Water Safety Guidance

Scottish Health Technical Memorandum

Part D - Disinfection of domestic water systems

SHTM 04-01 part D

Draft 1.11 - March 2026.

Contents

Executive Summary

Scottish Health Technical Memorandum (SHTM) 04-01 “Water safety guidance” is published in seven parts:

- part A: Design, installation, and commissioning
- part B: Operational management
- part C: Microbiological testing
- part D: Disinfection of domestic water systems
- part E: Alternative materials and filtration
- part F: Chloramination of water supplies
- part G: Operational procedures and Exemplar Water Safety Plan

The documents give comprehensive advice and guidance on the legal requirements, design implications, maintenance, and operation of safe water systems in healthcare premises. The use of these premises is very intense, the occupancy level high and the patients may be particularly susceptible to waterborne infection risks. Their condition may also require close control of the clinical and built environment.

This 2026 SHTM suite draws together developments and updates from the previous guidance, including recommendations for the safe management of water systems, via the integration of the principle of Water Safety Groups (WSGs) and Water Safety Plans (WSPs) and how to manage and minimise the risks to health from various aspects, ranging from clinical risks, microbial and chemical contamination, changes to the water system, resilience of the water supply and so on. It also introduces a stronger emphasis on staff competencies and the implementation of water hygiene awareness training.

There has been increasing evidence that the interaction of water supply and above ground drainage can each give rise to problems where the design and/ or operation is poorly configured. Therefore, a brief section on above ground drainage design has been included in this version.

Information regarding the mechanisms for compliance with the Scottish Water Byelaws are also discussed.

This 2026 version of SHTM 04-01 supersedes all previous versions of SHTM 04-01 “Water Safety for Healthcare Premises”.

Guidance in this SHTM applies to all healthcare facilities containing domestic water and above ground drainage systems.

Language used in technical guidance

In SHTMs verbs such as "must", "should" and "may" are used to convey notions of obligation, recommendation or permission. The choice of modal verb will reflect the level of obligation needed to be compliant.

The following describes the implications and use of these modal verbs in SHTMs (readers should note that these meanings may differ from those of industry standards and legal documents):

A. "Must" is used when indicating compliance with the law

B. "Should" is used to indicate a recommendation (not mandatory/ obligatory), for example among several possibilities or methods, one is recommended as being particularly suitable - without excluding other possibilities or methods

C. "May" is used for permission, for example to indicate a course of action permissible within the limits of the SHTM

D. "Shall", in the obligatory sense of the word, is never used in current SHTMs

Typical usage examples

A. "All water fittings used in the construction of systems referred to in this SHTM must comply with the requirements of the Water Supply (Water Fittings) (Scotland) Byelaws 2014." [obligation]

B. "Waterborne bacteria should be considered during the design, construction, installation, commissioning and maintenance of the hot and cold water systems and above ground drainage system in the healthcare-built environment," [recommendation]

C. "There are also other waterborne bacteria acknowledged to be in the water systems that may require further supplementary management practices to control)" [permission]

Project derogations from the Technical Guidance

Healthcare facilities built for the NHS are expected to support the provision of high-quality healthcare and ensure the NHS Constitution right to a clean, safe and secure environment. It is therefore critical that they are designed and constructed in accordance with appropriate technical standards and guidance. This applies to all new and refurbishment projects, regardless of procurement model.

Note 1: The healthcare organisation, and their project teams, should ensure that they have a fully documented list of technical standards and guidance that are applicable to the specific project.

It is recommended that the starting point for all projects should be one of full adherence to the SHTM guidance or better if that can be demonstrated. While it is recognised that derogations may be required in some cases, these must all be risk-assessed and documented in order that they may be considered within a structured derogation review and approval process. In all instances derogations must not compromise the health and safety or operational resilience of the healthcare facility. Healthcare organisations should ensure that any derogations do not impact on their legal or statutory obligations.

Derogations must be properly authorised by the project's senior responsible officer and informed and supported by appropriate technical advice including that of the WSG, irrespective of a project's internal or external approval processes.

A schedule of derogations should be created for any project, including details of approvals, risk assessment and identified mitigations.

Note 2: This guidance does not alter the healthcare organisations legal or statutory obligations.

NHS Scotland Sustainable Development Policy Drivers

Responding to the global climate emergency is one of the Scottish Government's highest priorities. Sustainable development, the concept that the needs of the present must be met "without compromising the ability of future generations to meet their own needs" is integral to the Scottish Government's overall purpose. The Scottish Government's National Performance Framework (NPF) shares the same aims as the United Nations' Sustainable Development Goals. It highlights the need for a 'whole system approach' to successfully deliver the NPF's national outcomes for Health and recognises the important role that NHS Scotland has in helping to achieve this.

Over recent years the current and future impact of climate change has been well documented, with risks to human health and to health and social care delivery highlighted within Scotland's summary report of the UK Climate Risk Independent Assessment*. NHS Scotland is committed to the delivery of a high quality, environmentally and socially sustainable health service that is resilient to the locked-in impacts of climate change. Director Letter (DL) (2021) 38 'A Policy for NHS Scotland on the Climate Emergency and Sustainable Development' provides the framework for this aim to become a reality, and to maximise NHS Scotland's contribution to mitigating and limiting the effect of the global climate emergency.

* NHS Scotland Climate Change Risk Assessments and Adaptation Plans: A Summary Report on the National Services Scotland (NSS) website.

Who should read this guidance?

This document is aimed at specifiers, designers, suppliers, installers, commissioners, WSGs, estates and facilities managers and operations, and Infection Prevention and Control Teams (IPCTs). Elements of the document will also be relevant to managers concerned with the day-to-day management of healthcare facilities and senior healthcare management. Infection prevention specialists who are involved with monitoring water quality and managing infections and outbreaks potentially linked to water supplies will also find it helpful to be familiar with this guidance.

Main changes since the 2014 suite

- This 2026 edition of SHTM 04-01 provides comprehensive guidance on measures to control waterborne pathogens.
- This edition has been updated to align with the Health and Safety Executive's (HSE's) revised Approved Code of Practice (ACOP) for Legionella (L8) and its associated Health and Safety Guidance (HSG) 274 guidance documents.
- A new chapter on above ground drainage has been added to SHTM 04-01 Part A.
- New guidance has been included in SHTM 04-01 Part A on the hygienic storing and installation of fittings and components and on the competency of installers/ plumbers working on healthcare water systems. The guidance also outlines that any person working on water distribution systems or cleaning water outlets needs to have completed a water hygiene awareness training course.
- Information is discussed in relation to compliance with the Scottish Water Byelaws in SHTM 04-01 Part A.
- SHTM 04-01 Part A and Part E now outlines requests for pipework manufacturers data sheets regarding the product limitations.
- Part B of the SHTM 04-01 now includes updated guidance on the remit and aims of the WSG.
- SHTM 04-01 Part B now includes information on Nontuberculous mycobacteria (NTM).
- Guidance on sampling techniques for, testing for, and the microbiological examination of *Pseudomonas aeruginosa* samples - originally in the Health Technical Memorandum (HTM) 04- 01 Addendum - is now included in SHTM Part C to complement the Total Viable Count (TVC) guidance.
- Whilst SHTM 04-01 Part G provides updated guidance on the WSP and in addition to the 2014 sample templates includes several more.

