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CONTROL OF LEGIONELLA IN PLUMBING SYSTEMS

Health Advisory
Office of Drinking Water
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The Health Advisory (HA) Program, sponsored by the Office of Drinking Water (ODW), provides information on the health effects, analytical methodology and treatment technology that would be useful in dealing with the contamination of drinking water. Most of the Health Advisories prepared by the Office of Drinking Water are for chemical substances. This Health Advisory is different in that it addresses contamination of drinking water by a microbial pathogen and examines pathogen control rather than recommending a maximum allowable exposure level. Thus, for a variety of reasons, the format and contents of this Health Advisory necessarily vary somewhat from the usual Health Advisory document.

Health Advisories serve as informal technical guidance to assist Federal, State and local officials responsible for protecting public health when emergency spills or contamination situations occur. They are not to be construed as legally enforceable Federal standards. The HAs are subject to change as new information becomes available.

This Health Advisory (HA) is based upon information presented in the Office of Drinking Water's Criteria Document (CD) for Legionella. Individuals desiring further information should consult the CD. The CD is available for review at each EPA Regional Office of Drinking Water counterpart (e.g., Water Supply Branch or Drinking Water Branch), or for a fee from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161, PB # 86-117843/AS. The toll-free number is (800) 336-4700; in the Washington, D. C. area: (703) 487-4650.

INTRODUCTION

Legionellae are bacteria that have been identified as the cause of legionellosis. Based upon an attack rate of about 1.2 cases of legionellosis per 10,000 persons per year (Foy et al., 1979), it has been estimated that more than 25,000 cases of this disease occur annually within the United States, and are caused primarily by one of the 23 currently recognized species of the genus Legionella. Most people who have developed Legionnaires Disease, the pneumonia form of legionellosis, were immunosuppressed or appeared to be more susceptible because of an underlying illness, heavy smoking, alcoholism, or age (more than 50 years old). In contrast, while some apparently healthy individuals have developed Legionnaires Disease, outbreaks involving healthy people have been limited mostly to the milder non-pneumonia form of the disease called Pontiac Fever.

Legionellae are widespread in lakes and rivers (Fliermans et al., 1979, 1981). There is some indication that these organisms may be either very sparse or absent in groundwater (Fliermans et al., 1982; Spino et al., 1984). Spino et al. (1984) was unable to isolate legionellae after aeration of groundwater through a redwood-slat aerator. The possibility that humans may be exposed transiently to legionellae because of their high rate of contact with water is highly probable, given the high frequency of seropositivity to legionellae in healthy populations (Wentworth et al., 1984) and the widespread occurrence of legionellae in water environments.

In a number of outbreaks of legionellosis that have occurred in the United States, aerosols of water documented to contain the specific type of legionellae that was recovered from the patient have been identified as the vehicle for transmission (Cordes et al., 1981; Stout et al., 1982; Garbe et al., 1985). It has been hypothesized that legionellae enter buildings in very low numbers via the treated drinking water. These bacteria may proliferate in warm water when factors not yet fully determined allow them. Even when this occurs, as has been shown in numerous buildings, disease usually does not result. Cases and outbreaks of legionellosis occur only when aerosols containing legionellae possessing specific virulence factors (not as yet determined) are inhaled (possibly ingested) by susceptible individuals. Foodborne outbreaks or secondary spread have not been reported.

This Health Advisory discusses the control of legionellae in drinking water. This includes finished water at the treatment facility, the distribution system, and plumbing systems. Plumbing systems include hot water tanks, taps, showerheads, mixing valves, the faucet aerators, all of which have been associated with the proliferation of legionellae. This guidance does not discuss legionellae control for whirlpools, respirators, or heat-rejection equipment such as cooling towers and air conditioners. These have all been associated with cases of Legionnaires Disease.

Presence of Legionellae in the Distribution System and Plumbing Systems

Legionellae are found in raw water, in treated waters, and in plumbing systems (Fliermans et al., 1981; Hsu et al., 1984; Witherell et al., 1984), but the occurrence and fate of these organisms in the distribution system between these points are unknown. The organism may survive the treatment and disinfection process and pass intact through the distribution system. In addition, opportunities exist for their introduction into the system by means of broken or corroded piping, repair of existing mains, installation of new mains, back siphonage and cross connections, any of which may result in contamination of the water supply. In older distribution systems, especially those dependent on gravity flow, deterioration of piping may be so severe that the treated water comes in intimate contact with soil and is subject to infiltration by surface water. Thus, legionellae may be introduced into potable water by these routes.

