Facilitating supplemental disinfection for *Legionella* control in plumbing systems

Slight changes to the way supplemental disinfection is currently regulated could lead to reductions in legionellosis and other diseases without a significant impact on other important drinking water quality parameters.

Regrowth of microorganisms is a common occurrence in treated water in distribution. The significant concern is that certain of those microorganisms, including *Legionella pneumophila*, are known pathogens and have caused disease and deaths—probably at an increasing rate. The risk of acquiring legionellosis from waterborne aerosol inhalation exposures is now the most significant waterborne-disease risk associated with distributed drinking water in the United States. The Centers for Disease Control (CDC) reported in 2009–2010 that there were 33 waterborne-disease outbreaks, 19 of which were from *Legionella* in plumbing systems or of drinking water supply origin, resulting in 105 cases and 14 deaths (CDC MMWR, 2013). These were the only outbreaks that reported deaths. US legionellosis cases reported annually increased 217%, from 1,110 in 2000 to 3,522 in 2009 (CDC MMWR, 2011). An estimated 8,000 to
18,000 people are hospitalized with Legionnaires’-related disease each year in the United States (CDC, 2013). Some unknown portion of those estimated cases were associated directly or indirectly with a drinking water-related exposure by elderly and immune-suppressed people and possibly smokers, in hospitals and long-term care, and perhaps associated with hotels, apartment buildings, cooling-system heat exchangers, humidifiers, or even home plumbing.

As a matter of public health protection, appropriate supplemental water treatment measures must be applied to reduce those risks, especially among high-risk populations. The current regulations and some state implementation practices actually impede the application of appropriate technologies by imposing unnecessary restrictions and requirements that increase the barriers to implementation of protective treatments and increase treatment costs, without apparent benefits. The current US Environmental Protection Agency (USEPA) regulations do not provide sufficiently specific direction, so state implementation varies widely. USEPA should modify those requirements to reflect the specific circumstances that warrant supplemental treatment and provide appropriate regulation modifications and national guidance that will ensure the general safety and drinking water quality in those facilities.

The problem is to define rationales and applicability for supplemental treatment and suitable requirements and, when needed, to judiciously establish appropriate and rather minimal monitoring and compliance controls on supplemental disinfection technology applied at the water supply entry point to buildings, or cold or hot water segments, without inappropriate burdens. This is especially important with the intent of reducing the regrowth of Legionella and other pathogenic microorganisms and thereby reduce the documented risks of respiratory diseases and deaths attributable to inhalation of those microorganisms.

**INHALATION RISKS NOT MANAGED BY CENTRAL TREATMENT**

Although drinking water is a transport vehicle for some volatile contaminants such as volatile organic compounds (VOCs) and radon, and inhalation exposure is part of their regulatory assessments, that route of exposure is not the traditional risk factor for the majority of regulated drinking water contaminants. It is, however, significant for some pathogenic microorganisms that are resistant to traditional treatment or can regrow in plumbing after water has left the treatment plant. Applications of supplemental disinfection technology at sites in plumbing systems fill an existing protection gap that is now understood to exist; it was not contemplated when the Safe Drinking Water Act (SDWA) and regulatory definitions of consecutive systems and supplemental treatment were produced more than 30 years ago. It may be difficult to address them by regulation under the limitations imposed on USEPA and water suppliers with respect to plumbing on private property (see USEPA’s Lead and Copper Rule, and 1994 12 06 US Court of Appeals AWWA v. EPA, and NRDC v. EPA). Thus, it is in the best interests of public health protection to allow and even encourage applications of effective and harmless supplemental technologies to address risks that are difficult to manage within current regulatory strictures. This can be done with minimal definitional changes of water system categories to allow for and encourage controlled supplemental disinfection where needed.

The risk of acquiring legionellosis from waterborne inhalation exposures is now the most significant waterborne disease risk associated with distributed drinking water in the United States.
APPLICABLE REGULATIONS

Legionella is regulated under the SDWA with a maximum-contaminant-level goal of zero and a Treatment Technique requirement under the Surface Water Treatment Rule at the public drinking water treatment plant. That rule deals with control of entry of certain pathogens into the distribution network but does not deal with growth of pathogens in the distribution network. No regulatory minimum contaminant level has been established for Legionella leaving the treatment plant or at the tap. USEPA believes that “if Giardia and viruses are inactivated that Legionella will also be controlled” (USEPA, 2012). That statement is substantially correct regarding water leaving the municipal treatment plant where the Surface Water Treatment Rule (SWTR) applies. It is not valid with regard to colonization and regrowth in parts of the distribution network, especially in plumbing systems and cooling towers, which are the risks being directly addressed by several point-of-entry supplemental technologies. Recontamination and regrowth can occur from original construction if the system is not adequately disinfected before being put into service, during line breaks, or perhaps during plumbing repairs.

