CHLORINATION:
INFORMATION FOR GROUP WATER SCHEMES

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National Federation
of Group Water Schemes

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This booklet would not have been possible without the co-operation of group water schemes the length and breadth of the country that provide access to their pumphouses/treatment plants and are always open to critical as well as positive evaluations of their facilities.

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To those who read the proofs and provided useful commentary and to Castle Printing for their professionalism in bringing this publication to print ... míle buíochas daoibh go léir.

Introduction

Simple disinfection, using a sodium hypochlorite solution (bleach) is the most common method of treating Irish drinking water supplies, but how much do we really know about this product and how it works? Do we really appreciate its importance, or is it something that is dosed reluctantly and only because drinking water suppliers are expected to chlorinate? Do group schemes understand what is required to achieve effective disinfection using a sodium hypochlorite solution and do they appreciate the risks that go with the handling and/or improper dosing of this chemical?

Evidence from NFGWS site visits and from chlorine residual readings taken as part of compliance monitoring sampling on group water schemes suggests that knowledge about and attitudes to this important subject vary widely within the GWS sector.[1]

Based on a series of articles on the subject published in *Rural Water News* — but with additional material also — this booklet aims to provide some useful information for those involved in drinking water disinfection. **It is not a manual**, however, and GWS treatment plant operators are strongly advised to avail of training in disinfection procedures (as per the Water Services Training Group) and should always seek competent technical advice where specific issues arise in relation to chlorination.

After explaining the evolution of chlorination in water treatment and the health benefits that have arisen as a direct result of its use, the booklet looks at what distinguishes a sodium hypochlorite 'suitable for potable use' from a bleach solution that is only suitable for non-potable uses. It discusses why not all potable disinfectants will suit a particular water supply, and why schemes with hard water or with relatively small water demand need to think carefully about what they are purchasing.

Having emphasised the importance of purchasing an appropriate sodium hypochlorite solution for the particular water supply, the booklet then considers the optimum set up for a dosing system and how to establish the correct dose.

After a brief look at chlorination by-products, the booklet concludes with an examination of some of the health & safety issues that need to be considered when using sodium hypochlorite in drinking water treatment.

[1.] Local authority returns to the EPA reveal that 23% of compliance monitoring samples on privately sourced GWS supplies in 2015 had less than the recommended 0.1 mg/litre chlorine residual. While data for some counties was not included, the available results reveal a significant regional variation and a clear link between the absence of residual and microbiological non compliance.

In addition to reading this infomation booklet, the operators of disinfection systems should complete all relevant technical training courses and should be familiar with the EPA's *Water Treatment Manual: Disinfection* (2011).

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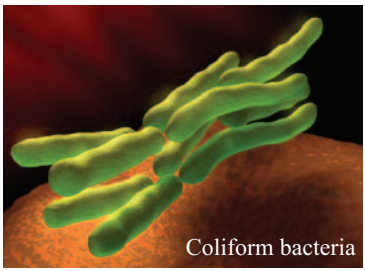
N.B. This booklet is not a manual

Why disinfect drinking water?

Disinfection is an essential water treatment process that every drinking water supply, no matter the size, should have in place. The purpose of disinfection is to protect the consumer from potentially harmful bacteria — such as *E.coli* and Enterococci — as well as from viruses that can result in illness, particularly in young children or people with vulnerable immune systems.


Coliform bacteria

Prior to the introduction of disinfection, the sickness and death from waterborne diseases that we associate with the developing world were endemic in Ireland, as elsewhere. It wasn't simply tummy bugs and diarrhoea: typhus, cholera, dysentery and hepatitis A were not uncommon and into the late 1950s the waterborne poliovirus resulted in many babies being born with physical deformities.

Escherichia coli (E.coli)

Enterococcus faecalis

Pathways

The potential for such diseases is still there, so long as there are pathways for pathogenic bacteria and viruses to enter the drinking water supply from source to tap. It is estimated that 30% of all private wells in Ireland are contaminated with *E.coli* and we can take it as read that all surface water supplies, as well as groundwaters influenced by surface flow, will be subject to microbiological contamination also ... sometimes grossly so.

The reason that there are relatively few illnesses/deaths from such contamination in the modern era is because our water supplies are disinfected to kill the pathogens that are present in the raw water and to protect against any pathogens that may enter the distribution network after the treatment process. The disinfectant that provides this source to tap protection is chlorine.

The presence of Coliform Bacteria in drinking water indicates that a supply may be at risk from a range of problematic bacteria. In particular, both *E.coli* and Enterococci are pathogenic bacteria, meaning that they can cause illnesses if ingested and diarrhoea, urinary tract infections, respiratory problems and pneumonia may result. VTEC *E.coli* (which is prevalent in Irish raw water supplies) can, in fact, be fatal.

Water-transmitted viral pathogens — including hepatitis A and E, rotavirus, norovirus etc. — are most commonly associated with gastroenteritis, but can also result in more serious conditions, including meningitis.

Effective disinfection destroys such pathogens in water, thereby protecting human health from source to tap.

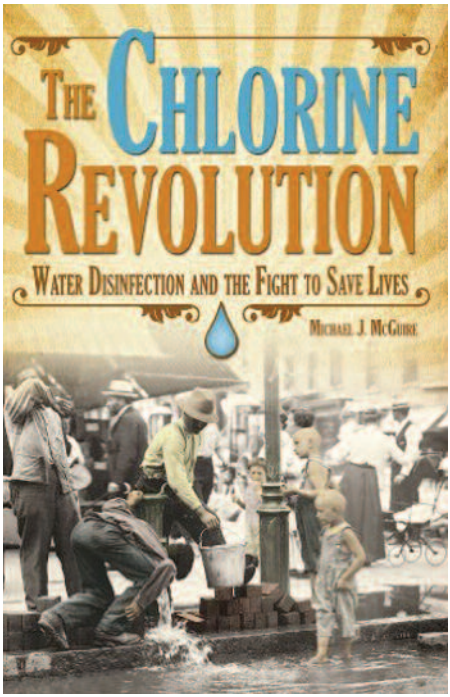
What is chlorine?

Chlorine is one of about 100 natural chemical elements, the basic building blocks of our planet, and is amongst a group of 5 elements known as halogens (salt-formers). It was first discovered in 1774, when a Swedish pharmacist released a few drops of hydrochloric acid onto manganese dioxide. As part of the chemical reaction, a pungent greenish-yellow gas was produced. 36 years later, in 1810, this gas was named as 'chloric gas' or 'chlorine' from the Greek word khloros, meaning greenish-yellow.