Legionellae surviving initial water treatment may colonize pipe joints and corroded areas or adhere to the surface or sediment of storage tanks, especially those constructed of wood. Here, they may find a habitat suitable for survival and growth (Engelbrecht, 1983). Cul-de-sacs, intermittently used storage tanks and other sites in which waterflow is absent or restricted also may be appropriate habitats for legionellae.

New distribution systems or their components that were not appropriately cleaned and disinfected before being put into use may introduce legionellae into the system. Although this has not been documented, it may not be coincidence that some of the serious outbreaks of Legionnaires Disease have occurred in newly-opened institutions or buildings (Haley et al., 1979; Marks et al., 1979; Helms et al., 1983). Construction activities may have included intervention into the water supply mains with introduction of contaminated water or, possibly, disturbance of sediment and sloughing of scale bearing high concentrations of legionellae by means of hydraulic shock or other perturbations.

There are numerous reports of legionellae occurring in plumbing systems, especially in hot water systems. Most of these investigations have been carried out in hospitals, and many were prompted by outbreaks of nosocomial (hospital-acquired) Legionnaires Disease. The primary reservoirs in hospitals are apparently hot water tanks in which water is maintained at temperatures below 55°C. Legionellae also have been found in showerheads, rubber fittings, aerator screens, faucet spouts, and other plumbing fixtures. This group of organisms has also been found in residential plumbing systems such as apartment buildings and homes (Wadowsky, 1982; Arnow and Weil, 1984), but disease has not been associated with these findings.

Control at the Water Treatment Facility

Only a few studies have been published on the effectiveness of various types of treatment for eradicating or reducing legionellae numbers at the water treatment utility. In one study, Tison and Seidler (1983) examined raw water and three kinds of distribution water supplies: (1) those treated by chlorine (free residual 0.2-0.6 mg/L); (2) those treated by sand filtration and chlorination (free residual 0.0-0.4 mg/L); and (3) those treated by flocculation, mixed media filtration, and chlorination (free residual 0.5-2.0 mg/L). *Legionella* were enumerated by direct fluorescent antibody (DFA) tests and all distribution waters contained about one order of magnitude fewer *Legionella*-like cells than did the raw waters, i.e., 10^3-10^4 per liter. While the evidence suggests that legionellae are common in treated water, the significance of these results is questionable because the authors were unable to isolate any legionellae by animal inoculation or culture procedures, and there are uncertainties about the specificity of the DFA technique used for legionellae detection.

Most water treatment plants in the United States use chlorine disinfection. Although extrapolation of laboratory studies to treatment plant situations is somewhat tenuous, Kuchta et al. (1983) reported that both *L. pneumophila* and *L. micdadei* (laboratory-adapted environmental and clinical strains) were much more resistant to chlorine than was *Escherichia coli*. At 21°C, pH 7.6, and 0.1 mg/L of free chlorine residual, a 99 percent kill was achieved in less than one minute for *E. coli* compared to 40 minutes for *L. pneumophila*. Under the same conditions, 0.5 mg/L of free chlorine resulted in a 99.9 percent legionellae kill in about 5 minutes. The contact time for a 99 percent kill of *L. pneumophila* at 4°C was twice as long as it was at 21°C. The authors concluded that legionellae can survive low levels of chlorine for rather long periods of time. In a subsequent study, Kuchta et al. (1984) compared agar-passaged (laboratory-adapted) and tap water-grown strains of *L. pneumophila* with respect to chlorine resistance, and showed that the latter were considerably more resistant. At 0.25 mg/L free residual chlorine, 21°C, and pH 7.6-8.0, a 99 percent kill of agar-passaged *L. pneumophila* was usually achieved within 10 minutes, compared to 60 to 90 minutes for tap water-maintained strains. These data suggest that normal chlorination practices at treatment facilities may not control legionellae.