While some guidance on other water- service applications is included, it is not intended to cover them fully. For example:

- process waters used for laundries, see HTM 01-04 - ‘Decontamination of linen in health and social care’
- endoscopy units, see HTM 01-06 - ‘Decontamination of flexible endoscopes’
- primary care dental premises, see HTM 01-05 Decontamination in primary care dental facilities
- renal units, see Health Building Note (HBN) 07-01 and HBN 07-02, the Renal Association's guidelines and ISO 13959 and 11663
- sterile services departments (SSDs), see Scottish Health Planning Note (SHPN) 13 - Part 1 Decontamination Facilities: Central Decontamination Unit
- hydrotherapy pools, see the Pool Water Treatment Advisory Group’s (PWTAG's) ‘Swimming pool water: treatment and quality standards for pools and spas’
- spa pools, the control of legionella and other infectious agents in spa-pool systems HSG282
- birthing pools, see HBN 21 - ‘Maternity’ and PWTAG’s ‘Swimming pool water: treatment and quality standards for pools and spas’

Acknowledgements

NHS Scotland Assure would like to thank the principal contributors for their efforts in the production of this updated version of Scottish Health Technical Memorandum (SHTM) 04-01 Part C, these include NHS England, NHS Wales and Department of Health Northern Ireland. The SHTM suite (Parts A to G) have been updated collectively from the four nations and will be adopted across the UK NHS as unified documents. For each nation, the publication will reflect the standards for that nation.

NHS Scotland Assure would like to thank the National Water Services Advisory Group (NWSAG), Scottish Engineering and Technology Advisory Group (SETAG) and colleagues from Antimicrobial Resistance and Healthcare Associated Infection Scotland (ARHAI) for their contributions and efforts to the production of the SHTM suite revision.

NHS Scotland Assure would also like to thank those who took the time to comment and send feedback during the scoping and technical engagement phases of this document.

NHS Scotland Assure acknowledge contributions from those individuals and organisations involved in the development and publication of previous versions of the SHTM 04-01 suite.

Key personnel involved in the production of this updated document:

- **Thomas Rodger**, Head of Engineering, NHS Scotland Assure
- **Richard Beattie**, Principal Engineering Manager, NHS Scotland Assure
- **Craig Morning**, Senior Engineer, NHS Scotland Assure
- **Jim Wishart**, Senior Engineer, NHS Scotland Assure
- **David Lowe**, Senior Engineer, NHS Scotland Assure
- **Simon Picking**, Head of Hard FM/Engineering, NHS England
- **Fiona Hammond**, Infection Prevention and Control Nurse Consultant, NHS England
- **John Scott**, Infection Prevention and Control Lead Healthcare Scientist, NHS England
- **Girish Mistry**, Water Scientific
- **Gavin Wood**, Hydrop
- **Harry Evans**, HDEAE
- **Andrew Mould**, NHS Associate Director of Operational Estates University Hospitals Birmingham, NHS Foundation Trust
- **Andrew Hallam**, NHS Deputy Head of Estates Leeds Teaching Hospitals, NHS Trust
- **Robert Baker**, NHS Wales Principal Mechanical Engineer, NHS Wales Shared Services Partnership
- **David Wilson**, Department of Health, Northern Ireland

1. Introduction

General

Note 1: **General Warning Regarding Chemical Disinfection of Hospital Water Systems**

It has been found that the renal water plants do not filter out hydrogen peroxide, copper-silver ions, chlorine, chloramines, and ozone. These disinfection systems should not be used where water serves a haemodialysis treatment area (Safety Action Notice (SAN) HAZ (SC) 08/07, 2008). Due to the extremely sensitive nature of renal water plants, no chemicals should be added to the water going to these units. If possible, these units should be kept on a separate mains supply, or at least isolated when any shock or campaign treatment is planned.

Note 2: **Thermal and chemical disinfection**

Adding a disinfectant or raising the temperature above 60°C creates a hazard to users by chemical exposure or scalding. A risk assessment must be carried out and a safe system of work put in place throughout the disinfection process. Signage and outlet warning labels should be fitted to all areas and outlets to alert occupants of the building for whom the risk is greater (such as the very young, elderly or those with sensory loss) not to use these outlets.

Introduction

1.1. The use of any chemical in the treatment of potable water carries a risk and the Water Safety Group (WSG) must undertake a documented risk assessment before a treatment is applied, any products selected should comply with the Biocidal Products Regulation (BPR). This is of particular relevance when continuous treatment is considered but should also be implemented when shock treatment is proposed.

1.2. There are many disinfection systems currently available, some are one off shock disinfectants whilst others are used continuously as a disinfectant, examples of which include:

- heat and flush
- chlorination
- chlorine dioxide
- ultraviolet light (UV)
- copper silver ionisation

- silver catalysed hydrogen peroxide
- ozone
- chloramines

1.3. All of these disinfection methods have advantages and disadvantages and work at their optimal performance within different parameters. The main aim of this guide is to investigate the different methods, analyse their advantages and disadvantages and determine the factors needed to ensure optimal results when using each system.

Physical parameters

1.4. When considering the most suitable method of disinfection for a healthcare facility a number of parameters must be taken into consideration, factors to be considered include the condition of the water assets, the health of the occupants, the quality of the incoming water supply, and the availability of resources to implement a particular regime.

Parameters of incoming water

1.5. There are many factors concerning the incoming water supply that should be taken into consideration when selecting the most suitable disinfection method. These include aspects such as:

- potential of hydrogen (pH)
- temperature
- taste and odour
- total dissolved solids (TDS)
- frequency of water turnover

Heat and flush (thermal disinfection) - shock disinfection

1.6. This process is distinct from normal temperature control applied to domestic hot water services (DHWS); this is used as a means of disinfection causing the destruction of disease-causing microorganisms. This chemical-free method requires no additional equipment.

Method

1.7. This disinfection is carried out through raising the temperature of the entire contents of the calorifier, or hot water heater, to 70°C followed by circulating the water throughout the system for at least an hour ensuring the temperature at the outlets does not fall below 60ºC. The calorifier/ heater must be capable of keeping the temperature sufficiently high to ensure that the temperature in all parts of the circulating system, and at the return connection, do not fall below 60ºC. Each tap and appliance should be run sequentially for at least 5 minutes at the full temperature (but not necessarily at full flow), and it should be measured and recorded.