Chlorine can exist as a solid, liquid or gas but it isn't found free in nature. Because it is a very reactive chemical, it is always found as a compound with other chemicals, and most commonly as sodium chloride (salt). Commercially produced through electrolysis of aqueous sodium chloride (i.e. brine), chlorine's bonding properties make it ideal in the manufacture of thousands of products, but it is as a disinfectant used in water treatment that it has proved the greatest benefit to humankind.

Emergence as a disinfectant

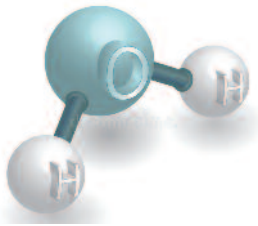
While chlorine was originally valued for its bleaching properties, its application as a disinfectant gathered momentum in the 19th century. As early as 1835, midwives were being advised by Oliver Wendel Holmes to wash their hands in calcium hypochlorite to prevent a spread of midwives' fever.



The relationship between water supply and the spread of disease was appreciated at an early stage by English Physician John Snow who proposed, in 1849, that water 'be filtered and boiled before it is used'. In 1854 Snow used a chlorine compound in an attempt to disinfect a pump in London's Broad Street that he correctly identified as the source of a cholera outbreak in the area.

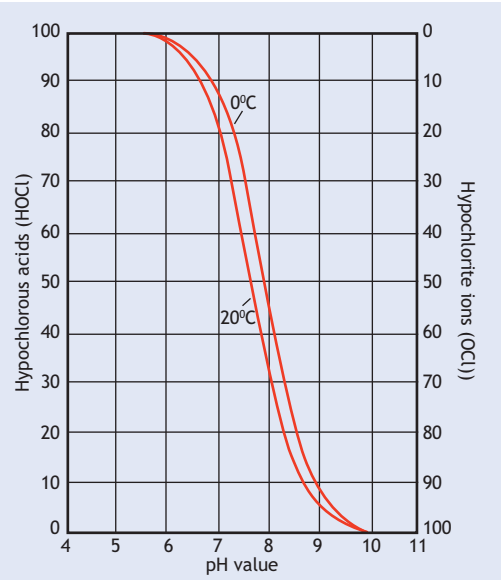
By 1893, a similar compound was being used on a larger scale for drinking water disinfection in Hamburg, Germany, while the first use of chlorine gas for water treatment disinfection was in Belgium in 1903. Full-scale water disinfection on a continuous basis using sodium hypochlorite was first used in Jersey City, New Jersey, USA in 1908. By the outbreak of the First World War in 1914, the establishment of a minimum standard for coliforms in drinking water in the USA heralded the widespread adoption of the technology.

Then as now, there were those who had a phobia about using chemicals in the treatment of water, unaware or forgetting that water is itself a combination of the chemicals hydrogen and oxygen (H_2O). Litigation failed to stop the advance of the technology, however, as evidence quickly mounted that the rate of water-borne diseases was vastly reduced as a direct result of chlorine being added to drinking water supplies.



How does chlorine disinfect water?

Chlorine kills pathogens such as bacteria and viruses by breaking the chemical bonds in their molecules. When the enzymes in bacteria and other cells come into contact with chlorine, one or more of the hydrogen atoms in the molecule are replaced by chlorine, causing the cell or bacterium to die.



pH has a major influence on the chlorination process. Where pH is <7.5, hypochlorous acids will predominate. These are 80%-100% more effective as a disinfectant than hypochloric ions.

In the case of water treatment, when chlorine is added, hypochlorous acids (HOCl) form, which are electrically neutral, as do hypochlorite ions (OCl), which are electrically negative. The pH of the water will determine the relative proportion of HOCl and OCl, with pH of less than 7.5 favouring HOCl, which is 80%-100% more effective as a disinfectant.

Hypochlorous acid splits into hydrochloric acid (HCl) and Oxygen (O). This oxygen atom is a powerful disinfectant. The negatively charged cell walls of pathogens are easily penetrated by the neutral HOCl. As a result, the micro-organisms either die or suffer from reproductive failure.

Disinfection time of faecal pollutants with chlorinated water

E. coli 0157 H7 bacterium	<1 minute
Hepatitis A virus	about 16 minutes
Giardia parasite	about 45 minutes
Cryptosporidium	about 9,600 minutes

Source: http://www.lenntech.com/processes/disinfection/chemical/disinfectants-chlorine.htm#ixzz4nlBzP1DM

Choosing your sodium hypochlorite

How sodium hypochlorite is manufactured

While chlorine can be dosed as a gas in water treatment, in the GWS sector it is much more commonly dosed as part of a sodium hypochlorite liquid solution. Rock salt is the basic ingredient of sodium hypochlorite. Mixed in a water solution as brine, it is decomposed by means of electrolysis, producing (in almost equal measure) chlorine and sodium hydroxide (caustic soda). When chlorine gas is then added to caustic soda, sodium hypochlorite, water (H_2O) and salt (NaCl) are produced.

The purity of the rock salts used in this process and in the subsequent production process will determine the quality and the life of the finished sodium hypochlorite solution. High quality sodium hypochlorite will only have trace amounts of nickel, copper, iron and suspended solids. It will also have minimum sodium chlorate, perchlorate and sodium bromate levels.

Salt produced from rock salt mines (as pictured) is the basic ingredient of sodium hypochlorite. The purity of the rock salt used will, therefore, influence the purity of the final product, as will the method of manufacture.

Potable v. non potable

Sodium hypochlorite products that are used for various other purposes — such as disinfecting dairy equipment or as ordinary household bleach — are also disinfectants and will kill a certain amount of bacteria. While this is true, it does not mean that they are suitable for drinking water treatment. Problems arise in relation to the strength of these disinfectants and the additional compounds that they contain. These will result in unwanted contaminants in the final drinking water and are likely to result in a higher rate of product decomposition.

While household bleaches, dairy washing chloros and other products contain sodium hypochlorite, they are not suitable for drinking water treatment.

Typically sodium hypochlorite of 6.5% to 15% is used to disinfect drinking water and Irish Water's National Disinfection Strategy specifies the use of 10-12% sodium hypochlorite.

Using a sodium hypochlorite product with a strength outside of the 6.5% to 15% range will impact on the length of time the sodium hypochlorite can be stored while remaining an effective disinfectant. It will also impact on the toxicity of the disinfectant in the final water.

While the concentration of suspended solids (including metals) in drinking-water-approved sodium hypochlorite will have met certain limits to ensure that there is no negative impact on human health, a product unapproved for drinking water will not have gone through the same approval process.