In contrast to these data, Hsu et al. (1984) reported that survivals of L. pneumophila and E. coli in various concentrations of chlorine were similar. In an in vitro study, laboratory-adapted strains of L. pneumophila Flint 1 serogroup 1 and E. coli B were inoculated into several dilutions of sodium hypochlorite in sterile tap water, and incubated at 24°C. At 0.2 mg/L residual chlorine, about an order of magnitude reduction occurred in two hours for both organisms. Neither organism could be recovered after two hours at concentrations equal to or exceeding 2.0 mg/L. The pH values were not reported. The reason for the discrepancy between this study and the Kuchta et al. (1983, 1984) studies may be due to strain or pH differences.

Control of Legionellae in Plumbing Systems

Chlorine and Heat

Studies on controlling legionellae in plumbing systems have examined primarily the effectiveness of heat and chlorine. The results of several of these are described below.

In an attempt to eradicate L. pneumophila from showers in a transplantation unit experiencing cases of Legionnaires Disease, Tobin et al. (1980) emptied the hot and cold water tanks and filled them with water containing 50 mg/L free chlorine. After three hours, this process was repeated. Shower fittings were removed and held at 65°C for 18 hours before replacement. Legionellae were not isolated from the shower samples after six months, but were found again at nine months.

Massanari et al. (1984) controlled a nosocomial outbreak of L. pneumophila infection by shock chlorination (15 mg/L) of both hot and cold water supplies for 12 hours. The system then was flushed and the hot water temperature raised from 41°C to 64°C for 41 days. These measures significantly reduced the frequency of positive cultures, but 3/35 of the outlets were still positive. Thereafter, a continuous-flow proportional chlorination unit was installed that provided free chlorine levels of 8 and 7.3 mg/L in hot and cold water, respectively. During the first 16 months of its use, virtually no samples (N=355) contained L. pneumophila and no new cases of legionellosis were identified. The few positive samples were obtained from rooms which had been vacant for at least 32 days. In this hospital, water is distributed in copper pipes.

Baird et al. (1984) hyperchlorinated their hospital water supply at a constant level of 4 mg/L of free chlorine. The rate of nosocomial Legionnaires Disease decreased by almost two-thirds and the total numbers of legionellae decreased, but the organisms persisted.

Witherell et al. (1984) attempted to eradicate L. pneumophila in hospital plumbing by adding chlorine to the cold water make-up that supplied the hot water heating system, in proportion to the water demands on the system. This was to avoid corrosion damage resulting from constant feed chlorination units during periods of low demand. A free chlorine residual of 3.0 mg/L was maintained in the hot water system for 10 days and then reduced to 1.5 mg/L. The organism was not detected by direct culture methods subsequent to disinfection. The corrosivity of the hot water increased slightly (Langelier index = -0.3).

Fisher-Hoch et al. (1981) used hypochlorite to obtain a level of 1-2 mg/L of free chlorine at all cold water outlets in Kingston Hospital where legionellae were present in both cold and hot water. The free chlorine levels in the hot water could not be maintained above 0.2 mg/L and legionellae were recoverable at this level. The water temperature was 45°C, which was warm enough to volatilize the chlorine and cool enough to allow growth of legionellae. Eradication was accomplished successfully by maintaining the hot water temperature at 55°-60°C, in addition to disinfection of cold water. Subsequently, these investigators reported that when a disconnected hot water tank containing stagnant water was turned on again, L. pneumophila was found in the water and a case of nosocomial Legionnaires Disease occurred (Fisher-Hoch et al., 1982). A second disconnected tank which had been drained incompletely contained a thick brown liquid deposit at the bottom. This deposit contained 5.4×10^8 L. pneumophila/L. Filling the second tank with water containing 50 mg/L of chlorine for 24 hours followed by descaling did not successfully eliminate the legionellae. Maintaining a constant water temperature of 70°C throughout the tank for 1 hour, however, eliminated the organism. Ciesielski et al. (1984) also noted that legionellae can proliferate in stagnant water inside hot water tanks.

Dennis et al. (1982) examined water samples from the plumbing of 52 hotels, none of which was associated with cases of legionellosis. Ten isolates of L. pneumophila were obtained from water samples from eight hotels. Seven of these were from hot water taps or hot-cold mixer showers with water temperatures ranging from 40° to 54°C at the time of sampling. Evidence that these temperatures are not sufficient for Legionella control was also provided by Meenhorst et al. (1983). In their study, guinea pigs exposed to aerosolized legionellae from contaminated hot tapwater (48°C) contracted pneumonia. The strain of L. pneumophila used was isolated from a series of patients in the Netherlands.

