-limiting disease. Apparently, there is no human carrier state or reservoir for legionellae bacteria in warm-blooded animals.

While this group of small, gram-negative bacteria have an absolute nutritional requirement for L-cysteine (92) it is somewhat surprising to find legionellae widespread in the aquatic environment. These organisms have been detected in freshwater streams and lakes in both North America and Europe, plus the tropical waters of Puerto Rico (93-95). In one study of 793 water samples collected from 67 different lakes and rivers throughout the United States, virtually all sources were positive for L. pneumophila, using the direct fluorescent antibody technique for detection (96). There is some indication that legionellae are very infrequently found in groundwater, unless there is some surface water runoff seepage or poor soil barrier protection (97,98).

Water treatment processes may play some role in the development of an ecological niche for Legionella through the release of assimilable organic nutrients, particulates and various heterotrophic organisms into the distribution system as a result of uneven, interrupted or failed treatment processes (99-104). Among the microorganisms in the raw source water that sequester Legionella and provide safe passage through the disinfection process are algae, amoebae and ciliates (105, 106). Airborne legionellae in dust or particulate laden rain showers may find their way to the open air treatment basins. Common pathways for their entry into the distribution system include reservoir air vents, main construction, pipe line repairs, cross-connections and back-siphonage (107).

Establishment of Legionella in the distribution system is most likely to occur in biofilm locations where symbiotic relationships with other heterotrophic bacteria (Flavobacterium breve, Pseudomonas, Alcaligenes, or Acinetobacter) provide the critical nutrient requirements necessary for long term persistence of this opportunistic pathogen (108-110). Many of these sites will be found at the periphery of the system (long pipe runs into dead ends) and in little used service connections throughout the pipe network where the water can stagnate. Densities of Legionella may be only a few cells per liter in water supply (105-106) and the mere presence of these few Legionella in drinking water does not pose a direct health threat until there are opportunities for amplification (hot water tanks, shower heads, water evaporator cooling devices, etc.).

Efforts to eliminate low levels of these organisms (a few per liter) in water supply treatment processes and in the distribution system network are not cost-effective. Water utility operations, however, can minimize regrowth potential through good housekeeping practices that include removal of scums and biofilm accumulations at air-water interfaces in treatment basins, connecting flumes and attachments to agitator paddles in flocculation basins. System-wide flushing with particular emphasis on dead end sections during warm water periods, will significantly suppress further development of biofilm and introduce detectable disinfectant residuals to those areas where Legionella and other heterotrophic bacteria may persist. The net effect desired is to suppress microbial symbiotic relationships that are essential to Legionella metabolism.

PSEUDOMONAS AERUGINOSA

Pseudomonas species are ubiquitous bacteria that are able to flourish in a wide variety of habitats (surface waters, aquifers, sea water, soils and vegetation). Some pseudomonads are among the prominent denitrifiers while others grow prodigiously in and on tertiary treatment devices such as reverse osmosis and electrodialysis membranes and in sand or carbon filtration beds. Pseudomonads reported in some drinking water supplies include: P. aeruginosa, P. cepacia, P. fluorescens, P. mallei, P. maltophilia, P. putida and P. testosteroni (111,112). Perhaps the most significant species of concern in drinking water is P. aeruginosa. To this list can be added: P. stutzeri, P. diminuta and P. acidovoran which have been found in bottled waters at densities ranging from 10^3 to 10^5 organisms per mL (113-115). These organisms metabolically adapt to survive on minimal nutrient concentrations typical of protected aquifers and treated drinking water.

The ability of P. aeruginosa to rapidly colonize a variety of environments, including the susceptible human, makes it a major opportunistic pathogen; particularly P. aeruginosa serogroups 11 and possibly serogroup 9 which are the most frequently isolated pathogenic strains. Bacteremia attributable to Pseudomonas has become a major concern in the management of trauma as well as in the management of susceptible patients recovering from burns, intensive surgery and others exposed to cancer therapy (116-120). Other serious infections for susceptible individuals involve eye, ear, nose, and occasionally the gastrointestinal tract (121, 122).