1.8. This form of disinfection can only be used as a shock treatment; therefore, it is not suitable for continuous disinfection. It must also be noted that when utilising this method for a cold-water system particular attention must be made to the thermal expansion of the system and this must be accounted for.

Advantages

1.9. The main advantages to this form of disinfection are that it requires no specialist equipment and therefore can be implemented immediately after bacteria has been detected. If also used to disinfect the cold-water system an additional connection from the hot water system is required, this must be disconnected after flushing and any branch connections must not result in extended dead legs being formed.

Disadvantages

1.10. One of the main disadvantages to using this method of disinfection is that this may not eradicate Legionella fully and recolonisation may occur. This disinfection method is also labour intensive due to the number of personnel required to monitor water temperatures and flushing times. Furthermore, the energy costs of maintaining a hospital hot water system above 60ºC may be substantial.

1.11. There is also a risk of scalding if staff/ patients access the system during the heat and flush process. A documented risk assessment should be carried out and a safe system of work put in place throughout the thermal process.

Continuous chlorination - continuous disinfection

1.12. Continuous chlorination is the process of adding chlorine to water as a means of disinfection and it is widely used in the disinfection of mains water distribution from the water supplier.

Method

1.13. Within building water systems chlorine is injected into the pipework or added to a water storage tank with calcium hypochlorite or sodium hypochlorite the most likely chemicals to be used to create the solution. The effectiveness of chlorine as a disinfectant is determined by the chlorine concentration, contact time, the pH level, temperature, the concentration of organic matter, and the number and types of microorganisms in the water. PD855468:2015 contains details on the current methods to be followed.

Advantages

1.14. Continuous chlorination provides a residual disinfectant concentration throughout the entire distribution system. The lower concentrations used allow this type of disinfection to be used whilst the system remains in use in most situations:

- well-established technology
- relatively simple and flexible dosing control
- well-known taste, if present
- can eliminate certain noxious odours during disinfection
- the residual that remains in the water can prolong disinfection even after initial treatment and can be measured to evaluate the effectiveness
- reliable and effective against a wide spectrum of pathogenic organisms
- effective in oxidising certain organic and inorganic compounds

Disadvantages

1.15. There are several disadvantages to using chlorine as a disinfectant:

- it is highly corrosive and causes damage to pipework
- can create carcinogenic compounds Trihalomethanes (THMs) in poor quality water. Chlorine combines with organic compounds and produces carcinogenic chloroform and carbon tetrachloride. It is the combination of chlorine and organic materials already in the water that produces cancer-causing by products. The more organic matter in the water, the greater is the accumulation of THMs
- the total oxidants levels should be below 0.5 mg/litre as stated in the drinking water quality guideline (World Health Organization (WHO) Drinking Water Guidelines, 2019); (page 334)
- Chlorine may only suppress Legionella and not kill it and rarely can Legionella be eradicated from a system using this method alone. Moreover, the inactivation of Cryptosporidium requires high chlorine dosages

- Chlorine has no detergent cleansing powers; therefore, it is essential that slime and debris are removed before chlorine is used. However, chlorine should not be used with some other biocides since they may neutralise each other unless they are known to be compatible. Such as ammonia which reacts with chlorine to form harmful THMs
- may dissipate rapidly if reacting with organic matter and other oxidizable contaminants. It may not reach all parts of the water system, even if high doses applied
- dosing equipment requires regular maintenance
- can create taste and odour problems in poor quality water
- neutralisation may be required before discharge to the environment. Long-term effects of discharging dechlorinated compounds into the environment are unknown
- any chemical discharge to a drain needs to be sanctioned by the Water Authority, who may then impose conditions on the discharge
- does not penetrate into centre of established biofilms
- all forms of chlorine are highly corrosive and toxic. Thus, storage and handling require increased safety regulations. System corrosion causes pipe leaks
- some parasitic species have shown resistance to low doses of chlorine, including oocysts of *Cryptosporidium parvum*, cysts, of *Endamoeba histolytica* and *Giardia lamblia*, and eggs of parasitic worms
- potentially dangerous in case of a leak of chlorine gas
- workers may need access to a wash down hose, chemical eyewash, and potentially a shower. Operators must also wear the proper safety equipment, including carrying an Acid Gas escape respirator
- must be removed from water prior to dialysis

Chlorine Dioxide ($Cl0_2$) - continuous and shock disinfection

1.16. Chlorine dioxide (ClO_2) can be continually dosed in a similar way to continuous chlorination, but it must be manufactured on site because it decomposes readily and presents toxicity hazards when stored (Kim et al., 2002). It can also be used as a shock disinfectant at higher concentrations. Use of ClO_2 as a legionella strategy is subject to British Standard (BS) EN 12671.

Method

1.17. The chemical is a gas that is generated mechanically or electrolytically from a sodium chlorite solution which is then introduced into the water distribution system. To manufacture ClO_2 on site, two precursor chemicals are required. These are drawn into the generator, where ClO_2 is produced through a controlled reaction. Different colours for the two chemicals or connector types may be implemented to assist with recognition and prevent cross-contamination. Nevertheless, there have been cases where mixing occurred directly at the drums or via compatible connectors or colours, leading to accidental chlorine gas generation. Robust risk assessments, staff training, and strict procedural controls must be in place to prevent such events and ensure safe handling of precursor chemicals. The effectiveness as a disinfectant is determined by the ClO_2 concentration, contact time, the pH level, temperature, the concentration of organic matter, and the number and types of microorganisms in the water. PD855468:2015 contains details on the current methods to be followed.

Advantages

1.18. ClO_2 continuous dosing provides a residual disinfectant concentration throughout the entire distribution system. The lower concentrations used allow this type of disinfection to be used whilst the system remains in use in most situations. Where higher concentrations are used the system may need to be isolated from use.

ClO_2 is a well-established technology:

- It is a very selective oxide, allowing lower dosages to be used.
- It is effective over a wide pH range; however, taste problems can become an issue at high dosage levels.
- ClO_2 generally forms less THMs, haloacetic acids (HAAs), and total organic halogen (TOX) than free chlorine.
- Reliable and effective against a wide spectrum of pathogenic organisms.
- Effective in oxidising certain organic and inorganic compounds.