Beam et al. (1984) attempted to control legionellosis outbreaks in two state development centers for the severely handicapped. In one center, hot water tanks that were positive for legionellae were heated to 71°C for 72 hours, followed by flushing for 15 minutes. Because of legionellae regrowth, a monthly heating schedule was established. Subsequently, the chlorine level was raised from 0.5 mg/L to 2 mg/L. This approach was successful in eradicating legionellae from water sources, but this chlorine level caused leaching from the iron pipes and consequent discoloration of the water, and was thus discontinued. Cement liners were installed in the hot water tanks and the first samples were positive for legionellae. The water temperature was not reported. Soon after, an outbreak of legionellosis occurred.

Plouffe et al. (1983) examined the relationship between the presence of L. pneumophila in potable water, nosocomial Legionnaires Disease, and hot water temperatures in six buildings. L. pneumophila was found in the hot water of all four buildings in which hot water was maintained at 43-49°C

(110°-120°F), and nosocomial Legionnaires Disease was found in three of these buildings. No organism and no disease was found in the two buildings where hot water was maintained at 57-60°C (135°-140°F). When the plumbing system of one of the buildings experiencing both L. pneumophila and Legionnaires Disease was flushed with 71°C water and the hot water then maintained at 57-60°C, no L. pneumophila and no new cases of Legionnaires Disease occurred for at least six months. The authors concluded that colonization and nosocomial Legionnaires Disease can be prevented by maintaining the hot water at 57-60°C.

In another attempt to eradicate L. pneumophila and nosocomial Legionnaires Disease, Yu et al. (1982) raised the temperature in the hot water storage tanks from 45° to 60°C for 72 hours and flushed 50 showers and 360 faucets for 20 minutes with the 60°C water to eliminate the organism from the sediment. A substantial reduction in counts occurred. After three months, colony counts increased rapidly from four colonies/mL to over 300 colonies/mL and nosocomial Legionnaires Disease again appeared. The authors concluded that a periodic schedule of short-term temperature elevation of the hot water system may control nosocomial Legionnaires Disease.

Stout et al. (1986) tested 75 legionellae isolates for their ability to withstand high temperatures. Tubes containing buffered yeast extract broth, sterile water, or hot water tank water plus sediment were inoculated and placed in 60°C, 70°C or 80°C water baths. At 60°C, four minutes were required for a one log reduction of L. pneumophila in the water plus sediment tube. Approximately 25 minutes were required at this temperature to sterilize a suspension of L. pneumophila which contains 10^8 colonies/mL. The authors recommend that when flushing distal outlets, that a flush temperature exceeding 60°C should be maintained for at least 30 minutes.

Muraca et al. (1987) compared the relative efficacies of heat (60°C), ozone (1-2 mg/L), UV (30,000 uW-scm^2 at 254 nm) and hyperchlorination (4-6 mg/L) to eradicate L. pneumophila in a model plumbing system. Non-turbid water at 25°C and 43°C and turbid water at 25°C were tested. When samples were taken of the circulated water, a 5-log kill of a 10^7 bacteria/mL concentration was achieved with all treatments within six hours. However, it is noteworthy that heat completely eradicated the Legionella in less than three hours, whereas UV light had produced its 5-log decrease in 20 minutes and no further inactivation was seen during the six-hour observation period. Chlorine and ozone required five hours to effect a similar 5-log decrease and chlorine achieved complete eradication only in the non-turbid samples during the six hours, while ozone killed the organisms in both turbid and non-turbid water in four to five hours.

Ozone Treatment

Edelstein et al. (1982) used ozone in an attempt to eradicate legionellae from the potable water supply of an unused wing of a hospital that was known to be contaminated with bacteria. The results were inconclusive because the organisms were eliminated from both the experimental wing and the control wing that was untreated. The latter was thought to be due to excess mechanical flushing and an unexpected rise in the chlorine content of the main water supply. The in vitro susceptibility of L. pneumophila to ozone was on the order of 0.36 mg ozone/L, but was not consistent. The ozone mean residual concentration used in the hospital water system was 0.79 mg/L.