The infrequent occurrence (3-19 percent) of Pseudomonas in the human intestinal tract (123) suggests that colonization of the gastrointestinal system rarely occurs in healthy adults, indicating that there are potent host-defense mechanisms against this group of gram negative bacteria (124, 125). Since municipal sewage contains a mixture of domestic wastes, industrial discharges and intermittent stormwater runoff, it is not unexpected to find P. aeruginosa in 90% of sewage samples (126). Densities of P. aeruginosa in surface waters receiving waste and stormwater discharges may range from 1×10^0 to 1×10^4 cells per 100 mL, and are influenced by available nutrients and seasonal water temperatures (127).

P. aeruginosa found in a contaminated water supply has been linked to one waterborne outbreak that occurred in a newborn nursery (128). In this case study, the ground water supply was contaminated by seepage of sewage and infiltration of contaminated surface water. Since P. aeruginosa is the most prevalent Pseudomonas in human disease (129) its occurrence has been limited to less than one organism in 250 mL of bottled drinking water by the European community. Other Pseudomonas species found occasionally in water (P. fluorescens, P. putida, P. multivorans, P. maltophilia and P. stutzeri) have not yet been linked to waterborne outbreaks suggesting they are indigenous aquatic bacteria in every water environment.

JOINT RESPONSIBILITY FOR WATER QUALITY

Fulfilling the obligation for the production, delivery, and maintenance of high quality water supply to the consumer is the joint responsibility of the water utility and the user community of hospitals, highrise building complex management and the individual family. Water quality is created at the water plant and is a reflection of treatment operations and distribution system maintenance and management. While treatment technology will provide a water free of health risks associated with primary pathogens, treatment processes were never intended to produce a sterile water supply. Opportunistic organisms will pass through or circumvent treatment barriers as now defined. Some of these pathways include passage of dust contaminants into open air process basins, organism protection in clumping, viable cell transport by aquatic invertebrates, movement with carbon fines, or unsettled particulates and infiltration through fractured pipes, line breaks and line repair practices.

WATER UTILITIES

Opportunistic organisms are very adaptable in establishment of a biofilm colonization that promotes the amplification of cell densities to levels that may be several logs higher than the initial levels. In treatment basins, colonization occurs at the solid surface-water interfaces of process basins and connecting flumes and agitator paddles in the coagulation basin. This problem is best controlled by scheduling application of high pressure washing of compartment walls and mechanical scraping of paddle surfaces. Colonization in the distribution system may occur in the slow flow and dead end sections of the pipe network, and on the walls and in the accumulated sediments of water storage tanks. Static water locations in the pipe system and stratified water in storage tanks promotes colonization by a variety of bacteria during warm water periods.

The key to suppressing colonization is to keep the water moving throughout the system and to remove accumulating pipe sediments. Flushing that is done at least every Spring in a systematic fashion from water plant to end of the pipe network often contributes to control of biofilm incursions. Draining and cleaning of all water storage tanks and standpipes may be more difficult to manage but nevertheless should be done as frequently as possible to suppress biofilm growth at these sites. For water utilities that use chloramination as the post-disinfectant, it may be desirable to change to free chlorine for a two week period each year to effectively reduce chloramine resistant heterotrophic bacteria population in biofilms.

HOSPITALS

Hospitals also have a responsibility in the management of water supply quality. The entire pipe network needs to be flushed every six months because this water is always in a warm environment regardless of seasonal weather changes. Flushing in this case needs to be done at each faucet throughout the facility for a 15 minute period or until a measurable disinfectant residual is obtained. Attachment devices must also be disassembled and cleaned of incrustations and sediments before reassembly. Flexible hose connections should be replaced at this time as well as any gaskets and washers that have visible slime growth or incrustations. Prior to the activation of a new hospital wing or reactivation of closed patient wards or operating theaters, all faucets should be opened for 24 hours to flush out the stagnate water and sediments in an effort to achieve water supply that is representative of public water supply quality.

BUILDING MANAGERS

Highrise buildings also have complex water supply networks that are subject to quality changes. Water supply tanks in apartment buildings, office buildings and hotels should be flushed and cleaned each year. Unoccupied apartments, office space and hotel rooms vacant for 3 months or more may have a significant deterioration in the water quality in the static service lines. Flushing overnight from each water tap in the vacant rooms will restore water quality which is characteristic of the building supply.