How do I know if my sodium hypochlorite is approved for drinking water?
Under the Biocide Regulations (Regulation (EU) No. 528/2012) all disinfectants approved for drinking water should be labelled and the label should contain the following information;

- a product approval number, usually beginning with the letters PCS
- a list of the active ingredients and their relative concentrations stated
- a statement that the product has been approved for drinking water
- instructions on use and storage *and*
- an expiry date or manufacture date.

If you cannot find this information on the drum, or if the supplier cannot provide you with this information, then the product is not suitable for use in drinking water, may contaminate your water supply and should not be used.

See Appendix 1 for the full text of the relevant section from Regulation (EU) No. 528/2012.

Types of sodium hypochlorite

There are a number of specific types of drinking water approved sodium hypochlorite products on the market (supplied by various companies), including H-grade sodium hypochlorite and ultra low bromate sodium hypochlorite. H-grade sodium hypochlorite can be used in schemes that are known to have highly alkaline or hard raw water. The product has been specifically manufactured to include water softening agents that prevent scaling and clogging of dosing lines.

Where the presence of bromide ions in either the raw water or in the sodium hypochlorite is resulting in an exceedance of the 10µg/l bromate limit in the final disinfected drinking water, an ultra low bromate sodium hypochlorite can be used to reduce the bromate levels.

Degradation

Sodium hypochlorite is a chemically unstable product meaning that as soon as it is manufactured it begins to degrade and the chlorine concentration (i.e. the disinfectant), begins to reduce. The rate of degradation is influenced by several factors, including exposure to natural light or to a heat source, the presence of contaminants and the strength of the solution (the higher the percentage the quicker the rate of degradation). For these reasons:

- opaque delivery and day drums are preferable and windows should be covered to exclude natural light,
- the ambient temperature in the pumphouse should be cool (the degradation rate doubles for every 6.5 degrees Celsius above 21 degrees).
- Sodium hypochlorite is best dosed neat but where water is added to the solution, only treated soft water should be used, as the use of untreated soft water, or of groundwater, will add suspended or dissolved solids and other contaminants and may precipitate out calcium carbonate that will speed up the process of degradation
- a sodium hypochlorite of 10% or less is preferable to a higher percentage solution, as this will degrade more slowly. [An added advantage on direct pump, low water demand schemes is that a lower percentage solution better maintains the activity of flow proportional dosing pumps.]

Care needs to be taken in choosing the correct sodium hypochlorite for your water supply. This will depend on the character of your raw water (hard or soft) and on daily water demand.

At a minimum, check that the product is appropriately labeled, is suitable for potable water treatment and that it carries a manufacture or 'use by' date.

Assuming that storage conditions are not influencing the process of product degradation, sodium hypochlorite that has passed its expiry date should not be used for two main reasons:

- the chlorine concentration has significantly reduced (e.g. a 10% sodium hypochlorite solution will drop to 8% after 100 days) and
- the formation of chlorate as a harmful by-product (see p.19 for more information on disinfection by-products, including chlorate).

Increased dose

As the sodium hypochlorite degrades it is necessary to increase the sodium hypochlorite dose to ensure disinfection. The older the disinfectant you have the more you have to dose to get the same chlorine residual and this will affect the costs of treating your water (e.g. you have to dose 20% more to get the same amount of chlorine in your final water if your disinfectant has dropped from a 10% solution to an 8% solution).

Schemes should implement a stock control system and limit their purchasing of sodium hypochlorite to ensure they do not have to dispose of sodium hypochlorite that is more than 3 months old. For smaller schemes that face additional delivery costs from ordering small batches, consideration should be given to working with neighbouring schemes so that all receive a delivery on the same day. Alternatively a (more expensive) laboratory standard sodium hypochlorite delivered in 2 litre bottles might be considered, or a move to electro chlorination [see below].

On-site electro hypochlorite (OSEC) generation uses high quality salt mixed with water to manufacture a fresh, very low percentage and safe disinfectant in the pumphouse/treatment plant.
This is an option that may suit smaller schemes in particular, as the ongoing costs and additional risks associated with the delivery and storage of sodium hypochlorite drums are avoided.
Sheepgrange GWS (above) uses a 25kg bag of salt every 3 months to provide disinfected water to its 80 members (including 70 households). The system is serviced twice annually and otherwise requires very little maintenance.

Dosing system set-up

Locating the dosing system

Sodium hypochlorite is highly corrosive in the presence of moisture, so placing the day drum and dosing pumps in the often damp surroundings of a pumphouse/ treatment plant is unwise as it is likely to result in premature rusting of metal fixtures and fittings. Locating the day drum and the dosing pumps in a dedicated, dark, dry, cool (not cold) and ventilated structure adjoining the pumphouse overcomes this issue, with the dosing tubing being fed through to the injection point in the pumphouse/treatment plant. The distance to the injection point should, however, be as short as possible to reduce the risk of air locks/blockages in the dosing tubing.

Where there is no option but to locate the day drum and dosing pumps in the pumphouse/treatment plant, every precaution should be taken to avoid water leaks, to stop them promptly if they occur, and to keep moisture out of valves, tubing, etc.

Sodium hypochlorite is highly corrosive where there is moisture (from water leakage), as above. Note that while the day tank is properly bunded, only a single dosing pump is fitted.

Focus on the day drum

Insufficient attention is paid to the day drum from which sodium hypochlorite is dosed into the water supply. These should preferably be opaque (dark coloured) to protect against natural light accelerating the process of decomposition. They should also be spotlessly clean, both inside and out, as should their surroundings. Small supplies (i.e. most group water schemes) should avoid oversized day drums as the temptation will be to overfill these and the sodium hypochlorite will lose its freshness. For safety reasons, bunded day drums should be placed on the floor and not on a raised shelf.

Wherever the day drum and back-up containers are housed, bunding should be provided for all vessels containing sodium hypochlorite. These bunds must be equal to holding the contents of those vessels should there be a spill. Moisture should not be allowed accumulate in bunds for the reason outlined above.

Because hard water is being used to dilute the sodium hypochlorite solution, this day drum is caked with calcium carbonate and a build-up is clearly visible on the floor of the drum. Besides shortening the useful life of the disinfectant, such a build-up is likely to result in blockages in the dosing system's tubing or pumps.

Hard water should not be used to dilute sodium hypochlorite in the day drum as it will introduce calcium carbonate, magnesium and other natural contaminants that will shorten the life of the solution. Moreover, the build up of calcium on the floor of the day drum can cause blockage in the dosing pumps. If dilution is considered necessary, use a safe soft water supply.

A sodium hypochlorite solution loses at least 1% of its volume as oxygen each day through 'air binding'. The rate of loss increases with age and temperature. Venting of the day drum is advisable as a guard against air-locks in the dosing system.