Disadvantages

1.19. There are several disadvantages to using ClO_2 as a disinfectant:

- it is highly corrosive and causes damage to pipework
- ClO_2 and its by-products, THMs, chlorate and chlorite ions, do have toxic properties
- ClO_2 forms more iodinated Disinfectant by Products (DBPs) than chlorine when iodide is present in the source water

- the legal requirement is that the combined concentration total oxidants should not exceed 0.5 parts per million (ppm)
- may dissipate rapidly if reacting with organic matter and other oxidizable contaminants. It may not reach all parts of the water system, even if high doses applied
- dosing equipment requires regular maintenance
- installing satellite-dosing systems may be needed to boost the residual at key areas, such as interposing tanks or upstream of calorifier
- if the precursor chemicals are inadvertently mixed outside of the generator, chlorine gas can be released - a highly toxic and volatile substance. It is therefore important that suitable gas alarms are installed in the areas where the equipment is installed that includes both an audible alarm and a visual alarm installed outside the access to the area
- neutralisation may be required before discharge to the environment. Long-term effects of discharging dechlorinated compounds into the environment are unknown
- any chemical discharge to a drain needs to be sanctioned by the Water Authority, who may then impose conditions on the discharge
- workers may need access to a wash down hose, chemical eyewash, and potentially a shower. Operators must also wear the proper safety equipment, including carrying an Acid Gas escape respirator
- must be removed from water prior to dialysis

UV light - continuous disinfection

1.20. UV inactivates microorganisms by damaging their nucleic acid, thereby preventing the microorganism from replicating. The most efficient and widely used device for this purpose currently is the mercury arc lamp. This can be used at the entry to the domestic water system where all the water is disinfected or can be used as a point of use system. Where other technologies are used to generate the UV light (light-emitting diode (LED) for example), the efficacy of the system should be assessed prior to installation with final sign off needed by the WSG.

Method

1.21. This disinfection method involves exposing water to radiation from UV light. Water passes through a chamber where it is exposed to the UV light, the effectiveness of the process relies on good water clarity, so filtration is often required to prevent contaminants reaching the distribution system.

Advantages

1.22. UV light can inactivate pathogenic microorganisms without forming the by-products that other chemical treatments create, and it has proven effective against some pathogens, such as Cryptosporidium, which are resistant to commonly used disinfectants like chlorine.

1.23. UV light is easy to install and has no adverse effects on water or plumbing systems. Studies suggest that the efficacy of UV light is only minimally affected by high water temperature (Malley, 2000). Studies also indicate that UV disinfection at doses of up to 200 millijoules per square centimetre (mJ/cm^2) do not change the pH, turbidity, dissolved organic carbon level, UV transmittance (UVT), colour, nitrate, nitrite, bromide, iron, or manganese of the water being treated (Malley et al., 1995).

1.24. UV light:

- requires no chemical handling
- effective in clean, low turbidity waters
- no special requirements for storage and transportation
- no formation of by-products
- not effected by pH or temperature

Disadvantages

1.25. The main disadvantage to this form of disinfection is its lack of residual protection. If used at the point of entry to a domestic water system, levels of contamination would have to be measured at outlets, as Legionella re-growth in the biofilm layers of scale and accumulated debris still allows for recolonisation. Maintenance of the water system is necessary and important to reduce this biofilm formation and Legionella recolonisation (Franzin et al., 2002).

1.26. UV treatment can be utilised as a point of use system. Although this system seems to be effective, in the case of a large hospital it would be uneconomical as there are many points of use.

1.27. Another possible disadvantage to using UV light as a disinfectant is that some of the microorganism cells damaged by the UV light can be repaired, either in the presence of light, termed ‘photoreactivation’, or through a ‘dark repair’ in the absence of light. As a result, the strategy in UV disinfection has been to provide a sufficiently high dosage to ensure that nucleic acid is damaged beyond repair.

1.28. The intensity of the lamps declines over time; therefore, they need to be replaced as per manufacturers recommendations and the quartz sleeves that contain the lamps/ bulbs/ LEDs need to be cleaned to ensure the UV light can pass through unobstructed.

1.29. UV light

- Only works at point of entry.
- Leaves no residual disinfectant in the water.
- Can be ineffective in turbid waters.
- Expensive in equipment and maintenance.
- Power supply deviations effect wavelength.
- May require prefiltration based on risk assessment and water source.
- May require frequent cleaning of tubes and chamber. Water velocity is critical so may require special chamber to provide appropriate dwell time.
- Poor penetrating power of UV light in established biofilms.

Copper Silver Ionisation - continuous disinfection

1.30. Metals such as copper and silver ions are known as bactericidal agents. Most studies on the use of copper-silver ionisation as a disinfection method have suggested good efficacy for Legionella control in water systems.

Method

1.31. This disinfection method is brought about by electrolysis, positive copper and silver ions are created from electrodes made of copper and silver, these ions are then distributed throughout water systems to eradicate bacteria. Copper ions penetrate the cell wall and as a result they will create an entrance for silver ions. Silver ions bond to various parts of the cell, such as the deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), causing all life support systems in the cell to be immobilized.

Advantages

1.32. Copper-silver ionisation systems have many advantages in that they are easily installed and maintained, and their efficacy is not affected by high water temperature. Additionally, Legionella is killed through this disinfection method rather than suppressed, which minimises the possibility of recolonisation.

1.33. Advantages:

- works in all temperatures
- high doses will remove biofilm
- disinfects drinking water for long periods of time
- will not corrode pipes
- easy to install and maintain

Disadvantages

1.34. Disadvantages to copper-silver ionisation are that:

- silver ions react easily with chlorines and nitrates, which are present in the water, causing them to no longer be effective, therefore, additional testing to ascertain the level of chlorines and nitrates present in the water must be established.
- the electrodes must be cleaned regularly to reduce scale build up and replaced as necessary to give optimal performance.
- monitoring the silver levels can be difficult and expensive.
- may need to be neutralised before discharge to the environment if in a high concentration. Any chemical discharge to a drain needs to be sanctioned by the Water Authority, who may then impose conditions on the discharge.
- Must not be used in water systems supplying dialysis machines.
- high concentrations of silver in the water can also stain porcelain
- elevated pH levels (>8.0) reduce the effectiveness of copper ions against Legionella. Although pH has little effect on silver ions, a higher pH can alter the positively charged copper ions to become negatively charged, and therefore less effective at eradicating Legionella.

1.35. The Health and Safety Executive (HSE) issued guidance on the control of Legionella bacteria. "The control of legionella bacteria in hot and cold-water systems (Health and Safety Guidance (HSG) 274)". Extract below;

"Where some of the outlets on the treated water system are used for domestic purposes, rigorous controls and regular water testing needs to be maintained to ensure that the copper level does not exceed 2.0 mg/l as Cu2+ and the silver level does not exceed 0.1 mg/l as Ag+ at these outlets".

Silver Stabilised Hydrogen Peroxide - continuous and shock disinfection

1.36. Available research suggests that combined Sliver and Hydrogen Peroxide has a moderate bactericidal effect on E. coli and only a mild virucidal effect.