INDIVIDUAL CONSUMERS

Consumers must also be aware of their responsibility to protect the public water supply in their home. Perhaps the most common problem with static water quality is in the first draw of water supply in the morning. Microbial growth will occur in the water during overnight periods of no flow due to warm ambient temperatures associated with proximity to furnace pipes, hot water lines and under the sink locations. As a general practice, it is a good habit to flush the tap water line for 30 seconds each morning before ingesting that first glass of water. If the family has been away on an extended vacation, again flushing water lines from the bathroom and kitchen taps for several minutes will do much to remove higher bacterial densities in static water lines. For families that attach point-of-use devices to the water supply line for additional treatment, there should be a scheduled effort to change carbon filters every 4 to 6 weeks, depending on usage, or as recommended by the manufacturer. Morning flush of these devices is very important because of the microbial build-up in the unit overnight that often exceeds what occurs in static water at other home faucets.

SUMMARY

Organisms that become established in water supply may also be opportunistic pathogens. Representative opportunistic pathogens that are waterborne include acid-fast bacteria, fecal klebsiellae, Legionella and Pseudomonas aeruginosa. These organisms may be found in the heterotrophic bacterial population of treated drinking water and if appropriate conditions exist, may colonize and become part of the biofilm.

Maintaining a high quality water supply requires careful treatment and a clean water distribution system. Users of the community water supply also have a responsibility to preserve this water quality from deterioration as it leaves the service meter and traverses the building supply lines. The goal is to minimize exposure to various heterotrophic bacteria that may pose a risk to those consumers of varying health status in the community of people.

Table 1. Documented Nosocomial Outbreaks Associated With Contaminated Potable Water*

Etiologic Agent	Illness	Reference
Pseudomonas	Wound	Cross, et al. (9)
	Wound	Bassett, et al. (10)
	Dermatitis	Highsmith, et al. (11)
	Meningitis	Ho, et al. (12)
	Respiratory	duMoulin, et al. (13)
	Respiratory	Saepan, et al. (14)
	Cellulitis	McGuekin, et al. (15)
Acinetobacter	Peritonitis	Abrutyn, et al. (16)
Mycobacterium	Septicemia	Carson, et al. (17)
	Bacteremia	Bolan, et al. (18)
	Peritonitis	duMoulin and Stottmeir (19)
Flavobacterium	Septicemia	Herman and Himmelsbach (20)
	Respiratory	duMoulin, (21)
Legionella	Respiratory	Cordes, et al. (22)
Klebsiella	Urinary, Respiratory	Kelly, et al. (23)

*Information adapted from Highsmith, et al. (8)

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TECHNICAL REPORT DATA

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1. REPORT NO.	2.	3.
EPA/600/A-92/094		

4. TITLE AND SUBTITLE	5. REPORT DATE
Opportunistic Organisms and the Water Supply Connection	
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Edwin E. Geldreich	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Risk Reduction Engineering Laboratory-Cincinnati, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED Published Paper
Risk Reduction Engineering Laboratory-Cincinnati, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268	14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES PO = Edwin E. Geldreich (513)569-7232, Technology Conference Proceedings, Part II, Sessions EB Through ST6, AWWA Water Quality Technology Conf, 11/10-14/91, Orlando, Florida, P:823-842

16. ABSTRACT

Organisms that become established in water supply may also be opportunistic pathogens. Representative opportunistic pathogens that are waterborne include acid-fast bacteria, fecal klebsiellae, Legionella and Pseudomonas aeruginosa. These organisms may be found in the heterotrophic bacterial population of treated drinking water and if appropriate conditions exist, may colonize and become part of the biofilm.

Maintaining a high quality water supply requires careful treatment and a clean water distribution system. Users of the community water supply also have a responsibility to preserve this water quality from deterioration as it leaves the service meter and traverses the building supply lines. The goal is to minimize exposure to various heterotrophic bacteria that may pose a risk to those consumers of varying health status in the community of people.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pseudomonas aeruginosa	opportunistic pathogens heterotrophic bacteria water supply quality Fecal Klebsiella Acid-fast bacteria Legionella	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	22
	20. SECURITY CLASS (This page)	22. PRICE
	UNCLASSIFIED	

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