Ultraviolet Radiation Treatment

Antopol and Ellner (1979) reported that 90 percent of L. pneumophila cells in distilled water were killed by 920 microwatt-sec/cm^2 of UV radiation. This could be compared with exposures ranging from 2,100 to 5,000 microwatt-sec/cm^2 for killing of E. coli, Salmonella, Serratia and Pseudomonas. If the latter values were obtained under the same conditions as those used for L. pneumophila, it would indicate that legionellae may be more than twice as susceptible to UV radiation than are the other organisms.

Gilpin (1984) reported laboratory and field experiments using UV radiation to inactivate Legionella spp. in standing and recirculating water systems. Times of exposure to one microwatt/cm^2 of UV radiation to produce 90 percent killing of six species of Legionella ranged from 17 to 44 minutes. A commercial UV apparatus killed 99 percent of the organism in less than 30 seconds in a three-liter recirculating water system.

In addition, Knudson (1985) reported that when agar plates seeded with L. pneumophila were exposed to 240 microwatt/cm^2 for 25 seconds or less, a reduction of six to seven orders of magnitude was observed. However, when UV-irradiated legionellae were exposed to indirect sunlight for 60 minutes, the recovery rates were two orders of magnitude greater than those not exposed to sunlight, due to photoreactivation.

Ethylene Oxide Treatment

Cordes et al. (1981) sterilized Legionella-contaminated showerheads with ethylene oxide but they were soon recontaminated.

Design of Hot Water Tanks

Legionellae often have been reported in hot water tanks, particularly in the bottom sediment. The design of these tanks is important in the control of these bacteria. Most residential hot water tanks are heated from the bottom near the cold water entrance pipe and are more likely to maintain a bottom temperature high enough (>55°C) to prevent growth of legionellae. However, if thermostats in homes have been set low (<55°C) as an energy conservation measure, growth of legionellae may result. Thermostats for hot water heaters in hospitals and other health care facilities are usually set at lower temperatures in conformity with the recommendations of the Joint Commission on Accreditation of Hospitals that the water temperature be "safe" (JCAH, 1985). This practice, which is done to prevent scalding of patients using the hot water, may promote the growth of legionellae. Larger institutional tanks also are heated more often by internal steam coils or by other heaters located midway from top to bottom of the tank. The water at the bottom may not be heated sufficiently to kill legionellae. Periodic partial draining of these tanks from the bottom to eliminate sediment may control legionellae proliferation. This is especially important, since environmental microflora in the sediment are known to produce metabolites, possibly including cysteine, which stimulate legionellae growth (Stout et al., 1985). Removal from other areas of the plumbing system where water stagnates may also prevent or control legionellae growth (Stout et al., 1985).

Type of Water Fittings

Information on the specific types of gaskets and fittings that support the colonization of legionellae is not well documented. One study of water fittings as sources of L. pneumophila in a hospital plumbing system was carried out by Colbourne et al. (1984a, 1984b). In well-controlled experiments, L. pneumophila was isolated from rubber washers and gaskets, but not from fiber or plastic fittings. The ability of the bacteria to multiply when in contact with the rubber fittings was demonstrated. When the rubber fittings were replaced with plastic fittings, L. pneumophila could not be isolated up to one year later. The authors concluded that shower and tap fittings that support growth of legionellae provide habitats protected from chlorine and heat. These foci may be seeded constantly or intermittently with legionellae from hot water tanks or other amplifiers within the distribution system.

When to Control Legionellae in Plumbing Systems

Legionellae are often found in the plumbing systems of hospitals which have not experienced any cases of Legionnaires Disease. One reason may be that some strains are more virulent than others. Currently, there is no practical method for distinguishing the virulent strains from avirulent strains. For this reason, some experts feel that the mere presence of legionellae in the absence of the disease is not sufficient grounds to undertake control measures (Jakubowski et al., 1984). They believe that health care institutions should focus initially on surveillance for respiratory illness, especially in high risk patients, rather than to control legionellae in plumbing systems. If nosocomial legionellosis is identified and environmental strains match patient isolates, then control in plumbing systems is indicated.

In contrast, Edelstein (1985) states that most authorities would probably agree that disinfection of a contaminated site is indicated when:

- it is implicated as a source of an outbreak of Legionnaires Disease or Pontiac Fever;
- it is present in a hospital ward housing especially high-risk patients, such as an organ transplantation unit, regardless of epidemiological findings; in this case, selective decontamination of certain ward areas may be feasible; and when
- it is found in a building which has not been used for some time and in which the water has stagnated.