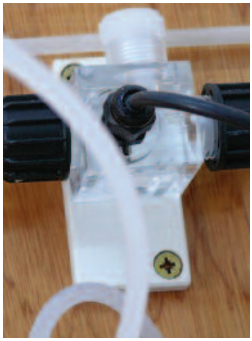
Repeated topping up of the day drum should be avoided. The older solution will be a weaker disinfectant and a chlorination by-product (chlorate) may have formed in it. The day drum should be fully emptied and cleaned on a regular (at least quarterly) basis as part of Quality Assurance implementation.

Dosing pumps, tubing & filters

The EPA recommends that a duty and standby dosing pump arrangement is in place, with automatic switchover between the duty and standby pumps. This provides reassurance that if the duty pump fails for some reason, the dosing will automatically switch over to the standby pump and the drinking water supply will continue to be disinfected. This avoids a situation where a caretaker visits a pumphouse/treatment plant to find that the chlorine dose has stopped working and that undisinfected water has been delivered to GWS members, possibly since the last visit!

Ideally, dosing pumps should have a lift of 1 metre from the point at which the solution is being abstracted from the day drum, but a lift of up to 2 metres can be tolerated. The abstraction nozzle should not rest on the floor of the day drum, as impurities may be drawn into the pumped system and cause blockages.

To guard against gas traps, loops should be avoided on the suction (and discharge) tubing. Protect against leaks from the tubing by ensuring that it is properly glued in place (bearing safety procedures in mind before carrying out any repairs). Routine inspection of tubing is advisable, as calcification and air blocks can restrict the transfer of sodium hypochlorite to the injection point. An alarmed discharge valve, through which the flow of the solution can be seen and heard, is very useful. Ideally both duty and standby pumps should be alarmed to notify the caretaker when a pump has stopped working so that the problem can then be quickly addressed.



Alarmed discharge valve

Dosing pumps should be alternated at least every 24 hours. Regular maintenance of dosing pumps and filters on small bore dosing lines is essential and all dosing systems should be serviced annually.

Injection point & calcification

Sodium hypochlorite disinfectant should be dosed into the pipework at a fixed delivery point. This should be after any other treatment steps at the water treatment plant and before the contact tank or reservoir, if there is one, or before the first household on the network in direct pump systems.

For schemes with hard water, particular attention must be paid to ensuring the free flow of solution through the injection point. This can be achieved using a water softener that feeds directly to the injection point.

Killaturley GWS has a dedicated sodium hypochlorite structure. The dosing tank is within a/bunded area and the tank itself is opaque so that natural light isn't degrading the solution. The duty and stand-by dosing pumps have a lift of about a metre and the lines are straight (with no loops), as recommended. This structure backs onto a building where the injection point is located after the water has passed through a UV disinfection unit.
Note the cleanliness of the surroundings and the availability of a pump to transfer the sodium hypochlorite from the delivery drum to the day drum.

Some schemes are using simple plungers to push out the calcium carbonate as part of routine maintenance. Soaking the injection valves in vinegar will also remove the build-up of scale, but this will require a duty and standby valve arrangement for schemes that don't have reservoir storage and pump directly to their members.

To further reduce the risk of scale blockages, consider using 5% sodium hypochlorite and digital dosing pumps as they can be set to dose small amounts.

Killeigh GWS (Offaly) installed its own simple plunger to push out calcium build-up at this injection point. This scheme employs water softening to reduce calcification at the injection point in another of its 3 treatment facilities.

Providing for contact time

Group schemes should understand the importance of contact time [see next section] and make allowance for it in the design of their disinfection system. While larger schemes will have dedicated contact tanks or reservoirs that allow contact, many small schemes do not. A priority for such schemes should be to either install a dedicated tank for this purpose or, where space is an issue, bury a coil of piping in the ground outside the pumphouse that will provide the required contact time. In the case of good quality groundwaters, this will be relatively short.

Online residual monitor

Chlorine residual must be monitored after contact time has been provided (i.e. at the outflow from a contact tank/coil of piping). It is pointless monitoring residual immediately after dosing and before such contact has been completed.

On-line systems to monitor chlorine residual require periodic calibration, as per manufacturer's instructions.

Where chemical reagents are used in online monitors, discharge pipes should not be directed into a borehole.

Getting the dose right

Fixed dosing v. variable

If the flow of water going through a treatment plant is always fixed at the same volume then the duty and standby pumps can be set up with the correct dose rate and this can also be fixed. If the flow through a treatment plant is variable, depending on water demand, then the EPA recommends having a flow proportional dosing system. This means that the duty and standby pumps are set up to automatically adjust the dose rate depending on the flow of water passing through the plant. Flow proportional dosing can also be adjusted or 'trimmed' to maintain a certain chlorine residual measurement at the outlet of the reservoir or at another fixed point in the water supply network.

Chlorine demand

Whatever grade and strength of sodium hypochlorite is being used, the process of determining the correct amount of sodium hypochlorite to dose is the same. Measured in mg/litre, the dose rate will depend on the chlorine demand of the raw water (i.e. the amount of chlorine that will be required to properly disinfect it), as well as being able to achieve a minimum chlorine residual of 0.1mg/litre at the end of the supply network. In simple terms:

Dose Rate = Chlorine Demand + Total Chlorine Residual

Assuming that a fresh consignment of quality sodium hypochlorite is being used, raw water factors that will determine the required dose include:

- **Turbidity**: this inhibits the ability of chlorine to get at bacteria that are being sheltered in particles of suspended matter. The lower the turbidity the better (and preferably below 0.2 NTU post filtration).
- **Metallic compounds**: a substantial amount of chlorine is used where there is dissolved iron and manganese, particularly at levels greater than 100μg/litre (Fe) and 50μg/litre (Mn).
- **Ammonia**: when sodium hypochlorite is dosed into water with ammonia levels greater than 0.01mg/litre, combined chlorine is formed, which is a less effective bactericide.
- **No. of coliforms**: to be confident of achieving 100% compliance, the water supply being disinfected should not contain more than 100 coliforms/100ml.

Where any of the above properties are not adequately addressed as part of pre-disinfection treatment processes, an allowance must be made for them in the chlorine dose.