Methods

1.37. Silver stabilised hydrogen peroxide solution is added to a water system by injecting it directly into the water or by adding to a water tank.

Advantages

1.38. In some instances, the combined bactericidal effects of silver and hydrogen peroxide are 1,000-fold higher than the sum of them being introduced on their own. Another benefit to using this disinfectant is that the biocidal action of silver catalysed hydrogen peroxide increases with rising temperature and pH levels. In addition, the slow and moderate bactericidal effect, and the prolonged stability and efficacy at low concentrations, point to its use as a secondary long-acting residual disinfectant for good quality drinking waters.

1.39. Advantages:

- rapid and effective disinfectant
- will remove biofilm
- works in all temperatures
- disinfects drinking water for long periods of time
- will not corrode pipes
- easy to install and maintain

Disadvantages

1.40. One area of concern is the level of silver contained in the water. The HSE and WHO guidelines should be adhered to.

1.41. Within the current Scottish Water regulations there is no reference to silver limitations.

1.42. Disadvantages:

- Residual Silver may need to be neutralised before discharge to the environment. Any chemical discharge to a drain needs to be sanctioned by the Water Authority, who may then impose conditions on the discharge
- requires the inclusion of a filter on the inlet to the sensor and regular inspection of it to ensure a clean sensor electrode
- biocidal efficacy of silver may be compromised by high concentrations of chloride
- high pH may affect efficacy
- not equally effective for all pathogens
- must not be used in water systems supplying dialysis machines

Ozone - continuous disinfection

1.43. Ozone disinfects water by damaging the DNA of microorganisms. Ozone in aqueous solutions may react with microbes either by a direct reaction with molecular ozone or by an indirect reaction with the radical species formed when ozone decomposes. Ozone decomposes quickly in potable water and is therefore normally used as a secondary disinfectant at point of use.

Method

1.44. Ozone is generated on site using dedicated machines before being injected into the water system.

Advantages

1.45. Ozone is one of the strongest and fastest acting disinfectants, and its high efficiency may have significant advantages in water treatment. The bactericidal activity of ozone is much less prone to variation in pH and ammonia content than chlorine and is more effective at low temperatures.

1.46. Ozone:

- rapid and strong disinfectant and oxidation agent
- helps with colour elimination, taste, and odour control
- does not form THMs
- very effective against Giardia, Cryptosporidium, and any other pathogenic microflora
- facilitates removal of turbidity from water
- can improve the palatability of the water
- package plants are available

Disadvantages

1.47. One of the main disadvantages to using ozone as a disinfectant is that it has been shown that mutagenic and possibly carcinogenic by products may be produced under certain conditions of ozonation.

1.48. One of the main reasons ozone on its own is not suitable as a disinfectant is that it has a very short life and carries no residual disinfectant into the distribution systems.

1.49. Ozone is also known to react with ferrous and manganous salts to produce a scum that must be filtered off.

1.50. Ozone:

- disinfects only at the point of injection
- specialised equipment required to generate ozone
- decomposes quickly
- hard to hold effective concentration
- ground level ozone is an air pollutant with harmful effects on lung function
- bromite mutagenic and carcinogenic by-products may be produced under certain conditions
- must use biologically active filters to remove by products
- no residual disinfection
- may cause precipitation of iron
- plant and equipment require regular maintenance
- when reacting with organic compounds, ozone disintegrates them into smaller components, which could become a feeding media for microorganisms' growth in water distribution systems
- requires high voltage equipment
- training and installation support required

Chloramines - continuous disinfection

1.51. Chloramines have bactericidal properties, which are more persistent in the water supply, lasting from 10 - 14 days. Chloramines offer prolonged bactericidal activity and are increasingly present in incoming mains water.

Method

1.52. Adding ammonia to water containing free chlorine, hypochlorous acid (HOCl) and hypochlorite ions (OCl-), can, depending on the pH, produce chloramines. The ideal pH value for this reaction is 8.4, at which point the water is slightly alkaline. The chloramines are then injected into the water.

Advantages

1.53. Primarily, chloramine technology is easily installed and maintained and forms fewer disinfection by-products. In addition, as chloramine is more stable and longer lasting and provides better protection against bacterial re-growth. Chloramine is also effective in controlling biofilm.

Disadvantages

1.54. There are some drawbacks to using chloramines, mainly because it can lead to the production of excess ammonia present in the water and leads to taste and odour problems. This can however be prevented by maintaining a pH level above 7.0 which must be tested for prior to implementation for this disinfection system to be deemed suitable and keeping the chlorine to ammonia ratio at 5:1 these levels must be continually observed, and the dose rate must be constantly adapted to maintain the specified ratio.

1.55. There are some potential problems with chloramines in relation to the corrosion of copper pipes and elastomer gaskets.

1.56. It has been noted that chloramines form more iodinated DBPs when iodide is present in the source water.

1.57. Risk assessments should consider the interaction of chloramines with internal disinfection protocols and infrastructure materials, particularly elastomeric seals and copper piping.

Abbreviations

ACOP: Approved code of practice

ARHAI: Antimicrobial Resistance and Healthcare Associated Infection

BPR: Biocidal Products Regulation

ClO_2: Chlorine dioxide

DBPs: Disinfectant by Products

DHWS: Domestic Hot Water Services

DL: Director Letter

DNA: Deoxyribonucleic Acid

HSE: Health and Safety Executive

HSG: Health and Safety Guidance

HAA: Haloacetic Acid

HOCl: Hypochlorous Acid

HTM: Health Technical Memorandum

IPCT: Infection Prevention and Control Team

LED: light-emitting diode

mJ/cm^2: millijoules per square centimetre

NPF: National Performance Framework

NPSA: National Patient Safety Agency

NSS: National Services Scotland

NTM: Nontuberculous mycobacteria

NWSAG: National Water Services Advisory Group

OCl-: Hypochlorite Ions

pH: potential of hydrogen

ppm: parts per million

PWTAG: Pool Water Treatment Advisory Group

RNA: Ribonucleic Acid

SAN: Safety Action Notice

SHPN: Scottish Health Planning Note

SHTM: Scottish Health Technical Memorandum

SSD: sterile services department

SETAG: Scottish Engineering and Technology Advisory Group

TDS: Total Dissolved Solids

THM: Trihalo Methanes

TOX: Total Organic Halogen

TVC: Total Viable Count

USEPA: US Environmental Protection Agency

UV: Ultraviolet

UVT: Ultraviolet transmittance

WHO: World Health Organization

WSG: Water Safety Group

WSP: Water Safety Plan

References

1. Legionnaires' disease, The control of Legionella bacteria in water systems, L8 (Fourth edition). Published 2013 Approved code of practice (ACOP) and guidance, Health and Safety Executive (HSE).