The SDWA requires that USEPA provide listings of affordable treatment technologies for use by public water systems to achieve compliance with regulations. Beyond providing technical guidance to water suppliers for compliance, the listing is legally important for the implementation of variances and exemptions for water suppliers that are not able to achieve compliance because of economic or water quality difficulties. It does not preclude unlisted technologies being used. Within the treatment approaches applicable to small systems that include the transient noncommunity systems as currently defined in which supplemental disinfection treatment for Legionella and other regrowth pathogens would occur, the SDWA specifically includes point-of-use and point-of-entry technologies.

TREATMENT TECHNOLOGIES USED FOR LEGIONELLA MANAGEMENT IN PLUMBING OR COOLING SYSTEMS

Legionella growth is observed especially in the water temperature range of about 25° to 50°C (77° to 122°F), and biofilms are a point of regrowth, so hot water plumbing is a key point of concern. Some authorities mistakenly recommend setting hot water heaters at 120°F (~ 48°C) for energy conservation without consideration of Legionella proliferation risk. Several technologies are or have been used to suppress Legionella regrowth in water applications. Growth and survival in biofilms, dead ends, minimal-use hot water systems, and heat exchanger blowdown are high-risk situations. Cold water plumbing is a likely concern in warmer climatic conditions. Once the biofilm is eradicated, sustained disinfection residuals can be effective to retard regrowth. All approaches require appropriate, active management and performance verification in practice (Lin et al, 2011).

Free chlorine is used in brief shock applications as well as in disinfectant residual mode. Free chlorine is effective for microorganisms in suspension but seems to have difficulty penetrating biofilms. As a chemically reactive species it will have shorter survival in hot water. Chloramine, despite its lower disinfection potency, has shown promise in suppressing biofilm-related regrowth. Chlorine dioxide, like chlorine, is a good biocide, but it must be produced on site and is less stable in hot water systems. Ozone and ultraviolet (UV) disinfection are best applied in recirculating systems because they do not provide a residual. Copper/silver ionization systems (EWGLI, 2011; KWR, 2006) are registered as biocides for Legionella by USEPA’s Pesticide Program, are stable in hot water systems, and are applied so as not to exceed primary or secondary regulations: Liquitech (EPA Reg. No. 68250-1) and Enrich (EPA Reg. No. 86131-1). Thermal shock treatment can be temporarily effective for acute...
situations but it would require other treatment for continuous protection.

CONSECUTIVE SYSTEMS

Supplemental treatment/disinfection in a facility, which redefines the status of the facility from part of a public water distribution system network to a separate consecutive public water supply, is based upon the original regulatory definitions of a public water supply as serving more than 25 persons and a consecutive system. Pertinent sections from the Part 141 regulations are listed here. Otherwise, such a treatment would have been considered point-of-entry treatment under section 141.100 of the SDWA regulations.

Definitions:

Combined distribution system is the interconnected distribution system consisting of the distribution systems of wholesale systems and of the consecutive systems that receive finished water.

Community water system means a public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 persons.

Consecutive system is a public water system that receives some or all of its finished water from one or more wholesale systems. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

Disinfectant means any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

Disinfection means a process that inactivates pathogenic organisms in water by chemical oxidants or equivalent agents.

Finished water is water that is introduced into the distribution system of a public water system and is intended for distribution and consumption without further treatment, except as treatment necessary to maintain water quality in the distribution system (e.g., booster disinfection or addition of corrosion control.)

Noncommunity water system means a public water system that is not a community water system. A non-community water system is either a "transient non-community water system (TNCWS)" or a "non-transient non-community water system (NTNCWS)."

Nontransient noncommunity water system or NTNCWS means a public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year.