Approximate volume of good quality sodium hypochlorite required to treat specific volumes of water to 1 mg/litre

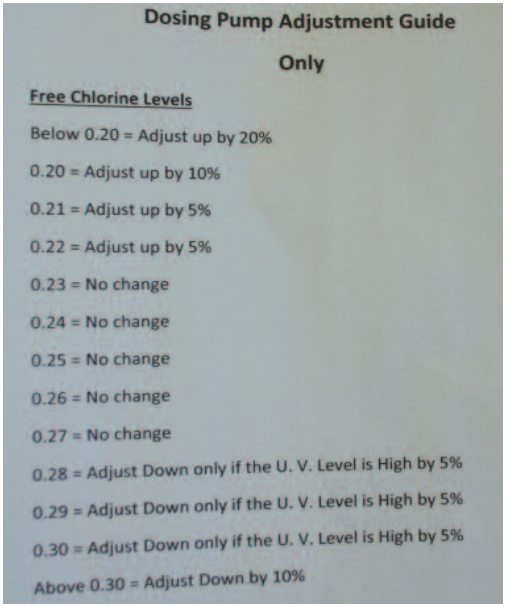
- 1 litre of 15% treats about150m^3
- 1 litre of 10% treats about100m^3
- 1 litre of 5% treats about 50m^3

Establishing the dose

Dosing with sodium hypochlorite as a primary disinfectant has two objectives: to kill or disable pathogens and viruses and to provide continued protection against recontamination in the distribution system. The dose must meet both these objectives. For schemes that use validated UV treatment as a primary disinfectant, the objective of using sodium hypochlorite is protection in the distribution network.

Whether it is used as a primary or secondary disinfectant, finding the correct chlorine dose for your supply will take time and experience, as the dose will vary depending on other factors. The quality of the water being dosed, the freshness of the sodium hypochlorite solution, variations in daily water demand and the condition of the distribution system will have a bearing on the dose that will be needed.

The first step is to establish the minimum level of free residual chorine needed at the point of delivery into the distribution system to offer protection to the last household on the pipe network. Adopting the precautionary principle, a little more than that minimum should be the lowest target in a range of target values. Once the range of values is decided upon, dosing levels can be increased or reduced as necessary, although short-term increases beyond the 'normal' range may be demanded on occasions (e.g. when repair works are being carried out on a section of the pipework).



Bunn GWS provides simple guidance linking residual chlorine readings to sodium hypochlorite dosing.

Dosing rate adjustments — due to changes in water quality/ strength of the sodium hypochlorite being used — will improve with experience that can only be gained through regular attention to chlorine residual levels at the treatment plant and in the distribution network.

If the minimum 0.1mg/litre is not being achieved at the end of the supply network then the dose rate must be increased until the cause of chlorine loss (e.g. dirty pipework) is addressed and the required residual is achieved at a lower dose. Similarly, if the residual being achieved is considered too high, then the dosing rate may be lowered.

While the disinfection process must never be compromised, the underlying cause of chlorine loss should be dealt with rather than relying on ever-higher dosage to achieve a residual. Besides the increased risk of THM formation [see page 19], excessively chlorinated water may be rejected by consumers because of chlorinous taste and odour. A danger then arises that they will turn to unsafe spring water supplies as an alternative.

Contact time

The disinfecting effect of chlorine is not instantaneous. Time must be allowed for the chlorine to kill organisms and, as already discussed, additional time will be required where water temperature is very low (close to freezing) or where various parameters have not been sufficiently filtered in advance of disinfection. After the sodium hypochlorite is dosed, it is very important that chlorine has enough 'contact time' to react with the raw water so that it is properly disinfected before reaching the first consumer tap on the network.

In calculating the period of disinfection required, therefore, free residual chlorine (C) and contact time (t) – referred to as *Ct* – have to be considered, in addition to pH, water temperature and water quality.* As an average, the EPA requires a *Ct* value of 15mg.min/litre, because this will provide a free residual into the network of 0.5mg/litre after 30 minutes contact time.

This value is for faecally polluted water, so may be varied depending on the bacteriological quality of the source water. A groundwater supply without *E.coli* and with no more than 10 coliforms/100ml could have a *Ct* value of 10mg.min/ litre with t not less than 15 minutes, while a higher *Ct* value would be advisable for more polluted surface waters.

*** For guidance on how to calculate *Ct*, see the EPA's *Water Treatment Manual: Disinfection* (2011) Section 4.13.4 (p.60) and Section 4.2 (pp.125-129).**

Contact Times (CT) required for 99.9% Giardia removal and a 0.6 mg/litre chlorine residual

	Water pH					
	6.0	6.5	7.0	7.5	8.0	8.5
Water temperature	**Required Contact Time (CT) [in minutes]**					
5° C	100	120	143	171	204	244
10° C	75	90	107	128	153	183
15° C	50	60	72	86	102	122
20° C	38	45	54	64	77	92

Source: ***Back to Basics Guide to Disinfection with Chlorine*** **(Denver, AWWA, 1991).**

If contact time is shorter than is required, then the water that enters the supply may not be fully disinfected and some microbiological bacteria or viruses may still be present. As already stated, contact time can be achieved by retaining the dosed water in a holding tank for a period of time before it is released into the network or by looping a section of the network to lengthen it before the first consumer's tap.

There are only two circumstances where chlorine contact time may not be required:

1. For pristine groundwater supplies in which *E.coli* and coliforms are absent, chlorine is simply being added to guard against contamination in the network, so achieving a residual is sufficient, without the addition of time.
   However, due to poor construction of many boreholes and the vulnerability of aquifers in several regions, group water schemes should never assume that their raw water is pathogen free. This can only be determined by robust and ongoing raw water sampling.
2. Where a validated UV system has already dealt with microbiological contaminants prior to chlorine dosing.

In both circumstances – and adopting a precautionary approach – some contact time might still be advisable in addition to achieving the required residual.

Chlorine free residual

A significant advantage of using sodium hypochlorite as a disinfectant is that it produces free residual chlorine (usually referred to as either 'free' or 'residual' chlorine), which can be measured to provide confidence that water is safe to the consumer's tap. In order to achieve the recommended minimum chlorine residual of 0.1mg/litre at the end of the distribution network, a specific higher chlorine residual is aimed for following contact time, whether at the outlet of a reservoir or at a fixed point before the first household.

This free residual can be constantly measured using an online chlorine monitor, which can be set up to alert the caretaker if the residual is outside the required range. Online monitors vary in sophistication and will require regular recalibration as per the manufacturer's instructions. Checking the online monitor against a chlorine residual reading from a hand-held monitor is also a good way of ensuring that everything is working correctly.

Taking chlorine residual readings along the distribution network — at consumers' kitchen taps or at designated sampling points — is an effective way of checking that the drinking water reaching GWS members is properly disinfected. As with online chlorine monitors, hand-held units need periodic (annual) recalibration and this can be organised centrally by your GWS development officer.

An operational sampling programme should be in place, with sampling frequency reflecting the length of the network and the level of risk. A GWS with a surface water supply and a lengthy distribution system should be conducting at least one residual sample daily, while secure groundwater supplies should take a residual sample at least once weekly. Sampling at (or close to) the end of the network ensures that the full length of the distribution network is accounted for and that all consumers up to the last consumer on the scheme are receiving adequately disinfected drinking water.