2. American national standard for haemodialysis systems, Association for the Advancement of Medical Instrumentation (AAMI) and the American National Standards Institute (ANSI), RD5-1992.

3. Drinking water quality division - List of Approved Products and processes, December 2003, The Scottish Government.

4. Drinking Water Quality Division - List of approved products, December 2007, The Scottish Government.

5. Risks to haemodialysis patients from water supply (hydrogen peroxide), National Patient Safety Agency (NPSA) (2008), RRR007 Rapid Response Report.

6. The Water Intended for Human Consumption (Private Supplies) (Scotland) Regulations 2017.

7. Simultaneous compliance Guidance manual for the long term 2 and stage 2 Disinfectant by Products (DBP) rules, U.S. Environmental Protection Agency (USEPA), (2007), Washington DC, USA.

8. Ultraviolet Disinfection Guidance Manual USEPA (2003), Washington DC, USA.

9. The Public Water Supplies (Scotland) Regulations 2014, World Health Organization (WHO), (2004), Pathogenic Mycobacteria in Water, IWA Publishing, London, UK, Pages 149-159.

10. WHO, (2019) Guidelines for drinking water quality, 4th Edition. Geneva.

11. The disinfection efficacy of a point-of-use water treatment system against bacterial, viral, and protozoan waterborne pathogens, Water Research, Volume 31, Issue 3, Pages 574-582, Abbaszadegan M, Hasan M N, Garba C P, Roessler P F, Wilson B R, Kuennen R and Van Dellen E., (1997).

12. The hospital Water Supply as a Source of Nosocomial Infections: A plea for Action. Archives of Internal medicine, Volume 162, Issue 13, Pages 1483-1492, Anaisse EJ, Panzak SR, and Dignani C., (2002).

13. UV Disinfection and Disinfection By-Product Characteristics of Unfiltered Water [project #2747]. Bellamy W, Wobma P, Malley J, Reckow D (2004).

14. Drinking water treatment processes for removal of Cryptosporidium and Giardia. Veterinary Parasitology, Volume 126, pg. 219-234. Betancourt W Q, Rose J B (2004).

15. Water disinfection with ozone, copper and silver ions, and temperature increase to control Legionella: seven years of experience in a university teaching hospital. Journal of Hospital Infection, Volume 60, Issue 1, Pages 69-72. Blanc DS, Carrara PH, Zanetti G, Francioli P., (2005).

16. Role of ozone and granular activated carbon in the removal of mutagenic compounds. Environ Health Perspect, Volume 69, Pages 159-163. Bourbigot M M, Hascoet M C, Levi Y, Erb F, Pommery N, (1996).

17. Feasibility of the silver-UV process for drinking water disinfection. Water Research. Volume 39, Issue 20, Pages 4925-4932. Butkus M A, Talbot M, Labare M P, (2005).

18. The health implications of water treatment with ozone, Life Sciences, Volume 30, Pages 117-129. Carmichael N G, Winder C, Borges S R, Backhouse B L, Lewis P D, (1982).

19. Abbreviated duration of superheat-and-flush and disinfection of taps for Legionella disinfection: Lessons learned from failure. American Journal of Infection Control. Volume 33 Issue 10, Pages 606-610. Chen Y, Liu Y, Lee S S, Tsai H, Wann S, Kao C, Chang C, Huang W, Huang T, Chao H, Li C, Ke C, and Lin Y E, (2005).

20. Advanced Physicochemical Treatment Processes. Humana Press. Chen J P, Yang L Wang L K Zhang B., (2006).

21. The Use of Chlorine Dioxide as a Hospital Potable Water Disinfection. NHS Scotland Estates Environment Forum, Borders General Hospitals Trust. Clark C F, Jackson M H, Wilson J (1999).

22. Presence of Legionella in London's water supplies, Israel Journal of Medical Sciences, Volume 22 Issue 9, Pages 633-9. Colbourne JS, Trew RM., (1986).

23. Outbreak of legionnaires disease at a university hospital, Nottingham: epidemiology, microbiology, and control. Epidemiology and Infection, Volume 110, Pages 105-16. Colville A, Crowley J, Dearden D, Slack RC, Lee J P V, (1993).

24. Degradation products formed during UV-irradiation of humic waters. Chemosphere, volume 33, Issue 2, Pages 245-255. Corin N, Backlund P, Kulovaara M., (1996).

25. Pasteurization of naturally contaminated water with solar energy, Applied and Environmental Microbiology. Volume 47, Issue 2, Pages 223-228. Douglass WC. (1994) Second Opinion, February 1994. Ciochetti D A and Metcalf R H, (1984).

26. The Relationship between Pool Water Quality and Ventilation, Journal of Environmental Health, Volume 61. Emanuel B P., (1998).

27. Evaluation of Ultraviolet light for disinfection of hospital water contaminated with Legionella, The Lancet, Volume 332, Issue 8612, Pages 669-672. Farr B M, Tatalingo J C, Gratz J C, Getchell-White S I, Groshell D H M., (1988).

28. Release of organic matter in a discontinuously chlorinated drinking water network. Water Research. Volume 37, Issue 3, Pages 493-500. Fass S, Block J C, Boualam M, Gauthier V, Gatel D, Cavard J, Benabdallah S and Lahoussine V., (2003).

29. Methods of Disinfection of the Water System of Dental Units by Water Chlorination, Journal Dent Res, Volume 67 Issue 12, Pages 1499-1504. Fiehn N E, and Henriksen K., (1998).

30. Investigation and control of an outbreak of legionnaires disease in a district general hospital, Lancet, volume 25, Issue, Pages 932-936. Fisher-Hoch SP, Bartlett CL, Tobin JO, Gillett MB, Nelson AM, Pritchard JE, et al., (1981).

31. Non-tuberculous mycobacteria in a hospital water supply. Journal of Hospital Infection, Volume 21, Issue 2, Pages 152-154. Fox C, Smith B, Brogan O, Rayner A, Harris G, Watt B (1992).

32. Evaluation of the efficacy of ultraviolet irradiation for disinfection of hospital water contaminated by Legionella. Journal of Hospital Infection volume 51, Pages 269-274. Franzin L, Cabodi D, Fantino C., (2002).

33. Formulating a risk reduction strategy for waterborne pathogens in hospital water systems. American Journal for Infection Control, Volume 33, Supplement 1 Pages S50-S53. Freije M R (2005).

34. Factors Governing Odorous Aldehyde formation as disinfection by-products in drinking water. Volume 33, Issue 6, Pages 1355-1364. Froese K, Wolanski A, Hrude S E., (1999).

35. Nosocomial contamination by Mycobacterium gordonae in hospital water supply and super-oxidised water. Journal of Hospital Infection, Volume 51 Pages 65-68. Fujita J, Nanki N, Negayama, Tsutsuiz S, Taminatoy T, Ishida T (2002).