The intent of the consecutive-systems designation is to ensure that the drinking water quality is not degraded in a facility by an interfering activity. For example, if the treatment would increase microbiological contamination, it could increase acute public health risks. There is more than one approach for that assurance, depending on the circumstances, that does not necessitate nontransient noncommunity water system (NTNCWS) designation in all categories of application.

It is interesting that applications of point of use or point of entry are not restricted for personal use, perhaps technically because the federal government and local utility do not have authority for drinking water on private property, or if fewer than 15 connections or fewer than 25 people are involved. However, these same concerns would exist in a personal treatment situation. That was dealt with by USEPA's suggesting that independent product and performance standards be established (American National Standards Institute/NSF International Standards) and adopted by states. However, for the specific applications of concern with health-care institutional supplemental treatment for Legionella control, there is no fundamental public health and safety reason to include these standards in the broad regulatory (not statutory) definition of consecutive systems without providing distinctions (or exclusions) for the legitimate public health-protection purpose of the supplemental treatment.
Currently these standards are subject to the anomaly the subsequent requirements accrue from becoming a public water system (PWS) by definition rather than in actuality. For example, several temporary techniques have been used to attempt control of Legionella, including hyperchlorination and shock heating to > 60° C. Each of these can be effective for an undefined period, but they do not provide long-term protection. In any case they should not require designation of the facility as a PWS because they are brief excursions. Moreover, they are frequently applied only to hot water plumbing. There are also other oversight processes available to hospitals.

NONTRANSIENT NONCOMMUNITY WATER SYSTEMS

On the basis of the current brief definitions, a prima-facie case could be made that hospitals and other buildings wanting to implement controls on Legionella in their plumbing systems could be considered NTNCWS if they added any treatment to the drinking water. However, definitions can be changed, especially when an important public health problem can be addressed. Because the intent of supplemental disinfection is to ensure that serious health risks are reduced, the positive risk-benefit basis provides a very different public health-based decision environment. The supplemental disinfection treatment is providing benefits that cannot be obtained at the central treatment plant. Thus, the situation is much more complex than a simple reading of the current definition implies, and it requires resolution.

TREATMENT AND MONITORING CONSIDERATIONS

Continuous chlorine/hypochlorite, chloramine, and chlorine dioxide supplemental disinfection of cold water might be appropriate for NTNCWS designation or at least for on-site management controls because these treatments can result in exceeding maximum contaminant levels (MCLs) or maximum disinfectant residual levels (MDRLs); however, these are chronic exposure issues that might not be relevant in an NTNCWS application. Chloramines and chlorine dioxide supplemental treatments could also be covered because their on-site generation can be problematic and require special skills and management. Chloramine has been known to interfere with insoluble lead chemical coatings that adhere to lead pipe and possibly also brass faucets and old lead-based solders and passivate them, so some taps could exceed the Lead and Copper Rule in cold water applications. UV treatment can potentially increase nitrite levels in drinking water; this would be a concern in hospitals where infants will be present.

Hot water plumbing systems should be exempt from NTNCWS because hot water supplies are de facto not considered drinking water for regulatory purposes. No drinking water MCL and treatment technique regulations are applicable to hot water systems, and no monitoring is required for them under the National Primary Drinking Water Regulations. Shock treatments of cold or hot water systems should also be exempt because they are infrequent and transitory.

Copper and silver ion treatments of cold or hot drinking water plumbing should be exempt because there is no reason to believe that they will increase disinfection by-product (DBP) or other MCL concentrations. They are slower acting but more persistent than other systems, and speed is not a need when dealing with regrowth in a stagnant water system.

The key monitoring needs for protecting public health are those associated with the functioning of the treatment process—i.e., increased presence of Legionella. Guidance should be established for Legionella monitoring and for appropriate monitoring and reporting related to specific disinfectant methods.
MCLS, MRDLs, Monitoring, and the Lead and Copper Rule