Group water schemes are increasingly availing of on-line monitoring systems that provide key information and early warning alerts of issues, not least in relation to chlorine residual levels. This information must be recorded as part of QA implementation.

Responding to poor chlorine residual readings

A minimum of 0.1mg/litre is recommended at the end of the distribution network and group schemes need to establish the relative values that are required at earlier points in the network to ensure that this minimum is achieved. Where insufficient residual readings are being recorded in the distribution network as part of operational monitoring or compliance monitoring, the causes should be investigated and addressed.

The investigation should begin by taking an additional reading after contact time (at the point of delivery into the distribution system). This will establish whether the problem might relate to deteriorating raw water quality or to problems with the dosing system. Where raw water deterioration has been ruled out as the cause, the following should be considered:

- poor quality/out-of-date sodium hypochlorite or poor quality salt where electrolytic generation (OSEC) is being employed.
- faults/blockages in dosing lines and injectors.
- dosing pumps not operating properly.
- filters on solution dosing lines blocked.
- lack of temperature control (a minimum 15°Celsius should be maintained in sodium hypochlorite storage and dosing areas, while excessive heat should be avoided).
- inadequate pressure at chlorine solution injection point.

Where a good chlorine residual is being achieved at the point of delivery into the distribution network, the chlorine dose should be increased until such time as the cause of chlorine loss is determined. This might include:

- a build up of dirt/floc carry-over in the rising main, reservoir or along the distribution pipeline.
- back-flow from a polluted source.
- ingress of contamination through a faulty valve or burst main.
- slime in the pipeline that chlorine cannot treat (but which uses up the chlorine residual).

Chlorination by-products

Sodium hypochlorite can produce harmful chemical by-products, including bromate, chlorate and trihalomethanes (THMs), all of which have implications for human health, while the issue of taste & odour can also have negative, if indirect, consequences. While **effective disinfection should never be compromised when dealing with such by-products**, steps can be taken to reduce the risk that they present for water supplies.

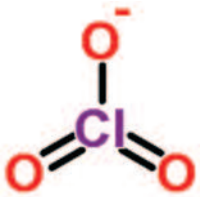
Bromate

Bromate is a drinking water quality parameter for which there is a limit of 10µg/litre because it is a possible carcinogen. It is formed by the oxidation of the bromide ion, which can be naturally occurring in the raw water, or may be a constituent of the salts that are used in the manufacturing of sodium hypochlorite.

An ultra-low bromate sodium hypochlorite can be used to reduce bromate levels where the presence of bromide ions in either the raw water or in the sodium hypochlorite are resulting in an exceedance of the 10µg/litre bromate limit in the final disinfected drinking water.

The storage of sodium hypochlorite can also affect bromate levels in the final water. The longer sodium hypochlorite is stored the more time the bromide ions have to oxidise to bromate in the drum. Exposure of sodium hypochlorite to sunlight can also speed up the oxidation of the bromide ion to bromate.

Chlorate



Sodium hypochlorite is a chemically unstable product, meaning that as soon as it is manufactured the product begins to degrade. A consequence of its degradation is the formation of chlorate (i.e. the salts of chloric acid). While the European Food Safety Authority continues to investigate the effect of chlorate exposure on humans, it is accepted that it damages red blood cells as well as inhibiting the intake of iodine into the thyroid gland. The World Health Organisation has established a guideline value of 0.7mg/litre of chlorate in drinking water.

As the sodium hypochlorite degrades it is necessary to increase the dose to ensure disinfection. This means that the levels of chlorate in the final water will also be increasing, both with the increased concentration of chlorate in the sodium hypochlorite over time and with the additional dose being applied to the water. This is particularly relevant where low doses of sodium hypochlorite are used or where the hypochlorite is diluted prior to dosing. The older the disinfectant, the more must be dosed to get the same residual.

Over-purchasing/stocking of sodium hypochlorite, heat, exposure to sunlight and the addition of suspended solids such as calcium and magnesium will all accelerate chlorate formation. Store the product in a cool, shaded environment and use soft water in the day drum if mixing.

THMs

Four chemical compounds — chloroform, bromoform, bromodichloromethane and dibromochloromethane — are known as trihalomethanes (THMs). These are formed when the chlorine in sodium hypochlorite reacts with organic matter in the raw water. This reaction at the point of contact continues in storage facilities and along the distribution network.

THM formation is particularly prevalent where the raw water is from a surface water source (including springs influenced by surface water) as these generally contain higher levels of organic matter. All THM exceedances in the GWS sector to date have been on such schemes.

In general, the higher the dose of sodium hypochlorite the more likely it is that THMs will form. Formation will also increase seasonally with a rise in surface water temperature. Excessive storage of treated, disinfected water can also lead to an increase in the formation of THMs.

The EPA recommends that all schemes served by a surface water or spring source and using chlorine disinfection should be sampled for THMs in the final water and for Total Organic Carbon as an indicator of the potential of the treated water to form THMs. If raw waters are highly organic and THM formation is an issue, additional water treatment processes may be necessary.

Taste and Odour

While chlorine can address (through oxidisation) taste and odour issues in raw water, such as smells from algae, overdosing of sodium hypochlorite should be avoided to minimise chlorinous taste and odour issues in treated water. The Drinking Water Regulations state that taste and odour should be acceptable to consumers. Where consumer complaints arise, the water supplier is obliged to investigate the possibility of lowering the sodium hypochlorite dose while still maintaining a minimum residual of 0.1mg/litre at the end of the distribution network. Failure to address this issue may persuade consumers to turn to an alternative and less safe drinking water supply.

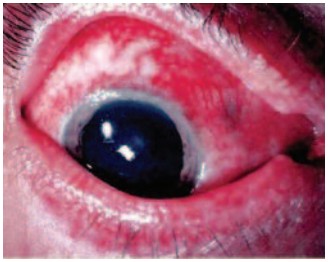
Health & Safety

There is a mistaken belief that sodium hypochlorite is quite harmless. In fact, it is a highly unstable substance and is extremely corrosive.

It is hard on storage containers and equipment, so there should be regular inspection for leaks.

More importantly, exposure to sodium hypochlorite at even low concentrations can cause extreme damage to the skin and to the eyes [see below].

Anyone who works in a water treatment facility should have completed appropriate health & safety training, particularly in regard to the handling and use of sodium hypochlorite and other dangerous chemicals.



Even dilute solutions may have a destructive effect on tissue after prolonged contact. Inhalation of mists can cause damage to the upper respiratory tract, while ingestion of sodium hypochlorite can cause severe damage to the mucous membranes or to other tissues where contact is made.