36. The Chlorine Dioxide handbook, American Waterworks Association, Denver, CO. Gates D., (1998).

37. Chlorination by products, their toxicodynamics and removal from drinking water. Gopala K, Tripathyb S S, Bersillonb J L and Dubey S P, (2007).

38. Journal of hazardous materials, Volume 140, Issues 1-2, Pages 1-6.

39. Pseudomonas aeruginosa in a neonatal intensive care unit: reservoirs and ecology of the nosocomial pathogen, Journal Infectious Disease Volume 168, Pages 943-947. Grundmann H, Kropac A, Hartung D, Berner R and Daschner F., (1993).

40. Two fatal cases of nosocomial Legionella pneumophila pneumonia associated with a contaminated cold water supply, European Journal of Clinical Microbiology & Infectious Diseases Volume 17, Page 740. Hoebe C J, Cluitmans J J M and Wagenvoort J H T., (1998).

41. Mycobacterium avium complex infection in the acquired immunodeficiency syndrome. New England Journal of Medicine volume 324, Issue 19, Pages 1332-1338. Horsburgh CR Jr., (1991).

42. Comparison of disinfection by-product formation from chlorine and alternative disinfectants, Water Research Volume 41, Issue 8, Pages 1667-1678. Hua G and Reckhow D A., (2007).

43. In vitro efficacy of copper and silver ions in eradicating Pseudomonas aeruginosa, Stenotrophomonas maltophilia and Acinetobacter baumannii: Implications for on-site disinfection for hospital infection control. Water Research, Volume 42, Issues 1-2, Pages 73-80. Huang H, Shih H, Lee C, Yang T C, Lay J and Lin Y E, (2008).

44. Sterilization by means of ozone, Journal of Applied Bacteriology, Volume 1717, Pages 246-271. Ingrams M and Barnes E M, (1954).

45. Introduction to Research in Ultraviolet Photobiology, Prentice Hall, Englewood cliffs. Jagger J, (1967).

46. Journal of Photochemistry and Photobiology A: Chemistry, Volume 169, Issue 3, Pages 279-287. Jeong J, Sekiguchi K, Lee W, Sakamoto K., (2005).

47. Literature review-efficacy of various disinfectants against Legionella in water systems, Water Research, Volume 36, Pages 4433-4444. Kim BR, Anderson J E, Mueller S A, Gaines W A, Kendall A M., (2002).

48. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on Cryptosporidium parvum oocyst viability, appl. Environ. Microbiol. Volume 56, Pages 1423-1428. Korich D G, Mead J R, Madore M S, Sinclair N A, Sterling C R., (1990).

49. Legionellosis: ecological factors of an environmentally ‘new’ disease. Zentralbi Hyg Umweltmed. Volume 195, Issue (5-6), Pages 470-482. Kramer M H, Ford T E., (1994).

50. Susceptibility of Legionella Pneumophila to chlorine in tap water. Appl Environ Microbiol, Volume 46, Issue 5, Pages 1134-1139. Kuchta J M, States S J, McNamara A M, Wadowsky R M, and Yee R B., (1983).

51. Factors Promoting Survival of Bacteria in Chlorinated Water Supplies, Applied and environmental Microbiology, volume 54, Issue 3 Pages 649-654. LeChevallier, M W, Cawthorn C D, and Lee R G., (1998).

52. Individual and combined effects of copper and silver and silver ions on inactivation of Legionella Pneumophila, Water Research, Volume 8, Pages 905-913. Lin Y E, Vidic R D, Stout J E, Yu V L, (1996).

53. Disinfection in water distribution systems for Legionella, Seminars in Respiratory Infections, Volume 13, Issue 2, Pages 147-159. Lin Y E, Vidic R D, Stout, J E and Yu V L., (1998).

54. Negative Effect of High pH on Biocidal Efficacy of Copper and Silver Ions in Controlling Legionella pneumophila, appl Environ Microbiol, volume 68, Issue 6, Pages 2711-2715. Lin Y E, Vidic R D, Stout, J E and Yu V L., (2002).

55. Legionella in water distribution systems, Journal American Water Works Association, volume 90, Pages 112-121. Lin Y U, Vidic, R D, Stout J E, Yu V L., (1998).

56. Controlled evaluation of copper-silver ionisation in Eradicating Legionella pneumophila from a hospital hot water system, Journal of Infectious Disease, Volume 169, Pages 919-922. Liu Z, Stout JE, Tedesco L, Boldin M, Hwang C, Diven W F, Yu V L., (1994).

57. Water chlorination and birth defects, Department of Population Health Sciences, national Institute of Public Health, Oslo, Norway Epidemiology, Volume 10, Issue 5, Pages 513-517. Magnus P, Jaakkola J J, Skrondal A, Alexander J, Becher G, Krogh T, Dybing E., (1999).

58. Evaluation of by-products produced by treatment of groundwaters with ultraviolet irradiation, Denver, Colorado: AWWA Research Foundation and the American Water Works Association. Malley, J P, Shaw, J P and Ropp, J R., (1995).

59. The state of the art in using UV disinfection for waters and wastewaters in North America, Proceedings of ENVIRO 2000 – Australian Water Association (AWA), Sydney, Australia. Malley, J., (2000).

60. Reduced Susceptibility of Legionella pneumophila to the Antimicrobial Effects of Copper and silver Ions, Proc, 45th Interscience Conference on Antimicrobial Agents and Chemotherapy, Washington. Miuetzner S M, Hangard A, Stout J E, Rohr U, Pedro-botet M L, Samore M H, and Yu V L., (2005).

61. Potential health effects of drinking water disinfection by-products using quantitative structure toxicity relationship, Toxicology, volume 147, Pages 109-131. Moudgal CJ, Lipscomb JC, Bruce RM, (2000).

62. Comparative assessment of chlorine, heat, ozone, and UV light for killing Legionella pneumophila within a model plumbing system Appl Environ Microbiol, Volume 53, Pages 447-53. Muraca P, Stout J E, Yu V L, (1987).

63. Health System Triumphs Over Legionella, AFE Facilities Engineering. Neurener A R., (2002).

64. Optimisation of the long-term efficacy of dental chair waterline disinfection by the identification and rectification of factors associated with waterline disinfection failure, Journal of dentistry Volume 35, Pages 438-451. O'Donnell M J, Shore A C, Russell R J, Coleman D C., (2007).

65. Treatment with ozone, American Journal Water Works Association, Volume 57, Pages 1167-1194. O'Donovan D C., (1965).

66. Hospital water point-of-use filtration: A complimentary strategy to reduce the risk of nosocomial infection. American Journal of Infection Control, volume 33, number 5, supplement 1, Pages S1-S19. Ortolano G, McAlister M, Angelbeck J, Schaffer J, Russell R, Maynard E, Wenz B (2005).