Some practices do not have specification needs for the operation of a supplemental treatment application. Given the specific nature of the particular disinfectant system selected, the provisions of §141.100 could be tailored to these narrow applications without the potentially excessive and costly requirements that are associated with designation as an NTNCWS consecutive water system. In that regard, we can assume that none of the regulated microbial contaminants would be increased by any of the disinfectants unless poor installation practice or design resulted in external microbial contamination. Addition of conventional oxidants such as chlorine, hypochlorite, chlorine dioxide, or chloramine would likely increase the presence of particular DBPs (depending upon the selected disinfectant) such as trihalomethanes (THMs), haloacetic acids (HAAs), and chlorine by exceeding the maximum residual disinfectant levels for chlorine, chloramine, or chlorine dioxide. In those cases appropriate limited monitoring for the regulated contaminants is appropriate. On the other hand, for copper/silver ionization, there is no indication that it would increase regulated DBPs. The added substances in copper/silver ionization are copper and silver ions. The addition levels are determined by the system controls, and they would be less than copper's action level, which is regulated in the Lead and Copper Rule at 1.3 mg/L as an indication of excessive corrosivity in stagnant first-draw 1-l samples, along with lead, whose action level is 15 µg/L. The nonfederally enforceable aesthetic secondary MCLs for silver and copper are 0.1 mg/L and 1 mg/L, respectively. The general operating range of the copper/silver system is 0.3 to 0.8 mg/L copper. Thus, the sum of any corrosion-related copper and added copper should not exceed 1 mg/L (USEPA, 2010). This can be readily determined by an appropriate flowing-water monitoring scheme. If the lead-and-copper corrosion rule is being applied, it should be determined by a separate stagnant water sample. On the other hand, it is unlikely that a lead/copper sample would have been collected in a large building because the sampling sites are supposed to be selected on the basis of corrosion and potential for lead contamination, which is frequently determined by the presence of a lead service line or lead–tin solder used on copper pipes.

§ 141.106 Criteria and procedures for public water systems using point-of-entry devices.

Treating supplemental disinfection as a point-of-entry process is a possible approach to avoid the consecutive system conundrum in a supplemental rather than raw water treatment mode.

(a) Public water systems may use point-of-entry devices to comply with maximum contaminant levels only if they meet the requirements of this section.

(b) It is the responsibility of the public water system to operate and maintain the point-of-entry treatment system.

(c) The public water system must develop and obtain State approval for a monitoring plan before point-of-entry devices are installed for compliance.

Under the plan approved by the state, point-of-entry devices must provide health protection equivalent to central water treatment.

“Equivalent” means that the water would meet all national primary drinking water regulations and would be of acceptable quality similar to water distributed by a well-operated central treatment plant. In addition to the VOCs, monitoring must include physical measurements and observations such as total flow treated and mechanical condition of the treatment equipment.

(d) Effective technology must be properly applied under a plan approved by the State and the microbiological safety of the water must be maintained.
(1) The State must require adequate certification of performance, field testing, and, if not included in the certification process, a rigorous engineering design review of the point-of-entry devices....

The basis of (d) is that the incoming water has not been treated and does not meet microbial standards at the entry point, and it is the function of the point-of-entry device to treat the water to meet the standards. Point-of-use devices are not permitted to be used in a small system to meet microbial standards.

Subpart L—Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors

§ 141.130 General requirements.
(1) The regulations in this subpart establish criteria under which community water systems (CWSs) and intermediate, noncommunity water systems (NTNCWSs) which add a chemical disinfectant to the water in any part of the drinking water treatment process must modify their practices to meet MCLs and MRDLs in §§ 141.64 and 141.65, respectively, and must meet the treatment technique requirements for disinfection byproduct precursors in § 141.135.

It is not logical that this requirement could be applicable to a NTNCWS consecutive system that is receiving treated water that already meets all drinking water regulatory requirements, and uses shock treatment or does not use a regulated oxidizing disinfectant or an MCL-regulated substance.

(a) The requirements of this subpart L constitute national primary drinking water regulations....

(d) Control of disinfectant residuals. Notwithstanding the MRDLs in § 141.65, systems may increase residual disinfectant levels in the distribution system of chlorine or chloramines (but not chlorine dioxide) to a level and for a time necessary to protect public health, to address specific micro-

biological contamination problems caused by circumstances such as, but not limited to, distribution line breaks, storm run-off events, source water contamination events, or cross-connection events.

This implicitly allows temporary shock treatments such as hyperchlorination to protect public health.

CONCLUSIONS/RECOMMENDATION

USEPA and states should encourage introduction of appropriate supplemental disinfection technologies by minimizing the current costly, mixed regulatory, administrative barriers of dubious public health benefit. It can begin with USEPA updating its definition of NTNCWS to exclude some disinfectant applications that can reduce the risk of legionellosis and other distribution-related diseases when they will not have a significant impact on other important drinking water quality parameters.