Mixing sodium hypochlorite with incompatible materials poses a particular risk. Those working with the chemical should refer to the Chlorine Institute's 'Sodium Hypochlorite Incompatibility Chart' in Appendix 2.

Group schemes should have printed instructions, informing staff what should be done in the event of a chemical spill (see Appendix 3 for Bunn GWS 'incident response instructions').

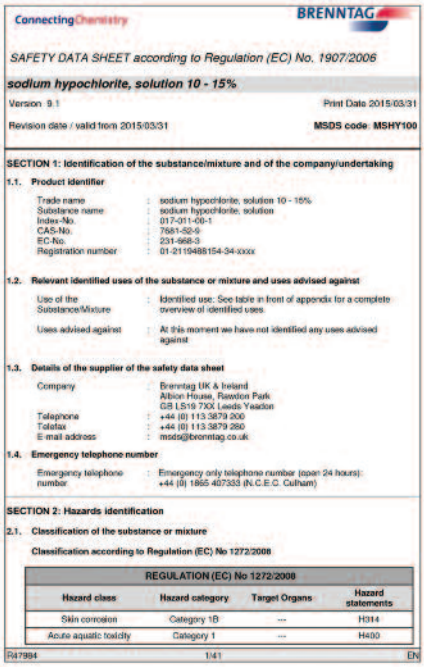
GWS boards/committees should ensure that treatment plant operators are fully aware of the health risks posed by sodium hypochlorite and are equipped to minimise those risks.

Transport & storage of sodium hypochlorite
Manual handling of sodium hypochlorite should be avoided where possible. A licence is required to transport more than three 25-litre containers. Where practical, a licensed supplier should deliver the drums to the pumphouse/treatment facility. As delivery costs on small volumes can be prohibitive (and may exceed the cost of the actual sodium hypochlorite being delivered), GWS committees might consider:

- joint purchasing as part of a group of neighbouring schemes.
- purchasing laboratory grade sodium hypochlorite which is more expensive but is available in 2-litre bottles.
- installing an on-site hypochlorite generation (OSEC) system, which manufactures a low percentage disinfectant from salt and water.

Upon delivery, sodium hypochlorite drums should be bunded in an area that is at least equal to the volume in the drums. A pump should be available to transfer sodium hypochlorite from delivered drums to the day drum from which it is dosed.

Safety Data Sheet
While the drum label provides some important information, it does not inform you about all of the health, fire, reactivity and environmental hazards associated with sodium hypochlorite. This information (and more) is included in the Safety Data Sheet (SDS) that should be read carefully before using a delivered sodium hypochlorite solution. The SDS includes information and advice on the use, storage, handling and emergency procedures for sodium hypochlorite.



ConnectingChemistry BRENNTAG

SAFETY DATA SHEET according to Regulation (EC) No. 1907/2006

sodium hypochlorite, solution 10 - 15%

Version 9.1 — Print Date 2015/03/31

Revision date / valid from 2015/03/31 — **MSDS code: MSHY100**

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier

Trade name	:	sodium hypochlorite, solution 10 - 15%
Substance name	:	sodium hypochlorite, solution
Index-No.	:	017-011-00-1
CAS-No.	:	7681-52-9
EC-No.	:	231-668-3
Registration number	:	01-2119488154-34-xxxx

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the Substance/Mixture	:	Identified use: See table in front of appendix for a complete overview of identified uses
Uses advised against	:	At this moment we have not identified any uses advised against

1.3. Details of the supplier of the safety data sheet

Company	:	Brenntag UK & Ireland Albion House, Rawdon Park GB LS19 7XX Leeds Yeadon
Telephone	:	+44 (0) 113 3879 200
Telefax	:	+44 (0) 113 3879 260
E-mail address	:	msds@brenntag.co.uk

1.4. Emergency telephone number

Emergency telephone number	:	Emergency only telephone number (open 24 hours): +44 (0) 1865 407333 (N.C.E.C. Culham)

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008

REGULATION (EC) No 1272/2008			
Hazard class	Hazard category	Target Organs	Hazard statements
Skin corrosion	Category 1B	---	H314
Acute aquatic toxicity	Category 1	---	H400

R47994 — 1/41 — EN

This multi-page document will also tell you what to expect if recommendations are not followed, what to do if accidents occur, how to recognise symptoms of over-exposure and what to do if such incidents occur. In short, the SDS is an essential starting point for the development of a complete health and safety programme in regard to sodium hypochlorite or any other chemical being used in water treatment.

Personal Protective Equipment
To minimise risk, those working with sodium hypochlorite must be provided with suitable personal protection equipment (PPE). This will include chemical resistant gloves appropriate to dealing with corrosive substances. These gloves should be long enough to come up over the lower arms, with sleeves tucked in. Goggles and face shields are required when dealing with corrosive substances, while other protective clothing, including a rubber apron and rubber boots, must be provided also. Again, trousers/overalls should be tucked into the boots. Why rubber? That fact is that leather, like many other materials, corrodes rapidly after contact with sodium hypochlorite!

It is pointless making PPE available to treatment plant operators if it is not being utilised. Boards of management/committees of group water schemes should ensure that plant operators are fully informed that use of PPE is mandatory when working with sodium hypochlorite and should also ensure that all appropriate health & safety training is completed.

Eye-wash/emergency shower/drench hose
Although the provision of appropriate PPE will minimise the risk to plant operators, where there is the potential for an employee's eyes or body to be exposed to corrosives such as sodium hypochlorite, emergency washing facilities are required to treat or minimise injuries that arise when PPE fails or where plant operators fail to use it.

Emergency washing facilities must be readily available and accessible:
- there should be no obstructions or obstacles on the path to them.
- they should be no more than 10 seconds away (there is a 15-20 second window within which serious eye damage may be avoided).
- they should be fully functioning, with an adequate water supply at an appropriate temperature (i.e. compatible with extended flushing).

The eyewash must irrigate and flush both eyes simultaneously and allow the user to hold the eyes open with both hands. The on-off valve must be activated in one second and remain open. It must deliver at least 2 litres per minute for 15 minutes.

Approved portable eyewashes can be used where there is no plumbing or where the raw water is too cold to be directed comfortably into the eyes for a prolonged period. Portable systems must meet the same standards as a plumbed eyewash and must contain at least 30 litres of water to provide for flushing over 15 minutes. **Eyewash bottles and low flow systems are not sufficient on their own.**

Emergency showers
If there is a potential for substantial portions of the body to come into contact with a corrosive, the emergency shower that is required must be capable of delivering 91 litres a minute for at least 15 minutes. A bathroom shower does not meet these water flow requirements.