67. Chlorine Dioxide Water Treatment - for hot and cold water services, Technical Note TN 2/98, BISRIA. Pavey N L, Roper M, (1997).

68. The efficacy of long-lasting residual drinking water disinfectants based on hydrogen peroxide and silver, Water Science and Technology Volume 42, Issue, 1-2, Pages 293-298. Pedahzur R, Katzenelson D, Barnea N, Lev O, Shuval H. I, Fattal B, and Ulitzur S., (2000).

69. Effect of temperature and disinfection strategies on ammonia-oxidizing bacteria in a bench-scale drinking water distribution system, Water Research, Volume 37, Pages 1805-1817. Pintara K D M, Slawson R M., (2003).

70. Persistent colonization of potable water as a source of Mycobacterium avium infection in AIDS, Lancet, Volume 343, Pages 1137-1141. Reyn C V, Maslow J N, Barber T W, Falkinham III J O and Arbeit R D, (1994).

71. Have utilities switched to chloramines? Journal American Water Works Association, Volume 97, Issue 10, Pages 87-97. Seidel CJ, McGuire M J, Summers R S, Via S., (2005).

72. Impact of hydrogen peroxide on nitrite formation during UV disinfection. Water Research, Volume 37, Pages 4730-4736. Severin B F, Suldan M T, Linden K G., (2003).

73. Impact of hydrogen peroxide on nitrite formation during UV disinfection. Water Research, Volume 37, Pages 4730-4736. Sharpless C M, Page M A, Linden K G., (2003).

74. Hospitals turn to ionization method for controlling Legionella infections (What Works), Healthcare Purchasing News. Shields T, (2002).

75. Silver as a Disinfectant, Review of Environmental Contamination Toxicology, volume 191, Pages 23-45. Silvestry-Rodriguez N, Sicairos-Ruelas E., Gerba C P, Bright K (2007).

76. Control of disinfection by-products in drinking water. Journal of Environmental Engineering. ASCE, Volume 120, Issue 4, Pages 727-744. Singer P C., (1994).

77. Purification of water supplies using ultraviolet light. In Developments in Food Microbiology, ed. R. K. Robinson. New York: Elsevier Applied Science, Pages 171-191. Snowball, M R, and Hornsey I S., (1988).

78. Thermal inactivation of water-borne pathogenic and indicator bacteria at sub-boiling temperatures. Water Research, volume 40, Pages 1326-1332. Spinks A T, Dunstan R H, Harrison T, Coombes P, Kuczera G (2006).

79. The Basic Benefits of Ultraviolet Technology, Water Conditioning and purification, December Issue, Pages 26-27. Srikanth B, (1995).

80. A 17-month evaluation of a chlorine dioxide water treatment system to control Legionella species in a hospital water supply. Infection control and hospital epidemiology 575 Volume, 24, Issue 8, Page 575. Srinivasan A, Bova G, Ross T, Mackie K, Paquette N, Merz W, Perl T M., (2003).

81. Controlling Legionella in Hospital Water Systems: Experience with the Superheat-and-flush Method and Copper-silver Ionisation, Journal of Infection Control and Hospital Epidemiology, Volume 9, No 12, Pages 911-914. Stout J E, Lin Y E, Goetz A M, Muder R R (1998).

82. Legionella in the Hospital Water Supply: A plea for decision making based on evidence-based medicine infect control Hosp Epidemiol, Volume 22, Pages 670-672. Stout J E, Yu VL., (2001).

83. Chlorine, Chloramine, Chlorine Dioxide, and Ozone Susceptibility of Mycobacterium avium. Applied and Environmental Microbiology, April 2000, Pages 1702-1705. Taylor R H, Falkinham III J O, Norton C D, LeChevallier M W (2000).

84. Health affects among newborns after parental exposure to ClO_2 disinfected drinking water. Environmental Health Perspectives. Volume 46, Pages 38-39. Tuthill R W, Giusti R A, Moore G S, Calabrese E J., (1982).

85. Inorganic by-products in waters disinfected with chlorine dioxide. Volume 79, Issues 1-2, January 2005, Pages 165-170. Veschetti E, Cittadini B, Maresca D, Citti G, Ottavian M., (2004).

86. Aeromonas spp. And traveller's diarrhoea: Clinical features and antimicrobial resistance, Emerging infectious diseases, Volume 9, No 5, Pages 552-555. Vila J, Ruiz J, Gallardo F, Vargas M, Soler L, Figuera M J, Gascon J (2003).

87. Trihalomethanes in drinking water and spontaneous abortion. Epidemiology, Volume 9, Issue 2 Pages 134-140. Waller K et al., (1998).

88. Performance of ozone as a disinfectant for combined sewer overflow. Critical reviews in Environmental Science and Technology, Volume 31, Issue 15, Pages 295-309. Wojtenko I, Stinson M K, Field R, (2001).

89. Mycobacterium xenopi and Mycobacterium kansasii in a hospital water supply, Journal of Hospital Infection, Volume 6, Pages 175-178. Wright E P, Collins C H, and Yates M D (1985).

90. August 23), Environmental tests help predict hospital-acquired Legionnaires’ disease risk. Science Daily. Yu VL, (2007), University of Pittsburgh Schools of the Health Sciences (2007).

91. Effect of heat flushing on the concentrations of Legionella pneumophila and other heterotrophic microbes in hot water systems of apartment buildings. Can J Microbiol. Volume 42, Issue 8, Pages 811-8. Zacheus O M, Martikainen P J., (1996).

92. Use of chlorine dioxide for Legionella control in hospital water systems. University of Pittsburgh. Zhang Z., (2007).

93. Legionella control by chlorine dioxide in hospital water systems, American Water Works Association, Pages 117-127. Zhang Z., (2009).

94. Effect of pipe corrosion scales on chlorine dioxide consumption in drinking water distribution systems, Water Research Volume 42, Pages 129-136. Zhang Z, Stout JE, Yu VL, Vidic R., (2008).

95. Safety and efficacy of chlorine dioxide for Legionella control in a hospital water system. Infect Control Hosp Epidemiol, volume 28, Issue 8, Pages 1009-12. Zhang Z, McCann C, Stout JE, Piesczynski S, Hawks R, Vidic R, Yu VL., (2007).

96. Effect of pipe corrosion scales on chlorine dioxide consumption in drinking water distribution systems, Water Research, Volume 42, Pages 129-136. Zhang Z, Stout JE, Yu VL, Vidic R, (2008).

97. BS EN 12671:2016 Chemicals used for treatment of water intended for human consumption. Chlorine dioxide generated in situ.