Because of the virulence of some of these strains and the fact that at least 25,000 cases/year or more occur in the U.S., a stronger preventive approach could also be supported.

In summary, there is no consensus on when measures should be undertaken to control legionellae in the plumbing system of health care institutions. Once virulence factors can be identified and virulent strains differentiated from avirulent strains, routine monitoring of the plumbing system may become more practical.

Until then, the Office of Drinking Water recommends that, on the basis of the high incidence and mortality rate, health care institutions consider preventive measures for the control of legionellae in their plumbing systems. These measures could also control other opportunistic pathogens in the system which might cause nosocomial infections.

Summary

Legionellae are abundant in ambient water, and may survive water treatment, especially since they are relatively resistant to chlorine. Once in the treated water, they then pass, probably at low levels, through the distribution system. It is also possible that legionellae enter the distribution system through broken or corroded piping, repair of existing mains, installation of new mains, back siphonage, and cross connections. When legionellae enter hot water tanks, they settle to the bottom and, under certain circumstances, will proliferate. If they proliferate, plumbing fixtures such as aerators, water fittings, and showerheads may be seeded, resulting in colonization and growth at these sites.

Inhalation of aerosolized potable water has been suggested from outbreak investigations as a primary route of infection, although ingestion is also a possibility. The most susceptible individuals are those with underlying diseases, especially those involving immunosuppression therapy. In several outbreaks, however, apparently healthy individuals have developed legionellosis. Other risk factors include alcohol abuse, surgery and smoking.

In order to reduce legionellae levels in drinking water, the presence of organic matter and growth of algae and protozoa should be minimized in storage reservoirs. Moreover, newly-repaired or constructed components of the water distribution system should be flushed thoroughly and disinfected before being put into operation. Even after flushing and disinfection, one cannot assume legionellae have been controlled, since design factors in the distribution system may impede the efficiency of these measures.

In order to control legionellae growth in hot water plumbing, several approaches may be considered. Most of the published data have examined the effectiveness of chlorine and/or heat. The maintenance of free chlorine has been found effective for controlling legionellae. Shock chlorination also is effective, but unless free chlorine is maintained within a system, the organism may reappear. Control probably can be achieved if free chlorine levels in the hot water are maintained at 8 mg/L, but at this level corrosion of pipes may occur. In some cases, control may be achieved at 1.5-2 mg/L free chlorine. Undoubtedly, the level of chlorine found effective will depend, in part, on the design criteria of the plumbing system. A pertinent facet in controlling legionellae is the difficulty of controlling batch chlorination and of maintaining a chlorine residual in hot water. This problem can be minimized by using a continuous-flow proportional chlorinator in the hot water system.

Heat shock may eradicate legionellae in hot water tanks, if the temperature at the bottom of the tank is maintained at 70°C for one hour, but this is a temporary measure which must be done routinely to be effective. Maintenance of hot water at 55°C or higher apparently controls the organism, while lower temperatures may not. If legionellae are controlled by heat, care must be taken to prevent scalding of persons using the water, especially in health care institutions.

Disinfection of a plumbing system by heat treatment or chlorine treatment alone may not be as effective as a combination of the two. For example, growth of legionellae may theoretically be enhanced on the cold water side of a hot-cold water mixing valve in a heat-treated plumbing system, a location where chlorine may be effective.

Effective disinfection of legionellae by ozone, ultraviolet radiation or ethylene oxide has not been demonstrated by field tests.

In addition to chemical and heat disinfection, other procedures may be effective in controlling legionellae. Hot water tanks should be designed to give uniform temperatures throughout. Hot or cold water tanks used intermittently should be disconnected from the system, drained, flushed, and disinfected before being reconnected. Hot water tanks should be drained regularly or at least bled to remove accumulated sludge that may serve as a substrate for growth of legionellae and other microorganisms. Taps and showers in unused areas of health care facilities should at least be flushed before patients are exposed to them. Finally, faucet sieves and aerators, and rubber washers and gaskets in the plumbing system should be used with caution, especially in institutions housing physically compromised individuals and where hot water is maintained at temperatures lower than 55°C.

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