Hand-held drench hoses are useful for small spills on extremities of the body, but may not be used as a substitute for required eyewash or emergency showers. Drench hoses must provide 13 litres per minute for 15 minutes.

Operational staff must complete training in the use of such safety equipment. In particular, use of the eyewash in training is essential as staff need to be prepared for the inevitable discomfort of flushing the eyes.

Activation/inspection
Plumbed eyewashes and drench hoses must be activated monthly and inspected annually. Emergency showers must be activated and inspected annually. Portable equipment must be inspected and maintained according to the manufacturer's instructions.

Appendix 1

SECTION 2
Information about biocidal products
Article 69
Classification, packaging and labelling of biocidal products

1. Authorisation holders shall ensure that biocidal products are classified, packaged and labelled in accordance with the approved summary of biocidal product characteristics, in particular the hazard statements and the precautionary statements, as referred to in point (i) of Article 22(2), and with Directive 1999/45/EC and, where applicable, Regulation (EC) No 1272/2008.
In addition, products which may be mistaken for food, including drink, or feed shall be packaged to minimise the likelihood of such a mistake being made. If they are available to the general public, they shall contain components to discourage their consumption and, in particular, shall not be attractive to children.

2. In addition to compliance with paragraph 1, authorisation holders shall ensure that labels are not misleading in respect of the risks from the product to human health, animal health or the environment or its efficacy and, in any case, do not mention the indications 'low-risk biocidal product', 'non-toxic', 'harmless', 'natural', 'environmentally friendly', 'animal friendly' or similar indications. In addition, the label must show clearly and indelibly the following information:

(a) the identity of every active substance and its concentration in metric units;
(b) the nanomaterials contained in the product, if any, and any specific related risks, and, following each reference to nanomaterials, the word 'nano' in brackets;
(c) the authorisation number allocated to the biocidal product by the competent authority or the Commission;
(d) the name and address of the authorisation holder;
(e) the type of formulation;
(f) the uses for which the biocidal product is authorised;
(g) directions for use, frequency of application and dose rate, expressed in metric units, in a manner which is meaningful and comprehensible to the user, for each use provided for under the terms of the authorisation;
(h) particulars of likely direct or indirect adverse side effects and any directions for first aid;
(i) if accompanied by a leaflet, the sentence 'Read attached instructions before use' and, where applicable, warnings for vulnerable groups;

(j) directions for the safe disposal of the biocidal product and its packaging, including, where relevant, any prohibition on the reuse of packaging;
(k) the formulation batch number or designation and the expiry date relevant to normal conditions of storage;
(l) where applicable, the period of time needed for the biocidal effect, the interval to be observed between applications of the biocidal product or between application and the next use of the product treated, or the next access by humans or animals to the area where the biocidal product has been used, including particulars concerning decontamination means and measures and duration of necessary ventilation of treated areas; particulars for adequate cleaning of equipment; particulars concerning precautionary measures during use and transport;
(m) where applicable, the categories of users to which the biocidal product is restricted;
(n) where applicable, information on any specific danger to the environment particularly concerning protection of non-target organisms and avoidance of contamination of water;
(o) for biocidal products containing micro-organisms, labelling requirements in accordance with Directive 2000/54/EC.

By way of derogation from the first subparagraph, where this is necessary because of the size or the function of the biocidal product, the information referred to in points (e), (g), (h), (j), (k), (l) and (n) may be indicated on the packaging or on an accompanying leaflet integral to the packaging.

3. Member States may require:
(a) the provision of models or drafts of the packaging, labelling and leaflets;

(b) that biocidal products made available on the market in their territories be labelled in their official language or languages.

Appendix 2

Sodium Hypochlorite Incompatibility Chart

Do NOT mix Sodium Hypochlorite (bleach) with ANY other chemical unless adequate engineering controls and personal protective equipment (PPE) are in place. Accidental mixing may cause dangerous conditions that could result in injury to personnel and/or damage to property or the environment.

Incompatible Material	Mixing May Result In
Acids, Acidic Compounds and Acid Based Cleaning Compounds such as: - Alum (Aluminum Sulfate) - Aluminum Chloride - Ferrous or Ferric Chloride - Ferrous or Ferric Sulfate - Chlorinated Solutions of Ferrous Sulfate - Hydrochloric Acid (HCl) - Sulfuric Acid - Hydrofluoric Acid - Fluorosilicic Acid - Phosphoric Acid - Brick and Concrete Cleaners	- Release of chlorine gas, may occur violently.
Chemicals and Cleaning Compounds containing ammonia such as: - Ammonium Hydroxide - Ammonium Chloride - Ammonium Silicofluoride - Ammonium Sulfate - Quaternary Ammonium Salts (Quats)	- Formation of explosive compounds. - Release of chlorine or other noxious gases.
Organic Chemicals and Chemical Compounds such as: - Solvents and Solvent Based Cleaning Compounds - Fuels and Fuel Oils - Amines - Propane - Organic Polymers - Ethylene Glycol - Insecticides - Methanol	- Formation of chlorinated organic compounds. - Formation of explosive compounds. - Release of chlorine gas, may occur violently.
Metals such as: - Copper - Nickel - Cobalt - Iron Avoid piping and material handling equipment containing stainless steel, aluminum, carbon steel or other common metals.	- Release of oxygen gas, generally does not occur violently. Could cause overpressure/rupture of a closed system.
Hydrogen Peroxide	- Release of oxygen gas, may occur violently.
Reducing agents such as: - Sodium Sulfite - Sodium Bisulfite - Sodium Hydrosulfite - Sodium Thiosulfate	- Evolution of heat, may cause splashing or boiling.

Source: The Chlorine Institute (USA)

Appendix 3

Bunn Water Co-op Society Ltd

Health & Safety Statement

Chemical Risk Assessment for Sodium Hypochlorite

Risk 1 Chemical Fumes/Smell

Leave the area immediately.

Report to Management a possible chemical leak.

Wait until the area is well ventilated before returning.

Risk 2 Chemical Handling

Always wear P.P.E. provided (full face mask, chemical gloves, protective apron).

Risk 3 Chemical Leakage

Never attempt to repair a chemical leak on your own. Always have another person there on standby.

Ensure chemical pumps are switched off before starting work.

Always wear P.P.E. provided, use a paper towel to find the leak.

Any paper towel used for this purpose should be flushed with water before being disposed of.

Risk 4 Chemical Burns

In the event of an accident, immediately use the water hose provided in the plant room to wash the area of the body effected.

Keep the water running for 15 minutes before seeking medical attention.

Risk 5 chemical spillage

In the event of chemical spillage, the area should be flushed with plenty of water.

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