Supplemental disinfection of plumbing systems should be encouraged rather than discouraged by regulations or guidance when they can provide significant public health benefits. Many respiratory illnesses and deaths are attributed to Legionella in hospital plumbing systems and drinking water supplies. Numerous other pathogenic microbes such as Pseudomonas aeruginosa, Stenotrophomonas maltophilia, and Acinetobacter baumannii are found in plumbing and distribution systems, and their nosocomial infections are documented. Beyond hospitals, these disease-causing microorganisms are endemic in many buildings’ plumbing networks and even home showerheads (Huang et al, 2008).

The purpose of NTNCWS designation is to ensure that their systems will be safe and will meet drinking water regulations. Other systems such as water-cooled air conditioners, heat exchangers, and humidifiers are also susceptible to microbial proliferation that must be addressed by supplemental disinfection. Hospitals and
other high-risk environments should be exempted from NTNCWS designation under several scenarios.

The intent of regulations should be to reduce the documented serious risks of disease and death caused by regrowth of pathogens in high-risk plumbing systems, which was not contemplated when the definitions were created. So there should be deference paid to those applications, and they should be encouraged with appropriate controls to ensure that they are not increasing other risks from drinking water. Unnecessary impediments that could result under the current definition will actually increase health risks by reducing the incentives for preventive or possibly corrective actions. The risk–benefit balance for supplemental treatment for Legionella control is positive, and potential for increased risk caused by the treatment process is much more hypothetical (and it can be addressed by other means), especially in otherwise regulated institutions like hospitals.

Certain processes continuously applied to cold water that could result in exceeding a national drinking water standard might warrant NTNCWS designation. Different types of applications will provide different concerns, so they should be addressed with specific procedures and controls tailored to the particular situation and process.

For example, continuous cold water disinfection with chlorination or chloramination could require periodic THM, HAA, and residual chlorine analyses if chronic exposure is a concern. Continuous chlorine dioxide treatment could require periodic analyses for chlorite, chlorine dioxide, and ultimately chlorate that may be regulated at some point. There are also management issues with regard to on-site generation of chlorine dioxide, as well as chloramination. Use of UV disinfection could be problematic because the UV treatment could decompose residual chlorinated disinfectants that were in the influent water, as well as convert nitrate to nitrite (Lu et al, 2008).

Intermittent short-term shock treatments of cold or hot water such as hyperchlorination or heat treatment should not be the basis for designation as NTNCWS. These are transient activities and the system will rapidly return to its original state after the treatment and subsequent flushing. If appropriate, process guidelines should be provided, but NTNCWS status should not be granted.

One important discriminator is that application of the technology to only the hot water side of the plumbing system should be exempted and not require designation of the facility as a consecutive system, because the hot water is not managed as drinking water in national drinking water regulations. No drinking water regulations are monitored for, or to be complied with, in hot water.

Processes such as copper/silver ionization continuously applied to cold water but not hot water would require some degree of monitoring for copper, which is regulated in the Lead and Copper Corrosion Rule, but not in the same corrosion detection context or sampling or compliance context. Recommended periodic operational tap analysis of nonstagnant water for total copper and possibly silver, which was removed from primary drinking water regulations many years ago, would be appropriate. The primary reason would be to ensure that the ionization process is functioning as designed. Although they are secondary MCLs, copper and silver should be monitored as part of a management—but not regulated—package of parameters.

It would be appropriate to recommend that targeted Legionella analyses be performed to manage the status of the suppression of Legionella being provided by the supplemental disinfection process.

Mandatory analyses for regulated microbial indicators are of questionable logic and probably superfluous if disinfectants are being applied because their purpose is to provide additional disinfection to influent water that is already required to meet coliform and fecal coliform standards. For example, measurement of a disinfectant
residual would probably suffice to demonstrate that the system is in disinfection mode. In fact, the irony is that such monitoring would not necessarily occur at all if the plumbing were not receiving supplemental disinfection.

A regulatory redefinition of a consecutive system and of NTNCWS would be appropriate, and the balance of public health risks and benefits demands it. Doing this by guidance alone would be a beginning, but a small adjustment by regulation would be essential because some states are restricted from making changes in their programs outside of USEPA regulations. Supplemental disinfection per se should not be a determinant of a PWS. It could also be possible to treat some situations as points of entry rather than as NTNCWS.

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